GOLDEN JUBILEE PUBLICATION

R&D ADVANCEMENTS IN INDIAN SERICULTURE

Proceedings of the Golden Jubilee National Conference
Sericulture Innovations: Before and Beyond
28-29th January, 2011

B. B. Bindroo
Mukund V. Kirsur

Central Sericultural Research and Training Institute
[ISO 9001:2008 Certified]
Central Silk Board, Ministry of Textiles, Govt. of India, Mysore-570 008

Published by
Dr. B. B. Bindroo
Director, CSR&TI, Mysore.

December 2013
400 copies

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Printed at
Revathi Printers
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Vidyaranyapuram, Mysore
Ph: 0821-4250774, 9141719518

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PREFACE

Central Sericultural Research and Training Institute, Mysore is one among the foremost sericulture institutes of the world, which was established in 1961 under the aegis of Central Silk Board, Ministry of Textiles, Govt. of India. It untiringly has been serving as a springboard for scientific/technological/extension and training activities that has helped India to usher in a scientific milieu by fostering and promoting science and technology developments related to mulberry sericulture and silk industry.

After prolonged and successful journey of five decades, this premier institute celebrated its Golden Jubilee, marked by a national event held during January 2011, thanks to the dedicated and tireless efforts of scientists/technologists/extension personnel/administrators/policy makers and more than all, the sericulturists. The institute encompasses the entire gamut of sericultural R&D activities to cater to the needs of on-farm sector of the country and southern states in particular. With its well equipped sericulture infrastructure and strong indigenously developed technological base, the institute has emerged as a leading R & D institution on tropical sericulture of the country and also recognized world over as a center for higher learning and advanced training in sericulture.

The bivoltine silkworm hybrids like CSR2 x CSR4, double hybrid, mulberry varieties like V1 and S-36 along with their package of practices besides disease management strategies have revolutionized sericulture, which enabled introduction and establishment of bivoltine sericulture in the country to produce bivoltine silk substantially under tropical conditions. The productivity and the quality of the silk have gone up enormously during the past five decades. The extension programmes like IVLP, CPP, etc., fully supported by Central Silk Board besides the Swiss assisted ICTRETS and JICA programmes implemented successfully by the Institute gave a new dimension to Indian Sericulture.

In the last 50 years, Indian Sericulture as mentioned elsewhere has witnessed a sea change mainly because of the efforts of CSRTI, Mysore. These efforts have metamorphosed the earlier sericulture, from a cottage industry into a full-fledged enterprising par excellence silk industry. And more importantly, these efforts have transformed the socio-economic status of poor sericulturist for a better living.

The commemoration of Golden Jubilee of the Institute had therefore a reason to recognize and pat the efforts of all those who helped to develop sericulture to such a

great extent. The real celebrities are our scientists/technocrats/administrators besides a big number of unsung heroes – the sericulturists! This Golden Jubilee, I hope not only have evoked the great feelings about these people, but also encouraged the silk men to make Indian sericulture more conspicuous in the silk map of the world.

Owing to the consistent demand from the participants of the conference and other persons connected with silk industry, efforts have been made to compile the papers presented, important deliberations and recommendations held during the conference in the form of this single volume R&D advancements in Indian sericulture. We profoundly thank all the contributors for their cooperation in presenting useful information in various aspects of sericulture. The opinions and the text contained here in are those of the authors and we have tried to improve the content without loss of originality. We are extremely thankful to Sri. H. Hanumanthappa, and Ms. M. Sathiyavathi IAS, the then Chairman and Member Secretary, respectively, Central Silk Board and also Sri. N. S. Bisse Gowda, Chairman, CSB and Ms. Ishitha Roy, IAS, Member Secretary, Central Silk Board for their constant encouragement and cooperation. We also express our sincere gratitude to the Chairpersons and Rapporteurs of different sessions of the conference and the members of the paper screening and editorial committee for their efforts in bringing out this valuable and memorable publication. Hope it would be useful to all those concerned with sericulture industry in the country and abroad.

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BREEDING OF EARLY SPROUTING AND HIGH YIELDING MULBERRY VARIETIES AMENABLE TO PROPAGATION BY STEM CUTTINGS WITH HIGH SURVIVAL ABILITY FOR RAINFED CULTIVATION IN KASHMIR AND OTHER TEMPERATE REGIONS OF NORTH INDIA

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ABSTRACT

The temperate climatic conditions of Kashmir are very supportive of mulberry growth and silkworm rearing to produce raw silk of international standard. Studies conducted in the valley have revealed virtues and weaknesses of local varieties and those introduced from Japan and Italy. In general, these varieties grow well in Kashmir with appreciable resistance to stem canker, but are late sprouters in spring and are not amenable to propagation by stem cuttings. While their late spouting nature leads to a clash with rearing activities and paddy cultivation in spring, their inability to produce sapling from cuttings necessitates propagation through root grafting method, which is a slow and expensive operation. In contrast, there are many varieties, which sprout early in spring and can easily be propagated from stem cuttings in Kashmir but are only moderately tolerant to stem canker. In view of the above, an attempt was made, using the variability created by controlled pollination, open pollination and mixed pollination, to develop new varieties, which are early sprouting and amenable to propagation through cutting, resistant to frost and stem canker besides being high yielding under rain fed conditions of temperate regions, particularly Kashmir.

Key words: Frost resistance, Mulberry**,** Rainfed cultivation, Stem canker, Winter buds

INTRODUCTION

The mulberry varieties cultivated in Kashmir, Goshoerami in particular, are multiplied on large scale by conventional grafting method, which is cumbersome, time consuming and costly. The grafting method of propagation is inevitable, as they do not respond to propagation through cuttings. Another shortcoming in local and introduced varieties is that they are late sprouters. However, they are, in general, tolerant to stem canker (Baksh *et al.*, 2002), in addition to being high yielding (Baksh *et al.*, 2001b). On the other hand, many genotypes including Chinese White have been found to be early sprouting and good rooting (Baksh *et al*, 2000; 2002b). It is therefore essential to combine the desirable traits found scattered in two set of varieties. (Japanese with high yield, disease tolerant characters and Chinese White and some others which are easy rooting and early sprouting). With this, in view, Baksh (2000) conducted breeding studies and made 76 selections based on visual observations in terms of growth, leaf characters, disease incidence, branching behavior etc. The propagation test indicated the possibility of multiplication of 58 selections through cuttings. The present paper deals with their performance *vis-à-vis* three controls, *viz*., Goshoerami, Rokokuyaso and Chinese white in terms of growth, leaf yield, propagation through stem cuttings, sprouting of winter buds, tolerance to frost and stem canker besides earliness of sprouting of winter buds. Finally, eleven were short listed as superior to the controls.

MATERIALS AND METHODS

The study was conducted during Oct. 2005 - Dec. 2007 on the well-established vegetative progeny of 58 selections and three controls *viz*., Chinese White, Rokokuyaso and Goshoerami (represented by five plants each).

a. Controlled pollinated hybrids (Goshoerami × Chinese White) S-137, S139, S-140, S-145, S-150, S-152, S-155, S157, S158 and S-160;

b. Open pollinated hybrids (Goshoerami as female parent) S-4, S-5, S-6, S-8, S-11, S-17, S-22, S-35, S-38, S-64, S-70, S-75, S-82, S-85, S-86, S-90, S-99, S-101, S-106, S-111, S-113, S115, S-119, S-125 and S-131;

c. C. Mixed pollinated hybrids [Goshoerami × (S-1301 + S-799)] - S-163, S-164, S-165, S-168, S-169, S-170, S-176, S-178, S-180, S-181, S-184, S-185, S-186, S-193, S-195, S-200, S-203, S-206, S209, S-212, S-213, S-214 and S-217

The plants were maintained as dwarfs at 90 × 180 cm spacing under rain fed condition at the Institute following recommended package (Mukherjee, 1992). Accordingly, the pruning was done once a year, in the form of basal cut at crown level at the end of spring (early June).

a. Growth and yield: Observations on following parameters were recorded in spring and autumn seasons, coinciding with the late age silkworm rearing, for two years.

1. No. of primary branches
2. Length of the longest branch
3. Stem diameter of longest branch
4. No. of nodes/meter length of shoot
5. Weight of 100 leaves
6. Leaf weight/meter of branch
7. Leaf yield/plant
8. Weight of wood/plant
9. Leaf shoot ratio (%)
10. Leaf moisture content
11. Moisture retention capacity after 6 hours of harvesting
12. Disease reaction

b. Rooting ability: The experiment was laid out in RBD with three replications in early march of 2006 and 2007. Sprouting of cuttings of 58 selections along with Chinese White (C) was recorded at different intervals of 60, 120 and 180 days of planting the cuttings (Baksh *et al.*, 2000b).

c. **Leaf shedding, effect of frost and sprouting of winter buds:** The sprouting of winter buds was recorded at weekly intervals from the fourth week of March till each selection recorded its maximum value in both the years of study. The effect of frost was studied by measuring the dry length of tagged branches in each selection at the end of winter. Analysis of variance was carried out as per Singh & Chaudhary (1977).

Short-listing of superior selections: It was done following the Evaluation Index method (Mano *et al,* 1993).

$$\text{Evaluation Index (EI)} = \frac{A - B}{C} \times 10 + 50$$

Where,

A= Mean of a particular genotype for a particular parameter

B= Mean of all the genotypes for that particular parameter

C= Standard deviation for the parameter

RESULTS

Preliminary evaluation of vegetative progeny of selected hybrids in terms of growth, quality parameters and disease reaction

(I) Leaf yield/plant/year: Consistent superiority of many selections was recorded in terms of leaf yield/plant in two crops (spring and autumn)/year over Chinese White and Rokokuyaso. Based on pooled data of two years (Table 1), it was found to vary from 3.8 kg to 4.3 kg among S-38, S-106, S-140, S -145, S- 158, S-186, being significantly higher than the two controls in which it was 1.7 to 3.1, kg respectively. These selections were, however statistically at par with Goshoerami.

(ii) Weight of branches/plant: The amount of wood produced by several selections was also significantly more than all the controls in both the years of study. It was 4.661 kg in S-38, 4.073 kg in S-106, 3.813 kg in S-140 and 3.622 kg in S-145 as against 1.957kg in Chinese White, 2.309 kg in Goshoerami and 2.386 in Rokokuyaso (Table 2).

(iii) No. of branches/plant: Some of the selections namely S-11, S-38, S-139, S-184 and S-209 produced significantly more number of branches than controls. The number of branches (total of spring and autumn crops) in these was in the range of 41 - 49 as compared to 32 35 branches in controls (Table 3).

(iv) Length of the longest branch: Many selections including S-85, S-106, S-140, S-145, S -158 produced branches of more than 2.5 meter length, being significantly higher than the controls in which it was 1.8 2.3 m (Table 4).

(v) Stem Diameter: It was more than 1.5 cm in all the entries except in a few (S-176, S-209, and Rokokuyaso) (Table 5).

(vi) Fresh weight of 100 leaves: A remarkable and consistent superiority of several selections over Chinese White and Rokokuyaso was evident with regard to this parameter. Some of the selections recording 0.8- 1.1 kg weight/100 leaves were S-22, S-85, S-99, S-106, S-125, S-140, S-145, S-152, S-158, S-168 and S-186. As against this, in Chinese White and Rokokuyaso, 100 leaves weighed about 0.5 kg only. The least value (0.36 kg) was recorded in S-38 (Table 6).

(vii) No. of nodes/meter length of shoot: S-11, S-217 and S-38 had 23 -25 nodes, being significantly more than the controls among which it varied from 15 21 (Table 7).

(viii) Leaf weight per meter length of longest branch: In a large number of selections (S-17, S-22, S-70, S-85, S-106, S-113, S-140, S-145, S-152, S-158, S-168, S-186, S-213, S-217) it was more than 0.100 kg as against 0.066 kg in Chinese White. It was 1.50 kg in Goshoerami, being significantly higher than those of the selections (Table 8).

(ix) Leaf shoot ratio: It ranged from 45-53% among several selection (S-85, S-106, S-113, S-140, S-145, S-152, S-158, S-186, S-213, S-217) as against 39% in Chinese White. In Goshoerami, it was 58%, being highest among all (Table 9).

(x) Moisture content: In both the years it varied in a narrow range from 74% in S-203 to 78% in S-168 and the general mean was 76% (Table 10). Thus the selections did not differ very strikingly from the controls.

(xi) Moisture retention capacity after six hours of harvest: In this respect also, the differences among the entries were not very striking, with the general mean being 88 in 2006 and 90% in 2007. Based on pooled data (Table 11), it was found to be about 90% in some of the selections including S-85, S-106, S-113, S-140, S-145, S-152, S-158, S-168, S-186, S-213, S-217 as against 86% in Chinese White and 87% in Rokokuyaso. In Goshoerami, it was 91%, being highest among the three controls.

(xii) Disease reaction: All the selections as well as the controls were completely free from leaf spot and powdery mildew diseases in spring season. In autumn they were free from leaf spot. Even powdery mildew was more or less absent till first week of September. Incidence of Stem canker was found in many selections particularly S-11, S-139, S-184 and S-209 with more than 15% of the branches being affected. Among the controls, heavy infestation was found in Chinese white with 37% branches affected by the disease while the other two controls (Goshoerami and Rokokuyaso) were free from it (Table 12).

Rooting test of selections and growth of their saplings: In all the selections as well Chinese White (c), maximum sprouting was registered in 45 -60 days after planting the cuttings, in early March, in both the years of study. In many of the selections, it was as 98 -100%. In Chinese White, however, it was inconsistent, being 98% in 2006 and 68% in 2007. In general, 97% sprouting was registered (Table 13).

The rooting data of two years confirms that most of the selections can be easily propagated from their hard wood stem cuttings. Based on pooled data of two years, it was found to be about 80% in S-85, S-106, S-113, S-140, S-186, S-213 and about 95% or more in S-5, S-70, S-152, S-145, S-217. In S-38 and S-158 it was 48% and 50% respectively (Table 14).

The saplings were erect and grew fast up to mid September. The growth was slow. They ceased to grow after mid October. By that time, they had in general attained a height of about 2 m and remained dormant until next March.

Leaf shedding, frost resistance and sprouting of winter buds

(i) Leaf shedding: A great deal of variation was noticed among the entries with some of them e.g. S-17, S-38, Rokokuyaso having shed less than 10% leaf at the beginning of October as against 20 -30% in S-5, S-22, S-86, S-101, S-131, S-137, S-160, S-176, S-180, S-206, S-209 and S-217 (Table 15).

(ii) Frost resistance: The notable selections in which damage was less than 10% length of branch were S-145, S-106, S-38, S-113, S-203 and S-217. On the other hand, the damage was more than 30% in S-75, S-86, S-137, S-178 and Goshoerami (Table 16).

(iii) Earliness of sprouting of winter buds: Observation recorded at the end of March showed highly significant and very striking differences between several selections and the controls (Table 17). About 50% of the winter buds had sprouted by that time in S-106, S-140, S-152, S-212, S-206, S-213 and Chinese White. In clear contrast, Goshoerami and Rokokuyaso (two of the three controls) had almost all their buds still in dormant state.

It is interesting to note that after basal pruning in early June (end of spring season), sprouting took 8 to 9 days in S-217, S-11, S-38, S-131, S-186, S-206 and Goshoerami while 10 to 13 days in the rest of the selections and the two of the three controls (Chinese White and Rokokuyaso).

(iv) Maximum sprouting of winter buds: Recorded at the end of April, it was found to be about 80% in most of the selections. Only a few viz. S-180, S-181 had recorded less than 70% (Table 18).

(v) Leaf area in the fourth week of April: Very striking differences were found among the selections and controls. Several selections including S-106, S-140 S-145, S-85 S-186 produced larger leaves (115-140 cm^2) as compared to Chinese White (70 cm^2) and Rokokuyaso (74.5 cm^2). In Goshoerami, leaf grew faster, attaining a size comparable with the selections mentioned (Table 19).

Short-listing of superior selections

Considering pooled data of two years in respect of fifteen characters, the selections were short listed by working out average Evaluation Index (Mano et al., 1993). Accordingly, S-106, S-140, S-145, S-85, S-158, S-186, S-38, S-213, S-152, S-217 were found to be the ten superior selections (Table 20). In addition, S-113 was also selected for its very distinct and attractive look and as it can be easily propagated through hard wood stem cuttings.

Characteristic morphological features of short-listed selections

1. All the superior selections except S-38, produced leaf larger than that of Chinese white and Rokokuyaso and comparable with Goshoerami. While S-85, S-145, S-152, S-158, S-186, S-213 and S-113 are homophyllous, bearing only entire leaf, S-38, S-106 and S-140 are heterophyllous, the number of lobes generally being 2-3. In S-217, however, the leaves are generally lobed, number of lobes being 5-7. Further, the leaves of S-113 and S-158 are very glossy. The leaf surface is smooth in all except S-38 in which it is slightly rough. The shape of leaf is cordate or ovate in all, with S-38, S-152, S-158, S-213, S-217 also producing slightly oblong leaf. The colour of leaf is green to dark green.
2. The leaf base is deep in S-85 and in the rest it is comparatively shallow.
3. The tip of the lamina is acuminate in all.
4. S-38, S-85, S-106, S-140, S-186 produced only female flowers. Rarely, however, male flowers were also found in S-85. Two selections viz S-145, S-152 are monoecious. The remaining selections (S-113, S-158, and S-213 and S-217) produced male flowers, the female ones occurring only rarely.
5. The colour of fully-grown woody stem during winter is greenish or yellowish grey in S-217 and S-152 while in the rest it is purplish/brownish grey.
6. The winter buds are purple or purplish brown in colour in all. The accessory buds, 1 2 in number, are commonly found in S-140 and S-217 but are uncommon in the rest (S-38, S-85, S-106, S-113, S-145, S- 152, S-158, S-186 and S-213).
7. The colour of ripe fruit is bluish black in S-38, S-106, S-140, and S-145. It is grey with occasional pinkish touch in S-85 and S-152, and grey in S-186.

DISCUSSION

Many exotic varieties such as Goshoerami, Ichinose, KNG, Kariyoroso, and Limoncina grow well in Kashmir valley, the main reason being the climatic similarity of Kashmir with that of the place of their origin. They are high yielder and tolerant to stem canker but are poor rooters and late sprouters. On the other hand varieties like Chinese White, M. multicaulis, C-4 are early sprouters and amenable to propagation through stem cuttings but are only moderately tolerant to stem canker. The selections short-listed from this study assume significance as they combine in them the characters desirable for sericulture in temperate region.

In terms of moisture content and retention capacity, which are indicative of leaf quality, the short listed ones qualify the bench mark fixed for the purpose, which is 70% for the former and about 65 % for the latter (Jolly and Dandin, 1986). As regards leaf weight and size, the selection, in general, produced much larger leaf than Chinese White and Rokokuyaso, with some of them e.g., S-85, S-113, S-145, S-158 and S-186 producing leaf comparable with Goshoerami. Thus, all these short listed selections need to be subjected to yield trial and full bioassay test so as to utilize them in field. In the past also, such studies involving conventional breeding have been successfully conducted leading to the evolution of high yielding V1 (Sarkar et al., 1999), BC259 (Das and Krishnaswami, 1965) and many other varieties for specific regions and rearing purposes (Sarkar, 2005).

CONCLUSION

The present study has led to the short-listing of superior selections viz. S-38, S-85, S-106, S-140, S-145, S-152, S-158, S-186, S-213, S-217and S-113. These selections yield 2.9 4.3 kg/plant/year and all of them, except S-38, bear much bigger leaf, weight of 100 leaves being about 1.0 kg, as against Chinese White in which the leaf yield was 1.7 kg/pl/yr and leaf weight 0.5 kg. And like Chinese White, these are amenable to propagation by stem cuttings and their winter buds sprout early in spring. All of them are, tolerant to stem canker.

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Table 1: leaf yield/plant/year (kg) -Mean of two years

Selections	Leaf yield/plant (kg)	Selections	Leaf yield/ plant (kg)	Selections	Leaf yield/ plant (kg)	Selections	Leaf yield/ plant (kg)
S-004	3.153	S-099	3.581	S-157	2.909	S-193	3.233
S-005	3.242	S-101	2.829	S-158	3.932	S-195	3.435
S-006	2.603	S-106	4.013	S-160	3.314	S-200	2.808
S-008	2.776	S-111	2.826	S-163	2.634	S-203	3.132
S-011	3.424	S-113	2.882	S-164	2.984	S-206	2.883
S-017	3.673	S-115	3.242	S-165	3.491	S-209	2.858
S-022	3.296	S-125	2.954	S-168	3.064	S-212	3.570
S-035	3.169	S-129	2.252	S-169	3.161	S-213	3.245
S-038	4.237	S-131	3.443	S-170	2.047	S-214	3.124
S-064	2.580	S-137	3.712	S-176	2.760	S-217	3.288
S-070	3.063	S-139	3.408	S-178	2.831	C.W (c)	1.754
S-075	3.497	S-140	4.329	S-180	2.958	Gosho (c)	3.802
S-082	3.219	S-145	3.809	S-181	3.379	Roko (c)	3.123
S-085	3.499	S-150	2.621	S-184	3.501	Mean	3.193
S-86	3.660	S-152	3.554	S-185	3.087	F test	**
S-090	3.255	S-155	2.665	S-186	4.009	CD at 5%	0.585

Table 2: Weight of branches/plant (kg) mean of two years

Selections	Weight of plant (kg)	Selections	Weight of plant (kg)	Selections	Weight of plant (kg)	Selections	Weight of plant (kg)
S-004	3.088	S-099	2.533	S-157	2.338	S-193	3.265
S-005	2.526	S-101	2.098	S-158	3.129	S-195	2.864
S-006	1.785	S-106	4.073	S-160	2.966	S-200	2.017
S-008	2.476	S-111	2.375	S-163	2.536	S-203	3.277
S-011	3.318	S-113	2.257	S-164	2.876	S-206	2.798
S-017	2.993	S-115	3.011	S-165	3.442	S-209	2.503
S-022	3.033	S-125	2.656	S-168	2.570	S-212	3.006
S-035	2.707	S-129	1.598	S-169	3.231	S-213	2.618
S-038	4.661	S-131	2.777	S-170	2.347	S-214	3.296
S-064	2.068	S-137	2.999	S-176	2.535	S-217	2.935
S-070	2.516	S-139	2.820	S-178	2.500	C.W (c)	1.957
S-075	3.234	S-140	3.813	S-180	2.637	Gosho (c)	2.309
S-082	2.915	S-145	3.622	S-181	3.148	Roko (c)	2.386
S-085	3.136	S-150	2.386	S-184	2.447	Mean	2.796
S-86	3.513	S-152	2.786	S-185	2.932	F test	**
S-090	2.346	S-155	2.292	S-186	3.305	CD at 5%	0.780

Table 3: No. of primary branches/plant (mean of two years)

Selections	No. of primary branches/ plant	Selections	No. of primary branches/ plant	Selections	No. of primary branches/ plant	Selections	No. of primary branches/ plant
S-004	40.00	S-099	29.88	S-157	36.63	S-193	31.50
S-005	39.50	S-101	36.38	S-158	32.63	S-195	38.75
S-006	31.88	S-106	34.38	S-160	39.13	S-200	32.13
S-008	36.13	S-111	31.88	S-163	30.25	S-203	36.88
S-011	42.13	S-113	25.63	S-164	29.38	S-206	37.38
S-017	31.13	S-115	33.63	S-165	34.75	S-209	46.75
S-022	37.63	S-125	26.63	S-168	35.25	S-212	36.13
S-035	31.75	S-129	24.25	S-169	40.25	S-213	38.50
S-038	49.38	S-131	37.50	S-170	37.63	S-214	35.63
S-064	27.63	S-137	39.25	S-176	40.13	S-217	32.25
S-070	36.25	S-139	41.13	S-178	32.75	C.W (c)	35.38
S-075	37.25	S-140	38.88	S-180	32.88	Gosho (c)	32.00
S-082	35.88	S-145	29.63	S-181	39.75	Roko (c)	35.25
S-085	30.25	S-150	38.00	S-184	42.75	Mean	35.14
S-86	39.13	S-152	31.25	S-185	33.50	F test	**
S-90	28.75	S-155	32.38	S-186	32.25	CD at 5%	4.79

Table 4: Length of longest branch (m) - mean of two years

Selections	Length of the longest branch (m)	Selections	Length of the longest branch (m)	Selections	Length of the longest branch (m)	Selections	Length of the longest branch (m)
S-004	2.25	S-099	2.40	S-157	2.24	S-193	2.44
S-005	2.30	S-101	2.02	S-158	2.60	S-195	2.27
S-006	2.45	S-106	2.63	S-160	2.30	S-200	2.15
S-008	2.17	S-111	2.22	S-163	2.47	S-203	2.26
S-011	2.27	S-113	2.45	S-164	2.22	S-206	2.30
S-017	2.57	S-115	2.41	S-165	2.66	S-209	2.02
S-022	2.25	S-125	2.38	S-168	2.16	S-212	2.36
S-035	2.27	S-129	2.20	S-169	2.37	S-213	2.32
S-038	2.12	S-131	1.92	S-170	2.36	S-214	2.83
S-064	2.33	S-137	2.41	S-176	1.95	S-217	1.95
S-070	2.32	S-139	1.94	S-178	2.24	C.W (c)	2.30
S-075	2.42	S-140	2.56	S-180	2.09	Gosho (c)	1.92
S-082	2.31	S-145	2.49	S-181	2.31	Roko (c)	1.84
S-085	2.60	S-150	2.08	S-184	2.27	Mean	2.29
S-86	2.43	S-152	2.35	S-185	2.65	F test	**
S-090	2.10	S-155	1.91	S-186	2.34	CD at 5%	0.13

Table 5: Stem diameter (cm) mean of two years

Selections	Stem diameter (cm)	Selections	Stem diameter (cm)	Selections	Stem diameter (cm)	Selections	Stem diameter (cm)
S-004	1.65	S-099	1.82	S-157	1.43	S-193	1.52
S-005	1.67	S-101	1.45	S-158	1.79	S-195	1.57
S-006	1.80	S-106	1.79	S-160	1.54	S-200	1.59
S-008	1.55	S-111	1.59	S-163	1.56	S-203	1.58
S-011	1.65	S-113	1.67	S-164	1.54	S-206	1.47
S-017	1.88	S-115	1.63	S-165	1.89	S-209	1.36
S-022	1.63	S-125	1.89	S-168	1.50	S-212	1.64
S-035	1.58	S-129	1.63	S-169	1.69	S-213	1.58
S-038	1.45	S-131	1.51	S-170	1.44	S-214	1.89
S-064	1.63	S-137	1.75	S-176	1.36	S-217	1.64
S-070	1.71	S-139	1.55	S-178	1.56	C.W (c)	1.51
S-075	1.65	S-140	1.86	S-180	1.47	Gosho (c)	1.52
S-082	1.61	S-145	1.81	S-181	1.66	Roko (c)	1.37
S-085	1.86	S-150	1.39	S-184	1.56	Mean	1.63
S-86	1.61	S-152	1.91	S-185	1.79	F test	**
S-090	1.78	S-155	1.52	S-186	1.73	CD at 5%	0.10

Table 6: 100 Leaf weight (kg) mean of two years

Selections	100 Leaf weight (kg)	Selections	100 Leaf weight (kg)	Selections	100 Leaf weight (kg)	Selections	100 Leaf weight (kg)
S-004	0.450	S-099	1.017	S-157	0.659	S-193	0.749
S-005	0.608	S-101	0.635	S-158	1.060	S-195	0.647
S-006	0.772	S-106	1.009	S-160	0.639	S-200	0.704
S-008	0.643	S-111	0.726	S-163	0.631	S-203	0.519
S-011	0.554	S-113	0.839	S-164	0.689	S-206	0.594
S-017	0.792	S-115	0.780	S-165	0.812	S-209	0.535
S-022	0.946	S-125	1.027	S-168	0.886	S-212	0.747
S-035	0.836	S-129	0.853	S-169	0.613	S-213	0.817
S-038	0.361	S-131	0.656	S-170	0.465	S-214	0.757
S-064	0.820	S-137	0.831	S-176	0.530	S-217	0.765
S-070	0.765	S-139	0.537	S-178	0.675	C.W (c)	0.474
S-075	0.666	S-140	0.834	S-180	0.760	Gosho (c)	1.058
S-082	0.755	S-145	1.121	S-181	0.807	Roko (c)	0.544
S-085	1.050	S-150	0.475	S-184	0.838	Mean	0.745
S-86	0.762	S-152	0.999	S-185	0.745	F test	**
S-090	0.876	S-155	0.752	S-186	0.970	CD at 5%	0.150

Table 7: No. of nodes/meter length of branch (mean of two years)

Selections	No. of nodes meter	Selections	No. of nodes meter	Selections	No. of nodes meter	Selections	No. of nodes meter
S-004	21.33	S-099	15.08	S-157	16.38	S-193	15.19
S-005	19.54	S-101	20.00	S-158	13.87	S-195	14.96
S-006	13.40	S-106	15.45	S-160	18.05	S-200	15.36
S-008	14.39	S-111	14.68	S-163	17.78	S-203	18.84
S-011	24.81	S-113	14.98	S-164	15.83	S-206	17.28
S-017	17.48	S-115	14.63	S-165	16.54	S-209	17.62
S-022	14.69	S-125	16.53	S-168	14.56	S-212	16.60
S-035	15.85	S-129	16.58	S-169	16.16	S-213	15.36
S-038	22.92	S-131	20.39	S-170	17.24	S-214	14.51
S-064	15.27	S-137	16.89	S-176	17.57	S-217	24.20
S-070	17.13	S-139	19.77	S-178	18.69	C.W (c)	15.03
S-075	15.67	S-140	16.43	S-180	17.47	Gosho (c)	18.38
S-082	16.45	S-145	14.99	S-181	15.68	Roko (c)	20.86
S-085	15.10	S-150	16.51	S-184	15.10	Mean	16.84
S-86	16.54	S-152	16.42	S-185	14.62	F test	**
S-090	15.57	S-155	17.87	S-186	14.12	CD at 5%	0.99

Table 8: Leaf wt (kg) per meter length of branch (mean of two years)

Selections	Leaf wt (kg) per meter	Selections	Leaf wt (kg) per meter	Selections	Leaf wt (kg) per meter	Selections	Leaf wt (kg) per meter
S-004	0.075	S-099	0.127	S-157	0.086	S-193	0.091
S-005	0.094	S-101	0.095	S-158	0.119	S-195	0.080
S-006	0.087	S-106	0.116	S-160	0.092	S-200	0.092
S-008	0.083	S-111	0.092	S-163	0.083	S-203	0.075
S-011	0.096	S-113	0.103	S-164	0.090	S-206	0.084
S-017	0.105	S-115	0.097	S-165	0.102	S-209	0.079
S-022	0.117	S-125	0.132	S-168	0.106	S-212	0.093
S-035	0.110	S-129	0.111	S-169	0.076	S-213	0.101
S-038	0.067	S-131	0.103	S-170	0.066	S-214	0.083
S-064	0.100	S-137	0.115	S-176	0.078	S-217	0.138
S-070	0.103	S-139	0.084	S-178	0.099	C.W (c)	0.066
S-075	0.082	S-140	0.106	S-180	0.102	Gosho (c)	0.156
S-082	0.103	S-145	0.134	S-181	0.103	Roko (c)	0.088
S-085	0.128	S-150	0.066	S-184	0.099	Mean	0.099
S-86	0.097	S-152	0.131	S-185	0.084	F test	**
S-090	0.118	S-155	0.108	S-186	0.113	CD at 5%	0.013

Table 11: Moisture retention capacity (%) -mean of two years

Selections	Moisture retention capacity (%)	Selections	Moisture retention capacity (%)	Selections	Moisture retention capacity (%)	Selections	Moisture retention capacity (%))
S-004	87.13	S-099	90.39	S-157	89.04	S-193	89.93
S-005	87.73	S-101	88.69	S-158	90.64	S-195	89.41
S-006	89.28	S-106	90.41	S-160	86.19	S-200	90.68
S-008	89.19	S-111	88.27	S-163	89.39	S-203	87.68
S-011	89.41	S-113	89.87	S-164	89.76	S-206	89.20
S-017	89.61	S-115	89.12	S-165	87.93	S-209	88.51
S-022	90.86	S-125	90.22	S-168	91.04	S-212	88.99
S-035	90.86	S-129	89.92	S-169	87.04	S-213	91.21
S-038	88.31	S-131	87.86	S-170	88.03	S-214	88.38
S-064	90.14	S-137	89.77	S-176	88.17	S-217	89.51
S-070	89.04	S-139	87.65	S-178	88.78	C.W (c)	86.11
S-075	89.91	S-140	89.64	S-180	89.63	Gosho (c)	91.26
S-082	88.61	S-145	90.78	S-181	90.10	Roko (c)	87.19
S-085	90.93	S-150	88.42	S-184	88.82	Mean	89.23
S-86	91.05	S-152	90.16	S-185	87.26	F test	**
S-090	89.49	S-155	89.80	S-186	90.48	CD at 5%	1.66

Table 12: Percentage of total branches infested by stem canker (mean of two years)

Selections	Percentage infestation	Selections	Percentage infestation	Selections	Percentage infestation	Selections	Percentage infestation
S-004	0.00	S-099	6.75	S-157	1.70	S-193	0.00
S-005	14.45	S-101	6.07	S-158	0.00	S-195	4.79
S-006	2.48	S-106	0.74	S-160	11.13	S-200	0.70
S-008	0.74	S-111	0.00	S-163	6.23	S-203	0.00
S-011	15.01	S-113	0.00	S-164	2.50	S-206	1.33
S-017	0.00	S-115	3.45	S-165	3.22	S-209	17.35
S-022	0.00	S-125	6.23	S-168	0.83	S-212	0.83
S-035	0.00	S-129	7.47	S-169	0.00	S-213	3.96
S-038	0.00	S-131	2.26	S-170	4.92	S-214	0.89
S-064	4.70	S-137	9.12	S-176	8.90	S-217	0.00
S-070	0.00	S-139	22.96	S-178	4.04	C.W (c)	37.44
S-075	0.00	S-140	2.60	S-180	0.74	Gosho (c)	0.00
S-082	0.66	S-145	0.00	S-181	0.66	Roko (c)	0.00
S-085	3.69	S-150	2.31	S-184	28.11	Mean	4.35
S-86	0.70	S-152	0.00	S-185	7.63	F test	**
S-090	1.80	S-155	0.00	S-186	3.23	CD at 5%	4.20

Table 13: Sprouting ability (%) of cuttings mean of two years

Selections	Sprouting ability (%)	Selections	Sprouting ability (%)	Selections	Sprouting ability (%)	Selections	Sprouting ability (%)
Selections	Sprouting ability (%)	Selections	Sprouting ability (%)	Selections	Sprouting ability (%)	Selections	Sprouting ability (%)
S-004	98.34	S-099	100.00	S-157	99.17	S-193	99.17
S-005	99.17	S-101	99.17	S-158	100.00	S-195	96.67
S-006	97.50	S-106	95.00	S-160	98.33	S-200	95.83
S-008	99.17	S-111	95.00	S-163	98.34	S-203	98.33
S-011	93.33	S-113	95.83	S-164	96.67	S-206	99.17
S-017	98.33	S-115	99.17	S-165	100.00	S-209	98.33
S-022	96.67	S-125	93.34	S-168	96.67	S-212	97.50
S-035	99.17	S-129	97.50	S-169	97.50	S-213	97.50
S-038	100.00	S-131	97.50	S-170	98.34	S-214	97.50
S-064	93.33	S-137	98.34	S-176	97.50	S-217	99.17
S-070	98.34	S-139	100.00	S-178	99.17	C.W (c)	83.33
S-075	98.33	S-140	98.34	S-180	96.67	Mean	97.44
S-082	100.00	S-145	100.00	S-181	99.17	F test	**
S-085	100.00	S-150	93.33	S-184	89.17	CD at 5%	3.97
S-86	100.00	S-152	99.17	S-185	98.33		
S-090	96.67	S-155	99.17	S-186	99.17		

Table 14: Rooting ability (%) mean of two years

Selections	Rooting ability (%)	Selections	Rooting ability (%)	Selections	Rooting ability (%)	Selections	Rooting ability (%)
S-004	41.67	S-099	84.17	S-157	71.67	S-193	74.17
S-005	99.17	S-101	88.33	S-158	50.00	S-195	83.33
S-006	75.83	S-106	80.83	S-160	90.00	S-200	40.00
S-008	85.83	S-111	84.17	S-163	70.00	S-203	87.50
S-011	57.50	S-113	79.17	S-164	68.33	S-206	95.83
S-017	22.50	S-115	67.50	S-165	85.00	S-209	65.83
S-022	90.00	S-125	30.00	S-168	90.83	S-212	78.33
S-035	73.33	S-129	44.17	S-169	70.00	S-213	79.17
S-038	48.33	S-131	84.17	S-170	77.50	S-214	44.17
S-064	68.33	S-137	34.17	S-176	44.17	S-217	95.83
S-070	95.83	S-139	85.00	S-178	86.67	C.W (c)	79.17
S-075	90.00	S-140	95.00	3.687	92.50	Mean	74.22
S-082	80.00	S-145	95.00	S-181	95.00	F test	**
S-085	76.67	S-150	82.50	S-184	59.17	CD at 5%	10.88
S-86	85.83	S-152	96.67	S-185	68.33		
S-090	44.17	S-155	91.67	S-186	79.17		

Table 15: Leaf shedding as on 1st October (mean of two years)

Selections	Leaf shedding (%)	Selections	Leaf shedding (%)	Selections	Leaf shedding (%)	Selections	Leaf shedding (%)
S-004	9.16	S-099	7.88	S-157	10.29	S-193	11.61
S-005	22.06	S-101	20.56	S-158	15.29	S-195	16.05
S-006	5.95	S-106	12.90	S-160	20.92	S-200	10.74
S-008	10.45	S-111	9.86	S-163	7.23	S-203	11.25
S-011	16.68	S-113	14.01	S-164	18.84	S-206	20.74
S-017	7.27	S-115	17.78	S-165	21.27	S-209	20.92
S-022	22.40	S-125	15.67	S-168	20.19	S-212	13.74
S-035	9.76	S-129	8.22	S-169	5.34	S-213	9.55
S-038	9.93	S-131	22.83	S-170	6.95	S-214	5.23
S-064	9.86	S-137	25.08	S-176	20.92	S-217	30.81
S-070	13.28	S-139	17.99	S-178	21.34	C.W (c)	18.69
S-075	17.24	S-140	12.18	S-180	29.33	Gosho (c)	18.78
S-082	17.80	S-145	16.26	S-181	20.06	Roko (c)	7.48
S-085	11.82	S-150	8.54	S-184	16.02	Mean	14.92
S-86	21.74	S-152	14.34	S-185	9.81	F test	**
S-090	10.42	S-155	17.07	S-186	13.61	CD at 5%	4.62

Table 16: Frost damage (%) - mean of two years

Selections	Frost damage (%)	Selections	Frost damage (%)	Selections	Frost damage (%)	Selections	Frost damage (%)
S-004	8.07	S-099	10.75	S-157	30.80	S-193	6.54
S-005	19.15	S-101	19.38	S-158	17.80	S-195	24.34
S-006	24.36	S-106	9.96	S-160	31.63	S-200	15.95
S-008	12.03	S-111	7.03	S-163	14.53	S-203	5.15
S-011	37.46	S-113	9.77	S-164	12.80	S-206	8.83
S-017	22.49	S-115	9.54	S-165	18.57	S-209	18.02
S-022	15.63	S-125	25.04	S-168	26.85	S-212	6.74
S-035	28.80	S-129	17.52	S-169	18.58	S-213	7.60
S-038	8.44	S-131	12.66	S-170	13.14	S-214	14.16
S-064	21.95	S-137	30.53	S-176	9.52	S-217	5.96
S-070	9.58	S-139	24.50	S-178	32.92	C.W (c)	23.38
S-075	30.14	S-140	13.07	S-180	17.65	Gosho (c)	38.06
S-082	12.71	S-145	5.58	S-181	25.14	Roko (c)	9.45
S-085	20.24	S-150	25.98	S-184	26.49	Mean	17.40
S-86	33.37	S-152	11.25	S-185	12.30	F test	**
S-090	9.82	S-155	9.76	S-186	11.98	CD at 5%	7.87

Table 17: Earliness of sprouting of winter buds (mean of two years)

Selections	Sprouting of winter buds by march end	Selections	Sprouting of winter buds by march end	Selections	Sprouting of winter buds by march end	Selections	Sprouting of winter buds by march end
S-004	58.00	S-099	17.00	S-157	47.45	S-193	60.47
S-005	37.15	S-101	43.16	S-158	25.86	S-195	21.79
S-006	11.74	S-106	58.04	S-160	52.35	S-200	18.54
S-008	62.74	S-111	21.52	S-163	69.52	S-203	35.69
S-011	50.07	S-113	35.02	S-164	34.02	S-206	58.99
S-017	11.33	S-115	25.91	S-165	47.36	S-209	54.26
S-022	31.23	S-125	29.52	S-168	46.59	S-212	51.91
S-035	33.89	S-129	47.50	S-169	34.38	S-213	56.49
S-038	26.44	S-131	55.60	S-170	70.25	S-214	37.16
S-064	41.91	S-137	56.44	S-176	45.01	S-217	27.17
S-070	56.25	S-139	50.37	S-178	30.44	C.W (c)	57.30
S-075	38.70	S-140	54.79	S-180	34.40	Gosho (c)	1.11
S-082	52.82	S-145	30.10	S-181	15.30	Roko (c)	1.61
S-085	49.90	S-150	39.05	S-184	20.60	Mean	39.27
S-86	15.82	S-152	48.59	S-185	46.36	F test	**
S-090	10.13	S-155	42.86	S-186	49.34	CD at 5%	9.82

Table 18: Maximum sprouting of winter buds (mean of two years)

Selections	Maximum sprouting of winter buds (%)	Selections	Maximum sprouting of winter buds (%)	Selections	Maximum sprouting of winter buds (%)	Selections	Maximum sprouting of winter buds (%)
S-004	88.17	S-099	73.21	S-157	87.20	S-193	81.29
S-005	82.63	S-101	76.45	S-158	78.52	S-195	74.56
S-006	69.57	S-106	81.73	S-160	84.74	S-200	87.37
S-008	91.06	S-111	80.50	S-163	95.54	S-203	84.77
S-011	79.11	S-113	85.87	S-164	63.21	S-206	91.01
S-017	78.84	S-115	79.03	S-165	77.59	S-209	88.84
S-022	72.71	S-125	75.45	S-168	90.98	S-212	84.20
S-035	84.75	S-129	82.38	S-169	86.44	S-213	88.81
S-038	91.22	S-131	88.68	S-170	91.90	S-214	88.16
S-064	94.35	S-137	83.77	S-176	85.22	S-217	88.80
S-070	87.65	S-139	92.73	S-178	70.45	C.W (c)	85.67
S-075	78.59	S-140	83.69	S-180	62.35	Gosho (c)	73.99
S-082	82.80	S-145	85.88	S-181	68.36	Roko (c)	84.17
S-085	82.42	S-150	88.78	S-184	80.09	Mean	82.15
S-86	73.96	S-152	74.03	S-185	76.85	F test	**
S-090	80.21	S-155	82.22	S-186	77.58	CD at 5%	7.80

Table 19: Leaf area (cm) in last week of April (mean of two years)

Selections	Leaf area (cm)	Selections	Leaf area (cm)	Selections	Leaf area (cm)	Selections	Leaf area (cm)
S-004	59.89	S-099	131.67	S-157	84.29	S-193	104.77
S-005	96.81	S-101	87.15	S-158	140.08	S-195	105.61
S-006	105.17	S-106	115.42	S-160	85.25	S-200	101.82
S-008	85.84	S-111	100.78	S-163	64.07	S-203	70.46
S-011	85.77	S-113	145.81	S-164	96.55	S-206	105.64
S-017	99.33	S-115	75.96	S-165	90.02	S-209	87.41
S-022	103.88	S-125	105.38	S-168	110.12	S-212	77.11
S-035	100.38	S-129	109.07	S-169	73.85	S-213	82.55
S-038	47.49	S-131	95.68	S-170	45.15	S-214	93.07
S-064	118.10	S-137	114.86	S-176	70.74	S-217	105.82
S-070	107.50	S-139	61.32	S-178	87.43	C.W (c)	70.05
S-075	88.25	S-140	110.82	S-180	109.53	Gosho (c)	132.48
S-082	102.91	S-145	133.68	S-181	96.42	Roko (c)	74.53
S-085	125.48	S-150	76.71	S-184	111.23	Mean	97.09
S-86	97.08	S-152	115.10	S-185	91.36	F test	**
S-090	110.27	S-155	103.43	S-186	138.42	CD at 5%	15.71

Table 20: Average Evaluation Index (EI) of selections based on mean values of two years of 15 characters

Selections	Average EI	Selections	Average EI	Selections	Average EI	Selections	Average EI
S-004	50	S-099	52	S-157	49	S-193	52
S-005	48	S-101	47	S-158	54	S-195	48
S-006	46	S-106	57	S-160	48	S-200	48
S-008	49	S-111	48	S-163	51	S-203	49
S-011	50	S-113	51	S-164	47	S-206	52
S-017	51	S-115	49	S-165	51	S-209	47
S-022	51	S-125	49	S-168	52	S-212	52
S-035	51	S-129	47	S-169	49	S-213	54
S-038	54	S-131	51	S-170	46	S-214	51
S-064	50	S-137	53	S-176	47	S-217	53
S-070	52	S-139	48	S-178	45	C.W (c)	39
S-075	49	S-140	56	S-180	48	Gosho (c)	51
S-082	51	S-145	56	S-181	49	Roko (c)	48
S-085	55	S-150	47	S-184	48		
S-86	50	S-152	53	S-185	48		
S-090	50	S-155	50	S-186	54		

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 16-19

EVALUTION OF MULBERRY VARIETY G2 FOR COMMERCIAL CHAWKI REARING

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ABSTRACT

The concept of commercial chawki rearing centers (CRCs) is well received by the farmers and many government and private CRCs have found favour with the farmers. Exclusive chawki mulberry garden and chawki rearing are the two important aspects of CRC, which in turn decide the growth, health, robustness of silkworms and quality of cocoon crop. A chawki garden with G2 variety was established in two acres with (120 +90) × 60 cm spacing. From 2009, the leaves were regularly used for chawki rearing of both cross breed and bivoltine silkworm races. The plantation was maintained adopting the package of practices recommended for chawki mulberry garden. Data on leaf yield, leaf moisture content, moisture retaining capacity, protein and sugars were recorded by following standard methods. Chawki silkworm growth parameters like weight of 100 larvae at the second moult, missing larval percentage were recorded periodically for two years. The chawki leaf yield was found to be 35 MT/ha/year and 62,000 dfls of both bivoltine and cross breed were chawki reared in one year per acre. The performance of this new variety was found to be promising and has been attracting the attention of farmers and other CRC entrepreneurs. Chawki leaves could be harvested from 35 days after pruning. Though peeling of bark during leaf harvest is frequently noticed, it did not affect the plant growth.

Key words: Chawki rearing centers, Growth parameters, Mulberry evaluation

INTRODUCTION

Among the technologies introduced in the field, concept of chawki rearing in commercial chawki rearing centres (CRC) found favour with both bivoltine and multivoltine silkworm rearers (Rajarajan and Balakrishna, 2011). Exclusive chawki mulberry garden and chawki rearing are the two important aspects of CRC, which in turn decides the growth of late age worms, their health, robustness and quality of cocoon crop. This is more so in case of bivoltine silkworms, as they are basically from temperate belt but being raised in sub-tropical conditions. Therefore, the quality of feed and greater assimilation of the nutrients is very important. The varieties should also have fast growth, good rooting and adaptability to the given conditions. To fulfill such requirements, development of mulberry varieties, which have genetic potential for high chawki leaf yield and nutritional supremacy is very essential.

Mishra *et al*., (1996) have recommended exclusive cultivation package for chawki rearing with Kanva-2 variety. Based on screening of existing varieties, some recommendations have been made to the effect that mulberry varieties S36 and V1 could be used for chawki rearing and V1 for late age rearing (Sarkar *et al.*, 2003). Keeping in view the demands of bivoltine sericulture industry, such as better quality mulberry leaves for effective young age silkworm rearing especially in CRCs, long term breeding approach was undertaken at CSRTI, Mysore and mulberry variety G2 has been identified as suitable for young age silkworm rearing (Mogili *et. al.*, 2005). In the present study, G2 variety has been evaluated in a private CRC along with existing S36 and V1 mulberry varieties to test verify its performance in terms of leaf quality, productivity, and feeding ability in commercial chawki rearing centre.

MATERIALS AND METHODS

The evaluation was conducted at Cheekuladinnepalle village CRC. Seed material of G2 was supplied during February, 2008. The plantation was established in two acres during July-August 2008 with (120 + 90) × 60 cm spacing to facilitate cultivation using power tiller. The plantation was maintained following the package of practices recommended for chawki mulberry garden *i.e*., FYM @ 40MT/ha/year; N: P: K @ 260:140:140 kg/ha/year. Irrigation was provided through drip system @ 3.75 ha cm per irrigation. Along with this new plantation, the entrepreneur has maintained 2 acres of V1 plantation and one acre of S36 plantation under similar cultivation practices. After the establishment, the leaves were regularly used for chawki rearing since January 2009. For harvesting of leaves, 8 crop schedule per year with alternate leaf picking and shoot let harvesting method as recommended by the CSRTI, Mysore was adopted (Mishra *et al*., 1996). Seven replications were maintained per variety in one acre plantation of each variety, for recording data.

To assess quality, the leaf samples were analyzed for moisture content, moisture retaining capacity, nitrogen, potassium, phosphorus, protein, sugars, total carbohydrates and fibre contents on dry weight basis by adopting standard methods. Ten silkworm feeding trials were conducted to ascertain the leaf quality using bivoltine silkworm hybrid (CSR F1) in terms of moulting test and chawki rearing. All the data collected were subjected to statistical analysis to study the variation among the three varieties.

RESULTS

The data on average leaf yield and yield contributing parameters are presented in Table 1. Data indicated that variety G2, a hybrid of *Morus multicaulis* x S-34 was significantly superior in chawki leaf yield (35,350 kg/ha/year) over S36 (25,495 kg/ha/year) by 38.6% and V1 (28,880 kg/ha/year) by 22.4%. The variety G2 also exhibited significantly higher values for average total shoot length/plant, leaf area and leaf area index over S36 and V1 mulberry varieties. Variety G2 exhibited faster sprouting, higher growth rate during early stages and lower rate of winter dormancy and higher rooting ability over S36 variety. The G2 variety exhibited distinctly larger leaves at 25 days after pruning in comparison to V1, where the early stage growth rate and leaf sizes were smaller.

The chemical composition of leaves of the G2 variety along with S36 and V1 is presented in Table 2. A perusal of data indicates that G2 variety recorded significantly higher contents of nitrogen, proteins and total sugars, in comparison to S36. The other parameters like phosphorus, potassium and fibre contents found at par in G2, S36 and V1 varieties.

The moulting test results indicated that G2 variety, though not significant, exhibited higher moulting percent and higher larval weight after coming out of first moult (Table 3). The chawki rearing results also indicated that G2 is on par in moulting percentage to both S36 and V1 (Table 4) and recorded significantly higher larval weight in comparison to both the check varieties.

DISCUSSION

The varieties like Kanva-2, S36 and V1 are presently cultivated for young age silkworm rearing. The Kanva-2 is a low yielder as well as inferior in leaf quality and its cultivation is gradually decreasing. Though S36 is superior in leaf quality and suitable for young age silkworm rearing, the yield level at chawki stage is quite low. More over, lower rate of rooting and higher dormancy in winter months are hindering its popularity. Though, V1 variety is recommended for both young age and late age silkworm rearings, lower growth rate at early stage coupled with smaller leaf size affects harvesting and CRC owners prefer to use the top leaves from grown up V1 plants.

The newly recommended G2 variety bred exclusively for chawki gardens (CRCs) exhibited significant increase in chawki leaf yield with marginal improvement in quality in terms of chemical composition of leaves, moulting and chawki rearing.

G2 variety recoded higher growth and leaf yield and quality attributing parameters like, total shoot length, leaf area, leaf area index, weight of 100 leaves, moisture content and moisture retaining capacity. The variety exhibited faster growth and larger leaves at early growth stage (25 to 40 days after pruning). It also exhibited lower rate of dormancy during winter, which is a favourable season for bivoltine rearing. Because of the higher chawki leaf production in G2, the variety is cost effective (Table 5). The partial budgeting made for comparing G2 indicated that G2 produces 9855 kg more chawki leaf yield than S36 and 6550 kg per hectare than V1 variety, which resulted in additional brushing of 43,963 dfls over S36 and 31,900 dfls over V1 in the chawki centre. The net gain with respect to G2 variety found high in comparison to S36 and V1.

The growth of silkworm larvae and moulting period are influenced by the nutritional level of mulberry feed. The quality of leaves fed to young age worms is of great relevance in view of its influence during the late age and ultimately on cocoon crop. The moulting test is one of the straight and sure methods of evaluating quality of mulberry leaves (Benchamin and Anantharaman, 1990; Rahman *et al*., 2002).

In addition to moulting test and chawki rearing, dependable characters like leaf moisture percentage, moisture retaining capacity, nitrogen, protein contents, sugars, total carbohydrate contents are also considered for

nutritional evaluation (Sujathamma and Dandin, 2000). Healthier and robust young age worms reared on leaves rich in carbohydrates are reported to be more resistant to disease in later stages (Watanabe and Imanishi, 1980). For young age, the leaves should be soft, succulent, rich in protein, sugar contents (Gabriel and Rapsuas, 1976) whereas for late age, mature and less succulent leaves are ideal (Krishnaswami, 1980).

The G2 variety recommended for exclusive chawki gardens (CRCs) exhibited significant increase in chawki leaf yield with marginal improvement in quality. This will directly help to improve the efficiency of chawki rearing centre to rear higher quantity of chawki worms with additional profits (Srinivasulu Reddy *et al.,* 2010). This technology alone will make CRC business more profitable and ensure higher cocoon crop at farmers' level.

Table 1: Chawki leaf yield, brushing capacity and yield contributing parameters of G2 and check varieties.

Parameter	S36 *	V1 (S-30 x Ber. C776)	G2 (*M. multi-caulis* x S-34)	CD at 5%	CV (%)
Chawki leaf yield kg/ha/year	25495	28800	35350	1445	3.52
No. of silkworm dfls brushed/acre/year	46686	59168	64272		
Moisture content (%)	78.7	79.2	79.1	NS	1.62
Moisture retaining capacity after 6h (%)	82.7	83.2	83.1	NS	2.25
Avg.total shoot length/plant (cm)	246	358	392	11.9	3.8
Avg. leaf yield/plant /crop (g)	201	227	279	10.6	3.7
Avg. leaf area/plant (cm^2)	11416	11443	14878	572.6	4.4
Leaf area index/plant	1.81	1.82	2.36	0.02	0.81
Weight of 100 leaves (g)	91.3	66.6	129.3	9.2	4.1

* Mutant derived from Berhampore local

Table 2: Biochemical parameters of G2 in comparison with S36 & V1

Character	S36	V1	G2	CD at 5%	CV %
Nitrogen (%)	3.98	4.1	4.2	0.021	1.44
Phosphorus (%)	0.31	0.3	0.2	0.074	2.13
Potassium (%)	2.19	2.1	2.2	0.416	1.15
Proteins (%)	25.2	26.2	26.3	0.138	1.48
Total sugars (%)	11.6	12.1	12.4	0.326	2.20
Total carbohydrates (%)	24.4	24.2	23.9	0.525	2.33
Fibre (%)	10.6	10.7	10.7	0.162	1.26

Table 3: Moulting percentage after 1st moult (CSR F1 hybrid)

Variety	Moulting %	Weight of 25 larvae after 1st moult
S36	85.8	0.101
V1	86.5	0.122
G2	87.8	0.126
CD at 5%	NS	NS
CV %	8.2	5.4

Table 4: Young age silkworm rearing results.

Variety	Moulting %	Weight of 100 larvae (g) (after 2nd moult)
S36	97.4	3.656
V1	96.2	3.725
G2	97.2	3.925
CD at 5%	NS	0.017
CV %	1.28	3.75

Table 5: Economic superiority of G2 chawki garden for CRC (ha/year)

Superiority of G2 over -	Additional leaf yield (kg)	Additional quantity of DFLs brushed	*Additional income generated (Rs.)	Net gain (Rs.)
S36	9855	43,963	2,41,799	1,45,080
V1	6550	31,900	1,75,450	1,05,270

* Leaf requirement @ 22 kg / 100 dfls : Chawki rearing charges @ Rs. 550 / 100 dfls and expenditures @ Rs. 220 / 100 dfls

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 20-23

HIGH FREQUENCY ADVENTITIOUS BUD INDUCTION AND PLANT REGENERATION FROM LEAF EXPLANTS OF MULBERRY (*MORUS SPP.*) GENOTYPES

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ABSTRACT

A reliable protocol for induction of adventitious buds and plantlets from leaf explants of promising mulberry genotypes *viz*., V-1, S-13, S-34, S-36 and AR-12 at high frequency was developed. The leaf explants were cultured on Murashige and Skoog's (MS) medium and on MS medium modified by altering the nitrogen ratio, supplementing with thidiazuron (TDZ), 6-benzylaminopurine (BAP), indole acetic acid (IAA), abscisic acid (ABA), gibberlic acid (GA_3), silver nitrate ($AgNO_3$) and carbon sources *viz*., sucrose, fructose and glucose either individually or in combinations to induce adventitious shoot buds and plant regeneration. The highest percentage (80 %) of adventitious bud formation was achieved in V-1 followed by S-34 (70 %) and S-36 (60 %) on MS medium supplemented with TDZ (1.1mg/l), IAA (2.0 mg/l) and $AgNO_3$ (2.0 mg/l). Whereas, in S-13 and AR-12, an average of 55% and 50 % adventitious bud formation was obtained, respectively on modified MS medium with TDZ (1.0 mg/l) and ABA (1.0 mg/l). The subsequent regeneration and shoot elongation were obtained on the MS + BAP (1.0 mg/l) + GA_3 (2.0 mg/l) + $AgNO_3$ (2.0 mg/l) medium. Among the carbon sources tested, the most suitable was found to be sucrose (3%) followed by fructose (2%) for adventitious bud formation. Excised *in vitro* shoots were rooted in half strength MS basal medium supplemented with indole-3-butyric acid or α-naphthalene acetic acid. The well-rooted plantlets were hardened in soil + sand + FYM mixture with a success rate of 70- 90 %.

Key words: Adventitious buds, Bud induction, Culture medium, Leaf explants, Plant regeneration

INTRODUCTION

Mulberry (*Morus* spp.) is a woody perennial, heterozygous plant with a prolonged juvenile period whose foliage is sole food for the mulberry silkworm (*Bombyx mori.* L). Owing to its long juvenile period and heterozygosity, improvement of specific characters through conventional breeding is rather cumbersome and time consuming. However, incorporation of specific genes encoding desired traits through modern biotechnological methods, such as tissue culture, offers a new avenue for its improvement. Efficient *in vitro* regeneration procedure is a pre-requisite for all kinds of genetic transformation studies.

Extensive studies have been carried out in mulberry on the impact of various growth regulators on *in vitro* organogenesis and plant regeneration by using different explants *viz*., leaf, internodal segment, hypocotyls and cotyledons (Oka and Ohyama, 1981; Narayan *et al*., 1989, Jain and Datta, 1992; Machii 1992; Sreenath Rao and Raghunath, 1993; Sawaguchi *et al*., 1997; Kathiravan *et al*., 1997; Vijayan *et al*., 2000; Kapur *et al.*, 2001; Bhatnagar *et al*., 2001). However, shoot differentiation from callus is confined to few genotypes only and repeatability is not assured due to the recalcitrant nature of the plant.

Of late, thidiazuron (TDZ), a substituted phenyl urea, has been shown to be an efficacious regulator of *in vitro* morphogenesis in many dicot plants, influencing callusing, shoot regeneration, somatic embryogenesis and protoplast division (Khurana *et al*., 2005). In the present investigation, a

repeatable protocol for obtaining high frequencies of adventitious buds induction and plant regeneration from leaf explants of elite mulberry genotypes has been developed.

MATERIALS AND METHODS

Explant preparation and surface sterilization

Fully expanded leaves (2-5th position) were collected from actively growing mulberry plants of five selected promising mulberry genotypes. The explants were thoroughly washed in running tap water for 1 hour, followed by immersion in a 1% (v/v) liquid detergent (Labolene, Qualigenes, India) for 4 5 minutes and again washed thoroughly in running tap water to remove the traces of the detergent. Surface sterilization was done with 0.1% (v/v) HgCl2 (Qualigens, India) for 3-4 minutes and rinsing in sterile distilled water to remove traces of mercuric chloride.

Culture Media for Induction of adventitious shoot buds and plant regeneration

The surface sterilized leaf explants were cultured on Murashige and Skoog's (MS) medium and on MS medium modified by altering the nitrogen ratio (1:0.5, 1:1, 1:2 and 1:3) supplementing with thidiazuron (TDZ) (1.0-2.0 mg/l), 6-benzylaminopurine (BAP) (0.5-2.0 mg/l), indole acetic acid (IAA) (1.0-2.0 mg/l), abscisic acid (ABA) (1.0-2.0 mg/), gibberlic acid (GA3) (1.0-2.0mg/l), silver nitrate ($AgNO_3$) (1.0-2.0 mg/l) and carbon sources *viz*., sucrose, fructose and glucose (1030 %), either individually or in combination to induce adventitious shoot buds. The pH of the medium was adjusted to 5.8 before gelling with 0.8 % Agar-agar (Himedia, India). The initially cultures were maintained at dark for about 30 days to induce shoot buds.

Plant Regeneration medium

The shoot buds were transferred to various shoot induction media supplemented with 6-benzylaminopurine (BAP) (0.5 - 2.0 mg/l), gibberlic acid (GA_3) (1.0 - 2.0mg/l) and silver nitrate ($AgNO_3$) (1.0 2.0 mg/l) for adventitious bud differentiation and shoot formation.

Rooting and hardening

Healthy shoots (3-4 cm in length) derived from leaf explants were transferred to ¼ or ½ strength MS media fortified with NAA or IBA (1.0 mg/l) to induce roots. The well rooted plantlets were gently washed in water to remove the sticking agar from the roots and transferred to soil, sand and farmyard manure (2:1:1) mixture for hardening under controlled conditions.

Culture conditions

The cultures were maintained at 26±2˚C under 16/8 h (day/night) photoperiod with light provided by four cool white fluorescent tubes (Phillips, TL 40 W/54) at a light intensity of 65 m mol/m^2 per second. All the chemicals used were analytical grade (Sigma, Qualigens, Himedia). The medium containing tubes / conical flasks were autoclaved at 104Kpa at 121˚C for 15 minutes.

Data recording

The experiments were repeated thrice and data on callus/adventitious bud formation and regeneration were recorded after 4 and 8 weeks of cultures.

RESULTS AND DISCUSSION

The differential response of leaf explants was observed in different media. The first sign of leaf expansion was observed after 10 to 15 days of initial culture. Thereafter, green adventitious buds formed either on the mid region or more frequently on the basal cut ends of the leaf (Fig. 1). The highest percentage of adventitious bud formation was achieved in V1 (80%) followed by S34 (70%) and S36 (60%) on MS medium supplemented with TDZ (1.1mg/l), IAA (2.0 mg/l) and $AgNO_3$ (2.0 mg/l). In S13 and AR12, an average of 55% and 50% adventitious bud formation was obtained, respectively, on modified MS medium with TDZ (1.0mg/l) and ABA (1.0 mg/l). The adventitious buds were transferred to regeneration and shoot elongation on the MS + BAP (1.0 mg/l) + GA3 (2.0 mg/l) + $AgNO_3$ (2.0 mg/l) medium (Table 1) (Fig. 2). The concentration of inorganic nitrogen considerably affected the formation of adventitious buds. These results confirmed the differential requirement of inorganic nitrogen, phyto- hormonal concentrations and combinations for adventitious bud formation and regeneration among different mulberry genotypes. These results are in agreement with the findings of Yamanouchi *et al*., (1993), Kapur (2001) and Raghunath *et al* ., (2009, 2011).

To investigate the effects of carbohydrate sources on shoot regeneration, different concentrations of sucrose, glucose or fructose were added to the above mentioned MS media. The results indicated that a continuous supply of carbohydrate from the medium is necessary for shoot regeneration. Leaf explants grown on a medium without carbohydrates did not form any callus and adventitious buds. Among the carbon sources tested, the most suitable was found to be sucrose (3%) for shoot bud induction and subsequent regeneration followed by fructose (2%). The results obtained indicated probable effect of sucrose on differentiation by influencing the metabolic activity in the leaf tissue. These result are in conformity with the earlier reports on mulberry (Oka and Ohyama, 1981; Narayan *et al*., 1989; Kapur *et al.,* 2001 and Raghunath *et al*., (2009, 2011).

In vitro raised shoots (3-4 cm) were rooted (60 - 80%) in half strength MS basal medium supplemented with indole-3-butyric acid or α-naphthalene acetic acid (1.0 mg/l) (Fig. 3). After three weeks of culture in rooting medium, the rooted plantlets were transferred to the soil + sand + FYM mixture.




Fig. 1.Adventitious bud formation from the leaf explants

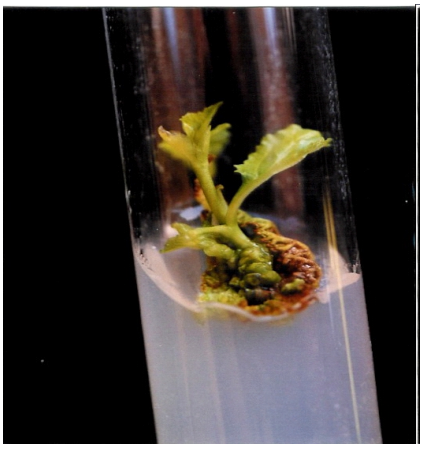



Fig. 2. Regeneration of shootlets

Fig 3. Rooting of regenerated shoot from adventitious buds




Fig. 4. Hardening of rooted plants and plants ready for field transfer

During the first two weeks, relative humidity of >80% was maintained. Under these conditions, 70 90 % of plantlets survived and resumed normal growth (Fig. 4).

CONCLUSION

High frequencies of adventitious bud from leaf explants of five selected promising mulberry genotypes was achieved. The ratio of nitrogen, concentrations and combinations of phyto-hormones in the MS medium contributed significantly in formation of adventitious buds. MS medium with suitable BAP, GA_3 and $AgNO_3$ combination were found necessary for the desirable shoot regeneration from adventitious buds. Among different sugars, sucrose was found to be best for promoting adventitious bud formation and shoot regeneration. The findings demonstrated that *in vitro* leaf explant is suitable for

Table 1: Response of leaf explants cultures of elite mulberry genotypes.

Medium	V1		S34		S36		S13		AR12	
	ABC (%)	RG (%)	ABC (%)	RG (%)	ABC (%)	RG (%)	ABC (%)	RG (%)	ABC (%)	RG (%)
A	80.00	60.00	70.00	55.00	60.00	35.00	25.00	00.00	45.00	15.00
B	45.00	00.00	55.00	10.00	30.00	00.00	20.00	00.00	30.00	10.00
C	45.00	25.00	45.00	30.00	30.00	10.00	00.00	00.00	40.00	00.00
D	55.00	00.00	25.00	00.00	40.00	00.00	30.00	00.00	30.00	00.00
E	45.00	15.00	55.00	25.00	45.00	15.00	55.00	35.00	50.00	35.00
F	55.00	25.00	45.00	30.00	20.00	00.00	20.00	00.00	20.00	00.00
G	25.00	00.00	10.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00

ABC (%): Adventitious bud callus (%),
RG (%): Regeneration (%),
A: MS+ TDZ (1.1 mg/l) + IAA (2 mg/l) + Ag NO3 (2 mg/l),
B: MS + TDZ (1mg/l) + ABA (1mg/l) + Sucrose + Fructose (1:1),
C: MS + TDZ (1mg/l) + ABA (1 mg/l) + Fructose (2 %),
D: MS + TDZ (1mg/l) + ABA (1 mg/l)) + Sucrose + Fructose (3%),
E: Mod. MS (1: 0.5) + TDZ (1.0mg/l) + ABA (1mg/l) + Fructose (2%),
F: Mod. MS (1: 1) + TDZ (1mg/l) + ABA (1mg/l) + Fructose (2%),
G: MS +TDZ (1 mg/l)) + Sucrose (15g/l) + Glucose (15g/l)

adventitious shoot organogenesis, which will be useful for further genetic transformation and advanced biotechnological studies.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 24-27

SODIUM: POTASSIUM RATIO AS AN INDEX FOR DETERMINING ALKALINITY TOLERANCE IN MULBERRY

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ABSTRACT

Mulberry cultivation occupies about 1.6 lakh hectares of cultivable area in India. Expansion of area under mulberry is a quicker and easier option for growth of sericulture provided, suitable additional land is available. At present, the growing demand for food crops and increasing population leave little scope of replacing food crops with mulberry in the available arable land. Four genotypes of mulberry, AR-12, AR-11, G-2 and V-1were grown in Wagner's pots under three different simulated soil alkalinity levels based on pH *viz*., T-1 Normal pH (7.0), T-2 Medium pH (8.5) and T-3 High pH (9.2) at the Central Sericultural Research & Training Institute, Mysore. Sodium and Potassium contents were estimated in leaves, stem and roots of all the four genotypes after 70 days. The increase in sodium content and decrease of potassium content in all the plant parts resulted in increase of Na: K ratio with the increase in alkalinity. Significant differences were observed among the genotypes for levels of Sodium and Potassium. Among the tested genotypes, AR-12 exhibited comparatively lower Na: K ratio in all the plant parts followed by AR-11, G-2 and V-1. The lower ratios in the tolerant genotype indicate selective uptake and transport and preferential partitioning of minerals. The relatively lower Na: K ratios might have contributed to more tolerance to alkalinity in AR-12, which paves the way for its use as a source of alkalinity tolerance or for commercial exploitation.

Key words: Alkalinity tolerance, Differential uptake, Mulberry, Na: K ratio

INTRODUCTION

India has about 1.6 lakh hectares of land under mulberry cultivation. Expansion of area under mulberry is a quicker and easier option for growth of sericulture provided, suitable additional land is available. Nearly ten million hectares of land in India is affected by soil salinity or alkalinity. Soil alkalinity condition affects nearly 5.5 million hectares of potential agricultural land, out of which, nearly 0.7 million hectares is in South India.

These soils contain excessive concentrations of exchangeable sodium carbonates (ESP) of more than 15 that usually exceeds 30% of the soil cat-ion exchangeable capacity, high pH of more than 8.5 and electrical conductivity (EC) of saturated extract of less than 4 mmhos/cm, which affects both the physical and nutritional properties of the soil and thus inhospitable for plant growth.

Soil alkalinity reduces plant growth because of the osmotic effect. Oxidative stress is a major damaging factor in plants exposed to alkalinity/salinity. Drastic reduction in plant growth is associated with large sodium accumulation in shoot resulting in cationic imbalance (Ayoub and Ishag, 1974).

Various studies have exhibited the vast scope of genetic improvement or critical assessment of inter-varietal genetic variability and its exploitation for improving salt tolerance in crops by screening them in salt affected soils (Levitt, 1980; Epstein, 1985; Ashraf and McNeilly, 1990).

Salt tolerance/salt stress resistance denotes a plants ability to prevent, reduce or overcome the possible injurious effects caused directly by the excessive presence of soluble salts/toxic ions in its root zone (Rana, 1986).

Genetic improvement of salt tolerance in crops is more effective, less costly, non-polluting and longer lasting

(Epstein *et al*., 1980, Downton, 1984). Several reports available on this aspect have emphasized the need to develop improved crop varieties best suited to specific adverse soil conditions (Wright 1976; Muhammed *et al*., 1977; Jung, 1978; Christiansen and Lewis, 1982; Stamples and Toenniessen, 1984).

The present study was undertaken to study the variation in the sodium and potassium levels in different plant parts of mulberry to understand their tolerance level.

MATERIALS AND METHODS

Established saplings of uniform size and thickness of genotypes, AR-12, V-1, G-2, and AR-11 in Wagner pots. The treatments comprised three levels of pH, *viz*.; T_1: Control (7.3), T_2: medium alkalinity (8.5) and T_3: high alkalinity (9.2).

The experiment was laid out in Randomized Block Design (RBD). Three replications were considered per variety for each treatment. The chemical analysis of soil with different levels of alkalinity was done at the beginning of the experiment and periodically to maintain the conditions.

Parameters	Control	Medium alkalinity	High alkalinity
pH	7.3	8.5	9.2
EC mmho/cm	0.65	0.79	0.92
Exchangeable sodium %	4.76	18.6	36.4
Na adsorption ratio (%)	3.5	12.5	18.6
Nitrogen (kg/ha)	240	190	140
Phosphorus (kg/ha)	20.2	10.6	7.2
Potassium (kg/ha)	312	450	470
Organic carbon (%)	0.55	0.38	0.24

The potassium and sodium content in leaf, stem and root of all genotypes under all treatments was estimated after 70 days of imposing the treatments. Flame photometry method was used for estimation of potassium (Tandon, 1993). Potassium content in the samples was calculated by the formula:

$$K\ (\%) = \frac{\text{Graph value}}{\text{Wt. of sample}} \times \text{Sample vol.} \times \frac{100}{10^6}$$

The sodium content was estimated using flame photometer method (Tandon, 1993). The sodium content of the sample was estimated by using the formula:

$$Na\ (\%) = \frac{\text{Graph value}}{\text{Wt. of sample}} \times \text{Sample vol.} \times \frac{100}{10^6}$$

The ratio between the Sodium and potassium content in leaves, root, stem and mean of leaf, root and stem were calculated and the data were statistically analyzed. The differences among the genotypes were tested for significance by using analysis of variance (Panse and Sukhatme, 1967).

RESULTS

Na:K ratio in leaves, stem, roots and mean of leaves, stem and root of different mulberry genotypes under control and alkalinity stress condition are presented in Tables 1 to 4. The data indicated that significant variability existed among the genotypes and between the treatments for Na: K ratio in all plant parts. The variable response of different mulberry genotypes at different levels of alkalinity were evident from the significant interaction between mulberry genotypes and alkalinity levels. In general, the Na: K values were lower in leaves and higher in roots. In all the plant parts, Na: K values increased significantly with increase in alkalinity level.

Under control conditions, AR-12 exhibited lower Na: K values in leaves and the same trend was recorded in medium and high alkalinity levels. The genotype means also indicated significant differences and AR-12 recorded lower value of 0.036, followed by AR-11 (0.038), V-1 and G-2 (0.041). Genotype AR-12 recorded significantly lower Na: K values in roots, which increased with increase in alkalinity stress. The genotype means also exhibited significant differences among the genotypes and V-1 recorded higher value (1.279) followed by G-2 (1.096), AR-11 (1.065) and AR-12 (0.702). The average values of Na: K ratios in leaves, stem and root also exhibited significant variability among the genotypes and between treatments. The mean values also indicated significantly lower values in AR-12 (0.808) under control and both the alkalinity levels studied followed by AR-11 (1.184), G-2 (1.227) and V-1 (1.411). The differential responses of different mulberry genotypes to different levels of alkalinity *viz.,* control (normal) medium and high were evidenced with significant interaction between mulberry genotypes and alkalinity levels.

DISCUSSION

Sodium absorption in response to alkalinity, increased with increase in alkalinity level and more distinct in roots. Since root is the primary organ, confronting the salt effect directly, sodium was more in roots and its translocation to the leaf remained low. Sodium concentration increased under alkalinity in all plant parts irrespective of genotypes.

Genotype AR-12 showed less rate of absorption of Na in comparison to other genotypes. Leaves generally accumulated more K than roots and the content decreased with increase in alkalinity. AR-12 recorded comparatively lower content of sodium and chlorides and higher amount of K in all plant parts, though with gradual change from control to high alkalinity. In general, the calcium content increased at medium alkalinity and decreased at higher alkalinity in all the parts. The chlorides increased in all the plant parts, with increase in alkalinity.

Increasing sodium and decreasing calcium, magnesium and potassium contents were recorded in Para grass, wheat, barley, gram, ladyfinger and daincha by many authors. Singh et al., (1980) observed increase in ESP, increased sodium, decreased calcium and magnesium content but had no effect on potassium and phosphorous content of the plant. Ali-Qadar and Azam (2007) evaluated the response of rice (Oryza sativa L.) genotypes as basis for sodicity tolerance and observed increase in sodium and decrease in potassium in all varieties with increasing sodicity stress.

Tolerant varieties had low sodium, low Na: K ratio and high potassium, but not without overlapping response. Joshi *et al.,* (1979 & 1980) studied differential sodium and potassium accumulation related to sodicity tolerance in wheat and observed that the Na: K index of shoots growing under sodic stress might be used to predict the tolerance or sensitivity of wheat varieties. The increase in Na content and decrease of K content in all the plant parts in response to increase in alkalinity level consequently resulted in increase of Na: K ratio with the increase in alkalinity.

Among the tested genotypes, genotype AR-12 exhibited comparatively lower Na: K ratio in respective alkalinity levels in all plant parts followed by AR-11, G-2 and V-1. The lower ratios in the tolerant genotype indicate the selective uptake and transport and preferential partitioning of minerals among the organs. Higher K: Na ratio in leaves and shoots in comparison to that in roots of mulberry (Agastian and Vivekanandan 1997a, b) and barley (Niazi *et al*., 1992) indicated the selective uptake of K in varieties tolerant to salinity. Afridi *et al*., (1988), Parvaiz and John (2005) and Loupassaki et al., (2002) revealed that the plants tolerant to salinity and alkalinity showed less accumulation of Na and Cl and maintained its specificity for K and lower Na: K. Johnson (1991) related high forage production under saline conditions to turgor maintenance, lower sodium: potassium ratios and mechanism for partial exclusion of sodium in leaves of crested and tall wheat grass accessions.

Better performance of tolerant genotypes of different crops appeared to be due to better regulation of ionic uptake and their distribution within the plant under salt stress (Flowers and Yeo, 1989) and also under high exchangeable sodium. The relatively lower Na: K ratios might have contributed to more tolerance to alkalinity in AR-12 which paves the way for its use as a source of alkalinity tolerance and its commercial exploitation.

Table 1: Na:K ratio in leaves of different mulberry genotypes under different levels of alkalinity.

Variety	T1 Control	T2 Medium	T3 High	Mean
V-1	0.030	0.038	0.056	0.041
AR-12	0.027	0.036	0.045	0.036
G-2	0.031	0.040	0.053	0.041
AR-11	0.030	0.038	0.047	0.038
Mean	0.029	0.038	0.050	
C.D. at 5% for				
Variety (A)	0.00036*			
Treatments (B)	0.00024*			
A × B	0.00061*			
C.V. %	5.6			

* Significant at 5 % level.

Table 2: Na:K ratio in stems of different mulberry genotypes under different levels of alkalinity.

Variety	T1 Control	T2 Medium	T3 High	Mean
V-1	0.069	0.092	0.111	0.090
AR-12	0.053	0.070	0.087	0.070
G-2	0.067	0.084	0.119	0.090
AR-11	0.059	0.086	0.097	0.080
Mean	0.062	0.083	0.103	
C.D. at 5% for				
Variety (A)	0.00078*			
Treatments (B)	0.00055*			
A × B	0.00131*			
C.V. %	5.2			

* Significant at 5 % level.

Table 3: Na:K ratio in roots of different mulberry genotypes under different levels of alkalinity.

Variety	T1 Control	T2 Medium	T3 High	Mean
V-1	0.786	1.335	1.716	1.279
AR-12	0.569	0.717	0.820	0.702
G-2	0.879	1.019	1.390	1.096
AR-11	0.753	1.094	1.350	1.065
Mean	0.746	1.041	1.319	
C.D. at 5% for				
Variety (A)	0.0227*			
Treatments (B)	0.0162*			
A × B	0.0379*			
C.V. %	4.6			

* Significant at 5 % level.

Table 4: Na:K ratio - mean of leaf, stem and roots of different mulberry genotypes under different levels of alkalinity

Variety	T1 Control	T2 Medium	T3 High	Mean
V-1	0.885	1.466	1.882	1.411
AR-12	0.650	0.823	0.953	0.808
G-2	0.977	1.142	1.562	1.227
AR-11	0.843	1.217	1.493	1.184
Mean	0.838	1.162	1.472	
C.D. at 5% for				
Variety (A)	0.089*			
Treatments (B)	0.060*			
A × B	0.153*			
C.V. %	4.8			

* Significant at 5 % level.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 28-31

GENETIC DIVERSITY IN THE MULBERRY GERMPLASM

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ABSTRACT

Genetic divergence was studied in 90 mulberry germplasm accessions. All the accessions were grouped into seven clusters, 38 in cluster II, 24 in cluster I, 15 in cluster IV, ten in cluster V and one each in cluster III, VI and VII. The clustering pattern showed that the genotypes fell in different clusters according to their geographical origin. The cluster means of different characters suggested a wide range of variation for all the characters within and among the clusters. Analysis for estimating the contribution of various characters towards the expression of genetic divergence indicated that total shoot length (82.5), number of leaves per plant (8.66%), single leaf area (3.07%), contributed maximum. Hence these parameters need to be given greater attention in selection. Intra-cluster D^2 values varied from 0 to 25.11 and inter-cluster D^2 values varied from 21.18 to 105.62. Cluster V showed highest mean value for number of branches per plant, total shoot length and leaf yield per plant.

Key words: Cluster analysis, Genetic diversity, Mulberry germplasm

INTRODUCTION

Mulberry leaf is the only source of food for silkworm *Bombyx mori* L. The improvement in quality and quantity has direct influence on the cocoon crop. It is reported that more than 50 per cent of the cost of production of silk is attributed to mulberry leaf production itself.

Genetic divergence measuring the heratability relationship among the population had been used as an important tool in crop improvement programme. Expression of heterosis mainly depends on the genetic closeness of the parents. Crossing between the most genetically divergent parents for recombination of genes has proved most effective and hence a study on genetic divergence was taken up. Murthy and Arunachalam (1966) and Jain *et al.*, (1981) stated the importance of studying the genetic divergence in breeding for high yielding varieties. D^2 analysis based on multivariate analysis as developed by Mahalonobis (1928) was carried out.

MATERIALS AND METHODS

The experimental material comprised of 90 mulberry accessions maintained at the Department of Sericulture, University of Agricultural Sciences, Gandhi Krishi Vignyan Kendra, Bangalore. Each mulberry accession was planted in rows with four plants/accession with spacing of 2.4 x 2.5 m during 2006. The experiment was conducted for two seasons *viz.,* rainy and winter of 2009. All the cultural practices like irrigation, weeding, fertilizer application were followed as per package of practices recommended for rainfed mulberry cultivation. Pruning was done at 1.2 m height from the ground level and there after data on all the characters were recorded from four plants in each accession, on 60th day after pruning.

RESULTS AND DISCUSSION

Based on D^2 values, 90 accessions were grouped into seven clusters, indicating the presence of diversity among the genotypes (Table1). Maximum number of accessions (38) was in cluster II; 24 were grouped in cluster I, 15 in cluster IV; ten were grouped in cluster V, one each in clusters III, VI and VII (Table 1). The dendrogram of 90 mulberry accessions depicting the spatial position of each cluster in relation to others is presented in Fig. 1.

Maximum inter cluster distance as revealed by D^2 value of 105.62 was found between the clusters V and VI while minimum D^2 value was between the clusters III and IV as

indicated by lowest inter cluster distance of 21.18 (Table 2). The intracluster divergence ranged from 0.0 in cluster III, VI and VII to 25.11 in cluster V (Table 2). Presence of diversity among mulberry accessions in the present study is in accordance with earlier reports (Rahman *et al*., 2005; Venkateshaiah *et al.,* 2008). Cluster VII had high mean value for plant height, number of branches per plant, number of leaves per plant and moisture content, cluster VI for internodal distance, single leaf area, petiole length and fruits traits (length and breadth), cluster V for total shoot length and leaf yield per plant and cluster III for weight of 100 fresh leaves moisture retention capacity at different hours (Table 3). The analysis for estimating the contribution of various characters towards the expression of genetic divergence indicated that total shoot length (82.45%), number of leaves per plant (8.66%) and single leaf area (3.07%) contribute maximum to the genetic divergence in the material (Table 4). Hence, it is clear they are the principal attributes of the genetic architecture of mulberry which must be given greater attention in selection. The choice of the characters for such studies is quite important as pointed out by Sokal and Daley (1961).

Genetically divergent genotypes are included in cluster V and VI and also III and IV. Such accessions can be incorporated in a hybridization programme.

Table 1: Distribution of 90 accessions in different clusters

Clusters No	No of accessions	Name of the genotypes
I	24	T-31, T-10, RFS-175, T-5, DD-1, T-1, MI-226, T-4, T-2, T-9, ME-182, ME-169, MI-018, MI-143, T-3, MI-506, MI-139, MI-565, ME-65, S-54, T-8, S-1635, ssME-06, MI-232.
II	38	ME-143, BC-259, MI-66, S-46, MI-524, MI-47, ME-86, MI-04,ME-18, Mysore local, S-13, MI-240, *M. ca*hyana , NO-5, *M. lavigata*, ME-05, MI-238, ME-144, MI-233, S36, MI-07, C-20, *M. macrora*, Lonvalli, T-33, ME-52, ME-18, Assombola, MI-178, MI-517, ME107, Karanalli, MI-224, RFS-135, ME-67, MI-515, *M. multicalis*, MR1.
III	1	M-10
IV	15	C-776, MI-012, ME-95, S-41, *M. indica*, MI-17, V1, Chinawhite, ME-01, MI-11, *M. alba*, ME-27, ME-03, MI-491, MI-231
V	10	ME-84, MI-32, Surat local, S-34, C-763, MI-79, MI-516, MR-2, Srinagar local, ME-08.
VI	1	S-34
VII	1	Mysore local

Table 2: Inter and intra cluster (D^2) distances for mulberry accessions based on growth parameters

Clusters	I	II	III	IV	V	VI	VI
I	15.92	38.54	55.99	66.86	100.90	23.31	50.18
II		19.27	26.49	35.88	68.30	44.11	34.50
III			0.00	21.18	51.27	61.17	45.26
IV				20.43	41.28	71.43	44.09
V					25.11	105.62	69.19
VI						0.00	51.59
VII							0.00

Table 3: Cluster means for different phenotypic characters in mulberry accessions

Clusters	Clusters															
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11				X12	
											3h	6h	9h	24h	L	B
I	85.79	11.89	331.51	3.88	157.47	117.80	2.66	190.77	278.70	66.40	71.58	63.08	52.50	38.2	2.95	0.89
II	156.29	16.84	1148.57	5.01	303.79	129.81	3.88	380.68	303.52	62.56	71.67	63.60	52.35	39.09	2.97	0.89
III	138.67	16.33	1615.67	4.33	210.33	151.58	2.80	187.30	436.77	66.01	72.68	65.23	50.59	35.50	2.83	0.72
IV	182.52	20.24	1874.53	4.95	410.42	150.22	3.86	479.56	308.34	64.25	72.01	64.32	53.61	40.00	3.10	0.89
V	196.27	27.63	2697.83	5.21	619.10	100.05	3.10	650.43	184.50	66.11	71.90	62.35	51.45	38.50	3.01	0.89
VI	132.67	21.00	277.33	5.67	282.67	366.58	4.70	381.54	610.70	65.20	68.31	61.09	51.58	43.88	3.50	1.11
VII	152.00	27.33	1178.67	3.83	812.67	1160[illegible]	2.57	576.30	116.25	72.06	69.85	55.89	45.23	39.41	2.50	0.89

X1: Plant height (cm) X2: Number of branches/plant X3: Total shoot length (cm) X4: Internodal distance (cm)

X5: No of leaves per plant X6: Sing le leaf area (cm^2) X7: Petiole length (cm) X8: Leaf yield per plant (g)

X9: Weight of 100 fresh leaves (g) X10: Moisture content (%) X11: Moisture retention capacity (%) X12: Fruit traits (L: length B: breadth) (cm)

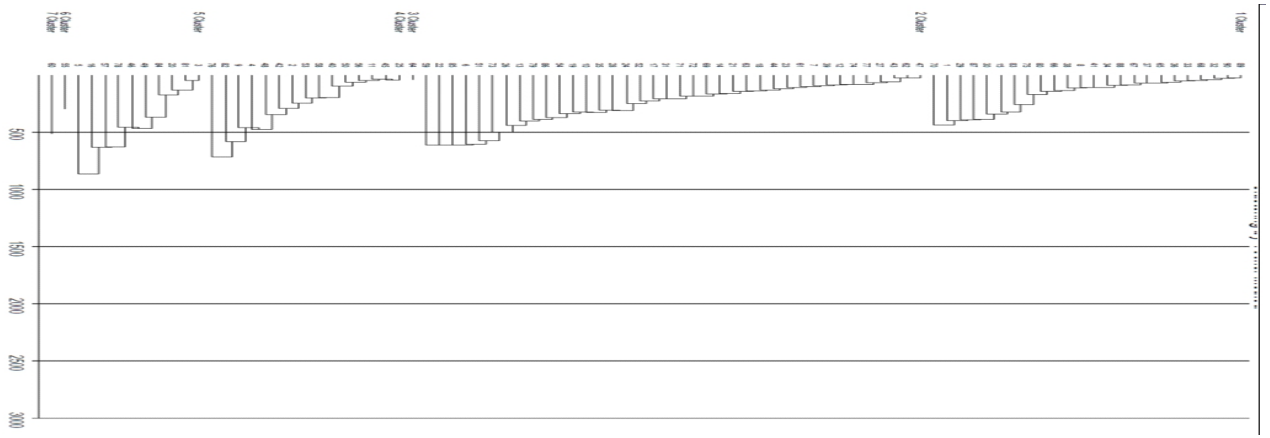


Fig 1: Dendrogram of 90 accessions of mulberry

Table 4: Contribution of characters towards divergence in 90 mulberry accessions

Sl. No	Source	Contribution%
1	Plant height (cm)	0.22%
2	Number of branches	0.00%
3	Total shoot length (cm)	82.45%
4	Intermodal distance	0.00%
5	Number of leaves per plant	8.66%
6	Single leaf area(cm^2)	3.07%
7	Petiole length (cm)	0.00%
8	Leaf yield per plant (g)	0.27%
9	100 fresh leaves weight (g)	0.37%
10	Moisture content (%)	0.40%
11	a) Moisture retention capacity at 3hr (%)	0.02%
	b) Moisture retention capacity at 6hr (%)	0.00%
	c) Moisture retention capacity at 9hr (%)	0.00%
	d) Moisture retention capacity at 24hr (%)	0.05%
12	a) Fruit length (cm)	0.00%
	b) Fruit diameter (cm)	0.00%

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 32-36

IN VITRO SCREENING OF PROMISING MULBERRY *(MORUS* SPP.*)* GENOTYPES FOR TOLERANCE TO ALKALINITY AND DROUGHT STRESS CONDITIONS

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ABSTRACT

Nodal explants of 11 promising mulberry genotypes from various yield trial experiments *viz.,* final yield trial (FYT no. 7, 8, 9), primary yield trial (PYT no. 7, 8, 13 and 16) and advanced generation breeding (AGB no. 7, 28, 34 and 37) were cultured on Murashige and Skoog (1962) medium fortified with Benzyl amino purine / Kinetin (1.0 mg/l) and Indole butyric acid/Naphthalene acetic acid (1.0mg/l) to standardize the optimum media for induction of growth and rooting response, respectively. The sprouting response varied from 22.6 % (FYT-9) to 98.3 % (AGB-37). Better sprouting was observed in most of the genotypes in MS medium incorporated with BAP (1.0 mg/l) as compared to Kinetin (1.0 mg/l). The shoot length ranged from 1.4 cm (AGB-28) to 3.1 cm (PYT-7). Rooting response varied from 50 to 100 % in the 11 genotypes studied. The media optimal for the individual genotype was supplemented with Sodium carbonate + Sodium bicarbonate (pH 9.0) and Polyethylene glycol (PEG 2.0 %) to create alkalinity and drought stress conditions, respectively. On the basis of sprouting and shoot growth on stress incorporated media (alkalinity and drought), 4 genotypes FYT no. 7, 8 and AGB no. 7, 37 were found to be tolerant to alkalinity stress and two genotypes FYT no. 8 and AGB no. 7 were found to be tolerant to drought stress conditions. The tolerant genotypes can be utilized as donor parents in specific breeding programmes to evolve abiotic stress tolerant varieties.

Key words: Alkalinity, Mulberry genotypes, Screening, Stress, Tolerance

INTRODUCTION

The total area under mulberry cultivation in India is about 1, 91,893 ha of which about 77,998 ha in Karnataka (Anonymous, 2007). The ever increasing demand for quality raw silk necessitates either horizontal expansion of mulberry garden or vertical improvement in productivity. Due to pressure on productive and irrigated lands for crop production for human needs, the expansion is possible only in problematic soils prone to alkalinity and drought stress conditions. In India 2.8 million hectares of land is affected by high alkali conditions (Abrol & Bhumbla, 1971). Cultivable land under irrigated conditions is 30.5% and 69.5% of cultivable area is under dry land conditions wherein water availability is the most overriding constraint for achieving potential crop productivity. Therefore, it is imperative to explore the possibilities of extension of sericulture in those problematic soil conditions. Since reclamation of problematic soils is a difficult task and expensive, it becomes increasingly important to develop genotypes that are better adapted to tolerate stress. Screening of mulberry genotypes for tolerance to abiotic stress through conventional techniques is rather cumbersome and labour intensive. In this context *in vitro* screening techniques offer an alternate tool (Tewary *et al.,* 2000, 2003; Raghunath *et al.,* 2003 and Khurana *et al*. 2003) for identifying tolerant genotypes within limited space, time and labour. Therefore, in the present study promising genotypes identified in various yield trial experiments have been subjected to *in vitro* screening for tolerance to alkalinity and drought stress.

MATERIALS AND METHODS

The promising mulberry genotypes identified in Final yield trial (FYT no. 7, 8, and 9), Primary yield trial (PYT no. 7, 8, 13, and 16), Advanced generation breeding trial (AGB no. 7, 28, 34 and 37) were utilized in the present study.

Single node explants excised from healthy plants (45 50 days after pruning) were agitated for 1 minute in 100 ml water containing 1 drop of liquid detergent (labolene) and

washed in water for 30 minutes. The explants were kept in 100 ml of distilled water containing Bavistin (0.2%), Streptomycin sulphate (0.05%) and Cephelexine (0.05%) for 2 hours. After repeatedly washing the explants in water, they were treated with 0.05% Mercuric chloride (w/v) for 5 7 minutes followed by repeated washing with autoclaved distilled water.

The surface sterilized nodal explants were cultured on two Murashige & Skoog (1962) media, one incorporated with BAP (1.0 mg/l) and the other with kinetin (1.0 mg/l) singly. The pH of the media was adjusted to 5.8 with help of 0.1 N Sodium hydroxide (NaOH) / 0.1 N Hydrochloric acid (HCl) before autoclaving at 104 kpa and 121°C for 15 minutes. All the cultures were maintained at 25±2°C under 16 / 8 hour (Day / light) photoperiod at a light intensity of 65 mmol/m^2 per second.

Data on sprouting were recorded after 3 weeks of culture and values represented as mean±SE of 20 cultures repeated thrice. After 6 weeks, the shoot length (cm) was recorded. *In vitro* raised shoots of the above genotypes were subcultured as nodal explants on two rooting media, one supplemented with Naphthalene Acetic Acid (1.0mg / l) and the other with Indole butyric Acid (1.0 mg/l) alone for root induction and maintained in the afore mentioned culture conditions. Data on root induction were recorded 2 weeks after culture and root length after 4 weeks.

Culture of nodal explants in stress incorporated medium

The optimum medium for individual genotype was supplemented with sodium carbonate and sodium bicarbonate to raise pH to 9.0 to create alkaline stress condition. For drought stress 2.0 % Poly ethyleneglycol (PEG) was incorporated into the medium. The surface sterilized nodal explants of the 11 test genotypes were cultured on the stress incorporated media to assess tolerance.

RESULTS

The sprouting and growth response of the promising genotypes in Benzyl amino purine (BAP) and kinetin incorporated media is presented in table 1. Sprouting varied from 22.6% (FYT-9) to 98.3% (AGB-37). The sprouting was higher in most of the genotypes in BAP (1.0mg/l) incorporated MS media as compared to kinetin (1.0mg/l) incorporated media. Kinetin could induce higher sprouting only in AGB-28. Shoot length ranged from 3.1 cm (PYT-7) to 1.40 cm (AGB-28). Higher shoot growth was observed in BAP incorporated media than kinetin incorporated media (Table-1).

Rooting response of the PYT, FYT and AGB genotypes in different IBA and NAA incorporated media is given in table 1. The rooting varied from 50.05 to 100.0% in the test genotypes. Highest rooting was recorded in PYT-7 and 13 (100%) and lowest in AGB-37 (50%). Length of roots varied from 1.2 cm (FYT-8) to 3.9 cm (AGB-7). Better root length was recorded in IBA incorporated media than in NAA incorporated media. However, length of roots was higher in NAA (1.0 mg/l) incorporated media in the genotypes PYT-7, PYT-13 and FYT-8 (Table 1). Variation was observed for number of roots per plant with maximum number of roots per plant (10) recorded in PYT-7 (MS + 1.0 mg/l IBA) and minimum (3.8) in PYT-8 (MS + 1.0 mg/l NAA). Root induction per plant was higher in MS + 1.0 mg/l IBA as compared to MS + 1.0 mg/l NAA (Table 1). The sprouting and growth response of the test genotypes in alkalinity (pH 9.0) and moisture stress (2.0% PEG) incorporated media is presented in table 2.

The sprouting of nodal explants of the test genotypes varied from 15 to 45 % and 0.0 to 35.46% in alkalinity and moisture stress incorporated media, respectively. The shoot growth ranged from 0.7 to 1.2 cm and 0.0 to 0.96 cm in alkalinity and moisture stress incorporated media, respectively (Table 2). On the basis of sprouting and shoot growth FYT-8, AGB-7 were found to be tolerant to moisture stress and FYT-7, FYT-8, AGB-7 and AGB-37 were found to be tolerant to alkaline stress.

DISCUSSION

In the present study, incorporation of BAP in MS medium supported sprouting and shoot growth in most of the genotypes as compared to kinetin. Variation was observed in the response of 11 genotypes indicating genotypic differences. Such variation for *in vitro* shoot development in mulberry genotypes was reported by Tewary *et al*., (1996). According to Ohyama and Oka, (1987), N6 benzyladenine (BA) was more effective in inducing bud break in nodal explants than Zeatin, while kinetin was of no use over a wide range of concentrations. Requirement of BAP in the MS basal medium for sprouting and shoot growth was reported in different mulberry species and genotypes (Mhatre *et al*., 1985; Chattopadhyay *et al*., 1990; Jain *et al*., 1990; Raghunath *et al*., 1992; Ravindran and Lakshmi Sita, 1994; Kathiravan *et al*., 1997; Sahoo *et al*., 1997; Wakhlu and Bhau, 2000; Bhau and Wakhlu, 2001; Thomas, 2002 and Khurana *et al.*, 2003; Sadiqul Islam, 2004).

In the present study incorporation of IBA (1.0 mg/l) in MS medium improved rooting in most of the genotypes except FYT-8, which showed higher rooting in 1.0 mg/l NAA. Similar response was observed for number of roots per plant. These results are in agreement with the studies of Islam *et al*., (1993 and 1994) and Tewary *et al*., (1995) who have observed that presence of IBA in MS medium resulted in good root development in mulberry. According to Bhatnagar *et al*., (2002) rooting was best in MS + 1.0 mg/l NAA + 1 % activated charcoal. In the present study, NAA induced better response than IBA for root length in the genotypes PYT-7, PYT-13 and FYT-8. Sujathamma *et al*., (2007) also reported higher level of rooting in *Morus* spp. in MS medium with NAA.

Table 1: Growth response of promising genotypes mulberry in various media

Genotype	Treatment	Sprouting %	Shoot length(cm)	Treatment	Rooting %	Root length (cm)	No. of roots
PYT -7	1.0 mg/l BAP	86.6±1.06	3.1±2.56	1.0 mg/l IBA	100.0±1.34	2.1±0.42	10.0±0.72
	1.0 mg/l kinetin	68.3±1.57	2.3±0.96	1.0 mg/l NAA	97.5±1.66	2.5±0.32	7.6±0.61
PYT -8	1.0 mg/l BAP	28.2±3.43	2.02±0.06	1.0 mg/l IBA	66.1±2.55	1.8±0.19	6.2±0.48
	1.0 mg/l kinetin	23.0±2.0	1.70±0.07	1.0 mg/l NAA	63.4±1.49	1.2±0.03	3.8±0.37
PYT-13	1.0 mg/l BAP	75.0±1.42	2.8±1.42	1.0 mg/l IBA	100.0±1.15	1.4±0.23	9.6±0.18
	1.0 mg/l kinetin	56.6±1.87	2.5±2.35	1.0 mg/l NAA	97.5±1.66	2.1±0.42	8.2±0.72
PYT-16	1.0 mg/l BAP	57.7±6.0	2.04±0.04	1.0 mg/l IBA	69.6±8.72	2.3±0.27	7.4±0.51
	1.0 mg/l kinetin	53.0±4.53	2.00±0.13	1.0 mg/l NAA	61.9±1.71	1.7±0.08	5.0±0.31
FYT-7	1.0 mg/l BAP	70.0±1.31	1.86±0.10	1.0 mg/l IBA	71.6±7.76	2.8±0.21	7.8±0.37
	1.0 mg/l kinetin	54.6±1.00	1.42±0.05	1.0 mg/l NAA	55.7±1.72	1.9±0.04	5.8±0.36
FYT-8	1.0 mg/l BAP	91.6±0.70	1.7±0.11	1.0 mg/l IBA	78.3±5.32	1.2±0.42	6.4±0.52
	1.0 mg/l kinetin	80.0±2.56	2.0±0.27	1.0 mg/l NAA	97.5±3.12	1.4±0.56	7.8±0.43
FYT-9	1.0 mg/l BAP	31.1±2.33	2.02±0.08	1.0 mg/l IBA	61.6±2.89	2.2±0.19	7.0±0.31
	1.0 mg/l kinetin	22.6±1.87	1.74±0.04	1.0 mg/l NAA	53.6±2.38	1.8±0.12	5.4±0.24
AGB-7	1.0 mg/l BAP	62.7±4.66	2.06±0.12	1.0 mg/l IBA	59.1±1.25	3.9±0.09	7.0±0.54
	1.0 mg/l kinetin	58.2±2.71	1.94±0.08	1.0 mg/l NAA	55.1±2.99	1.9±0.07	4.6±0.40
AGB-28	1.0 mg/l BAP	58.9±6.69	1.68±0.11	1.0 mg/l IBA	63.0±2.37	2.8±0.18	7.4±0.51
	1.0 mg/l kinetin	61.4±3.57	1.40±0.05	1.0 mg/l NAA	58.1±4.08	2.0±0.04	6.0±0.31
AGB-34	1.0 mg/l BAP	85.0±1.21	2.6±1.16	1.0 mg/l IBA	90.0±2.37	3.4±0.43	7.6±0.63
	1.0 mg/l kinetin	61.6±2.85	2.5±1.38	1.0 mg/l NAA	90.0±1.89	2.4±0.56	6.2±0.84
AGB-37	1.0 mg/l BAP	98.3±1.21	2.9±1.02	1.0 mg/l IBA	60.0±2.34	3.2±0.17	6.2±0.52
	1.0 mg/l kinetin	93.3±1.41	2.0±1.87	1.0 mg/l NAA	50.0±4.32	1.7±0.32	5.2±0.42

± Standard error

Table 2: Growth response of promising mulberry genotypes in alkalinity stress (pH 9.0) and drought stress media (PEG 2%).

Genotype	Treatment	Sprouting %	Shoot length (cm)
PYT-7	Control	86.66±1.06	3.15±1.56
	pH 9.0	20.00±6.98	0.95±0.32
	PEG 2%	20.00±7.07	0.87±0.59
PYT-8	Control	28.20±2.60	2.02±0.13
	pH 9.0	24.66±1.89	1.18±0.12
	PEG 2%	2.2±0.28	0.36±0.03
PYT-13	Control	75.00±0.90	2.86±1.42
	pH 9.0	15.00±9.19	0.80±1.68
	PEG 2%	0.00±0.00	0.00±0.00
PYT-16	Control	57.70±3.40	2.04±0.11
	pH 9.0	23.25±2.50	0.82±0.06
	PEG 2%	4.2±0.43	0.56±0.09
FYT-7	Control	70.00±2.90	1.86±0.23
	pH 9.0	36.79±3.39	0.70±0.06
	PEG 2%	4.20± 0.76	0.57±0.08
FYT-8	Control	91.67±0.70	1.74±0.19
	pH 9.0	45.00±1.06	1.16±1.98
	PEG 2%	35.46±7.07	0.93±0.32
FYT-9	Control	31.10±1.10	2.02±0.19
	pH 9.0	22.94±1.75	1.02±0.09
	PEG 2%	11.6±1.33	0.82±0.13
AGB-7	Control	62.70±5.0	2.06±0.27
	pH 9.0	42.60 ±3.66	0.72±0.11
	PEG 2%	35.40±3.30	0.96±0.15
AGB-28	Control	58.90±4.9	1.68±0.16
	pH 9.0	23.66±2.28	0.80±0.05
	PEG 2%	3.1±0.19	0.58±0.08
AGB-34	Control	85.00±1.21	2.62±1.16
	pH 9.0	18.00±10.61	1.00±0.17
	PEG 2%	0.00±0.00	0.00±0.00
AGB-37	Control	98.00±1.21	2.94±1.02
	pH 9.0	34.75±14.14	1.20±0.22
	PEG 2%	0.00±0.00	0.00±0.00

± Standard error

Ram Rao *et al*., (1997) observed that out of the 9 genotypes screened for moisture stress, the mulberry genotypes S-13, S-20 and S-27 were tolerant. In the present study, on the basis of sprouting and shoot growth response of nodal explants of 11 test genotypes to *in vitro* induced moisture stress, only two of the genotypes - FYT-8 and AGB-7 were found to be tolerant to moisture stress.

Tewary *et al*. (2000) screened 5 mulberry genotypes to salt and osmotic stress and reported that G-4 exhibited maximum sprouting and shoot growth as compared to G-2 and G-3 when the nodal explants were cultured in MS basal media with pH 8.5 and 9.0. Raghunath *et al*., (2003) screened 23 mulberry genotypes to *in vitro* alkaline stress (pH 9.0) and out of 23 genotypes tested, only 2 genotypes *viz.* China white and English black exhibited their tolerance to alkaline stress condition. In the present study, on the basis of sprouting and shoot growth response of nodal explants of 11 test genotypes to *in vitro* induced alkalinity stress, only 4 genotypes - FYT-7, FYT-8, AGB-7 and AGB-37 were found to be tolerant to alkaline stress.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 37-43

PRELIMINARY SCREENING AND SELECTION OF PROMISING BUD GRAFTS OF MULBERRY FOR TROPICAL RAINFED SITUATIONS

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ABSTRACT

Long term strategy for increasing mulberry leaf productivity in rainfed situations is selection of drought tolerant genotypes with deep and wide spread root system. Field screening under rainfed conditions was carried out for 2 years with 34 bud graft combinations of stocks of 4 triploid and one tetraploid with good rooting habit and bud scions of 7 diploid mulberry genotypes, along with 9 checks, with emphasis on leaf quality apart from yield improvements. Highly significant genotypic differences were observed among different bud graft combinations for the parameters studied. Fresh weight of 50 leaves ranged among bud grafts from 47.66 (TR8 + Lazuraso) to 117.44 g (Vishala + Lun-40-2). Leaf-water content ranged from 67.51 (Mysore Local tetraploid + Lazuraso) to 73.41 % (Vishala + Lun-40-2). Leaf-water retention at 6 hours of harvest ranged from 76.17 (TR8 + Lazuraso) to 86.89 % (Vishala + Lun-40-2). Relative water content ranged from 66.07 (Mysore Local tetraploid + Lun-40-1) to 79.99 % (Vishala + Lun-40-2). Leaf yield/plant/harvest ranged from 100 (Vishala + Noi-12) to 343 g (TR8 + Accession 304). The genotypes x season interactions were found to be significant. It was observed that bud grafts of triploid stock performed better. These genotypes maintained better leaf-water retention and relative water content, with higher leaf yield, suggesting their suitability for soil moisture stress, whereas bud grafts of tetraploid stock did not perform well. For rainfed conditions, bud grafts of triploid stocks, namely, Vishala + Lun-40-2, TR10 + Burilam-60 and TR8 + Accession 304 were identified as promising ones, which can be used as an alternative way for combating soil moisture stress.

Keywords: Mulberry bud grafts, Rainfed, Scions, Selection, Screening

INTRODUCTION

Cultivation of mulberry (*Morus* spp.) is carried out largely under moisture stress situations in both rainfed and irrigated conditions in the tropical regions of India and elsewhere. In rainfed mulberry cultivation, soil moisture plays a crucial role in growth and leaf productivity. But, under prevailing southern tropical situations, inadequate availability of soil moisture is the major production constraint owing to annual rainfall being low, very uneven and associated with long dry spells and high temperature regimes. Mulberry cultivation under rainfed or soil moisture stress conditions has several limitations. Though the area of irrigated mulberry is steadily increasing over the period, mulberry is still widely cultivated under rainfed and or soil moisture stress conditions. Apart from the Mysore Local mulberry variety, though low yielding, being popular under rainfed conditions, works have since been carried out with respect to different aspects of cultivation of mulberry under rainfed conditions (Kasiviswanathan *et al*., 1977; Choudhury *et al*., 1987) and in understanding adaptive characteristics and identification of drought tolerant genotypes (Susheelamma *et al*., 1992; Dorcus and Vivekanandan, 1997; Anonymous, 1996). Preliminary evaluation of eight mulberry bud grafts (S13, S34, Viswa, RFS135, S1635, S1, S36 and M5) on common stock of diploid Mysore Local mulberry genotype revealed that bud grafts in general performed better in respect of fresh weight of leaves, leaf-water content and leaf-water retention, while in leaf yield check genotypes performed better (Mallikarjunappa *et al*., 1997). Mulberry triploids are superior than diploids and tetraploids in leaf yield and quality as well as in adaptive response to adverse climatic conditions

(Tikader *et al*., 1996) with better rooting and higher potential to establish readily and rapidly in any climatic condition (Vijayan and Chakraborti, 1998). To replace old mulberry genotypes with improved ones, top working has been advocated as an optional technique in rainfed mulberry cultivation (Anonymous, 1996). The long term strategy for rainfed situations thus is development of drought tolerant mulberry genotypes/grafts. With this background, the study was conducted to exploit the better rooting habit of triploids and to monitor the response of different bud graft combinations in comparison with checks for selection of promising bud grafts to mitigate the soil moisture stress conditions.

MATERIALS AND METHODS

Empirical screening and selection was carried out for a total of 34 bud graft (patch budding) combinations of stocks of 4 triploids (TR8, TR10, S1635 and Vishala) and one tetraploid (Mysore Local tetraploid or ML 4x) and scions of 7 diploid mulberry genotypes, along with 9 checks (TR8, TR10, S1635, Vishala, Mysore Local diploid or ML 2x, ML 4x, Viswa, V1 and S13). Out of 7 diploid genotypes, 6 were exotic [Noi-12 (Vietnam), Burilam-60 (Thailand), Lun-40-1 (China), Lun-40-2 (China), Lazuraso (Japan) and Accession 304 (Thailand)] and one was indigenous (V1 or Victory-1). The 6 exotic mulberry genotypes selected as scions were poor rooters but had high leaf-water content (LWC) and leaf-water retention (LWR), in addition to higher leaf yields. Though mulberry tetraploids are poor in rooting in general, the roots of tetraploid Mysore local genotype were used as stocks for bud grafting since it has got good rooting capacity (Eswar Rao *et al.*, 2004) as also for comparison, whereas V1 genotype was utilized for bud grafting because of its high LWC and LWR traits. The following are the bud graft combinations and checks:

Trt. No.	Bud graft combination	Trt. No.	Bud graft combination	Trt. No.	Bud graft combination/check
T1	TR8 + Lazuraso	T16	S1635 + Burilam-60	T31	ML 4x + Lun-40-2
T2	TR8 + Burilam-60	T17	S1635 + Lun-40-1	T32	ML 4x + Accn. 304
T3	TR8 + Lun-40-1	T18	S1635 + Lun-40-2	T33	ML 4x + Noi-12
T4	TR8 + Lun-40-2	T19	S1635 + Accn. 304	T34	ML 4x + V1
T5	TR8 + Accn. 304	T20	S1635 + Noi-12	C1	S1635
T6	TR8 + Noi-12	T21	TR10 + Lazuraso	C2	Vishala
T7	TR8 + V1	T22	TR10 + Burilam-60	C3	TR8
T8	Vishala + Lazuraso	T23	TR10 + Lun-40-1	C4	TR10
T9	Vishala + Burilam-60	T24	TR10 + Lun-40-2	C5	ML 4x
T10	Vishala + Lun-40-1	T25	TR10 + Accn. 304	C6	V1
T11	Vishala + Lun-40-2	T26	TR10 + Noi-12	C7	S13
T12	Vishala + Accn. 304	T27	TR10 + V1	C8	S34
T13	Vishala + Noi-12	T28	ML 4x + Lazuraso	C9	ML 2x
T14	Vishala + V1	T29	ML 4x + Burilam-60		
T15	S1635 + Lazuraso	T30	ML 4 x + Lun-40-1		

The field experiment was conducted at the Karnataka State Sericulture Research and Development Institute (KSSRDI), Bangalore, India, during 2002-2005, under rainfed conditions, with augmented randomized block design, with 6 plants/bud graft combination or check. The soil of experimental plot was red sandy loam with pH - 6.9, OC - 0.72%, P_2O_5 - 30 kg/ha and K_2O - 215 kg/ha. About 150 days old bud grafts and saplings of checks were planted (1 graft or 1 sapling/pit) in pit system of 90 cm x 90 cm plant spacing and maintained for one year without pruning. The annual rainfall was 723.5 mm (59 rainy days) during 2003-04 and 1106.2 mm (74 rainy days) during 2004-05. Package of practices included one pruning at 15 cm height and 6 leaf harvests/year, one time application of farmyard manure @ 8 MT/ha/yr and N, P and K application @ 100, 50 and 50 kg/ha/yr, respectively, in 2 split doses (Jolly, 1986). Data on 5 important parameters, *viz*., fresh weight (FW) of 50 leaves, LWC, LWR at 6 hours after harvest, and leaf yield/plant/harvest by leaf picking method were collected following standard methods. The relative water content (RWC) was estimated at 65th day of pruning, using 6th/7th leaf, as per Kumar and Elston (1992).

RESULTS

Highly significant differences were observed among different bud graft combinations for FW, LWC, LWR, RWC and leaf yield parameters (Table I). The FW of 50 leaves among bud grafts ranged from 47.66 (T1) to 117.44 g (T11). Bud grafts T11, T22 (114.23 g), T12 (111.23 g), T2 (111.05 g) and T16 (109.14 g) showed significantly higher values. Among checks, the values ranged from 32.22 (C5) to 94.17 g (C1).

The LWC ranged from 67.51 (T28) to 73.41 % (T11) among the bud grafts and were significantly high in bud graft combinations with stocks of TR8, Vishala and S1635 triploid genotypes. Among checks, the values ranged from 68.07 (C9) to 71.53 % (C2).

The LWR at 6 hours of harvest ranged from 76.17 (T1) to 86.89 % (T11). The bud grafts T11, T12 (84.04 %), T22 (83.68 %), T17 (83.38 %), T18 (83.24 %), T16 (83.06 %) and T31 (83.03 %) had significantly higher values. Among the checks, values ranged from 74.71 (C9) to 81.56 % (C2). The values were significantly high in C1 (81.41 %) and C2 genotypes.

The RWC ranged from 66.07 (T30) to 79.99 % (T11). Significantly higher values for RWC were recorded in T11, T4 (79.22 %), T14 (78.06 %), T20 (77.48 %), T6 (77.47 %) and T12 (77.31 %). Among the checks, values ranged from 71.58 (C9) to 77.84 % (C4). The values were significantly high in C1 (76.42 %), C6 (75.97 %), C3 (75.85 %) and C4 genotypes.

The leaf yield/plant/harvest ranged from 100 (T13) to 343 g (T5). The bud grafts T5, T22 (323 g), T2 (293 g), T16 (280 g) had significantly higher values. In checks, the values ranged from 73 (C9) to 286 g (C1) and the value was significantly high in C1 genotype.

The genotypes x season interactions were found to be significant (Table I) and the bud grafts had differential response over the seasons (Table 2). When leaf yield/plant/harvest is considered only for summer season, bud grafts T22 (230 g), T11 (200 g) and T5 (190 g) performed better over best performed C1 (180 g) check genotype.

DISCUSSION

Drought stress is the major production constraint in growing mulberry in stored soil moisture conditions. To improve sericulture in tropics, emphasis must be laid to increase the cultivation of mulberry under water stress conditions. In mulberry, the mechanisms of drought tolerance are needed in obtaining optimal leaf yields under soil moisture stress. Putative drought tolerant traits have been discussed extensively by Boyer (1996). Singh *et al*., (2004), based on *in vitro* screening of root stocks of citrus for salt tolerance, opined that root stock affects the scion performance and determines its tolerance/susceptibility to many biotic and abiotic stresses.

The effect of LWC on silkworm growth is well documented earlier by Ito (1963). The LWC varied among the bud grafts screened in the present study and 12 bud graft combinations had highly significant values (Table 1). Susheelamma *et al*., (1992) observed that among 36 F1 hybrids evaluated for water retention capability of leaves after 7 and 24 hours of excision, genotypes S20 and S23 had the best LWR capability and they were named drought hardy hybrids. Assessment of LWR from excised leaves has shown promise for characterizing drought resistance in wheat genotypes according to Munjal and Dhanda (2005). In the present evaluation, among 34 bud graft combinations, 7 bud graft combinations had highly significant LWR values (Table I). The RWC has been reported as an important indicator of water stress in leaves as it closely reflects the balance between water supply to the leaf and transpiration rate. This influences the ability of the plant to recover from stress and consequently affects yield and yield stability (Munjal and Dhanda, 2005). Sharma and Ashok Kumar (2008) observed that cowpea genotypes which had higher ability to extract moisture at low soil moisture level maintained higher RWC. In the present field screening, bud grafts with root stock of triploid genotypes performed better in respect of RWC (Table 1).

A drought tolerant mulberry genotype must produce comparatively better leaf yield regardless of environmental variations. Dorcus and Vivekanandan (1997) screened 8 mulberry genotypes for drought resistance and based on yield as well as morpho-biochemical parameters, identified

Table 1: Overall performance of mulberry bud grafts and checks under rainfed conditions

Treatment No.	Bud graft	FW of 50 leaves (g)	LWC (%)	LWR at 6 h after harvest (%)	RWC (%)	Leaf yield/ plant/ harvest (g)
T1	TR8 + Lazuraso	47.66	69.83	76.17	76.26	120
T2	TR8 + Burilam-60	111.05	72.46	81.25	75.45	293
T3	TR8 + Lun-40-1	99.26	72.41	82.94	75.16	203
T4	TR8 + Lun-40-2	88.97	72.39	80.28	79.22	266
T5	TR8 + Accn. 304	97.86	72.59	81.50	76.12	343
T6	TR8 + Noi-12	93.19	70.30	81.09	77.47	223
T7	TR8 + V1	66.99	71.49	79.46	75.17	190
T8	Vishala + Lazuraso	60.16	72.79	77.41	76.14	106
T9	Vishala + Burilam-60	93.48	72.88	81.81	71.82	213
T10	Vishala + Lun-40-1	77.60	71.53	81.34	73.28	100
T11	Vishala + Lun-40-2	117.44	73.41	86.89	79.99	276
T12	Vishala + Accn. 304	111.23	72.88	84.04	77.31	200
T13	Vishala + Noi-12	50.02	70.18	78.94	75.19	100
T14	Vishala + V1	74.56	72.38	80.05	78.06	206
T15	S1635 + Lazuraso	79.40	70.49	79.80	76.27	110
T16	S1635 +Burilam-60	109.14	72.57	83.06	73.79	280
T17	S1635 + Lun-40-1	99.62	71.96	83.38	73.44	160
T18	S1635 + Lun-40-2	86.01	71.84	83.24	75.81	150
T19	S1635 + Accn. 304	96.60	72.64	82.12	75.56	190
T20	S1635 + Noi-12	86.54	69.79	82.21	77.48	216
T21	TR10 + Lazuraso	63.57	70.02	79.27	76.67	120
T22	TR10 + Burilam-60	63.57	70.02	79.27	76.67	323
T23	TR10 + Lun-40-1	78.66	70.73	82.01	74.81	150
T24	TR10 + Lun-40-2	90.13	70.75	82.10	75.06	180
T25	TR10 + Accn. 304	97.94	69.91	81.94	71.43	206
T26	TR10 + Noi-12	87.63	68.68	82.16	74.52	200
T27	TR10 + V1	56.18	70.63	79.04	73.31	153
T28	ML 4x + Lazuraso	62.54	67.51	77.47	67.34	110
T29	ML 4x +Burilam-60	86.12	69.64	80.35	69.22	160
T30	ML 4 x + Lun-40-1	72.82	69.60	80.74	66.07	110
T31	ML 4x + Lun-40-2	82.92	71.06	83.03	72.77	156
T32	ML 4x + Accn. 304	103.76	70.32	82.67	71.45	226
T33	ML 4x + Noi-12	94.36	69.78	82.01	72.55	253
T34	ML 4x + V1	74.71	70.81	80.15	71.48	170
C1	S1635	94.17	71.45	81.41	76.42	286
C2	Vishala	91.75	71.53	81.56	72.97	253
C3	TR8	67.81	71.30	79.37	75.85	203
C4	TR10	78.86	71.19	80.32	77.84	236
C5	ML 4x	32.22	68.07	77.10	71.58	73
C6	V1	62.59	70.95	79.45	75.97	233
C7	S13	45.12	70.10	78.85	72.66	213
C8	Viswa	58.90	71.66	79.08	72.18	180
C9	ML 2x	33.82	68.04	74.71	72.58	176
	Grand Mean	81.76	71.08	80.81	74.38	200
	F Test	HS	HS	HS	HS	HS
	Genotypes					
	CD @ 5 %	15.04	0.67	1.67	1.27	0.031
	CD @ 1 %	19.80	0.88	2.20	1.67	0.04
	Seasons					
	CD @ 5 %	3.97	0.18	0.44	0.33	0.008
	CD @ 1 %	5.23	0.23	0.58	0.44	0.011

FW - fresh weight; LWC - leaf-water content; LWR - leaf-water retention and RWC - relative water content

Table 2: Genotype x season interactions for mulberry bud grafts and checks under rainfed conditions (mean of 4 harvests/season)

Trt. No.	Bud graft/ check	Fresh weight of 50 leaves (g)			Leaf-water content (%)			Leaf-water retention at 6 h after harvest (%)			Relative water content (%)			Leaf yield/plant/ harvest (g)		
		R	W	S	R	W	S	R	W	S	R	W	S	R	W	S
T1	TR8 + Lazuraso	104.31	17.14	21.54	74.52	67.60	67.38	81.27	75.80	71.44	79.50	70.85	78.43	270	40	50
T2	TR8 + Burilam-60	247.85	48.33	36.98	76.00	71.11	70.28	89.29	81.34	73.13	75.90	69.90	80.55	640	100	140
T3	TR8 + Lun-40-1	225.54	38.82	33.43	76.42	70.71	70.09	90.58	80.25	78.01	69.36	73.84	82.28	470	40	100
T4	TR8 + Lun-40-2	193.55	33.75	39.60	76.76	70.09	70.33	87.52	77.71	75.60	72.62	82.35	82.70	560	90	150
T5	TR8 + Accn. 304	205.25	41.06	47.28	76.96	69.93	70.87	89.79	79.16	75.54	71.12	73.54	83.71	680	160	190
T6	TR8 + Noi-12	211.66	34.87	33.06	74.95	68.02	67.93	89.87	80.89	72.51	77.63	73.42	81.36	480	110	80
T7	TR8 + V1	143.13	34.60	23.25	75.20	69.66	69.62	85.61	78.97	73.82	73.55	70.76	81.19	340	110	120
T8	Vishala + Lazuraso	119.42	32.55	28.51	75.05	71.60	71.73	83.30	77.97	70.95	76.78	74.44	77.21	190	50	80
T9	Vishala + Burilam-60	196.84	50.22	33.37	76.33	71.80	70.56	89.29	79.66	76.48	70.00	67.36	78.11	480	60	100
T10	Vishala + Lun-40-1	160.07	43.41	29.33	72.63	71.37	70.59	86.43	80.15	77.45	76.26	69.66	73.93	190	70	40
T11	Vishala + Lun-40-2	255.91	52.03	44.39	76.41	73.15	70.67	90.34	82.89	87.45	79.86	80.12	79.99	520	110	200
T12	Vishala + Accn. 304	234.03	66.58	33.08	76.90	70.96	70.79	90.80	85.14	76.18	73.99	75.50	82.46	380	80	140
T13	Vishala + Noi-12	102.25	18.82	28.99	73.38	66.00	70.36	85.00	78.74	73.07	77.84	69.74	78.00	210	30	60
T14	Vishala + V1	147.33	39.59	36.77	75.92	70.54	70.68	87.74	77.55	74.85	77.58	76.61	80.00	340	140	140
T15	S1635 + Lazuraso	171.18	35.85	31.16	73.80	68.93	68.73	86.59	78.24	74.55	81.15	66.83	80.82	230	50	50
T16	S1635 +Burilam-60	233.49	53.00	40.93	76.14	70.33	71.24	88.54	83.28	77.36	70.58	71.10	79.69	570	130	140
T17	S1635 + Lun-40-1	213.44	50.65	34.78	75.74	69.95	70.20	89.30	84.05	76.79	76.58	65.58	78.17	350	50	80
T18	S1635 + Lun-40-2	181.63	44.85	31.53	74.57	71.08	69.87	90.77	82.51	76.44	74.84	71.13	81.47	330	40	80
T19	S1635 + Accn. 304	201.48	46.44	41.88	75.93	70.99	71.01	90.27	78.76	77.33	81.09	68.08	77.51	360	80	130
T20	S1635 + Noi-12	181.78	41.09	36.77	72.47	68.60	68.31	90.13	81.42	75.01	81.11	72.74	78.59	450	110	90
T21	TR10 + Lazuraso	145.78	19.44	23.68	75.32	65.66	69.18	89.57	75.88	72.35	75.74	68.05	80.20	240	50	70

Trt. No.	Bud graft/ check	Fresh weight of 50 leaves (g)			Leaf-water content (%)			Leaf-water retention at 6 h after harvest (%)			Relative water content (%)			Leaf yield/plant/ harvest (g)		
		R	W	S	R	W	S	R	W	S	R	W	S	R	W	S
T22	TR10 + Burilam-60	250.23	50.34	42.10	75.43	67.78	69.11	90.85	80.90	79.28	76.74	74.56	77.45	550	190	230
T23	TR10 + Lun-40-1	188.86	26.08	21.03	74.77	68.33	69.11	91.11	77.78	77.14	71.97	75.43	77.03	360	50	80
T24	TR10 + Lun-40-2	208.33	32.05	30.00	74.33	68.92	69.00	90.76	77.75	77.79	74.21	74.11	76.87	410	30	100
T25	TR10 + Accn. 304	225.15	39.15	29.51	74.88	66.62	68.24	89.27	78.45	78.10	70.34	67.45	76.50	390	100	130
T26	TR10 + Noi-12	185.38	35.94	41.57	72.35	65.16	68.51	90.75	76.54	79.20	73.37	74.51	75.88	410	80	110
T27	TR10 + V1	120.28	24.17	24.29	75.12	66.87	69.91	87.32	77.25	72.54	76.45	67.34	76.12	320	60	80
T28	ML 4x + Lazuraso	148.03	21.16	18.43	72.75	65.87	63.92	88.97	74.64	68.79	72.59	60.56	68.87	250	40	40
T29	ML 4x +Burilam-60	195.79	34.35	28.23	73.84	65.66	69.42	90.41	76.04	74.60	67.59	65.73	74.33	320	60	90
T30	ML 4 x + Lun-40-1	172.50	21.43	24.54	74.04	67.24	67.53	91.30	75.83	75.09	67.82	61.53	68.87	250	40	50
T31	ML 4x + Lun-40-2	181.34	28.61	38.80	73.65	69.48	70.06	92.43	79.09	77.58	72.23	71.16	74.91	340	40	90
T32	ML 4x + Accn. 304	229.98	42.08	39.23	75.67	67.53	67.76	92.59	79.24	76.18	72.05	68.00	74.30	480	80	120
T33	ML 4x + Noi-12	213.19	34.81	35.07	73.06	65.08	71.22	90.62	79.98	75.43	71.75	73.08	72.82	550	80	130
T34	ML 4x + V1	164.06	35.92	24.16	74.45	67.15	70.81	90.40	78.59	71.46	73.04	68.55	72.84	340	110	60
C1	S1635	193.56	48.39	40.56	75.06	69.38	69.90	88.92	79.75	75.56	76.74	74.49	78.02	520	140	160
C2	Vishala	200.20	40.30	34.76	75.31	69.20	70.13	90.63	79.39	74.66	73.39	71.03	74.50	500	120	140
C3	TR8	142.64	33.10	27.68	73.96	69.03	70.89	86.58	77.95	73.58	80.45	68.90	78.19	380	90	130
C4	TR10	160.67	38.40	37.50	73.85	69.38	70.34	88.22	78.10	74.64	79.16	74.17	80.19	420	130	160
C5	ML 4x	63.23	15.82	17.60	70.84	66.77	66.59	82.20	74.89	74.22	76.55	66.83	71.38	110	40	70
C6	V1	121.95	35.28	30.53	73.34	69.53	69.99	85.61	76.64	76.11	77.59	72.56	77.74	410	140	150
C7	S13	92.19	22.76	20.41	73.46	67.93	68.92	86.28	76.90	73.37	73.45	69.07	75.46	430	90	120
C8	Viswa	121.01	24.61	31.09	74.68	69.24	71.05	86.11	75.94	75.18	71.46	65.60	79.47	320	80	140
C9	ML 2x	66.23	18.83	16.40	70.94	66.34	66.83	82.18	72.33	69.63	72.66	67.81	77.26	320	100	110
	Mean over season	174.9	35.96	34.38	74.43	68.76	70.03	88.5	78.7	75.43	74.76	70.79	77.6	390	80	120

S13 and S34 genotypes suitable for cultivation in drought prone areas. When leaf yield/plant/harvest for summer season is considered, bud grafts TR10 + Burilam-60 (T22), Vishala + Lun-40-2 (T11) and TR8 + Accession 304 (T5) performed better over best performed S1635 (C1) check genotype (Table 2).

Mulberry leaf yield under rainfed conditions may relate to many parameters and it may not be used as sole selection criteria. The selection based on morpho-physiological parameters like LWC, LWR and RWC would be better in short-listing the promising genotypes. Based on overall performance, among the 34 bud graft combinations screened, bud grafts of triploid rootstock, namely, Vishala + Lun-40-2 (T11), TR10 + Burilam-60 (T22) and TR8 + Accession 304 (T5) performed better. These genotypes maintained better LWR and RWC suggesting that these genotypes could perform better even under soil moisture stress. This finding is further supported by higher leaf yield in these genotypes, especially during soil moisture stress period. Whereas bud grafts of tetraploid rootstock did not perform well. Among the 9 checks, genotypes S1635 (C1) and TR10 (C4) performed better in RWC and leaf yield parameters.

CONCLUSION

Identification of mulberry genotypes with enhanced tolerance to water stress offers great scope for increasing leaf productivity. The soil moisture stress tolerant bud grafts showed better performance under water deficit conditions. Hence, for rainfed conditions, bud grafts of triploid rootstocks, namely, Vishala + Lun-40-2 (T11), TR8 + Accession 304 (T5) and TR10 + Burilam-60 (T22) were identified as promising ones as an alternative way for combating soil moisture stress and for enhanced scale of field testing.

ACKNOWLEDGEMENT

The authors are thankful to the Director, Karnataka State Sericulture Research and Development Institute, for providing the facilities and encouragement, during the present field study and to the Statistical Officer, KSSRDI, for the analysis of data.

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INFLUENCE OF MULBERRY VARIETIES ON REPRODUCTION POTENCY OF MALE MOTH OF *BOMBYX MORI* L.

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ABSTRACT

Male silkmoth plays a pivotal role in fertilization and egg production in female moth and its potency influences the quality parameters in egg production. Silkworm during its entire life cycle of about 50 days completes four stages *i.e.*, egg, larva, pupa and moths, consumes food for about 20 days. Hence quality nutrition during its larval stage is very important for effective reproduction. In the present work, the interaction between foliage of the different varieties and reproductive ability of silkmoth was studied. Four mulberry (*Morus alba*) varieties predominently cultivated in south India were tested on six bivoltine silkworm breeds (CSR2, CSR4, CSR18, CSR19, KA and NB4D2). The interaction in between food plant and insect with special reference to reproduction parameters were studied. Mating ability (pairing efficiency), egg recovery (yield), rate of fecundity and unfertilized eggs were considered as prominent parameters. Each male moth was allowed to mate four times, each time with a virgin female and later the female moths were kept for oviposition. 384 test results were recorded from various combinations and were graded. Out of 96 top performance test results, 93 were recorded from treatments fed with leaves of V1 mulberry variety, followed by MR2 scoring second highest (77 test results). K2 and S36 varieties recorded relatively low performance in reproduction parameters. Greater pairing ability, highest fecundity high egg yield and lowest unfertilized egg occurrence were recorded with V1 mulberry variety. The results indicated that V1 mulberry variety has high positive correlation with reproductive quality parameters among the bivoltine silkworm breeds.

Key words: Fecundity, Male potency, Mulberry, Silk moth

INTRODUCTION

Mulberry being the sole food plant of silkworm *Bombyx mori*. L, its nutrient contents plays a vital role for silkworm reproduction. The effects of genotypic differences are prominent on silkworm growth and development in general and reproduction activities in particular. The silkworm during its metamorphosis passes through four phases *viz*., egg, larva, pupa and moth. Unique factor here is that feeding and nutrient-acquiring stage is only the larval stage and other three stages survive on the reserve food material acquired during larval stage. In a period of about 55 days of life cycle, the insect consumes food for a period of 22 to 23 days. The larva being voracious growth stage has to fulfill its nutrient needs and keep stock of reserve nutrients for the other three stages. In the present study, an attempt was made to critically evaluate four mulberry varieties *viz*., K2, S36, V1 and MR2, for their effect on male potency.

Male moth potency in mating (pairing ability) and fertility is an important aspect in silkworm egg production. It is one of the determining factors of the quality of eggs and economics of seed production. Gillott and Friedel (1997) observed that mating and other physical activities such as flight or flutter, influence the physiological availability of nutrients in many insects. Mating is a stimulus that induces mobilization of reserves in some females. The male make nutrient contributions to the female during courtship and

mating by offering nuptial gifts of food, and nutrients may be obtained from seminal fluid and spermatophore (Boggs, 1990). Hence while assessing the reproductive efficiency, male moth potency also becomes an important criterion. Male moth potency is mainly assessed with four parameters *viz*., pairing ability (%), egg recovery (%), unfertilized eggs (%) and fecundity.

Generally, in silkworm egg production, male moths are used for mating only once but in producing commercial hybrid seed, male moths are used twice with an intermittent gap for rejuvenation. At times due to unforeseen situations egg producers may have to resort to a third mating and on rare occasions a fourth, though not advisable. During such occasions, the male moth potency, which is basically depends on reserve nutrients reflect on the qualitative aspects of eggs. For assessing the male moth potency, all the four parameters are studied in four matings by individual male moths.

MATERIALS AND METHODS

Four popular mulberry genotypes *viz*., K2, S36, V1 and MR2 were subjected to critical evaluation through bioassay of six bivoltine silkworm races *i.e*., CSR2, CSR4, CSR18, CSR19, KA and NB4D2. Foliage was sourced from plantation of mulberry established in RBD and following standard package of practices. Seed cocoons were generated in the laboratory by adopting standard rearing techniques (Krishnaswamy, 1986; Datta *et al.,* 1996). Cocoons were cut open and the sex separated pupae were preserved under optimum conditions of 25±1ºC temp. and 75±5% RH. After emergence, male moths were allowed to copulate for three hours (58 a.m.) with virgin female moths of respective races raised on leaves of K2 variety. After de-pairing, female moths were kept on egg laying sheets and covered with cellules and allowed for oviposition under dark condition at temperature 25±1ºC and 75±5% RH. De-paired male moths were rested at 7.5±1ºC and 75±5% RH, allowed to copulate again with another set of virgin female moths for three hours (10 a.m. 1 p.m.) under optimal conditions. Similarly, two more copulations were conducted on second day with two separate sets of female moths. Each time after copulation unpaired moths were separated and number of properly coupled (paired) moths were counted and recorded. In all treatments, three replications of 50 moths each, were maintained for oviposition. Data on recovery of layings, rate of unfertilized eggs and fecundity were recorded from six trials and were analysed statistically.

RESULTS AND DISCUSSION

Pairing ability (%): In all four pairings, V1 leaf fed batches of all six silkworm races have showed significantly high pairing percentage, followed by MR2, K2 and S36 (Table 1).

Egg recovery (%): In all four matings the egg recovery was significantly high in V1 fed silkworms, closely followed by batches reared on MR2 leaf. K2 and S36 performed third and fourth respectively (Table 2).

Unfertilized eggs (%): Lowest occurrence of unfertilized eggs was recorded in the batches reared on V1 leaves (Table 3).

Fecundity: All six silkworm races fed with leaves of V1 mulberry variety recorded significantly high fecundity in all four pairings, over other varieties (Table 4).

Samsijah (1984) studied five mulberry varieties and established their varied effect on fecundity and hatchability and recommended *M .australis* and *M. alba* for egg production. Mishra *et al*., (1993) proved seasonal and food plant determined differences in reproduction parameters, such as, rate of emergence, hatching and fecundity of Indian tasar silk moth, *Antheraea mylitta* (Saturniidae). Silayach *et al.,* (1995) found variations in hatching and emergence when reared on various cultivars of mulberry. Reddy *et al*., (1988) found higher fecundity in tasar silkworms fed on *T. tomentosa* (501) than *T. arjuna* (409) and *T. bellirica* (381). Govindan *et al*., (1987) established the effects of mulberry varieties on cocoon weight, ovariole egg number and fecundity. The results of the present study on reproduction and male potency are in conformity with the earlier results.

CONCLUSION

It is quite evident from the foregoing discussions that the mulberry variety V1 is superior based on the overall performance among the four mulberry varieties evaluated in the present study. The genotypes are ranked in the order V1> MR2> K2 > S36. From the above observations it is suggested that V1 mulberry variety could be exploited for better reproduction in general and male potency in particular, for bivoltine silkworm egg production.

ACKNOWLEDGEMENTS

Authors acknowledge the support of Sri. Justin Kumar, J., Technical Assistant, CSB in compilation and tabulation of data and critical analysis and interpretations.

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Table 1:Male moth potency of Bivoltine Pure Race larvae reared on different mulberry genotypes - Pairing Efficiency (%)

MG	SWR>	I PAIRING						II PAIRING					
		CSR2	*CSR4*	CSR18	CSR19	KA	NB4D2	CSR2	CSR4	CSR18	CSR19	KA	NB4D2
K_2	Mean	96.00	94.00	95.11	95.56	96.00	95.78	92.44	89.89	90.33	89.78	90.89	92.44
	SD	1.41	1.22	0.93	1.51	1.00	1.39	3.47	1.62	3.61	3.56	3.59	3.50
S_{36}	Mean	96.44	93.67	94.78	94.89	94.78	95.11	90.67	89.44	90.11	89.78	89.11	90.00
	SD	1.13	1.00	0.67	1.83	0.97	0.93	4.21	2.70	4.31	5.45	4.65	4.00
V_1	Mean	98.00	96.44	96.89	96.11	97.56	98.11	95.22	93.56	94.33	92.56	94.33	95.00
	SD	1.00	1.13	1.17	1.76	0.88	0.78	1.39	1.88	1.73	1.51	1.73	2.40
MR_2	Mean	97.33	95.56	95.67	95.33	95.78	96.33	93.44	91.78	91.11	92.89	91.89	93.22
	SD	1.00	1.01	1.00	1.50	1.20	1.00	2.60	1.92	1.62	2.89	2.03	2.64
Grand Mean		96.94	94.92	95.61	95.47	96.03	96.33	92.94	91.17	91.47	91.25	91.56	92.67
SD		1.35	1.56	1.23	1.65	1.40	1.51	3.41	2.58	3.38	3.79	3.63	3.56
CD @5%				0.36						0.41			
		III PAIRING						IV PAIRING					
K_2	Mean	85.67	82.11	84.67	84.67	85.56	85.89	78.67	76.44	80.11	76.67	82.67	81.56
	SD	2.55	3.89	7.09	7.00	7.23	4.62	3.04	4.22	7.01	6.14	7.91	6.29
S_{36}	Mean	85.44	83.67	82.00	82.11	83.00	85.22	78.00	76.22	75.33	74.78	80.22	80.00
	SD	3.57	6.61	7.60	6.49	6.36	5.72	5.39	6.04	6.63	7.69	8.51	7.37
V_1	Mean	91.67	89.33	88.00	87.67	90.56	92.33	83.33	83.00	82.56	81.67	86.67	88.33
	SD	2.1	3.39	2.83	3.39	3.05	2.83	2.12	1.22	1.74	1.73	3.67	2.78
MR_2	Mean	88.56	86.11	85.89	85.00	86.89	87.22	81.00	79.11	78.56	77.44	84.33	83.22
	SD	3.71	4.11	4.65	5.00	4.65	3.80	1.87	2.67	3.09	4.64	6.18	4.87
Grand Mean		87.83	85.31	85.14	84.86	86.50	87.67	80.25	78.69	79.14	77.64	83.47	83.28
SD		3.90	5.25	6.02	5.76	5.99	5.05	3.89	4.70	5.59	5.86	6.95	6.22
CD @5%				0.53						0.55			

MG-Mulberry Genotypes; SWR- Silkworm Race

Table 2: Male moth potency of Bivoltine Pure Race larvae reared on of different mulberry genotypes - DFLs Recovery (%)

MG	SWR >	I PAIRING						II PAIRING					
		CSR2	*CSR4*	CSR18	CSR19	KA	NB4D2	CSR2	CSR4	CSR18	CSR19	KA	NB4D2
K_2	Mean	94.33	91.67	93.11	92.78	93.44	93.67	89.11	86.89	86.67	85.56	88.22	89.00
	SD	1.22	1.87	1.05	1.56	0.88	1.41	3.41	2.47	3.81	2.60	3.42	3.32
S_{36}	Mean	94.22	91.22	91.56	92.67	92.89	93.00	87.78	87.00	85.78	86.89	85.56	86.44
	SD	0.83	1.20	0.88	1.58	1.05	1.00	4.52	3.61	4.47	5.28	4.75	3.91
V_1	Mean	96.33	94.44	94.56	94.11	95.56	96.33	92.89	89.67	90.78	89.44	91.44	91.44
	SD	1.32	1.01	0.88	1.27	1.01	1.00	2.09	3.35	3.31	1.51	2.01	2.88
MR_2	Mean	95.22	93.33	93.22	93.11	93.56	94.56	90.67	88.33	87.56	89.67	89.00	89.33
	SD	0.97	1.00	0.83	1.05	1.24	1.13	3.74	2.65	2.51	3.46	2.06	2.78
Grand Mean		95.03	92.67	93.11	93.17	93.86	94.39	90.11	87.97	87.69	87.89	88.56	89.06
SD		1.36	1.82	1.39	1.44	1.44	1.68	3.90	3.14	3.93	3.78	3.78	3.59
CD @5%				0.39						0.43			
		III PAIRING						IV PAIRING					
K_2	Mean	82.00	77.78	78.22	77.89	79.44	83.11	71.22	69.56	72.44	70.00	77.22	77.22
	SD	3.35	5.14	6.59	4.76	6.23	4.76	3.38	2.65	4.95	3.87	6.28	5.26
S_{36}	Mean	81.67	78.67	76.33	76.78	79.56	81.67	69.89	68.56	69.33	67.78	74.89	76.33
	SD	5.36	7.42	6.86	5.54	6.88	4.90	4.08	4.19	6.00	5.36	7.22	6.82
V_1	Mean	87.11	84.11	83.56	83.11	86.11	88.22	73.78	75.00	76.33	75.33	80.78	83.56
	SD	2.71	3.26	2.07	2.57	3.89	4.32	1.72	1.87	1.00	1.00	3.80	3.54
MR_2	Mean	84.00	80.56	80.67	79.67	82.44	84.33	72.33	71.89	73.00	71.22	77.78	78.67
	SD	3.74	4.56	4.95	4.18	6.82	4.18	2.18	1.83	2.50	3.49	5.91	5.52
Grand Mean		83.69	80.28	79.69	79.36	81.89	84.33	71.81	71.25	72.78	71.08	77.67	78.94
SD		4.34	5.64	5.90	4.86	6.43	5.00	3.21	3.68	4.67	4.56	6.06	5.90
CD @5%				0.52						0.51			

MG-Mulberry Genotypes; SWR- Silkworm Race

Table 3: Male moth potency of Bivoltine Pure Race larvae reared on different mulberry genotypes - Un fertilized eggs (%)

MG	SR >>	I PAIRING						II PAIRING					
		CSR2	*CSR4*	CSR18	CSR19	KA	NB4D2	CSR2	CSR4	CSR18	CSR19	KA	NB4D2
K_2	Mean	5.04	4.64	4.69	4.74	4.62	4.72	5.73	5.59	5.58	5.43	5.30	5.63
	SD	0.62	0.45	0.46	0.43	0.35	0.49	0.67	0.78	0.66	0.50	0.48	0.48
S_{36}	Mean	5.46	5.38	4.88	4.97	4.70	4.62	6.61	6.71	5.99	5.98	5.80	6.33
	SD	1.00	1.04	0.55	0.56	0.44	0.43	1.13	1.00	0.60	0.65	0.48	0.52
V_1	Mean	3.83	4.39	4.77	4.44	4.39	4.41	4.46	4.88	5.32	5.02	5.08	5.29
	SD	0.69	0.50	0.65	0.58	0.39	0.39	0.91	0.58	0.66	0.59	0.43	0.52
MR_2	Mean	4.84	4.92	4.68	4.54	4.71	4.77	5.52	5.50	5.44	5.27	5.68	5.62
	SD	0.54	0.53	0.51	0.37	0.47	0.51	0.77	0.53	0.69	0.37	0.51	0.56
Grand Mean		4.79	4.83	4.75	4.68	4.61	4.63	5.58	5.67	5.58	5.43	5.46	5.72
SD		0.93	0.74	0.53	0.51	0.42	0.46	1.15	0.98	0.67	0.62	0.54	0.63
CD @5%				0.10						0.09			
		III PAIRING						IV PAIRING					
K_2	Mean	6.51	6.54	6.53	6.76	6.49	6.41	7.62	7.84	7.37	7.31	7.07	6.98
	SD	0.94	0.88	0.64	0.95	0.28	0.49	0.92	1.04	0.64	0.96	0.53	0.40
S_{36}	Mean	7.79	8.09	6.86	6.98	6.56	6.98	8.31	8.52	7.60	7.80	7.51	7.61
	SD	1.06	1.36	0.66	0.82	0.43	0.56	1.03	1.41	0.75	0.86	0.86	0.74
V_1	Mean	5.41	5.57	6.06	5.62	5.86	5.98	6.36	6.29	6.84	6.70	6.63	6.90
	SD	0.89	0.53	0.76	0.47	0.61	0.54	0.56	0.64	0.69	0.53	0.44	0.50
MR_2	Mean	6.34	6.30	6.17	6.39	6.23	6.43	6.59	6.79	7.12	7.14	7.26	7.36
	SD	0.56	0.83	0.60	0.64	0.53	0.67	0.56	0.66	0.61	0.62	0.53	0.77
Grand Mean		6.51	6.63	6.40	6.44	6.28	6.45	7.22	7.36	7.23	7.24	7.12	7.21
SD		1.21	1.30	0.72	0.88	0.53	0.65	1.11	1.30	0.70	0.83	0.67	0.66
CD @5%				0.08						0.08			

MG-Mulberry Genotypes; SR- Silkworm Race

Table 4: Male moth potency of Bivoltine Pure Race larvae reared on different mulberry genotypes - Fecundity (Nos)

MG	SWR >	I PAIRING						II PAIRING					
		CSR2	*CSR4*	CSR18	CSR19	KA	NB4D2	CSR2	CSR4	CSR18	CSR19	KA	NB4D2
K_2	Mean	564.22	533.22	557.89	555.00	566.89	550.44	551.56	524.11	549.00	538.11	551.67	545.22
	SD	7.21	8.87	10.08	7.97	8.57	5.32	8.05	9.52	6.56	7.03	6.58	4.55
S_{36}	Mean	548.67	531.00	553.44	552.33	575.56	546.33	542.22	522.67	541.11	535.33	546.78	539.67
	SD	6.65	7.79	5.62	5.02	8.69	5.77	7.08	10.06	7.32	7.26	3.70	6.69
V_1	Mean	623.89	593.78	589.00	578.67	620.00	583.44	614.22	587.78	579.67	572.67	607.56	575.67
	SD	6.41	8.15	10.03	7.83	6.14	6.56	7.07	6.22	7.68	6.89	4.90	4.77
MR_2	Mean	574.22	542.67	566.56	556.56	570.44	557.00	566.33	517.67	554.67	548.00	558.11	544.89
	SD	7.14	6.16	8.28	8.49	7.09	4.53	3.91	5.85	5.79	7.70	6.97	6.81
Grand Mean		577.75	550.17	566.72	560.64	583.22	559.31	568.58	538.06	556.11	548.53	566.03	551.36
SD		29.29	26.97	16.19	12.83	22.97	15.60	28.83	30.23	16.04	16.44	25.25	15.44
CD @5%				1.34						1.27			
		III PAIRING						IV PAIRING					
K_2	Mean	541.56	513.00	539.56	525.56	534.22	530.33	522.33	493.78	517.67	514.89	520.89	513.22
	SD	8.06	9.75	6.52	7.63	4.79	5.87	9.82	10.63	9.79	10.74	6.29	6.63
S_{36}	Mean	533.67	498.56	529.44	518.89	529.89	523.33	519.67	493.78	507.33	509.33	511.44	504.11
	SD	8.66	9.50	10.51	9.27	10.01	4.77	12.26	16.17	12.50	13.40	11.53	4.40
V_1	Mean	592.44	563.00	568.78	562.22	582.67	564.67	582.56	553.78	555.22	538.44	567.78	541.33
	SD	4.36	6.58	6.12	6.14	8.35	6.78	4.82	5.72	6.36	9.23	8.07	5.17
MR_2	Mean	551.33	532.67	539.56	531.22	538.78	528.33	529.56	506.89	524.00	520.11	524.11	511.33
	SD	6.10	6.87	9.23	8.44	6.10	9.03	9.25	6.33	8.22	8.58	9.18	6.27
Grand Mean		554.75	526.81	544.33	534.47	546.39	536.67	538.53	512.06	526.06	520.69	531.06	517.50
SD		23.92	25.75	16.89	18.48	22.67	17.82	27.56	26.99	20.26	15.06	23.63	15.37
CD @5%				1.20						1.26			

MG-Mulberry Genotypes; SWR- Silkworm Race

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 51-55

PERFORMANCE OF SOME IMPROVED MULBERRY VARIETIES UNDER RAINFED CONDITIONS IN THE EASTERN GHAT HIGH LAND ZONE OF ODISHA

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ABSTRACT

A field experiment was carried out for four years (2001-05) at the Regional Sericultural Research Station, Koraput farm to evaluate the performance and suitability of certain improved mulberry varieties for the eastern ghat highland zone of Odisha. The experiment was laid out in June/July, 2001 in a Randomized Block Design in three replications using eleven mulberry varieties viz. MV1 (V1), MV2(C1730), MV3(C2016), MV4(C2017), MV5(Anantha), MV6(RFS175), MV7(Thalaghattapura), MV8 (Vishala), S1635, S1 and K2 with a spacing of 90 x 90 cm , the gross plot size being 9.0 x 7.2 m. FYM@ 10 mt/ha/yr and N:P2O5:K2O @ 150:50:50 kg/ha/yr with N in two equal split doses were applied in July and September and the plantation was maintained following the recommended 'package of practices' for rain fed mulberry. The plantation was left for establishment for one year i.e. up to June, 2002 when an annual bottom pruning was given. Three leaf harvests were made during Sept, Nov & March every year in 2002-03, 2003-04 and 2004-05. However, the yield data of first year being unstable, average leaf yield of last two years was taken into consideration. Average annual leaf yield over two years indicated that MV8 was found to be the highest yielder (9371.732 kg/ha/yr) followed by MV3 (9211.161 kg/ha/yr) and MV2 (9050.102 kg/ha/yr) recording 10.37 %, 8.48 % and 6.58 % increase over S1635 (8491.254 kg/ha/yr); 50.8 %, 48.22 % and 45.63 % increase over S1(6214.556 kg/ha/yr) and 27.64 %, 25.45 % and 23.25 % increase over K2 (7342.540 kg/ha/yr). Bio-assay study was conducted with Multi X Bi hybrid during Oct-Nov' 04 and Feb-Mar '05 following the standard rearing techniques. No significant difference was observed with reference to different rearing traits such as weight of 10 mature larvae and SR %. No rearing could be conducted with var MV5 and MV6 during Feb-March due to very late sprouting following the half height pruning in 3rd week of December. Hence mulberry varieties viz. MV8, MV3 and MV2 being at par while recording significantly higher yield over S1635, S1 and K2, they may be popularized among the farmers of the Odisha state.

Key words: Bio-assay, Mulberry varieties, Rainfed condition, Rearing

INTRODUCTION

Mulberry (*Morus* spp) is the only food plant for silkworm, *Bombyx mori* L. . Hence the viability of mulberry sericulture industry largely depends upon the quantity and quality of silk cocoons produced, which in turn, depends on the quantity and quality of mulberry leaf output. Again, leaf productivity of mulberry mainly depends upon the potentiality of the varieties associated with proper 'package of practices'. Furthermore, yield potential of a variety is a genotypic character which is influenced by the edapho-climatic conditions, inputs and agronomical practices. Significant differences in leaf yield and quality due to different mulberry varieties were reported by Kashiviswanathan *et al* (1979), Kamble (1988), Saratchandra *et al* (1992), Sarkar (1993), Misra *et al.,* (1995) and Purohit and

Pavan Kumar (1996). Majority of mulberry gardens in Odisha state are maintained under rainfed conditions mainly with the varieties K2/ S1635 whose leaf yield at farmers' level ranges from 5000-6000 kg/ha/yr. This poses a great challenge for the viability of mulberry sericulture in the state. Over the years, the sericultural research institutes across the country have evolved a good number of improved mulberry varieties claiming higher yield potentiality than the existing ones. Thus, to find out a high yielding mulberry variety suitable for rainfed conditions in Odisha agro-climatic conditions a field experiment was conducted for four years (2001-05) at Regional Sericultural Research Station farm, Koraput with eight improved mulberry varieties evolved by different research institutes to test their suitability and yield performance *vis-à-vis* three check varieties S1635, S1 and K2 .

MATERIALS AND METHODS

Eight improved mulberry varieties *viz.,* MV1 (V1) and MV6 (RFS175) collected from CSR&TI, Mysore; MV2 (C1730), MV3 (C2016) and MV4 (C2017) from CSR&TI, Berhampore; MV5 (Anantha) from RSRS, Ananthapur and MV7 (Thalaghattapura) and MV8 (Vishala) from KSSRDI, Bangalore along with three check varieties S1635, S1 and K2 were planted in three replications in a randomized block design in June/July, 2001, with a spacing of 90 × 90 cm. The plot size was 9.0 × 7.2 m. The soil was red and sandy loam and acidic with pH 5.4-5.6, available nitrogen 379 kg/ha, P2O5 20.25 kg/ha, K2O 329 kg/ha and Organic carbon 0.20 %. The plantation was left for establishment for a year *i.e*., upto June, 2002. All the plants were maintained following the recommended 'package of practices' using FYM @ 10 mt/ha/yr and N:P2O5:K2O @ 150:50:50 kg/ha/yr with nitrogen in two equal split doses in July and September. Annual bottom pruning in mid-June and a half-height pruning (75 cm above ground level) in third week of December were given every year. Growth data such as plant height , number of primary shoots per plant, total shoot length, internodal distance and fresh leaf weight per plant were recorded every year for three crops and the average pooled data presented in Table 1. Three leaf harvests were made during September, November and March every year. However, the yield data of first year being unstable, average yield of last two years was taken in to consideration and presented in Table 2. Bio-assay study with Multi × Bi hybrid (N × NB4D2) was conducted during Oct-Nov '04 and Feb-March '05 rearing seasons following the standard rearing techniques and the data are presented in Table 3.

RESULTS AND DISCUSSION

Plant Height

From the pooled data, it was observed that variety MV8 had taller plants (131.8cm) followed by MV7 (127.78 cm) and S1 (124.78 cm) and the shorter plants were found in MV6 (102.73 cm) compared to other mulberry varieties tested (Table-1). Height of plant is an important character determining the production potentiality of a mulberry variety. A positive correlation between plant height and leaf yield was found by Vijayan *et al.,* (1999). Taller plants found in MV8, MV7 and S1 *vis-à-vis* the remaining varieties may be due to their inherent genotypic character.

Number of primary shoots per plant

Higher number of primary shoots per plant was observed in var MV3 (7.6) followed by MV2 (7.1) and S1635 (6.8) and the least in var MV6 (5.1) (Table 1). The variation in number of shoots per plant may be due to the genotype × environment interaction. Vijayan *et al.,* (1998) reported positive correlation between number of shoots per plant and leaf yield.

Total shoot length per plant

Maximum total shoot length was recorded in var MV2 (647.2 cm) followed by MV3 (627.6 cm) and S1635 (625.4 cm) and the least in var MV6 (410.7 cm) compared to other varieties (Table 1). This may be due to the higher number of primary shoots per plant coupled with plant height.

Internodal distance

As regards the internodal distance, MV8 and S1635 recorded the highest value (5.4 cm) followed by MV2 (5.1 cm) and MV4 and MV7 (4.9 cm). The shortest internodal distance was observed in MV5 (4.4 cm) which was at par with MV1, MV3, MV6, S1 and K2 (4.5 cm) (Table 1). The variation in Internodal distance among the varieties is also a genotypic character. Varieties having longer internodes indicate less number of leaves per unit length *vis-à-vis* those with shorter internodal distance.

Fresh leaf weight per plant

Maximum average fresh leaf weight per plant was found in var MV8 (260.7 gms) followed by MV3 (230.4 gms) and MV2 (220.7 gms) and the least in var S1 (152.1 gms) (Table 1). The higher leaf weight in the first three varieties may be due to larger leaf size and succulent nature of leaf.

Leaf yield

Seasonal variations in leaf yield was observed from September to March. During September, var MV8 recorded the highest leaf yield (4189.428 kg/ha) followed by MV2 (4115.740 kg/ha) and S1635 (4086.471 kg/ha) and MV3 (4076.594 kg/ha) and the lowest was in S1 (3023.199 kg/ha). In November crop also MV8 was the highest yielder (2963.220 kg/ha) followed by MV3 (2913.837 kg/ha) and MV7 (2723.817 kg/ha) with S1 again being the lowest yielder (1826 kg/ha) . During March harvest, however, MV2 recorded the highest yield (2326.080 kg/ha) followed by

Table 1: Growth data pooled over two years (2003-05) Average of six crops

Mulberry Varieties	Plant height (cm)	No. of shoots/plant	Total shoot length (cm)	Internodal distance(cm)	Fresh leaf wt. per plant (g)
MV1(V1)	119.78	5.2	508.6	4.5	192.5
MV2(C1730)	119.43	7.1	647.2	5.1	220.7
MV3(C2016)	109.18	7.6	627.6	4.5	230.4
MV4(C2017)	105.42	6.7	525.1	4.9	199.4
MV5(Anantha)	111.80	5.3	437.3	4.4	192.2
MV6(RFS175)	102.73	5.1	410.7	4.5	185.8
MV7(Thalaghattapura)	127.78	5.8	587.7	4.9	212.9
MV8(Vishala)	131.18	5.9	574.8	5.4	260.7
S1635(Check)	121.88	6.8	625.4	5.4	208.9
S1(Check)	124.78	6.0	564.9	4.5	152.1
K2(Check)	114.87	6.3	534.5	4.5	182.1

Table 2: Seasonal and annual leaf yield (kg/ha) – Average of two years (2003-05)

Mulberry Varieties	September	November	March	Annual yield (total of 3 crops)
MV1(V1)	3573.123	2317.615	1531.545	7422.283
MV2(C1730)	4115.740	2608.282	2326.080	9050.102
MV3(C2016)	4076.594	2913.837	2220.730	9211.161
MV4(C2017)	3867.001	2511.985	2186.111	8565.097
MV5(Anantha)	3816.461	2640.638	1617.592	8074.691
MV6(RFS175)	3678.241	2367.669	1830.709	7876.619
MV7(Thalaghattapura)	3155.710	2723.817	1825.848	7705.375
MV8(Vishala)	4189.428	2963.220	2219.084	9371.732
S1635(Check)	4086.471	2423.276	1981.507	8491.254
S1(Check)	3023.199	1826.003	1365.354	6214.556
K2(Check)	3275.669	2309.747	1757.124	7342.540

Table 3: Rearing Performance of silkworm race N × NB4D2 with different mulberry varieties

Seasons	Mulberry varieties	Wt. of 10 mature larvae (g)	No. of live cocoons harvested out of 200 larvae	Wt. of cocoons harvested (kg)	Single cocoon weight (g)	Single shell weight (g)	S.R. %
OCT – NOV , 2004	MV1(V1)	33.6	189.4	0.330	1.744	0.302	17.3
	MV2(C1730)	34.4	189.2	0.331	1.753	0.312	17.7
	MV3(C2016)	33.8	191.0	0.323	1.698	0.298	17.5
	MV4(C2017)	34.2	192.4	0.341	1.774	0.318	17.9
	MV5(Anantha)	34.0	191.4	0.326	1.709	0.299	17.4
	MV6(RFS175)	33.0	190.6	0.314	1.651	0.285	17.2
	MV7(Thalaghattapura)	33.4	191.4	0.311	1.628	0.290	17.8
	MV8(Vishala)	33.4	189.6	0.314	1.662	0.289	17.4
	S1635 (Check)	33.6	184.0	0.321	1.736	0.306	17.6
	S1(Check)	33.4	190.6	0.341	1.793	0.320	17.6
	K2(Check)	33.4	191.6	0.326	1.708	0.304	17.7
FEB – MARCH, 2005	MV1(V1)	34.95	195	0.314	1.608	0.275	17.09
	MV2(C1730)	35.56	191	0.326	1.704	0.283	16.59
	MV3(C2016)	34.92	187	0.308	1.642	0.275	16.74
	MV4(C2017)	34.61	195	0.318	1.631	0.274	16.81
	MV5(Anantha)	Rearing could not be done due to late sprouting					
	MV6(RFS175)	Rearing could not be done due to late sprouting					
	MV7(Thalaghattapura)	34.04	195	0.303	1.552	0.256	16.53
	MV8(Vishala)	34.71	196	0.326	1.663	0.280	16.86
	S1635(Check)	33.44	192	0.304	1.583	0.262	16.55
	S1(Check)	33.38	188	0.302	1.603	0.271	16.88
	K2(Check)	33.32	190	0.300	1.571	0.262	16.71

MV3 (2220.730 kg/ha) and MV8 (2219.084 kg/ha) all being at par and the S1 registered the lowest yield (1365.354 kg/ha) (Table-2). This indicates better adaptability of MV2, MV3 and MV8 to moisture stress condition than the other varieties in March crop. The gradual reduction in leaf yield from September to March may be due to reduction in soil moisture content with the cessation of monsoon, under rainfed conditions.

Average annual leaf yield over two years (2003-05) revealed MV8 as the highest yielder (9371.732 kg/ha/yr) followed by MV3 (9211.161 kg/ha/yr) and MV2 (9050.102 kg/ha/yr) with 10.37 % , 8.48 % and 6.58 % increase over S1635 (8491.254 kg/ha/yr) ; 50.8% , 48.2% and 45.6 % increase over S1 (6214.556 kg/ha/yr) and 27.6 %, 25.45 % and 23.25 % increase over K2 (7342.540 kg/ha/yr) (Table-2). The higher leaf yield in these three varieties might be due to their higher fresh leaf weight per plant coupled with plant height and number of shoots per plant.

Bio-assay studies conducted by feeding silk worms (N × NB4D2) with leaves of different mulberry varieties during Oct-Nov '04 and Feb-March '05 revealed little or marginal differences with regard to different rearing traits (Table 3). As such, variety MV8 (Vishala), MV3 (C2016) and MV2 (C1730) may be recommended in order of preference for the eastern ghat highland zone of Odisha under rainfed conditions. Varieties MV5 (Anantha) and MV6 (RFS175) being very late sprouters (after half height pruning in December) could not provide leaves for Feb-March rearing; hence may be rejected.

ACKNOWLEDGEMENTS

The authors express their sincere thanks to the Directors, CSR&TI, Berhampore and Mysore, KSSRDI, Bangalore and Joint Director, RSRS, Ananthapur for providing the planting materials of different improved mulberry varieties and to the Joint Director, RSRS, Koraput for providing necessary facilities and encouragement.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 56-62

INTERCROPPING LEGUMINOUS CROPS WITH MULBERRY AND ENHANCING SOIL HEALTH OF RAINFED MULBERRY GARDEN IN ODISHA

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ABSTRACT

Odisha State enjoys a tropical monsoonic climate with average annual rainfall of 1658.7 mm in 40.5 to 84.7 numbers of rainy days, relative humidity of 75 % in plains & of 60 % in upland region and mean annual temperature varying from 30^0 C to 40^0 C. Odisha being a non traditional state to Mulberry sericulture, presently it is practised in nine districts with 1246 numbers of farmers covering 993 acres of land under mulberry. The soil of these mulberry grown areas are mostly red in colour, acidic, poor in fertility & water holding capacity. And, about 74 % of net cultivated land is maintained under rainfed condition. Majority of Sericultural farmers are socio-economically very poor, marginal to small, belong to scheduled tribe community, have half an acre of mulberry garden under rainfed condition and do not apply the required quantity of organic manures and chemical fertilizers. Thus, the poor condition of soil health results in poor leaf yield and quality. To increase the soil health, intercropping of leguminous crops with mulberry thought to be beneficial as leguminous intercrops fix atmospheric nitrogen to soil and can add approximately 500 kg of nitrogen to soil per hectare per year (Shankar *et al.*, 2002) thereby making the soil more fertile. Also, intercrops are advantageous as the yield advantage in intercropping is probably due to better utilization of one or more growth factors by component crops due to their complementary effect which may explain better yield in mulberry (Willey, 1979). The quality of mulberry leaf did not deteriorate and remain same as that of pure crop of mulberry which was also confirmed through non-significant difference in economic traits of cocoon (Shankar *et al.*, 1998). Dry straw of intercrops also can be used in a cultivation cycle to replenish organic matter. Hence, this study has been undertaken to identify suitable leguminous intercrops in mulberry under the agro-climatic conditions of Odisha and to increase the soil health of mulberry garden thereby increasing the productivity of mulberry leaf and cocoon.

Key words: Inter cropping, Leguminous crops, Mulberry, Rainfed, Soil health

INTRODUCTION

Soil, the upper-most layer of earth's crust is a living and dynamic medium in which almost all life-support processes of plants and animals occur. All these life forms live in or on soil, perform their life-related activities and die to be decomposed in the soil (Strahler & Strahler, 1983). For plants soil is the active medium as all the required quantities of macro and micro nutrients for a plant are available in the soil. The availability of these nutrients in soil varies from place to place depending upon the composition, physical, chemical and organic properties of soil (March, 2000). The globalization and industrialization process has certainly increased productivity but with several negative ecological consequences like decline in soil fertility and its environment, increasing soil salinity, soil erosion, poor sustainability of agricultural lands and degradation of biodiversity. Soil factors *viz.* soil moisture, texture, structure, density, salinity, fertility, aeration, temperature and drainage are mostly responsible for plant growth and productivity in addition to plant factors, weather factors and miscellaneous factors (Marh, 2000). Since the rise of agriculture and forestry there has also arisen by necessity a practical awareness of soils and their management. Odisha State the beauty queen of Eastern India known as Kalinga and Utkal is situated in east coast of India between 17^0 45' to 22^0 31' north

latitude and 81^0 24' to 87^0 29' east longitude with a geographical area of 1, 55,707 sq km. Based on the stratigraphy, tectonic history and relief features along with erosional processes, the state presents four broad and well defined physical regions viz. 1) Northern Plateau, 2) Central table land, 3) Eastern Ghat and 4) East coastal plains. The state enjoys a tropical monsoon climate with average annual rainfall of 1658.7 mm in 40.5 to 84.7 numbers of rainy days and relative humidity of 75 % in plains & of 60 % in upland region. The mean annual temperature of the state is influenced by its altitude, latitude and proximity to the sea and varies from 30^0 C to 40^0 C. Major crops of the state are Paddy, Wheat, Maize, Ragi and Sugarcane. Mulberry sericulture was introduced in the state during sixth five year plan and considering the congenial agro-climatic conditions, it is presently practised in nine districts with higher elevations up to 1000 meters above MSL. Odisha being a non-traditional state in mulberry sericulture presently 1246 numbers of farmers have taken up mulberry sericulture in 993 acres of land. The soil of these mulberry grown areas are mostly red in colour, acidic, poor in fertility & water holding capacity where much of the rain water is lost by runoff as sloppy lands are poor in water holding capacity. And, about 74 % of net cultivated land is maintained under rainfed condition. Majority of sericultural farmers are socio-economically very poor, marginal to small, belong to scheduled tribe community and have half an acre of mulberry garden under rainfed condition and do not apply the required quantity of organic manures and chemical fertilizers. Thus, the poor condition of soil health results in poor leaf yield and quality. Leguminous crops are important intercrops which can be grown in mulberry garden as the same can add approximately 500 kg of nitrogen to the soil per hectare per year (Shankar *et al.*, 2002). However, this amount of nitrogen may vary from species to species of intercrops. Intercrops are advantageous as the yield advantage in intercropping is probably due to better utilization of one or more growth factors by component crops due to their complementary effect which may explain better yield in mulberry (Willey, 1979). They fix atmospheric nitrogen to soil, thereby making the soil more fertile (Mohan, 1988) and their dry straw are also used in a cultivation cycle to replenish organic matter. In addition, they are the important source of proteins in the dietary requirement of farmers. The quality of mulberry leaf did not deteriorate and remained same as that of pure crop of mulberry which was also confirmed through non-significant difference in economic traits of cocoon (Shankar *et al*., 1998). Hence, this study was undertaken to identify suitable leguminous intercrops in mulberry under the agro-climatic conditions of Odisha State.

MATERIALS AND METHODS

The present study intercropping of leguminous and seasonal vegetable crops in rainfed mulberry was undertaken at Regional Sericultural Research Station, Central Silk Board, Koraput in June 2006 for a period of two and half years. The experiment was laid out in Complete Block Design and gross size of each plot was 6.7 m x 6.7 m (22' x 22'). Mulberry variety S_{1635} was planted in July 2006 in paired row system [150 + (90 x 60) cm]. The Four leguminous crops viz. French bean (*Phaseolus vulgaris* L.), Soybean (*Glycine max* Merril), Black gram (*Phaseolus mungo* L. var. radiatus L.) and Cowpea (*Vigna sinensis* L.) were selected for intercropping with mulberry. A total of five treatments (T1- Mulberry sole, T2- Mulberry + French bean, T3- Mulberry + Soybean, T4 - Mulberry + Black gram, T5- Mulberry + Cowpea) were considered for the study with four replications each. Initial soil samples of five treatment plots were collected (before imposition of treatments) in July 2006. Soil samples of four replications of one treatment were collected separately and mixed to a composite sample and like wise five composite soil samples were collected for five treatments. Then soil samples were analyzed to know the hydrogen ion concentration, organic carbon, electric conductivity, nutrient nitrogen, phosphorus, potassium, micro nutrients (iron, manganese, zinc, copper, boron, sulphur), and microflora (bacterial, fungal, azotobacter, actinomycetes and rhizobium load) status of experimental plots. After the study in 2008 again the soil samples of five treatments were collected and all the parameters, nutrients and microflora were analyzed. The soil samples were analyzed at Orissa University of Agriculture and Technology, Bhubaneswar. Recommended package of practices (Dikshit and Purohit, 2007) was adopted to raise mulberry under rainfed condition. The intercrop seeds were treated with specific strains of rhizobium to increase the grain and dry forage yield and sown in the 150 cm space of mulberry plots at specific spacing of 45 cm (row to row) x 30 cm (plant to plant) for French bean, Soybean, Cowpea and 30 cm (row to row) x 10 cm (plant to plant) for Black gram. Intercultural operations were also carried out during each crop. Treatments were imposed during ravi (October-December 2006 & 2007) and kharif (July-September 2007 & 2008) crops only as the area experiences 90 % of annual rainfall during June to December months. However, treatments were not imposed in kharif (July-September) 2006, as mulberry was planted in July 2006 and under establishment. Growth parameters (plant height, number of branches / plant, total shoot length / plant) and leaf yield of mulberry were recorded for three seasons of the year (rainy, autumn and spring). Dry forage yield of intercrops were recorded during each crop and mulched in the respective experimental plots. The incidence of different diseases and pests of both mulberry and intercrops were recorded during each crop along with the meteorological data. Disease severity data were recorded by randomly selecting five branches from five plants. In each

plant, the total numbers of healthy and diseased leaves were graded in 0-5 scale on the basis of percent of leaf area infected. 0=healthy leaf, 1 = 1-5 % leaf area infected, 2 = 6-10 % leaf area infected, 3 = 11-25 % leaf area infected, 4 = 26-50 % leaf area infected, 5 = 51-100 % leaf area infected. And, Percentage Disease Index (PDI) was calculated by using the formula:

$$PDI = \frac{\text{Sum of all numerical rating}}{\text{No. of leaves counted} \times \text{Maximum grade (5)}} \times 100$$

The pest incidence data of each plot was recorded from 10 plants. The percent of infestation was calculated by counting number of plants infested (one shoot / plant), out of the total selected plants by the formula:

$$\text{Percent Infestation} = \frac{\text{No. of plants infested}}{\text{No. of plants selected}} \times 100$$

RESULTS AND DISCUSSION

Soil biology of mulberry garden

The initial soil status analysis (Table 1) revealed that, the soil was acidic (average pH of 6.57), medium in organic carbon (0.68); low in available nitrogen (179 kg / ha), phosphorus (1.06 kg / ha) and potassium (159 kg / ha); rich in iron (16.41), manganese (64.7), zinc (1.7) and copper (9.62); medium in boron (0.6); low in SO_4-S (10.14) and medium in microflora (bacterial, fungal, actinomycetes, azotobacter and rhizobium load) content. However, by imposing treatments for four times in two years period, all the nutrients and microflora of the experimental plot soil were increased except pH and iron content which were decreased slightly (Table 2) from 6.57 to 6.2 and 16.41 to 16.15 respectively.

Growth of mulberry

The growth attributing characters viz. no. of branches, average plant height and total shoot length (Table 3) of mulberry revealed that no. of branches per plant in mulberry sole was always more than the mulberry + intercrops (French bean, soybean, black gram and cowpea), but at par with mulberry. And, between the four intercrops, there was little difference but the difference was not significant.

Leaf yield of mulberry

The leaf yield of mulberry (Table 3) revealed that, during the first year (2006) *i.e.,* establishment phase of mulberry, sole mulberry crop was marginally higher than mulberry + soybean, mulberry + black gram and mulberry + cowpea and mulberry + french bean but, at par. In 2007, mulberry sole crop was at par with mulberry + soybean and significantly higher than mulberry + french bean, mulberry + cowpea, mulberry + black gram and registering an increase of 1540, 1368 and 1175 kg / ha respectively. However, in 2008, again mulberry sole crop was at par with mulberry + soybean and significantly higher than mulberry + french bean, mulberry + black gram and mulberry + cowpea.

Dry forage yield of intercrops

The dry forage yield of intercrops (Table 3), revealed that, in first year i.e. in 2006 black gram, soybean and cowpea was below norm but significantly higher in french bean (1047 kg / ha). However, in 2007, cowpea registered highest yield (6923 kg / ha) followed by black gram (4329), french bean (3274) and soybean (2303. The low yield in French bean and soybean was related to the rotting of plants. In 2008 also cowpea yielded highest (1906 kg / ha) followed by black gram (1844), soybean (592) and french bean (368).

Disease and pest of mulberry and intercrops

The disease and pest incidence data (Table 4) revealed that, during the kharif crops due to more rainfall (784 mm) in maximum (44 days) spell prevailed in the region with low temperature and high humidity, attack of fruit borer, leaf minor in french bean (10 %), cowpea (11 %) and black gram (7 %) and bacterial rotting of french bean (20 %) and soybean (5 %) plants were more than economic threshold level. During first year in ravi crop, attack of mealy bug, bihar hairy caterpillar and wingless grass hopper were confined to mulberry only with minimum infestation whereas, thrips infestation was higher in intercrops (black gram 17, soybean 16, french bean 15, cowpea 14). During ravi (October-December) crops PDI of powdery mildew was 14.4 in black gram and 7.9 in cowpea; and minimum in mulberry (7). The higher PDI of powdery mildew was related to the low temperature (15^0C) and high humidity (80.5%) prevailed during the crop.

CONCLUSION

From the above findings it may be concluded that, increase in nitrogen content of soil was due to the fixation of atmospheric nitrogen in the soil by the leguminous crops and in all other macro nutrients, micro nutrients and microflora were due to the mulching of dry forage of different intercrops in to the soil. Use of organic materials (Farmyard manure and Mulching of dry forage of intercrops) helped in speeding the conversion of poor quality subsoil into high quality top soil (Jayaraj *et al*., 2006) thereby increasing the soil fertility. Also it is confirmed that, decomposition of organic matter released organic acids, which mitigated the ill effects of high pH of soils and increased the microbial activity. It shows a positive and encouraging trend towards mitigating the plight of farmers who practice risk prone rainfed mulberry sericulture. Thus, adoption of intercropping of leguminous crops in mulberry is the ultimate solution to enhance the soil fertility and minimize the loss by generating extra income

Table 1: Initial soil status of mulberry garden before imposition of treatments

Treatments	pH	EC (ds/m)	OC (%)	Macro nutrients (kg / ha)			Micro nutrients (DTPA - ppm)						Microflora (cfu / gm)				
				N	P	K	Fe	Mn	Zn	Cu	B	So_4-S	Bacterial load	Fungal load	Actinomycetes load	Azotobacter load	Rhizobium load
T1- Mulberry sole	6.12	0.10	0.45	185	1.41	134	27.26	67.6	1.28	17.30	0.78	21.16	1.53×10^7	2.5×10^3	4×10^2	5.6×10^5	3.8×10^2
T2- Mulberry + French bean	6.75	0.07	0.64	188	0.93	135	10.04	49.8	2.26	10.00	0.48	7.66	4.2×10^3	1.8×10^2	4×10^4	7.5×10^5	1.4×10^2
T3- Mulberry + Soybean	6.94	0.09	0.68	174	0.65	179	13.26	76.4	1.96	3.26	0.34	10.95	2.52×10^7	3.6×10^4	5.6×10^5	2.6×10^5	2.7×10^3
T4- Mulberry + Black gram	6.82	0.11	0.49	168	1.12	213	14.26	75.0	1.58	4.26	0.70	8.40	1.46×10^6	2.3×10^4	2.9×10^3	4.7×10^5	2.6×10^3
T5- Mulberry + Cowpea	6.22	0.04	0.57	180	1.21	134	17.26	54.5	1.42	13.30	0.73	2.55	2.38×10^5	1.9×10^6	2×10^2	4.3×10^5	3.2×10^3

Table 2: Soil status of mulberry garden after (two years) imposition of treatments

Treatments	pH	EC (ds/m)	OC (%)	Macro nutrients (kg / ha)			Micro Nutrients (DTPA - ppm)						Microflora (cfu / gm)				
				N	P	K	Fe	Mn	Zn	Cu	B	So_4-S	Bacterial load	Fungal load	Actinomycetes load	Azotobacter load	Rhizobium load
T1- Mulberry sole	6.00	0.11	0.57	194	1.62	162	21.14	61.5	1.04	15.60	0.69	14.16	1.9×10^8	3.2×10^4	5.31×10^5	5.93×10^5	5.3×10^2
T2- Mulberry + French bean	6.50	0.09	0.69	198	1.12	159	08.65	44.2	2.07	08.35	0.57	10.43	4.7×10^5	2.7×10^6	$4 .92 \times 10^6$	7.86×10^5	3.6×10^2
T3- Mulberry + Soybean	6.53	0.09	0.72	188	0.98	196	09.72	57.9	1.79	4.82	0.48	13.54	3.4×10^7	3.9×10^6	5.91×10^7	4.24×10^5	4.5×10^4
T4- Mulberry + Black gram	6.54	0.10	0.56	190	1.42	222	08.20	63.7	1.43	2.50	0.75	8.40	2.6×10^6	3.5×10^5	3.62×10^6	5.23×10^5	4.1×10^5
T5- Mulberry + Cowpea	6.00	0.08	0.62	197	1.51	167	13.84	48.9	1.13	10.64	0.76	8.67	$3.7 \times 10\,6$	2.36×10^4	3.6×10^4	4.9×10^5	4.8×10^3

Table 3: Growth parameters and leaf yield of mulberry and dry forage yield of intercrops

Treatments	Growth parameters of mulberry									Leaf yield of mulberry (kg / ha)			Dry forage yield of intercrops (kg / ha)		
	Average no. of branches / plant			Average plant height (cm)			Average total shoot length (cm)								
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
T1- Mulberry Sole	2	5	6	152	155	159	262	528	627	1471	9850	9918	--	--	--
T2- Mulberry + French bean	2	4	5	148	152	155	258	491	621	1444	8310	8572	1047	3274	368
T3- Mulberry + Soybean	2	4	5	148	149	155	261	496	621	1440	9488	9756	224	2303	592
T4- Mulberry + Black gram	2	4	5	145	147	150	258	461	588	1430	8675	8448	162	4329	1844
T5- Mulberry + Cowpea	2	4	5	144	148	155	258	427	577	1425	8482	8361	922	6923	1906

Table 4: Disease and pest incidences of Mulberry & Intercrops and Meteorological data

Sl No	Treatment	Year 2006									Year 2007					Year 2008						
		WF	MB	BHC	WGH	PM	LR	TM	FB	PR	TP	LM	PM	LR	LS	WF	MB	FB	LM	PM	LR	LS
01	Mulberry sole	7	4	7	3	7.1	5.6	--	--	--	--	--	2.7	1.9	1.2	5	2	--	--	5	3.2	3.9
02	Mulberry + French bean	15	--	--	--	--	--	3	10	20	--	6	--	--	--	--	--	8	7	--	--	--
03	Mulberry + Soybean	16	--	--	--	--	--	4	--	5	--	7	--	--	--	--	--	--	6	--	--	--
04	Mulberry + Black gram	17	--	--	--	14.4	--	--	7	--	8	5	11.2	--	--	--	--	5	7	7.7	--	--
05	Mulberry + Cowpea	14	--	--	--	4.5	4.4	--	10	--	5	6	6	--	--	--	--	11	10	7.9	5.3	--
Meteorological data				(October-December)				(July-September)			(October-December)					(July-September)						
Temp-Av. min				15.4 ^{0}C				19.6 ^{0}C					14.7 ^{0}C					20.1 ^{0}C				
Av. max				27.8 ^{0}C				29.9 ^{0}C					26.0 ^{0}C					29.5 ^{0}C				
RH %-Av. min				61.4				79.1				55.3					82.9					
Av. max				85.2				90.3				75.8					87.4					
Rainfall- mm				46.2				776.2				160.2					792					
Days				10				55				13					43					

N.B.: WF- White Fly, MB-Mealy Bug, BHC- Bihar Hairy Caterpillar, WGH-Wingless Grass Hopper, TM- Termite, FB- Fruit Borer, TP- Thrips, LM- Leaf Minor, PR- Plant Rot (Bacterial), PM- Powdery Mildew, LR- Leaf Rust, LS-Leaf Spot

WF, MB, BHC, WGH, TM, FB, TP, LM, PR - presented as percentage and PM, LR, LS- presented as PDI

from same unit area of land (mulberry garden) with the production of quality mulberry leaf for silkworm rearing. The present study proved beneficial and advantageous for adopting leguminous intercrops preferably French bean and cowpea in mulberry. And, it is expected that, the knowledge on intercropping in Odisha State certainly encourage the farmers to take up mulberry sericulture and adopt intercropping of leguminous crops.

ACKNOWLEDGEMENTS

The authors express their sincere thanks to the Director, CSR&TI, Berhampore for providing necessary facilities and encouragements during the course of investigation; and to the Heads of Soil Science and Microbiology Department of OUAT, Bhubaneswar, Odisha for getting the soil nutrient status and microflora analyzed.

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EFFECT OF FOLIAR APPLICATION OF MULTI NUTRIENTS ON QUALITY AND LEAF YIELD OF MULBERRY

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ABSTRACT

Based on survey conducted in Karnataka, Andhra Pradesh and Tamil Nadu for identification of the chlorotic symptoms in the V1 mulberry gardens, it was found that the chlorotic symptoms related to the deficiency of manganese, zinc, magnesium, phosphorus, sulphur and iron are not due to deficiency of any single nutrient. Pigment content was also found to be lower in chlorotic leaves, leading to impaired metabolic activities, photosynthetic efficiency and decreased leaf yield, because of the non availability of nutrients due to high soil pH. Mulberry is a foliage crop responding well to the foliar nutrition. Foliar application is particularly relevant for application of specific nutrients during the growth period. Though the required nutrients are available in the soil, root absorption and translocation are poor under adverse soil conditions due to the fixation of nutrients in the soil. Based on the results of the survey four multi nutrient formulations were developed for correcting the deficiencies. The different nutrient formulations @ concentration of 10ml/lit were tested along with the control. First spray was done 25 days after pruning and the second spray was given after seven days of first. There was significant increase in growth and yield parameters in addition to N, P and K constituents of the leaf with all the four formulations in both the treatments compared to that of the control. Formulation 1 recorded higher values in plant yield (1.130kg/ plant), sugar contents (12.37%), protein contents (24.16%) and total chlorophyll contents (3.75m9/9) and was found to be economical. The effectiveness of the formulations in correcting the deficiencies is discussed.

Key Words: Foliar application, Leaf yield, Mulberry, Multinutrient, Quality

INTRODUCTION

Mulberry leaves is the prime food plant for the silkworm, Bombyx mori L. The fresh and nutritive quality of mulberry leaf plays an important role on the development worm stabilizing the cocoon production and silk productivity. Mulberry plant requires at least sixteen essential nutrients for growth, development and various metabolic processes. All soils contain nutrients, but reserves are limited. Additional stress on soil micronutrient status tends to increase the incidence and extent of micronutrient deficiencies. Deficiency of even a single nutrient can adversely affect the agronomic efficiency of other plant nutrients and productivity. Inadequate supply of nutrition ultimately reflects the growth of the plant and manifests its symptoms on the foliage (Balakrishnan 1999).

Extensive literature on nutritional disorders of a number of crops is available (Bennett, 1993). However, similar information on mulberry is scanty for the plants grown under field conditions (Shankar 1997). Chlorotic symptoms of nutritional disorder, noticed in different areas remain undiagnosed for lack of relevant literature and gradually result in reduction of leaf yield and quality. Visual symptoms of nutritional disorder were noticed in V1 mulberry gardens (Singhvi et al., 2002). Jones (1931) suggested that visual symptoms could serve as guide in identifying the deficiencies and in proper fertilization of the

crop. The rate of depletion of nutrients under use (high analysis) of inorganic fertrilisers and intensive cropping are the main reasons for exploitive nature of soil for mulberry cultivation. However, sufficient studies on such aspects are lacking in sericulture. Inadequacy of nutrients restricts plant growth and yield. The balanced fertilization is the quickest means to replenish the losses.

Mulberry exhibits number of nutrient deficiency symptoms under field conditions (Bongale 1997) and respond well to foliar nutrition. Foliar application is particularly relevant for timely application of specific nutrients during growth and development (Kannan, 1990). Though some of the nutrients are available in the soil, root absorption is slow and translocation is poor under adverse soil conditions viz. high pH, low SOC. Under this situation foliar nutrition is more effective than soil application for immediate availability of nutrients to the plant.

Over the past three decades, studies on the foliar nutrition have received considerable attention for improvement of quality and leaf yield. Based on analysis of soil and leaf samples and recovery studies with foliar sprays it can be inferred that the chlorosis in these areas is mainly due to multiple nutrient deficiency viz. phosphorus, sulphur, manganese, zinc and iron. Reports pertaining to the diagnosis of nutrient deficiencies and their recovery through foliar supplementation of nutrients in mulberry are scanty (Bongale et al., 1996). The present study was carried out in view of the limitations of the information on the feasibility of the foliar sprays in correcting chlorosis and improvement of yield and quality of mulberry.

MATERIALS AND METHODS

Four foliar formulations were evaluated using well-established V1 mulberry under RBD with IJ spacing at the CSR & TI campus. The soil was red loamy with pH of 8.3. The specific package was followed as per the recommendations of Krishnaswami (1990). Four different nutrient formulations @ concentration of 10ml/lit are tested along with the control. First spray was done 25 days after pruning. Second spray was given after seven days of first. Biometric parameters on number of shoots per plant, number of leaves per plant, shoot height, leaf area and leaf yield were recorded after 60 days of pruning and leaf samples were collected for biochemical analysis. Leaf samples were analysed for total proteins (Lowry et al., 1951), total sugars (Dubois et al., 1956) chlorophyll (Ronen and Galun, 1984) and moisture content by following the standard gravimetric method. The data were collected for five crops and statistically analysed (Sundararaj et al., 1972) and presented in Table 1 and 2.

RESULTS AND DISCUSSION

The foliar sprays expressed significant variation on mulberry leaf yield, yield attributing characters as well as leaf quality characters. All the sprays evaluated improved the leaf yield and yield attributing characters viz. number of shoots per plant, number of leaves per plant, shoots height per plant and leaf area. The data revealed that, among the four foliar sprays T1 (one and two sprays) recorded significantly higher values for single plant leaf yield (1.130 and 1.142kg/plant) number of shoots per plant (14 and 15 no./plant), number of leaves per plant(413 and 416 no./plant), shoot height(225 and 228cm/plant), leaf area(19704.96 and 20113.58 sq.mt/plant), total sugars (12.37 and 12.32%), total proteins (24.16 and 24.14%) and total chlorophyll content (3.75 and 3.82 mg/g fr. wt.) compared to control (Table 1 and 2).

Table1: Effect of foliar application of multinutrient formulations on the growth and mulberry leaf yield

Treatments	Spray schedule	Height of the plant (cm)	No. of shoots/ plant	No. of leaves/ plant	Leaf yield/ plant (kg)	Leaf area/ plant (Sq.mt)
T1	1st spray	225	14	413	1.130	19704.96
	2nd spray	228	15	416	1.142	20113.58
T2	1st spray	193	12	368	0.819	14317.25
	2nd spray	195	11	372	0.905	14516.28
T3	1st spray	195	14	389	0.935	19688.92
	2nd spray	212	15	403	0.952	19798.98
T4	1st spray	156	10	314	0.710	13438.45
	2nd spray	158	11	317	0.735	13652.32
Chlorotic (Control)	1st spray	108	7	209	0.305	82231.10
	2nd spray	118	9	215	0.325	82342.19
CD@ 5%		6.0	1.89	5.00	0.21	431.02

Table 2: Effect of foliar application of multinutrient formulations on the quality of mulberry leaf

Treatments	Spray schedule	Moisture (%)	Total proteins (%)	Total sugars (%)	Total chlorophyll (mg/g)
T1	1st spray	89.7	24.16	12.37	3.75
	2nd spray	89.8	24.14	12.32	3.82
T2	1st spray	86.1	21.83	10.83	2.85
	2nd spray	87.3	21.65	10.85	3.15
T3	1st spray	88.4	22.36	12.07	3.62
	2nd spray	88.6	22.29	12.09	3.68
T4	1st spray	79.8	21.20	11.78	2.54
	2nd spray	80.3	21.23	11.79	2.62
Chlorotic (Control)	1st spray	50.2	16.85	9.23	2.08
	2nd spray	55.3	16.69	9.45	2.12
CD@ 5%		0.21	0.32	0.24	0.72

In the present study, the foliar spray T1 has shown a positive effect on growth and yield of mulberry. The shoot length, number of shoots/plant, leaves/plant and leaf yield are found to be significantly higher in treated mulberry plants compared to the control. Though maximum increase was recorded in two sprays, the promontory effect was almost at par with one spray application. Increase in plant height may be due to the involvement of micronutrients in chlorophyll formation, which might have helped to influence cell division, meristematic activity in apical tissue, expansion of cell and formation of cell wall. Maximum number of branches micronutrients had a positive influence on physiological activity of plants. These results are in agreement with earlier works of Loknath and Shivashankar (1986), Bose *et al.,* (1994), Prasanna kumar *et al.,* (2001). Mishra *et al.,* (1995) have reported that the micronutrients such as zinc, manganese, iron, copper and boron along with sulphur and magnesium on mulberry significantly improve the growth and yield parameters. The moisture content determines the nutritive quality of the leaves and plays an important role in the production of quality and quantity of cocoon (Dandin and Kumar (1989). In the present study, the higher moisture content in T1 treated mulberry leaves can be due to the additional supply of nutrition to the leaves and also withstand the moisture for longer duration.

Data presented in Table 2 showed positive influence of multinutrient treatments on leaf mineral content. Maximum increase of nitrogen and phosphorus was recorded in T1 two sprays; the promontory effect was almost at par with one spray application compared to other treatments and control. Potassium content was marginally increased in all the treatments as compared to control. The improvement in nutrient status in leaves might have resulted from efficient mineral transport and increased mineral efficiency (Singhvi, *et al.,* 2003).

The biochemical constituent of the mulberry leaves *viz.* total proteins, total sugars and total chlorophyll showed an improvement in the treated leaves over the control. It is evident that the qualitative and quantitative parameters of mulberry leaves are dependent on the varieties, climate conditions, type of soil and method of planting. The improvement in the protein directly reflects on the leaf yield. Protein is the main constituent of the mulberry leaf, which contributes for the synthesis of silk (Kawase 1975) and this improvement indicates the effect of foliar spray. These results are in conformity with Loknath and Shivashankar (1986), Bose *et al.,* (1996) Singhvi *et al.,* (1996). Bongale *et al.,* (1996) reported that chlorosis in mulberry field did overcome by multinutrient foliar spray and recorded the improvement in leaf yield, its attributes and quality of leaves.

Thus, from the study it can be concluded that among the four spray formulations, T1 foliar spray recorded significant improvement in leaf yield and quality of mulberry leaf. The formulation can be effectively used in affected areas for correcting deficiencies and enhancing the leaf yield and quality of mulberry.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 67-69

EFFECT OF GRADED LEVELS OF PHOSPHORUS APPLICATION ON UPTAKE OF PHOSPHORUS, MULBERRY LEAF YIELD AND ECONOMIC PARAMETERS OF SILKWORM BOMBYX MORI L.

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ABSTRACT

Phosphorus is an essential element for growth and reproductive activities in silkworm besides other metabolic activities. Phosphorus along with nitrogen and potassium has been proved indispensable in increasing mulberry leaf yield compared to absence of phosphorus. Essentiality of phosphorus for better silkworm growth and increased cocoon production has been established. A field experiment was conducted at CSRTI, Mysore to study the effect of various levels of phosphorus application on mulberry leaf yield, uptake of phosphorus, protein nitrogen and carbohydrate content. Bioassay from different treatments shows variation and significant improvement in cocoon characters viz., cocoon yield, cocoon wt. shell wt. and silk percentage in T5 and T6 compared to T1. It was found that application of 150kg/ha/yr phosphorus is ideal to obtain the quality mulberry leaf and cocoon yield. The possible role of phosphorus application towards the yield and nutritive value improvement of mulberry leaf and silkworm cocoon is discussed.

Key Words: Bioassay, Mulberry, Phosphorus fertilizers, Quality leaf, Silkworm

INTRODUCTION

Mulberry (Morus spp.) is the sole food plant of the Silkworm, Bombyx mori L. and cultivated mainly for its foliage plays an important role on growth, development and overall performance of cocoon. Maximization of leaf yield and improvement in the quality are considered to be the important steps for enhancing the cocoon production. Improvement in the yield and quality of mulberry can be accomplished through the application of fertilizers (Krishnaswami, 1973; Minamizawa, 1997). With the introduction of high yielding mulberry varieties the demand of nutrients for optimum production per unit area has increased tremendously. It results exhaustion and plant nutrient imbalances in soil. The balanced fertilization is quickest means to replenish these losses. The role of nitrogen, phosphorus and potassium in plant nutrition and metabolism is well known. Essentiality of phosphorus for better silkworm growth and cocoon production has been established. It involves in root development and other metabolic activities especially in synthesis of proteins and reproductive activities in silkworm (Shankar 1997). Application of adequate amounts of phosphorus will stimulate mulberry plants to develop new roots, grow stronger, more resistant and increase the carbohydrate content in the leaves. Soil available phosphorus status of Karnataka, Tamil Nadu and Andhra Pradesh are low to medium (Subbaswamy et al., 1998). Phosphorus deficiency is reported to be widespread in Indian soils and its deficiency is major limiting factor for crop production (Hasan 1994 and Shankar 1997). Hence, the present study was carried out to find out the effect of various levels of phosphorus application on quality and yield of mulberry leaf and rearing performance of silkworm.

MATERIALS AND METHODS

A study was conducted with V1 mulberry variety planted as paired row system (150cm + 90cm) 60cm under irrigated conditions at Central Sericultural Research and Training Institute, Mysore. The soils were red loam having pH 8.2, OC 0.65%, available phosphorus 13.2kg/ha and

available potassium 210 kg/ha. All the treatments received equal quantity of N and K @300and 120 kg/ha/yr respectively with two split doses of FYM @20MT/ha/yr and 5kg PSB for one of the treatment. Experiment laid out in Randomized Block Design having seven treatments with three replications. Treatment 1, 2, 3, 4, 5, 6 and 7 constituted different levels of phosphorus viz., no phosphorus, 45kg, 60 kg, 90 kg, 120 kg, 150 kg and 180 kg per hectare per year was applied crop wise to mulberry gardens, the source of phosphorus being single super phosphate. Leaf yield was recorded for ten crops and mean values represented on hectare basis. Leaves collected at different levels of phosphorus were analysed during each harvest after drying at 60C, powdered and analysed for total nitrogen (Piper, 1942), phosphorus (Tandon 1993), protein nitrogen (Lowry et al. 1951) and total carbohydrate (Dubios et al. 1956) content. Rearing of the pure CSR2 silkworms was conducted with three replications of cellular batches and the trail was repeated three times during the period of the year. Data with respect to larval duration, weight of 10 mature worms, effective rate of rearing (ERR) percentage, single cocoon weight, shell weight and shell percentage was collected and statistically analysed using "t" test.

RESULTS AND DISCUSSION

Significant increase in leaf yield with progressive increase in P levels, the last two being non significant (Table.1). Nitrogen fertilization was found to enhance leaf of mulberry yield of mulberry, more than that with application of phosphorus and potash. Highest leaf yield was attained due to the application of phosphorus with nitrogen and potassium might be due to effective absorption and higher dry matter accumulation. The results corroborated with findings of Ray *et.al.,* (1973), Shivashankar and Krishnamurthy (1978), Bongale (1995) and Manjunath (1995).

No significant difference in nitrogen content among treatments. However, Protein nitrogen significantly increased with P levels, the last two being non significant (Table 2). The results indicated that addition of P enhances efficient utilization of N by its conversion to protein nitrogen. This finds support from work of Subbaswamy et al (1999). Prasad et.al (1992) reported that efficiency of nitrogen is affected by the availability of other plant nutrients and correcting the phosphorus deficiency is important for enhancing nitrogen efficiency in field crops. Carbohydrate content in leaf increased with each unit increase in P level up to 180kg/ha. This may be due to phosphorus involvement in

Table 1: Effect of graded levels of phosphorus application on leaf yield and soil phosphorus content

Sl. No	Treatments NPK kg/ha/yr	Leaf yield (kg/ha/yr)	Soil (kg/ha)
1	T1- 300:00 : 120: 20MT FYM	39576	6.4
2	T2- 300:45: 120: 20MT FYM	40643	7.2
3	T3- 300:90: 120: 20MT FYM	41675	9.6
4	T4-300:120:120: 20MT FYM	42773	14.2
5	T5-300:120: 120:20MT FYM+ 5Kg PSB	43821	18.5
6	T6- 300:150:120:20MT FYM	44842	21.4
7	T7- 300:180:120:20MT FYM	44992	24.9
	CD at 5 %	928.0	1.82

Table 2: Effect of graded levels of phosphorus application on leaf protein nitrogen and total carbohydrate content (values in dry weight basis)

Sl. No	Treatments	P Content (%)	Total Nitrogen (%)	Protein Nitrogen (%)
1	T1- 300: 00 :120: 20MT FYM	0.15	3.34	2.02
2	T2- 300: 45 :120: 20MT FYM	0.19	3.39	2.49
3	T3- 300: 90 :120: 20MT FYM	0.23	3.48	2.91
4	T4-300:120:120: 20MT FYM	0.34	3.62	3.14
5	T5-300:120:120: 20MT FYM +5 PSB	0.35	3.78	3.42
6	T6- 300:150:120: 20MT FYM	0.38	3.94	3.65
7	T7- 300:180:120: 20MT FYM	0.39	3.98	3.80
	CD at 5 %	0.06	NS	0.23

Table .3: Effect of graded levels of phosphorus application on silkworm rearing performance (CSR2)

Treatments NPK Kg/ha/yr	ERR by Number	Cocoon weight (gms)	Shell weight (gms)	Shell (%)
T0.300:120:120: 20MT FYM	8433	1.932	0.429	22.2
T1.300: 00 :120: 20MT FYM	7766	1.832	0.386	21.1
T2.300: 45 :120: 20MT FYM	8200	1.845	0.398	21.5
T3.300: 90 :120: 20MT FYM	8333	1.886	0.412	21.84
T4.300:120:120:20MTFYM+5kg PSB	8466	1.908	0.438	22.43
T5.300:150:120: 20MT FYM	8933	1.917	0.442	23.05
T6.300:180:120: 20MT FYM	9166	1.925	0.445	23.11
CD at 5 %	456	0.021	NS	0.18

nucleic acid metabolism and co enzyme activities. Rajegowda (1996) and Shankar (1997) have reported that more phosphorus will enhance protein, fat and carbohydrate content in leaf to get good quality cocoon.

Bioassay from different treatments shows significant improvement in cocoon characters viz., cocoon yield, cocoon wt. shell wt. and silk percentage in T5 and T6 compared to T1.(Table.3). Similarly Kasiviswanathan and Iyengar (1968) reported that mulberry leaves grown under nitrogen, phosphorus and potash fertilization improved the larval growth, cocoon yield and other cocoon parameters. According to Chauhan et. al. (1985), balanced level of all three elements N. P and K significantly improves the yield and physio-chemical property of mulberry leaf and nitrogen, potassium combination gives better results than nitrogen and phosphorus combination. However, balanced fertilization to mulberry is of prime importance to get quantity and quality of mulberry leaf, which in turn helps in the growth and development of silkworm.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 70-73

DISTRIBUTION OF SOIL MICROFLORA IN VARIOUS HABITATS OF MULBERRY *(MORUS* SPP.*)*

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ABSTRACT

An experiment was conducted in mulberry gardens of 3 farmers' fields to know the distribution, abundance and frequency of soil microflora in various habitats. The population of soil microflora was significantly higher in rhizosphere habitat followed by rhizoplane, sub-surface and non-rhizosphere. Total number of different forms of microflora isolated from rhizosphere, rhizoplane, sub-surface and non-rhizosphere soils were 23, 19, 19 and 16, respectively and based on their behaviour and pathogenicity, they were categorized into beneficial, harmful and saprophytic. S*ignificantly higher population of beneficial microflora was found in rhizosphere,* while harmful microflora was least in all the habitats. *Trichoderma harzianum*, *Azotobacter* spp. and *Bacillus subtilis* (beneficial group) were found most abundant and dominant. In saprophytic such as, *Aspergillus niger*, *A. flavus A. fumigatus* and *Penicillium* spp. were less abundant to occasional.

Key words: Habitats, Mulberry, Rhizoplane, Rhizosphere, Soil microflora

INTRODUCTION

Mulberry (*Morus* spp.), the sole food plant of silkworm (*Bombyx mori* L.) is a perennial crop intensively cultivated for leaf with repeated harvests of 5 times a year. This favours the survival, multiplication and inoculum build-up of certain soilborne pathogens. Among them, root rot (*Fusarium solani*/*F. oxysporum*/*Botryodiplodia theobromae*/ *Macrophomina phaseolina*) poses serious threat causing leaf yield loss up to 20% besides deteriorating the leaf quality (Sharma *et al*., 2003). The microhabitats in the vicinity of roots is distinguished into sub-surface, rhizosphere, rhizoplane and non-rhizosphere region where various categories of beneficial, harmful and saprophytic fungi, bacteria and actinomycetes survive together and influence the growth of mulberry (Bolton *et al*., 1993; Pal and Jalali, 1998; Subbarao, 1999). A comparative study on the prevalence of beneficial, harmful or saprophytic microflora in sub-surface, rhizosphere, rhizoplane and non-rhizosphere region is needed for developing an effective management package for soilborne diseases and also to identify the disease free localities.

MATERIALS AND METHODS

The experiment was carried out in mulberry gardens of 3 farmers' fields of 5-8 years old plantation (variety, V1) by selecting 300 sq. mt. area and dividing into 5 sub plots (60 sq. mt. each) with 150 plants/replication. The soil samples were collected from 10 randomly selected plants from each habitat, every garden separately in sterilized polythene bags. The soils of top layer up to 6 cm was collected for isolation sub-surface microflora while soil near the living roots at 15-30 cm depth for rhizosphere microflora and soil adhering to root surface of mulberry for rhizoplane microflora. The non-rhizosphere soil was collected in between the space of two rows of mulberry plants away from the living roots. Potato Dextrose Agar, Nutrient agar and Actinomycetes agar media (HI-Media, Mumbai, India) were used for isolation of fungi, bacteria and actinomycetes respectively by dilution plate technique (Waksman, 1927) using final dilution of $1:10^4$. The colonies of different microflora were recorded and population in terms of Colony Forming Units (CFU)/g soil was calculated (Sharma *et al*., 2009). The fungi were identified based on their morphological and reproductive characters (Barnett and Hunter, 1999) while bacteria based on morphological and biochemical characters (Krieg, 1984). Actinomycetes were identified on the basis of their colonies and sporophore characters on agar media (Shirling and Gottlieb, 1966). The percentage of abundance and frequency of isolated microflora were calculated (Sharma *et al*., 2009).

Three observations (after 30, 60 and 90 days) were recorded from each garden and average (3 gardens and 3 observations) data were subjected for test of significance using INDOSTAT statistical software.

RESULTS AND DISCUSSION

Distribution of microflora: The total population (Table 1) in terms of colony forming units (CFU/g) of fungi, bacteria and actinomycetes was significantly higher in rhizosphere (CFU/g; 73.5, 77.4 and 16.9 × 10^6) followed by rhizoplane (59.9, 62.7 and 10.7 × 10^6), sub-surface (50.3, 52.9 and 9.7 × 10^6) and non-rhizosphere (37.8, 40.7 and 5.7 × 10^6). The maximum population of different microflora in rhizosphere soils might be due to the secretion of root exudates by host plant in the vicinity of rhizosphere, which influences the built up of high microbial population (Bolton *et al*., 1993; Subbarao, 1999; Sharma *et al.,* 2009).

Prevalence of various: About 23 forms of different microflora (13 fungi, 8 bacteria and 2 actinomycetes) from rhizosphere soils and 19 from rhizoplane and sub-surface soils (10 fungi, 7 bacteria and 2 actinomycetes) and 16 from non-rhizosphere soils (9 fungi, 5 bacteria and 2 actinomycetes) were isolated. They were categorized based on their pathogenicity tests on mulberry and as per literature into three groups such as beneficial, harmful and saprophytic (Pal and Jalali, 1998; Sharma *et al*., 2009). The forms that were absent in rhizoplane and sub-surface soils but present in rhizosphere soils were *Azospirillum* spp. (beneficial group), *Curvularia lunata* (harmful group), *Penicillium oxalicum*, *Aspergillus fumigatus* (absent in sub-surface soils but present in rhizoplane) and *Rhizopus* spp. (absent in rhizoplane but present in sub-surface soils) belonging to saprophytic group. However, in case of non-rhizosphere soils, the 7 forms that were absent but present in rhizosphere soils were *Azospirillum* spp. and *Pseudomonas fluorescens* (beneficial), *Xanthomonas* spp., *Agrobacterium spp. and Curvularia lunata*. (harmful) and *Penicillium oxalicum* and *Rhizopus* spp. (saprophytic) (Table 2).

Significantly higher population of beneficial microflora followed by saprophytic and harmful microflora was recorded in all the habitats of mulberry. This suggests that the population of beneficial microflora was not affected by the competition of harmful and saprophytic microflora. Moreover, the serious pathogens causing various soilborne diseases (*F. solani*, *F. oxysporum*, *B. theobromae* and *M. phaseolina*) in mulberry were not observed in the present study. This is in conformity with the findings of Dhedhi *et al*. (1990) and Pandey and Upadhyay (2000), who reported that rhizosphere of diseased and healthy plants harbour several types of fungi and bacteria, which differ in their behavior. Further, it has been reported that certain non-pathogenic forms belonging to harmful group were found to colonize around the rhizosphere region and roots of healthy banana plants without inducing any symptoms on the plant

Table 1: Distribution of microbial load in various habitats (sub-surface, rhizosphere,rhizoplane and non-rhizosphere) of mulberry

Habitat	Colony forming units (CFU)/g × 10^6							
	Microflora				Microflora			
	Fungi	Bacteria	Actino-mycetes	Total	Beneficial	Harmful	Saproph-ytic	Total
Sub-surface	50.3 (44.5%)	52.9 (46.9%)	9.7 (8.6%)	112.9 (22.7%)	65.3 (57.8%)	21.9 (19.4%)	25.7 (22.8%)	112.9
Rhizosphere	73.5 (43.8%)	77.4 (46.1%)	16.9 (10.1%)	167.8 (33.6%)	96.7 (57.6%)	33.5 (20.0%)	37.6 (22.4%)	167.8
Rhizoplane	59.9 (44.9%)	62.7 (47.1%)	10.7 (8.0%)	133.3 (26.8%)	77.9 (58.5%)	24.9 (18.7%)	30.5 (22.8%)	133.3
Non-rhizosphere	37.8 (44.7%)	40.7 (48.3%)	5.7 (6.8%)	84.2 (16.9%)	56.3 (66.8%)	15.8 (18.8%)	12.1 (14.4%)	84.2
Total	221.5 (44.5%)	233.7 (46.9%)	43.0 (8.6%)	498.2 -	296.2 (59.4%)	96.1 (19.2%)	105.9 (21.3%)	498.2
Average	55.4 (44.5%)	58.5 (46.9%)	10.7 (8.6%)	124.6	74.0 (59.4%)	24.0 (19.2%)	26.5 (21.3%)	124.5
	SE ±		CD at 5 %		SE±		CD at 5%	
Habitat (A)	0.351		0.999		0.486		1.382	
Microbes (B)	0.405		1.154		1.561		1.596	
A × B	0.703		1.999		0.972		2.764	

Figures in parentheses represent the CFU percentage out of total microflora

Table 2: Abundance and frequency of beneficial, harmful and saprophytic microflora in various habitats (sub-surface, rhizosphere, rhizoplane and non-rhizosphere) of mulberry

Microflora	Abundance (Ab) and frequency (Fr)							
	Habitat							
	Sub-surface		Rhizosphere		Rhizoplane		Non-rhizosphere	
	Ab	Fr	Ab	Fr	Ab	Fr	Ab	Fr
			Beneficial					
Trichoderma harzianum	+++	D	+++	D	+++	D	+++	D
T. viride	++	C	++	C	++	C	+++	D
Bacillus spp.	++	F	++	F	++	C	++	O
B. subtilis	+++	D	+++	D	+++	D	+++	D
Azotobacter spp.	++	F	+++	C	+++	D	+++	F
Azospirillum spp.	**	**	+	F	**	**	**	**
Pseudomonas fluorescens	++	F	+	F	++	F	**	**
Streptomyces spp.	+	O	++	F	+	F	+	F
Nocardia spp.	+	O	++	F	+	F	+	F
Harmful								
Alternaria alternata	+	O	+	O	+	O	+	O
Helminthosporium spp.	+	O	+	O	+	O	+	O
Pseudomonas spp	++	C	++	F	+	O	+	O
Xanthomonas spp.	++	C	++	F	++	F	++	F
Agrobacterium spp.	+	O	++	O	+	O	**	**
Curvularia lunata	**	**	+	O	**	**	**	**
Saprophytic								
Aspergillus niger	++	C	++	C	++	C	+	F
A. flavus	+	F	++	C	+	C	+	F
A. fumigatus	**	**	++	F	+	F	**	**
Penicillium spp.	+	F	+	C	+	O	+	F
P. oxalicum	**	**	+	O	**	**	**	**
Chaetomium spp.	+	O	++	F	+	O	+	O
Rhizopus spp.	+	O	++	O	**	**	+	O
Cladosporium oxysporum	+	O	+	O	+	O	**	**

** Form is not found but present in rhizosphere habitat

Abundance (%)
Most abundant (>10 %) = +++
Abundant (5.1-10 %) = ++
Less abundant (0-5 %) = +

Frequency (%)
Dominant (81-100 %) = D
Common (61-80 %) = C
Frequent (41-60 %) = F
Occasional (0-40 %) = O

(Nel *et al*., 2006). Hence, the present findings confirm that all the three farmers' gardens selected for the study, are free from the serious soilborne diseases of mulberry.

Abundance and frequency of microflora: *S*everal most abundant and dominant forms like *Trichoderma harzianum*, *P. fluorescens*, *Bacillus subtilis* and *Azotobacter* spp. belonging to beneficial group observed in rhizosphere, rhizoplane, sub-surface and non-rhizosphere regions (Table-2) contribute to the growth of mulberry plant through microbial transformation of many complex plant nutrients into simpler and available forms. Among the above forms, *T. harzianum* and *T. viride* are being used for the control of root rot, root knot and root disease complex in mulberry (Sharma *et al*., 2003). With regard to harmful group, forms like *Alternaria alternata*, *Helminthosporium* spp., *C. lunata*, *Xanthomonas* spp., *Pseudomonas spp.* and *Agrobacterium* spp. were found abundant to less abundant and common to occasional in all the habitats of mulberry (Table 2), are known to cause various types of soilborne diseases in mulberry (Sharma *et al*., 2003), In case of saprophytic group, fungi like species of *Aspergillus* and *Penicillium* found to

occur as abundant to less abundant and common to occasional, are known for protection of plant roots against pathogens, as they produce various antibiotics (Bolton *et al*., 1993; Subbarao, 1999).

Present study indicates that a number of beneficial and saprophytic microflora co-exist in rhizosphere and rhizoplane habitats of mulberry, balancing the population in the ecosystem. The beneficial forms such as *T. harzianum*, *Azotobacter spp., B. subtilis* and *P. fluorescens* could be exploited after isolation to formulate an IDM package for management of *F. solani, F. oxysporum, B. theobromae* and *M. phaseolina* causing root rot disease.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 74-77

COMPATIBILITY OF *AZOTOBACTER CHROOCOCCUM* AND *BACILLUS MEGATERIUM* WITH CHEMICAL FERTILIZERS AND PLANT GROWTH PROMOTERS USED IN MULBERRY PRODUCTION

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ABSTRACT

The compatibility of *Azotobacter chroococcum* and *Bacillus megaterium* with chemical fertilizers (urea, ammonium sulphate, di-ammonium phosphate, single supper phosphate and murate of potash) and plant growth promoters (salicylic acid, triacontanol, zinc sulphate, ferrous sulphate & Seriboost) at 500, 1000 and 2000 ppm concentrations were assessed by poisoned food technique. Results revealed that *A. chroococcum* was found compatible with all nitrogenous fertilizers at all concentrations, whereas, *B. megaterium* was found compatible with di ammonium phosphate & triacontanol. Among the growth promoters, triacontanol exhibited excellent compatibility, zinc sulphate and Seriboost were found in compatible with both the bioagents in all concentrations. However, salicylic acid at 1000 & 2000 ppm and ferrous sulphate at 2000 ppm were found in compatible with *A. chroococcum* only.

Key words: *Azotobacter*, *Bacillus*, Compatibility, Fertilizers, Growth promoters

INTRODUCTION

In India, mulberry (*Morus* spp.), the sole food plant of silkworm, is cultivated under a wide range of agro climatic conditions. Post 1990, the leaf yield level of mulberry has increased from 30 - 35 tonnes/ha/yr and reached the present level of 50 - 60 tonnes. This increase has been brought about by the development of high-yielding varieties, and has resulted in higher cocoon production and crop stability (Dandin *et al*., 2003). Various research institutes of Central Silk Board have evolved high yielding mulberry varieties suitable for the different agro climatic conditions of the country. Further, it is very well established that the higher dose of fertilizers are required for maximizing the production of quality mulberry leaves. This in turn has increased cocoon productivity and reduced the leaf-cocoon ratio in southern states of India (Dandin *et al.,* 2003). For increased production of quality mulberry leaf various organic fertilizers (farm yard manure, green manures and oil cakes), chemical fertilizers (nitrogenous, phosphatic and potassium), biofertilisers (nitrogen fixers and phosphate solubulizers) and plant growth promoters (salicylic acid, Seriboost, triacontanol, zinc sulphate, ferrous sulphate) have been recommended. Simultaneously, bioformulations of *Azotobacter chroococcum* and *Bacillus megaterium* have also been recommended for mulberry crop production to economize the nitrogen and phosphorus fertilizer application (Dandin *et al.,* 2003; Sharma *et al*., 2003).

NPK at the rate of 350:140:140 kg/ha/year is recommended in five split doses with two split doses of farm yard manure (FYM) @ 20 MT/ha/yr at an interval of 6 months. The compatibility of bioagents with organic fertilizers in general and with FYM in particular is well documented. Sufficient research work has not yet been carried out on the compatibility of *A. chroococcum* and *B. megaterium* with chemical fertilizers *viz*., urea, ammonium sulphate, di-ammonium phosphate, single supper phosphate and murate of potash as well as plant growth promoters *viz*., salicylic acid, triacontanol, zinc sulphate and ferrous sulphate and Seriboost. Hence, the present study was undertaken to know the compatibility of useful microbes (*Azotobacter chroococcum* and *Bacillus megaterium*) with chemical fertilizers and plant growth promoters used in mulberry production for developing an integrated package for economization production of quality and quantity mulberry leaf.

MATERIALS AND METHODS

The experiments were conducted under *in vitro* conditions to understand the compatibility of *A. chroococcum* and *B. subtilis* with chemical fertilizers (urea, ammonium sulphate, di-ammonium phosphate, single upper phosphate and murate of potash) and growth promoters (salicylic acid, seriboost, vipul, zinc sulphate and ferrous sulphate) at 500, 1000 and 2000 ppm concentrations.

The compatibility was determined by poisoned food technique (Sharvelle, 1961). 100 ml of lukewarm medium was amended with chemical fertilizers and growth promoters used in mulberry production. The medium was poured in petri dishes and the bacterial bioagents were streaked on the medium. The plates without any amendment.

Five replications were maintained for each treatment. All the plates were incubated at 28±2°C for 72 h. After incubation, the bacterial growth was observed and visually categorized in to four groups as follows:

No growth	(-)
Good growth	(+)
Very good growth	(++)
Excellent growth	(+++)

RESULTS AND DISCUSSION

Compatibility of *Azotobacter chroococcum* and *Bacillus megaterium* with chemical fertilizers

Results revealed that the growth of *A. chroococcum* in treatments was recorded on par with the control and categorized as excellent growth in case of nitrogenous fertilizers (urea, ammonium sulphate and di-ammonium phosphate) at all three concentrations (500; 1000 & 2000 ppm). This suggests that all nitrogenous fertilizers are compatible with *A. chroococcum*. Results are in conformity with the findings of Sharma *et al*. (2005) who reported that Bionema [*Verticillium chlamydosporium* + neem oil cake] was found compatible with bacterial biofertilizer (*A. chroococcum)*, VAM and vermicompost and can be integrated for reducing the severity of root knot disease in mulberry.

The growth of *A. chroococcum* on media with phosphatic fertilizers was on par with control only at 500 ppm concentration of single super phosphate, while in rest of the concentrations (1000 & 2000 ppm) the growth of this microbe was arrested. In case of the potassium fertilizers (murate of potash) the organism exhibited very good growth, indicating that the organism is moderately compatible.

The growth of *B. megaterium* was recorded on par with the control in case of di-ammonium phosphate at all concentrations tested. Though excellent growth of the organism was recorded at 500 and 1000 ppm concentrations of urea and ammonium sulphate, these nitrogenous fertilizers at 2000 ppm concentration completely inhibited the growth of the *B. megaterium*. However, single supper phosphate yielded the very good growth of the organism at all concentrations and murate of potash at 500 and 1000 ppm exhibited very good growth of *B. megaterium* (Table 1). Various workers have reported the compatibility of bioagents with pesticides, botanicals and other bioagents (Chandra *et al*., 1981*,* Muthamilan and Jeyarajan, 1996*,* Gupta, 2004*,* Pandey *et al.,* 2006).

Compatibility of Azotobacter chroococcum and Bacillus megaterium with growth promoters

The result of compatibility test of *A. chroococcum* presented in Table 2 and Fig. 3. There was no growth of the organism on media with zinc sulphate and Seriboost indicating the bactericidal nature of these growth promoters. Triacontanol supported good growth of the organism at all concentrations tested. At 500 and 1000 ppm of ferrous sulphate recorded very good and good growth, respectively. Similarly, at 500 ppm salicylic acid good growth of the bacterium was recorded. Results indicated that there was no growth of *A. chroococcum* at 1000 & 2000 ppm of salicylic acid and 2000 ppm ferrous sulphate (Table 2). Triacontanol (500, 1000 & 2000 ppm) exhibited the growth of *B. megaterium* on par with the control and was rated as excellent growth. The growth of this useful bacterium was recorded very good at 500 ppm of Seriboost and salicylic acid. Whereas, in other concentrations of Seriboost and salicylic acid complete inhibition was recorded. Similarly, zinc sulphate and ferrous sulphate also inhibited the growth of *B. megaterium* at 2000 ppm. However, the growth of the bacterium was on par with the control in ferrous sulphate at lower concentration *viz*., 500 and 1000 ppm and was rated as excellent growth. Likewise, at 500 and 1000 ppm of zinc sulphate very good and good growth was recorded (Table 2).

Sharma *et al*. (1999*,* 2003) and Gupta *et al*. (1999)*,* reported that *T. harzianum* and *T. pseudokoningii* were found to be compatible with neem oil cake, phytohormones, Furadan (Carbofuran) and Dithane M-45 (Mancozeb) and can be used for formulating the IDM strategies along with oil cake or sub-lethal dose of agrochemicals for the management of root rot and nursery (stem canker and cutting rot) diseases of mulberry.

Among the growth promoters tested, triacontanol (500, 1000 & 2000 ppm) was found to be most compatible with *B. megaterium* as the growth was on par with control. However, in case of Seriboost and salicylic acid, the growth of this bacterium was recorded very good at 500 ppm indicating that they are moderately compatible. The rest other two

Table 1: Compatibility of *A. chroococcum* and *B. megaterium* with chemical fertilizers

Sl. No.	Chemical fertilizer	Conc. (ppm)	Growth of bacterial bioagents	
			A. chroococcum	*B. megaterium*
1.	Urea	C	+++	+++
		500	+++	+++
		1000	+++	+++
		2000	+++	-
2.	Ammonium sulphate	C	+++	+++
		500	+++	+++
		1000	+++	+++
		2000	+++	-
3.	Di-ammonium phosphate	C	+++	+++
		500	+++	+++
		1000	+++	+++
		2000	+++	+++
4.	Single supper phosphate	C	+++	+++
		500	+++	++
		1000	++	++
		2000	++	++
5.	Murate of potash	C	+++	+++
		500	++	++
		1000	++	++
		2000	++	+

Table 2: Compatibility of *A. chroococcum* and *B. megaterium* with growth promoters

Sl. No.	Plant grow th promoter	Conc. (ppm)	Growth of bacterial bioagents	
			A. chroococcum	*B. megaterium*
(I).	Salicylic acid	C	+++	+++
		500	+	++
		1000	-	-
		2000	-	-
(II).	Triacontanol (Vipul)	C	+++	+++
		500	++	+++
		1000	++	+++
		2000	++	+++
(III).	Zinc sulphate ($Zn SO_4$)	C	+++	+++
		500	-	++
		1000	-	+
		2000	-	-
(IV).	Ferrous sulphate ($Fe SO_4$)	C	+++	+++
		500	++	+++
		1000	+	+++
		2000	-	-
(V).	Seriboost	C	+++	+++
		500	-	++
		1000	-	-
		2000	-	-

C = Control; - = No growth; +++ = Excellent; ++ = Very good; + = Good

concentrations (1000 & 2000 ppm) of Seriboost and salicylic acid completely inhibited the growth of the bacterium non-compatible. Similarly, 2000 ppm of zinc sulphate and ferrous sulphate were found non-compatible with *B. megaterium*. Ferrous sulphate at 500 and 1000 ppm was found compatible. Likewise, at 500 and 1000 ppm of zinc sulphate recorded very good and good growth, respectively, and was found moderately compatible.

CONCLUSION

It can be concluded from the present study that among all the chemical fertilizer tested urea, ammonium sulphate, di-ammonium phosphate, single supper phosphate and murate of potash the bacterial bioagents (*A. chroococcum and B. megaterium)* exhibited excellent compatible with di ammonium phosphate. *A. chroococcum* was found compatibility with all nitrogenous (urea, ammonium sulphate and di-ammonium phosphate) fertilizers. Among the growth promoters tested (salicylic acid, triacontanol, zinc sulphate and ferrous sulphate and Seriboost), triacontanol (500, 1000 & 2000 ppm) was compatible with both *A. chroococcum* and *B. megaterium*. Zinc sulphate and Seriboost at all concentrations (500, 1000 & 2000 ppm), 1000 & 2000 ppm of salicylic acid and 2000 ppm ferrous sulphate were found in compatible with *A. chroococcum.* The findings of the present study would be helpful in formulating ecologically safer and economically viable package of practices for mulberry crop production and crop protection.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 132-138

BIVOLTINE FOUNDATION CROSS, SK6 × SK7 - A BREAKTHROUGH IN BIVOLTINE SEED CROP STABILIZATION IN EASTERN AND NORTH EASTERN INDIA

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ABSTRACT

Quality bivoltine seed cocoon is vital for production of quality multi × bi eggs and thereby ensures good commercial cocoon harvest. Unlike other traditional sericultural states of India, Eastern India especially in West Bengal rearing of bivoltine parent during seed crop for preparing multi × bi eggs is very difficult owing to unpredictable, fluctuating and harsh climatic condition prevails in most of the seed crops. As a result bivoltine seed cocoons are to be procured from other parts of the country. To overcome this, after series of study, a suitable bivoltine foundation cross (FC) namely SK6 × SK7 was identified and initially tested at RSRSs level. After encouraging performance at RSRS level, it was tested at four DOS, W.B farms in limited scale during 2004 -2006. Upon success, a large scale trial programme was undertaken from Dec. 2007 March 2010 and same was evaluated in different seed crop seasons in West Bengal through DOS, W.B and NSSO and also at RSRSs, RECs situated in Assam, Meghalaya, Jharkhand and Orissa states. A total of 31920 dfls of SK6 × SK7 was reared in different seed crop seasons for two years. During favourable seed crop seasons (Dec-Jan & Feb-Mar), SK6 × SK7 yielded an average of 43.5 kg / 100 dfls as compared to 27 kg in NB4D2 (control). Remarkably in the most unfavourable seed crop season *i.e.*, Sep-Oct, (the target seed crop season), it yielded an average of 34 kg / 100 dfls when other bivoltine rearing is near to fail. Data on the important grainage parameters collected from different grainages indicated on par performance with NB4D2 indicating superiority of SK6 × SK7 in local rearing conditions. Further multi x bi hybrid combinations prepared with this FC namely, Nistari × (SK6 × SK7) (15.0 lakhs dfls) and M6DP(C) × (SK6 × SK7) (1.0 lakh dfls) were evaluated at farmers level in different commercial seasons at West Bengal for two years shown encouraging performance. Thus with SK6 × SK7 (FC), bivoltine seed crop stabilization - the bottleneck for the development of sericulture industry in Eastern and North Eastern India particularly in West Bengal can be overcome and bivoltine seed cocoons can be raised at Eastern and North Eastern India states itself, hence avoiding transportation of seed cocoons from far flung places to save money and energy.

Key words: Bivoltine, Field trial, Multi × bi hybrid, Foundation cross, Seed crop

INTRODUCTION

Eastern and North Eastern states are characterized with luxuriant growth of mulberry due to high rainfall, high temperature and fertile soil and varied climatic condition. During winter temperature goes below 10°C whereas in summer above 40°C. Similarly rainfall greatly varies from 1500 mm to 4000 mm along with variable soil status. It is well known fact that these factors greatly affect the genetic expression of silkworm and mulberry especially

temperature. Due to variable climatic conditions, 3-5 commercial crops are conducted annually in Eastern and North eastern region. Each season has got its own characteristic in respect of temperature, humidity, rainfall, availability of leaf biomass and other agro climatic conditions.

Of the Eastern and North Eastern states, West Bengal is traditionally sericulture practicing state and lion share of silk production comes from this state. The tradition of mulberry sericulture in Bengal dates back to medieval period. Sericulture is practiced in plains as well as hills of West Bengal. The areas located in the plains of West Bengal where sericulture is practiced mostly are very hot and humid (Temperature: 23 - 43C and Humidity: 62 - 97%) during summer and cool and dry (Temperature: 6-23C and Humidity: 30-92%) during winter (Moorthy and Das, 2007). These conditions affect both growth of mulberry plants and silkworm rearing. In the plains of West Bengal, which comprises major sericulture practicing districts, seed and commercial crops are round the year activity. The important commercial crops seasons of this region are spring (February-March), early summer (March-April), rainy (June-July & August-September) and autumn (November-December). During spring (February), autumn (November) and early summer (March-April) productive silkworm hybrid preferably multi × bi can be reared. Other two seasons viz. June July (summer) and September-October (rainy) are considered as most unfavourable for silkworm rearing, when indigenous multivoltine breeds and multivoltine hybrids are reared (Das, *et al.,* 2006).

Though spring (February), autumn (November) and early summer (March-April) commercial crops are congenial for silkworm rearing. But for production of multi × bi hybrids, seed crops are conducted during preceding months of each commercial crop. Climatic conditions of seed crop seasons are highly variable. But to prepare commercial multi × bi hybrids, bivoltine parental rearing has to be conducted for seed cocoon generation at least during three seed crop seasons viz., September-October, December-January and February-March. Of which, Feb-March (seed crop of early summer) season is suitable for raising bivoltine, but subsequent commercial crop is unpredictable for rearing of Multi × Bi hybrids for prevalence of high temperature during late age rearing. On the other hand low temperature with low humidity during December and January (seed crop of spring) severely affects the production of mulberry leaf as well as growth of silkworm resulting poor bivoltine seed cocoon harvest. During Sept-Oct (Seed crop of autumn commercial crop, when 30% of dfls consumed annually) high temperature coupled with high humidity and unpredictable rainfall are the common barriers for raising bivoltine seed cocoon crop. Moreover, bivoltines are vulnerable to diseases and variable climatic conditions further weakened resulting poor cocoon harvest and some times nil cocoon harvest. Therefore, the seed producing agencies of this region have to depend on the other parts of the country for bivoltine seed cocoons throughout year. So, one of the major constraint of this region is production of bivoltine seed cocoon. Therefore, to overcome the hurdles, there is a need to identify a bivoltine foundation cross alternative to single bivoltine breed which can be reared during unfavourable seed crop seasons (Das *et al*., 1994).

Identification of suitable foundations cross:

It is well known fact that foundation crosses (FCs) are characterized with higher pupation%, shorter larval period and higher cocoon yield. Out of ten foundation crosses initially tested at laboratory level during different seed crop seasons, SK6 × SK7, a foundation cross involving two dumbbell breeds with plain larvae viz., SK6 and SK7 found as promising one. It showed pupation% of 92and 13.0kg cocoon yield / 10, 000 larvae during adverse seed crop season. Subsequently the foundation cross was tested during different seed crop seasons at three Regional Sericultural research stations viz., Koraput (Orissa), Ranchi (Jharkhand) and Jorhat (Assam) and SK6 × SK7 proved its potentiality including adverse seed crop seasons (Anonymous, 1999-2000). After satisfactory performances at RSRS level, it was evaluated in four DOS, West Bengal farms situated at Birbhum , Midnapur, Malda and Coochbehar districts from 2004-2006 in limited scale specially during the target seed crop i.e., Sept-Oct. During the period, it yielded 25-36 kg / 100 dfls when other bivoltine rearing near to fail.

Large scale trial

The encouraging performance shown by SK6 × SK7 at different DOS farms at West Bengal during adverse seed crop (Sep-Oct) leads to demand of authorization of same for commercial exploitation by DOS, W.B (Memo No.557 / Seri.Dev dated 18.07.07) to Central Silk Board. In turn central Silk Board advised for a large scale trial programme in collaboration with DOS, W.B, CSRTI, Berhampore and NSSO (Malda) for popularization of SK6 × SK7 in Eastern and North Eastern India and its hybrid (M × B) in West Bengal. Accordingly large scale trial programme was undertaken in collaboration with DOS, W.B and NSSO (Malda) for two years (Anonymous, 2008-09). Under this programme SK6 × SK7 was reared at different DOS farms situated in West Bengal, NSSO farm in Koraput (Orissa) and RSRS & RECs of CSRTI situated in different states viz., Jharkhand, Assam, Nagaland, Tripura, Chattishgarh and Megalaya in addition to selected seed farmers of West Bengal. The bivoltine cocoons (SK6 × SK7) raised at different places was brought to SSPCs of NSSO in West Bengal, Grainages of DOS, W.B and LSPs for use as male component in preparation of multi × bi layings. The trial was

started from March 2007 and continued till Feb-Mar 2010. In each seed crop the P1 layings of SK6 x SK7 was supplied from CSRTI, Berhampore to different test centres especially in Dec-Jan, Feb-Mar and Sep-Oct seed crop seasons. In addition May-June and June-July crop are undertaken in limited scale. The list of test centres are in fig1. Three important seed crops viz., Dec-Jan, Feb-Mar and Sep-Oct are undertaken in DOS farms of West Bengal. Only Sep-Oct seed crop was conducted at RSRSs & RECs situated in different Eastern and North Eastern states and NSSO farm at Orissa. Further selected seed rearers from different villages of Murshidabad and Birbhum districts of West Bengal in addition NGOs also participated in this programme.

Performance of SK6 × SK7 in different places of Eastern and North Eastern India

Altogether 31920 dfls of SK6 × SK7 was reared at different places in two years.

Dec-Jan seed crop

During Dec-Jan (2007-2009) seed crop, a total of 5025 dfls of SK6 × SK7 was reared in different places of DOS farms as well as other places in West Bengal. SK6 × SK7 yielded an average of 42.5 kg / 100 dfls. The yield ranged between 33-53kg/ 100 dfls. Higher production (53kg) was observed in NGO (Nabagram) followed by seed rearers (51kg) from Banjetia village (Murshidabad) and NGO (SPARSH) (49) from 24 Parganas district. Among the DOS farms of West Bengal, higher production was observed at Jalpaiguri i.e., 48kg/100 dfls and lower was observed in Bankura (33kg). An average of 37kg/ 100 dfls yield was observed within DOS farms (Fig1)

Feb-Mar seed crop

In Feb-Mar (2008-2009) seed crop, 8700 dfls of SK6 × SK7 was reared in different places and yielded an average of 45 kg / 100 dfls. The yield ranged between 37-52kg / 100 dfls. Higher production (52kg) was observed in NGO (Nabagram) and DOS Farm at Jalpaiguri followed by seed rearers (50kg) from Banjetia village, Murshidabad (Fig2).

Sep-Oct seed crop

During Sep-Oct (2008-09), the most unfavourable seed crop season and it was also important and target season of the year, the trial was conducted in all Eastern and North Eastern states. A total of 17595 dfls of SK6 × SK7 was reared at different RSRSs & RECs situated in Eastern and North Eastern India , DOS farms in West Bengal , selected seed rearers and NGOs from west Bengal. In this crop an average yield of 34kg / 100 dfls was observed. Among RSRSs & RECs tested, range of yield obtained was between 25 and 48.2 (Fig3) and highest production i.e., 48.2kg/100dfls was observed at REC, Aizwal (Mizoram) and 47.5kg in REC, Shillong (Megalaya). Amongst DOS farms, highest (45kg) production was observed in Kalimpong and Jalpaiguri (Fig4). Further 38kg / 100 dfls was observed in farm at DOS, Orissa.

May-June and June-July seed crops

In addition, SK6 × SK7 was also tested in two other seasons, when bivoltine cannot reared due to high temperature and high humidity (May-June and June-July), In this seasons, SK6 × SK7 yielded 30 & 22kg / 100 dfls respectively.

Overall SK6 × SK7 yielded better in all seed crop seasons, most importantly it yielded an average of 34kg in target seed crop season i.e., Sep-Oct. As because during this season rearing of bivoltine parent is unthinkable job in West Bengal due to prevailing of high temperature & humidity resulting entire (required) quantity of bivoltine seed cocoons are procured from other parts of country. But with this FC, bivoltine seed can be generated Eastern India itself.

Performance of multi × bi hybrids at farmers' level

Though parental bivoltine foundation cross is superior and hardy, the genetic worth can be determined if the hybrid (M × B) prepared using SK6 × SK7 fairing well in farmers level or not. Accordingly bivoltine cocoons produced in Eastern as well as North Eastern India are brought to West Bengal for preparing multi × bi hybrids. Grainages of DOS, West Bengal, NSSO and LSPs including NGOs are prepared Nistari × (SK6 × SK7) as well as M6DP(C) × (SK6 × SK7) and distributed to farmers of Murshidabad, Birbhum and Malda districts of West Bengal in different commercial seasons in two years.

Nistari × (SK6 × SK7): A total of 1522050 dfls were reared in three commercial seasons at the farmers of West Bengal. Of which, 381600 dfls were reared during Feb-Mar and obtained an average of 40kg cocoon yield / 100 dfls (Range: 33-46.3kg / 100 dfls) against 37kg in control, N × NB4D2. During April crop, 337600 dfls were reared and an average of 38.5kg / 100 dfls obtained, where as 30kg obtained in control i.e., N × NB4D2. The important commercial crop, Oct-Nov crop , highest amount of 802850 dfls were reared with farmers and obtained an average yield of 44 / 100 dfls (Range: 37-54.5kg) against 40 kg in control, N × NB4D2 (Table 1) .

M6DP (C) × (SK6 × SK7): Altogether 102658 dfls were reared in three commercial crops, out of which highest 48400 dfls during Feb-Mar, followed by 42258 dfls in April and 12000 during Oct-Nov crops. An average of 41kg / 100 dfls obtained during Feb-Mar with range of 33-47.5kg, 36.0kg during April with range of 30-41.5kg and 45.0kg (Range: 35-54.5) during Oct-Nov crop (Table 1).

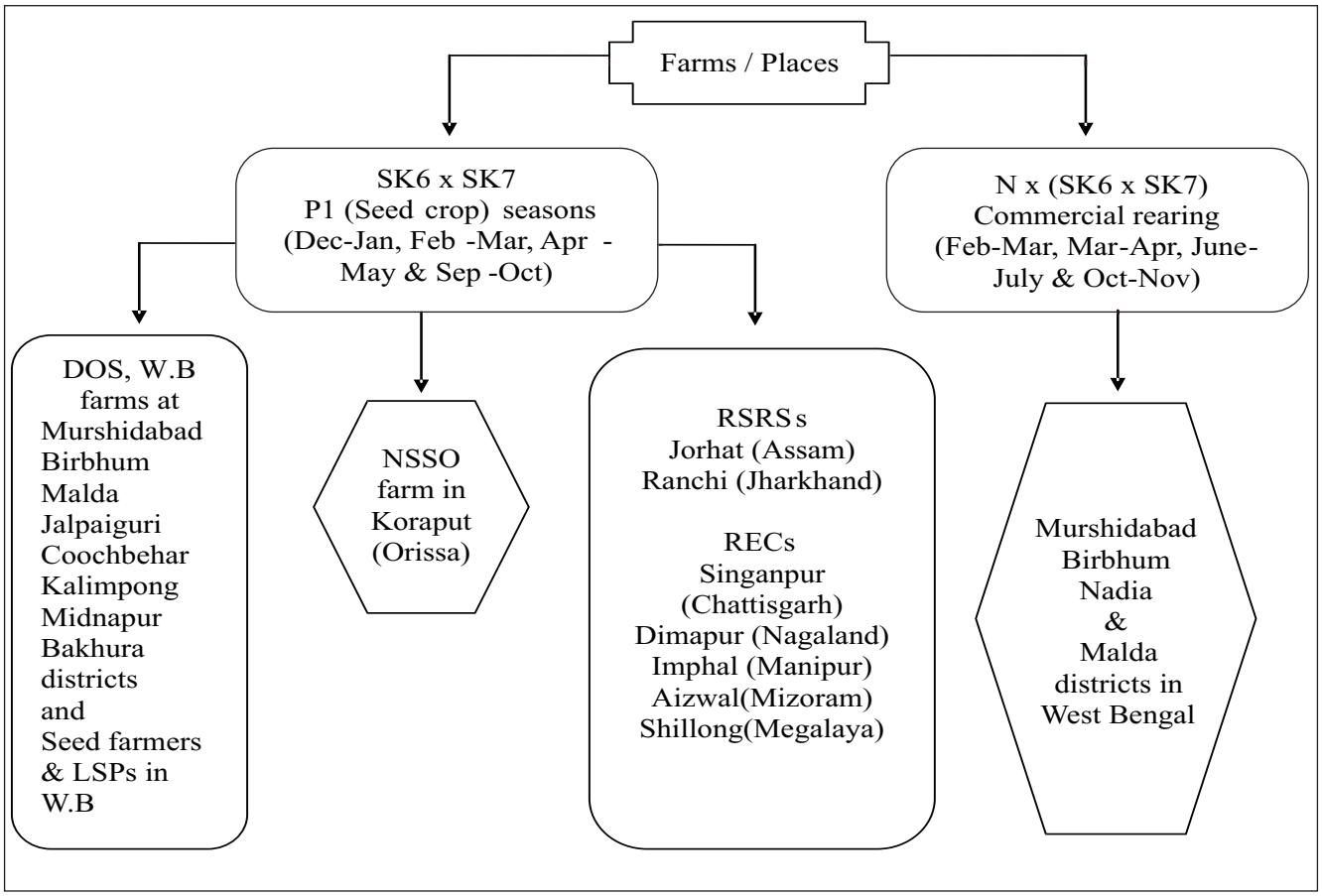


Fig. 1: List of centre/ places conducted seed and commercial crop

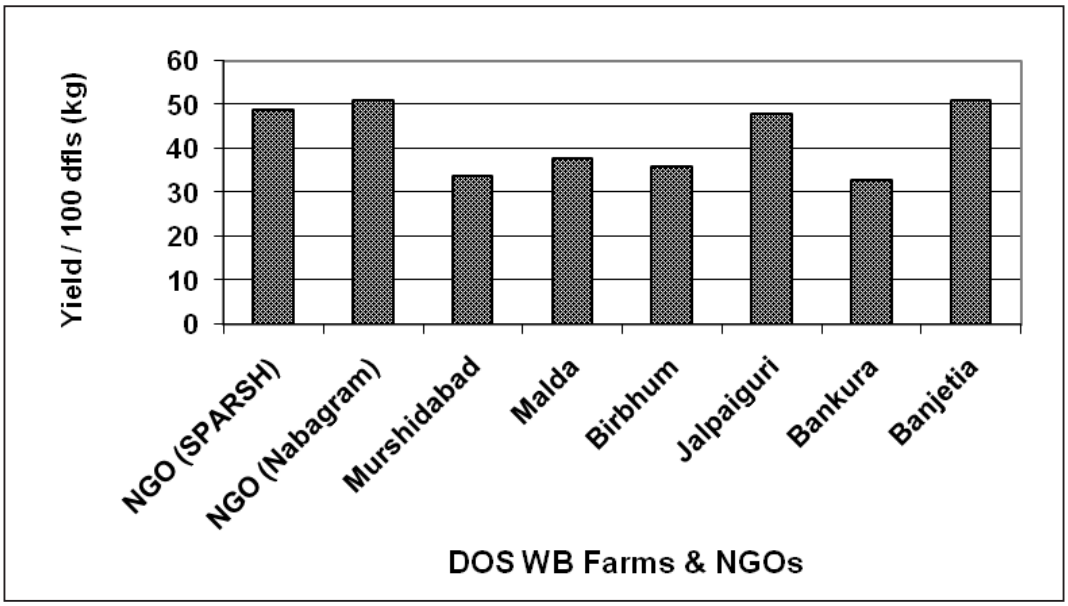


Fig. 2: Performance of Sk6 × SK7 during Dec-Jan seed crop season in DOS, W.B farms, NGOs farms & LSPs in West Bengal.

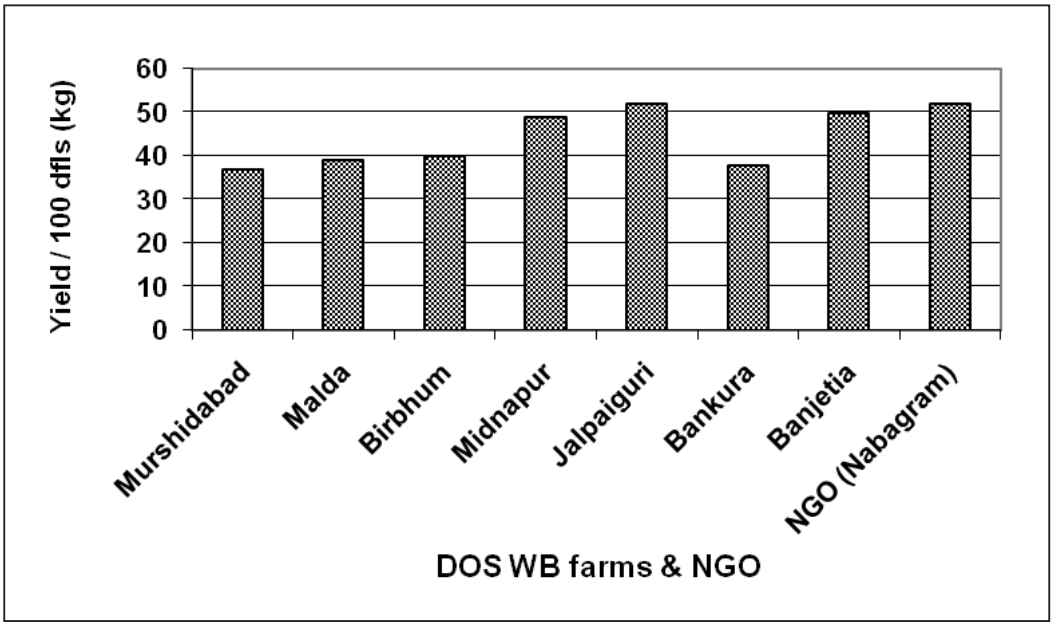


Fig. 3: Performance of SK6 x SK7 during Feb-Mar seed crop season in DOS, W.B farms, NGOs farms & LSPs in West Bengal.

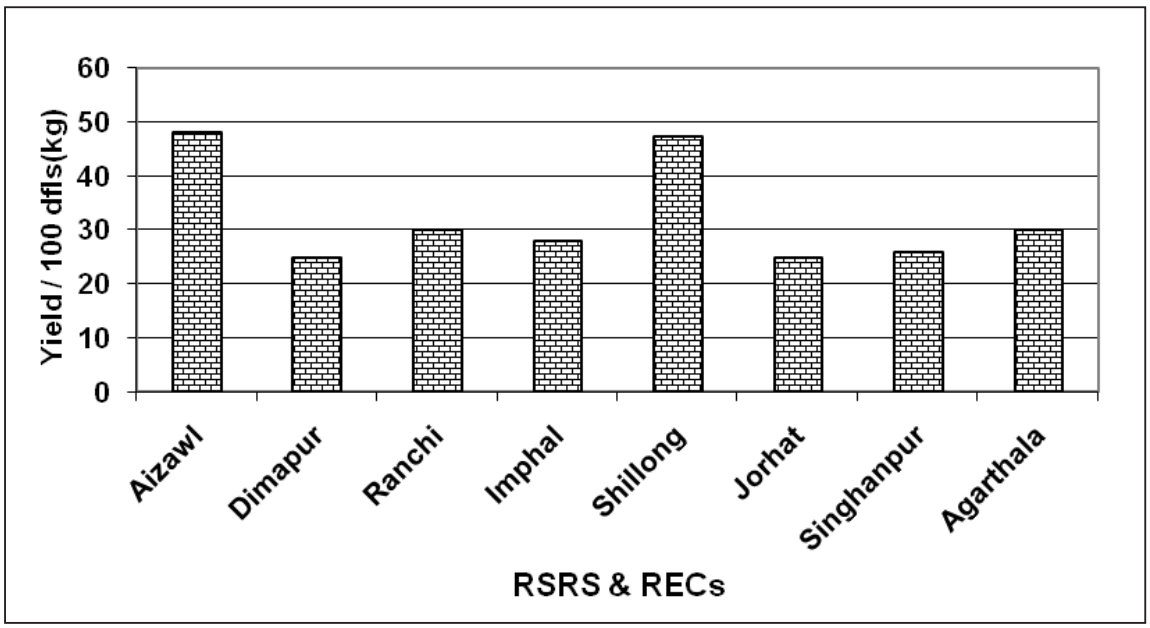


Fig. 4: Performance of Sk6 × SK7 during Sep-Oct seed crop season at different RSRSs and RECs

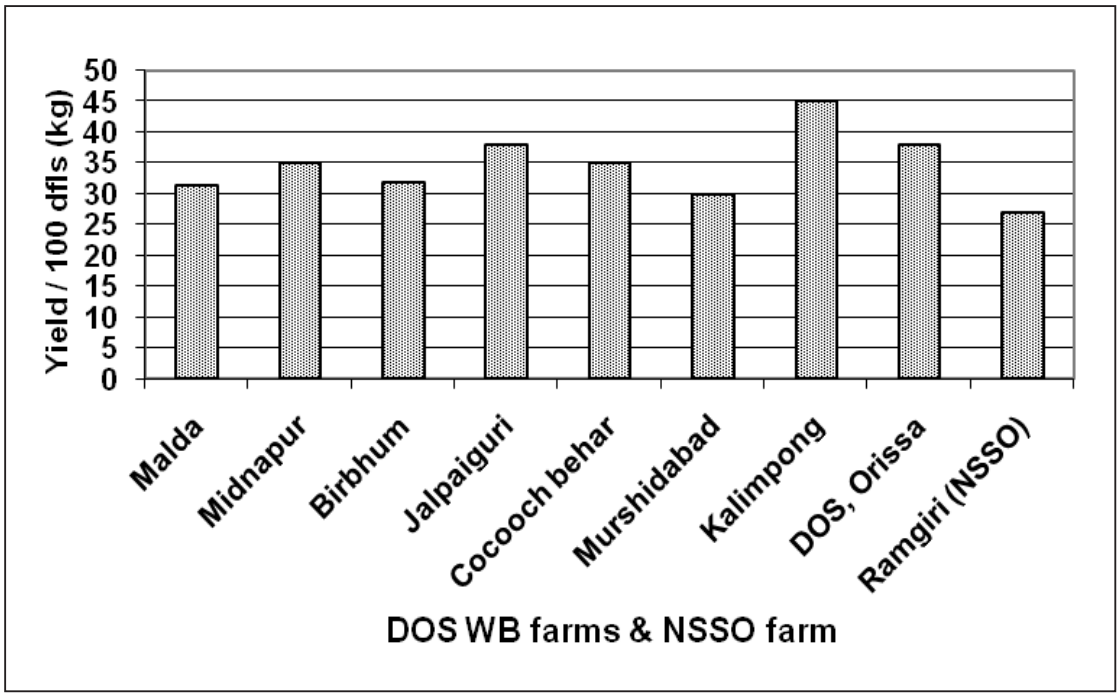


Fig. 5: Performance of Sk6 × SK7 during Sep-Oct seed crop season at different DOS farms of West Bengal, DOS, W.B farms , Orissa and NSSO farm

Table 1: Season wise yield performance of multi x bi hybrids reared at farmers level during 2008-2009.

Hybrid (Multi x Bi)	Season	No of dfls	Yield /100 dfls (kg)	
			Range	Average
Nistari x (SK6 x SK7)	Feb-Mar	381600	33-46.3	40.0
	April	337600	34-45.0	38.5
	Oct-Nov	802850	37-54.5	44.0
M6DP (C) x (SK6 x SK7)	Feb-Mar	48400	33-47.5	41.0
	April	42258	30-41.5	36.0
	Oct-Nov	12000	35-54.0	45.0
N x NB4D2 (Control)	Feb-Mar	34800	30-45.3	37.6
	April	47600	25.5-38.5	30.0
	Oct-Nov	54000	34.5-47.5	40.0

Both the hybrids prepared with SK6 × SK7 shown better yield than the control, hybrid N × NB4D2 in all the seasons confirming the potentiality of SK6 × SK7.

CONCLUSION

Trials at different levels and different farms situated at Eastern and North Eastern India indicated SK6 × SK7 can be raised at all seed crop seasons including unfavourable seed crop season (Sep-Oct) in West Bengal. Thus with SK6 × SK7, bivoltine seed crop stabilization - the bottleneck for the development of sericulture industry in Eastern India & North Eastern India particularly in West Bengal can be overcome. Further, it will avoid transportation of seed cocoons from far off places to save money and energy. Bivoltine seed cocoon production within West Bengal provides opportunity even to small LSPs to produce multi x bi hybrids which ultimately help to increase the production of quality cocoons. Further the hybrid N × (SK6 × SK7) performed well in commercial seasons (including adverse commercial season) and recorded 5-17% more cocoon yield compared to the ruling hybrid N × NB4D2. Presently the hybrid, N × (SK6 × SK7) is under National Race Authorization trial (Phase VIII) conducted by Central Silk Board.

ACKNOWLEDGEMENT

The authors are thankful to the Director, DOS, WB, different district level officers & officials of DOS, WB and In charge, Scientists and officials of NSSO (Malda) and SCTH Malda for their kind co-operation for conducting the trial. Thanks also extended to Scientists & Officials of RSRSs *viz*., Ranchi, Kalimpong, Jorhat and Koraput and RECs *viz*., Mothabari, Shillong, Dimapur, Aizwal, Imphal, Singhanpur for their support for successful completion of trial. Further thanks go to Dr. Kartik Chandra Mandal, Retired Joint Director, CSB & Head, NGO (SPARSH), Manmadan, Soumya Majumdar of Murshidabad sericulture society (NGO) and LSPs / seed rearers from different places of West Bengal for undertaking and successful completion of seed crop. Thanks also go to Dr. S. N. Bagchi, Dr. Swapan Mukherjee and Mr. N. B. Kar, Scientists of CSR&TI, Berhampore for their support for successful completion of this trial.

Last but not least, thanks to Mr.Pranab Basu, Joint Director, DOS, WB, Kolkata without his involvement this hybrid trial would not have been undertaken. His moral support, guidance, motivation, and personnel involvement in popularizing the foundation cross, SK6 × SK7 among DOS, WB in last five years is greatly acknowledged.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 139-142

COMPARATIVE ANALYSIS OF AMYLASE ACTIVITY IN THE DIGESTIVE JUICE OF BIVOLTINE HYBRIDS OF THE SILKWORM, *BOMBYX MORI* L. DEVELOPED BY AMYLASE MARKER ASSISTED SELECTION

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ABSTRACT

Among the biochemical enzyme markers, amylase has been identified as one of the useful marker as it is contributes for better digestibility and associated with the survival. In this direction, studies were made to ascertain the efficacy of using amylase activity as selection criteria for identifying promising and robust bivoltine hybrids. Ten single hybrids were prepared utilizing the oval and dumb-bell lines of bivoltines evolved through introgression of high activity amylase genes along with the control hybrid, CSR2 × CSR4 which were reared in three seasons, *i.e*., January-February, March-April and May-June 2009. Amylase activity was assayed in all the hybrids among which 2Cx4S recorded the highest activity of 240.5 followed by 2M × 4S (210.8) and 2S × 4S (209.3), which were more than four fold higher than that of the control hybrid, CSR2 × CSR4, where the activity was found to be 48.1. The survival of these new hybrids were also found to be significantly higher than that of the control. The results indicate the prospects of using amylase activity as an additional parameter for selection of hybrids in the breeding programmes which can assure higher survival and yield under sub-optimal conditions.

Key words: Bivoltne hybrids, Digestive amylase, Marker assisted selection, Survival

INTRODUCTION

Sericulturally advanced countries such as Japan, China and South Korea have made commendable progress in the development of silkworm (*Bombyx mori*.L) breeds with high productivity suiting to Sericultural practices of both temperate and tropical situations. Even though, India is the second largest producer silk in the world, contribution of quality silk is very meager. This drawback can be overcome if farmers rear more of bivoltine hybrids, which produce high quality silk. The most important factor to be analysed is the compliance of bivoltine breeds and hybrids to varying environmental conditions. Selection on economic merit among and within breeding stocks is the main tool for the genetic improvement of livestock.

The biochemical studies have been proved to be valuable tool for studying genetic variation in natural population and have been used as useful indicator in plant and animal breeding programmes (Tanksley *et al.,* 1982). The enzyme system in the silkworms plays a vital role in determining the performance of the larvae in terms of effective transformation of organic food molecules of the leaf into useful biomolecules. The silk industry demands higher survival and also quality yarn. The survival of silkworm depends upon conversion efficiency of food for growth and development.

The α-amylases (α-1,4-glucan-4-glucahydrolase) are among the digestive enzymes that degrade starch and related compounds. Amylase is one of the most well worked out enzyme system in *Bombyx mori* (Matsumura, 1951; Tazima, 1964; and Hara *et al.*, 1984). Hirata,Y.(1974) reported in his studies that survival rate was higher in Larvae with higher amylase activity when compared with lower activity. The importance of carbohydrate metabolism towards yield realization has been emphasized by Chatterji and Datta (1989). Abraham *et al*., (1992) have studied on haemolymph and digestive α amylase enzyme in diapausing and non diapausing strains of silkworm *B.mori* and reported that diapausing showed negligible amylase activity and the non diapausing strains had higher amylase activity. The genetic variability in digestive amylases of Indian silkworm breeds and other countries maintained at institute was studied by

Chatterjee *et al* ., (1992), which also indicated that the activity of amylase in polyvoltine races are two fold higher than the bivoltine silkworms. Correlation studies of Chatterjee *et al*.,(1993) confirmed the importance of digestive amylase activity for the survival of silkworms. Ashwath *et al.,* (2001) have developed near isogenic lines through isozyme marker based selection by introgressing digestive amylase as a marker in the breeding for improving the survival potential of productive breeds and reported the prospects of using digestive amylase as a marker in silkworm breeding. The evaluation of GEN3x GEN2 in the laboratory and on-farm trials has shown the highest index values for survival and other productivity traits (Ashwath *et al*., 2002). In the insect kingdom, amylolytic enzymes are known to play an essential role in carbohydrate metabolism and energy production (Pelegrini *et al.*, 2006).It has been reported that insects are totally dependent on α-amylase for their survival (Sivakumar *et al*., 2006). Large scale testing of GEN3xGEN2 at southern states in both favourable and unfavourable season has clearly shown stabilized yield (Sharmila *et al*., 2010). Six oval lines (GEN1, 2N, 2C, 2D, 2S, 2M) and 5dumbell lines(4P, 4C, 4D, 4S, 4M) are evolved by introgressing amylase genes from polyvoltine donors into productive breeds CSR2 and CSR4 as recurrent parents (RP) and the evolved lines have shown significantly higher survival than their respective RPs (Ashwath *et al.,* 2008).

Against this background, present study was undertaken with an object to ascertain the efficacy of using amylase activity as one of the selection criteria for identifying promising and robust bivoltine hybrids.

MATERIALS AND METHODS

Five oval lines of CSR2, viz.,, GEN1, 2C, 2D, 2S, 2M and three dumb-bell lines of CSR4, viz., 4C, 4D, 4S, introgressed with high activity amylase genes were used as parents. Ten single hybrids of oval × dumb-bell lines, namely, 2C×4S, 2M×4S, 2S×4S, 2D×4D, 2S×4C, 2D×4C, 2C×4C, 2M×4D, GEN1×4C, GEN1×CSR4 and the control hybrid, with 'null' type of amylase, CSR×CSR4 were prepared and reared under three seasons following the standard rearing technique. The digestive juice was collected on the 5th day of V instar from all the hybrids including control. Amylase activity was assayed following the method of Chatterjee et al. (1993) by incubating 10 ul of digestive juice in 0.2% starch as the substrate for 30 min at 37 °C and the reaction was stopped using 1% dinitrosalicylic acid followed by heating in boiling water for 5 min. Amylase assay was carried out in 3 replications for each of the 11 hybrids. Optical Density (OD) values were recorded at 525 nm and the enzyme activity was expressed as mg of maltose released per ml.

RESULTS AND DISCUSSION

Comparison of amylase activity (mg/ml) in the eleven hybrids rearing during I, II and III crops reared during January-February, March-April and May-June 2009 respectively showed that amylase activity was significantly lower during the favourable months of I crop, when compared to the unfavourable summer months of II crop, during which the amylase activity was much higher. Further, during the following crop of May-Jun., which is also unfavourable, the amylase activity was significantly lower than the preceding crop (Table 1). During I crop, the highest amylase activity (177.8) was recorded in the hybrid 2D × 4C followed by 2S × 4C (163.1) and 2M × 4S (137.7), while the control hybrid, CSR2 × CSR4 the activity (54.1) was about three fold lesser than the former. The amylase activity in the II crop was considerably higher than the preceding crop, which showed the highest activity of 490.1 in 2C × 4S, closely followed by 2S × 4S (469.3) and 2D × 4D (398.9) and the least activity of 47.0 was observed in the control hybrid, CSR2 × CSR4. During the III crop, 2C × 4S recorded the highest activity (152.9) followed by GEN1 × 4C (144.6) and 2D × 4D (104.5). The lowest activity of 43.1 was found in the control, CSR2 × CSR4.

By pooling the data of all the three crops mean values were determined and the results revealed the highest amylase activity of 240.5 in that the hybrid 2C × 4S, followed by 2M × 4S (210.8) and 2S × 4S (209.3). The least activity of 48.1 was observed in case of the control hybrid, CSR2 × CSR4. The low amylase activity in the control hybrid is in agreement with the previous reports of Chatterjee *et al*. (1992) and Abraham *et al*., (1992) who showed that the enzyme activity was higher in non diapausing strains and negligible in diapausing.

In addition to amylase assay of the hybrids, the rearing parameter data on pupation rate and cocoon traits was also recorded and the mean values of the three crops are given in Table 1. Comparison of the cocoon parameter data of the hybrids showed that the cocoon weight ranged from the lowest value of 1.533 g in 2M × 4S and the highest cocoon weight of 1.697 g was recorded in 2D×4C followed by GEN1×4C (1.695 g) and GEN1 × CSR4 (1.675). The shell weight was found to be lowest in 2S × 4S (0.337g) and the highest value was observed in the same hybrids which had higher cocoon weight, like 2D × 4C (0.385 g), followed by GEN1 × 4C (0.384 g) and GEN1 × CSR4 (0.371), clearly showing that the cocoon weight and shell weight are correlated traits. The shell % ranged from 21.60 in 2S × 4S to the highest value of 22.70 in 2D × 4D, followed by 2D × 4C (22.69%) and GEN1 × 4C (22.64%). However, it was observed that most of the hybrids had higher values for the cocoon traits than the control.

With regard to important trait like survival, the highest value of 88.1 % represented in terms of pupation rate was recorded in the hybrid 2C × 4S followed by 87.8 % in 2M × 4S and 86.6 % in 2S × 4S. The least survival of 78.5 % was

observed in the control, CSR2 x CSR4. Thus all the new hybrids showed higher survival when compared to control. It is pertinent to note that the amylase activity in the above three hybrids was also higher when compared to the other hybrids as well as control. To test the relationship between amylase activity and survival, correlation analysis was made between the mean values of amylase activity and pupation rate (Fig.1). The results clearly showed a positive correlation between amylase activity and pupation rate as indicated by the R2 value of 0.91, which is highly significant, suggesting the positive role of activity of amylase contributing towards survival.

These results confirm the observations of Hirata (1971; 1974) and Gamo (1983) who highlighted the importance of digestive amylase in improving the dietary efficiency in the silkworm and they showed that the silkworm strains with high amylase activity showed higher growth and survival than the low activity strains when the larvae were reared on hardened leaves. The present study also corroborates the work of Chatterjee *et al*.,(1992,1993) and Patnaik and Datta, (1995) who also showed a positive correlation between survival and amylase activity.

The present study confirms the role of amylase in survival and is in agreement with the reports of Pelgini *et al.,* (2006) and Sivakumar *et al.,* (2006) who highlighted the role of amylolytic enzymes in carbohydrate metabolism and survival. It has been reported that insects are totally dependent on α-amylase for their survival (Sivakumar *et al*., 2006). Earlier report on the large scale testing of GEN3×GEN2 which has been selected through amylase marker assisted selection has shown stabilized yields both in favourable and adverse climatic conditions (Sharmila *et al*.,2010). Introgression of high amylase activity genes into the productive bivoltine hybrids has resulted in realizing the twin advantage of both higher productivity as well as increased viability. Even today, due to erratic rainfall, lack of irrigation facilities and high cost of input, the farmers are not able maintain the optimum mulberry leaf quality suitable for bivoltines, which demands sufficient irrigation and fertigation. Hence bulk of the farmers are able to rear only crossbreeds and the rearing of productive bivoltine hybrids are being carried out on limited scale by elite farmers only who can provide the inputs and maintain the desired mulberry leaf quality.

The findings of the present study clearly indicate the prospects of using amylase activity as an additional parameter for selection of hybrids in the breeding programme. As per the results of the present investigation, the hybrid 2C×4S which has the highest amylase activity could perform better under the sub-optimal conditions of leaf quality. In view of the better digestibility and higher viability expected due to high amylase activity, this productive bivoltine hybrid can assure higher survival and yield under sub-optimal conditions of leaf quality and rearing management prevailing with the small and marginal farmers who are presently rearing crossbreeds and thus leading to increased bivoltine silk production in India .

Table 1: Amylase activity and rearing performance of bivoline hybrids

Sl. No.	Hybrids	Amylase activity (mg/ml)				Pupation Rate (%)	Cocoon Wt. (g)	Shell Wt.(g)	Cocoon Shell (%)
		I crop	II crop	III crop	Mean				
1	GEN1 x 4C	76.5	193.2	144.6	138.1	84.4	1.695	0.384	22.6
2	GEN1 x CSR4	66.7	164.6	5.6	95.7	82.1	1.675	0.371	22.2
3	2C x 4C	91.3	327.0	59.6	159.3	84.9	1.562	0.346	22.2
4	2C x 4S	78.6	490.1	152.9	240.5	88.1	1.647	0.366	22.2
5	2D x 4C	177.8	267.3	78.8	174.6	85.9	1.697	0.385	22.7
6	2D x 4D	108.5	398.9	104.5	204.0	86.2	1.538	0.349	22.7
7	2S x 4C	163.1	320.9	60.4	181.5	84.1	1.595	0.349	21.9
8	2S x 4S	105.8	469.3	52.9	209.3	86.6	1.560	0.337	21.6
9	2M x 4D	85.6	292.2	69.6	149.1	82.8	1.549	0.340	22.0
10	2M x 4S	137.7	397.6	97.1	210.8	87.8	1.553	0.344	22.2
11	CSR2 x CSR4	54.1	47.0	43.1	48.1	78.5	1.589	0.344	21.6
	Mean	104.2	306.2	83.6	164.6	84.7	1.606	0.356	22.2
	SD	39.9	134.1	37.2	55.8	2.8	0.06	0.02	0.39
	CV (%)	38.3	43.8	44.5	33.9	3.3	3.83	4.90	1.75

Note: I crop = Jan-Feb. 2009, II crop = Mar-Apr.2009, III crop = May-Jun.2009

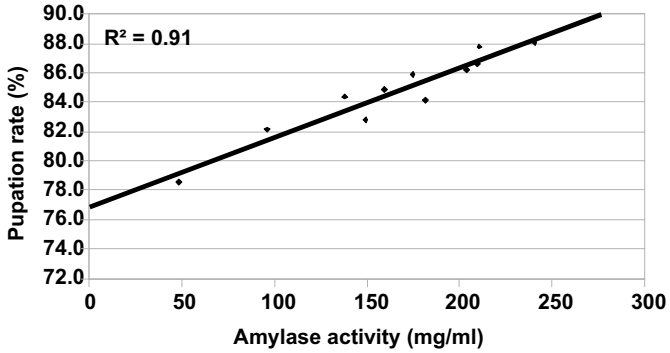


Fig. 1: Correlation between amylase activity and pupation rate

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 143-150

A NEW BREEDING APPROACH IN THE DEVELOPMENT OF POLYVOLTINE BREED(S) OF THE SILKWORM, *BOMBYX MORI* L. USING ANDROGENETIC TECHNIQUES

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ABSTRACT

An attempt was made to evolve a polyvoltine silkworm breed AGL3 through application of androgenesis. The breed was developed by crossing F2 males derived from a polyvoltine hybrid BL68 × BL69 with another polyvoltine race "Nistari" and exposing the eggs at 38 ºC for 200 minutes. Androgenetic larvae were obtained from these eggs which expressed paternal characters. Repeated backcrosses were adopted with androgenetic males for several generations. One line, AGL3 with plain larvae and greenish yellow oval cocoons was evolved. The line was evaluated utilizing five productive bivoltine silkworm breeds. Laboratory evaluation showed superiority of the hybrid AGL3 × CSR2 exhibiting higher fecundity (493), pupation rate (96.04 %), yield/10,000 larvae by weight (18.662 kg), cocoon shell weight (0.391 g), cocoon shell percentage (20.40 %), filament length (1010 m) and neatness (91 p). The new hybrid ranked first exhibiting maximum average evaluation index value and manifested maximum hybrid vigour for several characters. The possibility of application of androgenesis as a breeding tool in silkworm breeding for the evolution of superior silkworm breeds and hybrids has been discussed.

Key Words: Androgenesis, *Bombyx mori*, Evolution, Polyvoltine breed

INTRODUCTION

Induction of androgenetic development in the silkworm, *Bombyx mori* L. has been carried out by means of several agents such as ultraviolet light (Strunnikov, 1983), gamma rays (Xu *et al*., 1988; 1997), CO_2 and dry ice (Tazima and Onuma, 1967; Li *et al*., 1988), low temperature (Sugai *et al*., 1987) and high temperature (Ravindra Singh *et al*., 1991).Ravindra Singh *et al*. (2009a) have devised an improved method of androgenetic development in the eggs of the silkworm. Attempts have been made to explore the possibility of developing silkworm breeds through application of androgenesis (Strunnikov *et al*., 1982; Malinova *et al*., 1996, Xu *et al*, 1997; Nacheva *et al*., 1999). Recently, Ravindra Singh *et al*. (2009b; 2010) have developed some polyvoltine breeds of the mulberry silkworm, *Bombyx mori* L. utilizing androgenesis as a breeding tool. Hybrid vigour has been reported to a greater extent due to the homozygous nature of the breed involved (Strunnikov, 1986; Nacheva *et al.,* 1999). In the present study, an attempt was made to explore the possibility of application of androgenesis in the evolution of superior silkworm breed to raise hybrids of high viability, vigour, cocoon yield and better silk quality.

MATERIALS AND METHODS

Androgenetic development in the eggs of the silkworm was induced as per Strunnikov (1983). Nistari, an indigenous polyvoltine race of West Bengal which gives marked larvae and golden yellow spindle shaped cocoons and two evolved polyvoltine silkworm breeds BL68 and BL69 which give plain larvae and greenish yellow cocoons, were utilized in this study. F2 males obtained from the polyvoltine hybrid BL68 × BL69 were crossed with Nistari females. Moths were allowed to mate for 3 h at 25 ºC and after depairing, females were kept at 5 ºC for 48 h to synchronize the age of the egg. Oviposition was carried out in dark condition for 50 – 60 minutes. Then the eggs were exposed to hot air at 38 ºC for 200 minutes and transferred to 15 ºC for 72 h. Eggs were

incubated at 25 ºC and 75 % relative humidity till hatching. Androgenetic development of eggs was identified with the appearance of reddish-brown dark pigmentation in the serosa cells. The polyvoltine silkworm line AGL3 was developed by a series of backcrosses with androgenetic males. The breeding plan of AGL3 has been depicted in fig. 1. The breed was evaluated utilizing five productive bivoltine silkworm breeds *viz.,* CSR2, CSR3, CSR4, CSR12 and NB4D2. The promising polyvoltine × bivoltine hybrid AGL3 × CSR2 was evaluated along with the control PM × CSR2 in the laboratory as well as in Technology Validation and Demonstration Centre (TVDC) of CSRTI, Mysore. Evaluation of the developed hybrids has been carried out through multiple traits evaluation index method of Mano *et al.* (1993). Evaluation Index (E.I.) for different characters was calculated using the formula,

$$EI = \frac{A - B}{C} \times 100 + 50$$

Where,

A = value obtained for a particular hybrid combination.

B = mean value of particular trait of all the hybrid combinations.

C = standard deviation of particular trait of all the hybrid combinations.

10 = standard unit.

50 = fixed value.

Heterosis over mid parent (MPH) and better parent (BPH) was calculated by using the following formulae

$$MPH = \frac{F1 - MPV}{MPV} \times 100$$

$$BPH = \frac{F1 - BPV}{BPV} \times 100$$

Where,

MPV = mid parent value

BPV = better parent value

RESULTS

Performance of AGL_3 during breeding process: Generation-wise performance of AGL3 for thirteen characters namely, fecundity, hatching, total larval span, pupation rate, yield / 10,000 larvae by weight, cocoon weight, cocoon shell weight, cocoon shell percentage, filament length, filament size, reelability, raw silk percentage and neatness has been presented in Table 1.

Fecundity ranged from 474 (F9) to F2 (521). Maximum pupation rate was observed at F4 (95.20 %). Cocoon yield / 10,000 larvae by weight ranged from 1.511 (F8) to 12.634 kg (F2). Higher cocoon weight was observed at F4 (1.438 g) whereas it was minimum at F8 (1.142 g). Cocoon shell weight ranged from 0.193 (F8) to 0.262 g (F4). Cocoon shell percentage (18.46 %) was recorded maximum at F1.

Filament length ranged from 525 (F8) to 785 m (F4). Maximum reelability was observed at F2 (83.0 %). Raw silk percentage ranged from 11.6 (F2) to 13.9 % (F9). Maximum neatness of 90 p was observed from F8 onwards. To know stability of the breeding line, data pertaining to different economic characters at later generations from F10 – F12 were statistically analysed and CV % was calculated. The line was stabilized as the CV % ranged below the level of 10 % for all the characters.

Performance of polyvoltine breed AGL3 with bivoltine breeds in the laboratory:

The performance of AGL3 × bivoltine hybrids along with evaluation index values is given in Table 2. Two hybrids viz., AGL3 × CSR4 and AGL3 × CSR12 have recorded a fecundity of 505 and 513, respectively. The survival rate was observed maximum in PM × CSR2 (97.60%) followed by AGL3 × CSR3 and AGL3 × CSR12 (97.47 %). The cocoon yield/ 10,000 larvae by weight was recorded maximum (18.322 kg) in AGL3 × CSR2 followed by PM × CSR2 (16.917 kg). Maximum cocoon weight (1.928 g), cocoon shell weight (0.412 g), cocoon shell percentage (21.38 %) filament length (870 m), reelabilty percentage (82 %), raw silk percentage (16.2 %) and neatness (91 p) were recorded in AGL3 × CSR2.

The hybrid AGL3 × CSR2 exhibited higher evaluation index values of above 50 for nine characters namely, hatching (75.00), cocoon yield / 10,000 larvae by weight (68.48), cocoon weight (60.50), cocoon shell weight (69.33), cocoon shell percentage (61.27), filament length (69.13), reelability (61.62), raw silk percentage (64.57) and neatness (66.90). The hybrid ranked first on the basis of highest average evaluation index value of 63.85 followed by AGL3 × CSR3 (52.90) which recorded higher index value for ten characters.

Manifestation of hybrid vigour over mid and better parent values was estimated in six polyvoltine × bivoltine hybrids along with the control PM × CSR2 (Table 3). Positive and significant heterosis over mid parent value for survival was observed in all the six hybrids except AGL3 × CSR4. All the six hybrids have manifested positive and significant hybrid vigour over mid parent values for six characters namely, yield/10,000 larvae by weight, cocoon weight, cocoon shell weight cocoon shell percentage, filament length and raw silk percentage. AGL3 × CSR2 exhibited maximum hybrid vigour over better parent value for four characters *viz.,* yield/10,000 larvae by weight (26.53), cocoon weight (16.19), cocoon shell weight (15.72) and filament length

(7.94).

The promising polyvoltine × bivoltine hybrid AGL3 × CSR2 was further evaluated in the laboratory along with the control PM × CSR2. The performance of the hybrid is given in Table 4. The new hybrid performed better for all the eleven characters over the control. Maximum per cent improvement (25.77 %) was observed for filament length followed by cocoon shell weight (24.13 %) and yield/10,000 larvae by weight (21.14 %). The hybrid AGL3 × CSR2 was evaluated on large scale in TVDC of CSRTI, Mysore along with the control PM × CSR2. The average performance of 3 trials is given in Table 5. The new hybrid recorded maximum per cent gain over for cocoon rate/kg (20.81 %) followed by filament length (16.70 %) and cocoon shell weight (14.46 %). The hybrid was also evaluated with few farmers in a limited scale. The performance of the hybrid along with the control PM × CSR2 is given in Table 6. The new hybrid recorded maximum per cent gain over for cocoon rate/kg (25.68) followed by cocoon shell weight (15.53) and cocoon yield/ 100 dfls (10.34).

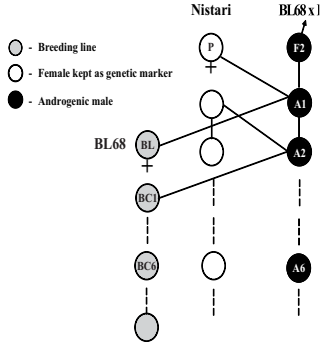


Fig.1. Breeding plan for AGL3

DISCUSSION

Androgenesis has been used for the development of homozygous silkworm breeds (Strunnikov *et al*., 1982; Malinova *et al*., 1996). Recently, Ravindra Singh *et al*. (2009b) has developed some bisexual polyvoltine silkworm breeds through application of androgenesis. Self bred silkworm lines have been isolated through irradiation of female pupae with 80 KR gamma rays, crossing the female moths with normal males and exposing the eggs at 38 ºC for 200 minutes (Xu *et al*., 1997). Nacheva *et al*. (1999) have developed bisexual silkworm lines by crossing F2 hybrid males to Ps race used as marker and exposing the eggs at 42 ºC for 200 minutes.

In the present study, an attempt has been made to develop promising polyvoltine silkworm breed with better silk quality. The hybrid AGL3 × CSR2 is characterized by high survival (>95 %), high cocoon weight (.1.9 g), high cocoon shell weight (>0.35 g), high cocoon shell percentage (>20.0 %), longer filament length (> 800 m) and high neatness (90 p). Dandin *et al*. (2007) have isolated one promising polyvoltine breed "ND7" with better silk quality without sacrificing other quantitative characters.

Manifestation of hybrid vigour was observed relatively high for some characters *viz*., yield/10,000 larvae by weight (46.63), cocoon weight (37.67) and cocoon shell weight (50.12) in AGL3 × CSR2. Efforts have been made on manifestation of hybrid vigour in hybrids involving polyvoltine and bivoltine silkworm breeds (Ravindra Singh *et al*., 1998; 2001; Datta *et al*., 2001; Gangopadhyay and Ravindra Singh, 2006, Dandin *et al*., 2007).

Laboratory evaluation of AGL3 × CSR2 has demonstrated the superiority of the new hybrid over the control PM × CSR2. The cocoons fetch more price which is more than 20 rupees as compared to the control. Presently, the hybrid is being tested on farm trials through the nested units of CSRTI, Mysore. Large scale trials at TVDC have recorded an average cocoon yield of 71.945 kg/100 dfls as against 68.643 kg in the control. The striking features of the new hybrid are that it produces cocoons with high cocoon shell weight, cocoon shell percentage, filament length and neatness.

The findings of this study can be useful to the silkworm breeders to assess the practical significance of androgenesis in the development of outstanding genotypes with uniform populations, high viability and hybrid vigour. Androgenesis can be successfully utilized in the transmission of homozygosity into existing pure lines to develop promising silkworm breeds. Recently, level of homozygosity using random amplified polymorphic DNA (RAPD) has been assessed in some silkworm breeds developed through application of androgenesis and parthenogenesis (Ravindra Singh *et al*., 2009 c). The main advantages of androgenesis in silkworm are that it provides an opportunity to shorten the breeding cycle and to develop bisexual homozygous silkworm lines which are of utmost importance in silkworm breeding.

Table 1: Performance of selected polyvoltine line AGL_3 during the process of breeding.

Generation	Fecundity (no.)	Hatching (%)	Total larval span (h)	Pupation rate (%)	Yield/10000 larvae by wt. (kg)	Cocoon wt. (g)	Cocoon shell wt. (g)	Cocoon shell (%)	Filament length (m)	Filament size (d)	Reelability (%)	Raw silk (%)	Neatness (p)
F_1	505	92.91	486	92.74	10.884	1.160	0.208	18.46	551	2.66	82	13.8	89
F_2	521	94.60	504	92.33	12.634	1.372	0.214	15.62	625	2.70	83	11.6	89
F_3	502	92.17	504	94.50	12.268	1.306	0.218	16.69	645	2.40	77	12.4	89
F_4	481	94.54	504	95.20	13.687	1.438	0.262	18.19	785	2.41	79	13.2	89
F_5	490	91.65	504	92.39	11.545	1.257	0.223	17.76	575	2.30	77	12.5	89
F_6	491	98.13	504	94.99	13.533	1.424	0.246	17.27	593	2.38	74	12.0	89
F_7	483	97.17	504	94.33	13.027	1.394	0.242	17.36	543	2.46	72	12.6	89
F_8	495	94.85	504	91.18	10.511	1.142	0.193	16.91	526	2.31	82	12.8	90
F_9	474	97.14	506	91.55	12.411	1.381	0.243	17.62	625	2.77	72	13.9	90
F_{10}	511	94.98	504	90.66	11.000	1.196	0.213	17.81	609	2.49	75	12.7	90
F_{11}	500	96.00	468	93.33	11.666	1.302	0.221	16.97	630	2.50	78	13.0	90
F_{12}	506	95.48	480	92.33	11.466	1.213	0.216	17.82	629	2.43	79	12.7	90
Mean	497	94.93	498	92.92	12.056	1.299	0.225	17.37	611	2.49	77	12.8	89
SD	13.59	2.01	12.50	1.57	1.04	0.10	0.02	0.76	67.00	0.15	3.68	0.68	0.55
CV % (F10-F12)	2.74	2.12	2.51	1.69	8.59	8.04	8.60	4.40	10.96	6.10	4.75	5.14	0.62
Mean	506	95.49	484	92.11	11.377	1.237	0.217	17.53	623	2.47	77	12.8	90
SD	5.51	0.51	18.33	1.35	0.34	0.06	0.00	0.49	11.85	0.04	2.08	0.17	0.00
CV %	1.09	0.53	3.79	1.46	3.00	4.60	1.87	2.78	1.90	1.53	2.69	1.35	0.00

Table 2: Performance of polyvoltine × bivoltine hybrids along with evaluation index values.

Hybrids	Fecundity (no)	Hatching (%)	Pupation rate (%)	Yield/ 10,000 wt. (kg)	Cocoon wt (g)	Cocoon shell wt (g)	Cocoon shell (%)	Filament length (m)	Reel-ability (%)	Raw silk (%)	Neat ness (p)
AGL3 × CSR2	493 (53.32)	96.21 (75.00)	96.60 (52.26)	18.322 68.48)	1.928 (60.50)	0.412 (96.33)	21.38 (61.27)	870 (69.13)	82 (61.62)	16.2 (64.57)	91 (66.90)
AGL3 × CSR3	490 (52.41)	95.44 (3561)	97.47 (57.44)	16.862 (51.11)	1.764 (50.25)	0.364 (53.33)	20.62 (55.93)	766 (47.73)	79 (51.66)	15.4 (56.06)	88 (52.41)
AGL3 × CSR4	505 (56.95)	95.58 (57.50)	94.33 (38.75)	16.605 (48.41)	1.751 (49.43)	0.356 (50.66)	20.34 (52.67)	739 (42.18)	74 (35.04)	15.1 (52.87)	86 (42.75)
AGL3 × CSR12	513 (59.37)	94.62 (30.83)	97.47 (57.44)	16.472 (47.01)	1.703 (46.43)	0.340 (45.33)	19.99 (48.60)	737 (41.76)	76 (41.69)	14.7 (48.61)	85 (37.92)
AGL3 × NB4D2	468 (45.75)	95.50 (55.27)	93.87 (36.01)	15.363 (35.33)	1.655 (43.43)	0.319 (38.33)	19.28 (40.34)	772 (48.97)	79 (51.66)	13.9 (45.57)	88 (52.41)
PM × CSR2	422 (31.85)	94.53 (28.33)	97.60 (58.21)	16.917 (51.69)	1.762 (50.12)	0.336 (44.00)	19.05 (37.67)	778 (50.20)	81 (58.30)	13.7 (37.97)	87 (47.58)
Mean	482	95.31	96.22	16.756	1.760	0.354	20.11	777	78.5	14.83	87.5
SD	33.07	0.36	1.68	0.95	0.16	0.03	0.86	48.66	3.01	0.94	2.00

Table 3: Heterosis over mid and better parent values

Hybrids	Fecun-dity	Hatching	Total Larval span	Pupation rate	Yield/ 10,000 wt.	Cocoon wt	Cocoon shell wt	Cocoon shell (%)	Filament length	Filame-nt size	Reel-ability	Raw silk	Neat-ness
Heterosis over mid parent values													
AGL3 × CSR2	-7.56	1.02	0.00	3.22*	46.63**	37.67**	50.12**	11.43**	30.68**	8.42	-0.20	9.60**	-0.18
AGL3 × CSR3	-0.57	0.44	-1.73	4.51**	28.56**	27.24**	36.29**	9.14**	21.56**	17.42	-2.46	6.08**	-2.21
AGL3 × CSR4	7.41**	0.51	-4.55*	2.25	29.98**	25.62**	33.50**	8.20**	9.65*	14.34	-10.34	5.48**	-4.78
AGL3 × CSR12	6.65**	-0.40	-3.41	4.89**	31.05**	29.10**	33.99**	5.43**	11.59**	1.49	-6.17	4.00**	-5.20
AGL3 × NB4D2	-0.92	1.01	-3.41	3.54*	25.63**	22.93**	29.41**	6.35**	18.49**	2.44	-1.24	1.46**	-1.68
PM × CSR2	-17.75	0.02	-4.35*	6.60**	44.92**	31.56**	32.41**	5.10**	31.38**	23.59	8.52**	0.61	-1.69
Heterosis over better parent values													
AGL3 × CSR2	-13.76	0.62	0.00	0.62	26.53**	16.19**	15.72**	-0.42	7.94*	0.87	-1.20	-3.39	-1.45
AGL3 × CSR3	-0.94	0.26	-4.49*	2.24	7.26**	8.13**	6.75**	-1.25	4.26	7.72	-2.86	-5.33	-2.93
AGL3 × CSR4	2.02	0.25	-8.70**	1.07	10.41**	6.38**	4.60**	-1.68	-10.10	4.55	-10.89	-4.64	-5.82
AGL3 × CSR12	3.70**	-0.55	-7.61**	2.96	12.61**	13.81**	8.04**	-5.05	-7.30	-0.42**	-6.94	-5.35	-5.20
AGL3 × NB4D2	-5.45	0.69	-7.61**	2.95	10.15**	6.73**	6.33**	-0.38	-0.73	-3.69**	-2.86	-4.81	-1.86
PM × CSR2	-26.12	-1.13	-12.00**	1.67	16.83**	6.17**	-5.80	-11.26	-3.51	7.84	-3.20	-17.93	-5.43
*and ** denote significantly different at 5 and 1% level, respectively													
PM × CSR2	- 17.75	0.02	- 4.35*	6.60**	44.92**	31.56**	32.41**	5.10**	31.38**	23.59	8.52**	0.61	- 1.69
PM × CSR3	- 10.56	0.42	- 7.94**	6.70**	26.94**	21.53**	27.14**	8.76**	34.69**	14.15	3.42	3.35**	- 2.27
PM × CSR4	- 11.92	- 0.35	- 7.64**	1.23	23.53**	22.75**	21.11**	2.52	22.65**	- 10.04**	0.90	0.63	- 1.51
PM × CSR12	- 20.62	- 1.44	- 7.64**	- 3.03*	12.73**	29.33**	22.98**	- 1.76	1.02	18.97	3.89	- 2.30	- 2.29
PM × NB4D2	- 9.54	0.37	- 7.52**	2.01	20.02**	20.21**	24.85**	6.74**	13.09**	18.12	6.70**	1.86**	- 1.34
CD@5%	4.383	1.503	3.573	2.590	4.884	0.456	0.128	2.591	7.961	0.132	4.18	1.031	1.948
CD@1%	5.205	2.224	5.289	3.833	7.228	0.675	0.189	4.575	10.777	0.195	6.197	1.190	2.883

Table 4: Performance of promising polyvoltine × bivoltine hybrids of the silkworm, Bombyx mori L. in the laboratory

Hybrids	Fecundity (No)	Hatching (%)	Pupation rate (%)	Yield/10,000 wt. (kg)	Cocoon wt (g)	Cocoon shell wt (g)	Cocoon shell (%)	Filament length (m)	Reel-ability (%)	Raw silk (%)	Neatness (p)
AGL_3 × CSR2	493 (9.07)	96.28 (1.27)	96.04 (2.54)	18.662 (21.14)	1.916 (11.92)	0.391 (24.13)	20.40 (10.93)	1010 (25.77)	82 (5.13)	15.87 (11.68)	91 (2.24)
PM × CSR2 (Control)	452	95.07	93.66	15.405	1.712	0.315	18.39	803	78	14.21	89

Values in parentheses indicate per cent improvement over control

Table 5: Evaluation of promising polyvoltine × bivoltine hybrids in Technology Validation and Demonstration Centre of CSR&TI, Mysore (Average of 3 trials)

Hybrids	Yield/100 dfls (kg)	Cocoon wt (g)	Cocoon shell wt (g)	Cocoon shell (%)	Filament Length (m)	Raw silk (%)	Neatness (p)	Cocoon rate / kg (Rs.)
AGL_3 × CSR2	71.945 (4.81)	1.806 (5.92)	0.364 (14.46)	20.15 (8.04)	922 (16.70)	13.82 (9.07)	91.3 (2.23)	137=76
PM × CSR2 (Control)	68.643	1.705	0.318	18.65	790	12.67	89.3	114=03

Values in parentheses indicate per cent improvement over control

Table 6: Field trial of promising multivoltine × bivoltine hybrids of the silkworm, *Bombyx mori* L.

Hybrids	No. of Dfls.	No. of farmers	Yield/100 dfls (kg)	Cocoon wt (g)	Cocoon shell wt (g)	Cocoon shell (%)	Cocoon rate/kg (Rs.)
AGL_3 × CSR2	300	3	70.139 (10.34)	1.829 (7.27)	0.357 (15.53)	19.52 (7.72)	137=00 (25.68)
PM × CSR2 (Control)	300	3	63.561	1.705	0.309	18.12	109=00

Values in parentheses indicate per cent improvement over control

ACKNOWLEDGEMENT

The authors wish to thank the Department of Science and Technology, New Delhi for financial assistance.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 151-156

EVALUATION AND IDENTIFICATION OF SUITABLE BIVOLTINE SILKWORM HYBRIDS FOR HILLY REGIONS OF EASTERN INDIA

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ABSTRACT

A total of forty two bivoltine silkworm hybrids prepared from the six oval bivoltine breeds (SK3, O2, O3, O4, MC3, KA) and seven dumbbell bivoltine breeds [SK4, SK6, D4, D6(P), D7, BHR2, MJ1) were evaluated in three seasons *viz*., autumn, spring and summer in the Darjeeling hills of West Bengal. Analysis of variance (ANOVA) indicated significant differences ($p<0.01$) for all the characters among hybrids and seasons with significant hybrid × season interactions. Out of forty two hybrids, nineteen hybrids scored evaluation index values (EI) of above 50 in autumn, twenty-three in spring and twenty-nine in summer seasons. Based on the overall mean data and evaluation index values, the hybrids viz., O3 × D6(P) and SK3 × D6(P) are adjudicated as most promising for commercial exploitation in the hilly regions of West Bengal / Eastern India.

Key words: Bivoltine hybrids, Evaluation index, Hilly regions, Seasons

INTRODUCTION

India has the distinction of being second largest silk producing country in the world, but around 90% of the silk produced are from multi × bivoltine hybrids popularly known as cross breed (Datta *et al.*, 2001). Though rearing of cross breed assures cocoon crop with moderate returns, but produces poor quality silk, which is not gradable. So, there is a need to replace cross breed by the bivoltine hybrids, which can produce gradable silk.

The Darjeeling district, the northern part of West Bengal, lies between 26°31' and 27°13' N latitude and 87°59' and 88°53' E longitude encompassing a total area of 3149 km^2. Climatic conditions vary from temperate to sub-tropical, though sericultural activities are mainly entrenched in the region having sub-tropical to tropical climatic conditions. In the hills, rearing is conducted thrice during the year *ie.,* spring (April-May), summer (June-July) and autumn (September-October). Cocoons produced from the spring and summer crops are utilized as commercial cocoons for reeling and cocoons generated from autumn crop are used as seed cocoons for preparation of multi × bi hybrids for rearing autumn crop in plains of West Bengal. The prevailing climate in Darjeeling hills perfectly match with required climate for bivoltine rearing which can give quantitatively and qualitatively superior cocoons. So, Darjeeling hills can be very well exploited for bivoltine rearing. The present work is an attempt to identify suitable bivoltine hybrids that can increase bivoltine silk production in hills of West Bengal and similar regions of Eastern and North Eastern India.

MATERIALS AND METHODS

Six oval bivoltine breeds (MC3, O2, O3, O4, SK3, KPG-A) and seven dumbbell bivoltine breeds [SK4, SK6, BHR2, D4, D7, MJ1, D6(P)] were crossed in Oval × Dumbbell fashion and prepared forty two bivoltine hybrids. These hybrids were reared following completely randomized design (CRD) with three replications each and 300 larvae in each replication in three commercial crop seasons *viz*., autumn, spring and summer for three years at Regional Sericultural Research station, Kalimpong, Darjeeling, West Bengal.

The economically important parameters like fecundity,

cocoon yield/ 10,000 larvae by no. and weight, cocoon weight, shell weight, cocoon shell %, filament length, Denier, reelability%, raw silk% and neatness were collected during rearing. The data obtained were subjected to ANOVA and the evaluation index (EI) was calculated as per the procedure outlined by Mano *et al*., (1993).

RESULTS

The mean data of forty hybrids reared in three seasons are presented in Table 1. Pooled analysis of data of three seasons revealed wide range of values for all the characters (Table 1). In case of fecundity the range was between 489 and 657. Highest fecundity was observed in O3 × D6(P) (657) and Lowest fecundity was observed in MC3 × SK4. Cocoon yield/ 10000 larvae (no.) was found in between 8379 and 9581. SK3 × D4 showed highest cocoon yield of 9581 and the lowest was observed in O4 × D6(P) (8379). As far as a cocoon yield/10,000 larva by weight is concerned the range was observed between 13.071 and 19.3 kg. O3 × D6(P) provided highest cocoon yield of 19.3 kg and lowest cocoon yield was obtained in MC3 × D4 (13.07 kg). In case of single cocoon weight, range was observed between 1.485 and 2.03. The highest cocoon weight of 2.003g was observed in O3 × D6(P) and lowest value of 1.485 g was obtained in MC3 × D4. In case of shell weight the highest value was obtained in O3 × D6(P) (0.405 g) and lowest in MC3 × D4 (0.293 g). Highest shell% of 20.66% was noticed in O4 × D6(P) and lowest in O4 × D4 (18.41%). Highest filament length was observed in SK3 × D6(P) (977 m) and the lowest in O4 × D4(883 m). In case of denier highest value was obtained in O3 × D6(P) (2.9) and lowest in MC3 × D6(P) (2.4). Highest reelability, raw silk and neatness were observed in O2 × SK6 (87.6%), SK3 × D6(P) (14.4%) and O2 × SK6 (88.4%), respectively. Similarly, lowest reelability, rawsilk and neatness were observed in MC3 × BHR2 (73.8%), O4 × BHR2 (11.71%) and KPG-A × SMJI (78.1%), respectively. Analysis of variance (ANOVA) of hybrids reared in three seasons for consecutive three years indicated significant differences ($p<0.01$) for all the characters among hybrids and seasons with significant hybrid × season interactions (Table1).

Season wise and mean evaluation index are presented in Table 2.

Autumn crop

During autumn crop SK3 × D6(P) ranked first with EI value of 61.3, O3 × D6(P) ranked 2nd with EI value of 60.3, O2 × SK6 ranked 3rd with EI value of 59.31, O2 × D4 ranked 4th with EI value of 59.06 and KPG-A × D6(P) ranked 5th with EI value of 56.5(Table 2).

Spring crop

During spring crop O3 × D6(P) ranked first with EI value of 64.43, SK3 × D7) ranked 2nd with EI value of 61.87, SK3 × D6(P) ranked 3rd with EI value of 56.89, SK3 × SK6 ranked 4th with EI value of 56.15 and O4 × SK4 ranked 5th with EI value of 55.67 (Table 2).

Summer crop

In summer crop O3 × D6(P) ranked first with EI value of 61.57, SK3 × D6(P) ranked 2nd with EI value of 58.52, O2 × D7 ranked 3rd with EI value of 56.9, O4 × SK4 ranked 4th with EI value of 56.85 and O2 × D6(P) ranked 5th with EI value of 55.95(Table 2).

Mean evaluation index

Ranking of hybrids based on average of three seasons indicated O3 × D6(P) ranked first with EI value of 64.13, SK3 × D6(P) ranked 2nd with EI value of 59.11, O2 × D4 ranked 3rd with EI value of 58.11, O2 × BHR2 ranked 4th with EI value of 56.77 and O2 × SK6 ranked 5th with EI value of 56.34 (Table 2).

DISCUSSION

The goal of a silkworm breeder is to select one or more good hybrid varieties, which can suit the local climatic conditions. So, before a decision can be made a careful analysis of phenotypic, genotypic and environmental variations & genotype × environmental interaction is necessary. Accordingly in the present study forty hybrids derived from six oval and seven dumbbell breeds were evaluated in three different seasons for three years. Each of the characters shown wide range of values within hybrids. Analysis of variance indicated significant differences among hybrid, seasons and season × hybrid demonstrating variability among hybrids. This variability among hybrids facilitates to select ideal and suitable one. In silkworm, *Bombyx mori*, the silk yield is contributed by more than 21 traits (Thiagarajan *et al.*, 1993) and there exists an interrelationship between multiple traits in silkworm. Any efforts to improve the yield requires consideration of cumulative effect of the major traits which influences the silk yield. It has been also established that selection pressure applied for one character results in correlated changes in other quantitative traits of economic importance. So in order to judge the superiority of the silkworm breed/ hybrid impartially, a common index method was found very much essential (Bhargava *et al.*, 1994). The evaluation index (E.I) method developed by Mano *et al*. (1993) was found to be very useful in selecting potential parents/ hybrids in silkworm breeding programme. In this method characters are

Table 1: Mean performance of hybrids pooled over three seasons

Sl. No.	Hybrid	Fecundity.	Yield/10000 larvae (no.)	Yield/10000 larvae (wt-kg)	Cocoon weight (g)	Shell weight (g)	Shell %	Filament Length (m)	Denier	Reel-ability %	Raw Silk %	Neatness
1	SK3 × SK4	609	9269	16.344	1.80	0.361	20.03	905	2.7	82.1	13.2	84.1
2	SK3 × SK6	601	9062	17.027	1.837	0.371	20.14	896	2.5	81.4	12.9	83.7
3	SK3 × BHR2	591	9257	17.743	1.907	0.356	18.62	922	2.6	77.8	12.1	81.4
4	SK3 × D4	585	9581	17.510	1.789	0.354	19.84	902	2.8	80.3	12.9	82.3
5	SK3 × D6(P)	551	9127	16.465	1.813	0.362	19.98	977	2.5	87.8	14.4	87.9
6	SK3 × D7	574	9227	17.609	1.928	0.378	19.38	956	2.8	81.0	12.9	80.0
7	SK3 × MJ1	552	9159	15.880	1.733	0.345	19.89	932	2.5	82.8	13.3	82.6
8	O2 × SK4	545	9240	16.680	1.805	0.349	19.32	949	2.5	87.6	13.0	87.2
9	O2 × SK6	527	8717	16.383	1.880	0.365	19.41	968	2.5	88.4	13.8	88.4
10	O2 × BHR2	595	9330	18.517	1.983	0.373	18.82	945	2.7	83.0	12.8	85.2
11	O2 × D4	559	9282	17.549	1.890	0.374	19.77	966	2.4	86.1	12.9	86.2
12	O2 × D6(P)	618	8974	17.880	1.942	0.385	19.76	941	2.8	79.6	12.5	83.5
13	O2 × D7	624	9019	18.349	1.996	0.393	19.58	906	2.7	78.1	12.3	84.7
14	O2 × MJ1	583	9405	17.726	1.903	0.359	18.80	954	2.6	77.8	11.9	82.8
15	O3 × SK4	547	8767	14.510	1.641	0.311	18.92	881	2.7	80.7	12.9	85.3
16	O3 × SK6	509	8686	15.989	1.840	0.366	19.91	919	2.6	84.4	13.4	85.0
17	O3 × BHR2	576	9002	18.174	1.933	0.366	18.90	919	2.7	78.1	12.2	82.4
18	O3 × D4	544	9008	17.831	1.925	0.366	19.28	931	2.7	78.4	12.9	85.0
19	O3 × D6(P)	657	9146	19.300	2.035	0.405	19.86	964	2.9	82.8	13.7	87.6
20	O3 × D7	526	8961	16.059	1.790	0.359	19.45	907	2.6	80.3	12.8	83.1
21	O3 × MJ1	521	8698	15.073	1.732	0.332	19.19	902	2.5	82.1	12.5	82.5
22	O4 × SK4	652	8605	16.901	2.000	0.385	19.20	912	2.7	75.1	12.4	81.7
23	O4 × SK6	573	8567	14.731	1.721	0.329	19.12	902	2.4	85.5	13.8	84.8
24	O4 × BHR2	575	8573	14.361	1.676	0.315	18.80	836	2.8	82.8	11.7	83.6
25	O4 × D4	587	8991	17.464	1.875	0.345	18.41	883	2.9	80.3	12.3	84.5
26	O4 × D6(P)	567	8379	14.843	1.773	0.367	20.69	909	2.4	85.6	14.3	84.7
27	O4 × D7	561	8599	14.399	1.676	0.323	19.30	881	2.7	84.9	13.1	86.1

Sl. No.	Hybrid	Fecun dity.	Yield/10000 larvae (no.)	Yield/10000 larvae (wt-kg)	Cocoon weight (g)	Shell weight (g)	Shell %	Filament Length (m)	Denier	Reel-ability %	Raw Silk %	Neatness
28	O4 × MJ1	638	9174	18.184	1.964	0.380	19.32	873	2.9	78.4	12.2	80.7
29	MC3 × SK4	489	8746	13.635	1.559	0.295	18.92	899	2.4	86.3	12.1	82.7
30	MC3 × SK6	548	9383	16.49	1.766	0.328	18.54	865	2.8	74.1	12.0	82.0
31	MC3 × BHR2	569	9119	16.241	1.780	0.340	19.05	869	2.6	73.8	11.9	82.6
32	MC3 × D4	497	8802	13.071	1.485	0.293	19.78	879	2.5	83.6	12.1	84.5
33	MC3 × D6(P)	493	9058	14.599	1.608	0.299	18.60	867	2.4	81.1	11.9	83.8
34	MC3 × D7	510	8999	15.806	1.782	0.332	18.64	858	2.7	78.4	12.5	85.8
35	MC3 × MJ1	518	9401	16.077	1.728	0.337	19.41	836	2.8	75.2	14.7	81.4
36	KPGA × SK4	506	8547	14.133	1.639	0.313	19.12	895	2.7	85.7	14.2	79.4
37	KPGA × SK6	523	8530	14.913	1.736	0.343	19.76	940	2.7	83.0	13.9	82.1
38	KPGA × BHR2	536	8576	14.718	1.701	0.338	19.85	953	2.7	78.1	13.8	86.1
39	KPGA × D4	527	8509	14.636	1.707	0.319	18.69	913	2.6	84.5	14.3	78.5
40	KPGA × D6(P)	609	8459	14.801	1.743	0.350	18.72	948	2.8	78.1	13.7	86.1
41	KPGA × D7	514	8558	14.751	1.708	0.335	19.63	953	2.7	78.1	13.8	86.1
42	KPGA × MJ1	515	8565	14.353	1.662	0.336	20.20	910	2.6	82.9	13.9	78.1
	Mean	560	8930	16.136	1.795	0.348	19.35	912	2.6	81.3	13.0	83.7
	Maximum	657	9581	19.300	2.035	0.405	20.69	977	2.9	88.4	14.7	88.4
	Minimum	489	8379	13.071	1.485	0.293	18.41	836	2.4	73.8	11.7	78.1
	Hybrid *	25.6	265.9	0.56	0.04	0.008	0.39	16.45	0.25	2.08	1.14	1.81
	Season*	6.12	63.1	0.13	0.01	0.002	0.09	3.84	0.18	0.49	0.27	0.42
	Hybrid × Season*	44.48	466.6	0.97	0.07	0.014	0.68	28.52	0.16	3.71	1.97	3.14

*Significant at 5% level

Table 2: Season wise and mean evaluation index values of hybrids

Sl. No.	Hybrid	Autumn	Spring	Summer	Mean	Rank
1	SK3×SK4	51.15	54.06	54.40	54.42	9
2	SK 3× SK6	49.82	56.15	53.80	53.96	10
3	SK3×BHR2	47.41	50.65	51.17	49.82	21
4	SK3× D4	52.63	52.73	53.33	53.20	13
5	SK3 × D7	49.50	61.87	49.67	53.77	11
6	SK3 × MJ1	51.36	50.65	51.58	51.52	18
7	SK3× D6(P)	61.13	56.89	58.52	59.11	2
8	O2×D6(P)	51.64	53.61	55.95	55.48	6
9	O2× D7	54.02	53.61	56.99	55.34	7
10	O2×MJ1	50.32	51.66	52.00	51.76	17
11	O2 × BHR2	55.74	55.36	55.76	56.77	4
12	O2 × D4	59.06	55.44	56.85	58.11	3
13	O2 × SK4	55.07	52.98	54.42	55.14	8
14	O2 × SK6	59.31	52.93	54.77	56.34	5
15	O3×D6(P)	60.43	64.43	61.57	64.13	1
16	O3 × SK4	40.79	44.86	47.48	44.21	35
17	O3 ×BHR2	45.22	53.78	51.45	50.51	20
18	O3 × D4	51.17	52.55	52.55	52.61	14
19	O3 × D7	48.11	47.72	50.55	48.84	24
20	O3 × SK6	50.38	51.16	52.12	51.86	16
21	O3 × MJ1	43.92	44.30	47.64	45.01	32
22	O4×SK4	50.45	55.67	48.89	50.97	19
23	O4×MJ1	52.37	52.54	52.53	52.20	15
24	O4 × D4	49.50	49.23	48.29	48.74	26
25	O4 × BHR2	42.80	39.82	44.15	41.41	39
26	O4 × D7	47.39	44.48	48.92	47.01	29
27	O4 × SK6	49.54	46.68	49.95	48.75	25
28	O4 × D6(P)	55.75	49.19	54.06	53.49	12
29	MC3×MJ1	41.35	44.90	49.77	46.83	30
30	MC3× SK6	47.17	47.04	40.64	43.62	37
31	MC3 × D7	41.02	43.42	49.06	44.63	34
32	MC3 × BHR2	47.85	41.36	47.62	44.74	33
33	MC3 × D6(P)	42.55	38.77	43.34	40.36	42
34	MC3 × D4	41.74	41.61	42.06	41.33	40
35	MC3 × SK4	42.58	40.21	42.50	40.94	41
36	KPG-A × D6(P)	52.65	51.69	46.74	49.24	22
37	KPG-A × BHR2	49.66	52.06	47.57	49.35	23
38	KPG-A × D7	50.00	50.74	46.34	48.39	28
39	KPG-A × SK6	52.67	49.55	46.80	48.73	27
40	KPG-A × MJ1	49.49	47.07	44.58	45.60	31
41	KPG-A × D4	48.68	44.72	43.42	43.94	36
42	KPG-A × SK4	48.59	44.99	41.23	43.38	38

given equal weightage because in hybrids expression of traits will be uniform, in other words no variability within traits. Many workers used this E.I for selecting potential hybrid (Kumaresan *et al*., 2000; Rao et al., 2006; Moorthy *et al*., 2007; Rayar, 2007). The selection of the hybrids ultimately depends on the excellence and performance of hybrids in many individual traits.Accordingly two hybrids *viz.,* O3 × D6 (P) (EI value: 64.13) and SK3 × D6 (P) (EI value: 59.11) were selected based on EI values considering average of three seasons and eleven economically important traits. These hybrids may be recommended for commercial exploitation in the hills of West Bengali and similar regions of West Bengal to boost up the silk production.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 157-166

BIOMETRIC EVALUATION OF BIVOLTINE SILKWOROM HYBRIDS SUITABLE TO NON-TRADITIONAL SERICULTURE REGION OF KARNATAKA

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ABSTRACT

The Indian tropical bivoltine sericulture could be successful by evolving hybrids suitable to specific location under varied agro climatic conditions. To accomplish this, the promising bivoltine breeds were collected to identify the hybrids suitable to northern traditional agro climatic conditions. After preliminary evaluation of pure breeds at Dharwad (Karnataka) seven oval cocoon breeds *viz.,* SH6, KPGA, CC1, CSR2, CSR27, KSO1, and APS5 and five peanut cocoon breeds *viz.,* NB4D2, NP2, CSR26, CSR4 and APS8 were selected by using multiple traits evaluation index. The females of oval cocoon breeds were crossed with males of peanut cocoon breeds in line × tester fashion to produce 35 hybrids. The hybrids were evaluated in three seasons viz., rainy, winter and summer for important traits. The overall performance the hybrids revealed the superiority of KSO1 × CSR4 cross for majority of the traits. This was followed by SH6 × CSR4, KSO1 × NB4D2, KSO1 × NP2, APS5 × NP2, APS5 × CSR26 and APS5 × APS8. The multiple traits evaluation index has identified twenty crosses as promising and KSO1 × CSR4 recorded the highest index value of 62.21. The above promising hybrids could be further exploited for commercial rearing in non-traditional sericulture region of Karnataka.

Key words: Biometric evaluation, Bivoltine hybrids, Non-traditional sericulture region, Silkworm

INTRODUCTION

Development of tropical bivoltine sericulture technology has made it possible to successfully rear bivoltine silkworms in tropics. In recent years several productive bivoltine breeds/ hybrids were evolved at different institutes across the country. The stability of the breeds/ hybrids is greatly influenced by the genotype- environment interactions. Hence, the choice of the breed / hybrid depends not only on the genotype itself but also on its performance in local environment (Rahman and Ahmed, 1988; Ren *et al*., 1988). In Karnataka the northern transitional agro climatic zone-8 has been classified as potential non traditional bivoltine sericulture region-II (Bongale and Raghuraman, 1999). Over a decade several attempts were made to popularize bivoltine rearing in this region by introducing several bivoltine hybrids. But none of the hybrids became popular due to lack of adaptability to the local environment. Limited studies have been made to identify the bivoltine hybrids suitable to this climatic condition. Keeping this in view a study has been made to evaluate hybrids by collecting promising breeds from various research institutes across the country.

MATERIALS AND METHODS

Seventeen bivoltine pure breeds *viz*., SH6, CC1, KPGA, KPGB, NB7, CSR2, CSR27, KSO1, APS5, NB4D2, NB18, CSR4, CSR-6, CSR26, NP2, APS4 and APS8 evolved at various research institutes were used for the study. The breeds were evaluated twice between August to November, 2008 at Dharwad. Dharwad is located in northern transitional agro climatic zone-8 of Karnataka state. Multiple traits evaluation index method (Mano *et al*., 1993) was used to select the promising parents (Table 1 and 2). Based on the evaluation index the breeds *viz*., SH6, KPGA, CC1, CSR2, KSO1, CSR27 and APS5 making oval cocoons and NB4D2, NP2, CSR26, CSR4 and APS8 making peanut cocoon were

selected. The hybrids were made in line x tester fashion by crossing oval cocoon breeds as females with each of peanut cocoon breeds as males, thus thirty five crosses were prepared. All the crosses were evaluated in three seasons *viz.,* rainy, winter and summer on V-1 mulberry by adapting standard rearing technologies (Dandin *et al*., 2000). In each rearing the data on the important traits was collected, pooled and analyzed (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The larval duration was significantly shorter in APS5 × CSR26 (621.78 hr), APS5 × APS8 (641.44 hr) and APS5 × NP2 (649.45 hr). The larvae of APS5 × NB4D2 (49.347 g/10 larvae), KA × NB4D2 (49.070 g), CSR2 × CSR26 (48.737 g), CSR2 × CSR4 (48.209 g), KSO1 × NB4D2 (48.187 g) and CSR27 × NB4D2 (47.910 g) recorded maximum weight at maturity. Except, KPGA × CSR4 (38.557 g) rest of the hybrids were on par with APS5 × NB4D2. The cross, KSO1 × NP2 recorded highest survival (94.00 %) and CSR2 × NP2 (92.80 %), KSO1 × APS8 (92.67 %), CC1 × CSR4 (92.11 %), CC1 × APS8 (91.89 %), KPGA × NB4D2 (91.89 %), CSR2 × CSR26 (90.56 %), CC1 × NP2 (91.56 %), SH6 × CSR4 (91.33 %), APS5 × NB4D2 (91.22 %), KPGA × NP2 (91.00 %), SH6 × NP2 (91.00 %), KSO1 × CSR4 (90.99 %) and CSR2 × NB4D2 (90.45 %) were at par. The pupal weight was highest in KPGA × APS8 (18.027 g/10 pupae), APS5 × APS8 (17.607 g), APS5 × CSR4 (17.353 g), CSR27 × NB4D2 (17.180 g), APS5 × CSR26 (17.153 g), CSR27 × NP2 (17.007 g) and KSO1 × NB4D2 (16.960 g) and all were on par (Table 3).

The cocoon weight was significantly more in KPGA × APS8 (22.370 g/10 cocoons), followed by APS5 × APS8 (22.003 g), CSR27 × NB4D2 (21.763 g), CSR27 × NP2 (21.733 g), APS5 × CSR26 (21.707 g), CSR27 × CSR4 (21.623 g), KSO1 × NB4D2 (21.783 g) and KSO1 × CSR4 (21.403 g) and were at par with each other. The cocoon shell weight was highest in KSO1 × CSR4 (4.667 g/10 shells), except KPGA × CSR4 (3.560 g) rest of the crosses were on par with KSO1 × CSR4. The cocoon shell ratio was highest in KSO1 × CSR4 (22.25 %) and excluding SH6 × APS8, KPGA × NP2, KPGA × APS8, CC1 × NB4D2, CC1 × APS8, KSO1 × APS8, APS5 × NB4D2 and APS5 × APS8 crosses all were at par (Table 4). The cocoon yield /25 dfls was maximum in KSO1 × CSR4 (21.05 kg) and the cross has also produced longer silk filament of 1327.00 mt. The cross CSR2 × CSR4 (20.44 kg), CSR2 × NP2 (20.15 kg), KSO1 × NP2 (20.09 kg), SH6 × CSR4 (19.60 kg), SH6 × APS8 (19.56 kg), KPGA × NP2 (19.48 kg), APS5 × NP2 (19.48 kg), CSR27 × CSR26 (19.22 kg) were on par with KSO1 × CSR4 in cocoon yield. While, fifteen hybrids were on par with KSO1 × CSR4 in silk filament length. Finer silk filament was obtained in KSO1 × CSR26 (2.49), KPGA × NP2 (2.51) and KPGA × CSR4 (2.50) and twenty one hybrids were on par with them (Table 5).

The estimation of evaluation index value for larval duration reveals twelve hybrids were in desired direction (Table 6). While, the average evaluation index value for rest of the traits was above 50 in twenty hybrids with the highest value being in KSO1 × CSR4 (62.21), CSR2 × CSR4 (56.60) and CSR27 × CSR26 (56.42) crosses were placed in second and third place (Table 7 & 8).

Analysis of variance of results indicated a significant difference among the hybrids for all the traits studied. However, it is well known that selection for one character is found to result in correlated changes in other quantitative character (Kobari and Fujimoto, 1966). The crosses exhibited high degree of variability and responded well to the local climatic condition of this region. Although different hybrids exhibited different values for different characters over seasons. The over all performance indicated that KSO1 × CSR4 has performed well in eight out of ten traits. While, SH6 × CSR4, KSO1 × NB4D2, KSO1 × NP2, APS5 × NP2, APS5 × CSR26 and APS5 × APS8 were found superior in seven characters.

Recently the hybrids are judged by applying a common index value giving due weightage to all the traits contributing to yield (Bhargava *et al*., 1994). Application of selection indices in plants and animals including silkworm has led to the identification of superior varieties / hybrids (Giridhar, 1996). Therefore, evaluation index method was employed to give equal importance to all the traits in selection of hybrids as per the method suggested by Mano *et al*. 1993. The results showed that twenty hybrids scored above 50 average index values and were found promising. Highest index value of 62.21 was recorded by KSO1 × CSR4. The promising hybrids identified through rearing performance and evaluation index method have to be further evaluated on a large scale in different locations of non traditional sericulture region of Karnataka to select the promising ones to different locations.

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Table 1: Evaluation index values for larval growth and grainage traits

Breeds	Total larval duration	Mature larval weight	Survival	Pupation	Pupal weight	Fecundity
SH6	44.75	50.94	65.46	59.18	52.68	44.82
NB7	44.56	39.77	44.54	37.32	40.18	48.99
KPGA	58.51	47.61	57.73	57.19	64.76	47.45
KPGB	59.18	43.50	39.09	51.23	41.98	59.54
CC1	46.11	53.27	44.09	63.15	57.81	44.40
CSR2	54.05	64.63	58.18	32.35	57.93	55.79
CSR27	65.67	46.00	53.64	51.23	44.40	43.91
KSO1	43.01	71.50	64.09	51.23	66.17	49.45
APS5	58.51	56.09	57.46	46.34	48.58	48.32
NB4D2	45.62	48.87	65.00	54.21	56.13	67.87
NB18	30.81	39.18	47.27	46.26	44.96	66.12
CSR4	50.76	52.53	49.55	32.35	48.00	44.32
CSR-6	39.91	37.37	40.45	54.21	37.98	52.74
CSR26	39.33	49.52	37.72	56.19	52.23	53.29
APS-4	61.02	38.19	37.27	51.23	28.95	50.03
APS8	64.80	45.01	37.27	59.18	48.20	52.91
NP2	43.40	66.04	53.18	59.18	61.08	49.03

Table 2: Evaluation index values for cocoon and silk traits

Breeds	Cocoon weight	Cocoon shell weight	Cocoon shell ratio	Cocoon yield	Cocoon filament length	Denier	Average EI
SH6	49.70	46.93	46.72	45.08	47.20	46.23	50.44
NB7	38.61	36.48	39.96	45.52	41.46	29.83	40.24
KPGA	60.11	47.90	35.01	46.08	52.34	51.82	51.64
KPGB	38.77	33.68	34.89	46.92	40.60	53.80	44.00
CC1	54.53	46.61	38.98	60.81	43.13	43.53	50.02
CSR2	58.69	63.70	61.52	64.20	61.39	53.32	57.42
CSR27	48.12	52.39	60.36	47.83	57.05	49.66	50.41
KSO1	73.53	73.14	57.21	58.60	65.80	63.11	63.07
APS5	50.40	51.53	52.45	53.17	43.58	45.63	50.32
NB4D2	54.46	49.67	44.48	45.39	46.61	50.98	53.06
NB18	44.43	43.77	46.25	30.52	34.58	56.14	45.40
CSR4	49.21	55.36	59.74	50.11	63.83	49.96	50.45
CSR-6	40.59	51.46	64.99	37.42	65.21	44.79	47.93
CSR26	52.11	56.90	60.22	59.66	53.63	60.71	53.83
APS-4	31.64	36.82	50.77	37.59	47.67	62.15	42.93
APS8	48.25	51.83	55.43	57.88	47.79	44.37	49.82
NP2	59.85	57.83	49.02	65.22	49.13	60.95	57.32

Table 3: Mean performance of bivoltine silkworm hybrids for larval growth and development

Hybrids	Larval duration(h)	Mature larval weight (g/10 larvae)	Survival (%)	Pupal weight (g/10 pupae)
SH6 × NB_4D_2	694.33^{def}	44.797^{ab}	88.33 (70.14)!$^{d-i}$	15.427^{i-n}
SH6 × NP2	671.33^{b-f}	42.720^{ab}	91.00 (72.83)$^{a-g}$	14.983^{l-o}
SH6 × CSR26	675.11^{b-f}	46.087^{ab}	89.11 (70.94)$^{b-i}$	15.563^{h-n}
SH6 × CSR4	693.55^{def}	46.697^{ab}	91.33 (73.44)$^{a-f}$	16.017^{e-l}
SH6 × APS8	671.11^{b-f}	46.213^{ab}	88.56 (70.31)$^{c-i}$	16.857^{b-f}
KPGA × NB_4D_2	693.67^{def}	49.070^{a}	91.89 (73.62)$^{a-d}$	16.550^{b-i}
KPGA × NP2	694.55^{def}	45.547^{ab}	91.00 (72.65)$^{a-g}$	16.673^{b-h}
KPGA × CSR26	674.22^{b-f}	44.607^{ab}	87.67 (69.53)$^{e-i}$	15.687^{g-n}
KPGA × CSR4	695.56^{ef}	38.557^{b}	88.00 (69.74)$^{d-i}$	14.170^{o}
KPGA × APS8	690.55^{def}	41.870^{ab}	87.33 (69.30)$^{f-i}$	18.027^{a}
CC1 × NB_4D_2	679.33^{c-f}	42.980^{ab}	89.00 (70.70)$^{b-i}$	15.187^{j-o}
CC1 × NP2	690.89^{def}	45.160^{ab}	91.56 (73.32)$^{a-e}$	16.737^{b-j}
CC1 × CSR26	667.67^{b-f}	46.580^{ab}	89.78 (71.47)$^{b-i}$	15.510^{h-n}
CC1 × CSR4	697.78^{ef}	45.980^{ab}	92.11 (73.92)$^{a-d}$	15.867^{f-n}
CC1 × APS8	683.44^{def}	44.230^{ab}	91.89 (73.69)$^{a-d}$	16.900^{a-f}
CSR2 × NB_4D_2	697.11^{ef}	43.807^{ab}	90.45 (72.19)$^{a-h}$	15.100^{k-o}
CSR2 × NP2	687.78^{def}	45.803^{ab}	92.89 (75.28)^{ab}	16.307^{c-j}
CSR2 × CSR26	671.99^{b-f}	48.737^{a}	90.56 (72.61)$^{a-g}$	15.947^{f-m}
CSR2 × CSR4	687.11^{def}	48.260^{a}	87.67 (69.59)$^{e-i}$	16.183^{c-k}
CSR2 × APS8	686.88^{def}	44.720^{ab}	89.11 (70.88)$^{b-i}$	16.043^{d-l}
CSR27 × NB_4D_2	684.88^{def}	47.910^{a}	87.33 (69.19)$^{f-i}$	17.180^{a-d}
CSR27 × NP2	681.77^{c-f}	45.277^{ab}	89.44 (71.07)$^{b-i}$	17.007^{a-f}
CSR27 × CSR26	664.33^{b-e}	44.307^{ab}	88.11 (69.84)$^{d-i}$	16.443^{c-i}
CSR27 × CSR4	680.67^{c-f}	44.890^{ab}	86.99 (68.89)^{ghi}	16.810^{b-g}
CSR27 × APS8	684.67^{def}	44.257^{ab}	89.00 (70.65)$^{b-i}$	16.027^{d-l}
KSO1 × NB_4D_2	698.44^{f}	48.187^{a}	89.55 (71.20)$^{b-i}$	16.960^{a-f}
KSO1 × NP2	700.89^{f}	45.897^{ab}	94.00 (76.20)^{a}	16.563^{b-i}
KSO1 × CSR26	680.89^{c-f}	42.840^{ab}	89.00 (70.69)$^{b-i}$	14.733^{no}
KSO1 × CSR4	689.22^{def}	45.873^{ab}	90.99 (72.61)$^{a-g}$	16.517^{c-j}
KSO1 × APS8	686.22^{def}	45.743^{ab}	92.67 (74.94)^{abc}	16.490^{b-i}
APS5 × NB_4D_2	664.11^{b-e}	49.347^{a}	91.22 (73.01)$^{a-f}$	16.807^{b-g}
APS5 × NP2	649.45^{abc}	47.133^{ab}	88.69 (70.40)$^{c-i}$	16.567^{b-i}
APS5 × CSR26	621.78^{a}	45.843^{ab}	85.78 (67.86)^{i}	17.153^{a-e}
APS5 × CSR4	661.11^{bcd}	47.590^{ab}	86.33 (68.51)^{hi}	17.353^{abc}
APS5 × APS8	641.44^{ab}	47.193^{ab}	89.11 (71.11)$^{b-i}$	17.607^{ab}
F Test	**	**	*	**
S.Em ±	11.966	1.491	1.455	0.405
CD (5%)	33.762	4.205	4.105	1.142

Figures in parentheses are angular transformed values, * Significant at 5%, ** Significant at 1%
In vertical columns, means followed by similar letters are not different statistically by Duncan's multiple range test (CD = 0.05)

Table 4: Mean performance of bivoltine silkworm hybrids for cocoon traits

Hybrids	Cocoon weight (g/10 cocoons)	Cocoon shell weight (g/10 cocoons)	Cocoon shell ratio (%)
SH6 × NB_4D_2	19.560^{h-l}	4.010^{ab}	20.35 (26.81)!^{abc}
SH6 × NP2	19.013^{j-m}	3.830^{ab}	20.73 (27.08)^{abc}
SH6 × CSR26	19.817^{g-l}	4.103^{ab}	20.91 (27.21)^{abc}
SH6 × CSR4	20.230^{e-j}	4.147^{ab}	20.08 (26.61)^{abc}
SH6 × APS8	20.977^{b-g}	4.047^{ab}	19.30 (26.06)^{bc}
KPGA × NB_4D_2	20.793^{b-h}	4.133^{ab}	19.92 (26.51)^{abc}
KPGA × NP2	20.860^{b-g}	4.060^{ab}	19.51 (26.21)^{bc}
KPGA × CSR26	19.790^{g-l}	3.970^{ab}	20.20 (26.71)^{abc}
KPGA × CSR4	17.833^{m}	3.560^{b}	20.02 (26.57)^{abc}
KPGA × APS8	22.370^{a}	4.220^{ab}	18.85 (25.73)^{c}
CC1 × NB_4D_2	18.973^{klm}	3.677^{ab}	19.44 (26.16)^{bc}
CC1 × NP2	20.937^{b-g}	4.147^{ab}	19.75 (26.39)^{abc}
CC1 × CSR26	19.800^{g-l}	4.127^{ab}	20.86 (27.17)^{abc}
CC1 × CSR4	20.113^{f-k}	4.133^{ab}	20.78 (27.12)^{abc}
CC1 × APS8	20.890^{b-g}	3.863^{ab}	18.50 (25.47)^{c}
CSR2 × NB_4D_2	19.197^{i-l}	4.047^{ab}	21.08 (27.33)^{abc}
CSR2 × NP2	20.547^{c-h}	4.117^{ab}	20.04 (26.58)^{abc}
CSR2 × CSR26	20.370^{d-i}	4.210^{ab}	20.63 (27.01)^{abc}
CSR2 × CSR4	20.997^{b-g}	4.520^{ab}	21.57 (27.67)^{ab}
CSR2 × APS8	20.247^{d-i}	4.080^{ab}	20.16 (26.68)^{abc}
CSR27 × NB_4D_2	21.763^{abc}	4.490^{ab}	20.58 (26.98)^{abc}
CSR27 × NP2	21.733^{abc}	4.593^{ab}	21.01 (27.28)^{abc}
CSR27 × CSR26	20.923^{b-g}	4.430^{ab}	21.00 (27.26)^{abc}
CSR27 × CSR4	21.623^{abc}	4.560^{ab}	21.06 (27.31)^{abc}
CSR27 × APS8	20.137^{e-k}	3.997^{ab}	19.84 (26.44)^{abc}
KSO1 × NB_4D_2	21.483^{a-d}	4.410^{ab}	20.54 (26.95)^{abc}
KSO1 × NP2	20.857^{b-g}	4.100^{ab}	20.24 (26.73)^{abc}
KSO1 × CSR26	18.670^{lm}	3.853^{ab}	20.61 (26.99)^{abc}
KSO1 × CSR4	21.403^{a-d}	4.667^{a}	22.25 (28.14)^{a}
KSO1 × APS8	20.387^{d-i}	3.780^{ab}	19.01 (25.85)^{bc}
APS5 × NB_4D_2	20.823^{b-g}	3.953^{ab}	18.98 (25.83)^{c}
APS5 × NP2	20.813^{b-g}	4.227^{ab}	20.34 (26.80)^{abc}
APS5 × CSR26	21.707^{abc}	4.510^{ab}	20.84 (27.16)^{abc}
APS5 × CSR4	21.347^{a-e}	4.370^{ab}	20.36 (26.80)^{abc}
APS5 × APS8	22.003^{ab}	4.273^{ab}	19.55 (26.24)^{bc}
F Test	**	**	**
S.Em±	0.434	0.177	0.422
CD (5%)	1.225	0.498	1.191

Figures in parentheses are angular transformed values, ** Significant at 1%
In vertical columns, means followed by similar letters are not different statistically by Duncan's multiple range test (CD = 0.05)

Table 5: Mean performance of bivoltine silkworm hybrids for cocoon yield and silk traits

Hybrids	Cocoon yield (kg/25 dfls)	Cocoon filament length (m)	Denier
SH6 × NB_4D_2	18.03^{e-i}	1039.89^{b}	2.75^{a-e}
SH6 × NP2	17.20^{i}	1019.67^{b}	2.80^{a-f}
SH6 × CSR26	18.67^{b-h}	1128.11^{ab}	2.77^{a-f}
SH6 × CSR4	19.60^{a-e}	1187.89^{ab}	2.65^{a-d}
SH6 × APS8	19.56^{a-f}	1090.56^{b}	3.01^{d-h}
KPGA × NB_4D_2	17.43^{i}	1088.56^{b}	2.64^{a-d}
KPGA × NP2	19.48^{a-g}	1127.33^{ab}	2.51^{a}
KPGA × CSR26	17.73^{f-i}	1050.44^{b}	2.71^{a-e}
KPGA × CSR4	17.39^{i}	1081.00^{b}	2.50^{a}
KPGA × APS8	18.00^{e-i}	1124.33^{ab}	2.60^{abc}
CC1 × NB_4D_2	18.27^{d-i}	994.89^{b}	2.57^{ab}
CC1 × NP2	18.11^{e-i}	1052.00^{b}	2.57^{ab}
CC1 × CSR26	17.91^{e-i}	1100.77^{b}	2.71^{a-e}
CC1 × CSR4	19.41^{b-h}	1140.44^{ab}	2.76^{a-f}
CC1 × APS8	19.18^{b-h}	1053.45^{b}	2.95^{b-h}
CSR2 × NB_4D_2	18.29^{c-i}	1111.22^{b}	2.71^{a-e}
CSR2 × NP2	20.15^{abc}	1038.22^{b}	2.74^{a-e}
CSR2 × CSR26	18.56^{c-i}	998.78^{b}	2.98^{c-h}
CSR2 × CSR4	20.44^{ab}	1108.55^{b}	2.86^{a-h}
CSR2 × APS8	18.94^{b-i}	1133.22^{ab}	2.62^{a-d}
CSR27 × NB_4D_2	17.56^{hi}	1014.22^{b}	3.15^{f-h}
CSR27 × NP2	18.80^{b-i}	1048.00^{b}	2.97^{e-h}
CSR27 × CSR26	19.22^{a-h}	1214.99^{ab}	3.25^{h}
CSR27 × CSR4	18.54^{c-i}	1159.33^{ab}	2.97^{c-h}
CSR27 × APS8	17.65^{ghi}	1028.00^{b}	2.76^{a-f}
KSO1 × NB_4D_2	18.93^{b-i}	1129.22^{ab}	2.77^{a-f}
KSO1 × NP2	20.09^{a-d}	1169.00^{ab}	2.66^{a-d}
KSO1 × CSR26	18.14^{e-i}	1103.89^{b}	2.49^{a}
KSO1 × CSR4	21.05^{a}	1327.00^{a}	2.64^{a-d}
KSO1 × APS8	18.44^{c-i}	1147.55^{ab}	2.98^{c-h}
APS5 × NB_4D_2	18.03^{e-i}	1036.22^{b}	2.92^{b-h}
APS5 × NP2	19.48^{a-g}	1134.56^{ab}	2.77^{a-f}
APS5 × CSR26	18.39^{c-i}	1146.00^{ab}	3.21^{g-h}
APS5 × CSR4	19.01^{b-i}	1097.55^{b}	3.07^{e-h}
APS5 × APS8	18.15^{e-i}	1115.22^{ab}	2.83^{a-g}
F Test	**	**	**
S.Em ±	0.656	36.351	0.140
CD (5%)	1.852	102.559	0.395

** Significant at 1%

In vertical columns, means followed by similar letters are not different statistically by Duncan's multiple range test (CD = 0.05)

Table 6: Evaluation index values of bivoltine silkworm hybrids for larval growth and development

Hybrids	Total larval duration	Mature larval weight	Survival	Pupal weight
SH6 × NB_4D_2	58.49	46.52	43.39	39.89
SH6 × NP2	45.09	37.11	56.86	34.62
SH6 × CSR26	47.26	52.37	47.32	41.49
SH6 × CSR4	57.97	55.16	58.55	46.88
SH6 × APS8	44.94	52.93	44.52	56.82
KPGA × NB_4D_2	58.04	65.91	61.35	53.21
KPGA × NP2	58.55	49.93	56.86	54.67
KPGA × CSR26	46.74	45.65	40.03	42.96
KPGA × CSR4	59.13	18.20	41.71	24.96
KPGA × APS8	56.23	43.25	38.34	70.75
CC1 × NB_4D_2	49.71	38.29	46.76	37.03
CC1 × NP2	56.42	48.17	59.67	55.42
CC1 × CSR26	42.94	54.62	50.69	41.59
CC1 × CSR4	60.42	51.90	62.48	45.10
CC1 × APS8	52.10	43.95	61.35	57.35
CSR2 × NB_4D_2	60.04	42.03	54.06	35.98
CSR2 × NP2	54.62	51.09	66.40	50.34
CSR2 × CSR26	45.45	64.40	54.62	46.03
CSR2 × CSR4	54.23	62.24	40.03	48.82
CSR2 × APS8	54.10	46.18	47.32	47.17
CSR27 × NB_4D_2	52.94	60.64	38.34	60.67
CSR27 × NP2	51.13	48.71	49.01	58.64
CSR27 × CSR26	41.00	44.30	42.27	51.94
CSR27 × CSR4	50.49	49.94	36.66	56.25
CSR27 × APS8	52.81	44.07	47.76	46.98
KSO1 × NB_4D_2	60.81	61.91	49.57	58.07
KSO1 × NP2	62.23	51.51	72.02	53.36
KSO1 × CSR26	50.62	37.64	46.76	31.67
KSO1 × CSR4	55.45	51.41	56.86	50.43
KSO1 × APS8	53.71	50.81	65.28	52.50
APS5 × NB_4D_2	40.87	67.17	57.99	56.26
APS5 × NP2	32.36	57.14	42.27	53.39
APS5 × CSR26	36.29	51.26	30.49	60.33
APS5 × CSR4	39.13	59.20	33.29	62.72
APS5 × APS8	51.70	57.40	47.32	65.71

Table 7: Evaluation index values of bivoltine silkworm hybrids for cocoon traits and yield

Hybrids	Cocoon weight	Cocoon shell weight	Cocoon shell ratio	Cocoon yield
SH6 × NB_4D_2	40.37	44.65	51.15	42.99
SH6 × NP2	34.95	37.93	55.92	34.01
SH6 × CSR26	42.90	48.22	58.21	49.87
SH6 × CSR4	46.99	49.86	47.78	59.95
SH6 × APS8	54.40	41.17	38.11	59.47
KPGA × NB_4D_2	52.56	49.36	45.92	36.41
KPGA × NP2	53.25	46.69	40.73	52.66
KPGA × CSR26	42.63	43.21	49.37	39.66
KPGA × CSR4	23.23	27.67	47.10	36.05
KPGA × APS8	68.21	52.64	38.55	42.65
CC1 × NB_4D_2	34.54	32.22	39.83	45.54
CC1 × NP2	53.97	49.83	43.74	43.78
CC1 × CSR26	42.74	49.22	57.51	41.62
CC1 × CSR4	45.84	49.51	56.56	57.90
CC1 × APS8	53.51	39.18	28.08	55.35
CSR2 × NB_4D_2	36.77	46.14	60.33	48.81
CSR2 × NP2	50.12	48.66	47.26	65.94
CSR2 × CSR26	48.39	52.28	54.68	48.71
CSR2 × CSR4	54.58	63.99	66.47	69.08
CSR2 × APS8	47.15	47.46	48.82	52.77
CSR27 × NB_4D_2	62.16	62.87	54.03	37.89
CSR27 × NP2	61.87	66.84	59.43	51.29
CSR27 × CSR26	53.89	60.61	59.39	55.86
CSR27 × CSR4	60.78	65.63	60.08	48.42
CSR27 × APS8	46.06	44.32	44.82	38.84
KSO1 × NB_4D_2	59.40	59.90	53.56	52.73
KSO1 × NP2	53.21	48.00	49.75	65.29
KSO1 × CSR26	31.51	38.78	54.45	64.08
KSO1 × CSR4	55.61	69.56	74.91	75.59
KSO1 × APS8	48.51	36.12	34.45	47.40
APS5 × NB_4D_2	52.89	42.57	34.13	42.99
APS5 × NP2	52.75	53.00	51.01	58.65
APS5 × CSR26	61.66	63.64	57.37	46.88
APS5 × CSR4	58.05	58.47	51.31	53.57
APS5 × APS8	64.56	54.80	41.19	44.31

Table 8: Evaluation index values of bivoltine silkworm hybrids for silk traits

Hybrids	Cocoon filament length	Denier	Average EI
SH6 × NB_4D_2	40.91	47.60	44.16
SH6 × NP2	37.91	50.26	42.17
SH6 × CSR26	54.00	48.82	49.24
SH6 × CSR4	62.87	42.95	52.33
SH6 × APS8	48.43	60.73	50.73
KPGA × NB_4D_2	48.13	41.95	50.53
KPGA × NP2	51.89	35.53	49.13
KPGA × CSR26	42.48	45.77	43.52
KPGA × CSR4	47.01	35.03	33.44
KPGA × APS8	53.44	40.40	49.80
CC1 × NB_4D_2	34.24	38.68	38.57
CC1 × NP2	42.71	38.91	48.46
CC1 × CSR26	49.95	45.94	48.20
CC1 × CSR4	55.83	48.38	52.61
CC1 × APS8	42.92	57.68	48.81
CSR2 × NB_4D_2	51.49	45.61	46.80
CSR2 × NP2	40.66	41.94	51.37
CSR2 × CSR26	34.81	59.46	51.49
CSR2 × CSR4	51.10	53.14	56.60
CSR2 × APS8	54.76	41.12	48.08
CSR27 × NB_4D_2	37.10	67.82	53.50
CSR27 × NP2	42.11	58.85	55.19
CSR27 × CSR26	66.89	72.69	56.42
CSR27 × CSR4	58.63	58.57	54.99
CSR27 × APS8	39.15	48.16	44.46
KSO1 × NB_4D_2	54.17	48.99	55.36
KSO1 × NP2	60.07	42.89	55.12
KSO1 × CSR26	50.41	34.75	43.33
KSO1 × CSR4	83.51	42.01	62.21
KSO1 × APS8	56.89	59.23	50.13
APS5 × NB_4D_2	40.37	56.24	50.06
APS5 × NP2	54.96	48.60	52.41
APS5 × CSR26	56.65	70.53	55.42
APS5 × CSR4	49.47	64.05	54.45
APS5 × APS8	52.09	51.70	53.56

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 167-169

SILK PRODUCTIVITY IN DIFFERENT BREEDS AND HYBRIDS OF THE SILKWORM *BOMBYX MORI* L.

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ABSTRACT

Silk productivity expressed in cg. of shell weight/day of 5th instar larval duration is an important breeding index. In the present study silk productivity in some breeds and hybrids of the silkworm *Bombyx mori* L. were estimated in three different seasons. In the silkworm, *Bombyx mori* L., larval duration is mostly determined by the fifth instar larval period which lasts for about 6 to 9 days depending on the silkworm breeds and seasons. In sericulture, shorter fifth instar period is preferred to save mulberry leaves, labour and also to avoid occurrence of diseases. It is necessary to develop silkworm breeds/hybrids with shorter larval duration and higher silk productivity/day. Results indicated significant (P< 0.01) variation between breeds and also between hybrids. Silk productivity ranged from 1.98 to 6.9 cg /day in breeds and 4.843 to 8.09 cg/day in F1 hybrids . Results also indicate significant variation between seasons. Heterosis studies indicated standard positive heterosis in majority of breeds/hybrids in summer. Silk productivity is an important parameter; hence it is essential that this breeding index should be included as one of the characters for evaluation of silkworm hybrids and also as parameter during selection process in the breeding.

Key words: Heterosis, Larval duration, Silkworm breeds, Silk productivity

INTRODUCTION

In the silkworm, *Bombyx mori* L. larval duration is mostly determined by the fifth instar larval period which lasts for about 6 to 9 days depending on the silkworm breeds and season. In sericulture, shorter fifth instar period is preferred to save mulberry leaves, labor and also to avoid occurrence of diseases. It is necessary to develop silkworm breeds/hybrids with shorter larval duration and higher silk productivity per day. Studies on silk productivity are very meager. Some attempts (Iyengar et al, 1983 and Udupa and Gowda, 1988) have been made to study the relative silk productivity and heterosis expression in some breeds of the silkworm *Bombyx mori* L. The present investigation was under taken during three different seasons to assess the relative silk productivity and also the extent of heterosis in some pure races and F1 hybrids.

MATERIALS AND METHODS

The following breeds/hybrids maintained at Central Sericultural Research and Training Institute, Mysore, India were utilized in the present study.

Breeds: Pure Mysore (PM), a traditional polyvoltine race; ND7, an improved polyvoltine breed, CSR2 and CSR4 are popular boivoltine breeds.

F1 hybrids: PM × CSR2 Popular cross breed, ND7 × CSR2 an improved cross breed and CSR2 × CSR4 a popular bivoltine hybrid.

Silkworm breeds along with the F1 hybrids were reared during April-May (summer), July-August (rainy) and November-December (winter) of 2010, each with three replications. Data on fifth instar larval duration and cocoon shell weight were recorded. Silk productivity (by the individual larva/cocoon) per day was calculated as per the following formula:

$$\text{Silk productivity/ day (cg / day)} = \frac{\text{Cocoon shell weight (cg)}}{\text{Fifth instar larval duration (days)}}$$

The mean performances of breeds and hybrids were compared and presented in Table 1. Relative heterosis (RH)

is calculated based on mid-parent value (heterosis over mid-parent value) and standard heterosis (SH) is calculated based on better parent value (heterosis over better parent) and presented in Table 2. Data were subjected for statistical analyses (ANOVA).

RESULTS AND DISCUSSION

Mean silk productivity in different breeds and F1 hybrids are presented in Table 1. Significant (P<0.01) differences in respect of silk productivity were recorded between breeds/hybrids. Traditional polyvoltine race PM recorded least silk productivity (1.983 to 2.41 cg/day), whereas, Bivoltine hybrids CSR2 × CSR4 recorded higher silk productivity (7.426 to 8.09 cg/day). In general, silk productivity is lesser in polyvoltine breeds compared to bivoltine breeds. Improved polyvoltine breed ND7 recorded higher silk productivity (4.61 to 4.813 cg/day). Always F1 hybrids show higher values for silk productivity (Table 1) compared to the pure breeds due to the expression of heterosis .

Improvement in silk productivity is presented in Table 3. An improvement of 39.98 to 43.91 % in silk productivity was recorded in bivoltines compared to polyvoltines in different seasons. F1 hybrids recorded 29.02 to 33.37 % improvement compared to pure breeds and among the F1 hybrids, bivoltine hybrids recorded 18.25 to 24.94% improvement compared to polyvoltine × bivoltine hybrids. Significant (P<0.01) differences were recorded in silk productivity in different seasons. In all the breeds and hybrids studied the results indicate that the silk productivity is higher in winter season followed by rainy season and least in summer. It is well known that most of the characters of economic importance in silk worms are quantitative in nature, phenotypic expression of which is greatly influenced

Table 1: Silk productivity (cg/day) in different breeds and hybrids of the silkworm *Bombyx mori* L. in different seasons.

Race / Hybrid	Summer	Rainy	Winter
Pure Mysore	1.983	2.260	2.410
ND7	4.647	4.610	4.813
Mean of polyvoltines	3.315	3.435	3.612
CSR2	5.333	5.677	6.900
CSR4	5.713	5.860	5.980
Mean of bivoltines	5.523	5.769	6.440
PM × CSR2	5.233	6.013	4.843
ND7 × CSR2	6.443	6.330	7.300
Mean of polyvoltine × bovoltine	5.838	6.172	6.072
CSR2 × CSR4	7.426	7.550	8.090
F1 hybrids mean	6.632	6.864	7.081

ANOVA

Source	DF	SS	MS	VR	CD at 5 %	Significance
Between races/ hybrids (A)	6	162.6106	27.1018	2001.9860	0.1481	**
Between Seasons (B)	2	0.3043	0.1522	11.2395	0.0969	**
Between A × B	12	8.1040	0.6753	49.8865	0.2565	
Error	42	0.5686	0.1350			

Table 2: Heterosis (%) in silk productivity in different hybrids of the silkworm *Bombyx mori*.L.

Combination		Summer	Rainy	Winter
PM × CSR2	RH	12.42	56.99	27.54
	SH	(-) 24.16	5.91	(-) 9.18
ND7 × CSR2	RH	10.01	22.67	46.82
	SH	(-) 6.62	11.50	36.88
CSR2 × CSR4	RH	15.31	30.87	46.47
	SH	7.62	28.84	41.60

RH - Relative Heterosis : SH - Standard Heterosis

Table 3: Silk productivity (cg/per) and its improvement (%) in different breeds/hybrids

Combination	Summer	Rainy	Winter
Polyvoltines	3.315	3.435	3.612
Bivoltines	5.523	5.769	6.440
Improvement % in bivoltines over polyvoltines	39.980	40.46	43.910
Polyvoltine × bivioltine	5.838	6.172	6.072
Bivoltine × bivoltine	7.426	7.550	8.090
Improvement % in bivoltine hybrids over polyvoltine hybrids	27.200	18.252	24.94
Pure breeds	4.419	4.602	5.026
F1 hybrid	6.632	6.864	7.081
Improvement % in F1 hybrids over pure breeds	33.370	32.950	29.020

by the environmental factors. It is essential to measure the degree of phenotypic manifestation for the characters of economic importance under both similar and variable environmental conditions in order to understand the genetic endowment pertaining to adaptability and productivity of the breeding material.

Heterosis studies (Table 2) indicated standard positive heterosis in majority of breeds except in PM × CSR2 and ND7 × CSR2 in summer. Negative heterosis in summer is due to the less shell weight because of biotic and abiotic stress factors. Realative heterosis ranged from 12.42 to 56.99 % and standard heterosis ranged from (-) 24.16 to 41.6 %. higher relative heterosis expression was recorded in rainy season in popular hybrid PM × CSR2 (56.99 %), whereas, higher standard heterosis was recorded in CSR2 × CSR4 (41.6 %). The higher degree of heterosis exhibited by these hybrids can be attributed to the influence of additive genes (Bhargava *et al.,* 1996)

Silk productivity is an important trait hence, it is essential that this breeding index should be included as one of the parameter for evaluation of silkworm hybrids and also as a parameter during selection process in the breeding programmes.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 170-173

STUDIES ON SOME ASPECTS OF ADULT LIFE SPAN AND ITS RELATION TO QUANTITATIVE TRAITS IN THE SILKWORM, *BOMBYX MORI* L.

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ABSTRACT

As in the case of a typical Lepidopteran insect, the silkworm passes through four distinct stages: egg, larvae, pupa and adult (moth). The duration of life cycle may last for 6 to 8 weeks depending upon the racial characteristics and climatic conditions. The adult moth emerging from the pupa is incapable of flight as a result of its domestication for more than four thousand years. It does not feed during its short adult life. The escape of the adult insect from the cuticle of the pupa of the last instar is known as eclosion. An adult moth sheds its pupal skin only during specific period of the day and is characteristic of the species. And the total life span in insect population is a genetically controlled phenomenon. In the domesticated silkworm, *Bombyx mori* L., the entire life span from eggs to adult death varies from race to race. Longevity in adult moths depend on the aboriginal races and there is a correlation of adult longevity and commercial characters of the silkworm, *B. Mori* L. Adult longevity in five polyvoltine breeds and in five bivoltine breeds was studied. In all the breeds studied, female moth longevity is more than the male moth longevity. Bivoltine adult longevity is longer than the polyvoltine breeds. Overall results indicate that there is a positive response of adult longevity and cocoon traits.

Key words: Adult life span, Bivoltine, Polyvoltine, Quantitative traits

INTRODUCTION

Silkworm *Bombyx mori* L. a Lepidopteron insect passes through four distinct stages, egg, larvae, pupa and adult (moth). The duration of life cycle may last for 6 to 8 weeks depending up on the racial characteristics and climatic conditions. The escape of the adult insect from the cuticle of the pupa of the last instar is known as eclosion. An adult moth sheds its pupal skin only during specific period of the day and is characteristic of the species. And the total life span in insect population is a genetically controlled phenomenon (Murakami, 1988a and 1988b). In the domesticated silkworm, *Bombyx mori* L., the entire life span from eggs to adult death varies from race to race. According to Kang *et al.,* (1999) longevity in adult moths depend on the aboriginal races and there is a correlation of adult longevity and commercial characters of the silkworm. At present very meager information is available on the adult life span of the silkworm breeds available in the Central Sericultural Research and Training Institute, Mysore. The present study has been carried out and the adult life span and its relation to quantitative traits studied in some of the polyvoltine breeds and polyvoltine × bivoltine hybrids.

MATERIALS AND METHODS

To investigate the adult longevity and also to study the relationship between longevity of adult and cocoon traits, five polyvoltine breeds namely, Pure Mysore, Nistari, ND5, ND7 and NDV6 were utilized. Of the five polyvoltine breeds, Pure Mysore and Nistari are traditional races and the other three are improved breeds. Initially all the five breeds were screened for the preliminary investigation on adult longevity. All the breeds were reared under standard rearing condition by feeding V1 mulberry leaves. Cellular rearing has been conducted. After cocooning defective cocoons were removed and the remaining were cut open and female and male pupae were kept separately in all the breeds. Virgin moths of the breeds were collected at 9 AM daily. Newly emerged moths for each sex were utilised to carry out experiment. Observations were made twice daily, at 10 AM and 4 PM as per the method followed by Doddaswamy *et al.,* (2004). The death of adult moth was judged when they did not biologically respond to being poked by the point of a pencil. The mean life span for each race/breed and sex was

calculated by taking average of all the individuals (Table 2, 3, and 4). After initial screening of the breeds, two breeds ND7 and Nistari were selected for further studies as they have recorded higher adult longevity compared to other breeds. The two breeds considered for further studies were brushed in cellular and rearing conducted under optimal conditions, and V1 mulberry was fed for all the batches. After cocooning, one batch each which recorded higher values for survival, cocoon weight, cocoon shell weight, cocoon shell percentage were selected and retained for further investigation. In each breed, all the good cocoons were cut open and pupae were kept for moth emergence. All the moths were allowed to mate randomly. After 3 hours of mating male moths were rejected and female moths were allowed to lay eggs. After 24 hours, layings were numbered serially and moths separated from the egg sheets and given same serial number for calculating the longevity. After calculating the longevity of each female moth in a breed, two batches were identified and continued as longest and shortest. Control batches were also maintained. Longest and shortest batches were identified based on the female longevity and continued and reared under optimal conditions for two generations and data were collected on fecundity, hatching percentage, total larval duration, cocoon yield, cocoon weight, shell weight, shell percentage. The data were analyzed statistically by employing ANOVA.

RESULTS AND DISCUSSION

The characteristics of the races/breeds selected for the study are presented in Table 1.Nistari is a traditional polyvoltine race from West Bengal and characterized by marked larvae, spindle shape and golden yellow cocoons. ND5, ND7 and NDV6 are newly developed breeds of Central Sericultural Research and Training Institute, Mysore. All the breeds are characterized by plain larvae, greenish yellow and oval shaped cocoons.

Female moth longevity: Female moth longevity of the five breeds studied is presented in Table 2. Data indicated that female moth longevity in the breeds studied ranged from 1 to 16 days. For each breed average longevity was calculated based on the mean of the total moths considered for the study. Average female moth longevity ranged from 8.5 to 10.4 days. ND5 female moths recorded shortest longevity if 8.5 days and Nistari recorded longest longevity of 10.4 days followed by ND7 (9.8 days).

Male moth longevity: Male moth longevity in the polyvoltine breeds studied was recorded in Table 3. Data indicated that individual male moth longevity ranged from 1 to 16 days. The same trend has been observed in female moths also. Average male moth longevity in different breeds ranged from 7 to 8.9 days. Pure Mysore recorded shortest male moth longevity (7 days) while, Nistari recorded longest longevity of 8.9 days followed by ND7 with 8.5 days.

Data recorded for 816 male moths and 554 female moths of five polyvoltine breeds, females survived (9.28 days) longer than male moths (7.98). The present results confirm the earlier studies conducted by Murakami (1988a, b, c and 1994), Suzuki and Murakami (1989) and Doddaswamy *et al.,* (2004).

According to Murakami (1988a, b, and c), average length of adult stage was 1.7 times longer in females and the ratio varied from 1.1 to 3.1 depending on the silkworm race/hybrid. In the silkworm, males have higher oxygen consumption per body weight, index of metabolic activity, than the females. The wing-beat frequency of male moths is higher than that of female moths for the first several days after eclosion until the last day of reproduction time. After the completion of oviposition in females, their wing-beat activity reduced. In the silkworm, the normal body weight of females is about 1.3 to 1.5 times heavier than that of males. From this it can be suggested that the metabolic rate or energy consumption may be one of the principal mechanisms for sexual differences in adult life span rather than other possibilities.

Murakami (1994) reported that there is no significant difference in the adult life span of mated moths from unmated ones. Suggesting that insemination stimulates only egg-laying and it does not affect the other activities in any way. Rockstein and Miquel (1973) reported that females in most species surveyed, live much longer than males irrespective of homogametic ZZ (XX) or heterogametic ZW (XY) females. These deny the participation of sex chromosomes, either Z (X) or W (Y), in sex differences in the adult life span. The possibility of involvement of certain autosomal factor(s) in adult moth longevity can't be excluded. Further, detailed studies are required to understand the factors responsible for differential longevity in females and males.

As discussed above it seems possible that certain extrinsical variables and genetic factors are involved in modifying the adult life span in *Bombyx mori* L.

Rearing performance of the lines selected based on the basis of adult life span: Rearing performance of the lines selected on the basis of adult longevity is presented in Table 4. Data indicates significant differences between the lines selected for the parameters studied except for fecundity and larval duration.

No significant differences were recorded between the lines for fecundity, hatching percentage and larval duration.

Cocoon yield/10,000 larvae by number: Significant ($P<0.01$ and $P<0.05$) differences were recorded for yield by number between the lines in both ND7 and Nistari. ND7 longest line recorded highest cocoon yield by number (9588) followed by ND7 control line (9370) and ND7 shortest line (9125). Improvement recorded in ND7 longest is 2.3% compared to

control line. In Nistari same trend was recorded between the lines. Nistari longest line recorded 9631 cocoons / 10000 larvae compared to control line 9522/1000.

Cocoon yield / 10,000 larvae by weight (kg): Significant (P<0.01 and P<0.05) differences were recorded for yield by weight between the lines in both ND7 and Nistari. In ND7 cocoon yield/10000 larvae ranged from 12.273 kg (ND7 shortest line) to 13.520 kg (ND7 longest line). Improvement recorded was 3.9 % in ND7 longest line compared to control. In Nistari same trend was observed between the lines and the yield ranged from 7.35 kg (Nistari shortest) followed by 7.53 kg (Nistari control line) and 7.905 kg in Nistari longest line. Improvement recorded in Nistari longest is 5.0 % compared to control line.

Cocoon weight (g): Data indicate significant (P<0.01 and P<0.05) differences were recorded for cocoon weight between the lines in both ND7 and Nistari. Cocoon weight ranged from 1.343 g (ND7 shortest) to 1.399 (ND7 longest). In Nistari cocoon weight ranged from 0.733 g (shortest line) to 0.809 g (longest line). Improvement recorded was 3 %.

Cocoon shell weight (g): In ND7 cocoon shell weight ranged from 0.234 to 0.252 g and no significant differences were recorded between the lines. However, significant (P<0.05) differences were recorded for this traint in Nistari lines and improvement recorded was 7.5 % in Nistari in longest line compared to control line.

Cocoon shell percent: Significant (P<0.01) differences were recorded for cocoon shell percent both in ND7 and Nistari. In ND7 cocoon shell % ranged from 16.63 (ND7 control line) to 17.85 (ND7 longest line) and the improvement was 8.2 % in longest line. In Nistari the cocoon shell percent ranged from 13.42 (Nistari shortest line) to 14.00 (Nistari longest line). Improvement recorded was 8.2 % in longest line compared to control line.

Table 1: Characteristics of the polyvoltine silkworm races used in the study.

Race/breed	Larval pattern	Cocoon colour	Cocoon shape
Pure Mysore	Plain	Greenish yellow	Spindle
Nistari	Marked	Golden yellow	Spindle
ND5	Plain	Greenish yellow	Oval
ND7	Two black spots on the head	Greenish yellow	Oval
NDV6	Plain	Greenish yellow	Oval

Table 2: Female moth longevity in polyvoltine races

Race/breed	No. of moths observed	Adult longevity (days)		
		Minimum	Maximum	Average*
Pure Mysore	116	2	12	8.9
Nistari	106	2	15	10.4
ND5	113	2	11	8.5
ND7	109	2	16	9.8
NDV6	110	1	12	8.9
Total	554			9.28

Based on average of total moths observed

Table 3: Male moth longevity in polyvoltine races

Race/breed	No. of moths observed	Adult longevity (days)		
		Minimum	Maximum	Average*
Pure Mysore	166	3	14	7.0
Nistari	156	2	15	8.9
ND5	160	2	11	7.5
ND7	169	1	16	8.5
NDV6	165	2	13	8.0
Total	816			7.98

* Based on average of total moths observed

Table 4: Rearing performance of polyvoltine races selected on the basis of moth longevity (mean of 3 trials)

Race	Fecundity	Hatching percent	TLD (days)	YLD/10000 larvae		Cocoon weight (g)	Shell weight (g)	Cocoon shell %
				By Number	By weight (kg)			
ND7 shortest	515	96.5	22:00	9125	12.273	1.343	0.234	17.66
ND7 longest	544	96.4	22:00	9588	13.520	1.399	0.247	17.85
ND7 control (C)	516	97.0	22:00	9370	13.010	1.383	0.252	16.63
Improvement in longest over (C)	5.4	-	-	2.3	3.900	1.150	-1.900	8.2
CD @ 5%	NS	NS	NS	228**	0.387**	0.049**	0.010*	0.36**
Nistari shortest	338	94.5	21:00	9477	7.350	0.773	0.103	13.42
Nistari longest	355	94.0	21:00	9635	7.905	0.809	0.114	14
Nistari control (C)	340	94.2	21:00	9522	7.530	0.785	0.106	13.63
Improvement in longest over (C)	4.4	-	-	1.2	5.000	3.100	7.500	2.7
CD @ 5%	NS	NS	NS	148**	0.239**	0.025**	0.011**	0.31**

TLD: Total Lraval duration: YLD Yield

Overall results indicate that the performance of the lines separated on the basis of adult longevity differs significantly (P<0.01) for most of the traits studied. The same trend was observed in both the races. However response level differs from breed to breed. Results indicate that the longest lines performed significantly (P< 0.05 – 0.01) well compared to the shortest and control lines. Data further indicate that the performance of the shortest lines is least compared to the other two lines longest and control. Performance of the control lines is in between the longest and shortest lines, indicating that there is positive response in terms of higher quantitative traits when the families are selected on the basis of female moth longevity. Longer the female moth longevity higher the quantitative traits.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 174-177

DEVELOPMENT OF A NEW POLYVOLTINE × BIVOLTINE HYBRID OF THE SILKWORM *BOMBYX MORI* L. WITH SUPERIOR FIBRE QUALITY

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ABSTRACT

The existing cross breed PM × CSR2 has few limitations like high renditta, low cocoon shell weight, cocoon shell percentage and low silk quality. Keeping these constraints, Silkworm Breeding Laboratory II of Central Sericultural Research and Training Institute, Mysore has developed a new multivoltine × bivoltine hybrid L14 × CSR2 which is superior both quantitatively and qualitatively over the existing cross breed PM × CSR2. At the time of selection of breeding resource material emphasis was given to fiber characteristics and the breeds which were showing high post-cocoon parameters namely, filament length, raw silk %, neatness, size deviation, cleanness, evenness, cohesion, tenacity were considered as parents in the new breeding programme and few promising lines were developed and stabilized. Improvement in crossbreed is not possible unless the female component is improved,. Hence, breeding programmes have been initiated to improve the quantitative and qualitative traits in pure multivoltine breeds. Introduction of PM × CSR2 enhanced the quality of silk yarn from B to A grade. For the first time attempts were made for selecting qualitative traits like neatness, tenacity, cohesion, elongation, boil-off loss ratio etc., during breeding process. The well designed selection criteria, meticulous follow up or procedures particularly in yarn grading and testing has resulted in the isolation of three pure lines designated as L13, L14 and l15. L14 and L15.T Further, repetitive hybrid evaluation studies ended up in identifying hybrid combination L14 × CSR2 which holds promise revolutionizing the quality parameters in crossbreed silk.

Key words: Cross breed, Fibre quality, Polyvoltine × Bivoltine hybrid, Silkworm

INTRODUCTION

Bulk of the cocoon production in India is from cross breeds with filament length of 550 to 700 m and renditta of 8 to 9. Even the best of the cross breed cocoons have certain inherent limitations for producing good quality raw silk. Efforts in promoting the production of bivoltine cocoons has not gained the expected momentum. The strategies towards raw material improvement would have to address mainly the quality improvement (Rama Mohana Rao, 2008 & Somashekar, 2000) of cross breed cocoons. Good quality cocoons is an important prerequisite for the production of high quality raw silk. Studies have shown that cocoon quality contributes almost 80% towards the quality of raw silk. The existing cross breed PM × CSR2 has few limitations like high renditta, low cocoon shell weight, cocoon shell percentage and low silk quality. Keeping these constraints, Silkworm Breeding Laboratory II of Central Sericultural Research and Training Institute, Mysore has developed a new multivoltine × bivoltine hybrid L14 × CSR2 which is superior both quantitatively and qualitatively over the existing cross breed PM × CSR2. Hybrid evaluation was done in the laboratory and identified the potential new hybrid L14 × CSR2.

MATERIALS AND METHODS

For the development of polyvoltine silkworm breeds with superior fibre quality four breeds developed at Central Sericultural Research and Training Institute, Mysore namely, ND7, NDV6, NP1 and 2000H were utilized as

breeding resource material . In the early breeding stage (Fig. 1) family selection was carried out and emphasis was given to fiber characteristics and the breeds which were showing high post-cocoon parameters namely, filament length, raw silk %, neatness, size deviation, cleanness, evenness, cohesion, tenacity were considered as parents in the new breeding programme and few promising lines were developed and stabilized. Hybrid evaluation (Mano *et al.*, 1993) was done in the laboratory and identified the potential new hybrid L14 × CSR2.

RESULTS AND DISCUSSION

Improvement in crossbreed is not possible unless the female component is improved,. Hence, breeding programmes have been initiated to improve the quantitative and qualitative traits in pure multivoltine breeds. Introduction of PM × CSR2 enhanced the quality of silk yarn from B to A grade. For the first time attempts were made for selecting qualitative traits like neatness, tenacity, cohesion, elongation, boil-off loss ratio etc., during breeding process. The well designed selection criteria, meticulous follow up or procedures particularly in yarn grading and testing has resulted in the isolation of three pure lines designated as L13, L14 and l15. L14 and L15.The line L14 is characterized by plain larvae, light greenish yellow and elongate oval cocoons with medium to fine grain (Table 1 & Fig2). The L14 (Tables 2 & 3) is superior over Pure Mysore in respect of cocoon weight (1.456g), shell weight (0.273g), cocoon shell percent (18.77%), raw silk % (13.86). Besides the larval duration in the new breed is shorter by 5 days compared to Pure Mysore.. Reproductive parameters in the new lines are significantly superior to Pure Mysore. Data (Table 2) indicate 42.3 % dfls recovery and 89.14 g egg recovery per kg of cocoons in L14. Further, repetitive hybrid evaluation studies ended up in identifying hybrid combination L14 × CSR2 which holds promise revolutionizing the quality parameters in crossbreed silk.

The new hybrid (Tables 4 & 5 and Fig3) recorded 96% pupation, 1.971 g cocoon weight, 0.424 g shell weight, 21.5 % cocoon shell percentage, 1008 m filament length, 16.58 % raw silk percent, 91 p neatness, 89 (strokes) cohesion, 1.45 size deviation, 99 % cleanness, 22 % elongation. The new hybrid cocoons produce gradable silk (2A). Large scale in-house testing recorded 78.6 kg cocoons/100 dfls. Cocoons fetched 15 – 20 % higher rate than control PM × CSR2. Improvement (Table. 6) recorded in the new hybrid compared to PM × CSR2 ranged from 2.3 to 28.9%. Further cocoon floss in the new cocoons reduced by 55%. This new hybrid is recommended for irrigated areas of south India for all seasons. Further fabric obtained from L14 × CSR2 yarn (both as warp and weft) was analysed for the physical properties. Results indicate the superiority of L14 × CSR2 yarn in respect of important traits like tensile strength (breaking strength and elongation%), crease recovery angle, stiffness test, drape co-efficient, *etc.,*

Table 1: Characteristics of polyvoltine breed L14

Characteristics	Pure Mysore	L14
Larval pattern	Plain	Plain
Cocoon colour	Light greenish yellow	Light greenish yellow
Cocoon shape	Spindle	Elongate yellow
Cocoon grains	Coarse	Medium to fine

Table 2: Reproductive parameters in L14 and control breed

Characteristics	Pure Mysore	L14
Number of cocoons per kg	985	686
Percentage of dfls. recovery	40.5	42.3
Number of eggs per g	2125	1843
Recovery of eggs per kg of cocoons (g)	62.5	89.14

Table 3: Rearing and reeling parameters in L14 and Pure Mysore

Characteristics	Pure Mysore	L14
Fecundity (No)	458	555
Larval duration (days)	26	21
Yield/10000 larvae by number	8854	9207
Yield/10000 larvae by weight (kg)	9.427	13.537
Cocoon weight (g)	1.053	1.456
Shell weight (g)	0.16	0.27
Shell %	15.11	18.77
Avg. filament length (m)	402	724
Non-breakable filament length (m)	362	643
Filament size (d)	2.1	2.06
Raw silk %	9.17	13.86
Neatness (p)	86	89
Raw silk recovery(%)	56.3	78.9

Table 4: Rearing and reeling parameters in L14 × CSR2 and Pure Mysore × CSR2

Characteristics	Pure Mysore × CSR2 (Control)	L14 × CSR2	Improvement in L14 × CSR2 over control (%)
Fecundity (No)	565	555	-
Larval duration (days)	22	21	-
Yield/10000 larvae by number	9400	9613	2.3
Yield/10000larvae by weight (kg)	16.368	18.783	14.8
Cocoon weight (g)	1.760	1.971	12
Shell weight (g)	0.33	0.42	28.9
Shell %	18.67	21.49	15.1
Average filament length (m)	785	1008	27.1
Non-breakable filament length (m)	732	932	27.3
Filament size (d)	2.57	2.62	-
Reelability (%)	85	88	3.4
Raw silk %	13.54	16.58	3.5
Neatness (p)	88	91	2.5
Raw silk recovery(%)	74.48	78.88	5.9
Boil-off loss ratio (%)	26.12	25.36	-

Table 5: Yarn characteristics of L14 × CSR2 and Pure Mysore × CSR2

Parameter	Pure Mysore × CSR2		L14 × CSR2	
	Value	Grade (18-22d)	Value	Grade (18-22d)
Yarn size deviation	2.15	A	1.48	2A
Maximum size deviation	4.70	A	1.90	2A
Tenacity (g/d)	3.40	2A	3.8	4A
Cohesion (strokes)	65	2A	61	2A
Cleanness (%)	86	B	99	4A
Average neatness (p)	87	A	94	2A
Low neatness (p)	78	A	88	2A
Elongation %	23	4A	22	4A
Winding breaks	6	A	0	4A
Overall grade		B		2A

Based on the CSTRI, Bangalore data

Table 6: Physical test report of fabric

Charcteristics	Tensile strength	PM × CSR2	L14 × CSR2
Breaking strength	Warp	338.3	353.9
	Weft	261.2	266.9
Elongation %	Warp	17.3	17.8
	Weft	12.2	12.5
Crease recovery angle	Warp	52	60
	Weft	55	68
Stiffness test	Warp	4.6	3.5
Bending length	Weft	3.8	3.4
Flexural rigidity	Warp	498	207.5
	Weft	276.6	190.2
Drape co-efficient (%)		89.9	82.5

Based on the CSTRI, Bangalore data

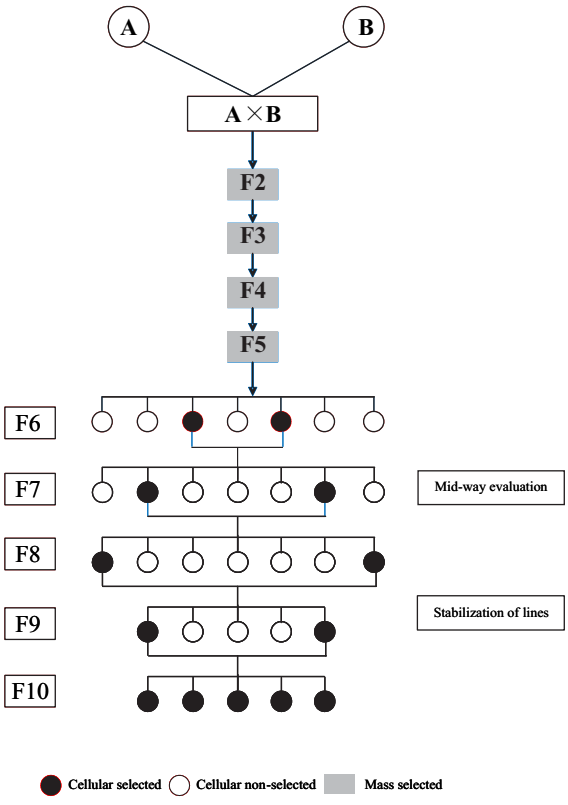


Fig.1: Breeding plan of L14

The silk yarn obtained from the new hybrids can be used both as warp and weft. Physical properties of the cloth prepared from the new hybrid yarn were studied and data indicated the superiority of the yarn compared to PM × CSR2 fabric (Table 6). Therefore the silk produced from this new hybrid will be a boon for the Indian hand-loom silk industry. Quality improvement should necessarily include quality based pricing in order to promote the new silk yarn.

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PERFORMANCE OF BIVOLTINE DOUBLE HYBRID, (CSR50 × CSR52) × (CSR51 × CSR53) OF THE SILKWORM, *BOMBYX MORI* L. WITH REFERENCE TO EGG YIELD PARAMETERS

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ABSTRACT

Silkworm eggs are the vital inputs for the production of cocoons in the silk industry. Egg yield is an important parameter for the egg producers in terms of cost of production of quality seed. The present study was undertaken to assess the performance of newly evolved bivoltine double hybrid, (CSR50 × CSR52) × (CSR51 × CSR53) with reference to egg yield parameters. By using two parental breeds *viz.,* CSR2 (oval type) and CSR4 (dumbbell type) and four foundation crosses (FCs) *viz.,* CSR2 × CSR27, CSR50 × CSR52 (oval × oval) and CSR6 × CSR26, CSR51 × CSR53 (dumbbell × dumbbell), popular single hybrids *viz.,* CSR2 × CSR4 / CSR4 × CSR2 and popular double hybrids (CSR6 × CSR26) × (CSR2 × CSR27) / (CSR2 × CSR27) × (CSR6 × CSR26) and new double hybrids, (CSR50 × CSR52) × (CSR51 × CSR53) / (CSR51 × CSR53) × (CSR50 × CSR52) were prepared and studied. Statistical analysis indicated that the FCs have shown significant ($p<0.05$) improvement over parental breeds in respect of pupation (5.15%), cocoon yield (14.78 %), cocoon weight (7.79%), shell weight (8.09%) with less melting percentage. The double hybrids are significantly superior over single hybrids in respect of egg yield (34.23%), layings recovery % (18.46%), eggs / dfl (20.11%), less unfertilized and non-diapause eggs. However, the results clearly indicated non-significant difference between single and double hybrids in terms of cocoon yield.

Key words: Bivoltine silkworm, *Bombyx mori* L, Double hybrids, Egg yield, Foundation crosses,

INTRODUCTION

Quality of silkworm eggs is the basis for sustenance of sericulture in the country and commonly judged by disease free, absence of unfertilized eggs, more number of eggs and effective hatching. Moreover, quality silkworm seed is one of the important factors for cocoon crop production. Egg yield refers to number of eggs laid by individual moth, number of eggs per gram and total egg yield per kilogram of cocoons which form the vital index for a egg producer in terms of cost of production of quality seed. The supply of loose eggs gaining momentum by virtue of advantages like easy production process, less man days utilization and equipment, significant reduction of time for production of eggs and less cost over that of traditional sheet eggs. Due to its multifarious advantages, attempts have been made to develop and identify suitable double hybrids at CSRTI, Mysore (Nirmal Kumar *et al.,*. 1998; Mal Reddy *et al*., 2005) However, information on comparative performance of egg yield in single and newly developed double hybrid is scanty. Hence, the present investigation was under taken to study the comparative performance of reproductive behaviour on eggs yield and other related parameters in the newly developed bivoltine double hybrid and popular single hybrid.

MATERIALS AND METHODS

By using two parental breeds *viz*., CSR2 (oval type) and CSR4 (dumbbell type) and four foundation crosses (FCs) *viz*., CSR2 × CSR27, CSR50 × CSR52 (oval × oval) and CSR6 × CSR26, CSR51× CSR53 (dumbbell × dumbbell), popular single hybrids *viz.,* CSR2 × CSR4 / CSR4 × CSR2 and popular double hybrids (CSR6 × CSR26) × (CSR2 ×

CSR27) / (CSR2 × CSR27) × (CSR6 × CSR26) and new double hybrids, (CSR50 × CSR52) × (CSR51 × CSR53) / (CSR51 × CSR53) × (CSR50 × CSR52) were prepared and studied. The required cocoons of parental breeds and FCs were generated by conducting rearings as per standard rearing techniques (Datta. 1992). One kilogram of cocoons were taken at random and the cocoons were cut open and pupae were sexed. The pupae of both sexes were kept separately (parents/foundation cross-wise) under optimum temperature (25±1°C) and relative humidity (75 – 80%). The pupae were preserved under dark condition to ensure uniform emergence and covered with a perforated paper to facilitate easy picking of moths. The emerged moths were paired with respective parents, foundation crosses separately. After 3 – 4 hr, the females were depaired smoothly and placed individually on starch coated egg sheets and allowed for egg laying for 24 hr in an oviposition room under dark condition. The depaired males were preserved at 5 – 7°C and were reused for coupling for a maximum of two times only. Loose eggs were prepared according to the method suggested by Samson *et al*., (1995).

RESULTS AND DISCUSSION

The data on the performance of F1 hybrids and double hybrids are given in Table 1 and the data of related egg yield are given in Table 2. Though there was no significant difference in shell percentage among the parental breeds and foundation crosses, significant difference ($P < 0.05$) was noticed for pupation, cocoon yield, cocoon weight, shell weight and cocoon melting percentage. In parental breeds, the cocoon weight varied from 1.784 (CSR4) to 1.874 g (CSR2). The shell percentage ranged from 22.2 (CSR 4) to 23.7 % (CSR 2). The maximum cocoon weight (1.964 g), shell weight (0.464 g) and shell percentage (23.6 %) were noticed in CSR50 × CSR52 which are the contributing commercial values for the grainuers deciding the cost of egg production. Melting percentage of cocoon was less in FCs (2.6 and 2.8%) as against pure lines CSR2 and CSR4 (4.2 and 5.2%). In all the breeds/foundation crosses, the percentage of male population was more than the female. The lowest (45.0 %) female and highest male population (55.0%) was recorded in CSR4 where as highest female (48.0 %) and lowest male population (52.0 %) was recorded in CSR50 × CSR52. Statistical analysis indicated that the FCs have shown significant ($p<0.05$) improvement over parental breeds in respect of pupation (5.15%) and cocoon yield (14.78 %), cocoon weight (6.26%), shell weight (6.55%) with less melting percentage (- 42.55%).

The egg yield per kilogram of cocoons ranged from 60.4 (CSR4 × CSR2) to 85.6 g (CSR50 × CSR52) (CSR51 × CSR52). Highest egg yield was recorded in double hybrids which is significantly higher than the F1 hybrid. The egg yield per kg of cocoons is considered as another important parameter, which reflects the quality of cocoons. The differences observed in egg yield can be attributed to the quality of seed cocoons, sex ratio, number of pairs obtained and egg recovery which also decide the cost of egg production for egg producers (Benchamin and Krishna Reddy, 1981). Gupta *et al*. (1991) observed that the egg yield was higher in bivoltine compared to multivoltine pure breeds and multivoltine × bivoltine hybrids owing to greater weight of cocoons, pupae and moths. The cocoon yield in double hybrids was almost similar to single hybrids. More number and heavy eggs are considered as indicative of good quality seed (Benchamin *et al*., 1998). The number of eggs / gram in double hybrid is less and varied from 1656 (CSR50 × CSR52) × (CSR51 × CSR53) to 1685 (CSR6 × (CSR26) × (CSR2 × CSR27) in double hybrids, where as, in single hybrid, it varied from 1786 (CSR2 × CSR4) to 1825 (CSR4 × CSR2). The fecundity (No. of eggs/moth) in single hybrid varied from 512 (CSR4 × CSR2) to 542 (CSR2 × CSR4) and in double hybrid, the same is expressed from 624 (CSR6 × CSR26) × (CSR2 × CSR27) to 640 (CSR50 × CSR52) (CSR51 × CSR53). The data clearly show that the double hybrids are significantly superior over single hybrids in respect of egg yield (34.23%), laying recovery (18.46%), eggs / dfl (20.11%) and less unfertilized (-23.08%) and non-diapause eggs (-28.21%). Moreover, marginal improvement in egg yield (6.42%) and layings recovery (8.15%) was recorded in new double hybrid (CSR50 × CSR52) (CSR51 × CSR53) / (CSR51 × CSR53 (CSR50 × CSR52) over control double hybrid (CSR6 × CSR26) × (CSR2 × CSR27) / (CSR2 × CSR27) × (CSR6 × CSR26). However, three is no significant difference between single and double hybrids in terms of cocoon yield.

The major differences among the pure strains and FCs are pupation and egg yields which in turn reduces the cost of egg production. The improvement in egg yield of 34.23 % in new double hybrid was recorded over single hybrids and parallels the finding of Nirmal Kumar *et al,* (2002) and Harada (1961). Gowda *et al.* (1989) reported that variation in fecundity is due to differential pupal weight which also confirms the present findings. In the silkworm, it is well known that selection for one trait results in correlated changes in qualitative traits of economic importance (Kobari and Fujimoto, 1996), For example with increase in qualitative traits beyond certain level, survival and fecundity are affected considerably. Although survival could be maintained in single hybrids, they are poor in egg number; unless the moth is a hybrid, the fecundity cannot be increased (Yokoyama, 1979). Moreover, the cost of maintaining these parental breeds especially strains with less fecundity and survival for the purpose of supply of parental stocks for preparation of single hybrid can be high. This has necessitated the development of FCs and inturn double hybrids containing genetic material from four parental strains to obtain sustainable cocoon yield for commercial exploitation.

Table 1: Performance of pure breeds and foundation crosses

Breeds/FCs	Pupation (%)	Cocoon yield/ 10,000 larvae (kg)	Cocoon weight (g)	Shell weight (g)	Shell percentage	Melting (%)	Sex ratio (%)	
							Female	Male
CSR2	91.2	16.33	1.854	0.439	23.7	4.2	46	54
CSR4	89.3	15.81	1.752	0.389	22.2	5.2	45	55
CSR50 × CSR52	95.2	18.70	1.964	0.464	23.6	2.6	48	52
CSR51 × CSR53	94.6	18.19	1.923	0.431	22.4	2.8	47	53
CD at 5%	3.2	1.4	0.08	0.04	1.3	1.5		
%improvement parents Vs foundation cross	5.15	14.78	7.79	8.09	0.22	-42.55		

Table 2: Egg yield in single and double hybrids

Hybrid	Cocoon yield/ 10,000 larvae (kg)	Egg yield / kg of cocoons (g)	Dfls recovery (%)	Unfertilized egg (%)	Non-diapause egg (%)	No. of eggs / g	No. of eggs / dfl
(CSR50 × 52) × (51 × 53)[1]	20.25	85.6	39.5	2.1	1.5	1656	640
(CSR51 × 53) × (50 × 52)[1]	19.35	83.4	38.8	1.9	1.3	1675	626
(CSR6 × 26) × (2 × 27)[2]	19.15	80.4	35.9	2.4	1.3	1685	624
(CS2 × 27) × (6 × 26)[2]	19.50	78.4	36.5	1.8	1.7	1660	630
CSR2 × CSR4 [3]	19.01	65.5	33.6	2.4	1.5	1786	542
CSR4 × CSR2[3]	18.78	60.4	32.5	2.9	2.4	1825	512
CD at 5%	ns	3.6	0.8	0.6	ns	ns	60.0
%improvement over control double hybrid	2.46	6.42	8.15	-4.76	-6.67	-0.42	0.96
% improvement over F1 hybrid	4.79	34.23	18.46	-23.08	-28.21	-7.75	20.11

[1]New double hybrid
[2]Control double hybrid
[3]Single hybrid

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 182-187

MANIFESTATION OF HETEROSIS FOR SURVIVAL PARAMETERS OF *BOMBYX MORI* L. UNDER B*m*NPV STRESS

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ABSTRACT

Six silkworm breeds consisting of three non-diapausing *viz.*, Pure Mysore, C-nichi and Nistari and three diapausing *viz*., Daizo, CSR2 and CSR4 were utilized to understand the manifestation of heteroses for survival parameters under *Bm*NPV infections. The breeds were crossed under diallel fashion and analyzed. Significantly positive relative heterosis (RH) for ERR under infected condition was found in the hybrids CSR2 × Nistari (12.77%), while heterobeltiosis (HB) was significantly negative in all the hybrids except in CSR2 × CSR4 (5.41%) and CSR4 × CSR2 (2.70%), though not significant. Under normal condition though relative heterosis was negative in most of the crosses, the extent was comparatively less. The relative heterosis for pupation rate under infected condition was significant and positive among the crosses PM × CSR2 (4.75%), CSR2 × PM (3.39%), PM × CSR4 (1.68%) and Nistari × CSR2 (1.46%). Under normal condition the crosses though exhibited similar trend as in infected condition, the magnitude of negative heterosis was less for all the three types of heteroses. Manifestation of heterosis under the *Bm*NPV infected condition for fecundity revealed significantly positive relative heterosis in the crosses C-nichi × CSR2 (9.12%), while, heterobeltiosis was significantly highest and positive in CSR4 × CSR2 (4.76%) cross, while standard heterosis was significantly negative for all the crosses. Under normal condition, the relative heterosis was significantly maximum in CSR2 × Daizo (15.28%). Standard heterosis was significantly negative among all the crosses while, heterobeltiosis was significantly negative among the majority of the crosses.

Key words: *Bombyx mori*, *Bm*NPV, Fecundity, Heterosis, Pupation

INTRODUCTION

Silkworm rearing in tropics is more often affected due to occurrence of diseases. Among the various diseases caused by pathogens like protozoans, bacteria, fungi and viruses, the viral diseases are known to inflict significant losses in cocoon crop. The Nuclear polyhedrosis virus (*Bm*NPV) causing grasserie disease of silkworm, *B. mori* belongs to the former group and produces polyhedral inclusion bodies (PIBs) and survives in the rearing vicinity for quite a long period. In India, the loss due to *Bm*NPV has been reported to the extent of 32.9 – 55.3 per cent of the total disease incidence in silkworm (Nataraju *et al*., 1998). In this regard several attempts have been made to study the tolerance of various silkworm breeds and hybrids to *Bm*NPV infection. Studies have also been carried out on the estimation of heterosis in silkworm hybrids under normal conditions (Harada, 1961; Nagaraja, 1996; Rahman and Jahan, 1997 and Singh *et al*., 2000; Datta *et al*., 2001). Likewise manifestation of heterosis for certain quantitative traits in silkworm under different temperature and humidity conditions has been reported by Sudhakara Rao *et al*. (2001). However, no information on heterotic effects of any trait under *Bm*NPV infection is available. Since, *Bm*NPV causes considerable damage to cocoon crops and hybrids have significant role in commercial silkworm rearing an attempt has been made in the present study to estimate the extent of heteroses among few silkworm hybrids for few survival traits under *Bm*NPV infection.

MATERIALS AND METHODS

Six silkworm breeds namely, three non-diapausing (Pure Mysore, C-nichi and Nistari) and three diapausing (Daizo, CSR2 and CSR4) were utilized to affect crosses and study the heterotic effects among their hybrids. The hybrids were orally infected by feeding the silkworms with virus suspension smeared mulberry leaves, soon after third moult. The suitable stage mulberry leaf bits of 100 cm^2 size were prepared and washed in running water and sterilized by using 70 per cent ethanol (by cotton swab). The sterilized leaves were shade dried and such leaves were smeared evenly with virus suspension (0.54 ml/ replication of 100 worms) of 2.169×10^7 polyhedral bodies per ml using non-absorbent cotton and fed to the worms. Control batches were fed with surface sterilized mulberry leaves, with or without water smear, for the first feed. For subsequent feedings, inoculum free leaves suitable for the age were provided for both treated and control batches. Three replications of hundred worms each were maintained for each treatment. Two such rearings were conducted and observations on ERR, pupation rate and fecundity were recorded. The mean values of two rearing were statistically analyzed following Haymans' approach (1954) by using Windowstat Version 8 statistical package to estimate relative heterosis, heterobeltiosis and standard heterosis.

RESULTS

Analysis of Variance: the analysis of variance for ERR, pupation rate and fecundity both under *Bm*NPV infection and normal conditions has been presented in Table 1. Significant differences were observed for the genotypes, parents, hybrids and parents *vs* hybrids. Significance of mean sum of squares for hybrids indicate the possibility of non-additive, dominance and other interaction effects and thereby its influence on the performance of the hybrids. Nevertheless the significance of parents indicates additive effects which could be attributed to wide diversity in the parental lines included in the study.

Heterotic effects: Significant positive relative heterosis (RH) for ERR under infected condition was found in the hybrids CSR2 × Nistari (12.77%), while heterobeltiosis (HB) was significantly negative in all the hybrids except in CSR2 × CSR4 (5.41%) and CSR4 × CSR2 (2.70%), though not significant (Table 2). The highest negative heterobeltiosis for ERR was noticed in CSR4 × Nistari (-36.84%), followed by CSR4 × Daizo (-35.09%). The least negative heterobeltiosis was observed in Daizo × PM (-1.75%). Similarly, standard heterosis was negative in all the hybrids, the highest being in CSR4 × C-nichi (-38.60%) followed by CSR4 × Nistari (-36.84%). The least negative standard heterosis was recorded in Daizo × PM (-1.75%). However, under normal condition the extent of negative relative heterosis was comparatively less, though negative in most of the crosses except in C-nichi × PM (0.51%), Daizo × PM (0.51%) and CSR4 × PM (1.05%). Also PM × CSR2 and C-nichi × CSR2 did not exhibit any heterosis over their mid-parental value. Similarly, the heterobeltiosis for ERR was also negative for all the crosses under study, except in C-nichi × PM and Daizo × PM. Higher negative heteroses was observed when CSR2 and CSR4 breeds were used as females than when PM, Nistari, C-nichi and Daizo were used as female parents.

The relative heterosis for pupation rate under infected condition was significant and positive among the crosses PM × CSR2 (4.75%), CSR2 × PM (3.39%), PM × CSR4 (1.68%) and Nistari × CSR2 (1.46%). It was significantly negative and highest in CSR4 × Daizo (-9.01%), followed by CSR2 × Daizo (-8.18%), Daizo × CSR4 (-6.65%), CSR4 × C-nichi (-6.08%) and Daizo × CSR2 (-5.59%) (Table 2). The use of CSR2 and CSR4 as females resulted in more negative relative heterosis for pupation than using PM, C-nichi or Nistari. Similarly heterobeltiosis and standard heterosis exhibited the same trend as relative heterosis, but with higher values. The highest significant negative heterobeltiosis was observed in the cross CSR4 × Daizo (-21.60%), followed by Daizo × CSR4 (-19.56%) and standard heterosis was also highest and significantly negative in CSR4 × CSR2 (-28.31%) followed by CSR2 × CSR4 (-27.91%) and CSR4 × Daizo (-22.59%). Under normal condition the crosses though exhibited similar trend as in infected condition, the magnitude of negative heterosis was less for all the three types of heteroses.

Manifestation of heteroses under the *Bm*NPV infected condition for fecundity revealed significantly positive relative heterosis in the crosses C-nichi × CSR2 (9.12%), Daizo × CSR2 (7.60%), Nistari × CSR2 (7.42%), C-nichi × CSR4 (6.64%), CSR4 × CSR2 (5.81%), CSR4 × Nistari (5.61%), Daizo × CSR4 (4.25%) and Nistari × CSR4 (4.06%). Heterobeltiosis was significantly highest and positive in CSR4 × CSR2 (4.76%) cross, while standard heterosis was significantly negative for all the crosses. Under normal condition, the relative heterosis was significantly maximum in CSR2 × Daizo (15.28%), followed by CSR2 × Nistari (13.85%) and CSR2 × C-nich (13.10%). Standard heterosis was significantly negative among all the crosses while, heterobeltiosis was significantly negative among the majority of the crosses.

DISCUSSION

In the present study the heterotic effects for ERR, pupation rate and fecundity were significant and negative, though positive heterotic effects were observed among few crosses. The results also revealed that the use of tolerant breeds, PM, C-nichi and Nistari as females had better heterotic effects or had less negative effect than using susceptible breeds, CSR2 and CSR4. Suresh Kumar *at al.*

Table 1: Analysis of variance (mean sum of squares) for some survival and reproductive traits under *Bm*NPV stress (I) and normal (N) conditions.

Sources of variation	Degrees of freedom	ERR (I)	ERR (N)	Pupation rate (I)	Pupation rate (N)	Fecundity (I)	Fecundity (N)
Replicates	2	15.361	2.583	0.249	0.189	1918.750**	50.694
Treatments	35	188.733 **	25.333 **	40.498 **	3.142 **	481.562 **	13199.280 **
Parents	5	32.900 **	38.100 **	77.708 **	2.686 **	1508.900 **	17857.700 **
Hybrids	29	164.638 **	22.569 **	20.782 **	3.005 **	3 12.486 **	12829.850 **
Parent *vs* Hybrids	1	166.667**	41.667 **	6.215**	9.417**	248.067 *	620.817**
Error	70	16.133	2.298	0.423	0.277	45.607	87.666
Total	107	72.576	9.838	6.239	1.212	223.221	4375.822

* Significant at 5%; ** Significant at 1%

Table 2: Heterosis (%) among *Bm*NPV infected and uninfected batches of silkworm hybrids for ERR and pupation rate

Hybrids	ERR						Pupation rate					
	Infected			Normal			Infected			Normal		
	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
PM × Nistar	-6.19	-7.02	-7.02	-1.01	-1.01	-1.01	0.11	-1.20	-1.20	-1.57**	-2.72**	-2.72 **
PM × C-nichi	-7.41	-10.71	-12.28 *	-2.02	-2.02	-2.02	0.16	-1.72*	-1.72*	-1.07**	-1.09*	-3.39 **
PM × Daizo	-7.96	-8.77	-8.77	-0.51	-1.01	-1.01	-2.24 **	-2.86 **	-2.86 **	-0.44	-0.73	-2.47 **
PM × CSR2	-9.68	-25.00**	0	0.00	-3.03*	0	4.75**	-7.99**	0	-0.56	-0.59	0
PM × CSR4	-13.33*	-30.36**	-31.58**	-1.05	-5.05**	-5.05 **	1.68 *	-12.84 **	-12.84 **	-0.66	-0.85	-3.15 **
Nistari × PM	-4.42	-5.26	-5.26	-1.01	-1.01	-1.01	-0.61	-1.92 **	-1.92 **	-0.53	-1.68**	-1.68 **
Nistari × C-nichi	-2.75	-7.02	-7.02	-4.04**	-4.04**	-4.04 **	-1.48 *	-2.05 **	-4.62 **	-0.51	-1.68**	-1.68 **
Nistari × Daizo	-7.02	-7.02	-7.02	-4.57**	-5.05**	-5.05 **	-2.35 **	-3.02 **	-4.25 **	-0.26	-1.14*	-1.14 *
Nistari × CSR2	-10.64	-26.32 **	-26.32 **	-1.04	-4.04**	-4.04 **	1.46 *	-9.84 **	-12.21 **	0.18	-0.95*	-0.95 *
Nistari × CSR4	-16.48 *	-33.33 **	-33.33 **	-3.16**	-7.07**	-7.07 **	-0.21	-13.50 **	-15.77 **	-0.39	-1.72**	-1.72 **
C-nichi × PM	1.85	-1.79	-3.51	0.51	0.00	0.00	-0.73	-2.58 **	-2.58 **	-0.97*	-0.99*	-3.29 **
C-nichi ×Nistari	-0.92	-5.26	-5.26	-1.01	-1.01	-1.01	-0.26	-0.83	-3.43 **	-0.86*	-2.03**	-2.03 **
C-nichi × Daizo	-6.42	-10.53	-10.53	-0.51	-1.01	-1.01	-2.76 **	-3.98 **	-5.19 **	-0.62	-0.92*	-2.66 **
C-nichi × CSR2	-10.11	-23.08 **	-29.82 **	0.00	-3.03*	-3.03 *	-2.99 **	-13.36 **	-16.60 **	-0.80*	-0.86	-3.10 **
C-nichi × CSR4	-13.95 *	-28.85 **	-35.09 **	-2.11	-6.06**	-6.06 **	-3.84 **	-16.25 **	-19.38 **	-1.33**	-1.49**	-3.82 **
Daizo × PM	-0.88	-1.75	-1.75	0.51	0.00	0.00	-1.96 **	-2.58 **	-2.58 **	-0.54	-0.83	-2.57 **
Daizo × Nistari	-5.26	-5.26	-5.26	-0.51	-1.01	-1.01	-1.66 **	-2.33 **	-3.57 **	-0.16	-1.03*	-1.03 *
Daizo × C-nichi	-4.59	-8.77	-8.77	-2.54*	-3.03*	-3.03 *	-0.53	-1.78 *	-3.02 **	-0.22	-0.53	-2.27 **
Daizo × CSR2	-8.51	-24.56 **	-24.56 **	-4.71**	-7.14**	-8.08 **	-5.59 **	-16.61 **	-17.66 **	-0.69	-0.95*	-2.68 **
Daizo × CSR4	-9.89	-28.07 **	-28.07 **	-4.76**	-8.16**	-9.09 **	-6.65 **	-19.56 **	-20.58 **	-0.58	-1.05*	-2.79 **
CSR2 × PM	11.83	-7.14	-8.77	-2.08	-5.05**	-5.05 **	3.39 **	-9.18 **	-9.18 **	-0.82*	-0.86	-3.10 **
CSR2 × Nistari	12.77 *	-7.02	-7.02	-4.17**	-7.07**	-7.07 **	-0.54	-11.62 **	-13.94 **	-0.10	-1.23**	-1.23 **
CSR2 × C-nichi	-14.61 *	-26.92 **	-33.33 **	-3.13**	-6.06**	-6.06 **	-5.00 **	-15.15 **	-18.33 **	-1.54**	-1.60**	-3.82 **
CSR2 × Daizo	-12.77 *	-28.07 **	-28.07 **	-4.71**	-7.14**	-8.08 **	-8.18 **	-18.90 **	-19.93 **	-1.11**	-1.37**	-3.10 **
CSR2 × CSR4	9.86	5.41	-31.58 **	-2.17	-3.23*	-9.09 **	-1.99 *	-4.75 **	-27.91 **	-0.22	-0.43	-2.68 **
CSR4 × PM	-17.78 **	-33.93 **	-35.09 **	1.05	-3.03*	-3.03 *	-1.45 *	-15.53 **	-15.53 **	-2.93**	-3.11**	-5.36 **
CSR4 × Nistari	-20.88 **	-36.84 **	-36.84 **	-4.04**	-4.04**	-4.04 **	-3.39 **	-16.27 **	-18.46 **	-1.29**	-2.61**	-2.61 **
CSR4 × C-nichi	-18.60 **	-32.69 **	-38.60 **	-1.05	-5.05**	-5.05 **	-6.08 **	-18.20 **	-21.26 **	-2.39**	-2.55**	-4.85 **
CSR4 × Daizo	-18.68 **	-35.09 **	-35.09 **	-1.59	-5.10**	-6.06 **	-9.01 **	-21.60 **	-22.59 **	-1.46**	-1.92**	-3.64 **
CSR4 × CSR2	7.04	2.70	-33.33 **	-3.16**	-1.08	-7.07 **	-2.53 **	-5.28 **	-28.31 **	-0.64	-0.86	-3.10 **

* Significant at 5%; ** Significant at 1%

Table 3: Heterosis (%) among *Bm*NPV infected and uninfected batches of silkworm hybrids for Fecundity

Hybrids	Fecundity					
	Infected			Normal		
	RH	HB	SH	RH	HB	SH
PM × Nistar	1.40	-5.25**	-5.25 **	2.84	-1.88	-24.04 **
PM × C-nichi	-1.18	-3.61*	-3.61 *	3.39*	0.47	-22.22 **
PM × Daizo	0.18	-6.23**	-6.23 **	4.36*	-1.41	-23.68 **
PM × CSR2	3.62*	-6.23**	0	-11.32**	-20.63**	0
PM × CSR4	-0.18	-8.85**	-8.85 **	-12.94**	-22.77**	-22.77 **
Nistari × PM	-2.11	-8.52**	-8.52 **	-3.33*	-7.76**	-28.60 **
Nistari × C-nichi	-2.34	-6.55**	-11.15 **	-4.19*	-5.99**	-31.33 **
Nistari × Daizo	2.45	2.26	-10.82 **	0.26	-0.78	-30.24 **
Nistari × CSR2	7.42**	3.77	-9.84 **	-14.72**	-26.77**	-28.23 **
Nistari × CSR4	4.06*	1.51	-11.80 **	-17.65**	-29.87**	-29.87 **
C-nichi × PM	-3.19	-5.57**	-5.57 **	-4.36**	-7.06**	-28.05 **
C-nichi ×Nistari	1.26	--3.10	-7.87 **	0.89	-1.00	-27.69 **
C-nichi × Daizo	2.52	-1.72	-6.56 **	2.44	-0.50	-27.32 **
C-nichi × CSR2	9.12**	1.03	-3.93 *	-15.44**	-26.21**	-27.69 **
C-nichi × CSR4	6.64**	-0.34	-5.25 **	-16.84**	-28.05**	-28.05 **
Daizo × PM	-7.53**	-13.44**	-13.44 **	-6.35**	-11.53**	-31.51 **
Daizo × Nistari	2.82	2.63	-10.49 **	-0.26	-1.30	-30.60 **
Daizo × C-nichi	-6.83**	-10.69**	-15.08 **	-4.24*	-6.98**	-32.06 **
Daizo × CSR2	7.60**	3.76	-9.51 **	-16.59**	-29.00**	-30.42 **
Daizo × CSR4	4.25*	1.50	-11.48 **	-18.66**	-31.33**	-31.33 **
CSR2 × PM	-1.45	-10.82**	-10.82 **	9.87**	-1.67	-3.64 *
CSR2 × Nistari	3.13	-0.38	-13.44 **	13.85**	-2.23	-4.19 **
CSR2 × C-nichi	-0.19	-7.59**	-12.13 **	13.10**	-1.30	-3.28 *
CSR2 × Daizo	2.92	-0.75	-13.44 **	15.28**	-1.86	-3.83 **
CSR2 × CSR4	2.61	1.59	-16.07 **	3.04*	2.00	2.00
CSR4 × PM	-1.62	-10.16**	-10.16 **	5.75**	-6.19**	-6.19 **
CSR4 × Nistari	5.61**	3.02	-10.49 **	10.37**	-6.01**	-6.01 **
CSR4 × C-nichi	-1.85	-8.28**	-12.79 **	7.16**	-7.29**	-7.29 **
CSR4 × Daizo	3.86*	1.13	-11.80 **	10.46**	-6.74**	-6.74 **
CSR4 × CSR2	5.81**	4.76*	-13.44 **	1.01	0.00	0.00

* Significant at 5%; ** Significant at 1%

(2001) and Sudhakara Rao *et al*. (2001) have observed maternal effect for temperature tolerance among the different crosses involving temperature tolerant breeds. It is also well established that heterotic effects are influenced by the environmental factors and also due to infection with *Bm*NPV as observed in the present study. It is thus concluded that using tolerant breeds like Pure Mysore, C-nichi and Nistari as female parents in commercial crosses can enhance their ability to tolerate *Bm*NPV infection. Further, it indicates that such breeds can be a very good source of tolerance to *Bm*NPV for future breeding programme. Studies on the inheritance of tolerance to *Bm*NPV among few mulberry silkworm breeds indicated that the tolerance to the virus was predominantly additive (Manjunath Gowda, 2008) which can be transferred to other parents through guided crossing and selection.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 188-194

GENETIC FITNESS AND MANIFESTATION OF TRAITS IN SOME GENOTYPES OF THE SILKWORM, *BOMBYX MORI* L. AT DIFFERENT GENERATIONS OF SEED CHANNEL

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ABSTARCT

Behaviour of silkworm *Bombyx mori* L. is greatly influenced by rearing environment, climate, nutrition and management. Rearing performance of parent races SH6, NB4D2, CSR2, CSR4 at P3 and P2 level were far superior than P1 level rearing. The cocoon yield per 100 Dfls and cocoon characters such as single cocoon weight, shell weight and cocoon shell ratio drastically decreased from P3 to P1 level. This decrease was more pronounced during autumn season. The shell weight and shell ratio were most affected characters during autumn season particularly in CSR2 and CSR4 races at P1 level. There was a marked decrease in the cocoon yield in parent races from P3 to P2 and P2 to P1 level. The levels of decrease in cocoon yield from P3 to P1 and P2 to P1 were 39.56% and 34.15% respectively. The egg recovery per kg of cocoons was higher in NB4D2 (63.20g) and CSR2 (63.30g) followed by SH6 race (59.89g). CSR4 recorded lowest egg recovery of 47.90g. SH6 and NB4D2 recorded highest moth longevity while CSR4 had lowest moth life span among the genotypes studied. The quality of mulberry leaf available with P1 seed rearers was the biggest source of variation in cocoon yield and cocoon characters from P3 and P2 to P1 level. Farmers had tree type of mulberry plantation of 10 to 30 years old. No input or cultural operation was provided to these mulberry trees.

Key words: Genetic fitness, Genotypes of silkworm, Heterosis, Moth longivity

INTRODUCTION

Rearing of parent silkworm races is always difficult because parent races are sensitive to changes of environment and are susceptible to diseases. However, vigour of the hybrid genotypes helps them to overcome these problems. The genetic potential of a silkworm genotype is expressed in a good rearing environment with good quality mulberry leaf. Qualitative cocoon characters of silkworm being polygenic in nature tend to express differently in different seasons. Rearing of these silkworms in undesired rearing conditions in successive generations changes the genetic potential of genotypes.

Elite silkworm genotypes such as CSR2, CSR4, CSR5, CSR18 and CSR19 are highly productive breeds and need good quality mulberry leaves with high protein contents and a good rearing environment. Rearing of these genotypes is economical in good rearing environment with perfect hygienic condition and best quality mulberry leaves (Dutta *et al*., 1996). The degree of economic gain in rearing of these genotypes gradually decreases with the inferior conditions of rearing environment (Tonk *et al*., 2006 a,b).

'Doon Valley' in Uttarakhand and Jammu and Kashmir state are predominantly a bivoltine cocoon producing zones. Quality bivoltine cocoons are produced in these area. There are two major silkworm cocoon crops in spring and autumn season. Spring season contributes about 65% in Uttrakhand and more than 90% in J&K of the total cocoon production. Hybrids of these elite silkworm genotypes CSR2 & CSR4 and the traditional races SH6 and NB4D2 are reared to produce silkworm cocoons for raw silk production.

The grand parents (P4, P3 & P2) of these CSR hybrids are reared in most conducive and optimum rearing conditions in the laboratory. Utmost care is taken in selection of the individuals with true phenotypic characters for continuation of generations.

In contrast parents (P1) are reared by the seed farmers of specified area in Dehradun (UA) and Udhampur (J&K) who have comparatively better rearing infrastructure and mulberry plants. Parent silkworm rearing is conducted under the strict supervision of skilled technical staff of sericulture department. But, field rearing is influenced by many biotic and abiotic factors. Rearing environment is not uniform at rearers' level. Rearing performance of a genotype varies considerably among the rearers in the same reason which is influenced by the rearing environment, feed quality and quantity.

This study is undertaken to analyze the rearing performance of CSR parent genotypes together with traditional genotypes SH6 and NB4D2 which are in vogue in the commercial sericulture in Northern India. Cocoon yield, silk yield (cocoon shell ratio) and the reproductive potential which are important parameters for healthy hybrid egg production are focused in this study.

MATERIALS AND METHODS

Behaviour of four silkworm races (*Bombyx mori* L.) SH6, NB4D2, CSR2 and CSR4 were studied at P1, P2 and P3 levels of race maintenance and multiplication during spring and autumn seasons.

Young age silkworm rearing (1st and 2nd instar) of P1 level was conducted centrally at silk farms and third instar larvae were distributed to P1 seed rearers/farmers for conduct of 3rd, 4th and 5th instar rearing with their own resource and mulberry leaf. Ten randomly selected farmer's crops in each race were closely monitored from the day of distribution till completion of rearing in Dehradun (Uttarakhand).

Observations on rearing parameters *viz.,* cocoon yield /100 Dfls, , single cocoon weight, single shell weight, cocoon shell ratio, moth life span, heterosis in hybrids and egg recovery per one kg of cocoon were recorded.

Heterosis study

Two silkworm hybrids namely; CSR4 × CSR2 and SH6 × NB4D2 were selected for the study. The heterosis over mid parent value (MPV) was calculated by following formulae.

$$\text{Heterosis over MPV} = \frac{F1 - MPV}{MPV} \times 100$$

F1 = Hybrid value
MPV = Average of two parents values

Egg production efficiency of silkworm genotypes (grainage parameters)

The egg production efficiency was studied during spring season in Doon valley (Dehradun). Study was conducted during hybrid seed production in commercial grainage involving these genotypes. The egg production efficiency of female moth was considered as reproductive potential of silkworm genotypes. Cocoon: pair ratio percent was indicative of the female moths in cocoon population of genotypes. Similarly, pairs: egg laying ratio and cocoon : egg laying ratio indicated the reproductive potential of female moths. The production of viable and fertilized eggs was finally judged by egg recovery per kilogram of cocoons in hybrid seed production.

RESULTS

Rearing performance of silkworm races at different levels of race multiplication

The present study recorded a drastic reduction in cocoon characters from P3 to P1 level, especially the single cocoon weight, cocoon shell weight and cocoon shell ratio percentage in all the silkworm races (SH6, NB4D2, CSR2, CSR4) studied. The average single cocoon weight in these races ranged from 1.82 to 1.93g at P3, 1.51 to 1.82g at P2 and 1.52 to 1.53g at P1 level during spring season. Almost same trend was followed during autumn season. Similarly, average single cocoon shell weight in these races ranged from 0.387 to 0.44g at P3, 0.30 to 0.445g at P2 and 0.24 to 0.33g at P1 level during spring season. Cocoon shell ratio percentage being racial character was also found decreasing at P1 level in almost all the races and in both seasons. Cocoon shell ratio in CSR2 race decreased from 24.18% at P3 level to 21.05% at P1 level during spring season. Similarly, shell ratio percentage in NB4D2 and SH6 races decreased from 20.21 and 20.69% at P3 level to 17.76 and 17.65% at P1 level during spring season. This decrease in cocoon shell ratio percentage from P3 to P1 level was further intensified during autumn seasons. Number of cocoons per kilogram did not differ significantly between P2 and P3 levels in silkworm genotypes during spring and autumn rearing while, cocoons per kilogram was higher at P1 level in all the genotypes (Table 1).

The fecundity (number of eggs laid by single moth) in CSR2 and CSR4 races gradually decreased from P3 to P2 and P2 to P1 level during spring season. Fecundity in SH6 and NB4D2 races did not show significant variation between P3 and P2. These races surprisingly registered an increase in fecundity at P1 level during spring. Similar trend of gradual decrease in fecundity from P3 to P2 and P2 to P1 was observed during autumn season.

In the present study, a gap of 4.19 and 5.57% were recorded from P2 to P1 and P3 to P1 level in fecundity

character. There were gaps of 14.69 and 17.49% in single cocoon weight from P2 to P1 and P3 to P1 level. Single cocoon shell weight recorded 24.46 and 29.80 % gap at P1 level from P2 and P3 level respectively. The cocoon shell ratio percentage recorded 11.86 decrease from P2 to P1 and 15.16% from P3 to P1 level (Table 1).

The study envisaged a sharp decrease in cocoon yield from P3 and P2 to P1 level of silkworm rearings (Table 2). The cocoon yield at P3 level varied from 65.52 to 72.84 kg in spring and 64.87 to 67.60 kg per 100 Dfls during autumn season . Similarly, the cocoon yield at P2 level varied from 55.24 to 59.80 kg in spring and 62.88 to 70.28 kg during autumn season with a yield gap of 8.21% from P3 level. The cocoon yield at P1 level decreased sharply from P3 and P2 level with yield gap of 39.56% and 34.15% respectively. The cocoon yield at P1 level ranged between 35.92 to 50.28 kg during spring and 32.70 to 44.89 kg during autumn season.

Longevity of moth in different genotypes

The study was undertaken on mated moths of 4 silkworm genotypes and the results are presented in Table 3. The present study revealed that female moths of NB4D2 and SH6 genotypes recorded longest life span of 298 and 272 hours while female moth of CSR2 and CSR4 recorded shorter longevity of 216 and 164 hours respectively. SH6 recorded highest male moth longevity of 219 hours while CSR4 had least longevity of 180 hours. NB4D2 and CSR2 recorded male moth life span of 200 hours. In general, SH6 and NB4D2 recorded highest moth longevity while CSR4 had lowest moth life span among the genotypes studied.

Study of heterosis over mid parent value (MPV) of the silkworm genotypes in their hybrids

The heterosis percentage over MPV for cocoon yield per 100 Dfls, single cocoon weight, single shell weight and cocoon shell ratio percentage were calculated in CSR4 × CSR2 and SH6 × NB4D2 silkworm hybrids (Table 4). Cocoon yield per 100 Dfls showed maximum heterosis over MPV as compared to other characters studied. Single cocoon shell weight also expressed higher heterosis in both the hybrids while cocoon shell ratio percentage showed minimum heterosis of 6.39 and 14.57 in CSR4 × CSR2 and SH6 × NB4D2 respectively.

Expression of higher positive heterosis for cocoon yield, single cocoon weight and single cocoon shell weight in the hybrids indicated the homozygocity in their parent races.

Egg production efficiency of silkworm genotypes

The results are presented in Table 5. The cocoon pair percentage among the races varied from 28.84 (CSR4) to 40.77 (CSR2). SH6 and NB4D2 races recorded 36.94 and 40.17 % cocoon pair ratio. Egg laying ratio percentage varied between 92.72 to 98.62% . CSR4 recorded highest moth pair egg laying ratio percentage while CSR2 recorded lowest. SH6 and NB4D2 recorded around 95% moth pair egg laying ratio percentage.

Cocoon versus egg laying ratio percentage was highest in NB4D2 (38.31%) and lowest in CSR4 (28.44%). SH6 and CSR2 recorded cocoon to egg laying ratio percentage of 35.44 and 37.81% respectively. The egg recovery per kilogram of cocoons was highest in NB4D2 and CSR2 with value of 63.20 g and 63.30 g. SH6 recording 59.80 g egg recovery was third highest while CSR4 was lowest with egg recovery of 47.90g.

The number of unfertilized eggs were more in CSR genotypes during spring and autumn season. CSR4 recorded highest number of unfertilized eggs of 7.94% and 5.97% in spring and autumn season followed by CSR2 of 5.32% and 3.62% during both seasons. CSR5 genotypes recorded lowest unfertilized eggs of 1.97% and 0.95% among CSR races SH6 and NB4D2 genotypes recorded unfertilized eggs to the tune of 1.75% and 1.24% in spring and 1.97% and 0.95% in autumn season respectively.

DISCUSSION

Nutrition is known to play a key role in the larval growth, development and also on the manifestations of economic cocoon characters in silkworm. The major ecological factors namely temperature and relative humidity greatly influence the feeding activity of silkworm (Dutta *et al.,* 1996). The rate of food consumption, larval growth rate, weight gain and survival in insect are influenced by leaf quality (Murugan and Ancy George, 1992).

The present study, recorded a drastic reduction in cocoon characters from P3 to P1 level, especially the single cocoon weight, cocoon shell weight and cocoon shell ratio in all the silkworm races (SH6, NB4D2, CSR2, CSR4) studied.

Cocoon shell ratio percentage though is a racial character, decreased sharply at P1 level in almost all the races, in both seasons. Cocoon shell ratio in CSR2 race decreased from 24.18% at P3 level to 21.05% at P1 level during spring season. Similarly, shell ratio percentage in NB4D2 and SH6 races decreased from 20.21 and 20.69% at P3 level to 17.76 and 17.65% at P1 levels during spring season. Similar decrease in cocoon shell ratio percentage from P3 to P1 level was noticed during autumn seasons. There existed a gap of 14.69% and 17.49% in single cocoon weight from P2 to P1 and P3 to P1 level respectively.

Siddiqui *et al.* (2004) have also noticed similar decrease in cocoon weight and single shell weight from P3 to P1 level in CSR2 and CSR4 races. They reported single cocoon weight of 1.70 and 1.88g at P3 level, 1.68 and 1.67 at P2 level and 1.02 and 1.15g at P1 level in CSR2 and CSR4

races in Doon valley (Uttarakhand), India. Similar decrease in shell weight was noticed by them in these parent races.

A sharp decrease in cocoon shell ratio from P3 to P1 level in silkworm races in present study can be attributed to poor quality of mulberry leaf fed to silkworms during obligatory feeding stage and starvation of 5th instar larvae during facultative feeding period at farmers' level as has been observed by Janarthanan *et al.* (1994).

In the present investigation, the cocoon yield per 100 Dfls at P1 level decreased sharply from P3 and P2 level with yield gap of 39.56% and 34.15% respectively. The cocoon yield at P1 level ranged between 35.92 to 50.28 kg during spring and 32.70 to 44.89 kg during autumn season among the races. The lower cocoon yield realized at P1 farmers' level can be a correlated response of poor rearing environment and poor quality of feed during silkworm rearing at farmers' house. The mulberry leaves available with farmers' were devoid of required moisture and nutrients resulting poor growth in silkworms and lower cocoon weight.

The longevity or life span of silkworm moth has much consequence on reproductive potential of silkworm genotypes and production of viable eggs. Egg producers prefer genotypes with higher life span in male and female. Russian breeders realized the importance of moth longevity in silkworm genotypes. They collected eggs from the mother moths having longer life span more than 10 days, arguing that the progeny would be stronger with higher survival. (Iyengar, 2001).

In the present observation, SH6 and NB4D2 recorded higher moth longevity while CSR4 had lowest which are in conformity with the observation of Shabalina (1994). They reported race specific silkmoth life length varing from 11.91 to 17.17 days in different genotypes of Bombyx mori L. They also established a negative correlation of silk moth life with cocoon weight and also female cocoon shell weight in one of the genotype.

The expression of higher positive heterosis for cocoon yield, cocoon weight, shell weight and poor heterosis for cocoon shell ratio suggests the homozygocity in the parent races. In our observation, cocoon yield recorded highest heterosis of 41.35% and 33.05% respectively for $CSR_4 \times CSR_2$ and $SH_6 \times NB_4D_2$ silkworm hybrids at F_1 rearing over MPV (mid parent value) of P1 parent rearing in the field. Cocoon shell weight was also found to have higher heterosis in both the hybrids closely followed by higher heterosis in single cocoon weight and least in cocoon shell ratio. These observations are in conformity with the observations of Basavaraja (2002). Highest positive heterosis for cocoon yield in both the hybrids in the present study might be due to the poor cocooning percentage in parent races at P1 level. Arnaut De Toledo *et al.* (1995) also reported higher heterosis for cocooning percentage in autumn season (27.98 to 32.04%) than in spring (9.43% to 12.34%).

Silkworm races with higher egg production efficiency are preferred by silkworm egg production centres as they are economical for hybrid silkworm seed production. The egg production efficiency is judged through male and female sex ratio, cocoons to pair percentage, pairs to egg laying ratio, percentage of fertilized eggs and finally the egg recovery by weight per kilogram of green cocoons (Chen, 2000).

The silkworm races SH6, NB4D2 and CSR2 recorded higher fecundity, higher seed recovery and higher male and female moth life span. In contrast CSR4 race recorded lower fecundity, lower seed recovery and lowest male and female moth life span confirming the positive correlation between silkworm seed recovery and moth life span in the present study.

Shankar *et al.* (1999) opined that improvement in grainage parameters could be due to the fact that, organic source of fertilizers provided elements like calcium other than nitrogen which may be needed for synthesis of sulphur containing amino acids like cystine and L methionine, which are essential for the synthesis of chorion and other proteins necessary for embryo and egg shell.

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Table 1: Comparative rearing performance of silkworm races for certain economic characters at different levels of race maintenance and multiplication (Season : Spring)

Genotypes	Fecundity			Single cocoon weight (g)			Single shell weight (g)			Cocoon shell Percentage (%)			No of cocoons per Kg.		
	P_3	P_2	P_1	P_3	P_2	P_1	P_3	P_2	P_1	P_3	P_2	P_1	P_3	P_2	P_1
CSR_2	569	546	400	1.82	1.82	1.52	0.44	0.445	0.32	24.18	24.45	21.05	547	548	654
CSR_4	532	528	410	1.83	1.81	1.53	0.39	0.381	0.33	21.31	21.10	21.57	549	562	674
NB_4D_2	569	561	640	1.93	1.51	1.52	0.39	0.30	0.24	20.21	19.87	17.76	522	661	671
SH_6	577	591	630	1.87	1.65	1.53	0.387	0.33	0.27	20.69	20.00	17.65	536	606	647
Mean	562	557	520	1.86	1.70	1.53	0.402	0.345	0.30	21.61	20.29	19.48	539	594	662
Season : Autumn															
CSR_2	513	522	410	1.78	1.81	1.48	0.432	0.400	0.25	24.27	22.05	16.89	570	566	668
CSR_4	509	510	440	1.78	1.83	1.46	0.376	0.397	0.26	21.10	21.68	17.81	569	561	670
NB_4D_2	597	570	670	1.82	1.85	1.52	0.375	0.389	0.27	20.60	21.00	17.76	560	542	669
SH_6	587	562	608	1.80	1.83	1.49	0.376	0.376	0.25	20.38	20.52	16.78	568	550	659
Mean	552	541	532	1.80	1.83	1.48	0.390	0.391	0.255	21.67	21.37	17.23	567	555	667
Grand Mean	557	549	526	1.83	1.77	1.51	0.396	0.368	0.278	21.64	20.83	18.36			
Yield gap (%)			4.19			14.69			24.46			11.86			
			5.57			17.49			29.80			15.16			

Table 2: Performance of cocoon yield per 100 Dfls at different levels of multiplication and yield gap therein.

Genotypes / Race	Cocoon yield (Kg)					
	P_3		P_2		P_1	
	Spring	Autumn	Spring	Autumn	Spring	Autumn
CSR_2	68.60	64.87	59.80	65.20	50.28	32.70
CSR_4	65.52	65.12	55.24	62.88	40.81	36.75
NB_4D_2	72.84	67.60	55.32	70.28	45.27	40.23
SH_6	70.16	66.06	58.68	68.96	35.92	44.89
Avg. of spring and Autumn	67.60		62.05		40.86	
Yield gap (%)						8.21
						39.56
						34.15

Table 3: Longevity of mated silk moths (*Bombyx mori* L.)

Sl. No	Genotype	Longevity of moth (h)	
		Female (X ± SD)	Male (X ± SD)
1.	SH_6	272 ± 27	219 ± 21
2.	NB_4D_2	298 ± 39	200 ± 20
3.	CSR_2	216 ± 18	200 ± 17
4.	CSR_4	164 ± 15	180 ± 07

Table 4: Expression of heterosis percent (MPV) in silkworm hybrids

Hybrid	Heterosis in rearing and cocoon characters (%)			
	Cocoon yield / 100 Dfls	Single cocoon weight	Single shell weight	Cocoon shell percent
$CSR_4 \times CSR_2$	41.35	10.49	16.22	6.39
$SH_6 \times NB_4D_2$	33.05	8.93	21.97	14.57

Table 5: Egg production efficiency of silkworm genotypes in hybrid seed production

Genotype	Cocoon Pair ratio (%)	Pair : Egg laying ratio percent	Cocoon : Egg laying ratio percent	Egg recovery per kilogram of cocoons (g)	Percentage of unfertilized eggs	
					Spring	Autumn
SH_6	36.94	95.94	35.44	59.80	1.75	1.97
NB_4D_2	40.17	95.39	38.31	63.20	1.24	0.95
CSR_2	40.77	92.72	37.81	63.30	5.32	3.62
CSR_4	28.84	98.62	28.44	47.90	7.94	5.97
Average	36.68	95.67	35.00	58.55	4.06	3.13
SD	5.49	2.42	4.55	7.28		

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 195-198

ANALYSIS OF GENETIC DIVERSITY IN SOME MULTIVOLTINE SILKWORM GENOTYPES OF *BOMBYX MORI* L.

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ABSTRACT

Genetic divergence is one of the useful tools for selection and efficient use of parents for hybridization to develop potential breeds as well as hybrids. The nature and the magnitude of genetic divergence was estimated in twenty one multivoltine silkworm genotypes using Mahalonobis's D^2 – statistic. The genotypes were grouped onto seven clusters showing fair degree of genetic divergence. The cluster III contained the maximum number of genotype and the cluster II and VII contained the single genotype. The highest inter-cluster distance between cluster I and cluster VII followed by between cluster II and cluster VII showing wide diversity among the groups. The inter cluster distance in most of the cases were higher than the intra-cluster distance indicating wider genetic diversity among the genotypes of different groups. The character wise shell%, fecundity, shell weight and cocoon weight showed maximum contribution towards total divergence among the genotypes. Thus based on inter-cluster distances, diverse lines from different clusters (I, II, III, VI and VII) should be chosen for hybridization programme for yield improvement in multivoltine silkworm.

Key words: Genetic divergence, Hybridization, Multivoltine, Silkworm genotypes

INTRODUCTION

In tropical countries like India, multivoltine silkworm strains play important role in the production of silk, since they are well acclimatized to the tropical climatic conditions. Moreover more than ninety percent of the raw silk in India is still coming from multivoltine silkworm hybrids *i.e.,* multi × bi only. Further in West Bengal still in some seasons (June-July and Aug-Sep) multivoltine × multivoltine hybrids are being reared due to harsh climatic conditions prevails in those seasons. Therefore identification multivoltine resource material for effective utilization in hybridization progarmme and other breeding programme is very much necessary.

Assessment of genetic diversity is an essential pre-requisite for identifying potential parents for hybridization. Diverse parents are expected to yield higher frequency of heterotic hybrids in addition to generating a broad spectrum of variability in segregating generations (Marker and Krupakar, 2009). In addition quantitative estimation of genetic diversity guides the breeder for rapid progress of the breeding programme. D^2 statistics is a useful multi varietal statistical tool for effective discrimination among various genotypes on the basis of genetic diversity (Murthy and Arunachalam, 1966). The use of Mahalanobis D^2 statistic for estimating genetic divergence has been emphasized in many crop plants viz., maize (Singh *et al*., 2005), potato (Gaur *et al*., 1978), mung bean (Tommoko, 1991), Sesame (Kumaresan and Nadarajan, 2003), chickpea (Ahmed *et al*., 2002) and Rice (Bose and Pradhan, 2005) and in silkworm *Bombyx mori* L(Jolly *et al.,* 1989; Mukherjee *et al*., 1999; Kumaresan *et al*., 2007; K.Mandal, 2010).The present study was undertaken to analyze the magnititude of genetic diversity among twenty one multivoltine silkworm (*B. mori* L.) genotypes and to select suitable genotypes for further utilization in breeding programme.

MATERIALS AND METHODS

Twenty one multivoltine silkworm comprising of indigenous and evolved genotypes were used for the present study. The data were collected from the six rearing seasons viz., April – May, June – July, August – September, October - November, December - January and Feb.- March for three years were used. Seven economically important quantitative traits viz.,fecundity (FEC), total larval duration (hrs) (TLD), cocoon yield (No.)/10,000 larvae (YLN), cocoon yield (Kg)/10,000 larvae (YWT), cocoon weight (g) (CW), shell weight (g) (SW) and shell % (SR%) were considered. Mahalanobis D^2 (1939) analysis was used to estimate genetic divergence among the twenty one genotypes. Grouping of genotypes into clusters was carried out following Tocher's methods.

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences among the genotypes for all the seven characters indicating the existence of genetic variability among the genotypes studied. Based on genetic distance, twenty one genotypes were grouped into seven clusters (Table 1). Cluster III was the largest having 5 genotypes indicating overall genetic similarity among them, whereas cluster V and VI consisted 4 genotypes each and cluster I and III consisted 3 genotypes each and the remaining cluster had only one genotype. Interestingly the indigenous breed Nistari (Marked) and its sister lines namely Nistari(Plain), Nistari (Shibnivas), Nistari (Chalsa), Nistari (Balapur), Debra (Plain) and Debra (Marked) are distributed in different clusters. This type of distribution *i.e.,* genotypes from the same centre of origin were distributed in different clusters, which may be due to differential adaptation to variable climatic conditions. According to Jolly *et al.* (1989), Siddiqui et al. (1992) silkworm genotypes originating from different geographical regions fell in one cluster while those originating from a single region fell in different clusters. Breeds like Debra (Plain) and Debra (Marked) are in same cluster indicating homogeneity between them and practically they don't show any differences in rearing performance justifying their presence in same cluster. Similarly Nistari (Marked), Sarupat (W) and MKS are in same cluster depicting homogeneity in their quantitative characters. In the same way breeds with in cluster V and VI are shows more or less similar type of rearing performance justifying their presence in same cluster. Out of twenty one genotypes, Sarupat (W) and Nistari (M) are indigenous and sister lines of Nistari are might be made through line selection or adaptive selection. Others are evolved by utilizing these indigenous breeds and bivoltine breeds or other multivoltine. Overall the clustering pattern revealed that the genotypes from different sources clustered together indication that there was no association between indigenous and evolved genotypes and genetic divergence. The possible reason for grouping of genotypes of different types in one cluster could be the unidirectional selection practiced by breeders (Moorthy *et al*., 2007).

The inter and intra cluster distance ($D = \sqrt{D^2}$) values were worked out from divergence analysis and are presented in Table-2. The inter cluster distances were higher than the average intra cluster distances, which indicated wide genetic diversity among the genotypes of different groups than those of same cluster. The highest inter cluster distance was observed between cluster I and VII (D = 13.83) followed by cluster II and VII (D = 11.479), II and VI (9.665) and III and VII (9.292), suggesting more variability in genetic makeup of the genotypes included in these clusters I, II, III, VI and VII. The genotypes belonging to the clusters separated by high statistical distance could be used in hybridization programme for obtaining a wide spectrum of variation among the segregates. In this context, genotypes from cluster I, II, III, VI and VII should be selected as parents in hybridization programme and future breeding programme.

A two dimensional scatter diagram was constructed using the values of the first two canonical vectors, Z_1 and Z_2 as coordinates (Z_1 as X axis and Z_2 as Y axis) for graphic presentation (Fig.1). As per scatter programme the groupings obtained by D^2 analysis are super imposed on two dimensional representations of the entries by canonical analysis. The scatters points on Z_1-Z_2 graph were broadly in an agreement with the magnitude of divergence, measured by D^2 statistic, thus very well corroborating the grouping by Tochers's method.

The results on the contribution of individual characters towards the total divergence (Table-3) suggested that the percent contribution was the highest from shell% (31.43) followed fecundity (23.33), shell weight (21.43), cocoon weight (11.9), yield / 10000 larv.No (6.19), yield / 10000 larv.Wt (4.76) and larval period (0.95).

It has been well established fact that more the genetically diverse parents used in hybridization programme, greater will be the chances of obtaining high heterotic hybrids and broad spectrum variability in segregating generations (Arunachalam, 1984).It has also been observed that the most productive hybrids may come from high yielding parents with a high genetic diversity. Therefore, based upon inter-cluster distances, diverse lines from different clusters (I, III, VI and VII) should be chosen for hybridization programme for yield improvement in multivoltine silkworm.

Table 1: Distribution of 21 multivoltine silkworm genotypes among 7 clusters

Cluster	I	II	III	IV	V	VI	VII
Breeds	Nistari (Marked)	Nistari (Balapur)	M12 (W)	Nistari (Chalsa)	M9A	O	M2
	Sarupat (W)		Debra (P)	M6DP (C)	M2B	M83 (C)	
	MKS		Debra (M)	Nistari (Plain)	CB5	M6M81	
			Nistari (Shibnivas)		OS616	G	
			M15				

Table 2: Average inter and intra cluster distance (D = $\sqrt{}$D2) values.

Cluster	I	II	III	IV	V	VI	VII
I	1.137	1.223	2.307	2.947	6.203	11.052	13.833
II		0	2.846	1.895	5.751	9.665	11.479
III			1.426	2.266	3.827	7.164	9.292
IV				0.974	2.111	4.619	5.581
V					1.287	2.796	2.972
VI						3.933	2.634
VII							0

Table 3: Percentage contribution of characters towards genetic divergence

Characters	Fecundity	Larval. Period (d)	Yield/10000 lar (No)	Yield/10000 lar. (wt_kg)	Cocoon wt (g)	Shell wt (g)	Shell%	Total
Contribution (%)	23.33	0.95	6.19	4.76	11.90	21.43	31.43	100.00

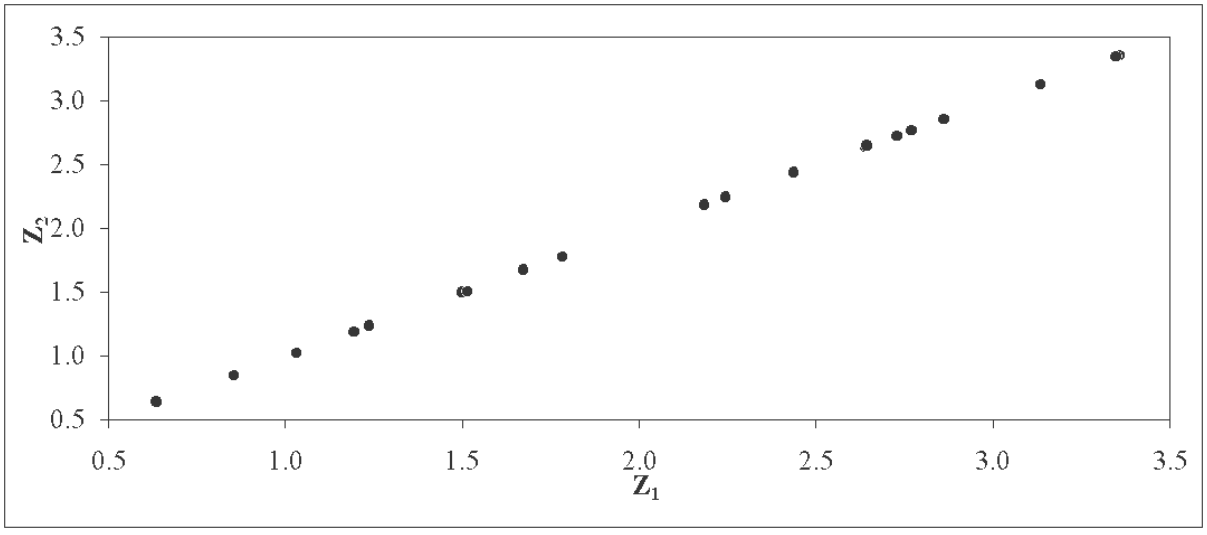


Fig. 1: Two dimensional representations of divergence of 21 multivoltine silkworm genotypes

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 199-203

EVALUATION AND IDENTIFICATION OF IMPROVED POLYVOLTINE × BIVOLTINE HYBRIDS OF THE SILKWORM *BOMBYX MORI* L. THROUGH LARGE SCALE IN-HOUSE TESTING

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ABSTRACT

In the present study six new polyvoltine × bivoltine hybrids developed at Central Sericultural Research and Training Institute (CSRTI), Mysore along with the control hybrid were assessed under large scale in-house testing for the various economic traits. The hybrids evaluated showed significant differences for the economic traits over the control hybrid PM × CSR2. Among the new hybrids evaluated ND7 × CSR2 recorded highest evaluation index value (62.19) followed by NDV6 × CSR2 (57.46). Of the six new hybrids evaluated, ND7 × CSR2 and NDV6 × CSR2 recorded higher improvement over control in respect of cocoon yield (19.87 and 25.35 %), single cocoon weight (10.57 and 10.19 %), cocoon shell weight (29.02 and 17.31 %), cocoon shell (13.43 and 6.59 %), filament length (29.75 and 15.52 %) and raw silk (19.16 and 10.05 %). Overall data indicate the stability in the performance of ND7 × CSR2 and NDV6 × CSR2 compared to other hybrids studied.

Key words: *Bombyx mori ,* Cocoon uniformity, Economic traits, Evaluation index, Silkworm hybrids

INTRODUCTION

The present raw silk production in the country indicates more than 90 % of the mulberry raw silk production in the country depends only on polyvoltine × bivoltine hybrids (Anonymous, 2010). In southern states, raw silk is mainly produced from PM × CSR2. Tazima (1958) opined that the existing polyvoltine breed, Pure Mysore (PM) though a hardy race and withstands varied climatic conditions but spins poor quality cocoons resulting in production of inferior quality raw silk. Hence, he has emphasized the necessity of replacing the PM to bring qualitative and quantitative improvement in sericulture. Several attempts were made earlier to replace the existing PM × CSR2 in the field with many productive polyvoltine × bivoltine hybrids (Ragavendra Rao *et al.,* 2005; Nazia Choudhary and Ravindra Singh, 2006; Ravindra Singh *et al.,* 2006; Dandin *et al.,* 2007; Nirupama *et al.,* 2008; Premalatha *et al.,* 2010). However their full potential has not been exploited with the farmers due to various reasons (Nagaraju *et al*., 1993; Vijayaprakash and Dandin, 2005; Dayananda, 2009). Even though they are known for their productive merit, absence of genetic plasticity to buffer against adverse conditions prevailed in the field acts as a constraint to exploit the full economic potential of these new hybrids (Suresh Kumar *et al*., 2001, 2003a, 2003b and 2003c). A wide and sudden fluctuation in the environment coupled with poor quality of mulberry and management practices by the farmers requires more flexible hybrids. Selection of potential hybrids to serve as commercial exploitation material is one of the pre-requisites contributing to the success of hybrids under the prevailing environment. Proper evaluation of silkworm hybrids under large scale at in-house level helps to critically analyze the most effective hybrid combination in terms of effectiveness, easiness and economic benefit of the new hybrids before choosing them for commercial exploitation.

In this background the present study has been undertaken to evaluate the newly developed productive polyvoltine × bivoltine hybrids under large scale at in-house level as per the simulated conditions of farmers and identify the promising polyvoltine × bivoltine hybrids for commercial exploitation to increase the cocoon production and raising the returns of the farmers to a higher level.

MATERIALS AND METHODS

The six newly developed polyvoltine × bivoltine hybrids of silkworm *Bombyx mori* L. viz., ND7 × CSR2, NP1 × CSR2, NDV6 × CSR2, ND5 × CSR2, AGL3 × CSR2 and AGL5 × CSR2 along with the existing control hybrid, PM × CSR2 were reared thrice at Central Sericultural Research and Training Institute (CSRTI), Mysore during 2008-09 under large scale as per simulated conditions of farmer with a minimum of 50,000 eggs (Equaling to 100 disease free layings) per hybrid in four replications by following shoot rearing technique of Srinivasa Babu *et al.,* (2010) on V1 mulberry leaf and evaluated for their various economic traits. The cocoons were harvested on 6th day of mounting and assessed the next day. Samples of three kg cocoons from each replication were reeled on multiend reeling machine at Silk Reeling Unit of CSRTI, Mysore for assessing the reeling parameters. To assess the uniformity of cocoon shape and size, 100 cocoons were taken at random from each replication. The individual cocoon length and width were measured using Vernier calipers. Cocoon length and breadth uniformity index was calculated by using the following formula (Mano, 1994):

$$\text{Cocoon uniformity Index (\%)} = \frac{\text{Length of cocoon (cm)}}{\text{Width of cocoons (cm)}} \times 100$$

Observations on various economic traits recorded from three rearing trials were pooled together and analyzed statistically by 2way ANOVA using Indo-stat package. Evaluation Indices (E.I) were also determined as per Mano *et al*. (1993):

$$\text{Evaluation Index} = \frac{A - B}{C} \times 10 + 50$$

Where,

A= Value obtained for a particular hybrid combination.

B= Mean value of particular trait of all the hybrids combinations.

C= Standard deviation of particular trait of all the hybrids combinations.

10= Standard Unit.

50= Fixed value

The cocoon indices were analyzed statistically to know the Standard Deviation (SD) and Co-efficient of Variation (CV). Variability in cocoon size was determined on the basis of SD and CV. The batch of cocoons possessing less SD and CV were considered uniform in cocoon shape and size.

RESULTS

Comparative performance and its statistical analysis along with Evaluation Index values of different polyvoltine × bivoltine hybrids combinations are presented in Table 1. Among six hybrids ND7 × CSR2 exhibited maximum average evaluation index value (62.19) followed by NDV6 × CSR2 (57.46) and ND5 × CSR2 (51.77). Results indicated significant variation in most of the parameters among the new hybrids studied.

Survival: The results indicated that the new polyvoltine × bivoltine hybrids Viz., ND7 × CSR2 and NDV6 × CSR2 were superior to other hybrids tested with a survival of 83.59 % and 91.96 % respectively.

Cocoon yield/50,000 egg: The cocoon yield/50000 egg was higher in NDV6 × CSR2 (85.246 kg) followed by ND7 × CSR2 (81.519 kg) compared to 68.009 kg in the control hybrid, PM × CSR2.

Cocoon traits: Single cocoon weight and shell weight were significantly higher in ND7 × CSR2 (2.040 g and 0.449 g) followed by NDV6 × CSR2 (2.033 g and 0.408 g) and ND5 × CSR2 (1.997 g and 0.409 g) as against the cocoon and shell weight of 1.845 g and 0.348 g respectively in the control hybrid, PM × CSR2. The cocoon shell percent was maximum in ND7 × CSR2 (21.37 %) followed by NP1 × CSR2 (21.29 %) and ND5 × CSR2 (20.47 %) where as the minimum cocoon shell percent was recorded for PM × CSR2 (18.84 %).

Reeling traits: The filament length in the hybrids tested was ranged from 827 to 1073 m. ND7 × CSR2 recorded significantly higher filament length of 1073 m followed by ND5 × CSR2 (965 m) and NDV6 × CSR2 (955 m) compared to 827 m in PM × CSR2. Similarly the raw silk percent was ranged from 12.82 to 15.28 %. Significantly higher raw silk percent of 15.28 was recorded in ND7 × CSR2 followed by ND5 × CSR2 (14.58 %) and NDV6 × CSR2 (14.11 %) as against the raw silk percent of 12.82 in the control hybrid, PM × CSR2.

Improvement percent in the performance of new hybrids over the control hybrid, PM × CSR2 are presented in Table 2. ND7 × CSR2 recorded maximum improvement in cocoon yield (19.87 %), cocoon weight (10.57), cocoon shell weight (29.02 %), cocoon shell percent (13.43), filament length (29.75 %) and raw silk percent (19.16 %) over the control hybrid, PM × CSR2. NDV6 × CSR2 and ND5 × CSR2 are also showed considerable improvement in most of the economic traits over the control.

Cocoon size uniformity: Cocoon size variability in the different hybrids studied is presented in Table 3. It is evident from the data that SD on cocoon indices of the hybrids

studied ranged from 5.91 to 8.30 with a minimum value of 6.50 observed for ND5 × CSR2. All the new hybrids studied have exhibited standard deviation less than 8 and their CV % ranged from 3.78 to 4.84 against SD of 8.30 and CV % of 4.80 in PM × CSR2. Cocoons of four hybrids viz., ND5 × CSR2, NP1 × CSR2, NDV6 × CSR2 and ND7 × CSR2 were found comparatively uniform in cocoon size showing standard deviation less than 8 (considered as optimum) and CV % ranging from 3.78 to 4.61.

DISCUSSION

Analysis of data on the basis of multiple traits in the hybrids tested revealed that the hybrid, ND7 × CSR2 with average evaluation index value of 62.19 ranked first among the polyvoltine × bivoltine hybrids tested. Besides to this, the hybrids NDV6 × CSR2 and ND5 × CSR2 were also found promising with an average evaluation index values of 57.46 and 51.77, respectively. Multiple traits evaluation index method of Mano *et al*., 1993 is an important tool for the identification of promising silkworm hybrids. Studies have been made by several workers on the identification of promising polyvoltine × bivoltine hybrids using multiple traits evaluation index method (Vidyunmala *et al*., 1998; Narayanaswamy *et al*., 2002, Gangopadhyay *et al*., 2006; Nazia Choudhary and Ravindra Singh, 2006; Rao *et al*., 2007; Nirupama *et al.,* 2008).

Higher survival, a measure of robustness coupled with higher cocoon weight recorded in the new hybrids tested confers their superiority with regard to tolerance against adverse conditions and consistency in the expression of productivity traits. Cocoon filament length is one of the important economic traits and is considered to have direct bearing on the merit of the hybrid. ND7 × CSR2, NDV6 × CSR2 and ND5 × CSR2 recorded significantly higher filament length among the hybrids tested. Higher values recorded for raw silk percent are due to the recombinant genetic vigor of the breeds utilized in the hybrid preparation.

The less cocoon size variability observed in the hybrids is due to more uniformity of cocoons shape and size, which are important for getting the quality yarn. To obtain uniform filament size especially in auto and semi-automatic reeling machine cocoon size uniformity is very important (Mano, 1994). Cocoon size variability was found less in the new hybrids as indicated by standard deviation for cocoon index, which is within the admissible limit ($\leqslant$ 8.00) and minimum Co-efficient of Variation. The results are in agreement with that of Ravindra Singh *et al*. (1998).

Table 1: Performance of the polyvoltine × bivoltine hybrids of silkworm *Bombyx mori* L. under large scale at in-house testing.

Sl. No.	Hybrid	Survival (%)	Cocoon Yield/50,000 Eggs (kg)	Cocoon Weight (g)	Cocoon Shell Weight (g)	Cocoon Shell Percent	Filament Length (m)	Raw Silk (%)	Average Evaluation Index
1	ND7 × CSR2	83.59 (49.82)	81.519 (61.31)	2.040 (62.33)	0.449 (67.05)	21.37 (61.74)	1073 (67.64)	15.28 (65.45)	62.19
2	NP1 × CSR2	82.85 (47.97)	70.475 (45.15)	1.842 (40.85)	0.392 (49.18)	21.29 (60.73)	897 (43.99)	13.43 (41.99)	47.12
3	NDV6 × CSR2	91.96 (70.75)	85.246 (66.76)	2.033 (61.56)	0.408 (54.27)	20.08 (46.48)	955 (51.80)	14.11 (50.58)	57.46
4	ND5 × CSR2	80.68 (42.54)	71.714 (46.97)	1.997 (57.64)	0.409 (54.45)	20.47 (51.12)	965 (53.11)	14.58 (56.55)	51.77
5	AGL3 × CSR2	81.30 (44.08)	67.710 (41.11)	1.854 (42.15)	0.375 (43.99)	20.25 (48.52)	933 (48.72)	14.01 (49.38)	45.42
6	AGL5 × CSR2	84.84 (52.95)	71.848 (47.16)	1.873 (44.26)	0.381 (45.77)	20.35 (49.60)	943 (50.19)	14.21 (51.86)	48.83
7	PM × CSR2	80.42 (41.89)	68.009 (41.55)	1.845 (41.21)	0.348 (35.28)	18.84 (31.81)	827 (34.56)	12.82 (34.19)	37.21
	Mean	83.66	73.789	1.926	0.395	20.38	942	14.06	
	SD	4.00	6.84	0.09	0.03	0.84	74.28	0.79	
	CD	10.76*	12.59*	0.149**	0.038**	1.40*	108.55*	1.69*	
	SE	3.49	4.09	0.048	0.012	0.45	35.23	0.55	

Values in parentheses are evaluation Indices, * and ** denote significant difference at 5% and 1% respectively

Table 2: Improvement percent in the performance of improved polyvoltine × bivoltine hybrids over control (PM × CSR2) under large scale at in-house testing.

Sl. No.	Hybrid Combination	Survival (%)	Cocoon Yield/50,000 Egg (kg)	Cocoon Weight (g)	Cocoon Shell Weight (g)	Cocoon Shell Percent	Filament Length (m)	Raw Silk (%)
1	ND7 × CSR2	3.94	19.87	10.57	29.02	13.43	29.75	19.16
2	NP1 × CSR2	3.02	3.63	-0.18	12.64	12.98	8.50	1.78
3	NDV6 × CSR2	14.35	25.35	10.19	17.31	6.59	15.52	10.05
4	ND5 × CSR2	0.32	5.45	8.22	17.48	8.67	16.70	13.71
5	AGL3 × CSR2	1.09	-0.44	0.47	7.89	7.51	12.76	9.32
6	AGL5 × CSR2	5.50	5.65	1.53	9.52	7.99	14.07	10.83

Table 3: Cocoon size uniformity in polyvoltine × bivoltine hybrids of the silkworm, *Bombyx mori* L. under large scale at in-house testing.

Sl. No.	Hybrid	Cocoon length (cm)	Cocoon width (cm)	Cocoon length / width ratio	C.V
1	ND7 × CSR2	3.46±0.08	2.06±0.06	167.96±7.75	4.61
2	NP1 × CSR2	3.28±0.12	2.09±0.10	156.69±6.50	4.15
3	NDV6 × CSR2	3.29±0.09	2.06±0.07	160.13±7.24	4.52
4	ND5 × CSR2	3.36±0.11	2.15±0.07	156.37±5.91	3.78
5	AGL3 × CSR2	3.34±0.13	2.07±0.11	161.25±7.80	4.84
6	AGL5 × CSR2	3.36±0.12	2.10±0.08	159.90±7.65	4.78
7	PM × CSR2	3.39±0.09	1.96±0.07	172.96±8.30	4.80

Data are mean ± SD of 100 cocoons and measurement of cocoon width was taken in the central region

Results clearly indicate that, new silkworm hybrid combinations have profound influence in expressing the full potentiality in the field. Evaluating and identifying the promising silkworm hybrid under large scale at in-house level as per the farmers simulated conditions should be the first step before popularization of new hybrids in the field in order to judge the potentiality of the new hybrids in the field. ND7 × CSR2 and NDV6 × CSR2 were found to be significantly superior in most of the quantitative and qualitative traits *viz.,* survival, cocoon yield, cocoon weight, shell weight, shell percent, filament length and raw silk percent over the existing hybrid and hence they can be effectively popularized in the field to increase the silk productivity in India.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 204-215

STUDIES ON SEX DISCRIMINATION BASED ON MOULTING AND SPINNING BEHAVIOUR IN SILKWORM, *BOMBYX MORI* L.

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ABSTRACT

Sex separation is a very crucial operation in the process of silkworm seed production. Over 95% of raw silk production in India is from multivoltine × bivoltine hybrids. The hybrids are produced by crossing the female of multivoltine with the male bivoltine. Use of reci-procal crosses (bivoltine × multivoltine) is not commercially practiced. As a result, half of the bivoltine female and Poly-voltine male components are not being utilized, resulting in huge loss. In the bivoltine hybrid seed production sex separation is resorted to, to ensure quality egg production. Several sex separation techniques at cocoon level (sex-linked cocoon weights, sex limited cocoon colour) and at pupal (pupal sex markings and differential weight) *etc.,* are in practice. Exploiting the principle of differential growth in male and female silkworm larvae, an experiment was under taken to evolve a simple technique for discriminating male and female larvae during moulting (1st, 2nd, 3rd and 4th) and spinning period. During rearing, the larvae were allowed to settle for moult normally. Later, the moulted worms were divided in to four groups based on the time they complete moulting process. At every moult, the appearance of first moulted out larva was considered as 0 h. Thus, the four groups (treatments) contained larvae resumed from 0 - 3 h., 4 - 6 h., 7 - 9 h. and 10 - 12 h., of time. The larvae were continued till completion of cocooning. For observation on spinning larvae, the division of larvae in to four groups was on six hours interval (0 - 6 h; 7 - 12 h; 13 - 18 h and 19 - 24 h). After cocoon harvest, they were cut opened and sex determined. Results revealed maximum number of female (79.89%) in the first batch (treatment, 0 - 3 h) in Nistari. However, NB18 recorded maximum male larvae (82.06%) in the first batch (treatment, 0 - 3 h). Further, the study also established higher moulting rate of female larvae in earlier instars and it gets reversed in later stages. Results are discussed towards development of sex separation technique for seed preparation.

Key words: Moulting behaviour, NB18, Nistari, Seasons, Sex discrimination, Spinning behaviour

INTRODUCTION

In India at present more than 95% of the total of the total silkworm raised for the production of cocoons are the hybrids of indigenous multivoltine females and bivoltine males. Hence, the activity, the separation of males and females to prevent the mating between the individuals of the same parental race is very important in the preparation of correct hybrids. Several techniques were evolved for isolation of male and female with the sole aim of reducing the labour cost and avoiding cutting open of every cocoon rendering the cut cocoons useless for reeling, which fetch less income due to less number of spun silk mills. Benchamin and Nagaraj (1987) reported isolation of male and female larvae at Chawki stage where leaf requirement is very meager such as 0.33%, 1.0% and 5.0% in 1st, 2nd and 3rd instars, respectively. Morohoshi (1957) conducted a study on the developmental trends in male and female larvae of European races *viz*., Diazo, Combodge etc. Reports on the studies of similar nature on the silkworm breeds popularly

used for hybrid laying preparation in various parts of India is found not available. Hence, the present study was undertaken to evolve a economically viable technique for sex discrimination by utilizing the two popular silkworm breeds *viz*., NB_{18} (bivoltine) and Nistari (multivoltine) in Indian conditions

MATERIALS AND METHODS

The experiment was carried out at Central Sericultural Research and Training Institute (CSRTI), Mysore during the year 1991-92 to study the relative developmental trends of female and male larvae during moulting and spinning in the experimental silkworm breeds *viz*., NB18 (bivoltine) and Nistari (most popular multivoltine breed in the state of West Bengal) in three consecutive seasons *viz*., season-1 (S1) November December; season 2 (S2) January February and season 3 (S3) March April. The ecological parameters were recorded inside the rearing room in each treatment /moulting / spinning / breed/season in every six hours a day (Table-1). Silkworm rearing was conducted following the standard method (Krishnaswami, 1990), except temperature and relative humidity levels. One dfl/replication/silkworm breed/moult/spinning/treatment were maintained.

Treatments: The larval populations were grouped into four equal units depending on their moulting duration and were referred to as treatments. The time when first out of moult larva was sighted was counted as "0" hour and from then onwards the duration for each treatment was counted as follows;

0 hours to 3 hours (Treat.-1) Moult-1(MT1)

4 hours to 6 hours (Treat.-2) Moult-2(MT2)

7 hours to 9 hours (Treat.-3) Moult-3(MT3)

10 hours to 12 hours (Treat.-4) Moult-4(MT4)

In case of spinning duration of 24 hours was divided in to four equal time units and were referred to as 'treatments".

0 hours to 6 hours (Treatment-1)

7 hours to 12 hours (Treatment-2)

13 hours to 18 hours (Treatment-3)

19 hours to 24 hours (Treatment-4)

The larvae grouped under each treatment (moulting / spinning) were maintained separately till cocoon formation. On the sixth day of harvest, the cocoons were cut open and assessed for male and female populations in each treatment. The data recorded for rate of moulting and spinning were analysed statistically following the method of analysis of variance and simple percentage values.

RESULTS

The actual ecological conditions recorded in the moulting / spinning environment (in rearing beds) during different seasons are presented in Table-1. The relative developmental trends in female and male populations (treatment wise) on the basis of moulting pattern inbivoltine pure breed NB18 and multivoltine pure breed Nistari are given in Tables 2 - 4.

I A: Moulting rates of Silkworm breedsNB18 and Nistari in different treatments during 1st moult (MT1)

In NB18 breed , the highest moulting rate (30.46%) was recorded with T-1 (0 3 hrs) in season-3 (March April) followed by T-2 (27.62%) in season-2 (January February) and T-2 (27.06%) in season-1 (November December), while the least rate of moulting was recorded with T-1 (22.35%) in season-1 followed by T-1 (22.96%) in season-2 and T-4 (22.14%) during season-3.

In Nistari breed, the highest moulting rate (35.87%) was noticed with T-2 during season-1 followed by T-2 (34.36%) during season-2 and T-2 (33.23%), while the lowest rate of moulting was recorded with T-2 (33.23%) during season-1 followed by T-2 (34.36%) in season-2 and T-4 (35.87%) in season-3.

1B: Moulting rates in female and male larval populations of NB18 and Nistari in different treatments and seasons during 1st moult:

NB18 female larvae: The highest moulting rate in female was recorded in the order of T-1 (63.41%) in season-3 > T-1 (61.01%) in season-2 >T-1 (60.52%) in season-1, while the least rate of moulting was recorded in the order of T-4 (25.55%) in season-1 > T-4 (27.69%) in season-2 > T-4 (28.20% in season-3.

NB18 Male larvae: The maximum moulting rate in male of breed was recorded in the order of T-4 (74.45%) in season-1 > T-4 (72.31%) in season-2 > T-4 (71.80%) in season-3 (71.80%), while the lowest moulting rate was noticed in males in the order of T-1 (39.48%) in season-1 > T-1 (38.99%) in Season-2 > T-1 (36.59%) in season-3.

Nistari female larvae: The highest rate of moulting in females was recorded in the order of T-1 (68.66%) in season-3 > T-2 (94.44%) in season-2 > T-1 (61.44%), while the least rate of moulting was recorded in the order of T-4 (24.32%) in season-1 > T-4 (28.28%) in season-3 >T-3 (35.41%) in season-2.

Nistari male larvae: The maximum rate of moulting in males was recorded in the order of T-4 (75.68%) in season-1 > T-4 (71.72%) in season-3 > T-4 (75.68%) in season-1, while the lowest rate of moulting was recorded in the order of T-2 (05.56%) in season-2>T-1 (33.34%) in season-3> T-1 (38.56%) in season-1.

2A: **Moulting rates with different treatments during II moult in silkworm breeds NB18 and Nistari**

In NB18 breed, the highest rate of moulting was recorded in the order of T-4 (39.55%) in season-3 > T-4 (31.50%) in season-2 > T-3 (30.95%) in season-2, while the lowest rate of moulting was recorded in the order of T-4 (14.69%) in season-3 > T-2 (18.65%) in season-1 > T-2 (19.44%) in season-2.

In Nistari breed, the maximum moulting rate was recorded in the order of T-1 (36.84%) in season-2 > T-1 (31.61%) in season-1 > T-1 (36.84%) in season-2, while the lowest rate of moulting was noticed in the order of T-4 (12.28%) in season-2 > T-4 (18.38%) in season-1 > T-4 (19.62%) in season-3.

2B: Moulting rates in female and male larvae of NB18 and Nistari in different treatments and seasons during II moult

NB18 Female larvae: The highest rate of moulting was recorded in the order of T-1 (73.33%) in season-3> T-1 (67.21%) in season-2 > T-1 (64.55%) in season-1, while the lowest rate of moulting was in the order of T4 (19.23%) in season-3> T-4 (34.37%) in season-2 > T-4 (36.89) in season-1.

NB18 Male larvae: The maximum moulting rate was recorded in the order of T-4 (80.77%) in season-3 > T-4 (65.63%) in season-2 > T-1 (63.11%) in season-1, while the lowest moulting rate was in the order of T-1 (26.67%) in season-3 > T-1 (32.79%) in season-2 > T-1 (34.45%) in season-1.

Nistari female larvae: The highest moulting rate was recorded in the order of T1 (65.30%) in season-1 > T-1 (62.63%) in season-3 > T-1 (57.14%) in season-2, while the lowest rate of moulting was in the order of T1 (31.14%) in season-2 > T-3 (35.71%) in season-1 > T-3 (36.61%) in season-3.

Nistari male larvae: The maximum moulting rate was recorded in the order of T-1 (30.41%) in season-2 > T-1 (30.10%) in season-3 > T-1 (28.61%) in season-1, while the minimum rate of moulting was in the order of T-4 (17.56%) in season-2 > T-4 (21.11%) in season-3 >T-3 (21.68%) in season-1.

3A: Moulting rates of NB18 and Nistari with different treatments during III moult (MT3)

In silkworm breed NB18, the highest rate of moulting showed in the order of T-1 (42.20%) in season-3 > T-1 (31.14%) in season-2 > T-1 (27.15%) in season-1, while the lowest rate of moulting was in the order of T-3 (14.29%) in season-3 > T-3 (21.05%) in season-2 > T-2 (21.85%) in season-1.

In the case of silkworm breed Nistari, the maximum rate of moulting was recorded in the order of T-1 (30.41%) in season-2 > T-1 (30.10%) in serason-3 > T-1 (28.61%) in season-1, while the lowest rate of moulting was in the order of T-4 (17.56%) in season-2 > T-3 (21.11%) in season-3 > T-3 (21.68%) in season-1.

3B: Rates of moulting in female and male larval populations in NB18 and Nistari with in treatments and seasons in III moult (MT3):

NB_{18} Female larvae: The highest moulting rate was recorded in the order of T-1 (67.69%) in season-3 > T-4 (56.25%) in season-1> T-3 (47.91%) in season-2, while the lowest rate of moulting was in the order of T-4 (23.52%) in season-3 > T-1 (29.26%) in season-1 > T-4 (46.55%) in season-2.

NB_{18} Male larvae: The maximum rate of moulting was recorded in the order of T-4 (76.48%) in season-3 > T-1 (70.74%) in season-1 > T-1 (53.53%) in season-2, while the lowest rate of moulting was in the order of T-1 (32.81%) in season-3 > T-4 (43.75%) in season-1 > T-3 (52.09%) in season-1.

Nistari female larvae: The highest rate of moulting was obtained in the order of T-1 (64.64%) in season-1 > T-4 (61.53%) in season-2 > T-1 (58.62%) in season-3, while the lowest was in the order of T-4 (24.44%) in season-1 > T4 (34.61%) in season-1 > T-1 (28.88%) in season-2.

Nistari male: The highest rate of moulting was recorded in the order of T4 (75.56%) in season-1 > T-1 (71.12%) in season-2 > T-4 (65.39%) in season-3, while the lowest was in the order of T-1 (35.38%) in season-1 > T-4 (38.17%) in season-2 > T-4 (41.38%) in season-2.

4A: Moulting rates in female and male larvae in NB18 and Nistari in different treatments and seasons during IV moult (MT4):

In NB18 breed, the highest rate of moulting was pronounced in the order of T-1 (37.90%) in season-3 > T-3 (29.00%) in season-1 > T-1 (28.73%) in season-2, while the lowest was in the order of T2 (15.26%) in season-3 > T-2 (23.26%) in season-1 > T-2 (23.75%) in season-2.

In Nistari breed, the maximum moulting rate was recorded in the order of T-1 (38.84%) in season-2 > T-2 (32.29%) in season-1 > T-1 (29.78%) in season-3, while the lowest was in the order of T2 (14.05%) in season-2 > T-3 (19.49%) in season-3 > T-3 (20.38%) in season-1.

4B: Rate of moulting in female and male larval populations with in the treatments in NB18 and Nistari and seasons during IV moult (MT4):

NB18 female: The highest rate of moulting was recorded in the order of T-1 and T-4 (62.50%) in season-1 and season-3 > T-4 (53.22%) in season-2, while the least was in the order of T-4 (30.23%) in season-3 > T-1 (35.89%) in season-1 > T-2 (40.32%) in season-2.

NB18 male: The maximum rate of moulting was recorded in the order of T-4 (69.77%) in season-3 > T-1 (64.11%) in season-1 > T-2 (59.68%) in season-2, while the lowest was in the order of T-1 and T-4 (37.50%) in season-1 and season-3 > T-4 (46.78%) in season-2.

Nistari female: The highest rate of moulting was recorded in the order of T-1 (70.37%) in season-3 > T-3 (60.00%) in season-2 >T-2 (59.22%) in season-1, while the lowest was in the order of T-4 (26.92%) in season-3 > T-4 (39.02%) in season-1 > T-2 (35.29%) in season-2.

Nistari male: The maximum rate of moulting was obtained in the order of T-4 (73.08%) in serason-3 > T-4 (70.63%) in season-2 > T-1 (60.98%) in seasoin-4, while the lowest was in the order of T-1 (29.63%) in season-3 > T-3 (40.00%) in season-2 > T-2 (40.78%) in season-1.

5A: Moulting /spinning trends in female and male larval populations in different treatments as compared to the total female and male populations, respectively:

NB18 female populations under moult-1 (MT1): The highest rate of moulting was recorded the order of T-1 (34.20%) in season-3 >T-2 (33.12%) in season-1 > T-2 (31.12%) in season-1, while the lowest rate of moultin was in the order of T-4 (14.54%) in season-1 >T-4 (14.56%) in season-3 > T-4 (14.94%) in season-1 >T-4 (14.56%) in season-3 > T-4 (14.94%) in season-2.

NB18 male populations under moult-1 (MT1): the maximum rate of moulting was recorded in the order of T-4 (36.73%) in season-1 > T-4 (33.26%) in season-2 > T-2 (32.33%) in season-1, while the lowest moulting rate was in the order of T-1 (15.69%) in season-3 > T-1 (16.36%) in season-1.

Nistari female population under moult-1 (MT1): The highest rate of molting was recorded in the order of T-2 (39.23%) in season-2 > T-1 (34.74%) in season-1 >T-1 (34.63%) in season-3, while the least rate of moulting was in the order of T-4 (11.89%) in season-1> T-3 (17.59%) in season-3 > T-3 (19.31%) in season-2.

Silkworm breed Nistari male populations under moult-1 (MT-1): The maximum moulting rate was recorded in the order of T-4 (49.44%) in season-3>T-4 (33.57) in season-1 > T-2 (30.78%) in season-2, while the lowest rate of molting was recorded in the order of T-4 (10.99%) in season-2 > T-4 (16.22%) in season-3 > T-3 (18.50%) in season-1.

5 B: Moulting trends in different treatments inSilkworm breeds NB18 and Nistari at moult-2 (MT-2):

NB18 female populations: the highest rate of moulting was recorded in the order of T-3 (40.33%) in season-3 > T-1 (35.57%) in season-2 > T-1 933.87%) in season-1, while the lowest moulting rate was recorded in the order of T-4 (5.72%) in season-3 > T-2 (18.39%) in season-2 > T-2 (19.59%) in season-1.

NB18 male populations: The highest rate of moulting was recorded in the order of T-1 (40.33%) in season-3 > T-4 (35.78%) in season-1 > T-3 (33.79%) in season-3, while the lowest rate of moulting was in the order of T-1 (12.18%) in season-3 > T-1 (14.60%) in season-2 > T-1 (15.86%) in season-1.

Nistari female populations: The highest rate of moulting was recorded in the order of T-3 (43.14%) in season-2 > T-1 (42.50%) in season-1 > T-1 (35.53%) in season-2, while the lowest rate of moulting was in the order of T-4 (13.67%) in season-1 > T-4 (14.31%) in season-2 >T-4 (14.65%) in season-3.

6 A: Moulting trends in different treatments in NB18 and Nistari in moulting-3 (MT-3):

NB18 female populations: The highest rate of moulting was recorded in the order of T-1 (56.15%) in season-3 >T-4 (33.01) in season-1 >T-1 (30.75%) in season-2, while the lowest rate of moulting was in the order of T-3 (12.96%) in season-3 > T-2 (20.24%) in season-1 > T-3 (20.29) in season-2.

NB18 male populations: The highest rate of moulting was recorded in the order of T-1 (34.93%) in season-1>T-1 (31.81%) in season-2 >T-4 (34.18%) in season-3, while the lowest rate of moulting was in the order of T-3 (12.96%) in season-3 > T-2 (20.24%) in season-1 > T-3 (20.29%) in season -2.

Nistari female populations: The highest rate of moulting was in the order of T-1 (38.45%) in season-1 > T-1 (35.67%) in season-3 > T-3 (33.83%) in season-2, while the lowest rate of moulting was in the order of T-4 (13.14%) in season-1 > T-2 (18.32%) in season-2 > T-4 (21.00%) in season-3.

Nistari male populations: the highest rate of moulting was recorded in the order of T-4 (37.33%) in season-1 > T-4 (33.79%) in season-3 >T-1 (32.85%) in season-2, while the lowest rate of moulting was in the order of T-4 (15.13%) in season-2 > T-1 (19.28%) in season-1 > T-2 (20.60%) in season-3.

6B: Moulting trends in different treatments in NB18 and Nistari during 4th moult (MT-4):

NB18 female populations: the highest rate of moulting was recorded in the order of T-1 (50.03%) in season-3, T-4 (32.42%) in season-1 >T-1 (29.20%) in season-3, while the least rate of moulting was in the order of T-4 (13.67%) in season-3 >T-1 (17.70%) in season-1 > T-2 (20.39%) in season-2.

NB18 male populations: The highest rate of moulting was recorded in the order of T-3 (30.4%) in season-3> T-3 (28.79%) in season-1 >T-1 (28.18%) in season-2, while the lowest rate of moulting was in the order of T-3 (15.23%) in season-3 > T-4 (16.95%) in season-1 > T-4 (21.14%) in season-2.

Nistari female populations: The highest rate of moulting was recorded in the order of T-1 (14.30%) in season-3>T-2 (39.17%) in season-1 > T-2 (35.60%) in season-2, while the lowest rate of moulting in the order of T-2 (12.32%) in season-2 > T-4 (15.75%) in season-3 > T-4 (19.44%) in season-1.

N**istari male populations**: The highest rate of moulting was recorded in the order of T-4 (44.63%) in season-2 > T-4 (42.41%) in season-3 > T-1 (30.05%) in season-1, while the lowest rate of moulting was in the order of T-3 (14.63%) in season-2 > T-1 (17.34%) in season-3 >T-3 (20.35%) in season-1.

7: Spinning trends in different treatments in NB18 and Nistari during spinning (SP):

NB18 female populations: The highest rate of spinning was recorded in the order of T-3 (40.02%) in season-3 > T-3 (30.92%) in season-2 > T-3 (27.46%) in season-1, while the least rate of spinning was in the order of T-1 (13.92%) in season-3 > T-1 (18.90%) in season-2 > T-1 (21.49% in season-1.

NB18 male populations: The highest rate of spinning was recorded in the order of T-2 (46.15%) in season-3 > T-1 (36.67%) in season-1> T-1 (31.45%) in season-2, while the lowest rate of spinning was recorded in the order of T-4 (14.36%) in season-3 > T-4 (15.59%) in season-2 > T-4 (16.89%) in season-1.

Nistari female populations: The highest rate of spinning was recorded in the order of T-4 (62.78%) in season-2 > T-2 (34.00%) in season-3 > T-2 (34.30%) in season-1, while the lowest rate of spinning was recoded in the order of T-1 (4.63%) in season-2 > T-1 (15.87%) in season-3 > T-1 (16.02%) in season-1.

Nistari male populations: The highest rate of spinning was recorded in the order T-2 (35.33%) in season-2 > T-2 (33.82%) in season-3 > T-2 (33.40%) in season-1, while the least rate of spinning was in the order of T-4 (14.26%) in season-3 > T-4 (14.67%) in season-1 > T-3 (16.88%) in season-2.

DISCUSSION

Moulting is a very sensitive stage in the growth and development of silkworm, *Bombyx mori* L., and was the target of several general experimentations (Tanaka, 1972; Reynolds, 1980; Choe, 1986, Ramadevi *et al*., 1990; Natarajan, 1991) but the works related to the sex discrimination was found to be meager in abroad (Morohoshi, 1957; Tazima, 1972) and in India. Sex discrimination in silkworm is an essential operation for the production of hybrid layings and works conducted on this line were very meager.

Relative developmental trends in male and female sexes in silkworm were reported to be influenced by genetic compositions, silkworm breeds, seasons and lastly the temperature and relative humidity (Morohoshi, 1957).The experiments conducted by Morohoshi (1957) on European races *viz*., Diazo, Combodge etc., and reported some significant trends in male and female sexes in different developmental stages. The present study was conducted on two most popular silkworm breeds *viz.*, NB_{18} (bivoltine) and Nistari (multivoltine) with regard to their male and female ratios, based on the moulting rates, in all the four moulting stages besides the spinning stage of larvae. The study established the female and male populations occur in 45:55 ratios. The study highlighted the clear trends in the moulting and spinning rates, based on the sex discrimination in both the test breeds under three set conditions and relative humidity. These trends could be exploited to discard the unwanted sex component of a race at the earliest possible stage i.e., 1st moult itself, which means saving of hard labour, money besides judicious use of available rearing space, mulberry leaf etc.

The study also indicated that the maximum number of female larvae (79-89%) in multi-voltine race (Nistari) complete the 1st moulting in first nine hours, from the time of sighting the first out of moult larva. Similarly, about 82-96% of male larvae in bivoltine race (NB18) complete 1st moulting between 4th and 12th hour, when reared under temperature and relative humidity ranges 24^{o} -28^{o} C and 41% to 72% respectively. Further, the study clearly established that the rate of moulting is higher in female larvae in the early instars and get reversed in the later instars. The results are in conformity with the findings of Morohoshi (1957). In the case of male larvae the reversal of trend is observed in the spinning stage.

Based on the above experiment a ready reckoner (Table-7) was developed and it could be explained that in a larval population of 40,000 numbers, 18,000 are females and 22,000 are males (45:55 ratio) out of the 18,000 females 15850 numbers in case Nistari could isolated during the period 0-9 hrs in case of 1st moult in season-1. Similarly, out of 22,000 males, 18400 numbers in case of NB_{18} could be isolated during 4-12 hours of 1st moult.

Economic viability in silkworm seed production is essential and there is a need to cut-down production costs in commercial egg production centres .At present sex

separation is a laborious operation in grainages involving huge expenditure and it is to state that one man day is required for sex separation of every 12,000 to 15,000 pupae (Jolly, 1986). Considering the annual production of hybrid silkworm seed in the country at an estimated 25 crores dfls, the total requirement of male and female cocoons could be 25 and 50 crores, respectively, to be sex separated. Thus with a sex separation efficiency of 12,000 to 15,000 pupae per head (in 8 hours) 50,000 to 62,500 man days are required for the cocoon cutting and sex separation of the male and female pupae required for the production of 25 crores hybrid dfls. Even at a modest rate of Rs. 150/= per man day, it costs our country anywhere between Rs. 75,00,000 to 93,75,000 per annum. By resorting to sex separation based on relative developmental rates of male and female larvae a minimum of Rs. 75,00,000 could be saved besides saving valuable work force, which could be diverted for other essential operations.

Table 1: Temperature and relative humidity recorded in the moulting /spinning beds also in the ambience and during experimental seasons

Observation	S1		S2		S3	
	Temperature °C	Relative humidity (%)	Temperature °C	Relative humidity (%)	Temperature °C	Relative humidity (%)
MT1	26	72	24	41	28	72
MT2	26	67	24	61	28	75
MT3	25	72	24	62	29	66
MT4	24	71	25	58	29	49
Spinning	24	73	28	59	30	48
AMBIENCE						
Maximum	27	--	29	--	31	--
Minimum	24	--	21	--	27	--
Relative humidity (%)	--	68	--	59	--	60
Rain fall (mm)	Nov-Dec	61	Jan-Feb	Nil	Mar-Apr	39

It can be concluded that the method of isolating male and female larvae on the basis of rate of moulting is a simple technique and can easily be popularized among the seed rearers who adopt the new technologies ,if found economical ,very fast .This technique ensures the maximum number of larvae from the desired sex group at a very early stage. The other sex component either could be rejected at the first and second instar level itself, thus saving 50% of the total expenditure on seed rearing. There is a need to conduct these studies with the Silkworm breeds being currently exploited for commercial seed production to confirm the developmental trends in them under varied ecological conditions.

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Table 2: Relative developmental trends in female and male populations (treatment wise) on the basis of moulting pattern in silkworm breeds (NB18 and Nistari) in season-I (November - December)

Observation (Moulting)	Total larvae (No.) *	Race	T-2 (4 -6 hrs)			T-3 (7 – 9 hrs)			T-4 (10 – 14 hrs)					
			Female larvae	Male larvae	Total larvae	Female larvae	Male larvae	Total larvae	Female Larvae	Male Larvae	Total larvae	Female Larvae	Male larvae	Total larvae
MT-1	340	NB_{18}	46 (60.52)	30 (39.48)	76 (22.35)	52 (56.52)	40 (43.48)	92 (27.06)	36 (43.90)	46 (56.10)	82 (24.12)	23 (25.55)	67 (74.45)	90 (26.47)
	319	Nistari	51 (61.44)	32 38.56)	83 (26.02)	54 (50.94)	52 (49.06)	106 (33.23)	25 (44.64)	31 (55.36)	56 (17.55)	18 (24.32)	56 (75.68)	74 (31.50)
MT-2	327	NB_{18}	51 (54.55)	28 (34.45)	79 (24.16)	29 (47.54)	32 (52.43)	61 (18.65)	32 (38.09)	52 (61.91)	84 (25.69)	38 36.89)	65 (63.11)	103 (31.50)
	310	Nistari	64 (65.30)	34 (34.70)	98 (31.61)	36 (50.70)	35 (49.30)	71 (22.90)	30 (35.71)	54 (64.29)	84 (27.10)	21 (36.04)	36 (63.16)	57 (10.30)
MT-3	302	NB_{18}	24 (29.26)	58 (70.74)	82 (27.15)	32 (48.48)	34 (51.52)	66 (21.85)	35 (47.29)	39 (52.71)	74 (24.50)	45 (56.25)	35 (43.75)	80 (26.49)
	346	Nistari	64 (64.64)	35 (35.36)	99 (28.61)	45 (54.87)	37 (45.13)	82 (23.70)	34 (45.33)	41 (54.67)	75 (21.68)	22 (24.44)	68 (75.56)	90 (26.01)
MT-4	331	NB_{18}	28 (35.89)	50 (64.11)	78 (23.57)	31 (40.25)	46 (59.79)	77 (23.26)	45 (46.87)	51 (53.13)	96 (29.06)	50 (62.50)	30 (37.50)	80 (24.17)
	319	Nistari	32 (39.02)	50 (60.98)	82 (25.70)	61 (59.22)	42 (40.78)	103 (32.29)	32 (49.23)	33 (50.77)	65 (20.38)	29 (42.02)	40 (57.98)	69 (21.63)
Spinning	367	NB_{18}	31 (32.63)	64 (67.37)	95 (29.23)	38 (53.52)	33 (46.48)	71 (21.85)	41 (44.56)	51 (55.44)	92 (28.31)	38 (56.71)	29 (43.29)	67 (20.61)
	253	Nistari	20 (33.84)	39 (66.11)	59 (22.32)	43 (48.31)	46 (51.69)	89 (35.18)	30 (53.57)	26 (46.43)	56 (22.13)	31 (63.26)	18 (36.74)	49 (19.37)

*Mean of three replications; Values in parentheses are percentages.

Table 3: Relative developmental trends in female and male populations (treatment wise) on the basis of moulting pattern in silkworm breeds (NB18 and Nistari) in season-II (January - February)

Observation (Moulting)	Total larvae (No.) *	Race	T-1 (0 – 3 hrs)			T-2 (4 -6 hrs)			T-3 (7 – 9 hrs)			T-4 (10 – 14 hrs)		
			Female larvae	Male larvae	Total larvae	Female larvae	Male larvae	Total larvae	Female Larvae	Male Larvae	Total larvae	Female Larvae	Male larvae	Total larvae
MT-1	257	NB_{18}	36 (61.01)	23 (38.99)	59 (22.96)	36 (50.70)	35 (49.38)	71 (27.62)	27 (43.54)	35 (56.96)	62 (24.12)	18 (27.69)	47 (72.31)	65 (25.29)
	195	Nistari	19 (38.00)	32 (62.10)	51 (26.15)	34 (94.44)	33 (85.56)	67 (34.36)	17 (35.41)	31 (64.59)	48 (24.62)	17 (58.62)	12 (41.38)	29 (14.87)
MT-2	252	NB_{18}	41 (67.21)	20 (32.79)	61 (24.20)	21 (42.85)	28 (57.15)	49 (19.44)	32 (41.02)	46 (58.98)	78 (30.95)	22 (34.37)	42 (65.63)	64 (25.40)
	114	Nistari	19 (31.14)	23 (68.86)	42 (36.84)	16 (43.24)	21 (56.76)	37 (32.45)	11 (52.38)	10 (47.62)	21 (??.??)	08 (57.14)	06 (42.38)	14 (12.28)
MT-3	228	NB_{18}	33 (46.47)	28 (53.53)	71 (31.14)	24 (47.05)	27 (52.95)	51 (22.32)	23 (47.91)	25 (52.09)	48 (21.05)	27 (46.53)	31 (53.45)	58 (25.44)
	148	Nistari	13 (28.88)	32 (71.12)	45 (30.41)	12 (32.43)	25 (67.57)	37 (25.00)	18 (45.02)	22 (55.00)	40 (27.03)	16 (61.53)	10 (38.17)	26 (17.56)
MT-4	261	NB_{18}	36 (48.00)	39 (52.00)	75 (28.73)	25 (40.32)	37 (59.68)	62 (23.75)	29 (46.77)	33 (53.23)	62 (23.76)	33 (53.22)	29 (46.78)	62 (23.76)
	121	Nistari	18 (38.29)	29 (61.71)	47 (38.84)	06 (35.29)	11 (64.71)	17 (14.05)	15 (60.00)	10 (40.00)	25 (20.66)	19 (59.37)	13 (70.63)	32 (26.44)
Spinning	266	NB_{18}	24 (34.78)	45 (65.22)	69 (25.94)	32 (44.44)	40 (55.55)	72 (27.07)	38 (52.05)	35 (47.95)	73 (27.44)	30 (57.69)	22 (42.31)	52 (19.55)
	139	Nistari	03 (16.66)	15 (83.34)	18 (12.96)	14 (34.14)	27 (65.86)	41 (29.49)	07 (35.00)	13 (65.00)	20 (14.39)	39 (65.00)	21 (35.00)	60 (43.16)

*Mean of three replications; Values in parentheses are percentages.

Table 4: Relative developmental trends in female and male populations (treatment wise) on the basis of moulting pattern in silkworm breeds (NB18 and Nistari) in season-III (March - April)

Observation (Moulting)	Total larvae (No.) *	Race	T-1 (0 – 3 hrs)			T-2 (4 -6 hrs)			T-3 (7 – 9 hrs)			T-4 (10 – 14 hrs)		
			Female larvae	Male larvae	Total larvae	Female larvae	Male larvae	Total larvae	Female Larvae	Male Larvae	Total larvae	Female Larvae	Male larvae	Total larvae
MT-1	174	NB_{18}	26 (63.41)	15 (36.59)	41 (23.56)	21 (39.62)	32 (60.38)	53 (30.46)	17 (41.46)	24 (58.48)	41 (23.56)	11 (28.20)	28 (71.80)	39 (22.41)
	276	Nistari	46 (68.66)	23 (33.34)	69 (25.10)	35 (58.33)	25 (41.67)	60 (21.73)	23 (47.91)	25 (52.09)	48 (17.39)	28 (28.28)	71 (71.72)	99 (35.87)
MT-2	177	NB_{18}	33 (73.33)	12 (26.67)	45 (25.42)	13 (36.11)	23 (63.89)	36 (20.34)	30 (42.85)	40 (57.15)	70 (39.55)	05 (19.23)	21 (80.77)	26 (14.69)
	270	Nistari	57 (62.63)	34 (37.37)	91 (33.70)	29 (52.72)	26 (47.28)	55 (20.37)	26 (36.61)	45 (63.39)	71 (26.30)	20 (37.73)	33 (62.27)	53 (19.62)
MT-3	154	NB_{18}	44 (67.69)	21 (32.31)	65 (42.20)	14 (42.42)	19 (57.58)	33 (22.43)	12 (54.54)	10 (45.46)	22 (14.29)	08 (23.52)	26 (76.48)	34 (22.08)
	289	Nistari	51 (53.62)	36 (41.38)	87 (20.10)	31 (49.20)	32 (50.80)	63 (21.80)	27 (44.26)	34 (55.74)	61 (21.11)	27 (34.51)	51 (65.39)	78 (26.99)
MT-4	190	NB_{18}	45 (62.50)	27 (37.50)	72 (37.90)	18 (39.13)	28 (60.87)	46 (24.21)	14 (48.27)	15 (51.73)	29 (15.76)	13 (30.23)	30 (69.71)	43 (22.53)
	272	Nistari	57 (70.37)	24 (29.63)	81 (29.78)	33 (55.00)	27 (45.00)	60 (22.06)	25 (47.16)	28 (52.84)	53 (19.49)	21 (26.92)	57 (73.08)	78 (28.67)
Spinning	207	NB_{18}	16 (38.09)	26 (61.91)	42 (20.29)	25 (34.24)	48 (65.76)	73 (35.27)	36 (65.45)	19 (34.55)	55 (26.57)	23 (62.16)	14 (37.84)	37 (17.87)
	258	Nistari	19 (30.15)	44 (69.35)	63 (24.42)	42 (47.19)	47 (52.41)	89 (34.50)	30 (53.57)	26 (46.43)	56 (21.52)	31 (63.00)	19 (38.00)	50 (19.37)

*Mean of three replications; Values in parentheses are percentages.

Table 5: Moulting trends- Interactions among test breeds, treatments and seasons in 1st, 2nd, 3rd and 4th moults (out of total female and male larval populations)

Race/Treatment	MT-1			MT-2			MT-3			MT-4		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
T-1 (0-3 hrs)												
NB_{18} Male	29.40	31.12	34.20	33.87	35.57	40.33	17.64	30.75	56.15	17.70	29.20	50.03
Female	16.26	16.39	15.69	15.86	14.60	12.18	34.93	31.81	27.65	28.41	28.18	26.93
Nistari Male	34.74	21.96	34.64	42.53	35.53	43.14	38.45	20.55	35.67	20.34	27.38	41.30
Female	18.60	29.11	16.22	21.61	37.73	24.07	19.28	32.85	22.77	30.05	44.63	17.34
T-2 (4 -6 hrs)												
NB_{18} Male	33.12	30.89	28.03	19.59	18.39	16.46	23.82	22.18	18.46	20.17	20.39	19.88
Female	21.85	25.40	32.33	18.45	20.66	24.24	20.44	22.48	25.21	25.85	26.66	27.37
Nistari Male	36.53	39.23	26.18	23.75	29.76	22.47	25.53	21.86	15.10	39.17	12.32	24.06
Female	29.33	30.78	17.17	21.89	34.92	19.41	23.43	20.29	12.96	25.00	21.74	19.56
T-3 (7-9 hrs)												
NB18 Male	22.94	23.05	23.21	21.43	27.43	37.49	25.53	21.86	15.10	29.71	24.54	16.42
Female	25.06	24.95	23.94	29.91	33.79	42.09	23.43	20.29	12.96	28.79	24.02	15.23
Nistari Male	16.84	19.31	17.59	20.05	20.40	19.74	20.84	33.88	21.30	21.05	24.70	18.69
Female	18.50	29.12	17.17	33.98	15.90	32.67	22.82	26.53	22.84	20.35	14.63	20.89
T-4 (10-12 hrs)												
NB18 Male	14.54	14.94	14.56	25.11	18.61	5.72	33.01	25.21	10.29	32.42	25.87	13.67
Female	38.73	33.26	28.04	35.78	30.95	21.49	21.20	25.42	34.18	16.95	21.14	30.47
Nistari Male	11.89	19.50	21.59	13.67	14.31	14.65	13.14	27.39	21.00	32.42	25.87	30.47
Female	33.57	10.99	49.44	22.52	11.45	23.65	37.33	15.13	33.79	16.95	21.14	13.67

S. E. : 1.627; C.D: 4.51

Table 6: Spinning trends-Interactions among test breeds, treatments and seasons in spinning with different moulting larval population (out of total larval populations)

Race/Treatment	MT-1			MT-2			MT-3			MT-4		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
T-1 (0-6 hrs)												
NB_{18} Male	13.60	14.13	15.07	15.56	16.27	18.45	7.93	14.48	25.50	8.28	13.67	23.08
Female	8.80	8.95	8.79	8.56	7.91	6.60	19.11	16.82	13.65	15.26	15.12	14.47
Nistari Male	16.28	9.92	16.71	20.79	16.46	20.85	18.33	8.48	17.03	9.85	10.03	20.58
Female	9.91	16.05	8.42	11.03	20.58	12.34	10.01	19.40	11.78	15.57	22.80	8.72
T-2 (7 -12 hrs)												
NB_{18} Male	15.30	14.03	12.35	9.00	8.41	7.54	10.74	10.38	9.27	9.29	9.47	9.26
Female	11.73	13.85	18.08	9.97	11.21	13.15	11.28	11.93	12.51	13.88	14.25	14.60
Nistari Male	16.83	17.64	12.54	11.59	14.25	10.83	13.12	7.19	10.39	18.95	6.18	12.01
Female	15.87	16.90	8.90	11.22	18.37	10.12	10.77	14.10	10.90	12.89	10.88	9.86
T-3 (13-18 hrs)												
NB18 Male	10.58	10.46	10.23	9.84	12.55	17.17	11.50	10.22	7.48	13.72	11.27	7.46
Female	13.51	13.62	13.37	16.17	18.34	22.79	12.89	10.80	6.46	15.42	12.84	8.15
Nistari Male	7.86	8.73	8.45	9.79	9.63	9.51	9.93	14.96	9.71	10.16	11.79	9.30
Female	9.85	15.87	8.91	17.37	8.46	17.01	11.93	16.05	12.41	10.45	7.71	10.57
T-4 (19-24 hrs)												
NB18 Male	6.74	6.80	6.40	11.54	8.52	2.61	14.96	11.90	5.24	15.09	12.08	6.38
Female	19.74	18.16	15.71	19.36	16.79	11.69	11.60	13.47	16.89	9.06	11.30	16.60
Nistari Male	5.62	8.73	10.30	6.68	6.71	7.08	6.25	11.72	9.53	9.37	17.71	7.72
Female	17.28	6.16	25.77	11.53	5.54	12.26	19.55	8.10	18.26	12.76	9.90	21.24

S. E. :	1.8012	2.016	1.485
C.D.:	2.55	2.861	2.099

Table 7: Time schedule to obtain above 70% of the total female population in multivoltine breeds Nistari and male populations in bivoltine breeds NB_{18} in different moults and spinning stages, respectively. (duration counted for the time of sighting the first out moult / spinning larva).

Stage of development	Temperature (°C)	Relative humidity (%)	Nistari Female	NB_{18} Male
1st Moult	26 (S_1)	72	0-9 hrs (88.11%)	4-12 hrs 83.64%)
	24 (S_2)	41	0-9 hrs (80.50%)	4-12 hrs (83.61%)
	28 (S_3)	72	0-9 hrs (80.41%)	4-12 hrs (84.30%)
2nd Moult	26 (S_1)	67	0-9 hrs (86.33%)	4-12 hrs (84.14%)
	24 (S_2)	61	0-9 hrs (85.69%)	4-12 hrs (85.40%)
	28 (S_3)	75	0-9 hrs (85.35%)	4-12 hrs (87.82%)
3rd moult	25 (S_1)	72	0-9 hrs (86.86%)	0-9 hrs (78.80%)
	24 (S_2)	62	4-12 hrs (79.54%)	0-9 hrs (74.58%)
	29 (S_3)	66	0-9 hrs (79.00%)	4-12 hrs (72.35%)
4th Moult	25 (S_1)	71	0-9 hrs (80.56%)	0-9 hrs (83.05%)
	25 (S_2)	58	4-12 hrs (72.62%)	0-9 hrs (78.86%)
	29 (S_3)	49	0-9 hrs (84.25%)	4-12 hrs (73.07%)
Spinning	24 (S_1)	73	7-24 hrs (83.98%)	0-18 hrs (83.11%)
	28 (S_2)	59	7-24 hrs (95.37%)	0-18 hrs (84.81%)
	30 (S_3)	48	7-24 hrs (84.13%)	0-18 hrs (85.64%)

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 216-217

DEVELOPMENT OF A SIMPLE LOW COST HEATING DEVICE FOR SILKWORM REARING HOUSE

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ABSTRACT

Getting an excellent silkworm cocoon crop is always the dream of sericulturist. A bumper crop is a result of interplay of many parameters like good seed nutritions mulberry leaf, ideal environmental conditions and better management level. In developing countries particularly under high altitude conditions, with frequent interruption of electricity, the task of increasing and maintaining a temperature of about 24-26°C during winter months using electrical equipments is extremely difficult and expensive. In comparison to chawki rearing room, maintaining optimum temperature and humidity levels for IV and V age rearing is some what difficult as its scale of operation is larger in the latter. Considering this difficulty, an innovative device consisted of a perforated earthen pot with a lid and a base and in which wood charcoal was used for heating purpose. This device helped to increase the temperature from 20°C to 26°C and even more. It has many advantages over electrical methods. It is of low cost, has simple operational efficiency and affordable by small and marginal farmers also. The paper describes this device and operational details connected with it.

Key Words : Cost effective, Heating device, Silkworm rearing, Temperature maintenance

INTRODUCTION

Getting an excellent cocoon crop is always the dream of every sericulturist. A bumper crop is a result of interplay of many parameters like good mulberry leaf, ideal environmental conditions, healthy parental seed, careful management *etc*. Maintaining the optimum temperature of 27-28ºC during chawkie stage and 24-25ºC during later instars is the main prerequisite which significantly contributes to the robust growth of silkworms. (Krishnaswami, 1990) During winter months when the atmospheric temperature is less, it is necessary to increase the temperature of the rearing house artificially by a reliable methods. A reliable heating instrument is essential for this. Electric room heaters are quite good but they need continuous supply of electric power. With frequent fluctuation in voltage and power failure in rural areas electric heaters are not reliable. With power failure, temperature in the rearing house comes down which affects the larval growth. In addition to this, the heaters also need regular servicing for which farmers have to depend on cities. Keeping these difficulties in mind, a simple, low cost maintenance free device is innovated and practiced at our unit to increase the temperature inside the silkworm rearing house (Fig. 1).

MATERIALS AND METHODS

It is an ordinary earthen pot of about one foot height with a capacity to hold 2 to 2.5 kilograms of wood charcoal pieces. The pot is placed on an earthen ring and its mouth is covered by an earthen plate as shown in the Fig. 1. Small holes are made on the surface of the pot while making the pot. It costs about 20 to 25 rupees per set and with careful handling lasts for many months.

Usage: Keep the pot outside the rearing house and fill it with dry charcoal pieces. Using small quantity of kerosene ignite the charcoal pieces till all of them glow to red hot. Transfer the pot to the rearing room and keep its mouth covered. The glowing charcoal gradually releases the heat over a period of 8-10 hours during which time the pot need not be disturbed. Then by using a thick cloth piece take the pot out side, shake it well so that all the ash formed in the pot goes out leaving behind few hot glowing pieces of charcoal inside the pot. Now once again fill the pot with fresh charcoal pieces, bring it back to the rearing room and keep its mouth covered. This

Table 1: Temperature recorded inside and outside of adult age rearing room over five years period

Year	Maximum average temperature outside the room (°C)	Average temperature inside the rearing room (°C)	Difference in temp. (°C)
2005	21.62 ± 0.42	25.15 ± 0.23	3.53 ± 0.30***
2006	21.68 ± 0.60	24.85 ± 0.20	3.18 ± 0.66**
2007	21.83 ± 0.77	24.98 ± 0.28	3.15 ± 1.03*
2008	21.53 ± 058	24.88 ± 0.38	3.35 ± 0.62**
2009	22.02 ± 0.70	24.72 ± 0.30	2.70 ± 0.89*

*P<0.05, **P<0.01, ***P<0.001 (Paired t test)

process to be repeated till the rearing is complete. Use some pieces of glowing charcoal from the first pot to extend the number of pots. Continuous smoke coming from the pot indicates the presence of half burnt wooden pieces in the pot. So care should be taken while filling the pot that such half burnt wooden pieces are not used. And also wet pieces of charcoal should not be used as they will take long time for glowing and start emanating smoke. If the size of the rearing house is bigger and outside temperature is too low, more number of such pots are required. After completion of the rearing, wash the pots in plain water and keep dry.

RESULTS AND DISCUSSION

The mean temperature recorded in the rearing room for vth age silkworms over five years period is presented in Table 1. One such pot is able to increase the temperature of a room of size 15 feet × 12 feet by 3-4°C. The increase in temperature was found to be significant to highly significant over five years period.

Low cost options for energy are advocated even in Tissue culture (Ahloowalia and Savangikar, 2002). Hence work on that direction is not irrelevant. Some information is available on the low cost heating devices for silkworm rearing.

Sreekumar *et al*., (1993) suggested passing hot smoke through a metallic pipe running through the rearing room. This device needs continuous attention throughout the night to burn the firewood and send the hot smoke through the pipe. In the present device, some advantages are noticed such as 1) depending on the degree of increase required in the temperature, no of pots may be increased or decreased in number. 2) Continuous attention is not required.3) No cost is involved in servicing the device as it consists of washing in water. 4) Low cost compared to Electrical equipments as 8 hours burning costs about Rs. 25 against Rs. 50.00 for



Fig. 1: Low cost heating device

electrical equipment. This device has been found to be highly dependable and very effective in increasing the temperature of the Silkworm rearing house over many years.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 218-222

STUDIES ON LONG TERM REFRIGERATION OF POLYVOTINE EGGS OF THE SILKWORM, *BOMBYX MORI* L. FOR TROPICS.

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ABSTRACT

The threshold period of refrigeration of selected polyvotine eggs *viz.*, Nistari, MY1, Nistid, MU303, Thai, Sarupat, MH1 and PM in cold storage after 24-30, 36-42 and 48-50 hours of oviposition under the tropical condition were identified. Silkworm eggs of pure races can be cold stored for a longer time by adopting a two-step refrigeration method. Further it is also inferred that early stage layings can be cold stored for longer duration. Among the nine polyvotine races studied, except in Nistari (w) the safe period of cold storage is between 30 to 45 days. As the age of the embryo advances, the safe period of preservation comes down by 5-10 days depending upon the race. Among the polyvotine studied, it is observed that MH1, MU303, Sarupat, Nistid, and Thai have higher cold tolerance than Nistari (w), Nistari (gy), MY1 and PM. The hatching of eggs obtained >90 % in all the batches under study.

Key words: *Bombyx mori*, Hatching percentage, Oviposition, Polyvotine eggs, Refrigeration, Safe period.

INTRODUCTION

Sericultural activities in tropical countries like India are practiced throughout the year irrespective of the season. Preparation of sufficient quantity of seeds during favourable seasons, processing them under optimum conditions and preservation in the cold storage by manipulation of environmental conditions followed by releasing of layings at the time of demand is an area which needs greater emphasis (Hurkadli *et al.*, 1998).

Silkworm eggs are usually preserved under cold conditions by employing refrigeration techniques and different methods of refrigeration have been recommended for univoltine, bivoltine and polyvotine races (Seijiro Morohoshi, 1959). In non-diapause or polyvotine silkworm eggs, embryonic development is uninterrupted and completes by the ninth day after oviposition under proper incubation (Datta, 1988; Hiratsuka, 1975) and hatching of eggs takes place on the 10th day. Hatching of silkworm eggs can be delayed by employing refrigeration (Narayanaswamy and Govindan, 1987). Eggs of polyvotine breeds of silkworm cannot be refrigerated for longer duration, as they cannot tolerate the cold conditions, because of lack of biochemical mechanisms particularly glycerol metabolism (Chandrashekar and Geetha Bali, 1987). However, it is established that the polyvotine eggs can be preserved at 5°C for 20 days without affecting the rearing characters (Hiratsuka, 1975).

In practice and as per the government of Karnataka (Mysore) order (Anonymous, 1956), the crossbreed silkworm eggs are cold stored for a maximum period of 20 days. In the recent past, prolonged refrigeration of polyvotine silkworm eggs beyond 20 days has been attempted and the effect of refrigeration on hatching and subsequent rearings was studied by many researchers (Datta *et al.*, 1972; Narayanaswamy and Govindan, 1987; Tayade *et al.*, 1987, Anonymous, 1989 and Hurkadli *et al.*, 1998). At present, during demand season it is not possible to meet the requirement of polyvotine and cross breed silkworm eggs to the farmers. Realizing the lacunae and its importance, the present study was undertaken on the eggs of silkworm race viz., Nistari, MY1, Nistid, MU303, Thai, Sarupat, MH1 and PM to workout the threshold period of refrigeration of these non-hibernating polyvotine eggs in cold storage after different hours of oviposition so as to obtain normal hatching and overall rearing performance under the prevailing tropical condition by adopting a two step refrigeration method.

MATERIALS AND METHODS

Nine polyvotine breeds *viz*., Nistari, MY1, Nistid, MU303, Thai, Sarupat, MH1 and PM were raised in the laboratory. Seed cocoons were processed, preserved and disease free layings (dfls) were prepared as per the standard procedure (Narasimhanna, 1988).

The pure layings of the selected nine polyvotines were divided into five batches based on the duration after oviposition and embryonic stage. The above five batches of layings were categorized into 3 groups *viz*., dfls of 24-30 hrs, 36-42 hrs and 48-50 hrs of oviposition. These layings were refrigerated in the cold storage at 5 °C for a period of 18 days by passing through intermediate temperatures of 20 °C for 1h, 15 °C for 2hrs and 10 °C for 2hrs. Thereafter, layings of respective combinations were transferred to 15 °C through intermediate care (10 °C for 3 hrs) and preserved for 2 days, followed by re-refrigeration of the dfls at 2.5 °C upto 90 days. 75 ± 5 % of relative humidity was always maintained throughout the preservation period. From 2.5 °C, the layings were released in batches once in 5 days through 5 °C (2 hrs), 10 °C (2 hrs) and 15 °C (1 hr) and were incubated following standard practice. Silkworm eggs without refrigeration served as control. The experiments were repeated five times with three replications of 20 dfls each. On the 8th day at pinhead stage, layings were black boxed for two days and on the 10th day they were exposed to normal light at 8 AM to 10 AM for hatching. The numbers of hatched, unfertilized and dead eggs were visually counted and the hatching percentage was calculated.

RESULTS

The results on the hatching percentage of the eggs of nine polyvotine races are presented in the table 1, 2, 3 and 4. Hatching percentage in the pure polyvotine races varied significantly between different periods of refrigeration at 2.5 °C.

Eggs of 24-30hrs oviposition

In MU303 hatching was 95.30 % in the control batch while in experimental batches, the percentage of hatching was significantly less when the refrigeration was beyond 35 days (Table 1). The hatching percentage in the batch refrigerated for 35 days at 5 °C and 2.5 ° C was on par with the control (94.9 %). In MY1 no significant difference was observed in the hatching percentage in the batches refrigerated up to 30 days. Beyond which there was a significant decrease in the hatching percentage (95.7 % in control and 94.4 % in 30 days). In Nistari (w), although significant decrease in the hatching percentage was recorded in all the refrigerated batches when compared to control (97.15 %), the hatching was appreciably high (>94 %) up to 35 days. In Sarupat no significant difference in hatching percentage was observed in 35 days refrigerated batch(93.6 %), compared to the control (95 %), while in the remaining batches the hatching percentage decreased. In Thai, significant decrease in the percentage of hatching was observed in the batches refrigerated beyond 35 days. While in 35 days batch (95.95 %), hatching was on par with the control (97.53 %). Nistari (gy) eggs refrigerated beyond 30 days exhibited decreased hatching (95.2 % and control 96.15 %) whereas refrigeration of Nistid eggs up to 35 days did not show significant difference in hatching percentage. Further, the MH1 batches refrigerated for a period of 35 days did not show significant variations (96.5 %) in hatching when compared to control (96.15 %). Though hatching of eggs at 40 days of preservation was as high as 93.5 %, it decreased significantly with further cold storage. In PM, hatching was 94.58 % in control batch, while batches refrigerated beyond 30 days, the percentage of hatching significantly decreased.

Eggs of 36 - 42hrs oviposition

In the batches refrigerated after 36-42 hrs of oviposition, the results (Table 2) indicate that in almost all the test races there is a slight decrease in the cold tolerance. In MU303, compared to 24-30 hrs of oviposition, the hatching percentage was 92.4 at 30 days of refrigeration, which is on par with the control. Similarly in MY1, Sarupat, Thai, Nistari (gy), Nistid and PM maximum percentage of hatching was observed in 25, 30, 25, 30, 30 and 25 days of refrigeration respectively**.** However, in MH1 and Nistari (w) no difference in cold tolerance was observed. The hatching percentage was on par with the control in the batches refrigerated for 35 days and 18 days respectively.

Eggs of 48 - 50hrs oviposition

Similar trend of reduced cold tolerance was observed in almost all the races studied when refrigeration of eggs was carried out at the later stages of development (48 - 50hrs). In MU303, MY1, Nistari (w), Sarupat, Thai, Nistid and PM compared to their respective control batches the layings refrigerated for more than 25 day exhibited significantly less hatching (Table 3).

DISCUSSION

Refrigeration of silkworm eggs is an indispensable activity in sericulture. Depending upon of the type of eggs *viz.*, bivoltine and polyvotine, period of cold preservation and also the stage of preservation vary and play an important role (Tazima, 1978). The cold tolerance in silkworms mainly depends on the biochemical status of the eggs, particularly with reference to glycogen and sorbitol levels (Chandrashekar and Geethbali, 1987). Compared to bivoltine the glycogen level in polyvotine is low because of which polyvotines have poor cold tolerance than bivoltines.

Table 1: Hatching performance of long term cold stored polyvoltine layings at 24- 30 hours of oviposition.

Race	Duration of refrigeration (days) at 5° C and 2.5°C (total period)													NC	F Test	CD at 5 %
	C-18d	25d	30d	35d	40d	45d	50d	55d	60d	65d	70d	75d	80d			
MU 303	95.0	94.1	93.9	94.9	91.3	90.7	89.8	87.7	85.1	83.9	83.0	81.2	79.9	95.3	**S**	1.12
MY1	95.6	94.8	94.4	92.4	91.7	91.1	89.8	87.7	85.1	82.4	82.4	80.4	77.7	95.7	**S**	2.59
Nistari (W)	97.0	94.7	94.4	94.1	92.9	92.1	90.2	89.0	87.8	85.3	84.4	79.7	76.1	97.2	**S**	2.06
Sarupat	93.8	95.7	94.1	93.6	90.4	90.0	87.7	86.9	85.4	83.1	80.2	75.4	74.4	95.0	**S**	3.38
Thai	96.9	96.1	95.6	96.0	92.4	91.6	89.5	88.9	85.2	82.3	80.9	75.1	70.4	97.5	**S**	1.90
Nistari (GY)	96.2	95.5	95.2	93.6	93.3	92.6	91.9	89.4	88.9	88.7	86.2	82.5	79.1	96.2	**S**	1.46
Nistid	96.5	95.2	94.7	93.5	92.0	91.4	89.1	82.6	78.9	75.4	72.4	70.2	68.6	94.4	**S**	1.51
MH1	97.5	97.0	96.0	96.5	93.5	94.0	90.0	85.0	84.2	80.4	78.3	77.0	76.3	96.2	**S**	3.25
PM	94.9	94.6	92.9	90.2	90.8	89.9	89.0	87.7	85.1	82.8	82.5	80.6	77.9	94.6	**S**	2.04

S-Significant, d- days, NC- Normal Control

Table 2: Hatching performance of long term cold stored polyvoltine layings at 36- 42 hours of oviposition.

Race	Duration of refrigeration (days) at 5°C and 2.5°C (total period)													NC	F Test	CD at 5 %
	C-18d	25d	30d	35d	40d	45d	50d	55d	60d	65d	70d	75d	80d			
MU 303	94.3	94.0	92.4	91.5	91.5	90.2	89.2	86.9	84.4	81.8	81.1	76.2	73.9	94.3	**S**	1.92
MY1	94.5	94.4	93.1	92.4	90.2	89.2	87.7	86.2	84.1	80.5	77.6	72.0	71.2	94.9	**S**	1.47
Nistari (W)	94.3	93.8	93.9	91.9	91.3	88.7	86.4	84.7	82.1	81.2	79.9	76.9	66.2	95.9	**S**	1.52
Sarupat	94.2	93.3	92.5	91.6	91.0	88.9	88.7	85.6	83.1	81.3	78.8	74.2	70.3	94.7	**S**	2.27
Thai	94.0	94.0	93.1	92.2	91.1	89.0	88.3	84.4	81.7	80.6	76.5	72.8	68.8	95.6	**S**	1.68
Nistari (GY)	93.7	93.3	92.6	91.8	91.6	91.1	88.8	86.7	82.7	80.5	76.6	75.2	72.2	93.8	**S**	1.23
Nistid	95.3	95.9	95.6	94.1	93.3	90.6	85.3	82.4	78.3	75.5	71.4	69.9	67.1	95.0	**S**	1.50
MH1	96.2	95.5	93.3	92.8	90.8	89.2	85.4	82.2	82.1	80.4	78.3	75.3	76.3	94.9	**S**	1.88
PM	94.5	94.2	92.2	90.6	89.3	88.9	87.7	86.2	83.9	80.6	78.1	71.7	70.8	94.4	**S**	1.30

S-Significant, d- days, NC- Normal Control

Table 3: Hatching performance of long term cold stored polyvoltine layings at 48- 50 hours of oviposition.

Race	Duration of refrigeration (days) at 5°C and 2.5°C (total period)													NC	F Test	CD 5 %
	C-18d	25d	30d	35d	40d	45d	50d	55d	60d	65d	70d	75d	80d			
MU 303	93.1	93.4	92.6	91.1	89.6	88.5	84.7	92.7	81.1	79.4	74.3	71.6	69.3	94.1	**S**	1.72
MY1	94.3	94.2	92.5	92.1	91.1	90.0	87.4	82.1	78.6	75.5	71.2	67.2	61.0	95.5	**S**	2.80
Nistari (W)	92.6	93.3	92.7	91.6	90.4	89.4	88.1	84.2	80.8	74.9	69.6	65.9	59.1	94.4	**S**	1.68
Sarupat	94.1	94.1	93.0	92.1	88.8	88.4	87.5	84.7	82.2	81.0	73.1	69.4	59.8	95.0	**S**	1.71
Thai	95.2	94.8	94.2	89.6	90.4	89.2	85.5	80.4	79.4	75.3	72.9	70.3	65.2	95.1	**S**	1.82
Nistari (GY)	94.7	94.6	93.6	92.5	90.7	89.0	85.3	82.6	78.9	75.4	72.4	70.2	68.6	94.4	**S**	1.16
Nistid	95.1	94.9	93.4	92.4	90.2	88.9	86.0	82.4	78.3	74.5	71.4	69.7	66.7	95.3	**S**	1.73
MH1	95.8	95.3	92.3	90.3	89.4	88.4	82.3	80.6	77.3	75.2	70.6	65.0	65.3	94.1	**S**	3.25
PM	93.8	94.2	91.1	90.6	90.0	89.8	87.7	82.6	80.1	76.0	71.7	70.0	64.7	94.3	**S**	2.63

S-Significant, d- days, NC- Normal Control

Table 4 : Safe period of cold storage of polyvoltine silkworm eggs after different hours of oviposition

Sl. No.	Race	Hours of oviposition	Duration for safe preservation of eggs in the cold storage (°C)												Total period (days)
			15°	10°	5°	10°	15°	10°	5°	2.5°	5°	10°	15°	24°	
1	MY1, Nistari (gy),	24 - 30 h Stage	3h	2h	18h	3h	48h	3h	1h	10d	3h	2h	1h	Release	30d
	Nistari (W) and PM									15d					35d
	MU303, Sarupat, Thai, Nistid, MH1														
2	Nistari (w), Nistari (gy)	36 - 42 h Stage								5d					25d
	Thai and PM														
	MU303, MY1, Sarupat, Nistid and MH1									10d					30d
3	MU303, MY1, Thai,	48 - 50 h Stage								5d					25d
	Nistary (gy), Nistid and PM														
	Nistari (gy) and MH1									10d					30d

h- hour, d-days

Pure Mysore and crossbreed layings are generally refrigerated for a maximum period of 18 to 20 days (Narasimhanna, 1988). Polyvotine silkworm eggs incubated for shorter periods are able to withstand long cold preservation in comparison with eggs incubated for longer periods (Datta *et al*., 1972). Meera Verma and Chauhan (1996) suggest that eggs of Nistari, MY1 and '0' polyvoltine strain can safely be refrigerated at 5 °C for a period of 30 days and refrigeration beyond 30 days yield poor hatching, decreased cocoon weight. Chen and Hsieh (1993) suggest that eggs refrigerated at 30 hrs after oviposition, could be preserved at 5 °C up to 50 days with 90 % of hatching. Further, the eggs can still be preserved for longer duration (110 days) by adopting three phase refrigeration *i.e.,* at 25 °C for 30 hrs, 15 °C for 50 days and 5 ° C 0 ° C for 80 days. Hurkadli *et al*. (1998) have identified safe period of cold preservation of cross breed PM X NB4D2 by adopting a two- step refrigeration.

The results of the present study indicate that the polyvotine pure races can be cold stored for a longer time by adopting the two-step refrigeration method (Table 4). Further it is also inferred that early stage polyvotine layings can be cold stored for longer duration. Among the nine polyvotine races studied, except in Nistari (w) the safe period of cold storage is around 30 to 35 days. There were no changes in the hatching percentage up to this duration when compared to that of control. However, taking the accepted norms of hatching percentage in the field into consideration, more than 90 % of hatching can be obtained in the polyvotine batches refrigerated at 24 - 30 hrs of oviposition up to 45 days. This cold storage period comes down by about 5 to 10 days when refrigerated 36 - 42 hrs and 48 - 50 hrs. Among the polyvotines studied, it is observed that MH1, MU303, Sarupat, Nistid, and Thai have higher cold tolerance than Nistari (w), Nistari (gy), MY1 and PM.

From the results it can be inferred that early refrigeration (24-30 hrs) gives scope for longer period of cold storage than the batches which are refrigerated in the advance stage of development (48 - 50 hrs).

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EFFECT OF DIFFERENT EGG MANAGEMENT METHODS ON QUANTITATIVE CHARACTERS IN BIVOLTINE SILKWORM *BOMBYX MORI* L.

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ABSTRACT

Quality seed is not only the vital input for the success and stabilization of cocoon crop but also has great impact on production and productivity of cocoon crop. This can be attained only by adopting efficient and suitable management techniques of bivoltine eggs. Hence, the present investigation was carried out to study the effect of different egg management techniques on quantitative characters in bivoltine silkworm. The eggs of bivoltine silkworm hybrids namely, CSR2 × CSR4, CSR4 × CSR2 were utilized. The egg management methods like hot acid and cold acid treatment, short term and long term chilling methods and hibernation schedules were followed. The data clearly indicated that there was no significant difference in cocoon yield and shell percentage among the different egg management methods. However, significant difference was noticed in hatching percentage, survival, cocoon and shell weight. The study also revealed that the cocoon yield was almost similar in all the egg handing methods. The incubation period required for optimum hatching for different egg management techniques was determined based on incubation temperature.

Key words: Bivoltine, *Bombyx mori*, Egg management methods, Quantitative characters

INTRODUCTION

The success of silkworm crop depends on many factors like quality of eggs, environmental factors, mulberry leaf, management of rearing *etc*. Preservation of eggs without affecting its quality and viability is an important factor in sericulture. The conditions under which the eggs are preserved directly affect the hatching rate, rearing and quality of cocoons. Preservation of eggs refers to management and protection of eggs during the period from egg laying to hatching. Diapause is a special phenomenon in insects to avoid unfavorable environmental conditions and is dormant state characterized by low physical activities such as respiration and metabolism (Wang, 1983). Diapausing eggs can be made to hatch either through artificial treatment (hydrochlorization) or through preservation at low temperature for specific periods. The term incubation is used especially to those eggs, which are naturally active or artificially activated eggs and not to those eggs which are kept under aestivation. Incubation is one of the most important step to obtain uniform hatching, normal growth of larvae and quality cocoon crop and there by harvesting of quality cocoons. The silkworm eggs can be preserved under different method of preservation methods like immediate acid treatment, short and long term chilling methods and hibernation schedule. However, information on effect of different egg management techniques on quantitative parameters is scanty. Therefore, the present study was undertaken to assess the on effect of different egg management methods on quantitative characters in bivoltine silkworm.

MATERIALS AND METHODS

In the present study, two popular bivoltine hybrids *viz.,* CSR2 × CSR4, CSR4 × CSR2 were utilized. The parental seed cocoons of CSR2 and CSR4 were preserved at 25± 1°C with 75.5 % RH. The eggs of CSR2 × CSR and CSR4 × CSR2 were prepared by utilizing the parental seed cocoons and were sterilized in 2 % formalin solution for 10 minutes. The egg cards dried under shade and different egg handing methods were followed.

1. **Hot acid treatment:** The 20 hrs eggs were subjected for hot acid treatment (1.075 specific gravity at 15°C). The acid was heated to 46.1°C and egg cards dipped for 5 –6 minutes.

2. **Cold acid treatment:** The 20 hrs eggs were subjected for cold acid treatment (1.11 specific gravity at 15°C) for 90 minutes.

3. **Short term chilling (STC) (40 ~ 50 days):** The eggs were cold stored at 5°C after 30 to 35 hrs at 25°C. After completion of 40 days, the eggs were released from cold storage through intermediate temperature of 15°C for 3 hrs and acid treated with 1.1 specific gravity at 15°C (1.085 at 48°C) for 6-7 minutes.

4. **Long term chilling (LTC) (60 ~ 80 days):** The eggs were cold stored at 5°C after 48 hrs at 25°C. After completion of 60 days eggs were released from cold storage through intermediate temperature of 15°C for 3 hrs and acid treated with 1.1 specific gravity at 15°C (1.085 at 48°C) for 6-7 minutes.

   After hydrochloric acid treatment, the egg cards thoroughly washed in running water for about 1 hour and then dried.

5. **Four (120 days) and six months (180 days) hibernation schedule:** The eggs were preserved at 25°C for 10 and 20 days aestivation for 4 and 6-month hibernation schedules respectively. Then the eggs were shifted to 5°C or 2.5°C (after appropriate period) after passing through the intermediate temperature of 20°C, 15°C and 10°C. The cold stored eggs were released through intermediate temperature of 10°C (one day) and 15°C for 2 days.

The eggs were incubated at 25±1°C with 805 % relative humidity and were black boxed in the eye spot stage *i.e.,* 72 hours before hatching. The eggs were exposed to light at 6.00 AM on the day of hatching to get uniform and single day hatching. The rearing was conducted as per the standard rearing technology. After III moult, three replications with two hundred fifty larvae per replication for each hybrid were maintained. The data for important quantitative parameters such as hatching percentage, survival percentage, cocoon yield, cocoon weight, cocoon shell weight and cocoon shell percentage were recorded.

RESULTS AND DISCUSSION

The effect of different egg management techniques on quantitative characters in bivoltine hybrid is presented in Table 1. The data clearly showed that there was no significant difference for the parameters hatching percentage, cocoon yield and shell percentage. However, significant difference was noticed for the traits survival, cocoon and shell weight. The maximum hatching (96.9 and 95.8 %) was recorded in hot acid treated eggs, where as minimum (92.2 and 91.6%) was found in STC. The survival was found maximum (95.4 and 94.8 %) in LTC, where as minimum (89.1 and 91.3 %) was recorded in 6 month hibernation. The cocoon weight was found maximum (1.987 and 1.974 g) in 4 months hibernation schedule, where as minimum cocoon weight (1.925 and 1.928 g) was recorded in cold acid treated. The shell weight was also found maximum (0.469 and 0.462 g) in 4 months hibernation schedule, where as minimum cocoon weight (0.445 and 0447 g) was recorded in cold acid treated. The shell percentage ranged from 23.1 to 23.7%. Though there was significant difference in pupation, cocoon and shell weight among the different egg management techniques, the cocoon yield was found almost similar in all egg handing methods. The incubation duration varies from 10 (acid treated eggs) to 14 (hibernated eggs) days. The effective accumulated temperature in term of points (EATPs) also varied from 150 (acid treated eggs) to 180 (STC and LTC) points for different egg management methods. The details of EATPs for different egg management methods was given in Table 2. By calculating the EATPs, the expected day of hatching can be predicted.

Calculation of effective accumulated temperature (points) (EATPs): Based on effective accumulated temperature (in terms of points), the expected day of hatching can be predicted. The EATPs can be calculated as follows: It is known that at 10C, the development of embryo in silkworm is negligible. Based on these observation a simple formula is developed and is as follows

EATPs = Actual incubation temperature -- invalid temperature (10°C)

If the incubation temperature is 25°C than the points per day is = 25°C – 10°C = 15 points. The EATPs are to be added every day when the total EATPs of particular preservation method are reached, the eggs can be exposed to light to obtain the optimum hatching.

The termination of diapause can be expressed in terms of hatchability of the eggs. The regular practice of terminating the duiapause of the bivoltine races, which are extensively used for commercial purpose, is hydrochlorization. Postponement of acid treatment of eggs refrigerated at 5°C at the age of 20 hours was reported by several investigators (Yokoyama, 1962,, Ayuzawa, *et al.,* 1972, Tazima 1978, Biram Seheb *et al*. 1996). Reports on termination of diapause in bivoltine eggs after short term (STC) and ordinary chilling (LTC) were also available (Tazima 1978, Manjula and Hurkadli 1986 and 1995, Hurkadli, 1997). The diapause of univoltine and bivoltine eggs can be terminated by following cold storage methods for longer duration (hibernation schedule) by adopting preservation schedules (Tazima, 1978, Vemanada Reddy *et al*. 2004 and Ichiiwata, *et al.* 2005). However, comparative performance of silkworm eggs preserved under different egg hardening methods is scanty.

Table1: Effect of different egg preservation methods on incubation days, hatchability and quantitative traits in silkworm

Category of eggs	Breed/ hybrid	Incubation period (Days)	EATP s*	Hatching (%)	Survival (%)	Cocoon yield/ 10000 larvae (kg)	Cocoon weight (g)	Shell weight (g)	Shell (%)
Hot acid	CSR2×CSR4	10	150	96.9	94.7	18.42	1.945	0.449	23.1
treated	CSR4×CSR2	10	150	95.8	93.9	18.20	1.938	0.453	23.4
Cold acid	CSR2×CSR4	10	150	94.6	93.8	18.06	1.925	0.447	23.2
treated	CSR4×CSR2	10	150	95.3	94.2	18.16	1.928	0.445	23.1
STC	CSR2×CSR4	12	180	92.2	92.5	18.07	1.954	0.459	23.5
(30 ~ 50 days)	CSR4×CSR2	12	180	91.6	93.2	18.13	1.945	0.455	23.4
LTC	CSR2×CSR4	12	180	94.5	95.6	18.81	1.968	0.455	23.1
(50 ~ 80 days)	CSR4×CSR2	12	180	93.3	94.8	18.51	1.953	0.457	23.4
4 months	CSR2×CSR4	14	175	95.3	92.6	18.40	1.987	0.469	23.6
hibernation	CSR4×CSR2	14	175	96.0	93.2	18.40	1.974	0.468	23.7
6 months	CSR2×CSR4	14	175	95.2	89.1	17.63	1.979	0.457	23.1
hibernation	CSR4×CSR2	14	175	95.6	91.3	18.01	1.973	0.462	23.4
				1.9	3.1	ns	0.08	0.016	ns

EATPs - Effective accumulated temperature (points)

Table 2: Number EATPs required for different category of eggs for hatching

Days / Category of eggs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Incubation Temp. °C	25	25	25	25	25	25	25	25	25	25	25	25	25	
Acid treated (points)		15	30	45	60	75	90	105	120	135	150 (H)			
STC (points)		15	30	45	60	75	90	105	120	135	150	165	180 (H)	
LTC (points)		15	30	45	60	75	90	105	120	135	150	165	180 (H)	
Incubation Temp. °C	10	15	15	25	25	25	25	25	25	25	25	25	25	25
Hibernation (4 and 6 months) (points)	0	5	10	25	40	55	70	85	100	115	130	145	160	175 (H)

Relative humidity 80±5, H: Hatching, EATPs: Effective accumulated temperature (points)

The present investigation clearly showed that various methods of egg preservation techniques have great effect on incubation, hatching percentage, survival, cocoon shell weight. However, there was no significant difference in cocoon yield and shell percentage. The ultimate cocoon yield is the cumulative effect of many quantitative traits. In tropics, the seed requirement is essential throughout the year due to continuous availability of mulberry foliage and ideal environmental conditions for silkworm rearing. Bivoltine eggs are supplied to sericulturists after common acid treatment or by following artificial wintering depending on the demand**.** Incubation plays an important role to ensure good health and robustness of early instar larvae. It is known that still confusion prevails among the sericulturists regarding prediction of the hatching day due to varied environmental temperature. The information generated in the present study has a direct bearing upon the seed producers, suppliers as well as to sericulturist to predict the hatching day while incubating the eggs.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 227-230

EFFECT OF RELATIVE HUMIDITY ON HATCHING OF BIVOLTINE SILKWORM *BOMBYX MORI* L. EGGS DURING BLACK BOX CONDITION

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ABSTRACT

The present study was under taken to assess the effect of different regimes of humidity on silkworm eggs particularly at black box condition. The commercial bivoltine hybrids (single and double hybrids) *viz.,* CSR2×CSR4, CSR4×CSR2 (single hybrids), (CSR6×CSR26) × (CSR2×CSR27) and (CSR2×CSR27) × (CSR6×CSR26) (double hybrids) and their parental breeds *viz*., CSR2, CSR27 (Oval type), CSR4, CSR6 and CSR26 (Dumb-bell type) were utilized for the study. The eggs were incubated at constant temperature of 25±1°C and relative humidity of 80±5% with a photoperiod of 18 hours light and 6 hours dark up to egg pigmentation stage. From egg pigmentation stage, these eggs were exposed to varying relative humidity regimes *viz.,* 40±5, 50±5, 60±5, 70±5, 80±5 and 90±5 percent with constant temperature of 25±°C. The data revealed that significant reduction in hatching percentage was observed in parental breeds, single hybrids when the relative humidity is below 70%. In double hybrids, the hatching percentage is significantly reduced only when the relative humidity is below 60%. The parental breeds are found to be more sensitive to low humidity condition during black boxing than hybrids. Among the hybrids, the double hybrids are found to be more tolerant to low humidity than single hybrids. Moreover, the humidity regimes of 70, 80 and 90% RH have comparatively similar effect on the hatching percentage in all the parental breeds and hybrids.

Key words: Bivoltine breeds/hybrids, *Bombyx mori*, Egg pigmentation, Hatching, Relative humidity

INTRODUCTION

Silkworm seed, which forms the basic requirement for sericulture plays a decisive role in the success of silkworm crop and stabilization of sericulture industry. The success and development of sericulture industry is greatly influenced by the quality of the silkworm seed supplied to the farmers. Timely production and supply of required quantity of the quality silkworm seed is one of the pre-requisites for sustainability of cocoon production. Incubation is one of the most important steps to obtain uniform hatching, normal growth of the larvae and quality cocoon crop. Adoption of proper incubation techniques enhances the uniform growth and development of embryo. The systematic method of incubation apart from enforcing uniform hatching provides newly hatched larvae with health and vigor. It is well established that temperature of 25±1°C and relative humidity of 80±5% is optimum for incubation of silkworm eggs to obtain maximum hatching (Tribhuvan Singh and Saratchandra, 2004). Humidity plays an important role in the physiology of the eggs and variation in humidity during incubation results increase in the percentage of dead eggs, weak larvae and poor hatching. Low humidity during incubation causes desiccation of the eggs.

Earlier, the silkworm eggs were being supplied to the sericulturists at different stages of incubation after release from the cold storage. Unfortunately the farmers were lack of facilities for maintenance of optimum temperature and humidity and experienced lot of irregularities in hatching. To overcome these problems, now-a-days the silkworm eggs are being supplied only at black boxing stage *i.e.,* egg

pigmentation or blue egg stage. Though humidity plays an important role in the incubation of egg, its effect on hatching is not much published in open literature. Hence, the present study on effect of different regimes of humidity on blue egg stage was undertaken.

MATERIALS AND METHODS

The commercial bivoltine hybrids (single and double hybrids) *viz.,* CSR2×CSR4, CSR4×CSR2 (single hybrids), (CSR6×CSR26) × (CSR2×CSR27) and (CSR2×CSR27) × (CSR6×CSR26) (double hybrids) and their parental breeds *viz.,* CSR2, CSR27 (Oval type), CSR4, CSR6 and CSR26 (Dumb-bell type) were utilized for the study. A quantity of 60 disease free layings for each of parental breeds and hybrids were utilized for the study. The eggs were cold preserved by adopting 4 months hibernation schedule. After completion of hibernation the eggs, which are due for incubation were released through intermediate temperature at 10°C for 1 day and 15°C for 2 days. The eggs were incubated at constant temperature of 25±1°C and relative humidity of 80±5% with a photoperiod of 18 hours light and 6 hours dark up to egg pigmentation stage. Ten disease free layings for each of parental breed and hybrids were exposed to constant temperature of 25±1°C with varying relative humidity regimes, *viz.,* 40±5, 50±5, 60±5, 70±5, 80±5 and 90±5 percent at black box condition (egg pigmentation). The required humidity regimes were maintained using different salt solutions in humidity cabinets (Hodgman, 1948) *viz.*, potassium nitrate (KNO_3) (94%), sodium carbonate decahydrate ($Na_2CO_3.10H_2O$) (88%), sodium chloride (NaCl) (76%), calcium nitrate tetrahydrate ($Ca(NO_3)_2 4H_2O$) (52%), Calcium chloride hexahydrate ($CaCl_2.6H_2O$) (32%). The layings were black boxed at egg pigmentation stage *i.e.,* 72 hours before hatching and exposed to light at 6.00 a.m. Hatching was allowed till 9.00 a.m. and was considered as one day's hatching.

RESULTS AND DISCUSSION

The data presented in Tables 1 and 2 indicate that the variation in relative humidity at pinhead stage influenced the hatching of bivoltine silkworm eggs. The data revealed that significant reduction ($p<0.001$) in hatching percentage was observed in parental breeds and single hybrids (CSR2×CSR4), (CSR4×CSR2), when the relative humidity is below 70%. However, in double hybrids (CSR6×CSR26) × (CSR2×CSR27) and (CSR2×CSR27) × (CSR6×CSR26) the hatching percentage was significantly ($p<0.01$) reduced only when the relative humidity is below 60%. This indicates that the double hybrids have relatively more resistance to low humidity than single hybrids and pure breeds. The lowest hatching of 77.8% in CSR2, 76.4% in CSR27, 80.7% in CSR4, 76.8% in CSR6 and 78.8% in CSR26 was recorded when the silkworm eggs of bivoltine breeds exposed to 40% relative humidity during blue egg stage (Table 1). Similarly, the lowest hatching of 84% in CSR2×CSR4, 85.03% in CSR4×CSR2, 86.3% in (CSR6×CSR26) × (CSR2×CSR27) and 86.7% in (CSR2×CSR27) × (CSR6×CSR26) was recorded in hybrids at the said humidity (Table 2). However, the observation clearly shows that the humidity regimes of 70, 80 and 90% RH have comparatively similar effect on the hatching percentage in all the parental breeds and hybrids. The ANOVA indicate the significant ($p<0.001$) interactions between humidity treatments and between races ($p<0.01$) in hatching of parental breeds was observed. Though no significant different between hybrids, significant difference ($p<0.001$) between humidity treatments was observed in hybrids.

Incubation is one of the most important techniques in silkworm seed management. Proper incubation of eggs is very essential to obtain uniform higher hatching, robust/healthy larvae which lead to obtain optimum growth of larvae and finally quality cocoons with higher yield. Among the environmental factors humidity is one of the most important factors, which directly affect the physiology of the silkworm eggs particularly during blue egg stage.

The effect of temperature and humidity on silkworm eggs, was investigated by several workers (Nino, 1983; Barah *et al*., 1993; Meenal *et al*., 1994; Muniraju *et al*., 2001; Shirota, and Toshio, 1999). Upadhyay and Gaur (2002) observed in *Bombyx mori* eggs that variation in temperature and humidity influence the incubation period. Nino, (1983) reported that the exposure of head pigmentation stage eggs to different humidity conditions revealed positive correlation between high humidity and high hatching percentage and low humidity with low hatching. Silkworm eggs are very sensitive to temperature and humidity prevailing in the environment (Manjula, 1990). Low light intensities resulted in less hatching, while high light intensities increases the hatching of silkworm eggs (Sivarami Reddy *et al.,* 1988).

The present study clearly revealed that the hatching percentage found varied with the variations in humidity during incubation of bivoltine silkworm. Wide variation in the hatching percentage was observed among the parental breeds when the humidity is less than 70 per cent. However, the hatching percentage is found to be more in dumb-bell type breeds (CSR4, CSR6 and CSR26) than oval type breeds (CSR2, CSR27). The ANOVA also revealed that significant interaction was observed between humidity treatments and between breeds. In the case of hybrids, the significant reduction in hatching percentage was noticed when the incubation humidity is less than 60 per cent. The observations indicate that the parental breeds are found to be more sensitive to low humidity condition during incubation than hybrids. Among the hybrids, the double hybrids (CSR6×CSR26) × (CSR2×CSR27) and (CSR2×CSR27) × (CSR6×CSR26) are found to be more tolerant to low humidity than single hybrids (CSR2×CSR4) and

Table 1: Effect of different relative humidity regimes during egg pigmentation stage on hatching in bivoltine breeds.

	Breed				
RH (%)	CSR2	CSR27	CSR4	CSR6	CSR26
40	77.8	76.4	80.7	76.8	78.8
50	84.9	85.7	91.4	87.9	88.9
60	91.8	90.7	93.3	91.8	93.0
70	93.7	94.6	95.4	94.4	94.1
80	96.5	95.8	96.4	95.7	95.0
90	96.2	96.3	96.7	95.6	95.7

ANOVA for hatching in parental breeds

Source of Variation	df	Mean Squares	Std. Error	C.D at 5%
Treatment	5	718.937 ***	0.48677	1.377
Hybrids	4	16.276 ***	0.44436	1.25703
Treatment × Hybrids	20	3.802	1.08846	3.07907
Error	60	3.554		

*** Significant (P < 0.001); ** Significant (< 0.01)

Table 2: Effect of different relative humidity regimes during egg pigmentation stage on hatching in hybrids

	Hybrid			
RH (%)	CSR2×CSR4	CSR4×CSR2	DH1	DH2
40	83.9	85.0	86.3	86.7
50	92.5	92.7	93.4	93.7
60	94.8	94.1	95.7	95.6
70	96.4	96.6	97.4	96.3
80	96.6	97.0	97.2	96.8
90	96.7	96.5	97.4	97.1

DH1 (CSR6×CSR26) × (CSR2×CSR27); DH2 (CSR2×CSR27) × (CSR6×CSR26)

ANOVA for hatching in hybrids

Source of Variation	df	Mean Squares	Std. Error	C.D at 5%
Treatment	5	236.469 ***	0.55846	1.58795
Hybrids	4	5.086	0.45598	1.29655
Treatment × Hybrids	20	0.818	1.11692	3.1759
Error	60	3.742		

*** Significant (p < 0.001)

(CSR4×CSR2) as indicated by more hatching percentage even at incubation humidity of 60%. However, drastic reduction in hatching percentage in both parental breeds and hybrids was recorded below the incubation humidity of 60 per cent. The observed reduction in hatching percentage was mainly due to dead embryos. The data shows that egg pigmentation and blue egg stages are very sensitive to low humidity. These observations corroborate with the findings of Nino (1983), who had observed the reduction in embryonic movements inside the egg when the humidity is less in the environment. The reduction in embryonic movements is mainly due to desiccation of eggs at low humidity conditions and subsequently the larvae find it difficult to bite the eggshell and eventually fail to hatch. Therefore, it is concluded that the ideal temperature of 25±1°C and humidity of 80±5% is invariable during black box condition of silkworm egg for higher hatching of robust larvae.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 231-234

INNOVATIONS, CHALLENGES AND FUTURE PROGRAMMES OF SILKWORM EGG RESEARCH IN TROPICS

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ABSTRACT

The different activities of silkworm seed sector especially seed handling and commercial seed production have been tremendously supported by the practices and technologies formulated by Silkworm Seed Technology Laboratory (SSTL) during the past many years. The major initiatives and contributions by SSTL were made in various areas of quality seed production such as disease management and efficient egg handling. The inventions of high order such as the broad spectrum silkworm rearing bed disinfectant, Resham Jyothi, broad spectrum general disinfectant, Decol and the newly developed eco-friendly silkworm bed disinfectant, Rakshak which improved the cocoon yield by 7~10 kg / 100 dfls could make considerable impact. Similarly, the Laboratory could establish various hibernation schedules for preservation of bivoltine silkworm eggs for 110~300 days. Loose egg production technology is a remarkable achievement of the institute which is adopted largely in bivoltine hybrid seed production centres. Advanced pebrine detection methods have also been formulated for all the developmental stages of silkworm. Of late, a long-term preservation schedule has been worked out for cross breed layings (PM × CSR2) up to 50 days under double step refrigeration. This technology could elicit interest in a wide range of stake holders and it is understood that the seed production units of NSSO could tide over the problems of adverse conditions and slackness. The layings preserved under this scheme could record a hatching of 92~93 % and cocoon yield of 60 kg/100 dfls which was at par with that of the layings preserved under the normal schedule. Based on the field feed back and thorough analysis of constraints associated with sustenance of seed cocoon crop, a few new research premises have been conceived and proposed to take the quality seed production to newer heights. The programmes such as 1) Introduction of diapause to polyvoltines for long-term preservation, 2) Advanced technique for long-term cold storage for diapause eggs 3) Usage of artificial diet for development of silkworm race to increase egg production efficiency 4) Advanced techniques for pebrine identification and 5) Disease resistant breeds for stability in cocoon yield and egg production have been identified as the thrust areas on priority.

Key Words : Challenges, Future programmes, Innovations, Silkworm seed, Tropics

INTRODUCTION

The idea of establishing an exclusive research unit to address various issues related to silkworm seed was a catapulting leap towards organized scientific seed production and putting scientific procedures in place for all the different facets of production. This is quite understandable because silkworm seed plays the most decisive role in the success of commercial cocoon crops and profitability of the enterprise. Silkworm Seed Technology Laboratory was thus established in 1989 and has been a serious contributor in developing suitable technologies for improving the quality of silkworm seed produced in the country. The centre gives priority to need based adaptive research leading to simple-to use and low cost technologies. Greater thrust is attached to test the technological achievements in the field from time to time, fine-tune and then transfer them effectively to the end users. This model has been largely successful as epitomized by the higher level of adoption of the centre's technologies.

The centre carries out all research works related to silkworm seed apart from training on seed production, conducting surveys in respect of pebrine disease at different levels of seed production in the field and oversees prevention and control of all silkworm diseases. The core competence of the centre lies in the areas of silkworm egg production technology, seed crop rearing, silkworm seed pathology, developmental biology, reproductive physiology & biochemistry and silkworm seed oriented maintenance of the host plant. In the process of addressing various field problems and elevating the standards of silkworm seed production, a number of need based technologies have been developed and fine-tuned for its adoption in a short span of time.

Major Achievements

- A broad spectrum silkworm bed disinfectant, *Resham Jyothi* was developed and commercialized in 1999 for prevention and control of silkworm diseases (Sasidharan *et al*., 2000).
- The general disinfectant, *Decol* was released in 2005 which is user and eco-friendly besides being economical (Singh *et al*., 2006).
- The silkworm bed disinfectant, *Rakshak* is the most recent product which has already been proven effective in the field.
- Formulation of standard schedule for acid treated and short term preservation schedules for bivoltine × multivoltine silkworm eggs.
- Various hibernation schedules for preservation of bivoltine silkworm eggs for 110 ~ 340 days with an intermediate care which helps in further postponing of hatching up to 30 days without affecting vitality of eggs (Vemananda Reddy *et al*., 2004).
- A long term preservation schedule has been worked out for cross breed layings (PM × CSR2) up to 50 days under double step refrigeration. This has turned out to be of great advantage in helping the seed producers to tide over unfavourable conditions and avoid loss during slack period. This technology is currently at use by the units of NSSO and is being test verified.
- The embryo isolation technique was standardized to identify appropriate embryonic stages for the preservation of bivoltine eggs for chilling, hibernation and re-refrigeration (intermediate care) and to subsequently enable precise decision making at proper time of egg handling.
- The large scale loose egg production technology is a remarkable achievement (Samson *et al*., 1995) which is adopted largely in F1 bivoltine hybrid production centres. This technology facilitates supply of superior quality eggs in uniform quantity irrespective of race,season or zone.

In this context, it is also noteworthy to mention the remarkable achievements registered by NSSO. The parental organization has produced 279.52 lakh dfls (91.35 lakh of bivoltine hybrids and 188.17 lakh of cross breeds) during the year 2008-09 achieving 97.73 % of the target. Adopted Seed Rearers could generate 4.08 crore bivoltine seed cocoons thereby meeting 98.21 % of the requirement for both cross breed and bivoltine hybrid production. Cross breed (multivoltine × bivoltine) egg production could witness a recovery of 31.11 % in south zone SSPCs against a norm of 28 %. In bivoltine hybrid egg production, an average egg yield of 66.37 g per kg seed cocoon was recorded in CSR hybrids and 74.04 g per kg seed cocoon in the case of double hybrids in southern zone against the norm of 55 g and 65 g / kg, respectively (Anonymous, 2008-09).

Future Strategies

Needless to say the problems and constraints encountered by the seed farmers and seed producers naturally form the basis of the thrust areas and the knowledge emanated from the scientific studies conducted elsewhere contribute to collective wisdom. The future programmes envisaged are directed towards solving the present problems and to address the immediate needs of the field.

a. Introduction of diapause to polyvoltines for long-term preservation

It could be truly a revolutionary breakthrough in the multivoltine and cross breed egg handling arena, if the diapause character can be introduced into the traditional polyvoltine races *viz*., Pure Mysore and Nistari so that the eggs can be preserved for a longer period to overcome unfavourable seasons / slackness. The diapause induced multivoltine eggs can be preserved up to six months by cold preservation schedule leading to cost effective conservation of multivoltine genetic resources. It also envisages developing protocols for diapause induction through photoperiod and temperature regulation (Nagayama and Yamamoto, 1987). The maximum percentage of egg diapause induction was revealed in Rong Daizo, Daizo and MW13 *i.e.,* 94, 93 and 92 %, respectively (Saravanakumar and Ponnuvel, 2007). Selection of multivoltine silkworm germplasm has been made based on the information on the susceptibility status to 45 days of cold preservation at 5 ^{0}C (Kumaresan *et al*., 2004). To induce diapause in eggs of multivoltine silkworm, the general methodology proposed by Kogure (1933) will be followed *i.e.,* incubation of eggs at 25 ^{0}C, 80% RH and 16L: 8D conditions followed by rearing the 4th and 5th instar worms at 18 – 20 ^{0}C with 6L: 18D besides using Daizo as one of the initial materials for induction of

diapause to desirable multivoltine races such as PM and Nistari. This project will be taken up in collaboration with Seribiotech Research Laboratory to understand the expression of introduced genes.

It is highly imperative that the silkworm breeds must cater to the needs of the farmers, graineurs, reelers, weavers and fabric makers. Though a number of elite silkworm hybrids have been introduced in the field from time to time, only a few farmers in certain geographical pockets with favourable environmental conditions were able to exploit the full potential of the races. In this context, Basavaraja and Dandin (2008) opined that the breeders should reorient their thinking that their efforts should focus on new strategies of silkworm breeding one of them being development of sustainable double hybrids with high egg recovery and which can withstand adverse climatic conditions (Watanabe, 2002) of the tropics. The shell percentage and raw silk percentage were generally found to be negatively correlated to egg number. A totally new breeding approach may have to be devised to develop silkworm races having high fecundity with no serious compromise in shell and raw silk percentage.

b. Advanced technique for long-term cold storage for diapause eggs

The basic stocks (currently in use) of silkworm races are multiplied 3 ~ 4 cycles per year. Similarly, maintenance of univoltine and bivoltine silkworm races requires a large investment in terms of both time and labour, since they are indispensable for rearing new batches every year. The most effective method for rearing silkworms biannually was recently proposed. The diapause eggs of two hybrids, J01 × C01 and J137 × C146 and their reciprocal crosses were stored successfully for two years using new techniques. Hatching was recorded between 87.6 ~ 90.9%. Shimizu *et al*. (1994) reported that the viability of eggs after two years storage varies among races. Matsuno and Shimizu (1979) demonstrated that a high magnitude of heterosis effect is observed in the viability of eggs stored for a long period. Similarly, two year storage method was recently reported by Mochida *et al*. (2003) wherein it requires six intermediate temperature conditions. Therefore, there will be need to determine whether the new method of egg preservation with only one intermediate care procedure can be applied to parental breeds and genetic stocks, using a high humidity refrigerator (Tetsuya *et al*., 2008).

c. Usage of artificial diet for development of silkworm race to increase egg production efficiency

Shirota (2009) has generated some valid information that are expected to be useful in the silkworm egg production field. Regarding the usage of artificial diet to increase the efficiency of silkworm egg production, it was found that addition of certain ingredients such as 1% tannic acid to diet of high protein content was effective in raising the digestibility, pupation and oviposition rate. They have also established the differences in reactions of various categories (very active and normal) of male moths to sex pheromone. Sex pheromone production in male moth is thought of as one of the quantitative characters.

d. Advanced techniques for pebrine identification

The most important aspect of seed production has always been disease freeness. The quality of the seed greatly implies seed free from pebrine. The meticulous detection procedures presently followed are manual. They are highly effective as long as individual mother moths are examined for pebrine spores but remained untenable in mass production centres. The statistical sampling methods followed for testing though cannot be foolproof, an alternate method is still not available. The immunodiagnosis based molecular approaches such as latex agglutination, immunoperoxidase staining, fluorescent antibody test and enzyme linked immunosorbent assays though promised initially, never took off at the end user level possibly because of practical difficulties. However, monoclonal antibody based immunodiagnostic kits developed in Japan to discriminate different microsporidians infecting silkworm are of practical utility and such kits need to be developed in India as well. Multiplexing PCR approach developed and standardized for identification of pebrine spores may emerge as an effective pebrine detection method as the spore detection is possible even at the lowest intensity (Ravikumar, 2008). The concerted efforts in fine-tuning the diagnostic techniques for efficient detection of infection at all developmental stages will be the true way forward for further sericulture progress.

e. Disease resistant breeds for stability in cocoon yield and egg production

An equally or more important consideration could be development of disease resistant silkworm strains, possibly by utilizing advanced breeding programmes coupled with molecular biology techniques. Apart from bypassing the long breeding trail and assuring definite end result, such programmes are believed to enable in developing disease resistant silkworm breeds which will be robust and vigorous. Quite understandably, the egg production efficiency of such disease resistant robust breed will be superior. Research efforts are on in this line wherein the DNA markers associated with NPV resistance will be validated and introduced into the desired silkworm breeds (Nagaraju, 2002).

Attempts on developing NPV resistant transgenic silk moth are also underway. In the ambit of this work, the first phase deals with generation of silkworm lines carrying transgene and expressing dsRNA for essential multiple viral

targets to enhance the efficiency of protection against viral infection (Nagaraju, 2002). The second phase includes introduction of viral resistance trait from the transgenic lines to commercial silkworm strains through conventional breeding coupled with transgene marker selection.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the help extended by Dr. Jula Nair Scientist C, SSTL during preparation of the manuscript.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 235-238

EFFICACY RATIO OF CSR2 MALE MOTHS IN THE PRODUCTION OF CROSS BREED SILKWORM (*BOMBYX MORI.*L) EGGS

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ABSTRACT

Production of silkworm eggs (*Bombyx mori*.L) is an art as well as science. Different agencies are involved in production activity, but work more or less in isolation having very little exchange/sharing of materials and information. Cross between PM(♀)X CSR2 (♂) popularly known as 'Kolar gold' is currently the ruling combination superseding all traditional multivoltine cross breeds. The general norm of parent (♂ & ♀) seed cocoon ratio (1:2) in this combination has experienced imbalance on most occasions by almost every seed producer, which demanded for a detailed study in different forums. Small scale sample study at laboratory level may not find authentic indication of optimum ratio for large scale seed production, hence the present study conducted at SSPC, Ramanagaram. Sixteen trials comprising seed cocoons of 6.22 lakh CSR2 and 13.12 lakh PM studied during May-July, with a ratio of 1:2.1 (as per general norm) conducted. PM seed cocoons yielded 4.98 lakh ♀ moths as against 1.96 lakh CSR2 ♂ moths, resulting in shortage of 0.53 lakh ♂ moths for remaining 1.06 lakh ♀ moths at the rate of double copulation. On an average of 90% pupation, proportionately additional 1.69 lakh CSR2 good seed cocoons were required. The study indicated the requirement of CSR2 good seed cocoons in total to the extent of 7.91 lakh, as a male component for processing 13.12 lakh PM seed cocoons which works out to 1:1.70 ratio. The seed cocoons subjected for study were generated during moderately dry season hence low ratio is attributed. Whereas the cocoons generated during favorable season i.e., August to February may work positively with slightly higher ratio of 1:1.75 to 1:1.8. Additional observations were also made in the study on the rate and range of pupation, (90% , 81-95%), moth emergence (31.5 - 51%) of the race, which are in conformity with the established breeding principles that the high silk yielding parameters generally have negative co-relation with survival & performance qualitative parameter which is true in the case of high yielding CSR breed in comparison with the performance of traditional NB4D2 or NB18. However, in view of silk quality and quantity, the egg production needs to be managed with the efficacy parent components 'ratio' of 1:1.70 to 1:1.8 for better results.

Key words: Egg production, Kolar gold, Moth emergence, Rate of pupation.

INTRODUCTION

Multibivoltine Crossbreed (CB) silkworm hybrid eggs are the mainstay of commercial egg production in Southern India where every year 22.82 crore CB (Kolar Gold) dfls are produced. A cross between Pure Mysore (Multivoltine) female and CSR2 (Bivoltine) male, results in the popular CB (Kolar Gold). Seed production is also an entrepreneurship. The cost benefit ratio besides scientific qualitative approaches will support the sustainability (Dwarakinath and Ramanjaneyulu Y.V., 1994) In practice these two components are to be utilised in the ratio of 1:2 where the male component is used twice for copulation i.e, upto 2 matings. Though in theory the male cocoon procurement has to be half that of the female cocoon procurement, the number of males obtained need not necessarily be as desired due to various factors like number of live pupae and male population in each lot procured which is very rarely upto 50% in any given lot (Dwarakinath and Ramanjaneyulu Y.V.,

Table 1 : Pupation and moth emergence pattern in experimental batches of CSR2 and Pure Mysore

No. of Trials	Bivoltine Seed Cocoon					Pure Mysore cocoon no.	No. of female moths	% female moths
	Actual no.	Good no.	Pupation %	No. of Male moths	% of Male moths			
1	56600	50900	89.93	26000	51.08	128982	43980	34.10
2	54050	47658	88.17	17000	35.67	105620	41700	39.48
3	16800	15625	93.01	4000	25.60	49988	18140	36.29
4	83550	75300	90.13	16600	22.05	130895	52300	39.96
5	38871	35910	92.38	8650	24.09	72030	24900	34.57
6	101722	92310	90.75	28000	30.33	187426	72680	38.78
7	9975	8995	90.18	1900	21.12	15670	5940	37.91
8	39440	35496	90.00	8520	24.00	69083	27600	39.95
9	25740	22185	86.19	9500	42.82	44000	16020	36.41
10	36960	34440	93.18	10500	30.49	73590	26940	36.61
11	31320	28836	92.07	11000	38.15	60140	23200	38.58
12	37200	35400	95.16	9200	25.99	80055	31000	38.72
13	23346	21360	91.49	8500	39.79	42600	17500	41.08
14	61200	53856	88.00	17000	31.57	103835	41846	40.30
15	49692	45903	92.38	14500	31.59	96815	34720	35.86
16	21730	17660	81.27	5000	28.31	51480	19700	38.27
Total	688196	621834	90.36	195870	31.50	1312209	498166	37.96

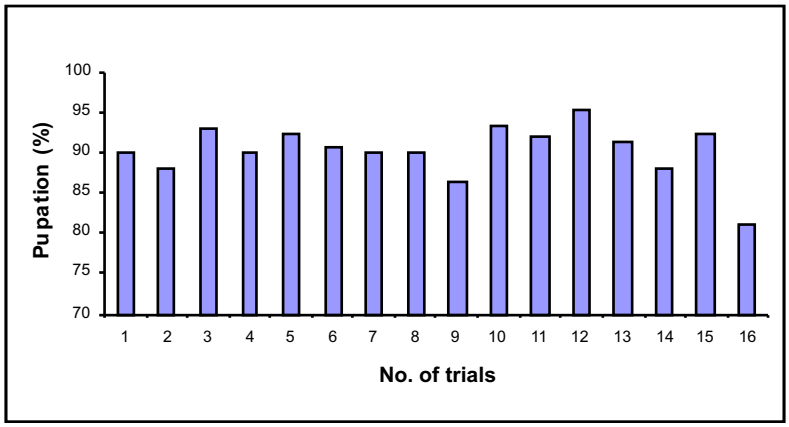


Fig. 1 : Rate of Pupation in CSR2 seed cocoons

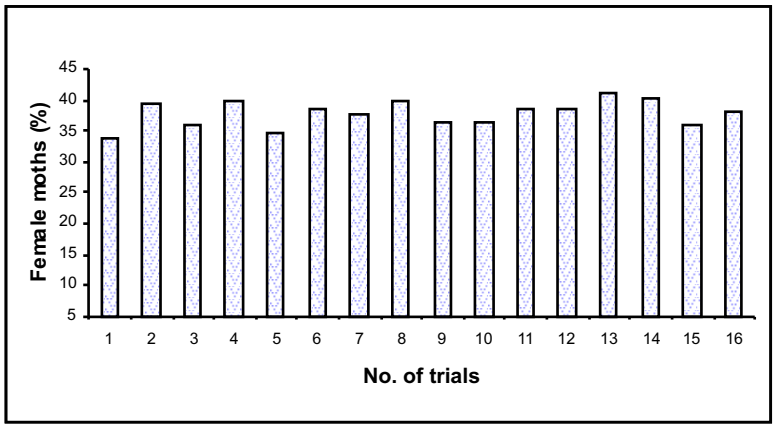


Fig. 2 : Female Moth Emergence in Pure Mysore

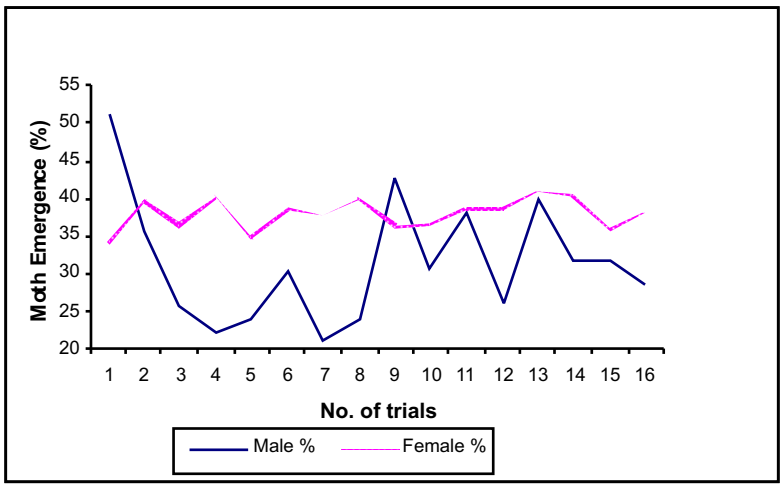


Fig. 3 : Male (CSR2) Female (PM) Moth Emergence

1995). Accordingly, the ratio of ♂ ♀ component that can be obtained is less in case of CSR2 breed as experienced by most of the seed producers, instead of the set norm of 1:2.Also studies on the seed production activity in the orientation of Rate of pupation in Bivoltine seed cocoons is very important (RamanjaneyuluY.V., *et al* 2008, 2009) but sparse. But substantial scientific data in large scale studies is seldom available. The seed producing units themselves experience such problems at large scale seed production as they procure and handle enormous quantities of Pure Mysore and CSR2 cocoons for the production of CB dfls. In the present study an experiment was conducted with large scale sample to establish accuracy of the required ratio of ♂ ♀ component in the production of CB dfls.

MATERIALS AND METHODS

Bivoltine Seed Cocoons CSR2 of 6.88 lakh and Multivoltine Seed Cocoon of 13.12 lakh were procured and processed, spread-over sixteen trials (Table 1). The pupation range in the processed batches of BSC was from 81.27 to 95.16 % with an average pupation rate of 90.36% (Fig. 1). The average males percentage obtained was 31.5% with a range of 21.12-51.08% (Fig. 3).

RESULTS AND DISCUSSION

Production of CB dfls in commercial sector is an important activity, which requires well synchronized, good ratio and quality male/female components. Though the norm fixed for CB production is 1:2 *i.e*., 1 bivoltine to 2 multivoltine seed cocoons and the dfls cocoon ratio is 1:6 *i.e*., 1 dfl to be obtained from 4 MSC and 2 BSC, it can be seen from the experimental batches (Table 1) that procurement of 16 batches of BSC was 6.88 lakh (Actual cocoons) and good cocoons obtained from these lots were 6.22 lakh *i.e*., with an average pupation rate of 90.36%. The loss of pupae in BSC due to melt was 0.66 lakh cocoons, which indicates that the ratio is already skewed. Being a vibrant animal group the ratio of male-female in any given population is always assorted and does not follow precisely any particular pattern/norm, hence the population of males in the bivoltine seed cocoons under trials ranged from 21.12% to 51.08%, which means that there is a variation in male population expected in the experimental lots. For the 13.12 lakh MSC procured the female population obtained was 4.98 lakh (Fig. 2). Now for the total 4.98 lakh number of female moths, the male moths obtained is 1.95 lakh number only *i.e*., a deficiency of 62700 males, which need to be managed. Hence, the ratio obtained in reality is 1:1.5 only though the norm is 1:2, which mean there is a shortage of male for every 0.5 female. In other words based on rate of pupation, to process 13.12 lakh PM seed cocoons the requirement of CSR2 male component cocoons is to the extent of 7.91 which works out to the extent of 1:1.7 ratio. Hence, for effective processing 1:1.5 to 1:1.7 ratio will be most appropriate.

Seed producers across government and private sector, NSSO/DOS/LSP have invariably been facing this problem of shortage of males to the extent that achieving the set norm of 1:2 and 28-30% recovery is difficult, given the piquant condition of dealing with live material. However, the PM seed cocoon performance has indicated more or less consistency in the rate of moth emergence which is different from CSR2 (Fig. 3).

There are no fixed conditions and guarantees of obtaining good, live pupae and/ or particular number of males in a lot. Hence, the fixed ratio of 1:2 seems very unrealistic in commercial CB seed production, while processing CSR2 as male component This is in conformity with the observations made by most of the egg producers who also expressed the same at different forums.

The basic need for seed cocoons of good quality and quantity is mandatory for live and healthy pupal population to be high such that the loss in male moths is minimal. This helps in good synchronization between male, female population and the pairing process.

CONCLUSION

The findings are in conformity with the established breeding principles that the high yielding breeds will have negative correlation on the parameters like survival and performance. The experiment opens the field for other such thorough studies to establish the fact for revisiting the norm of BSC: MSC to 1:1.5 and/or 1:1.7 as well as Dfl Cocoon ratio which is highly relevant in case of the new breeds like CSR2. There is also need for organized co-operation among the seed producers particularly with Bivoltine hybrid egg producers to share and effectively utilize the male population in case of exigency.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 239-242

ARTIFICIAL GERMINATION OF THE SPORES OF DIFFERENT MICROSPORIDIA BY A TWO-STEP PROCEDURE

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ABSTRACT

In the present study, artificial germination of spores of five different microsporidia designated as NIK-1Pr, NIK-1Cc, NIK-1Cpy, NIK-1So and NIK-1Dp isolated from insect pests of mulberry and other agricultural crops has been investigated. The microsporidian spores were induced to germinate artificially by a two-step procedure. In the first step, the purified spores were activated by incubating them in different concentrations of potassium hydroxide (KOH) solution at different pH. In the second step, the treated spores were neutralized with Phosphate Buffer Saline (PBS, pH 7.00). Percentage of germination varied among the different microsporidia in different concentrations of KOH. The microsporidian NIK-1Cc showed the poorest germination (1-60%) whereas the standard microsporidian strain *Nosema bombycis* showed highest germination (41-100%) in KOH solution. The other microsporidia *viz.,* NIK-1Pr, NIK-1Cpy, NIK-1So and NIK-1Dp showed intermediate levels of germination.

Key words: Artificial germination, Microsporidia, Phosphate Buffer Saline, Potassium hydroxide

INTRODUCTION

Microsporidiosis of silkworm is caused by a highly virulent parasitic microsporidian, *Nosema bombycis* Naegeli. Different strains and species have been isolated from the infected silkworms and the disease epizootic has become increasingly complex as more number of strains and species are being identified to be infecting silkworm (Ananthalakshmi *et al.*, 1994; Kishore *et al.*, 1994; Samson *et al.*, 1999; Sharma *et al.*, 2003; Nageswara Rao *et al.*, 2004; Shabir Ahmad Bhat and Nataraju, 2004; Ifat Bashir and Sharma, 2008 a). They differ in their infectivity, target tissues, mode of transmission and *in vitro* germination (Fujiwara, 1984; 1985, 1993). The germination of microsporidia occurs in the gut of the host when spores are ingested and the sporoplasm is inoculated into the epithelial cells of the gut wall. However, the spores of different microsporidia can be induced to germinate artificially by various chemical and physical treatments (Keohane and Weiss, 1999). The viability of different microsporidian spores can be assessed by their capacity to germinate (Undeen, 1997). The process of *in vitro* spore germination is an interesting and unique biological phenomenon. The spores germinate by extrusion of the polar filament on incubation in potassium hydroxide (KOH) followed by rapid neutralization in Phosphate buffered saline (Ohshima, 1964; Petri, 1969; Weidner, 1972; Kawarabata, 2003). Germination is the simplest method to extract nuclear DNA (Undeen and Cockburn, 1989) and other intrasporal macromolecules as well. Germinated spores appear black under phase contrast microscope and the thin polar filaments extrude from the spore with sporoplasm at their tips (Bhat and Nataraju, 2007; Singh *et al*., 2007).

Five different microsporidia designated as NIK-1Pr, NIK-1Cc, NIK-1Cpy, NIK-1So and NIK-1Dp isolated from *Pieris rapae*, *Catopsilia crocale*, *Catopsilia pyranthe*, *Spilosoma obliqua* and *Diaphania pulverulentalis* have been reported to differ from each other and also from the standard strain, *Nosema bombycis* in terms of their morphology,

infectivity, transmission and rate of spread (Ifat Bashir and Sharma, 2008 a, b). The present study has been undertaken to investigate on the artificial germination of these microsporidian spores by neutralization method.

MATERIALS AND METHODS

The spores of the five different microsporidia isolated from insect pests of mulberry and some other agricultural crops were purified by the standard percoll centrifugation method described by Sato and Watanabe (1980). Germination response of the spores of these microsporidia was studied and compared with the germination of the spores of the standard strain *N.bombycis* by following neutralization method (Ohshima, 1937). The freshly purified spores of the isolated microsporidia and *N.bombycis* (2×10^7 spores/ml) were incubated for 10 and 20 minutes in 5 different concentrations of Potassium hydroxide (KOH) solution *viz.*, 0.2, 0.4, 0.6, 0.8 and 1.0% at a pH of 13.00, 13.23, 13.43, 13.57 and 13.72 respectively. The pH of KOH solution was adjusted either with HCl or NaOH. The pH of KOH solution was measured by Lacom tester pH Scan Series pH meter. The treated samples after incubation were neutralized with Phosphate Buffer Saline (PBS, pH 7.00) following the method of Fujiwara (1993) and were observed for germination under phase contrast microscope at 600X magnification. The percentage of germination was estimated by counting the germinated and non-germinated spores following the standard method (Undeen and Avery, 1984). The spores which appeared black under phase contrast microscope and had an attached polar filament were considered as germinated whereas the white and refringent spores as non-germinated. The observations were recorded as follows:

1-20% germination was recorded as +, 21-40% as ++, 41-60% as +++, 61-80% as ++++ and 81-100% as +++++.

RESULTS

The results on the germination response of the isolated microsporidia and *Nosema bombycis* are presented in Table 1. Among the different microsporidia tested, the microsporidian, NIK-1Cc showed poor germination (1-20% at 0.2-0.6% concentration of KOH) when incubated for 10 minutes. The spores of the said microsporidian showed a germination of 21-40% when incubated at a KOH concentration of 0.8-1.0% for 10 minutes. However, the highest germination (41-60%) of the said microsporidian was observed when incubated at a KOH concentration of 0.8 to 1.0% for 20 minutes.

The microsporidia *viz.,* NIK-1Cpy and NIK-1So showed a germination ranging from 21-40% and 41-60% respectively on incubation in KOH solution of 0.2 and 0.4-0.6% concentration for 10-20 minutes. Highest germination of the said microsporidia (61 to 80%) was observed on incubation in KOH solution of 0.8 to 1.0% concentration for 10-20 minutes.

The other microsporidia (NIK-1Pr and NIK-1Dp) showed an intermediate level of germination (1 to 60%) when incubated at 0.2 to 1.0% concentration of KOH for 10-20 minutes. Compared to the isolated microsporidia, the standard strain, *N. bombycis* showed the highest germination ranging from 41 to 100% when incubated for 10-20 minutes at KOH concentration of 0.2 to 1.0%.

DISCUSSION

Artificial germination methods of microsporidian spores have been studied by several investigators (Undeen, 1978, 1983; Ohshima, 1964; Ishihara, 1967). Spores of invertebrate and vertebrate microsporidia can be induced to germinate artificially by various chemical treatments (Keohan and Weiss, 1999). Artificial germination of the microsporidian spores requires two steps - the first is priming and the second is the induction of sporoplasm extrusion. In suitable buffer or salt solution, the spores germinate within a few seconds after priming by the action of certain chemicals. Since the priming effect of KOH is reliable to any microsporidia, this chemical is being used commonly. The germination of spores begins with an environmental trigger that varies for different species depending on their habitat (Keeling and Fast, 2002) but is poorly understood (Keohan and Weiss, 1999; Keeling and Fast, 2002). Germination of the microsporidian spores coincides with extrusion of the polar filament. It is affected by several factors like changes in pH, types of ions present, osmotic pressure around spores, temperatures, inhibiting substances and biochemical properties of the spores (Undeen, 1990).

The spores germinate on incubation in potassium hydroxide (KOH) followed by neutralization with PBS (Petri, 1969; Weidner, 1972; Kawarabata, 2003). The germinated spores lose their refringency and appear black under phase contrast microscope due to the extrusion of polar filament whereas the non-germinated spores remain bluish in color and exhibit refractive index. Hence, it is necessary to use highly purified spores for artificial germination study so as to avoid the confusion of immature or dead spores with that of the germinated spores while estimation of the germination percentage.

The spores of the isolated microsporidia differ in their physiological ability to germinate. The microsporidian NIK-1Cc is a poor germinator and germinates to an extent of 1-60% only in KOH solution of 0.2 to 1.0% concentration. The environmental spores of *Nosema* sp. NIS-M11 are also poor germinators (Yasunaga *et al*., 1991). The microsporidia *viz.*, NIK-1Cpy and NIK-1So showed highest germination (21-80%) in KOH of 0.2 to 1.0% concentration, whereas the other microsporidia (NIK-1Pr and NIK-1Dp) showed intermediate

Table 1: Artificial germination of the microsporidian spores isolated from insect pests of mulberry and some other agricultural crops.

Microsporidian isolates	KOH concentration (%)	KOH (pH)	Percentage of germination	
			10 min.	20 min.
NIK-1Pr	0.2	13.00	+	++
	0.4	13.23	++	++
	0.6	13.43	++	++
	0.8	13.57	++	++
	1.0	13.72	+++	+++
NIK-1Cc	0.2	13.00	+	+
	0.4	13.23	+	++
	0.6	13.43	+	++
	0.8	13.57	++	+++
	1.0	13.72	++	+++
NIK-1Cpy	0.2	13.00	++	++
	0.4	13.23	+++	+++
	0.6	13.43	+++	+++
	0.8	13.57	++++	++++
	1.0	13.72	++++	++++
NIK-1So	0.2	13.00	++	++
	0.4	13.23	+++	+++
	0.6	13.43	+++	+++
	0.8	13.57	++++	++++
	1.0	13.72	++++	++++
NIK-1Dp	0.2	13.00	+	++
	0.4	13.23	++	++
	0.6	13.43	++	++
	0.8	13.57	++	++
	1.0	13.72	+++	+++
Nosema bombycis (Control)	0.2	13.00	+++	+++
	0.4	13.23	+++	+++
	0.6	13.43	+++	++++
	0.8	13.57	++++	+++++
	1.0	13.72	+++++	+++++

Germination index: +: 1-20%; ++: 21-40%; +++: 41-60%; ++++: 61-80% & +++++: 81-100%.

level of spore germination. The spores of the standard strain, *N. bombycis* germinated to an extent of 41-100% at 0.2 to 1.0% concentration of KOH. The present investigation therefore, reveals that the microsporidia which showed higher germination tend to indicate more pathogenicity towards silkworm and vice-versa.

ACKNOWLEDGMENT

The authors express their gratitude to the scientific and technical staff of the Silkworm Pathology Laboratory, CSRTI, Mysore for their encouragement during the study. The authors are also grateful to the Director of the Institute for providing the necessary facilities during the study.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 243-248

EFFECT OF CERTAIN ANTIVIRAL DRUGS AGAINST NUCLEAR POLYHEDROSIS IN SILKWORM, *BOMBYX MORI* L.

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ABSTRACT

Nuclear polyhedrosis of *Bombyx mori* L. is one of the major viral diseases of silkworm and is commonly known as Grasserie. The disease is prevalent in all the sericultural countries including India. Though prevention has been greatly successful, sometimes the disease breaks out leading to crop loss. Such situation needs to be managed and disease curative methods would be an appropriate option. There are few studies on the development of curative measures against silkworm diseases such as bacterial and infectious flacherie, nuclear polyhedrosis, pebrine and white muscardine. Anti-viral drugs, antibiotics, anti-viral botanicals have been tested with some success. In the present study a few anti-viral drugs used to cure viral diseases in human beings have been tested to develop suitable curative measure against nuclear polyhedrosis. Four antiviral drugs *viz*, Herpikind™- 400, Valcivir-1000, Penvir-250 and Amantrel were selected for the study which showed that among the four drugs screened Herpikind™- 400 is most effective. Herpikind™- 400 at 0.15% (T3) was observed to reduce the mortality due to nuclear polyhedrosis by 50.57%, when treatment was given 24 h after BmNPV inoculation. In treatment 24 h after BmNPV inoculation, the reduction in mortality due to nuclear polyhedrosis ranged between 1.15 (0.05% Amatrel) to 50.57 % (0.15% Herpikind). It is also observed that the treatment with Acyclovir did not affect significantly the economic parameter of the silkworm.

Key words: Antiviral drugs, BmNPV, Curative measures, Grasserie, Silkworm disease

INTRODUCTION

Prevention of diseases is the major strategy in management of diseases in silkworm in all sericulture countries. Though prevention has been greatly successful, sometimes the disease breaks out leading to crop loss. Such situation needs to be managed and cure would be an appropriate option. There are few studies on the development of curative measures against silkworm diseases such as bacterial and infectious flacherie, nuclear polyhedrosis, pebrine and white muscardine. Anti-viral drugs, antibiotics, anti-viral botanicals also have been tested with some success. Amruth, a botanical based formulation is developed to suppress bacterial and viral flacherie (Balavenkatasubbaiah *et al*., 2008). Systemic fungicides have been identified for control of white muscardine (Virendrakumar *et al*., 2002). Antibiotics Tetracycline, Gentamycin, Leucomycin and Fructosazine are reported to suppress nuclear polyhedrosis in silkworm (Steinhaus, 1963, Liu Shi Xian and Zhong, 1988).

Nuclear polyhedrosis is a disease where the symptoms become clear only at late stage of disease development and cure of the disease require drug which could be effective even at the late stage of infection. The available curative measures are not good enough and need to look for a better curative measure. In the present study a few anti-viral drugs used in human beings to cure viral diseases have been tested to develop more suitable curative measure against nuclear polyhedrosis. Anti-viral drugs are a class of medication specifically used to treat viral infections in human and domestic animals. The antiviral drugs normally do not destroy the pathogen but inhibit the virus development. Some of them interfere with their ability to invade the target cell. There are anti-viral drugs which synthesis antiviral components after a virus invades a cell. Some anti-viral drugs enhance the body's immune system to counter the invading virus.

MATERIALS AND METHODS

Selection of Anti viral drugs: Anti-viral drugs used to combat viral diseases in humans were selected for the study. Literature formed the basis for the selection of the drugs. The drugs were:

Herpikind™- 400: "Herpikind™ - 400" marketed by M/s Life Star, Mankind group Co. 207, Okhla industrial estate -3, New Delhi – 110 020, contains antiviral drug Acyclovir BP 400 mg. It is used to cure herpes simplex virus, Chicken pox virus *etc*. in human beings.

Valcivir-1000: Valcivir-1000 is an antiviral drug containing Valacyclovir hydrochloride. It is available in the market as Valacyclovir 1000 mg, by the trade name of "Valcivir-1000", manufactured and marketed by M/s Protec. Division of Cipla Ltd., Verna industries estate, Goa 403 722. It is used against herpes zoster virus and genital herpes in HIV – infected humans.

Penvir-250 (Famciclovir)**:** Penvir-250 is available as Famciclovir tablets marketed by the trade name of "Penvir - 250". It is marketed by M/s Hetero drug limited. 22-110 IDA, Jeedimetla, Hyderabad. 500 055. The drug is used against acute herpes zoster (shingles) virus, and immuno-competent patients.

Amantrel (Amantadine hydrochloride)**:** Amantrel is available as Amantadine hydrochloride capsules 100 mg, by the trade name of "Amantrel". It is marketed by M/s Cipla Ltd. Maipur. Dist. Solan – 173 205. It is used against influenza – A virus in humans.

The drugs are prescribed as per the body weight (30 kg and above) of the patient in humans. The dose prescribed for different drugs are Herpikind - 400 is twice a day; Valcivir-1000 once a day; Famciclovir-250 thrice a day and Amantrel-100 after every four hours. The antiviral drugs were selected based on literature and obtained from chemists in the form of tablets or capsules. The tablets or the content of capsules were grinded, if required into fine powder and weighed. The powder was suitably mixed with distilled water to obtain the drugs in required concentrations.

Screening the drugs for toxicity, repellency and palatability:

Silkworm breed: The larvae of silkworm hybrid SH6 × NB4D2 were used for screening all four drugs for their toxicity, repellency and palatability. The silkworm eggs received from CSRTI, Pampore, were reared following the standard procedure.

Preparation of required concentration of drug: All the four drugs were tested prior to screening for anti BmNPV activity, for toxicity, repellency and palatability to silkworms. To test the toxicity, repellency and palatability, the drug dissolved in distilled water was used. Drugs of 2 % concentration were prepared by dissolving 0.2g or 0.2ml of drug in 10 ml of distilled water. The aqueous drug solution was stored at 5C for further use.

Treatments: All the four antiviral drugs at 2% concentration prepared as detailed above was smeared on mulberry leaf discs of 100 sq cms and fed to 3rd instar silkworm @ two discs per 100 larvae. The larvae were allowed to feed the drug smeared leaves for 24 h and then they were fed with normal untreated mulberry leaves. Each treatment had 5 replications of 100 larvae. There was a control with larvae fed on mulberry leaves smeared with water. There was one more control with the larvae fed on mulberry without any treatment.

Observation: The larvae were reared till cocooning and observed for mortality with the symptoms of toxicity, and recorded. The larvae were also observed for repellency and palatability to the drug treated and recorded the observation.

Screening the drugs for antiviral activity against BmNPV infection in silkworm:

Preparation of BmNPV inoculum: The BmNPV polyhedral occlusion bodies were collected from the hemolymph of nuclear polyhedrosis diseased silkworm and isolated by repeated centrifugation following the standard procedure (Sugimori *et al*., 1990). The stock inoculum was quantified and diluted with sterile distilled water to obtain inoculum of conc. 1×10^6 POB/ml.

Preparation required concentration of drugs: Keeping in view the body weight of third instars larvae which works out to 2.6 g / 100 larvae, three concentrations, *viz*, 0.05, 0.1 and 0.15 % of drugs were fixed and screened for their antiviral activity in silkworm. The selected concentrations *viz*., 0.05, 0.1 and 0.15% were prepared by dissolving separately 0.05, 0.1 and 0.15g of drug in 100 ml of distilled water. The aqueous drug solution was stored at 5°C for further use.

Treatments: Three different concentrations (0.05, 0.1 and 0.15%) of all the four drugs were given in two sets. In the first set, treatment was given 24h after the silkworm was inoculated with BmNPV. In the second set, the treatment was given 24 h before the silkworms were inoculated with BmNPV. The treatment details are presented in Table 1.

In first set, the third instar silkworm larvae reared under aseptic conditions and inoculated with inoculum of BmNPV of a dose of 1×10^6 POB/ml. The inoculum was smeared on two mulberry leaf discs @ 0.5ml/disc of 100 Sq cm. Two such discs were fed to 100 silkworm larvae. The larvae were allowed to feed on the inoculum smeared leaf discs for 24h to ensure complete consumption of pathogen. After 24h, the larvae were fed on mulberry leaf discs smeared with specific drug of specific concentration @ 0.5ml/disc and two discs

were fed to 100 silkworm larvae. Similarly in the next set treatments were given except for the time of drug administration. In this set drug was administered 24h before BmNPV inoculation. The larvae were reared after the treatment till cocooning on normal mulberry leaves.An inoculated control where the larvae were inoculated with the inoculum and had no drug treatment and another control with neither inoculation with pathogen nor drug treatment were also maintained. Each treatment had five replications of 100 larvae.

Observations: Observations were made for mortality/ infection on daily basis due to nuclear polyhedrosis and recorded. Observation were also made on different rearing parameters and recorded. The data was tabulated and analyzed statistically. The percent reduction in mortality as compared to inoculated control was calculated as per the following formula

$$\% \text{ reduction in mortality} = \frac{\text{Mortality in inoculated control} - \text{Mortality in treated batch}}{\text{Mortality in inoculated control}} \times 100$$

RESULTS

None of the four antiviral drugs *viz*., Herpikind - 400, Valcivir-1000, Penvir -250 and Amantrel-100 were toxic, repellant and affected palatability. The larvae fed on these drugs at 1% concentration in distilled water, along with mulberry did not cause mortality or toxicity. Visual observation of larvae associated with treated mulberry did not indicate repellency to drug. The consumption of treated mulberry by larvae also indicated that the drug has not affected the palatability.

Treatment 24 h after BmNPV inoculation: The result of the studies on the treatment of silkworm with drug 24 h after BmNPV inoculation is presented in Table 2. Among the four drugs screened Herpikind™ 400 is observed to be most effective. Herpikind at 0.15% (T3) of Acyclovir BP 400 mg was observed to reduce the mortality due to nuclear polyhedrosis by 50.57% while 0.1% and 0.05% reduced the mortality by 44.01 and 38.99% respectively. It is also observed that the treatment with Herpikind did not significantly affected the economic parameter of the silkworm. The drug, Penvir 250 follows Herpikind in its efficacy but its efficacy was significantly lower. Penvir at 0.15% is observed to reduce the mortality due to nuclear polyhedrosis by 30.50% while 0.1 and 0.05% of Penvir reduced the mortality by 26.64 and 23.16% respectively. Amantrel is least effective with reduction in mortality ranging from 1.15 (T10, 0.05%) to 9.20% (T12, 0.15%). Valcivir (0.15%) is observed to reduce the mortality due to nuclear poyhedrosis by 28.18% but at 0.05 and 0.1%, the reduction in mortality was only 5.79 and 10.81%, respectively.

Treatment 24h before BmNPV inoculation: The treatment of silkworm with drug 24 h before BmNPV inoculation was comparatively more effective than treatment with drug 24 h after BmNPV inoculation (Table 3). The reduction in mortality due to nuclear polyhedrosis ranged from 16.60 (0.05% Penvir) to 81.46% (0.15% Herpikind).

Compared to the mortality in inoculated control, the highest reduction in mortality due to nuclear polyhedrosis was obtained with the drug Herpikind (Tables 2 and 3). In batch treated with drug Herpikind 24 h after inoculation, irrespective of concentration, the reduction was 44.52% where as in batch treated with drug 24 h before inoculation it was 68.68%. The drug Herpikind of 0.15% concentration was most effective if fed 24 h before BmNPV inoculation with reduction in mortality by 81.46%. The drug at 0.05 and 0.1% concentration could reduce the mortality by 61.67 and 62.93%, respectively when administered 24 h before inoculation. The drug Valcivir, was also found comparatively less effective in reduction in mortality due to nuclear polyhedrosis. At 0.15% reduction in the mortality if fed 24 h before inoculation was 61.00% and at 0.05 and 0.1% concentrations, it could reduce the mortality by 54.05 and 55.59%, respectively. The drug Amatrel was least effective if fed 24 h before inoculation and the reduction in mortality was in the range of 40.54 and 52.50%. The drug Penvir was also comparatively less effective with reduction in mortality in the range of 16.60 to 48.64%. None of the drugs had any ill effect on the economic parameters such as larval period, larval weight, cocoon weight, cocoon shell weight and silk content of cocoon.

DISCUSSION

Results on chemotherapy against BmNPV shows all the antiviral drugs were able to inhibit the polyhedrosis infection in silkworm *B. mori*. (Tables 2 and 3). Antiviral drugs used in the present study *viz*, Herpikind, Valcivir, Penvir and Amatrel at different concentrations were found to reduce the mortality in curative set of experiment (Treatment 24h after BmNPV inoculation). Mortality was recorded in different concs. of the antiviral drugs was in the range of 25.60 % to 50.40 %. In the inoculated control where no drug was given, the mortality was 51.80% where as mortality was least in the set of experiment, where drugs were given before inoculation. Here, the mortality was in the range of 9.60 % to 43.20 % as against mortality (51.80%) in the inoculated control. Results also showed that the above drugs when used 24 h before BmNPV inoculation were more effective than the administration of drugs 24 h after inoculation. Antiviral drug, Herpikind was observed as effective at all the concentrations and higher effectiveness was observed with the concentration of 0.15 %. Penvir was found least effective as compared to other drugs.

Table 1: Treatment details for screening of drugs for antiviral activity, effective concentration and treatment period.

Drugs	Concentration	Treatment 24 h	
		After BmNPV inoculation	Before BmNPV inoculation
Herpikind -400	0.05%	T1	T13
	0.1%	T2	T14
	0.15%	T3	T15
Valcivir - 1000	0.05%	T4	T16
	0.1%	T5	T17
	0.15%	T6	T18
Penvir - 250	0.05%	T7	T19
	0.1%	T8	T20
	0.15%	T9	T21
Amatrel	0.05%	T10	T22
	0.1%	T11	T23
	0.15%	T12	T24
Inoculated control		T25	
Control		T26	

Table 2: Efficacy of different drugs fed 24 h after BmNPV inoculation on rearing performance of silkworm hybrids and mortality due to nuclear polyhedrosis

Treatment	Nuclear polyhedrosis		Larval duration (h)	Larval Wt. (g)	SCW (g)	SSW (g)	SR %
	% Mortality	% reduction in mortality					
T1 0.05% Herpikind	31.60	38.99	648	46.28	1.782	0.314	17.65
T2 0.1% Herpikind	29.00	44.01	644	48.53	1.786	0.312	17.46
T3 0.15% Herpikind	25.60	50.57	622	49.65	1.808	0.324	17.92
T4 0.05% Valcivir	48.80	5.79	643	44.67	1.710	0.288	16.84
T5 0.1% Valcivir	46.20	10.81	653	45.23	1.696	0.292	17.27
T6 0.15% Valcivir	37.20	28.18	647	43.30	1.726	0.298	17.27
T7 0.05% Penvir	39.80	23.16	643	45.42	1.724	0.296	17.18
T8 0.1% Penvir	38.00	26.64	635	41.56	1.720	0.306	17.57
T9 0.15% Penvir	36.00	30.50	652	44.41	1.756	0.298	16.98
T10 0.05% Amatrel	51.20	1.15	650	41.52	1.676	0.294	17.53
T11 0.1% Amatrel	50.40	2.70	648	41.28	1.702	0.282	16.56
T12 0.15% Amatrel	47.00	9.20	657	41.18	1.758	0.288	16.39
T25 Inoc. control		51.80	667	39.13	1.664	0.272	16.34
T 26 Control		00.00	649	54.83	1.834	0.334	18.18
S.E ±	1.13		5.25	0.92	0.014	0.006	0.39
CD at 5 %	3.20		15	2.60	0.040	0.018	1.12
CD at 1 %	4.26		20	3.46	0.054	0.024	1.48

Table 3: Efficacy of different drugs fed 24 h before BmNPV inoculation on rearing performance of silkworm hybrids and mortality due to nuclear polyhedrosis

Treatment	Nuclear polyhedrosis		Larval duration (h)	Larval Wt (g)	SCW (g)	SSW (g)	SR %
	% Mortality	% reduction in mortality					
T13 0.05% Herpikind	20.40	61.67	647	51.70	1.806	0.302	16.71
T14 0.1% Herpikind	19.20	62.93	647	51.82	1.802	0.312	17.31
T15 0.15% Herpikind	09.60	81.46	642	54.34	1.838	0.332	18.06
T16 0.05% Valcivir	23.80	54.05	639	51.21	1.746	0.298	17.07
T17 0.1% Valcivir	23.00	55.59	644	51.00	1.712	0.284	17.29
T18 0.15% Valcivir	20.20	61.00	639	51.68	1.750	0.298	17.03
T19 0.05% Penvir	43.20	16.60	657	48.75	1.682	0.270	16.04
T20 0.1% Penvir	35.40	31.66	652	49.93	1.706	0.298	17.51
T21 0.15% Penvir	26.60	48.64	648	50.99	1.726	0.300	17.37
T22 0.05% Amatrel	30.80	40.54	643	50.08	1.694	0.282	16.64
T23 0.1% Amatrel	24.60	52.50	646	51.13	1.748	0.312	18.08
T24 0.15% Amatrel	29.20	43.62	648	50.08	1.728	0.298	17.12
T25 Inoc. control	51.80	-	649	39.13	1.667	0.272	16.34
T26 Control	00.00	00.00	649	54.83	1.834	0.334	18.18
S.E ±	1.09		5.03	0.52	0.19	0.01	0.31
CD at 5 %	3.09		-	1.46	0.546	0.015	0.88
CD at 1 %	4.11		-	1.95	0.726	0.020	1.16

Chemotherapy has been used against BmNPV to suppress the disease in other insects and silkworm earlier. There are reports of their effectiveness as well, 0.1 % tetracycline and gentamycin (Steinhaus, 1963) are reported to be effective in reduction of loss due to nuclear ploy hedrosis. Leucomycin and Fractosazine were reported to inhibit the development of nuclear polyhedrosis (Liu Shi Xian and Zhong, 1988). Three antibiotics *viz,* Rifampicin, Chloramphenicol and Cifran at 0.05 % concentration were tested against BmNPV (Bhattacharya *et al*., 1998) and Rifampicin was found effective.

The mode of action of drugs may be due to inhibitory activity against viral particles (Anon 2003). The drug Acyclovir, when adminisered to living organism, for management of viral disease, the enzyme kinase in virus infected cells initiates the activation of acyclovir in tri-phosphate, which interferes with viral DNA polymerase and inhibits viral duplication. The drug Valcivir ranks second in efficacy is the hydrochloride salt of L-valyl ester of acyclovir. The replication of viral DNA is stopped by three ways i) inhibition of viral DNA polymerase ii) incorporation and termination of the growing viral DNA chain iii)inactivation of the viral DNA polymerase. Antiviral drug Famcyclovir, has no direct antiviral activity but is metabolized to pencyclovir a potent antiviral agent (Anon, 2003). Amatrel interferes with viral protein to stop the uncoating which is essential requirement for infection. (Deyde *et al*., 2007; Bright *et al*., 2006).

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 249-252

PATHOGENICITY AND TRANSMISSION RATE OF A NEW MICROSPORIDIA ISOLATED FROM THE SILKWORM, *BOMBYX MORI* L.

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ABSTRACT

Microsporidiosis or Pebrine is one of the earliest known diseases of silkworm. It causes considerable damage to the cocoon crops. A number of strains of microsporidia, which differ significantly in their pathogenicity, virulence and transmission are reported to cause the disease in silkworm. Six different microsporidia designated as NIK-1Bm, NIK-2Bm, NIK-3Bm, NIK-4Bm, NIK-5Bm and NIK-6Bm isolated from larval/pupal/moth samples of silkworm, *Bombyx mori* collected from K. R. Nagar, Mysore and Kollegal of Karnataka state, India were studied for their morphology, pathogenicity and transmission in comparison with the standard strain, *Nosema bombycis.* Morphological studies showed wide variation in their shape and size, which varies significantly from *N. Bombycis*. The microsporidia, NIK-1Bm was comparatively bigger in size (length 5.46µ, width 2.77µ and length width ratio of 1:0.51) followed by NIK-5Bm (length 5.02µ width 2.60µ and length width ratio of 1:0.51). The other microsporidia are of intermediate size. Pathogenicity of these microsporidia revealed that at an inoculum dose of 1×10^6 spores/ml NIK-5Bm resulted in highest mortality of 31% followed by NIK-6Bm with 17.67%. NIK-4m is found to be low pathogenic to silkworm with only 4% mortality in larval and pupal stages. With the other microsporidia, the mortality ranged from 11.33 to 15.67%. The infection rate at moth stage was also high in NIK-5 Bm (62%) followed by NIK-1Bm (54.67%). In *N. bombycis* the moth level infection was as high as 100%. Out of six microsporidia studied, only NIK-1Bm did not exhibit transovarial transmission whereas in other microsporidia, the rate of transovarial transmission varied from 13.66 to 92% as against 100% in *N. bombycis*.

Key words: Microsporidia, Morphology, *Nosema bombycis,* Pathogenicity, Transmission

INTRODUCTION

Pebrine disease is chronic in nature and causes varied degree of mortality in egg, larva, pupa and moth stages of silkworm. The causative agent, *Nosema bombycis* belongs to phylum, microsporidia. The pathogen is unique as the infection is also transmitted from the maternal parent to the progeny through infection in egg, apart from the usual mode of *per os* infection, which takes place by consuming mulberry leaves contaminated with microsporidian spores. Till some years ago, *N. bombycis* was considered as the only pathogen causing pebrine disease in silkworm. However, later on, it became clear that several microsporidia cause microsporidiosis in silkworm (Ananthalakshmi *et al*., 1994; Nageswara Rao *et al*., 2004). These microsporidia differ in their morphology, serology, site of infection and virulence. Among them, the most common ones belong to the strain of *Nosema* sp. (NIS-001, NIS-M11, NIS-M14, NIK-2r and NIK-3h), species of *Vairimorpha* (NIS-M12 and NIK-4m), *Pleistophora* (NIS-M27), *Thelohania* (NIS-M32) and *Leptomonas* cause infection of varied intensity in silkworm. Recently six microsporidia, which are different from *N. bombycis*, have been isolated from silkworm, *Bombyx mori* from silk farms in and around Mysore. The present study was carried out to characterize the isolated microsporidia for their morphology, pathogenicity and transmission.

MATERIAL AND METHODS

Isolation and purification of microsporidia: The microsporidian spores were isolated from the larval/moth

samples collected from Basic seed farm, K. R. Nagar, P3 B.S.F., Mysore and cocoon market of Kollegal and tentatively designated as NIK-1 Bm, NIK-2 Bm, NIK-3 Bm, NIK-4 Bm, NIK-5 Bm, NIK-6 Bm. The samples were homogenized in 0.6% K_2CO_3 using mortar and pestle and the homogenate was filtered through a layer of absorbent cotton and centrifuged at 3,000 rpm for 5 minutes. After centrifugation, the supernatant was discarded and sediment was mixed using Cyclomixer. The microsporidian spores in the sediment were further purified using percoll gradient centrifugation method as described by Sato and Watanabe (1980). The stock concentrations of microsporidian spores were estimated using haemocytometer (Cantwell, 1970).

Morphological characters of microsporidia: The microsporidian spores were first immobilized using a drop of mineral oil. 50 spores of each microsporidia were measured for their length and width following the standard micrometry method (Fujiwara, 1980).

Pathogenicity of microsporidia to silkworm: The stock solution of each microsporidian spore was suitably diluted to get 1×10^6 spores/ml and inoculated to the silkworms immediately after II moult by *per os* method. Three replications of 100 larvae were maintained for each microsporidian. The mortality due to concerned microsporidian was recorded during larval and pupal stages. The harvested cocoons were kept for moth emergence and all the emerged moths were tested for respective microsporidian infection.

Determination of Transovarian transmission: The transovarial transmission was determined for each microporidian by per orally inoculating the microsporidia at a dose of 1×10^7 spores/ml to the silkworms on 1st day of fifth instar as described above and continued the rearing. The harvested cocoons were kept for moth emergence. The emerged moths were allowed to pair and after mating the female moths were kept for egg laying. After egg laying, the female moths were tested for the presence of concerned microsporidian infection and the layings of the infected moths were incubated for next generation rearing.

The progeny larvae were reared as per the standard method (Datta, 1992). After I moult 50 larvae/batch were collected randomly and homogenized individually and the smears were observed under microscope 600 × magnification. The dead eggs of the respective laying were also examined individually for the presence of concerned microsporidian infection. The transovarial transmission rate was calculated as per the formula (Han and Watanabe, 1988). All the above parameters were also observed with *N. bombycis* microsporidian spores for comparison.

RESULTS

Morphological characters *viz.,* length, width and length width ratio of different isolated microsporidia are presented in table-1. The spores of NIK-1Bm were largest in size exhibiting length of 5.46µ and width of 2.77µ with length ratio of 1:0.51. NIK-5Bm was next in size having 5.02µ length and 2.60µ width with length width ratio as 1:0.51. Other microsporidia were intermediate in size with length ranging from 3.47 to 4.08µ and width ranging from 2.30 to 2.60µ.

The pathogenicity of different microsporidia to silkworm is presented in Table-2. It is clear from the table that NIK-5Bm caused highest mortality (27.33%) during larval stage followed by NIK-6Bm (15%), NIK-3Bm (12%), NIK-2Bm (10.33), NIK-1Bm (9.67%). Lowest mortality of 3% was recorded in the batches inoculated with NIK-4Bm. However, the standard strain, *Nosema bombycis* causing pebrine disease in silkworm, which was kept as control caused as high as 72% mortality. Similarly, in emerged moths, highest incidence of microsporidiosis (62%) was recorded in NIK-5Bm microsporidia inoculated batches followed by NIK-1Bm (54.67%), NIK-6Bm (38%), NIK-2Bm (35%), NIK- 3Bm(33%) and NIK-4Bm (30%). In the standard strain, *N. bombycis*, 100% moths were found infected.

Rate of transovarian transmission of different microsporidia in the slkworm, was also studied and presented in Table-3. The highest rate of transovarial transmission (92%) was recorded in NIK-3Bm inoculated batches followed by NIK-2Bm (59.33%). The lowest rate of transovarial transmission (13.67%) was observed in NIK-4Bm. In other microsporidia, the rate of transovarial transmission ranged between 27.00 and 30.67%. In the standard strain, *Nosema bombycis*, rate of transovarial transmission was 100%.

DISCUSSION

Microsporidiosis of silkworm constitute a major threat to sericulture industry in India. The disease is kept under a reasonable check following strict mother moth examination during the seed production process. Despite all these precautions, sporadic outbreak of the disease is noticed from time to time. Of late, several other strains and species of microsporidia have been reported as infecting the silkworm, *Bombyx mori*. (Ananthalakshmi, *et al*., 1994, Shabbir Ahamad Bhat and Nataraju, 2004) and other lepidopteran insects (Sharma *et al*., 1989, 2003, Kishore *et al*., 1994, Ifat Bashir and Sharma, 2008 a, b, c). Under the present study, six different microsporidia have been isolated and characterized for their morphology, pathogenicity and rate of transovarial

Table 1: Morphological characters of different microsporidia isolated from the silkworm, *Bombyx mori* L.

Microsporidia	Place of collection	Morphological char acterization		
		Length (µm)	Width (µm)	L × W ratio
NIK-1 Bm	K. R. Nagar	5.46 ± 0.40	2.77 ± 0.22	1: 0.51
NIK-2 Bm	K. R. Nagar	3.84 ± 0.30	2.41 ± 0.22	1: 0.63
NIK-3 Bm	K. R. Nagar	3.76 ± 0.15	2.30 ± 0.14	1: 0.74
NIK-4 Bm	Mysore	4.08 ± 0.40	2.48 ± 0.15	1: 0.67
NIK-5 Bm	Kollegal	5.02 ± 0.24	2.60 ± 0.14	1: 0.51
NIK-6 Bm	Kollegal	3.47 ± 0.15	2.56 ± 0.15	1: 0.73
Nosema bombycis	Mysore	3.80 ± 0.01	2.60± 0.01	1: 0.68

Table 2*:* Pathogenicity of different microsporidia to silkworm, *Bombyx mori L.*

Microsporidia	% Mortality due to Microsporidiosis		% infection at moth stage
	Larva	Pupa	
NIK-1 Bm	09.67	01.67	54.67
NIK-2 Bm	10.33	02.33	35.00
NIK-3 Bm	12.00	03.67	33.00
NIK-4 Bm	03.00	01.00	30.00
NIK-5 Bm	27.33	03.67	62.00
NIK-6 Bm	15.00	02.67	38.00
Nosema bombycis	72.00	03.00	100
SE ±	01.32	01.18	01.01
CD at 5%	04.00	-	03.10

Table 3. Rate of transovarial transmission of different microsporidia in the silkworm, *Bombyx mori L.*

Microsporidia	Infection in dead eggs with microsporidia (%)	Infection of microsporidia in larvae (%)	Rate of transovarial transmission (%)
NIK-1 Bm	0.00	0.00	0.00
NIK-2 Bm	40.00	63.20	59.33
NIK-3 Bm	84.00	93.60	92.00
NIK-4 Bm	14.00	13.60	13.67
NIK-5 Bm	30.00	26.40	27.00
NIK-6 Bm	32.00	30.40	30.67
Nosema bombycis	100	100	100

transmission. The morphology included length, width and length width ratio of the isolated spores of different microsporidia. The data on the spore morphology clearly suggests that isolated six microsporidia are different from *N. bombycis* and also from each other. Out of the six microsporidia, microsporidia, NIK-1Bm has shown comparatively bigger size than all the other microsporidia. This microsporidian was ovo cylindrical in shape and exhibited high rate of sporulation in various tissues of silkworm.

In the present study, these isolated microsporidia showed significant infectivity to silkworm. Highest pathogenocity was shown by the microsporidia NIK-5Bm with 27.33% larval mortality whereas NIK-4Bm showed least pathogenicity. However when compared with *N. bombycis*, the infectivity of all the six microsporidia was significantly less indicating that these microsporidia are comparatively less damaging towards the silkworm crops. In this context it is noteworthy that several authors have also isolated microsporidia from lepidopteron pests of mulberry and other agricultural crops which were found to be infective to silkworm (Sharma *et al* 1989 and 2003, Ifat Bashir and Sharma, 2008 a, b). Kishore *et al.(*1994) studied the cross infectivity of microsporidia isolated from wild lepidopteron insects to the silkworm, *B. mori* and found that three microsporidia *viz*. McpyB1, McpoB1 MCcrB1 isolated from *C.pyranthe*, *C.pomonae* and *C.crocale* respectively were infective to silkworm and caused about 86 - 88% infection in moth stage of silkworm. These studies clearly indicate that the source of microspopridia other than *N. bombycis* isolated from the silkworm is wild lepidopteran insects as these microsporidia are generally less pathogenic to silkworm.

Present study also reports that except NIK-1Bm, the other five isolated microsporidia showed varying degrees of transovarial transmission ranging from 13.67 % (NIK-4Bm) to 92% (NIK-3Bm). NIK-1Bm did not exhibit transovarial transmission in the silkworm. As evident from the data, the size of NIK-1Bm is biggest among all the isolated microsporidia, it is possible that size of the microsporidia may have some relationship with the phenomenon of transovarial transmission which needs to be further investigated.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 253-257

USER FRIENDLY APPROACHES FOR THE MANAGEMENT OF SILKWORM DISEASES

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ABSTRACT

There are different approaches for the management of silkworm diseases during rearing. Disease prevention, disease suppression and development of disease resistant/tolerant breeds are such approaches presently used for the control of diseases in silkworm. Most of the technologies recommended earlier were based on preventive approaches, which include use of disinfectants for eliminating pathogens from the rearing environment and use of bed disinfectants to prevent the spread of diseases during rearing. Maintenance of personal and rearing hygiene during rearing was also recommended. In the present paper, different user friendly approaches for the management of silkworm diseases developed at CSR&TI., Mysore *viz.*, Use of Asthra, a new spray disinfectant, use of Ankush, an eco and user friendly bed disinfectant and use of Amruth, a curative botanical based formulation for the suppression of grasserie and flacherie diseases and use of disease resistant/tolerant hybrids have been tested and their impact discussed.

Key words: Disease management, Disease resistance, Disease suppression, Prevention, Silkworm breeds

INTRODUCTION

Mulberry sericulture industry consists of mulberry cultivation, silkworm rearing, silk reeling and weaving. Among these, the rearing of silkworm is considered most sensitive and delicate activity, which leads to the production of silk cocoons. The main constraint faced during silk cocoon production is the loss due to incidence of diseases. The diseases are prevalent throughout the year with varying degree of incidence in different seasons. An annual loss of 15 - 20% in cocoon production was reported in India due to diseases alone (Chitra *et al*., 1975). The diseased silkworm extrudes pathogens into the rearing environment, which form the source for disease spread of in the silkworm population. To contain silkworm diseases during rearing, certain preventive/curative measures are to be adopted. Accordingly, different practices for the management of silkworm diseases are recommended before the beginning of silkworm rearing as well as during the course of silkworm rearing. Use of disease resistant/tolerant breeds or hybrids for rearing is another approach for minimizing the loss during silk cocoon production.

Persistence of pathogen in the silkworm rearing environment, atypical symptoms of diseases in early stages of infection and fast dispersal of pathogens in silkworm colony are the primary constraints in disease management. The environmental factors such as temperature, humidity and the quality of mulberry leaves influence the intensity of diseases in silkworm. To overcome these constraints, Nataraju *et al*. (2002) formulated a practical technology for the management of diseases during rearing using Chlorine dioxide as a disinfectant and Vijetha as silkworm body and rearing seat disinfectant. These technologies are extensively popular among the farmers due to their efficacy in containing the incidence of diseases. However, there are some constraints in using these products. Though Chlorine dioxide is effective as a disinfectant, it's cost is comparatively high. Vijetha, though very effective in preventing all silkworm diseases, is not user and eco friendly. Hence, to solve these problems, CSR&TI., Mysore has developed different technologies for the management of diseases and the present study reports the results of validation of them through trials at farmers' level and their adoption in sericulture.

MATERIALS AND METHODS

Spray disinfection

A new chlorine based spray disinfectant "Asthra" is recently developed jointly by CSRTI, Mysore and M/s Seri-Gro Products, Bangalore which is found highly suitable for disinfection and hygiene maintenance in Indian rearing condition. The product is effective at a concentration as low as 0.05% against all silkworm pathogens. Therefore, only 50g Asthra powder is required to prepare 100 liters of disinfectant solution. Asthra should be dissolved in water at least 2 hours before taking up spray disinfection of the rearing house. As very small quantity of Asthra is sufficient to prepare large quantity of spray disinfectant, its handling and transportation is easy. The disinfectant was sprayed to silkworm rearing house and appliances and its surroundings at the rate of 1.5 liters/sq. m of floor area and also used for personal and rearing hygiene. Disinfection was conducted twice. First disinfection of the rearing house and appliances was carried out after completion of the rearing and second, 2-3 days before commencement of next rearing. Field-testing of Asthra was conducted at farmers' level during the period September, 2008 to April, 2009 in different sericulture areas of Karnataka, Tamil Nadu and Andhra Pradesh against the existing spray disinfectants as control.

Bed disinfection

Disinfection of the rearing bed is also an important component of overall sanitization process of the silkworm rearing. Recently "Ankush", an eco and user friendly bed disinfectant was developed which is highly effective in preventing the spread of all common diseases during silkworm rearing (Sharma *et al*., 2008). Based on experimental results, Ankush was recommended to dust after every moult before resumption of feed and 3rd day and 5th day of final instar. During the trials, Ankush was dusted 3 - 4 g/ sq. ft. bed area. The approximate quantity of Ankush used for 100 dfls is around 4.00 kg for tray rearing method and 6.00 kg for shelf rearing method.

Control of Grasserie and Flacherie diseases in silkworm

While the preventive measures against these two diseases are to a greater extent successful in containing the damage, there are occasional reports on the outbreak of these two diseases. Initially a few individual larvae get infected and later spread fast in the colony resulting in crop failure during final instar. To address this problem, Balavenkatasubbaiah *et al.,* (2008) developed a product, Amruth which is an eco and user friendly botanical based powder formulation which has to be fed to silkworm to control these two diseases. This formulation is non-toxic, non pollutant and biodegradable. The product is the first ever disease control measure and could also be used as precautionary measure against the possible outbreak of these two diseases. Amruth powder was mixed in clean water @ 20g/litre and the solution was sprinkled @ 70ml/kg mulberry leaves/shoot. These leaves were air dried for about half an hour and fed to the silkworms as per the schedule given below:

Application schedule of Amruth

Instar	Quantity of suspension	Approximate Qty. of leaf or shoot / 100 dfls. Rearing
III instar (2nd feed)	350 ml	5.00 kg
IV instar (2nd feed)	2,650 ml	38.00 kg
V instar (2nd feed)	4,500 ml	67.00 kg

Development of Disease resistant/tolerant breeds of silkworm

Rearing of commercial silkworm hybrids resistant to important silkworm diseases and adverse climatic conditions is better option particularly in tropical areas. In this direction, recently CSRTI, Mysore has developed a bivoltine hybrid, CSR21DR × CSR28DR (Sudhakar Rao *et al.,* 2006) and one multi × bivoltine hybrid, NDV6 × CSR2 (Premalatha *et al*., 2010) resistant to BmDNV1. In the present paper the performance of these new hybrids were compared with the existing hybrids which are popularly used in the field.

RESULTS

Spray disinfection using Asthra

Asthra was field tested as a disinfectant for disinfection and hygiene maintenance at farmers level in different sericultural areas of Karnataka, Tamil Nadu and Andhra Pradesh by keeping the existing spray disinfectants as control. A total of 135 crops were tested with Asthra disinfectant and 129 farmers who used other disinfectants served as control. The results showed an improvement of 11.25 kg/100 dfls. in cocoon yield by the use of Asthra over the existing disinfectant (Table 1). The rearing results as well as the farmers' opinion indicated that the Asthra disinfectant is suitable for disinfection and hygiene practice in sericulture.

Bed disinfection using Ankush

The data on the results of field trials of Ankush as a bed disinfectant for the prevention of spread of diseases during rearing is presented in Table 2. A total of 50 farmers' crops were covered with 6,968 dfls. The evaluation studies reveal that an average of 60.75 kg cocoons/100 dfls. were harvested in Ankush dusted batches when compared to 60.07 kg yield harvested in Vijetha dusted batches. The percent incidence of diseases was 3.072 in Ankush dusted batches when

compared to 3.304 % in Vijetha dusted batches. The field trials carried out under DBT funded project (Table 3) resulted in 68.35 kg cocoons yield/100 dfls. in Ankush dusted batches and 62.53 kg yield/100 dfls. in case of Vijetha dusted batches.

Disease suppression by using Amruth

The data on the field trials of Amruth is presented in Table 4. A total of 141 farmers' crops were covered consisting 17,660 dfls. The evaluation studies revealed that an average of 60.14 kg cocoons/100 dfls were harvested in Amruth treated batches with 62.02 and 59.82% reduction in grasserie and flacherie diseases respectively. In the control batches only 48.86 kg/100 dfls yield was obtained.

Use of disease resistant/tolerant breeds

The results on the performance of CSR21DR × CSR28DR (a newly developed bivoltine hybrid) and NDV6 × CSR2 (a newly developed Multi × bivoltine hybrid) is presented in Table 5. The results indicated that the performance of BmDNV resistant hybrids *viz*., CSR21DR × CSR28 DR and NDV6 × CSR2 were found to exhibit better survival both in natural condition and inoculated conditions. The cocoon characters recorded were also superior over the existing hybrids.

DISCUSSION

Earlier, this Institute has identified and recommended the use of Bleaching powder and Chlorine dioxide (Balavenkatasubbaiah *et al.*, 1994, 1999 and 2006) for elimination of pathogens from silkworm rearing environment. However, based on the lower cost and better efficacy another new spray disinfectant Asthra was recommended. Field trials of Asthra conducted at farmers' level in different sericultural areas of Karnataka, Tamil Nadu and Andhra Pradesh indicated that the disinfectant was effective for the disinfection and hygiene maintenance in silkworm rearing house. It has improved the cocoon yield and farmers have harvested an average of 71.05 kg cocoons/100 dfls. The rearing results as well as the farmers' opinion indicate that the disinfection with Asthra is suitable and the technology is well received by the sericulturists. Within a short span of time this disinfectant became very popular in the field due to following reasons:

- Preparation of disinfectant solution is easy. 50g of Asthra powder dissolved in 100 liters of water. It does not form slurry and do not block sprayer nozzle.
- Storage and transportation of Asthra is easy as the disinfectant is in powder form (100 g of Asthra powder pouch contains two small packets with 50g Asthra powder in each.
- Asthra disinfectant is effective at a very low dose, effective under all environmental conditions and less corrosive at recommended concentration.

Apart from disinfection of rearing house and appliances, it is essential to use bed disinfectant to sanitize rearing bed and body surface of silkworm larvae during rearing. Earlier, a number of bed disinfectants were developed and recommended by various researchers (Baig *et al*., 1990, Subba Rao *et al*., 1992, Datta *et al*., 1998, Patil and Shardamma, 1999 and Sasidharan *et al*., 2000) for the management of different diseases. Majority of the bed disinfectants though effective in preventing the silkworm diseases, were not user and eco friendly. To address this problem, CSR&TI, Mysore had initiated research work on the development of eco-friendly and user friendly bed disinfectant in the year 2000–2003 and developed "Ankush" a new bed disinfectant using biodegradable chemicals and plant products having anti-microbial properties (Sharma *et al*., 2008). The validation studies on the efficacy of Ankush in preventing the spread of major silkworm diseases in silkworm rearing at farmers' level confirmed its efficacy. The product became popular among farmers and to meet the growing demand, the product was licensed to M/s Sericon technologies, Bangalore during 2005 as (Ankush as trade name), M/s Sericare, Bangalore during 2006 (Ankush Vijetha Green as trade name) and M/s Rainbow Agro-Technologies, Cuddapah during 2010 (Rainbow Ankush as trade name) and M/s Pure Chemical Laboratories, Bangalore during 2010 (Ankush Green as trade name) for large scale production and supply to farmers.

Amruth is the first ever curative approach against silkworm diseases and it is a botanical based formulation for the control of grasserie and flacherie diseases. The results of the field trials of Amruth indicated that the product as effective in controlling Grasserie and flacherie diseases and there by increasing the cocoon yield. There was no adverse effect on silkworm larval health and cocoon characters by feeding Amruth to silkworm. To popularize Amruth, 28 demonstrations cum awareness programmes were conducted in three southern states *viz*., Karnataka, Andhra Pradesh and Tamil Nadu under a DBT funded project. The Novel features of Amruth are:

- First time in Sericulture, a technology has been developed for suppression of Grasserie and Flacherie diseases in silkworm.
- This technology is eco and user-friendly in nature
- The ingredients are botanical based, indigenous in nature and easily available.
- The application is simple and no additional labour is required.

For commercial silkworm rearing, the use of hybrids

Table 1. Performance of Asthra at farmers level

Treatment	No. of farmers covered	No. of dfls. tested	Yield/ 100 dfls. (kg)	Single cocoon wt. (g)	Single shell wt. (g)	Shell %	% of diseases			
							Grasserie	Flacherie	Muscardine	Total
Asthra	135	18,716	71.05	1.786	0.323	18.007	0.724	0.765	0.101	1.590
Control	129	16,105	59.80	1.718	0.309	17.923	1.585	1.533	0.455	3.573

Table 2. Performance of Ankush at farmers level

Treatment	No. of farmers Crops tested	No. of dfls. covered	Yield/ 100 dfls (Kg)	% of disease			
				Grasserie	Flacherie	Muscardine	Total
Anksuh	50	6,796	60.75	1.673	0.529	0.87	3.072
Vijetha	46	6,968	59.43	1.701	0.743	0.86	3.304

Table 3. Large scale field trials of Ankush at farmes level under DBT programme

Treatment	RSRS, Anantapur		RSRS, Salem		RSRS, Ch.Nagar		RSRS, Bangalore		Mean
	Yield/ 100dfls. (kg)	Diseases (%)	Yield/ 100dfls. (kg)	Diseases (%)	Yield/ 100dfls. (kg)	Diseases (%)	Yield/ 100dfls. (kg)	Diseases (%)	Yield/ 100dfls. (kg)
Ankush	62.53	1.425	70.40	2.200	66.34	5.183	74.16	0.044	68.35
Vijetha	61.44	0.875	62.14	3.890	63.88	5.326	62.66	0.088	62.53

Table 4. Field trials of Amruth

Product	No. of farmers crops tested	No. of dfls. covered	Yield/ 100 dfls. (kg)	% diseases		
				Grasserie	Flacherie	Total
Amruth	141	17,660	60.14	0.820 (62.02%)	0.655 (59.82%)	1.475 (61.07%)
Control	70	6,505	48.86	2.159	1.630	3.789

Figures in parentheses are percent disease reduction over control

Table 5. Performance of disease resistant breeds

Hybrid	Pupation (%)	Cocoon weight (g)	Shell wt. (g)	S.R.%	Filament length (m)	Survival % under inoculated conditions		
						Bm DNV1	BmIFV	BmNPV
BmDNV1 resistant bivoltine hybrid								
CSR21DR × CSR28DR	94.30	1.885	0.440	23.4	1062	80.0	86.0	65.0
CSR2 × CSR4 (Control)	96.10	1.815	.417	23.0	1021	10.3	15.8	40.0
BmDNV1 resistant Multivoltine × Bivoltine hybrid								
NDV6× CSR2	96.10	1.991	0.407	20.5	904	96.0	80.0	63.0
PM ×CSR2 (Control)	95.40	1.896	0.344	18.1	801	5.0	10.0	45.0

resistant / tolerant to diseases will be more economical and therefore will be a better option especially in tropical countries, where inadequate disinfection is not practiced. Among the major silkworm diseases, flacherie caused by Densonucleosis virus is controlled by a single recessive gene, nsd-1 or a dominant gene, Nid-1, whereas other viral diseases are controlled by polygenes. Earlier studies at this Institute indicated one multivoltine (C. Nichi) and three bivoltine breeds (A, 644 and NJ) as resistant against BmDNV1 infection and later developed a bivoltine hybrid, CSR21DR × CSR28DR and one multi × bivoltine hybrid, NDV6 × CSR2 resistant to BmDNV, BmIFV and moderately tolerant to BmNPV. These new hybrids were test verified at laboratory level and under in-house trials and the breeds were selected for race authorization trials in various parts of the country. These hybrids will help in improving the survival of silkworm in areas where disease management is not practices fully.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 258-263

INTEGRATED MANAGEMENT OF MUSCARDINE DISEASE DURING SILKWORM REARING

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ABSTRACT

Muscardines, caused by the fungal pathogens are the most contagious among the silkworm diseases. It generally prevails during rainy and winter seasons *i.e.,* from July - February in India. High humidity and low temperature predisposes muscardine disease in silkworm. Fungal pathogens persist in the sericulture ecosystem by harbouring on the mulberry pests and also as saprophytes in the soil. Mulberry pests act as the alternate hosts for *B. bassiana* and help to build up the inoculum in the environment and thus play significant role in muscardine epizootics during winter season. Regulation of humidity by dusting slaked lime at the time of moult, and if necessary in between, to keep the rearing bed dry is recommended to control muscardine disease. Earlier, fungicides like dithane M – 45 and captan were recommended for the prevention of muscardine disease during rearing. Later, several specific and general silkworm body and rearing seat disinfectants *viz*., Vijetha and Vijetha supplement/ Ankush or Ankush vijetha green were recommended for preventing the spread of muscardine disease. In addition to these, other rearing practices like maintenance of optimum temperature and relative humidity, proper ventilation, proper spacing and providing quality mulberry to silkworm are the other integral components in the management of the disease.

Key words: *Beauveria bassiana*, *Bombyx mori,* Integrated management, Muscardine disease

INTRODUCTION

Among the different diseases of silkworm, muscardine or mycoses, caused by fungal pathogens, is the most contagious and common disease inflicting significant cocoon crop loss (Steinhaus, 1949). Fungal pathogens spread by body contamination. The infectious conidia are very light in weight and often become air borne in nature and drifts in the atmosphere according to the wind circulation. The environmental conditions in the rearing house plays a vital role in the spread of fungal diseases. Both low temperature and high humidity play major predisposing roles on the muscardine disease out break during these seasons. Muscardine does the greatest havoc to cocoon crop in cold weather followed by rainy season. Generally its prevalence was reported more in rainy season in West Bengal (Mukerji, 1919). Selvakumar *et al*. (2002) reported that incidence of muscardine as high during rainy (17.96%) and winter (17.36%) seasons.

B. bassiana is an aggressive parasite of different insect host species and this versatility helps the fungus to persist in the sericulture ecosystem by harbouring on the mulberry and silkworm pests. These alternate hosts of *B. bassiana* have a great significance in developing an epizootic in the silkworm rearing during the favourable seasons. Gowda *et al*. (2001) studied the incidence of natural enemies on the leaf roller *Diaphania pulverulentalis* infesting mulberry crop and reported that two fungal pathogens *i.e.*, *Aspergillus tamarii* and *B. bassiana* infect the pest. Studies carried out by Sharma *et al.* (2003) also indicated the presence of various pathogens including *B. bassiana* in leaf roller and the *B. bassiana* isolated from the leaf roller caused 100% mortality in silkworm, establishing the cross infectivity of the pathogen. Chandrasekharan and Nataraju (2006) reported the incidence of white muscardine caused by *B. bassiana* in the uzi fly and on the possibility of the spread of white muscardine in silkworm rearing by the uzi fly.

Rearing conditions or rearing practice adopted has great influence on the severity of this disease, as it is highly contagious (Chandrasekharan and Nataraju, 2009). If spacing provided during rearing is less than optimum, bed

cleaning performed using hands, irregular cleaning of bed, non maintenance of optimum rearing temperature and relative humidity particularly during winter, improper disposal of litter and bed residues, irregular feeding, under-feeding and starvation aggravate muscardine incidence.

Management of muscardine disease has been the top most priority to the sericulturists and many authors studied on the management and control aspects of this disease and various technologies were recommended for adoption. The right approach to eliminate the pathogens from the rearing environment is to disinfect the rearing environment prior to the commencement of silkworm rearing (Nataraju *et al.,* 2005). By the adoption of specific disease control technology measures muscardine disease can be effectively controlled at the farmers' level and in this paper the results of the field trials for the management of this disease have been discussed.

MATERIALS AND METHODS

For the effective management of muscardine disease in addition to Vijetha/Vijetha supplement a new bed disinfectant Ankush was recommended. Ankush was test verified in house and further extensive field trials were conducted in 3 southern states. To reduce the cocoon crop loss due to muscardine at the farmers' level the following technology components were recommended for practice in the field.

- Effective disinfection of silkworm rearing house, including chawki rearing house, mounting room/place, leaf preservation room *etc.*
- Use of bleaching powder/slaked lime/chlorine dioxide as spray disinfectant in an effective concentration and quantity.
- Application of slaked lime to reduce the bed humidity
- Application of Vijetha along with Vijetha supplement or Ankush as silkworm body and rearing seat disinfectant.
- Practice of rearing and personal hygiene in chawki and late age rearing.
- Use of shoot feeding method with feeding of good quality mulberry leaves.
- Proper incubation and maintenance of optimum rearing conditions.

Disinfectants recommended

- 2% Bleaching powder in 0.3% slaked lime,
- 0.3 % Slaked lime
- 2.5 % Sanitech / Serichlor in 0.5% Slaked lime

Requirement of disinfectant solution

The total requirement of disinfectant solution for disinfection of rearing house, its surroundings and appliances were estimated based on the floor area of the rearing house. The quantity required is 1.5 lt./sq. m floor area or 140 ml/sq. ft. floor area of rearing house + 10% of total quantity (for disinfection of rearing house surroundings).

Estimation of requirement disinfectant solution

Floor area of rearing house = Length × Width

Disinfection Schedule

Farmers were advised to follow meticulously a disinfection schedule as indicated below so as to avoid any contamination so as to manage the disease effectively.

Disinfection schedule recommended for silkworm raring

Day	Activity	Details of Activity
After the completion of rearing	1	Collection and burning of diseased larvae, melted and flimsy cocoons.
	2	1st disinfection of rearing house and appliances (2% Bleaching powder in 0.3% slaked lime solution / 2.5% Sanitech/ Serichlor in 0.5% Slaked lime solution.
5 days before brushing	3	Cleaning and washing.
	4	Sun drying of appliances.
4 days before brushing	5	Optional disinfection of rearing house with 0.3% slaked lime solution
3 days before brushing	6	2nd disinfection of rearing house and appliances (2% Bleaching powder in 0.3% slaked lime solution / 2.5% Sanitech/Serichlor in 0.5% Slaked lime solution).
2 days before brushing	7	Dusting disinfectant (5% Bleaching powder in slaked lime) surrounding the rearing house.

Hygiene practices during rearing

- Wash hands and feet with disinfectant solution at the time of entry into rearing house. Also Wash hands with disinfectant after picking diseased larvae, after bed cleaning and before feeding and after feeding.
- Disinfect and destroy the diseased worms.
- Disinfect silkworm body and rearing seat by dusting Vijetha before resumption of feeding after every moult and on the 4th day of final instar @3g/sq.ft. (2nd and 3rd instar) and 5g/sq.ft. (4th and final instar). During winter and rainy seasons, when the prevalence of muscardine disease is more, dust Vijetha supplement on 3rd day of IV instar, 2nd day and 6th day of V instar in addition to the Vijetha dusting or dust Ankush before resumption of feeding after every moult and on the 3rd day and 5th day of final instar @3-4 g/sq.ft.

RESULTS AND DISCUSSION

The prevalence of muscardine disease is highest during winter season followed by rainy season and in summer no muscardine incidence is noticed in the field. On the other hand, the other diseases, grasserie and flacherie were prevalent through out the year with fluctuation in their intensity (Figure 1). Even though, prevalence of muscardine is confined to rainy and winter seasons, it accounted for 43% of the total disease occurrence in a year (Figure 2).

Several fungicides like bavistin, mancozeb, zineb, dithane M - 45, captan *etc.* have been evaluated against *B. bassiana* by various researchers and the most effective among them are recommended for the prevention of white muscardine disease. Muscardine can also be prevented by dusting 1 - 2% dithane M-45 mixed with kaolin (Samson *et al*., 1986). Studies at CSRTI, Mysore indicated an effective dust formulation against grasserie and muscardine diseases, which was recommended to the field as RKO (Baig *et al*., 1990, 1993). In 1998, Datta *et al.,* recommended Vijetha for preventing the spread of all silkworm diseases during silkworm rearing. Later Vijetha Supplement, a bed disinfectant formulation effective for the prevention of spread of muscardine disease in silkworm was also recommended and commercialised (Anon. 2001). Virendrakumar *et al.* (1998, 2002) studied the efficacy of two systemic fungicides against *B. bassiana* and results of the successful field trial of the effective systemic fungicide *i.e*. bayelton was reported. An integrated silkworm disease control technology (Nataraju *et al.* 1999, 2002, Kamble *et al.,* 2008) which was test verified at farmers' level for containing various silkworm diseases including white muscardine was also recommended. An eco friendly and plant based bed disinfectant formulation named 'Ankush' was developed at CSRTI, Mysore for preventing the spread of all silkworm diseases including white muscardine (Sharma *et al*. 2008).

Different silkworm body and rearing seat disinfectants were evaluated for their comparative efficacy against the spread of muscardine disease during silkworm rearing. The results indicated that (Table 1) all the tested bed disinfectants were effective against the disease even though Vijetha and Ankush showed slightly more efficacy. Dusting of Vijetha along with Vijetha supplement was recommended for the effective management of muscardine disease. Instead of dusting these two bed disinfectants to control muscardine disease, dusting of Ankush was recommended later. Ankush was test verified at farm and farmers' level (Table 2 & 3) and later it became very popular for the management of silkworm diseases in general and muscardine diseases in particular during the mega projects PEBS and IVLP.

The silkworm rearings were carried out following the integrated silkworm disease management technology under the JICA funded PEBS (3 years) project and under IVLP (2 years) programme. Under PEBS project 3,704 farmers' crops were covered during a period of three years with 52.24 lakh silkworm layings. Under IVLP programme, 883 crops with 12.10 lakh layings were covered. The average cocoon yield at farmers' level was 65.73 kg/ 100 dfls under PEBS (Table 4) and 63.32 kg under IVLP (Table 5). The defective cocoon%, which reflects mainly the disease incidence was within the admissible 5 – 6% level under PEBS project.

Under IVLP project the improvement obtained due to adoption of disease management technology was assessed which indicate an average of over 28% improvement in yield. All these are a clear indication of control of silkworm diseases with the adoption of technology. Adoption of technologies has brought significant improvement in the cocoon productivity at farmers' level.

The results indicated that by adopting the disease management technologies meticulously muscardine disease can be effectively controlled at farmers' level and the cocoon yield increases substantially.

Table 1: Efficacy of bed disinfectants in preventing the spread of muscardine during silkworm rearing.

Sl. No.	Bed disinfectants	% Reduction in Muscardine
1.	Vijetha	92
2.	Captan (1&2%)	89
3	Dithane-M-45 (1&2%)	91
4	Vijetha supplement	91
5	Ankush	92

Table 2: Efficacy of Ankush bed disinfectant in controlling muscardine disease during silkworm rearing.

Product	Test verified at	No of Dfls	Muscardine (%)	Yield/ 100 dfls (kg)
Ankush	CSRTI, TVDC	7050	0.000	68.00
Ankush	Sericulturists	13,585	0.649	65.75
Control	Sericulturists	7000	0.860	59.43

Table 3: Results on the large scale testing on the efficacy of Ankush bed disinfectant at field level in controlling diseases during silkworm rearing.

Product dusted	RSRS, Anantapur		RSRS, Salem		RSRS, Ch.Nagar		RSRS, Bangalore	
	Yield/ 100dfls. (kg)	Diseases* (%)	Yield/ 100dfls (kg)	Diseases* (%)	Yield/ 100dfls (kg)	Diseases* (%)	Yield/ 100dfls. (kg)	Diseases* (%)
Ankush	62.53	1.425	70.40	2.200	66.34	5.183	74.16	0.044
Control	57.31	2.296	51.96	7.764	57.79	7.993	56.66	0.608

* Including muscardine disease

Table 4: Performance of CSR hybrids reared following silkworm disease (including muscardine) management technology under PEBS, JICA

Name of State	No. of crops	No. of dfls.	Yield/100 dfls. (kg)	Defective cocoons %
Karnataka	1637	17,99,025	64.37	4.80
Andhrapradesh	1246	17,76,330	66.98	5.20
Tamil Nadu	821	16,49,555	65.86	4.70
Grand Total /Average	3704	52,24,910	65.73	4.90

Table 5: Performance of CSR hybrids reared following silkworm disease management technology under IVLP program

Name of Centre	No. of crops	No. of dfls.	Cocoon yield/100 dfls.		% improvement
			Before	After	
CSRTI, Mysore	225	4,57,125	48.10	65.50	36.17
RSRS, Kodathi	200	2,47,780	50.00	62.00	24.00
RSRS, Ch.Nagar	54	17,500	45.00	64.00	37.63
RSRS, Anantapur	250	2,92,373	49.00	62.08	26.69
RSRS, Salem	154	1,95,718	51.60	63.00	18.42
Total	883	12,10,496	48.74	63.32	28.58

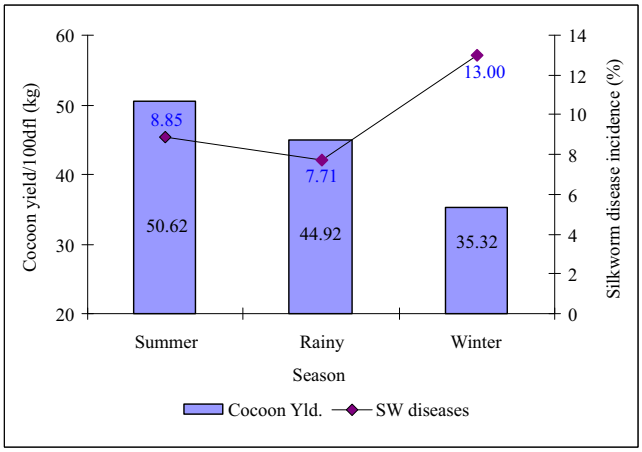


Fig. 1: Relation between silkworm disease incidence and cocoon yield

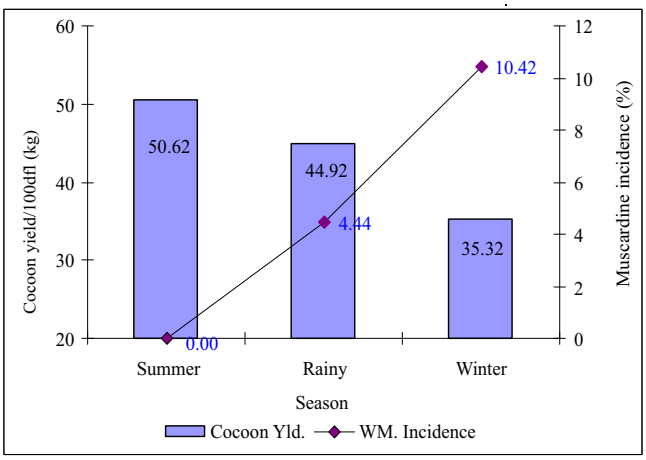


Fig. 2: Relation between white muscardine incidence and cocoon yield

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 264-266

FORMULATION AND SCREENING OF NEW BED DISINFECTANTS AGAINST NUCLEAR POLYHEDROSIS OF SILKWORM, *BOMBYX MORI* L.

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ABSTRACT

Heavy mortality of silkworm larvae occurs due to viral diseases resulting in major crop loss. To prevent the loss, disease management strategies are essential and in the present study an experiment was conducted to study the efficacy of various combinations of bed disinfectants against grasserie disease. Locally available finely powdered kaolin clay was the base material, which was mixed with different chemicals, most important ones being paraformaldehyde, bleaching powder, streptocycline and captan. Silkworms after third moult were surface inoculated with the suspension of Polyhedral Inclusion Bodies with a load of $1x10^6$ PIBs per ml. Bed disinfectants of various formulations were applied one hour before feeding, uniformly on the silkworms, twice during fourth instar and thrice during fifth instar after thorough bed cleaning. The results showed that bed disinfectants significantly reduced the mortality of silkworms in contrast to treatments where no bed disinfectants were applied. The formulations comprising of paraformaldehyde, bleaching powder and streptocycline showed highest survival rate of 78.66. Among other treatments, those having Streptocycline as one of the component also showed good survival rate. No adverse effect on the larval and cocoon characters of the silkworms due to the application of these treatments was observed.

Keywords: Bed disinfectant, *Bombyx mori,* Nuclear polyhedrosis, Silkworm

INTRODUCTION

Silkworm, *Bombyx mori* is prone to various diseases caused by bacterial, fungal, viral and microsporidian pathogens. Among these, the viral disease Grasserie caused by BmNPV is most common, causing heavy mortality of silkworm larvae during rearing which results in considerable reduction to cocoon production. Patil and Sharadamma (1999) reported that more than 30% crop loss is due to the viral and bacterial diseases. Among various silkworm races, bivoltine races have been found more susceptible to viral diseases than the multivoltine races (Singh *et al*, 1990 and Baig *et al*, 1991). For the management of viral diseases, Noamani and Mukherjee (1975) found Papzol (mixture of paraformaldehyde and other constituents) as an effective disinfectant. Jawale and Tayade (1987) reported paraformaldehyde, while as Baig *et al.,* (1989) found combination of paraformaldehyde, benzoic acid and lime effective against nuclear polyhedrosis. Venkata Reddy, *et al*., (1990) found 2% Asiphor as significantly effective against various pathogens of silkworm including nuclear polyhedral virus. Topical application of dust formulation of lime-bleaching powder mixture also inactivates the viral pathogens (Subha Rao *et al.*, 1992). Balavenkatasubhaiah *et al.,* (1994) reported different disinfectants *viz*., salicylic acid, paraformaldehyde, benzoic acid, slacked lime, formaline, bleaching powder and Asiphor as effective in the inactivation of nuclear polyhedrosis virus. In Kashmir also, the disease causes heavy mortality (25-32%) to silkworm larvae during rearing (Chishti and Sahaf, 1990) and causes loss to the silkworm rearers. The disease is more prevalent during summer season when abiotic factors like temperature and humidity favour pathogen multiplication. The present study was undertaken to develop a suitable bed disinfectant for the management of the disease.

MATERIALS AND METHODS

Rearing of prominent silkworm hybrid NB4D2 × SH6 was conducted under optimum environmental conditions.

Table 1: Effect of various bed disinfectants on the economic characters and survival of silkworm, *Bombyx mori* infected with grasserie.

Treatment	Larval weight (10 Larvae)	Single Cocoon Weight (g)	Single Shell Weight (g)	Shell Ratio (%)	Survival Rate (%)
T1	31.50_{b}	1.54_{c}	0.30_{a}	$19.50\ (26.18)_{a}$	$47.66\ (43.65)_{e}$
T2	30.92_{c}	1.65_{b}	0.29_{ab}	$17.52\ (24.74)_{a}$	$47.16\ (43.37)_{e}$
T3	28.66_{e}	1.40_{d}	0.27_{b}	$19.28\ (26.04)_{a}$	$47.16\ (43.36)_{e}$
T4	31.47_{b}	1.59_{c}	0.29_{a}	$18.60\ (25.54)_{a}$	$41.83\ (40.29)_{f}$
T5	29.97_{d}	1.65_{b}	0.32_{a}	$19.53\ (26.21)_{a}$	$33.16\ (35.15)_{g}$
T6	33.98_{a}	1.84_{a}	0.32_{a}	$17.33\ (24.60)_{ab}$	$71.33\ (57.62)_{b}$
T7	32.73_{ab}	1.70_{b}	0.29_{ab}	$17.19\ (24.49)_{b}$	$63.50\ (52.86)_{c}$
T8	33.10_{a}	1.72_{b}	0.31_{a}	$18.14\ (25.20)_{a}$	$78.66\ (62.50)_{a}$
T9	31.43_{bc}	1.59_{c}	0.30_{a}	$18.84\ (25.70)_{a}$	$67.00\ (54.95)_{c}$
T10	31.45_{b}	1.71_{b}	0.31_{a}	$18.10\ (25.17)_{a}$	$57.83\ (49.51)_{d}$
T11	31.15_{c}	1.87_{a}	0.33_{a}	$17.65\ (24.83)_{a}$	$55.50\ (48.15)_{d}$
T12	32.05_{b}	1.74_{ab}	0.32_{a}	$18.74\ (25.64)_{a}$	$43.83\ (41.43)_{ef}$
T13	30.58_{c}	1.62_{bc}	0.30_{a}	$18.49\ (25.46)_{a}$	$41.16\ (39.90)_{f}$
T14	25.34_{f}	1.41_{d}	0.21_{c}	$14.88\ (22.69)_{c}$	$14.50\ (22.36)_{h}$
T15	32.79_{a}	1.67_{b}	0.32_{a}	$19.09\ (25.90)_{a}$	$68.33\ (55.77)_{bc}$
CD (0.05)	1.41561	0.147433	0.0470550	1.79963	3.18174

Figures within parenthesis are angular transformed values.

Treatments

Treat-ments	Composition
T1	Paraformaldehyde (2%)
T2	Bleaching Powder (2%)
T3	Captan (2%)
T4	Streptocycline (2%)
T5	Potassium meta-bisulphite (2%)
T6	Paraformaldehyde(2%) + Bleaching Powder(2%) + Streptocycline(1%)
T7	Paraformaldehyde(2%) + Benzoic acid(1%) + Captan(1%)
T8	Paraformaldehyde(2%) + Bleaching Powder(2%) + Streptocycline(1%) + Captan(1%)
T9	Paraformaldehyde(2%) + Streptocycline(1%) + Captan(1%)
T10	Paraformaldehyde(2%) + Potassium meta-bisulphite(2%) + Streptocycline(1%)
T11	Potassium meta-bisulphite(2%) + Bleaching Powder(2%) + Captan(1%)
T12	Potassium meta-bisulphite(2%) + Streptocycline(1%) + Captan(1%)
T13	Kaoline
T14	Inoculated only
T15	Normal Rearing

Various combinations of bed disinfectants comprising of paraformaldehyde, bleaching powder, benzoic acid, potassium meta-bisulphite, streptocycline and captan were used in the present study with locally available finely powdered kaolin clay as the base material for the preparation of bed disinfectants. After third moult, silkworm rearing bed was contaminated by spraying with the suspension of BmNPV Polyhedral Inclusion Bodies (PIBs) at the rate of 3 ml per 100 larvae (1×10^{6} PIBs per ml) in the rearing trays. After one hour bed disinfectants were applied uniformly over the rearing bed along with the larvae. The bed disinfectants were applied twice during fourth instar and thrice during fifth instar after thorough bed cleaning and one hour before feeding at the rate of 3g per sq. ft. Three control rearings were also maintained, one where silkworms were reared on the rearing bed contaminated with *PIBs* without any bed

disinfectant, second where only base material (Kaolin) was applied and the other batch was normal rearing without any contamination or bed-disinfection application. For each treatment three replications were maintained and each replication was of 100 silkworms. Mortality due to grasserie observed during the process of rearing was recorded. Observations on the survival rate and also on the economical characters of the silkworms (Larval weight, cocoon weight, shell weight and shell ratio) were recorded. The data thus obtained was statistically analyzed by adopting R.B.D. method.

RESULTS AND DISCUSSION

The results presented in Table 1, showed that bed disinfectants significantly reduced the mortality of silkworm larvae due to polyhedrosis as compared to untreated silkworms. Among various treatments the batches of silkworms treated with treatment T8 showed highest survival rate of 78.66 percent followed by T6 and T9 with a survival rate of 71.33 and 67.00 percent respectively. The least effective treatment was T5 with a survival rate of only 33.16. The treatments did not show any adverse effect on the economical characters of the silkworms. Among treatments the larval weight was higher in T6 treated silkworms which were at par with normal rearing and that of T8 treatment. Cocoon weight was recorded highest (1.87g) in T11 followed by T6 (1.84g) and lowest in treatment T3 (1.40g). The shell weight of 0.33 g was recorded maximum in T11 which was followed by T5, T6, T12 and normal rearing with 0.32 g. The minimum shell weight among treatments was recorded in T15 (0.25g). The shell ratio of T13 (19.77%) was maximum followed by T5 (19.53%), T1 (19.50%), T3 (19.28%) and in normal rearing (19.09%).

The above observations clearly indicate that the treatments are effective against the polyhedrosis disease. These combinations in different formulations with lime have also been reported as effective against virus diseases of silkworm by Baig *et al.,* (1993). Captan, a contact fungicide used in the present study as one of the ingrients in formulations T7, T8 and T9 can also prove effective against *Beauveria bassiana*, the causal agent of fungal disease of silkworm (Muscardine) as this fungicide has been proved effective against the muscardine by Munshi *et al.,* (2005) In this study it was also observed that the treatment combinations having Streptocycline as one of the ingredients were more effective as compared to other treatments.

Since the main reason of nuclear polyhedrosis outbreak is the heavy pathogen load in the rearing bed, the present study provides a solution for the prevention of the disease. Topical application of the effective bed disinfectant can be utilized as effective prophylactic measure against the occurrence of this disease.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 267-270

MOBILE DISINFECTION UNIT: A NEW APPROACH FOR EFFECTIVE DISINFECTION AT FIELD LEVEL - SOME OBSERVATIONS ON MODALITIES AND ECONOMIC FEASIBILITY

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ABSTRACT

A mobile disinfection unit was developed, which consists of a Jeep (engine with 35 hp power output) for easy mobility and for generating sufficient power to run the sprayer, a high capacity power sprayer capable of discharging 10-15 liters of solution per minute up to a height of 20 meters which is fitted and integrated to the engine power of the jeep. Two water containers (each 200 liters capacity) necessary for the preparation of the disinfectant solution, were fixed to the vehicle at a convenient position. A flexible pipe of 50 meters, mesh filters and other plastic containers necessary for the preparation and filtering of the disinfectant solution are also aligned in the vehicle. As a result, the mobile unit can not only reach longer distances in a short period of time; but also can deliver a powerful spray which can reach all the nooks and corners of the rearing house making the disinfection process highly effective even without the need of electricity. Farmers found it most convenient and highly useful for conducting disinfection on regular basis. This method of the management of disinfection activity was also found effective for the control of silkworm diseases in the area and resulted in increased stability of bivoltine crops. It is also proved as a profitable venture to the entrepreneur. The advantages, economic viability of the unit and its impact on the crop stability in the area are discussed.

Key words : Disease management, Economic feasibility, Mobile disinfection unit

INTRODUCTION

The pathogens released by diseased silkworms easily accumulate and spread in the rearing environment through different routes. They can persist for long periods in the rearing premises under congenial conditions. There are no easy curative methods for any of the silkworm diseases and they can be best prevented than cured. The disinfection of rearing house, appliances, use of bed disinfectants and practice of hygiene are the most essential activities for assured crop success and high cocoon yield (Kotikal *et al.,* 1989; Krishnaswamy, 1993; Pallavi and Kamble, 1997). Disinfection is an integral part of healthy and successful silkworm rearing. It aims at the total destruction of disease causing pathogens like bacteria, viruses, fungi and protozoan (Nataraju *et al.,* 2004).

The disinfectants like bleaching powder-slaked lime, chlorine dioxide (Sanitech), Asthra etc are recommended (Baig *et al.,* 1988). These disinfectants have to be sprayed to drench all the nooks and corners of the rearing house, and all appliances using powerful sprayers. However, many of the sericulturists are not having sprayers either by their own or at the village level. Some farmers sprinkle the disinfectant solution with the help of mug or broomstick, which will not reach all the area and pathogens persist in the rearing house.

Constraints for disinfection

Though farmers are aware of the importance of disinfection for the success of silkworm crops, they are unable to conduct disinfection effectively. Marginal, small and medium scale sericulturists sprinkle the disinfectant

using traditional methods. Due to high cost and non-availability, high capacity power sprayers are not affordable. Moreover, transportation of hired sprayers from one area to another area, one village to another village and arrangement of bigger vessels for preparation of required quantity of solution at a time are tedious, time consuming and hence act as limiting factors for organizing perfect disinfection. Nowadays, majority of the farmers are practicing multiple crops and are busy in one or the other activities and finds the disinfection a drudgery. As the Central Silk Board is encouraging private entrepreneurs in different activities of sericulture like Chawki Rearing Centres, poly-clinics and Automatic reeling units *etc.,* encouraging the use of mobile disinfection units is certainly be highly helpful to the sericulturists to achieve better cocoon harvest.

Improved Mobile disinfection Unit

Improper disinfection hampered the performance of bivoltine crops on several instances leading to low cocoon yield. It also affected the larval population in private chawki rearing centres very often. Such field experiences have prompted to explore the possibility of facilitating a suitable and effective disinfection system at field level without any drudgery. In this line of thought, one mobile disinfection unit integrated with a four-wheeler is developed in coordination with an enthusiastic private enterpreuner., Sri. R. Venkatramappa of Dasarlapalle village, in V. Kota area of Chittoor district.

This mobile disinfection unit consists of a 1) Old Jeep (engine with 35 hp out put) for mobility and power to run the sprayer, 2) High capacity power sprayer (3 piston Model) capable of discharging 10-15 liters of solution per minute up to a height of 20 meters which is integrated to the engine power of the jeep, 3) Two water containers (200 liters capacity each) for preparation of disinfectant 4) Flexible pipe of 50 meters, 5) Buckets, plastic containers and mesh filters necessary for the preparation of disinfectant solutions, and for spraying the prepare solutions.

The high pressure 3 piston sprayer and the water containers are fixed on the body of the jeep. Due to high out put capacity, the power sprayer discharges 10 to 15 liters of disinfectant per minute up to a height of 20 meters. As a result, the spray is powerful and hence can reach all the nooks

Table 1: Details of expenditure incurred on different components used for assembling the Mobile Disinfection Unit:

Sl. No.	Name of the component	Cost in Rupees
1	Jeep (second hand) with 35 hp output	1,52,000
2	High pressure power sprayer (3 piston)	17,500
3	Water container – 200 liters capacity -two	1500
4	Assembling pump, gear box, and water containers	20,800
5	Buckets, Filters, Miscellaneous expenditure	700
	Total cost of the unit	1,92,500

Table 2: Month wise Operational cost and income details of the Mobile Disinfection Unit for a period of one year:

Month	Gross income (Rs.)/month		Expenditure (Rs.)					Net income (Rs.)
	No. of sheds	Service charges collected	Expend-iture on fuel	Transporta-tion	Labour	Mainte-nance	Total expen-diture	
Sept. 2009	135	27000	8141	1900	4000	200	12341	14659
Oct. 2009	128	25600	7719	2100	4000	350	12069	13531
Nov. 2009	122	24400	7357	2450	4000	350	11707	12693
Dec. 2009	132	26400	7969	3125	4000	1000	12969	13431
Jan. 2010	128	25600	7719	2965	5000	250	12969	12631
Feb. 2010	134	26800	8081	2845	5000	300	13381	13419
Mar. 2010	132	26400	8553	2762	5000	0	13551	12847
April 2010	126	25200	8190	2438	5000	300	13490	11710
May 2010	122	24400	7930	2975	5000	250	13180	11220
June 2010	120	24000	8260	2335	5000	400	13660	10340
July 2010	122	24400	7983	2245	5000	1000	13983	10417
Aug. 2010	128	25600	8811	4125	5000	250	14061	11539
Yearly	1529	305800	96712	32265	56000	4650	157362	148438

Parameters	Traditional method	Mini -tractor based mobile disinfection unit	Bike based mobile disinfection unit	Jeep based mobile disinfection unit
Spray	Mugs, broom sticks, Gattar sprayer, 0.5 hp 1-2 piston sprayers	3 piston power sprayer	2 piston power sprayer	3 piston power sprayer
Power supply for spray	Physical, mechanical and electricity	Integrated Mini-tractor engine power (18 hp)	Separate fuel operated engine along with the Bike (1-2 hp)	Jeep engine power (35 hp)
Mobility/Transportation of sprayers	Physical, on two wheelers.	Through mini-tractor	Through motor bike.	Through jeep
	Mobility to distant areas difficult and drudgery.	Mobility to distant areas difficult.	Mobility to distant areas easy	Mobility to distant areas very easy
Disinfectant solution -water.	To be arranged by the farmer himself	One water can with 200 litres capacity is available	To be arranged by the farmer himself	2 water cans with 400 litres capacity are available
Technical expertise in disinfection	Low	Trained	Trained	Trained
Buckets, Filters, Miscellaneous	Has to be arranged by the farmer	Available with the mobile unit	Available with the mobile unit	Available with the mobile unit
Availability	Requires time to get sprayers on rent and power availability.	Easily available	Easily available	Easily available
Expenditure (Per rearing house of 20 x 50 ft)	Rs. 100-150/- shed	Rs. 200/-	Rs. 200/- shed	Rs. 200/- shed

Table 3: Cost Benefit Analysis of the Mobile Disinfection Unit:

Particulars of expenditure	Expenditure
No. of sheds disinfected	1529
Cost on Fuel (Rs.)	96712
Labour charges (Rs.)	56000
Maintenance cost (Rs.)	4650
Apportioned cost (Rs.)	24062
Total Expenditure (Rs.)	181424
Gross revenue (Rs.)	305800
Net Returns in a year (Rs.)	124376
C:B ratio	1:1.69

and corners of the rearing house and appliances and kills the pathogens more effectively as compared to traditional methods. In addition to the disinfection activity, the jeep can also be used for other purposes making it more viable. The total expenditure incurred for development of the mobile disinfection unit was Rs. 1,92,500. The details of the expenditure are furnished in Table-1.

Advantages

1. The mobile disinfection unit is easily available on hired basis to any sericulturists in the area for periodical disinfection of their rearing houses, appliances and mounting halls.
2. The Unit can reach distant areas as the mobility is faster with the 4-wheeler.
3. It can reach the needy farmers in the area at the right time.
4. Due to high out put capacity of the sprayer, disinfection is more effective and time saving.
5. The preparation of disinfectant and required dosages are managed by the trained operator as per the guide lines given by the scientists/officials.

The other advantages of improved mobile disinfection unit in comparison to other methods /units are presented below.

Because of the timely and easy availability, farmers found the improved mobile disinfection unit most convenient and practicing disinfection regularly. The disinfection also found effective in the control of diseases in the area and resulted in increased stability of bivoltine crops. Farmers have well accepted the technology and it was found

to improve crop stability in the field. Hence, farmers of Kuppam area have been rearing bivoltines throughout the year including summer months.

At present, the entrepreneur is collecting service charges of Rs. 200/- for disinfecting a rearing house of 40 x 20 feet size and appliances *i.e*., for spraying of 200 liters solution. The water and disinfectants have to be provided by the farmer. The operator prepares the disinfectant solution as per the recommendations and sprays the solution. Some times farmers perform the spraying process by themselves by using this facility.

It was also proved as a profitable venture to the private entrepreneur (Table 2). The mobile unit has started functioning from September 2009 and the cost benefit analysis of this technology for a period of one year indicated that the entrepreneur obtained a net income of Rs. 1,24,376.

The disinfection also found effective in the control of silkworm diseases in the area and resulted in increased stability of bivoltine crops. Because of stable bivoltine crops, farmers are rearing bivoltines throughout the year including summer months, achieving better cocoon productivity in the area. Hence, replication of this type of facilitatory disinfection system in other sericultural areas is useful to improve crop stability and cocoon productivity by virtue of systematic disinfection at field level.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 271-275

DETERIORATION OF POST-COCOON PARAMETERS AS INFLUENCED BY BmNPV INFECTION IN DIFFERENT STRAINS OF SILKWORM, *BOMBYX MORI* L.

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ABSTRACT

Silkworm (*Bombyx mori* L.) is one of the important economic insects. Silkworm rearing and silk industry plays an important role in China, India and other developing countries. In the long history of sericultural practice, introduction of silkworm strains with high resistance to diseases has greatly improved cocoon traits. The laboratory studies on *Bm*NPV stress of different silkworm genotypes and their hybrids during fourth and fifth instar revealed significant results. However, the experimentally inoculated batches recorded significant decrease in filament length, weight and denier. However, The longer filament length and more weight was showed in CSR2 lots of fourth and fifth instar (856.67 & 957.67m, 826.67 & 855.00m) and (0.24 & 0.28g, 0.24 & 0.25g) Whereas, in filament denier maximum of 2.67 & 2.79 and 2.64 & 2.79 were noticed in CSR16 and CSR4 bivoltine breeds at 10^{-1} and 10^{-3} viral dilutions respectively. In PM, the deterioration of above parameters found maximum in its components *viz.,* PM×CSR2 and PM×CSR16 (512.33 to 541.00m) and PM×CSR2 and PM×CSR4 (528.67 to 649.33m) than bivoltine breeds in fourth instar inoculated batches. The trend is in positive order in *Bm*NPV inoculated bivoltine hybrids during fifth instar. Which was ranging from 470 to 616.33m and 622 to 722.67m (CSR4×CSR16 and CSR2×CSR4) respectively as compared to control batch of CSR4×CSR16 (702.33m).

Keywords: *Bm*NPV, Denier, Filament length, Filament weight, Post cocoon parameters

INTRODUCTION

Nuclear polyhedrosis virus (NPV) is one of the dominant diseases in almost all sericultural areas in the country. It occurs in all larval stages but more commonly in 4th and 5th instars. Nuclear polyhedrosis alone accounts for 43-50% crop loss (Nataraju *et al., 1998*). The disease is caused by an occluded baculovirus, *Bombyx mori* Nuclear polyhedrosis virus (*Bm*NPV) and it is prevalent during all the rearing seasons. However it's severiorty was noticed during summer followed by rainy season (Selvakumar *et al., 2002*). Prevention of these silkworm diseases has become one of the most-important aspects in the success of commercial sericulture. In order to obtain high and stable cocoon yield it is necessary to make efforts to reduce the incidence of the disease which inturn decrease pathogen quantity and pathogenicity and strengthen larval health by increasing their disease resistance ability (Singh *et al*., 2003). Larval susceptibilty to viral disease greatly differed in various hybrids. Many researchers reported that, inter-breed/strain differences were noticed in susceptibility to *Bombyx mori* NPV, but very few studies have been carried out on the development of resistance of insects to pathogens (Furuta, 1995). The resistance in silkworm hybrids have physiological and genetic origins that are controlled by polygenes (Chen *et al*., 2003)

MATERIAL AND METHODS

To know the susceptibility of silkworm breeds against *Bm*NPV, the first day of fourth and fifth instar larvae of PM, CSR2, CSR4, CSR16 and their crosses *viz*., PM×CSR2, PM×CSR4, PM×CSR16, CSR2×CSR4, CSR2×CSR16 and CSR4×CSR16 were used for *Bm*NPV viral stress. All the parents and their hybrids were reared in three replications. After third moult 50 larave per each replication were taken

Table 1: Deterioration of cocoon parameters of fourth instar inoculated batches of silkworm breeds and their hybrids due *to Bm*NPV.

Silkworm Breeds/ Hybrids	Filament length (m)		Control	Filament weight (g)		Control	Filament Denier		Control
	10^{-1}	10^{-3}		10^{-1}	10^{-1}		10^{-1}	10^{-3}	
PM	294.00 (17.15)	323.00 (17.95)	340.67 (18.42)	0.07 (0.75)	0.09 (0.77)	0.08 (0.76)	2.13 (1.62)	2.41 (1.71)	2.35 (1.69)
CSR2	856.67 (29.27)	957.67 (30.95)	951.67 (30.86)	0.24 (0.86)	0.28 (0.88)	0.28 (0.88)	2.16 (1.61)	2.50 (1.73)	2.69 (1.79)
CSR4	731.00 (27.04)	749.33 (27.37)	853.33 (29.22)	0.21 (0.84)	0.22 (0.85)	0.24 (0.86)	2.67 (1.78)	2.64 (1.77)	2.71 (1.79)
CSR16	685.33 (26.19)	742.67 (27.26)	782.67 (7.98)	0.20 (0.83)	0.23 (0.85)	0.22 (0.85)	2.67 (1.78)	2.79 (1.81)	2.61 (1.76)
PMxCSR2	512.33 (22.64)	528.67 (23.00)	516.33 (22.72)	0.16 (0.81)	0.14 (0.8)	0.16 (0.81)	4.48 (1.72)	2.86 (1.83)	2.65 (1.77)
PMxCSR4	566.67 (23.27)	649.33 (25.49)	646.67 (25.43)	0.19 (0.83)	0.20 (0.84)	0.25 (0.87)	2.77 (1.80)	3.08 (1.89)	3.19 (1.92)
PMxCSR16	541.00 (23.27)	548.33 (23.41)	574.00 (23.92)	0.18 (0.83)	0.21 (0.84)	0.20 (0.83)	3.23 (1.93)	3.44 (1.98)	3.14 (1.91)
CSR2 xCSR4	0.00 (0.71)	619.33 (24.90)	733.33 (25.17)	0.00 (0.71)	0.24 (0.86)	0.21 (0.84)	0.00 (0.71)	3.49 (1.99)	3.22 (1.93)
CSR2 xCSR16	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
CSR4 xCSR16	628.67 (25.08)	693.67 (26.34)	685.33 (26.18)	0.20 (0.83)	0.21 (0.84)	0.22 (0.85)	2.73 (1.80)	2.92 (1.85)	2.35 (1.69)
Mean	481.57 (19.59)	581.20 (22.74)	598.40 (23.06)	0.15 (0.80)	0.087 (0.82)	0.19 (0.83)	2.09 (1.55)	2.61 (1.73)	2.49 (1.69)
F test	*	*	*	*	*	*	*	*	*
SEm ±	13.297 (0.27)	17.40 (0.389)	23.172 (0.526)	0.008 (0.005)	0.013 (0.007)	0.015 (0.009)	0.131 (0.039)	0.162 (0.043)	0.016 (0.004)
CD at 5%	39.228 (0.800)	51.33 (1.148)	68.359 (1.553)	0.025 (0.015)	0.038 (0.023)	0.045 (0.026)	0.387 (0.114)	0.479 (0.127)	0.047 (0.013)

*: Significant; NS: Non-Significant

Table 2: Deterioration of cocoon parameters of fifth instar inoculated batches of silkworm breeds and their hybrids due *to Bm*NPV.

Silkworm Breeds/ Hybrids	Filament length (m)		Control	Filament weight (g)		Control	Filament Denier		Control
	10^{-1}	10^{-3}		10^{-1}	10^{-1}		10^{-1}	10^{-3}	
PM	302.67 (17.41)	375.00 (19.37)	386.00 (19.66)	0.07 (0.76)	0.09 (0.77)	0.13 (0.79)	2.09 (1.61)	2.25 (1.66)	2.38 (1.70)
CSR2	826.67 (28.76)	855.00 (29.25)	982.00 (31.34)	0.24 (0.86)	0.25 (0.86)	0.30 (0.89)	2.53 (1.74)	2.62 (1.76)	2.71 (1.79)
CSR4	773.67 (27.82)	805.33 (28.39)	860.67 (29.35)	0.23 (0.86)	0.24 (0.86)	0.27 (0.87)	2.64 (1.77)	2.79 (1.79)	2.77 (1.81)
CSR16	790.67 (28.11)	790.67 (28.10)	792.33 (28.16)	0.21 (0.84)	0.22 (0.85)	0.24 (0.86)	2.65 (1.76)	2.72 (1.79)	2.73 (1.79)
PMxCSR2	447.67 (21.15)	525.00 (22.92)	561.50 (23.70)	0.16 (0.81)	0.16 (0.81)	0.18 (0.82)	3.14 (1.91)	3.22 (1.92)	2.74 (1.80)
PMxCSR4	539.00 (23.22)	606.00 (24.62)	670.33 (25.90)	0.20 (0.84)	0.17 (0.82)	0.27 (0.87)	3.02 (1.87)	3.07 (1.89)	3.21 (1.93)
PMxCSR16	473.67 (21.72)	510.00 (22.57)	651.00 (25.52)	0.15 (0.81)	0.18 (0.82)	0.21 (0.84)	2.88 (1.84)	3.17 (1.91)	3.22 (1.93)
CSR2 xCSR4	616.33 (24.84)	622.00 (24.95)	642.33 (25.35)	0.20 (0.84)	0.28 (0.88)	0.23 (0.85)	3.02 (0.87)	3.66 (2.04)	3.25 (1.94)
CSR2 xCSR16	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.70)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
CSR4 xCSR16	470.00 (21.66)	722.67 (26.88)	702.33 (26.51)	0.17 (0.82)	0.20 (0.83)	0.20 (0.84)	2.45 (1.72)	3.27 (1.94)	2.36 (1.69)
Mean	524.67 (21.54)	581.17 (22.78)	624.80 (23.62)	0.16 (0.81)	0.18 (0.82)	0.22 (0.84)	2.44 (1.68)	2.67 (1.74)	2.54 (1.71)
F test	*	*	*	*	*	*	*	*	*
SEm ±	27.003 (0.575)	27.782 (0.421)	3.145 (0.059)	0.011 (0.007)	0.015 (0.009)	0.008 (0.005)	0.145 (0.040)	0.193 (0.051)	0.011 (0.003)
CD at 5%	79.660 (1.695)	64.257 (1.243)	9.277 (0.174)	0.034 (0.020)	0.043 (0.026)	0.024 (0.014)	0.846 (0.119)	0.570 (0.150)	0.031 (0.009)

*: Significant; NS: Non-Significant

and inoculated per orally. The leaf bits (10×12 cm size) were prepared, washed in running water and shade dried and sterilized. These mulberry leaf bits were smeared evenly with the virus suspension @ 0.25ml of *Bm*NPV PIB's by using non-absorbent cotton. After shade dried for five minutes they are fed to the silkworms. Control batches were fed with surface sterilized mulberry leaves for the first feed. Subsequent feeding was inoculum free leaves for both treated and untreated batches. These pure breeds and their hybrids were reared according to standard rearing practices (Dandin *et al.,* 2003). Data was collected on two rearing traits such as ET_{50} for symptom Expression (days) and Total larval mortality (%) for both the treated and untreated batches. To know their sensitivity against *Bm*NPV.

RESULTS AND DISCUSSION

Filament length was significantly influenced in all the silkworm breeds and their hybrids, when infected with different doses of *Bm*NPV. The longer filament length was showed in CSR2 (856.67 and 957.67m) when the larvae administered with 10^{-1} and 10^{-3} viral dilutions respectively. The same trend was seen in control batch (951.67m). Among hybrids, CSR4×CSR16 recorded longer filament length of 628.67 and 693.67m, but in control batches the filament length was ranged from 516.33m (PM×CSR2) to 733.33m (CSR2×CSR4). The PM and its components showed comparatively shorter filament length in case of PMxCSR2 and PM×CSR16 (512.33 to 541.00m) and PM×CSR2 and PM×CSR4 (528.67 to 649.33m) respectively (Table 1). A significant difference was noticed between the doses of *Bm*NPV administered to the silkworm breeds and hybrids with respect to filament weight. In pure breeds the more filament weight was recorded in CSR2 (0.24 and 0.28g) when administered with 10^{-1} and 10^{-3} respectively, the trend was same even in control batch (0.28 g). Among hybrids, CSR4×CSR16 has recorded highest filament weight of 0.20 and 0.21g when administered with 10^{-1} and 10^{-3} respectively. In control batch PM×CSR4 has recorded highest value of 0.25g followed by CSR4×CSR16 (0.22g) (Table 1). Maximum of 2.67 and 2.79 filament denier was noticed in CSR_{16} breed at 10^{-1} and 10^{-3} respectively. However on the other hand, the highest denier was seen in CSR2×CSR4 (3.49) when administered with 10^{-3} dilution, the same trend was registered in control lot (3.22) (Table 1).

In fifth instar also the filament length was significantly influenced in all the silkworm breeds and their hybrids, when larvae administered with different doses of *Bm*NPV. The longer filament length was showed in CSR2 (826.67 and 855.00m) when the larvae administered with 10^{-1} and 10^{-3} dilutions, but the control lot of the same breed was recorded 982.00m filament length. Among bivoltine hybrids, filament length ranging from 470 to 616.33m and 622 to 722.67m (CSR4×CSR16 and CSR2×CSR4), but in control batches the longer filament length was found in CSR4×CSR16 (702.33m). The PM and its components showed comparatively shorter filament length *viz.,* PM×CSR2 (447.67 and 525.00m), PM×CSR4 (539.00 and 606.00m) and PM×CSR16 (473.67 and 510.00m) (Table 2). A significant difference was noticed between the doses of *Bm*NPV administered to the silkworm breeds and hybrids with respect to filament weight. In pure breeds the more filament weight was recorded in CSR2 (0.24 and 0.25g) when administered with 10^{-1} and 10^{-3} respectively, the trend was same even in control batch (0.30 g). Among hybrids, CSR2×CSR4 has recorded highest filament weight of 0.20 and 0.28g when administered with same dilutions. In control batch of PM×CSR4 has recorded highest value of 0.27g and lowest (0.20g) was encountered in CSR4×CSR16 (Table 2). Data on administration of *Bm*NPV to fifth instar silkworms revealed significant results. Among, pure breeds and hybrids maximum filament denier was noticed of in CSR4 (2.64 and 2.79) and CSR2×CSR4 (3.02 and 3.66) when administered with 10^{-1} and 10^{-3} dilutions. The same trend was registered in control lot (2.77 and 3.25) (Table 2). It is very vivid that, CSR2×CSR16 has not recorded any of the cocoon parameter which indicates its high sensitivity to *Bm*NPV.

The larvae administered with dilutions of NPV on filament length, weight and denier exhibit significant results among pure breeds and their hybrids. Significantly longer filament length (957.67m) and maximum weight (0.28g) and shorter (323m) filament length and minimum filament weight (0.90g) was noticed in Pure Mysore and CSR2 of fourth instar administered with 10^{-3} dilutions. Further, denier found to be maximum (2.79 and 3.66) and minimum (2.13 and 2.09) was registered for (CSR4 and CSR2×CSR4) and PM at 10^{-1} and 10^{-3} of fourth and fifth instar respectively. The effect due to NPV on filament length, weight and denier was very vivid even with multivoltine and bivoltine hybrids. The same trend was seen in fifth instar inoculated lots of all pure breeds and their hybrids. These results are inparity with findings of Bhaskar *et al.* (1991) accordings to them the cocoon filament length reduction were significant among experimental breeds. PM×C-nichi and Pure Mysore differ significantly with each other. The maximum of 65.06% and minimum of 14.54% reduction were noticed in NB7 and NB7×NB18 irrespectively. Further, the stock suspension and 10^{-5} dilution fed kenchu virus batches recorded maximum (84.8%) and minimum (10.76%) reduction and the same trend was seen even in reduction of cocoon filament denier. The maximum (68.25%) and minimum (9.8%) were exhibited for PM and NB7×NB18. Among kenchu viral dilutions administered, maximum of 82.86% and minimum of 11.33% reduction were encountered in stock and 10^{-5} fed suspension respectively. These results further supported by Govindan *et al*. (1989) have also recorded the extent of deterioration in quantitative parameters of cocoon in infected lots of *Bm*NPV.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 276-281

EFFECT OF BIOTIC AND ABIOTIC STRESS ON THE QUANTITATIVE TRAITS OF SILKWORM (*BOMBYX MORI* L.)

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ABSTRACT

Temperature is one of the abiotic factors which can influence the diversification of life with the interaction of other environmental components such as humidity and light. In the present investigation, mean values for eight economic traits of importance *viz.,* fecundity, pupation rate, cocoon yield, cocoon weight, shell weight, shell percentage, filament length and raw silk of newly evolved lines SR1, SR2, SR4 and SR5 and their hybrids SR1×SR4 and SR2×SR5 under hot (36°C±1°C) and dry climate (RH, 50±5%) conditions were analysed and recorded drastic changes. Another important biotic stress is the pathogen load of BmNPV (1×10^{7} POB /ml), BmIFV ($1\times10^{-4.0}$ dilutions/ml) which have profound effect on quantitative traits. The newly developed hybrid SR1×SR4 and SR2×SR5 recorded promising features when compared to control. Under BmNPV/BmIFV stress, SR2×SR5 and SR1×SR4 have shown significant economic traits indicates that the newly developed hybrids are superior. The profound effect of biotic and a biotic stress on quantitative traits were discussed.

Key words: Abiotic stress, Biotic stress, BmIFV, BmNPV, High temperature, Quantitative traits, Silkworm

INTRODUCTION

Synthesis of new gene combinations by conventional breeding techniques is one of the important tools for exploiting the phenomenon of hybrid vigour in the silkworm. Hybridization of silkworm breeds with different genetic constitution can be made either by crossing two or four parents depending on the traits that the breeder desires to introduce for improvement of productivity (Mano *et al.,* 1988). The quantitative traits of economic importance are under the control of cumulative action of polygenes with modifiers and the influence of environmental condition to which they are exposed during different stages of development and growth. The genetic mechanism of polygenic effect in relation to environmental factors make it difficult for the breeder in understanding the nature of genes that contribute to the expression of commercial traits. The improvement of quantitative traits needs clear understanding of inheritance pattern, response to selection, the mating systems and the manifestation of the characters under different environmental conditions.

According to Falconer (1960), the improvement obtained by selection under favourable conditions will not help in realizing the full potential when the selected strain is transferred to unfavourable conditions. Performance was best improved by selection under the conditions in which the performance was subsequently measured in future. Thus, the choice of a breed depends not only the genotype but also its performance under variable environmental conditions. Temperature is one of the biotic factor which can influence the diversification of life with the interaction of other environmental components such as humidity, light etc. If a substantial temperature change takes place, the ability of the organism to survive is dependent on its genetic capacity to compensate for the temperature change. In tropics, the traditional polyvoltine races, which are more robust and can, withstand the severe climate and have higher adaptability to tropical climate but the silk produced is qualitatively and quantitatively poor. On contrary, bivoltine breeds have better yield potential under optimum rearing conditions and produce superior quality silk (Murakami, 1989). Tropical

races are endorsed with an adaptive ability to the change of environmental conditions (Murakami, 1988). The growth rate of the tropical race tends to be earlier than that of the temperate race under the relatively higher temperature ranges prevailing in the tropics. Another important effect of pathogen load is having profound effect on economic traits in silkworm. Bivoltine silkworm breeds are reported to be more susceptible to grasserie and flacheri diseases compared to polyvoltine breeds (Sivaprakasam and Rabindra, 1995).Thus, an attempt has been made to know the effect of biotic stress of high temperature and abiotic stress of pathogen load on quantitative traits of bivoltine silkworm breeds/ hybrids.

MATERIALS AND METHODS

The present study was initiated by utilizing newly evolved thermo-tolerant breeds and their hybrids. The newly evolved lines SR1, SR2, SR3, characterized with plain larvae spinning white oval cocoons and SR4, SR5 and SR6 characterized with marked larvae except SR6 with plain larvae, spinning white dumbbell cocoons and their hybrids SR1 × SR4 and SR2 × SR5 forms the study materials. The disease free layings were collected and composite layings were prepared from 10 broods each. The brushing of larvae was carried out from the composite layings and rearing was conducted as per the standard rearing methods of Datta (1992). After passing fourth moult, on second day of fifth instar, 100 larvae each were counted in three replications and subjected to high temperature (36°C±1°C) and low humidity conditions (RH, 50±5%) in SERICATRON (an environmental chamber having precise mechanism for controlling desired temperature and humidity) for 6 hours daily from 10 a.m. to 4 p.m. (Kato *et al.,* 1989). Daily the larvae were brought back to prevailing temperature in the remaining hours and rearing continued till spinning in SERICATRON. Observations were recorded on ten metric traits of economic traits such as Fecundity, larval duration, pupation rate, cocoon weight, cocoon shell weight, cocoon shell ratio, filament length, raw silk percentage, reel-ability and neatness. The control batches were reared in the prevailing room temperature having 100 larvae each in replication.

In another set of experiment, 100 larvae each in three replications were separated after passing second moult and per os inoculation was carried out with Bombyx mori Infectious Flacherie Virus (BmIFV) of $1\times10^{-4.0}$ and Bomyx mori Nuclear polyhedrosiss virus BmNPV with 1×10^{7} POB/ml doses in separate rooms. The stocks of BmNPV inoculum containing BmNPV polyhedral inclusion bodies and BmIFV virus inoculum were received from silkworm pathology laboratory of this institute and multiplied in a susceptible silkworm breed CSR2 by per os inoculation in silkworm during fourth instar. The nuclear polyhedral bodies were extracted from haemolymph of the infected larvae and purified by repeated washing and centrifugation, followed by sucrose gradient centrifugation (Sugimori et. al., 1990) using Hitachi ultra Centrifuge. The final suspension was quantified by haemocytometer and three different inoculum doses of polyhedral suspension of 1 × 107 PIB/ml were prepared for inoculation. Like wises BmIFV stock solution was inoculated to CSR2 and collected diseased larvae and centrifuged with distilled water and prepared required (1 × 10-4.0) concentration by serial dilution method. The silkworm larvae were reared in disinfected rearing house, using disinfected rearing appliances. The feeding, cleaning and sanitation schedules were followed as per standard methods up to 3rd moult. The larvae were inoculated with 1 ml of BmNPV /BmIFV separately by per os inoculation immediately after third moult for (100 larvae/replication/ treatment). The inoculums were smeared on to the mulberry leaf surface and fed to the larvae. The larvae were allowed to consume the entire treated leaves and further rearing was carried out with fresh mulberry leaves till beginning of final in separate rooms. The daily mortality rate was recorded 12 days of PI. The survived larvae were mounted and cocoons harvested. The experiment was repeated twice and statistically analyzed. In the control batches, after 3rd moult, 100 larvae of uniform growth were counted and retained till spinning. The cocoons were harvested on $6^{th}/7^{th}$ day of spinning and kept for cocoon assessment. The batches were analyzed for the effect of biotic and abiotic stress on economic traits.

RESULTS

Mean values of eight economic traits of importance viz. fecundity, pupation rate, cocoon yield, cocoon weight, cocoon shell weight, cocoon shell percentage, filament length and raw silk percent of bivoltine breeds SR1 and SR4 and their hybrid SR1 × SR4 under hot 36°C±1°C (HT) and normal room temperature (RT), 25°C±1°C conditions are presented in Table 1. SR1(HT) recorded a mean fecundity of 488, pupation rate of 84%, cocoon yield 13.531 by wt., cocoon weight 1.543, cocoon shell weight 0.364, cocoon shell percentage of 22.8, filament length 854m with a raw silk of 12.40 percent when compared to SR1(RT) batch, fecundity of 526, pupation rate of 91.2%, cocoon yield 16.010 by wt., cocoon weight 1.747, cocoon shell weight 0.398, cocoon shell percentage of 22.8, filament length 969m with a raw silk of 16.45.Significant t test values were recorded for fecundity, pupation rate, shell weight, filament length and raw silk%. SR4 (HT) recorded a mean fecundity of 502, pupation rate of 87.10%, cocoon yield13.816 by wt., cocoon weight 1.577, cocoon shell weight 0.350, cocoon shell percentage of 22.26, filament length 811m with a raw silk of 13.81% when compared to SR4(RT) batch, fecundity of 511, pupation rate of 92.00%, cocoon yield16.080 by wt., cocoon weight 1.764, cocoon shell weight 0.397, cocoon shell percentage of 22.4, filament length 941m with a raw silk of 13.81%. Significant t test values were recorded for cocoon yield, cocoon weight, shell weight and filament

length. The newly developed hybrid SR1× SR4 (HT) recorded a mean fecundity of 522, pupation rate of 91.9%, cocoon yield 16.250 by wt., cocoon weight 1.800, cocoon shell weight 0.460, cocoon shell percentage of 23.00, filament length 982m with a raw silk of 15.50 percent when compared to SR1× SR4 (RT) recorded a mean fecundity of 526, pupation rate of 93.4%, cocoon yield 18.230 by wt., cocoon weight 1.937, cocoon shell weight 0.448, cocoon shell percentage of 23.00, filament length 1097m with a raw silk of 17.98 percent. Significant t test values were observed for cocoon yield.

Mean values of eight economic traits of importance viz. fecundity, pupation rate, cocoon yield, cocoon weight, cocoon shell weight, cocoon shell percentage, filament length and raw silk percent of newly evolved lines SR2 and SR5 and their hybrid SR2 × SR5 under hot (HT) 36°C±1°C and room temperature (RT) 25°C±1°C conditions are presented in Table 2. SR2 (HT) recorded a mean fecundity of 508, pupation rate of 88.0%, cocoon yield 13.567 by wt., cocoon weight 1.463, cocoon shell weight 0.328, cocoon shell percentage of 22.4, filament length 812m with a raw silk of 14.11 percent when compared to SR2 (RT), fecundity of 506, pupation rate of 91.0%, cocoon yield 15.765 by wt., cocoon weight 1.763, cocoon shell weight 0.404, cocoon shell percentage of 22.7, filament length 922m with a raw silk of 16.20percent.Significant t test values were recorded for cocoon weight, shell weight, and filament length.SR5(HT) recorded a mean fecundity of 496, pupation rate of 82.2%, cocoon yield 13.106 by wt., cocoon weight 1.476, cocoon shell weight 0.322, cocoon shell percentage of 21.79, filament length 881m with a raw silk of 12.89 percent when compared to SR5(RT), fecundity of 513, pupation rate of 92.4%, cocoon yield 16.100 by wt., cocoon weight 1.730, cocoon shell weight 0.398, cocoon shell percentage of 21.1, filament length 906m with a raw silk of 15.78.Significant t test values were recorded for fecundity, pupation rate, cocoon weight, shell weight and filament length. The newly developed hybrid SR2 × SR5 (HT) recorded a mean fecundity of 526, pupation rate of 89.2%, cocoon yield16.320 by wt., cocoon weight 1.880, cocoon shell weight 0.448, cocoon shell percentage of 23.11, filament length 997m with a raw silk of 16.80 percent when compared to SR2×SR5 (RT), fecundity of 530, pupation rate of 94.0%, cocoon yield 18.545 by wt., cocoon weight 1.980, cocoon shell weight 0.465, cocoon shell percentage of 23.7, filament length 1100m with a raw silk of 18.75 percent. Significant t test values were recorded for cocoon yield, filament length and raw silk percent.

Mean values of eight economic characters of the evolved breeds SR1, SR2, SR4 and SR5 and their hybrids SR1×SR4, SR2×SR5 under BmNPV (1×107 POB/ml) pathogenic conditions are presented in Table 3. SR1 recorded a mean fecundity of 502, pupation rate of 48.6.%, cocoon yield 12.167 by wt., cocoon weight 1.458, cocoon shell weight 0.310, cocoon shell percentage of 21.26, filament length 812m with a raw silk of 14.11 percent. SR4 recorded a mean fecundity of 488 pupation rate of 39.0%, cocoon yield 13.400 by wt., cocoon weight 1.500, cocoon shell weight 0.304, cocoon shell percentage of 20.20, filament length 881m with a raw silk of 12.89 percent. SR2 recorded a mean fecundity of 488, pupation rate of 39.00.%, cocoon yield12.656 by wt., cocoon weight 1.500, cocoon shell weight 0.346, cocoon shell percentage of 21.62, filament length 708m with a raw silk of 12.35 percent. SR5 recorded a mean fecundity of 502, pupation rate of 41.0%, cocoon yield11.560 by wt., cocoon weight 1.488, cocoon shell weight 0.296, cocoon shell percentage of 19.89, filament length 768m with a raw silk of 11.82 percent. Significant CD values were recorded for all the traits except fecundity and cocoon yield. The newly developed hybrid SR1 × SR4 recorded a mean fecundity of 516, pupation rate of 56.3%, cocoon yield 14.115 by wt., cocoon weight 1.503, cocoon shell weight 0.322, cocoon shell percentage of 21.42, filament length 797m with a raw silk of 12.80 percent and SR2 × SR5 recorded a mean fecundity of 516, pupation rate of 54.00%, cocoon yield 14.400 by wt., cocoon weight 1.574, cocoon shell weight 0.345 cocoon shell percentage of 21.91, filament length 798m with a raw silk of 13.00 percent. Significant CD values were recorded for all the traits except fecundity and pupation rate.

Mean values of eight economic traits of newly evolved lines SR1, SR2, SR4 and SR5 and their hybrids SR1×SR4, SR2×SR5 under BmIFV (1×14.0dilutions/ml) pathogenic conditions are presented in Table 4. SR1 recorded a mean fecundity of 488, pupation rate of 39.0.%, cocoon yield 11.567 by wt., cocoon weight 1.526, cocoon shell weight 0.336, cocoon shell percentage of 22.0, filament length 788m with a raw silk of 12.20 percent. SR4 recorded a mean fecundity of 511, pupation rate of 49.6%, cocoon yield 12.300 by wt., cocoon weight 1.503, cocoon shell weight 0.290, cocoon shell percentage of 19.23, filament length 712m with a raw silk of 12.70 percent. SR2 recorded a mean fecundity of 498, pupation rate of 52.60.%, cocoon yield13.500 by wt., cocoon weight 1.594, cocoon shell weight 0.355, cocoon shell percentage of 22.27, filament length 818mts with a raw silk of 13.40 percent. SR5 recorded a mean fecundity of 507, pupation rate of 47.8%, cocoon yield11.300 by wt., cocoon weight 1.493, cocoon shell weight 0.325, cocoon shell percentage of 21.76, filament length 765mts with a raw silk of 11.85 percent. Significant CD values were recorded for all the traits except for fecundity and pupation rate. The newly developed hybrid SR1 × SR4 recorded a mean fecundity of 512, pupation rate of 53.0%, cocoon yield 14.320 by wt., cocoon weight 1.724, cocoon shell weight 0.358, cocoon shell percentage of 20.76, filament length 797m with a raw silk of 12.95 percent and SR2 × SR5 recorded a mean fecundity of 510, pupation rate of 57.0%, cocoon yield14.700 by wt., cocoon weight 1.651,

cocoon shell weight 0.364, cocoon shell percentage of 22.04, filament length 882m with a raw silk of 13.85 percent. Significant CD values were recorded for all the traits except for fecundity and pupation rate.

DISCUSSION

The climatic conditions prevailing in the tropics are most unpredicted and the problems of tropical sericulture are occurrence of aggravated silkworm diseases, unsuitable mulberry leaf for bivoltine silkworms and lack of sustainable silkworm strains. Investigations carried out on the effect of constant temperature and fluctuations in temperature during the later larval instars showed adverse effects in case of bivoltines (Kobayashi *et al.,* 1966). In the present investigation when same breeds are reared under high and normal temperature, the fecundity was reduced in the HT batch. Regardless of the timing of gonadal development (either occurring before or after metamorphosis), temperature affects the total number of eggs laid per female moth (Choet and David 1978). Gonadal differentiation takes place even in the earlier instars (Sugai and Takahashi 1981) and the high temperature might have affected the ovarioles resulting in reduced number of eggs without affecting the fertility status. Fluctuations noticed in the pupation rate under high temperature can be partially attributed to the influence of environmental factors and the interaction of alleles responsible for the expression of the trait. In the pure breeds SR1 and SR4, the pupation rate was lower when exposed to high temperature compared to normal batches (Table 1). The high and extreme temperature may tax the physiological mechanism of the silkworm (Jolly, 1987) and the imposition of exposure to high temperature levels in 5th instar will result in low pupation rate, could be attributed to the low feeding activity of the silkworm. Ueda and Lizuka (1962) demonstrated that silkworms are more sensitive to temperature during 4th and 5th ages. The present findings are in conformity with the earlier findings and when it comes to hybrids (SR1×SR4 and SR2×SR5), though they were reared under high temperature, there is not much variation in the pupation rate confirms with the findings of Suresh Kumar et al. (2001) who noticed higher survival in the hybrids than the pure races under high temperature. Nagaraju et al.. (1996) observed that the cocoon yield/10,000 larvae, cocoon weight, shell weight and shell ratio were also low in the high temperature treated batches when compared to the batches reared under optimum rearing conditions. This may be due to the fact that high temperature coupled with low humidity, which will cause leaf-withering leading to low rate of ingestion by the silkworm. In tropical countries like India, the temperature gradually increases from March and reaches its peak during May. The effect of high temperature simultaneously reduces the cocoon weight and cocoon shell weight but the cocoon shell ratio was maintained as it was observed in present study (Table 2) .All these responses indicate the strive of Bombyx mori to adapt to the changes in environmental conditions. Le thi Kim (1988) observed that the influence of high temperature effects the reel-ability of cocoon there by wastage of silk is more and ultimately filament length will reduce. In the present investigation, filament length and raw silk were reduced in the HT batches when compared to normal reared batches which indicate detrimental effect of high temperature on post cocoon traits (Table 1 & 2). Naik *et al.,* (2003) studied the effect of high temperature and high/low humidity on post cocoon parameters without air current conditions and concluded that both have synergistic effect on reel-ability and other related traits.

If any pathogenic infection takes place in the later part of larval period of silkworm, the larvae completes its larval period, but the disease occurs in the post cocoon stage. Nuclear polyhedrosis virus which causes grasserie disease when infects the silkworm larvae during late fourth or fifth instar, the larvae manages to survive and form cocoons, but the pupa may die inside the cocoon resulting in the formation of melted cocoons. In the present study, pupation rate was

Table 1: Performance of SR1, SR4 and their hybrid SR1×SR4 under high (HT) and room temperature (RT)

Breed/ Hybrids	Fecun-dity (No)	Pupation rate (%)	Cocoon yield (kg)	Cocoon wt. (g)	Shell wt. (g)	Shell ratio (%)	Filament length (m)	Raw silk (%)
SR1 (HT)	488	84.0	13.531	1.543	0.364	22.8	854	12.40
SR1 (RT)	526	91.2	16.010	1.747	0.398	22.8	969	16.45
t value	2.37*	0.04**	0.005ns	0.14ns	5.24**	0.09ns	7.58**	6.90**
SR4 (HT)	502	87.1	13.816	1.577	0.350	22.2	811	13.81
SR4 (RT)	511	92.0	16.080	1.764	0.397	22.4	941	15.99
t value	0.002ns	0.01ns	2.150**	3.905**	3.035**	1.34ns	6.96**	0.37ns
SR1×SR4 (HT)	522	91.9	16.250	1.800	0.460	23.0	982	15.50
SR1×SR4 (RT)	526	93.4	18.230	1.937	0.448	23.0	1097	17.98
t value	-	-	0.65**	-	-	0.074	31.2	0.66

* Significant at 5%; ** Significant at 1%.

Table 2: Performance of SR2, SR5 and their hybrid SR2 × SR5 under high (HT) and room temperature (RT)

Breed/ Hybrids	Fecun-dity (No)	Pupation rate (%)	Cocoon yield (kg)	Cocoon wt. (g)	Shell wt. (g)	Shell ratio (%)	Filament length (m)	Raw silk (%)
High temperature								
SR2 (HT)	508	88.0	13.567	1.463	0.328	22.4	812	14.11
SR2 (RT)	506	91.0	15.765	1.763	0.404	22.7	922	16.20
t value	0.006ns	1.10	0.036	4.631**	3.877**	0.009	4.31**	0.378ns
SR5 (HT)	496	82.2	13.106	1.476	0.322	21.7	881	12.89
SR5 (RT)	513	92.4	16.100	1.730	0.398	21.1	906	15.78
t value	.495**	32.370**	0.011ns	3.905**	3.035**	0.345ns	6.96**	0.40ns
SR2×SR5	526	89.2	16.320	1.880	0.448	23.1	997	16.80
SR2×SR5	530	94.0	18.545	1.980	0.465	23.7	1100	18.75
t value	0.286ns	1.52ns	3.76**	0.020ns	0.146ns	0.55ns	4.025**	2.047**

* Significant at 5%; ** Significant at 1%.

Table 3: Susceptibility status of thermo-tolerant breeds/ hybrids against BmNPV (1×10^{7} POB/ml) in normal rearing

Breed/ Hybrids	Fecun-dity (No)	Pupation rate (%)	Cocoon yield (kg)	Cocoon wt. (g)	Shell wt. (g)	Shell ratio (%)	Filament length (m)	Raw silk (%)
High temperature								
SR1	502	48.6	12.167	1.458	0.310	21.2	812	14.11
SR4	488	39.0	13.400	1.500	0.304	20.2	881	12.89
SR2	488	39.0	12.656	1.600	0.346	21.6	708	12.35
SR5	502	41.0	11.560	1.488	0.296	19.8	768	11.82
CD at 5%	-	4.95	-	0.60	0.047	0.010	0.40	0.39
SR1×SR4	516	56.3	14.115	1.503	0.322	21.4	797	12.80
SR2×SR5	516	54.0	14.400	1.574	0.345	21.91	798	13.00
CD at 5%	-	-	0.34	0.040	0.007	0.62	22.2	0.34

Table 4: Susceptibility status of thermo-tolerant breeds/ hybrids against BmIFV ($1\times10^{-4.0}$ dilutions/ml) in normal rearing

Breed/ Hybrids	Fecun-dity (No)	Pupation rate (%)	Cocoon yield (kg)	Cocoon wt. (g)	Shell wt. (g)	Shell ratio (%)	Filament length (m)	Raw silk (%)
High temperature								
SR1	488	39.0	11.567	1.526	0.336	22.0	788	12.20
SR4	511	49.6	12.300	1.503	0.290	19.2	712	12.70
SR2	498	52.6	13.500	1.594	0.355	22.2	818	13.40
SR5	507	47.8	11.300	1.493	0.325	21.7	765	11.85
CD at 5%	-	-	0.34	0.040	0.007	0.62	26.8	0.52
SR1×SR4	512	53.0	14.320	1.724	0.358	20.7	797	12.95
SR2×SR5	510	57.0	14.700	1.651	0.364	22.04	882	13.85
CD at 5%	-	-	1.00	0.077	0.024	0.69	40.7	0.86

drastically reduced due to BmNPV and BmIFV infection (Table 3 &4).Earlier studies of Aruga et al., (1963) indicated that the stage of inoculation and the dosage of BmIFV inoculation play a vital role in the post cocoon mortality. The stressors accelerate the multiplication of the virus in the infected cell and effects the survivability and other related traits. Nataraju (2002) studied the incidence of post cocoon mortality in CSR hybrid rearing and it ranged from 3.39 to 15.7% and the mortality was mainly due to grasserie and flacherie. Sivaprasad et. al., (2003) studied the effect of BmNPV inoculation on the larval and cocoon parameters as well as on the larval and pupal mortality in different silkworm breeds and noticed their adverse effect. It is concluded that both biotic effect of pathogen load and abiotic stress of high temperature exposure is detrimental to the silkworm survivability and badly effects the economic traits and cocoon productivity.

ACKNOWLEDGEMENT: The authors are thankful to the scientists of silkworm breeding and silkworm pathology laboratory for supplying silkworm breeds and Bm NPV/BmIFV inoculum respectively and to J. Justin Kumar for assisting in the laboratory work.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 282-285

AN INNOVATIVE METHOD FOR TRANSFER OF CRAWLERS FROM OLD MEALYBUG COLONY TO FRESH SWEET PUMPKIN TO REDUCE COLONY DEVELOPMENTAL PERIOD

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ABSTRACT

It is a common practice that, for the mass multiplication of predatory ladybird beetles of tukra mealybug, *Maconellicoccus hirsutus*, the host insect is raised on sweet pumpkin. In most of the commercial insectaries, it is raised by inoculating sweet pumpkins with few gravid females/ovisacs containing egg masses. Through this process, one has to wait for 31 – 33 days to get a fully developed colony of mealybug all around the pumpkin for subsequent utilization of the same for mass production of predatory ladybird beetles. Also, by chance, if the sweet pumpkin with fully developed mealybug colony rots early in the middle, due to some qualitative problems, the entire mealybug colony so raised becomes a waste, and cannot be used. Hence a novel method is evolved at the Pest Management Laboratory of CSRTI, Mysore wherein, the mealy bug crawlers are separated from the colony easily by using leaves of certain alternate host plants and transferred over to fresh sweet pumpkins where the colony gets established within 25 to 27 days. Based on the number of crawlers trapped in one hour on four different host leaves tested, *Glyricidea* was found the best carrier followed by Hibiscus, Mulberry and Croton. In addition, from the early rotten sweet pumpkins also, crawlers as well as nymphs can be easily collected by employing the above method and well utilized for either to feed the predatory ladybird beetles or for inoculating fresh sweet pumpkins. This method besides reducing the time gap required to raise a good mealybug colony on fresh pumpkin saves the wastage of crawlers emerging from old mealybug colony to a greater extent.

Key words: Commercial insectary, Crawlers, *Glyricidea,* Mealybugs, Sweet pumpkin

INTRODUCTION

Pink mealy bug, *Maconellicoccus hirsutus*, is a major pest of mulberry, *Morus* spp. which causes a typical symptom called Tukra (a deformity of apical portion of plant leading to arrest of growth due to the toxin released by mealy bug) and causes a leaf yield loss to the tune of up to 4,500 kg/ha/year (Dandin *et al*., 2000). As they posses white waxy coating over their body surface, it makes any insecticide almost impossible to penetrate inside. Also, they have developed resistance against systemic insecticides. Under such situation, biological control of this pest has evolved as a boon. Therefore, biological control is regarded as one of the important components in its management strategies, wherein host specific coccinellid beetles are mass produced in the insectary and released in the field to keep the pest population below economic threshold level (Mani, 1988). In mulberry crop, two species of predatory ladybird beetles namely *Cryptolaemus montrouzieri* Muls. and *Scymnus coccivora* Ayyar are recommended as bio-control agents of mealybug (Rajadurai, 2005). But, the availability of these predatory beetles is a major constraint and hence farmers are not able to use this bio-control agent. However, a simplified technology has been developed at CSRTI, Mysore for mass production of these predatory beetles using mealy bugs grown on sweet pumpkins and rearing the beetles in aerated plastic boxes (Shekhar *et.al*., 2009) as against the earlier standard method of keeping mealybug raised sweet pumpkins inside a cage and inoculating with ladybird beetles (Mani, 1988).

The standard production technique followed for the mass production of host insect ie., mealybug is very well described by DeBach (1964), Fisher (1963), Manjunath (1988) and Singh (1995) and is being followed till today which mainly involves inoculating sweet pumpkins with few gravid females or ovisacs containing egg masses. The crawlers emerging from these egg masses settle and develop on the pumpkin by sucking the pumpkin juice. By this

process, it takes more than 30-35 days (4 to 5 weeks) to get a fully developed colony of mealybug all around the pumpkin for subsequent utilization of the same for mass production of predatory ladybird beetles (Manjunath, 1998). Also, by chance, if the sweet pumpkin with fully developed mealybug colony rots in the middle due to some qualitative problems, the entire mealybug colony so raised becomes a waste, and cannot be used further. Therefore by keeping these points in mind, studies were conducted at the Pest Management Laboratory mainly to reduce the colony developmental period of mealybug on sweet pumpkin as well as some ways to collect and effectively utilize the mealybug crawlers from early rotten pumpkins as well as those wandering on pumpkin racks for establishing new colony on fresh sweet pumpkins.

MATERIALS AND METHODS

The present work was carried out in the insectary of the Pest Management Laboratory, CSR&TI, Mysore at 28± 2°C and 55-70% R H. The culture of host mealy bug *Maconellicoccus hirstus* as well as crawlers and nymphs were obtained from the mealybug stocks maintained on sweet pumpkin at PML insectary.

I. Determination of suitable host leaf for attracting mealybug crawlers.

Mealybugs are polyphagous in nature and keeping this point in view, few alternate host leaves were tested for their preference and in turn to use the same for trapping the crawler population. For this, single leaf each of Mulberry, *Hibiscus*, *Glyricidea* and croton were placed side by side over a single sweet pumpkin containing fully developed mealy bug colony from where large number of crawlers were emerging. After an hour, all the four host leaves were removed from the sweet pumpkin and the minute crawlers clinging on to them were brushed and collected separately on white paper by using camel hair brush and measured in small volumetric graduated tube. The process was replicated thrice. The number of crawlers present in 0.5 ml was counted physically so as to quantify them. The host leaf which attracted more number of mealybug crawlers was determined as the best suited host leaf for attracting and trapping them. Similarly, crawlers trapped in the leaves when kept for 2 h & 3 h intervals were also determined in 3 replications and analyzed statistically for significance.

II. Raising of mealybug colony on sweet pumpkins by release of gravid females v/s crawlers.

Twenty numbers of ripened sweet pumpkins with ridges & grooves and small stalk were brought from the market, initially washed with running water, subsequently dipped in 0.5% Bavistin solution and air dried under fan. Damaged portion of the sweet pumpkins, if any was plugged with melted paraffin wax to avoid secondary contamination.

(i) Release of gravid females:

In the first set, ten sweet pumpkins were inoculated with gravid females @ 25/kg of sweet pumpkin with the help of a needle and a camel brush and kept in well ventilated place on a stainless steel stand in a rack for observation till development of mealy bug colony.

(ii) Release of crawlers:

In the second set, remaining ten sweet pumpkins were inoculated with freshly emerged crawlers. For this purpose, *Glyricidea* leaves were used for trapping & transfer of crawlers from old mealybug colony (as it was found to be most effective host leaf in trapping of mealybug crawlers). They were inoculated with 5,000 to 6,000 crawlers per kg of sweet pumpkin and kept for observation.

RESULTS AND DISCUSION

I. Determination of suitable host leaf for attracting mealybug crawlers.

The results obtained clearly reveal that, a maximum of 8246.00±45.71 crawlers were trapped by *Glyricidea* leaves followed by *Hibiscus* (6129.33±82.48), Mulberry (4987.00±83.62) and Croton (4005.00±67.73) when kept for 1 h on sweet pumpkin having crawler population (Table 1). Further, the number of crawlers trapped by *Glyricidea* leaf significantly increased with the increase in trapping duration up to 3h., whereas with other host leaves tested, the difference was non significant. This indicated that the mealybugs preferred *Glyricidea* leaves over the other three host leaves tested.

In addition, the above results clearly supports utilization of *Glyricidea* leaves even for trapping the crawlers/nymphs in the mealybug colony on rotting pumpkins, which otherwise might have gone as wastage. Sometimes, in the insectary, the crawlers moving on iron racks as well as on the insectary floor when collected using wide flat brush, measured even upto 25 to 30 ml which may be quantified as 5 to 6 lakhs (@ 20,000 crawlers/ml), which otherwise can be well utilized for raising mealybug colony, instead of leaving it as going waste (Fig.1 – 6).

II. Raising of mealybug colony on sweet pumpkins by release of gravid females v/s crawlers.

From the results at Table 2 it is evident that the total colony development period was 25.90±0.28 days on inoculating sweet pumpkins with crawlers as compared to 32.00±0.23 days on inoculating with gravid females, leading to a saving of almost a week.

CONCLUSION

- *Glyricidea* leaf was found the most suitable for trapping the mealybug crawlers followed by Hibiscus, Mulberry and Croton.

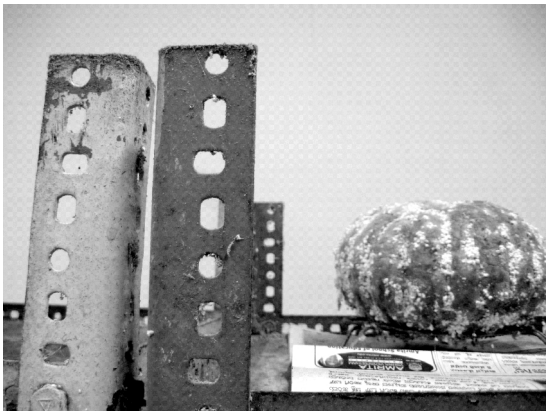


Fig. 1: Crawlers congregating onthe tip of iron rack in an insectary



Fig. 2: Crawlers & nymphs being trapped from rotting sweet pumpkin using *Glyricidea* leaf



Fig. 3: Crawlers collected in an insectary

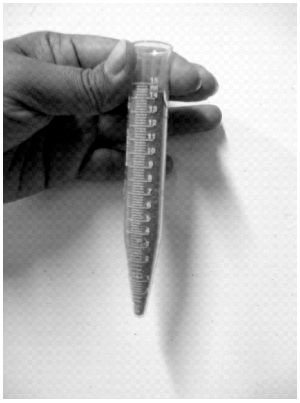


Fig. 4: Collected crawlers being quantified



Fig. 5: Inoculation with Gravid female v/s crawlers – development after 1 week



Fig. 6: Development after 3 weeks

Table 1: Number/Quantity of crawlers trapped by different leaves at diferent time intervals

Duration of exposure to mealybug colony (h)	(T1) *Glyricidea*[$]	(T2) *Hibiscus*[#]	(T3) Mulberry[#]	(T4) Croton[#]
1 h	8246.00±45.71 [c]	6129.33±82.48 [b]	4987.00±83.62	4005.00±67.73
2 h	9271.33±83.72 [b]	6367.00±56.47 [a]	5123.33±70.40	4047.33±42.12
3 h	10733.67±386.23[a]	6548.33±45.83 [a]	5162.00±48.01	4092.33±14.19
F value	29.627 **	10.954 **	NS	NS
r	0.948 **	0.883 **	NS	NS

([$] one compound leaf with 15 to 19 leaflets considered)
([#] one single simple leaf considered)
(0.5 ml crawlers quantified as 10,000 on an average)
Mean values followed by the same superscript in columns are statistically not significant;
** - Significant at 1 %; r- correlation coefficient NS- Non significant

Table 2: Days taken for development of mealybug colony on sweet pumpkin

Treatments	Duration (days)
Inoculated with gravid females	32.00±0.23
Inoculated with crawlers	25.90±0.28
F value	293.186
r	- 0.971 **

Values given in the Table are the mean of 10 replications (Mean ± SE);
** - Significant at 1 %; r- correlation coefficient

- Inoculation of sweet pumpkins with crawlers instead of gravid female leads to one week reduction in developmental duration of the colony on the sweet pumpkins besides uniform settlement of the crawlers.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 286-288

REARING OF *TETRASTICHUS HOWARDII,* A PUPAL PARASITOID OF THE LEAF ROLLER, *DIAPHANIA PULVERULENTALIS* ON LABORATORY REARED HOUSE FLY PUPA

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ABSTRACT

***Tetrastichus howardii* is recommended as a biocontrol agent of leaf roller *Diaphania pulverulentalis*. Success of biological control mainly depends upon easy availability of bio control agents at an affordable price to the farmers. To achieve the same, an effort was made to rear the *T. howardii* on laboratory reared host *i.e*., house fly pupa. The parasitization rate, adult recovery, sex ratio and developmental period were recorded up to six generations and the results revealed that these parameters did not vary significantly up to three generations. Thereafter, parasitization rate, progeny production and sex ratio were significantly reduced. The feasibility of using house fly pupa for mass production of *T. howardii* is discussed in the paper.**

Key words: *Diaphania pulverulentalis,* Housefly pupa, Leaf roller, Pupal parasitoid, *Tetrastichus howardii*

INTRODUCTION

Tetrastichus howardii (Olliff) (Hymenoptera: Eulophidae) is a widely distributed parasitoid across the Indian subcontinent and the far east parts of Australasia. In India, it is common pupal parasitoid of several species of lepidopteran borers (Cherian and Subramanian, 1940). The pupae of maize stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) are reported to be parasitized by *T. howardii and pupal parasitism ranged between 2.5% and 9.5% (Rao et. al. 2001) under field conditions.* It has also been reported as a parasitoid on the pupa of several natural enemies including Tachinid flies (Kfir *et al.,* 1993). *T. howardii* is reported to be an ecto-pupal parasitoid of Uzi fly, *Exorista bombycis* (Louis), a serious pest of silkworm (*Bombyx mori* L.) larva (Ram Kishore e*t al.,*1993). Attempts have been made to utilize *T. howardii* as a biological control agent against the spotted stem borer, *Chilo partellus* (Swinhoe) in South Africa (Kfir *et al*., 1993). *T. howardii* is also a vital component of IPM against leaf roller *Diaphania pulverulentalis* which inflicts 12-18% loss in mulberry in the southern silk producing states *i.e.* Karnataka, Andhra Pradesh and Tamil Nadu (Siddegowda *et.al.*,1995; Rajadurai *et.al.,*1999 and Mahendra, 2000). Leaf roller is also an important pest of mulberry in Kashmir valley and Jammu (Sharma and Tara, 1985), China (Veeranna, 1998), Formosa (Maki, 1920), Malaysia (Sengupta *etal.,1990)* and Japan (Rangswamy *et.al.,*1976).

A commercially viable mass rearing method of bio control agents is a prerequisite in translating biological control from percepts to practice. To make use of *T. howardii* as a biocontrol agent of leaf roller in the field, there is a necessity for mass multiplication of this parasitoid. Sathya Prasad *et. al.* (2007) reported that *T. howardii* can parasitize both naturally occurring Uzi fly pupa and laboratory- reared factitious host *i.e*. house fly pupa. Due to the reduced availability of Uzi fly pupa in cocoon markets, a need was *felt to produce T. howardii on laboratory reared house fly pupa. In the present investigation, the rearing of T. howardii* was carried out up to six generations on house fly pupa and the observations on the parasitization rate, progeny production, sex ratio and development period were made to find out the feasibility of using housefly pupa for production of T. *howardii.*

MATERIALS AND METHODS

Parasitization of house fly pupa by *Tetrastichus howardii*

Freshly pupated 20 ml house fly (800 pupae approximately) were kept in a single layer in a plastic container (6' diameter). One day old *T. howardii* adults (200 adults) drawn from the stock culture maintained on Uzi fly pupa (23-28ºC, 60-80%RH) were released in the ratio of (1:4) on housefly pupae. Fifty percent aqueous honey solution was smeared on a plastic paper strip and kept in the container which served as a food for the adults. Five

replications were maintained. After completion of the housefly emergence in a week time, parasitized pupa were collected. From each replication 20 pupa were kept in a test tube plugged with cotton to record data on development period, successful parasitization (No. of parasitized pupa from which *T. howardii* adults are able to emerge by making circular hole out of total parasitized pupa kept after house fly emergence), adult recovery and sex ratio and the remaining pupae were used for continued multiplication for the next generation. Same procedure was repeated from F2 to F6 generations.

RESULTS AND DISCUSSION

Housefly emergence

The percent fly emergence of 29.90, 29.70, 32.60 34.0, 35.70, and 36.70 was recorded in f1 – f6 generations respectively. It is evident from the results that fly emergence did not vary significantly from F1-F3 generation. However, it was significantly higher from F4 toF6 generation when compared with F1 generation. Thus the parasitisation rate of house fly pupa by *T. howardii*, which ranges from 63.3% to 70.35in different generations, is lower as compared to other gregarious parasitoid of house fly pupa *i.e. Nesolynx thymus*. The unemerged pupae left after fly emergence were considered as parasitized pupae and kept to record successful parasitisation.

Successful parasitisation rate

The percent successful parasitisation of 41.28, 41.98, 40.62, 37.96, 38.98, and 33.32 was recorded in F1-F6 generations respectively. The variation observed was not significant till F5generation but it was significantly lower in F6 generation compared to earlier generations. Thus parasitisation rate of factitious host *i.e*. house fly pupa by *T. howardii* is considerably low as compared to its natural host *i.e.* pupa of Uzi fly *Exorista bombycis*. Ram Kishore *et.al* (1993) reported 100% parasitisation of 1-4 day old pupa of Uzi fly by *T. howardii* which gradually declined to 15% with the advancement of pupal age to 9 days and no parasitisation was recorded with 10 -12 day old pupa .

A striking observation was the level of host mortality (58.02% to 66.68%) caused by *T. howardii* was beyond that caused by actual parasitism (33.32% to 41.98%). It appears that high mortality rate may be due to stinging of host pupa by the parasitoid and these stung pupa do not transform themselves into fly, but are killed. Another reason for higher mortality was attributed to partial development of parasitoid inside the host pupa. Dissections indicated that in some of the parasitized puparia, *T. howardii* has developed but failed to emerge.

Number of adults/successfully parasitized Pupa

The number of adults per successfully parasitized pupa was 19.14, 15.30, 16.60, 17.48, 15.90, and 15.22 in F1-F6 generations respectively. The variations in the parameter were non significant irrespective of the generation. The number of adults produced per successfully parasitized pupa of factitious host *i.e*. house fly pupa by *T. howardii* is considerably low as compared to its natural host *i.e.* pupa of Uzi fly *Exorista bombycis*. Ram Kishore *et. al.* (1993) reported that 64.95 adults emerged from 1- day old pupa of Uzi fly parasitized by *T. howardii*. The lower progeny production in house fly pupa compared to Uzi fly pupa may be due to seven times lesser size of the former than the latter. The lesser number adult parasitoids emerging from smaller pupa is due to deficiency of food material for the developing larvae of parasitoid.

Number of adults per parasitized pupa

The no. of adults per parasitized pupa was 7.88, 7.50, 7.0, 6.14, 4.20, and 3.96 in F1-F6 generation respectively. The variation observed did not vary significantly till F4 generation but it was significantly lower in F5 & F6 generation compared to earlier generations. The lower progeny production per parasitized pupa is due to higher mortality rate of host pupa by the parasitoid.

Percent Female Emergence

The percent female emergence was 74.28, 72.30, 73.42, 67.64, 63.08, and 65.68 in F1-F6 generations respectively. The variation observed did not vary significantly till F3 generation but it was significantly lower in F4 - F6 generation compared to earlier generations.

Development Period

The development period from egg to adult was 15.20, 15.40, 15.20, 15.40, 15.60, and 15.20 days in F1-F6 generation, respectively which did not vary significantly. It is evident from the above results that *T. howardii* can be mass multiplied on house fly pupa for three generations without any adverse effect on parasitisation rate and progeny production. However, its stock culture should me maintained on natural host *i.e.,* Uzi fly pupa. Further, the directional selection in F1 generation did not improve the parasitisation potential of the parasitoid in future generations.

Table 1: House fly emergence and parasitisation rate of house fly pupa parasitized by *T. howardii*

Generation	Fly Emergence (%)	Parasiti-zation (%)	Rate of Succcessful Parasitization (%)	Per cent Pupal Mortality
F1	29.90	70.10	41.28	58.72
F2	29.70	70.30	41.98	58.02
F3	34.00	66.00	40.62	59.38
F4	32.60	67.40	37.96	62.04
F5	35.70	64.30	38.98	61.02
F6	36.70	63.30	33.32	66.68
S.E.	3.23	3.23	2.05	2.05
CD at 5%	3.51	4.91	4.05	5.15

Table 2: Progeny production and development period of *T. howardii* emerged from parasitized house fly pupa

Generation	No. of Adults/Successfully Parasitized Pupa	No. of Adults/ Parasitized Pupa	Percent Female	Development Period
F1	19.14	7.88	74.28	15.20
F2	15.30	7.50	72.30	15.40
F3	16.60	7.00	73.42	15.20
F4	17.48	6.14	67.64	15.40
F5	15.90	4.20	63.08	15.60
F6	15.22	3.96	65.68	15.20
S.E.	1.51	0.51	2.91	0.26
CD at 5%	--	1.50	3.58	--

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 289-291

STUDIES ON THE PARASITIZING EFFICIENCY OF *NESOLYNX THYMUS* REARED ON COLD STORED HOST PUPAE OF HOUSEFLY

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ABSTRACT

***Nesolynx thymus* is an ectopupal parasitoid of Uzi fly, *Exorista bombycis* and is recommended as a biocontrol agent of the later in the field. The synchronization between availability of host pupa and parasitoid is an essential prerequisite for mass production of this parasite, which can be achieved by storing the host pupa at low temperature. The parasitization rate, progeny production, sex ratio and developmental period of *N. thymus* were recorded on parasitizing 0, 1and 2 day old pupae of house fly stored at 5 ±1ºC and 10±1ºC for a period of 2-16 days. One day old pupa was found most suitable for refrigeration at both the temperature *i.e.*, 5 ±1ºC and 10±1ºC and can be refrigerated upto 14 days with no adverse effect on parasitization rate, adult emergence, developmental period and sex rate as compared to the control.**

Key Words: *Exorista bombycis,* Housefly pupae, *Nesolynx thymus,* Parasitizing efficiency, Uzi fly

INTRODUCTION

Several measures like cultural, mechanical, chemical and biological are available for management of Uzi fly, *Exorista bombycis* (Louis)(Diptera:Tachinidae) which causes 10-20% loss to silkworm crops by way of parasitizing silkworm larva (Kumar,1987). Among these methods, biological control is considered long lasting, self-perpetuating, safe, economical and environment friendly. A number of parasitoids parasitizing uzi fly pupa have been identified (Kumar *et.al*., 1993). Among them, *Nesolynx thymus* is recommended as a bio control component of IPM package against Uzi fly as it possess the desirable attribute of a good bio control agent like efficient host searching ability, adaptability to host habitat, amenability to laboratory multiplication *etc*.

For bio control programme, the mass production of *N. thymus* is being carried out on laboratory- reared house fly pupa. The synchronization between availability of host pupa and parasitoid is an essential prerequisite for bulk production of *N. thymus* which can be achieved by storing the host pupa at low temperature. Floate (2002) assessed the effects of age, status (fresh vs. freeze) , and storage regime on the suitability of house fly pupae as hosts for *Muscidifurax raptor* Girault and Saunders, *Muscidifurax raptorellus* Kogan and Legner, *Muscidifurax zaraptor* Kogan and Legner, *Spalangia cameroni* Perkins, *Trichomalopsis sarcophagae* (Gahan) and *Urolepsis rufipesi* (Ashmead). The production of all species was maximized on pupae aged 24-hour post pupation. Fresh pupae could not be refrigerated at 10^0C or less without a significant decline in their suitability as host. No work is reported on the suitability of the cold-stored host pupa of house fly for production of *N. thymus.* It has been attempted in the present study by cold storing 0,1 and 2-day old house fly pupa at 5^0C +1^0C and 10^0C +1^0C for a period of 2-16 days at an interval of 2 days.

MATERIALS AND METHODS

Cold storing of host pupa: 300 host pupa of house fly (0, 1and 2 - day old) were kept in plastic containers with mesh lid. These containers were stored at 5 ±1ºC and 10±1ºC for 2-16 days. Twelve pupae were removed from each container at an interval of 2 days and kept at room temperature of 25º C for 3 hours prior to parasitization by *N. thymus.* Three replications of 4 pupae each were maintained for each treatment.

Parasitization of house fly pupa: In three test tubes (15 cm × 1.5 cm) 4 host pupae were kept and 2 pairs of *N. thymus* adults were released. Fifty percent aqueous honey solution was smeared on small plastic strips and hanged in the test tubes. The mouth of the test tube was plugged with cotton.

Table 1: Percent parasitization of *Nesolynx thymus* on rearing 0- day old pupa of house fly cold stored at 5±1ºC and 10±1ºC

Temperature	Storing period in days									Mean	SE±	CD@5%
	0	2	4	6	8	10	12	14	16			
5 ±1ºC	92	61	31	0	0	0	0	0	0	20.4	3.5	10.4
10 ±1ºC	92	69	31	22	0	0	0	0	0	23.8	3.2	11

Table 2: Performance of *Nesolynx thymus* on rearing one-day old pupa of house fly cold stored at 5 ±1ºC and 10±1ºC

Storing duration in days	Per cent Parasitisation		No. of adults/pupa		Developmental duration in days		Per cent female emergence	
	5±1ºC	10±1ºC	5±1ºC	10±1ºC	5±1ºC	10±1ºC	5±1ºC	10±1ºC
0	80	80	12	12	17	17	89	89
2	92	89	14	17	17	18	94	86
4	92	92	12	18	16	18	89	74
6	92	80	11	15	17	17	86	79
8	92	92	11	13	16	17	88	81
10	69	92	10	14	17	16	89	88
12	69	92	15	17	18	18	87	84
14	69	69	16	12	18	18	74	89
16	59	56	5	10	18	17	69	79
Mean	79	82	12	14	17	17	86	83
SE±	7.8		1.7		0.5		3.6	
CD@5%	22.5		4.9		0.8		10.6	

Table 3: Performance of *Nesolynx thymus* on rearing two- day old pupa of house fly cold stored at 5 ±1ºC and 10±1ºC

Storing duration in days	Percent Parasitisation		No. of adults/pupa		Developmental duration in days		Per cent female emergence	
	5±1ºC	10±1ºC	5±1ºC	10±1ºC	5±1ºC	10±1ºC	5±1ºC	10±1ºC
0	61	61	13	13	17	17	89	89
2	58	61	9	14	18	18	91	92
4	44	92	12	14	18	18	83	93
6	69	80	14	12	17	17	90	87
8	61	61	14	16	17	17	85	83
10	61	55	12	12	17	16	81	76
12	54	39	6	10	19	18	77	78
14	22	22	8	10	17	18	89	73
16	39	39	4	7	17	17	86	76
Mean	52	57	11	12	17	17	86	83
SE±	5.4		1.5		0.6		4.3	
CD@5%	18.4		4.2		1.1		12.5	

The observations on parasitization rate, progeny production, development period and sex ratio were made.

RESULTS AND DISCUSSION

On cold storing 0, 1 and 2-day old host pupa of house fly at 5±1ºC and 10±1ºC for a period of 2-16 days, it was observed that 0-day old pupa was not suitable for refrigeration at both temperatures, since parasitization by *N.thymus* was drastically reduced after 2 days of refrigeration and no parasitisation was recorded after 6 days of refrigeration at 5±1ºC and after 8 days at 10±1ºC (Table – 1). Floate (2002) also reported that fresh pupa of house fly could not be refrigerated at 10^0C or less without a significant decline in their suitability as hosts.

Irrespective of period of regrigeration, the mean parasitization rate on refrigerated 1- and 2 day old pupae was 79% and 52% at 5±1ºC, 82% and 57% at 10±1ºC, respectively (Table 2 and 3). It clearly indicates that one day old house fly pupa is most suitable for refrigeration. These results are *Muscidifurax raptorellus*, *Muscidifurax zaraptor*, *Spalangia cameroni*, *Trichomalopsis sarcophagae* and *Urolepsis rufipesi* was maximized on house fly pupae aged 24-hour post pupation. Further, one- day old pupa can be refrigerated up to a maximum of 14 days at 10±1ºC without affecting the parasitisation rate, number of adults emerged from each parasitized pupa, development period and sex-ratio as compared to the control.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 292-294

AGE-SPECIFIC EGG LAYING PATTERN OF LADY BIRD BEETLE *CRYPTOLAEMUS MONTROUZIERI* – A MEALY BUG PREDATOR

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ABSTRACT

The ladybird beetle *Cryptolaemus montrouzieri is a* voracious feeder of mealy bugs, scale insects and aphids. The mass production of this beetle is being carried out on mealy bug colony raised on sweet pumpkin. To refine the mass production technology of *C. montrouzieri* and to optimize their use in mass production, a study was taken up to determine the reproductive potential of 0, 5, 10, 20 and 30 day old beetles. The results revealed that maximum of 367.0 and 368.0 eggs were laid by 5 and 10 days old beetles where as minimum of 147.4 eggs were laid by 30 day old beetles. Further, observations were also recorded on female longevity, pre-oviposition, oviposition and post oviposition period in relation to the age of the beetles. Based on the present results it was concluded that 5-day-old beetles can be utilized four times at weekly interval for oviposition against present practice of using one time. It will help in optimizing the use of the beetles and thereby reducing the production cost.

Key words: *Cryptolaemus montrouzieri,* Egg laying pattern, Ladybird beetle, Mealy bug, Predator

INTRODUCTION

Coccinellids are important natural enemies of pest species specially mealy bug (Hagen, 1974; Harren and Neuenschwander, 1991), Whitefly (Gerling, 1990) and Aphids (Frazer, 1998; Hagen, 1974). The effectiveness of a predator species as a bio control agent is linked to the quality of an individual predator's fitness (Ridgeway and Morrison, 1985). Fecundity is one of the biological parameters that can be used in the assessing predator's fitness (Huettel, 1976). Parental age has been suggested to influence progeny production and sex ratio of parasitoids (Abdelrahman, 1974). Mishra and Omkar (2006) investigated the influence of maternal and paternal ages on reproductive performance of an aphidophagous ladybird, *Propylea dissecta* (Mulsant). Maternal age strongly influences fecundity and pre-oviposition period while paternal age strongly influences the egg viability. The results revealed that the fecundity and percent egg viability increased up to the respective maternal and paternal ages of 30 days and thereafter declined, indicating the onset of senescence. The results of present study can help in better multiplication of ladybird concerned and in laying foundation for further age related studies.

The predaceous coccinellid beetle, *Cryptolaemus montrouzieri*, is a voracious feeder of mealy bug in both the larval and adult stages. A single larva may consume up to 250 small mealy bugs in the course of its development. It is a vital component of IPM against mealy bug, *M. hirsutus* causing Tukra symptoms in mulberry.

The mass production of this beetle is being carried out on mealy bug colony raised on sweet pumpkin. To refine the mass production technology of *C. montrouzieri* and to optimize their use in mass production, a study was taken up to determine the reproductive potential of 0, 5, 10, 20 and 30 day old beetles.

MATERIALS AND METHODS

Age specific fecundity

To determine age specificity fecundity, 0, 5, 10, 20, 30-day old beetles were utilized. They were fed with 50% aqueous honey solution till the initiation of the experiment. A pair of beetle was left to lay eggs on 10-12 mealy bugs for 24 hours in a plastic container. Thereafter, the pair was transferred to another box with 10-12 mealy bugs for oviposition, every 24 hours until the death of female. Each pair was considered as one replicate and 5 replications were made for each age. After 8-10 days, the number of grubs

Table 1: Female longevity and egg laying parameters of *Cryptolaemus montrouzieri*

Age of the beetle (days)	Female longevity(days)	Preoviposition period (days)	Oviposition period (days)	Post oviposition period (days)	Fecundity	Daily egg laying rate
0	31.80	3.20	23.20	3.40	278.40	12.18
5	35.40	3.00	26.80	1.60	367.0	15.84
10	55.40	1.00	32.60	11.80	368.00	14.37
20	44.80	2.20	20.20	2.40	229.20	11.15
30	49.80	2.00	15.40	2.40	147.40	10.80
S.E.	11.19	0.79	07.79	3.97	66.44	1.95
CD at 5%	NS	NS	8.50	NS	52.50	NS

Table 2: Weekly Fecundity (No.) of *Cryptolaemus montrouzieri* in relation to age of the beetles

Week	Age of the beetles					Average
	0 day	5 day	10 day	20 day	30 day	
I	35.00	69.20	82.00	57.80	44.60	57.72
II	78.00	88.80	116.40	78.40	56.80	83.68
III	66.40	70.80	38.60	48.00	42.00	53.16
IV	45.80	51.40	27.20	29.00	4.00	31.48
Average	56.30	70.05	66.05	53.30	36.85	56.51

hatched/ day till the death of female were recorded and considered as fecundity in term of viable eggs. The parameters like female longevity, pre-oviposition, oviposition and post-oviposition periods, total life fecundity and daily fecundity were recorded.

RESULTS AND DISCUSSION

It is evident from the results that maximum female longevity of 55.4 days was noticed on feeding 50% aqueous honey solution for first 10 days followed by mealy bug host feeding and minimum longevity of 31.5 days was recorded on feeding beetles directly with host from the day of emergence. It shows that *C. montrouzieri* needs supplementary foods along with host- derived foods for their better survival. These results are in conformity with Haque *et al*, (2002) who reported that *Leptomastrix nr*. Epona (Walker) needs honey or honey dew along with host-derived foods for their survival. It is interesting to note that honey feeding improves the longevity of female beetles but it failed to induce egg laying in them and no egg laying was observed even after 30 days feeding of 50% aqueous honey and host feeding is must to induce egg laying. Food is a component of the environment and may influence an animal's chance to survive and multiply by modifying its fecundity, longevity or speed of development (Andrewartha and Birch, 1954)

The present study reveals that maximum of 367.0 and 368.0 eggs were laid by 5 and 10 day old beetles whereas minimum of 147.4 eggs were laid by 30 day old beetles. Similar observations were also made by Mishra and Omkar (2006) who investigated the influence of maternal and paternal ages on reproductive performance of an aphidophagous ladybird, *Propylea dissecta* (Mulsant). Maternal age strongly influenced fecundity and pre-oviposition period while paternal age strongly influenced the egg viability. Maternal age also influenced egg viability, however, at low levels of significance. The results revealed that the fecundity and percent eggs viability increased up to the respective and maternal and paternal ages of 30 days and thereafter declined, indicating the onset of senescence. Maximum egg laying rate (15.84 eggs/ day/ female) was recorded in 5 day old beetles followed by 10, 0, 20 and 30 day old beetles. A female beetle lives approximately 2 months and lay 10 eggs a day in a mealy bug colony (Table 1).

With regard to weekly reproductive potential of beetle, it was recorded that irrespective of the age of the beetles, maximum eggs were laid during 2nd week followed by 1st, 3rd and 4th week after adult emergence (Table 2). Age dependent egg laying pattern and weekly reproductive output of the

predator are important findings that can help in better mass multiplication of the ladybird beetle.

Presently, *C.montrouzieri* beetles are being used only once for oviposition for their mass production. The data on weekly reproductive output of different age beetles indicated that beetles of all ages can be used for a minimum of two times for oviposition whereas 5 day old beetles can be used four times also. It will help to optimizing the use of the beetles and thereby reducing the production cost.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 295-298

IMPACT OF TEMPERATURE AND RELATIVE HUMIDITY ON THE PROGENY PRODUCTION AND SEX RATIO IN *NESOLYNX THYMUS* (GIRAULT) DEVELOPED ON *MUSCA DOMESTICA*

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ABSTRACT

The tachinid fly, *Exorista bombycis* (Louis), popularly known as uzi fly in India, is a major pest of the silkworm *Bombyx mori* L. and reported to cause 10-15% cocoon yield loss in the southern silk producing states of India. An IPM package has been formulated, comprising *N. thymus*, and eulophid parasitoid of *E. bombycis* as a biocontrol component, to combat the pest. Though extensive work has been carried on this parasitoid still there is no information is available on the combined effect of temperature, which play a key role in the development of the parasitoid. However, an attempt has been made in the present study to understand impact of these factors on development of *N. thymus using M. domestica* as host. After adult eclosion, data on percent parasitization, developmental duration and progeny production and sex ratio were recorded. The developmental duration has been influenced by temperature rather than relative humidity as the developmental duration decreased significantly with increase in temperature irrespective of the humidity. High temperature in combination with low and high relative humidity resulted in higher progeny yield and sex ratio.

Key words: *Exorista bombycis*, *Nesolynx thymus*, Temperature, Relative humidity, Progeny production

INTRODUCTION

The production of silk is often hampered by attack of pests and diseases of mulberry and silkworm. Among the silkworm pests, the tachnid fly, *Exorista bombycis* (Louis), popularly known as uzi fly in India, is reported to cause 10-15% cocoon yield loss (Sathya Prasad *et al*., 2006). An Integrated Pest Management (IPM) package comprising physical (use of an adult attractant uzitrap), chemical (spray of an ovicide uzicide), and biological (release of an eulophid ecto-pupal parasitoid *Nesolynx thymus*) has been found effective in keeping the uzi menace below the economic injury level (Anonymous, 1996).

The use of biocontrol agents (Parasitoids, predators and pathogens) for pest management has been realized to be effective, economical, eco-friendly and long lasting in several crop systems. Employing biocontrol agents in the field of sericulture assumes great significance, as the use of chemical insecticides is highly restricted owing to high sensitivity of silkworm to chemicals. As far as biocontrol of *E. bombycis* using parasitoids is concerned, there is an ample scope for exploiting a number of these bioagents in view of the availability of a vast parasitoid complex. However, before doing so there is a dire need to conduct in depth investigation on the basic aspects of the parasitoid biology keeping in view the influencing factors such as host-related factors, parasitoid associated factors and environment governed factors.

Among environment-governed factors, temperature is understood to have profound influence on fecundity in insects, although such an influence may be modified by other factors such as light intensity (Wyatt and Brown, 1977) and relative humidity (Emana, 2007). Temperature is also reported to play a role on the insect behaviour (Wyatt and Brown, 1977; Dent, 1995; Enkeguard, 1993; Yang I 1994; Campbell *et al*., 1974).

Though studies on life cycle, parasitism potential and mass production of *N. thymus* have been well documented (Kumar *et al*., 1992, 1993), efforts are yet to be made on the

investigation related to role of temperature and relative humidity on the life cycle, adult longevity, parasitisation potential, progeny production and sex ratio of the parasitoid.

Hence, an attempt has been made in the present investigation to understand the impact of temperature and relative humidity on the developmental duration, progeny production and sex ratio of *N. thymus.*

METERIALS AND METHODS

The Nucleus cultures of *N. thymus* were procured from the insectary of Pest Management Laboratory (PML), of the Central Sericultural Research and Training Institute (CSR&TI), Mysore. The parasitoid cultures were further maintained on the puparia of *E. bombycis* following the methods suggested by Kumar *et al*. (1996). To understand the impact of temperature and relative humidity, different constant temperatures ranging from 15 to 30ºC with difference of 5ºC and relative humidity varying between 40 and 80 with a difference of 20% were selected. A 2 day old gravid female of *N. thymus along with a male was* allowed to parasitize 2 day-old puparia of *Musca domestica* for oviposition at a parasitoidhost ratio of 1:20 for three days. During the period of oviposition, an aqueous honey solution at (50%) smeared on a strip of paraffin paper was provided as parasitoid adult food. Thereafter, the parasitized pupae were kept individually in a glass test tubes at selected temperatures and relative humidity till the emergence of the parasitoid. Observations were recorded on per cent parasitization, developmental duration, progeny production and sex ratio. The experiment was repeated thrice each with 5 replications.

The results were subjected to one way analysis of variance (ANOVA) followed by Duncan Multiple Range Test (DMRT) for testing the level of significance using Statistical Package for Social Science (Brace, Kemp, and Snelgar, 2003)

RESULTS

From, the result presented at Table 1, it is evident that, the per cent parasitization was significantly lower at all temperatures over the control when subjected to constant humidity of 40%. While the developmental duration was significantly longer ($P \leq 0.01$) at 15°C followed by 20, 25 and 30°C with increase in temperature. The progeny production also increased which is significantly higher ($P \leq 0.01$) at 30°C compared to other treatments. While no significant variation was recorded in sex ratio (M: F).

From the results presented at Table 2, it is observed that, at a constant humidity of 60% the parasitization rate increased with increase in temperature, while the developmental duration was significantly longer ($P \leq 0.01$) at 15 and 20°C with the developmental duration being *at par* with control, 25 and 30°C. The progeny production increased with increase in temperatures and no significant variation in sex ratio was observed.

At constant humidity of 80%, the parasitization rate was significantly higher ($P \leq 0.01$) at 25°C and the developmental duration decreased with increase in temperature. But the developmental duration was significantly longer ($P \leq 0.01$) at 15°C compare to other temperatures. Further, significantly higher ($P \leq 0.01$) progeny production was observed at 30°C when compared at other temperatures and sex ratio was significantly higher ($P \leq 0.01$) at 25°C compared to other treatments.

DISCUSSION

The rate of reproduction in insects is dependent on temperature, usually up to a critical maximum (Dent, 1995). The number of offspring produced are reported to increase with temperature (Enkeguard, 1993; Yang, *et al.,* 1994) while the temperature beyond the critical maximum reduce the fecundity. Many insects enter into a state of arrested development and reproduction to survive during periods of unfavorable conditions such as extremely low and high temperatures.

In the present investigation, irrespective of relative humidity, rate of parasitism increased with increasing temperature upto 25ºC and then declined significantly implying that temperature has profound influence on the rate of parasitism by *N. thymus*. The optimal temperature is found to be 25ºC for maximum parasitization at a relative humidity of 60-80%. However, at times when the relative humidity is less than 50% the best temperature for maximum parasitisation is 20ºC. Similar observations were reported by Duale (2005) who has reported increased parasitization activity of *Pediobius furvus* (Gahan). The developmental duration has been influenced by temperature rather than relative humidity as the developmental duration decreased significantly with increase in temperature irrespective of the humidity. As regard to developmental duration, the parasitoid reacted sharply to changes in rearing temperatures between 15 and 30±2ºC, but its response to any amount of variation in relative humidity was not pronounced. Similar observations were reported by Yadav and Chowdhary (1987) in the egg parasitoid, *Tetrastichus pyrillae.*

The brood allocation was found to be influenced by the combined effect of relative humidity and temperature. In the present study, high temperature in combination with low, optimum and high relative humidity resulted in higher progeny yield. The results of the present study with respect to higher brood allocation at higher temperature with lower relative humidity fall in line with the reports of Emana (2007). The low progeny production at low temperature combined with low relative humidity may be attributed to low physiological activity leading to decline in egg

Table 1: Influence of varying temperatures at constant humidity of 40% on brood allocation by *Nesolynx thymus.*

Temperature (ºC)	Parasitization (%)	Developmental duration (days)	Progeny production (No.)			Sex ratio (♂ : ♀)
			Male	Female	Total	
15	16.00±1.87 [c]	34.20±0.37 [a]	0.80±0.19	6.00±0.74 [b]	6.80±0.79 [b]	1:9.83±3.57
20	23.00±2.55 [c]	32.00±0.32 [b]	0.82±0.22	6.28±1.33 [b]	7.11±1.55 [b]	1:8.07±0.61
25	60.00±4.74 [b]	15.60±0.24 [c]	0.86±0.11	10.04±0.52 [a]	10.90±0.46 [a]	1:12.65±2.11
30	52.00±4.64 [b]	14.40±0.24 [d]	0.93±0.10	11.66±0.84 [a]	12.59±0.92 [a]	1:12.85±0.89
Control	74.00±3.67 [a]	15.60±0.24 [c]	0.72±0.07	10.74±0.29 [a]	11.46±0.33 [a]	1:15.67±1.91
F-value	45.105 **	1154.381 **	0.256 NS	10.155 **	8.349 **	1.962 NS

Values are mean of 5 replications (Mean ± SE);
Mean values followed by the same superscript in columns are statistically not significant;
@ - Out of 5 pupae provided for parasitization; ** - Significant at 1 %; NS Nonsignificant
Control: 25±2°C and 65±5% RH

Table 2: Influence of varying temperatures at constant humidity of 60% on brood allocation by *Nesolynx thymus*.

Temperature (ºC)	Parasitization (%)	Developmental duration (days)	Progeny production (No.)			Sex ratio (♂ : ♀)
			Male	Female	Total	
15	13.00±2.00 [d]	34.20±0.37 [a]	0.80±0.12	6.10±0.46 [d]	6.90±0.56 [d]	1:8.20±1.07
20	25.00±3.54 [c]	32.40±0.24 [b]	1.05±0.22	7.17±0.43 [c]	8.22±0.40 [c]	1:8.09±1.70
25	76.00±1.87 [a]	15.60±0.24 [c]	0.87±0.09	9.87±0.34 [b]	10.74±0.41 [b]	1:11.73±1.04
30	42.00±6.24 [b]	14.60±0.24 [d]	1.30±0.24	11.42±0.19 [a]	12.73±0.24 [a]	1:10.16±1.96
Control	74.00±3.67 [a]	15.60±0.24 [c]	0.72±0.07	10.74±0.29 [ab]	11.46±0.33 [b]	1:15.67±1.91
F-value	55.690 **	1291.211 **	2.017 NS	42.381 **	35.571 **	3.871 NS

Values are mean of 5 replications (Mean ± SE);
Mean values followed by the same superscript in columns are statistically not significant;
@ - Out of 5 pupae provided for parasitization; ** - Significant at 1 %; NS Nonsignificant
Control: 25±2°C and 65±5% RH

Table 3: Influence of varying temperatures at constant humidity of 80% on brood allocation by *Nesolynx thymus*.

Temperature (º C)	Parasitization (%)	Developmental duration (days)	Progeny production (No.)			Sex ratio (♂ : ♀)
			Male	Female	Total	
15	18.00±2.00 [c]	34.80±0.20 [a]	0.94±0.16	7.19±0.44 [c]	8.13±0.59 [c]	1:8.32±0.93 [b]
20	20.00±1.58 [c]	33.20±0.58 [b]	1.11±0.15	8.64±0.69 [b]	9.75±0.70 [b]	1:8.53±1.69 [b]
25	71.00±4.30 [a]	15.60±0.24 [c]	0.78±0.10	10.38±0.19 [a]	11.16±0.28 [ab]	1:14.15±1.81 [a]
30	50.00±4.18 [b]	14.40±0.24 [d]	1.23±0.18	10.70±0.55 [a]	11.93±0.68 [a]	1:9.33±1.21 [b]
Control	74.00±3.67 [a]	15.60±0.24 [c]	0.72±0.07	10.74±0.29 [a]	11.46±0.33 [a]	1:15.67±1.91 [a]
F value	64.357 **	951.714 **	2.328 NS	11.241**	8.042 **	4.902 **

Values are mean of 5 replications (Mean ± SE);
Mean values followed by the same superscript in columns are statistically not significant;
@ - Out of 5 pupae provided for parasitization;
** - Significant at 1 %;
Control: 25±2°C and 65±5% RH

production. Such a situation of low fecundity at low temperature and low relative humidity in the egg parasitoid *T. pyrillae* has also been observed by Yadav and Chaudhary, (1987). The progeny sex ratio (M:F) is significantly lower at lower temperatures (15 and 20ºC) in combination with low, optimum and high relative humidity. The results are in consonance with the observations of Aruna (2007) who has observed a lower sex ratio at low temperature.

CONCLUSION

From the present study it is evident that the temperature in combination with relative humidity affects the progeny production while temperature alone has an impact on sex ratio. Hence, in an insectary depending on the requirement higher production in a shorter duration can be achieved by manipulating the temperature and relative humidity (30ºC and 70 80 %) and if the emergence need to be delayed the parasitized hosts could be subjected to low temperature and low relative humidity thus prolonging the developmental duration.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 299-303

SECONDARY NUTRIENT COMBINATIONS: BOOSTER FOR TASAR CROPS

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ABSTRACT

An experiment was carried out to study the role of different combinations of secondary nutrients in boosting tasar crops. Under this experiment, effect of ten different combinations of secondary nutrients was studied on the quality and quantity of leaves of tasar food plant *Terminalia arjuna* Bedd and also the rearing performances of tasar silkworm *Antheraea mylitta* Drury on the treated plants. Results indicated that secondary nutrient combinations have promotary effect in crop improvement. It improves the quality and quantity of leaves as well as the commercial characters of cocoons. Among ten combinations of secondary nutrients, combination SM_5 [Foliar application of Magnesium sulphate (2%, w/v) and basal application of Calcium carbonate (3 quintal / ha)] was found to be the best among all. Under this combination, leaf yield increased by 27.45% over control. Further, chemo assay indicated a significant improvement in the quality of leaves with this combination. Moisture, total mineral, crude protein and total carbohydrate increased by 3.53%, 19.44%, 18.50% and 16.66%, respectively over control. The increase in leaf quality was further confirmed by bio assay which revealed that under this combination cocoon weight, shell weight and silk ratio percent increased by 20.17%, 35.71% and 13.01% as compared with control.

Keywords: *Antheraea mylitta,* Bio assay, Chemo assay, Secondary nutrient combinations, Tasar*, Terminalia arjuna*

INTRODUCTION

Secondary nutrients are as important to plants as major nutrients (Pasricha and Sarkar, 2002). Deterioration in soil fertility is often observed in crops/cropping system, even with adequate use of NPK fertilizers. It has been found to be associated with the deficiency of micro and secondary nutrients. Several studies have been carried out for improvement in tasar crops through application of major and micronutrients (Sinha *et al.,* 1999, 2002 & 2006). But no study has so far been undertaken for the improvement of tasar crops through application of secondary nutrients which are the key nutrients responsible for increasing productivity in acidic soils (Sarkar and Singh, 2003). Soils of tasar producing areas are generally acidic. Hence, the present study aims to improve tasar crops through application of secondary nutrients combinations.

MATERIALS AND METHODS

The experiment was conducted in the experimental field of Central Tasar Research & Training Institute, Nagri, Ranchi on *T. arjuna* plants with 1.2 m × 1.2 m spacing under rain fed condition during first (July- Aug.) and second (Sept.-Oct.) rearing seasons. Before the layout of the experiment, the fertility gradient of the field was studied following the method described by Hesse (2002). The plot was quite uniform having sandy loam laterite soil with pH 5.4, organic carbon 0.37%, available phosphorus 14.6 kg/ha and available potassium 62.0 kg/ha. Secondary nutrient status of the soil is given below:

Name of secondary nutrients	Status in soil
Available Calcium	2.90 Cmol (P^+) kg^{-1}
Available Magnesium	0.95 Cmol (P^+) kg^{-1}
Available Sulphur	8.70 ppm

The experiment was laid out in Randomized Block Design with ten treatments in three replications, each replication having 24 plants. The usual package of practices of major nutrients *i.e*., Nitrogen (200 kg/ha/yr), Phosphorus

(50 kg/ha/yr), Potassium (50 kg/ha/yr) and Farm Yard Manure (6 MT/ ha) was also followed.

Ten treatments including control are as follows:

SM_1 – Foliar application of $MgSO_4$ (1.5 %, w/v) & basal application of $CaCO_3$ (2 q ha^{-1})

SM_2 – Foliar application of $MgSO_4$ (1.5 %, w/v) & basal application of $CaCO_3$ (3 q ha^{-1})

SM_3 – Foliar application of $MgSO_4$ (1.5 %, w/v) & basal application of $CaCO_3$ (4 q ha^{-1})

SM_4 – Foliar application of $MgSO_4$ (2 %, w/v) & basal application of $CaCO_3$ (2 q ha^{-1})

SM_5 – Foliar application of $MgSO_4$ (2 %, w/v) & basal application of $CaCO_3$ (3 q ha^{-1})

SM_6 – Foliar application of $MgSO_4$ (2 %, w/v) & basal application of $CaCO_3$ (4 q ha^{-1})

SM_7 – Foliar application of $MgSO_4$ (2.5 %, w/v) & basal application of $CaCO_3$ (2q ha^{-1})

SM_8 – Foliar application of $MgSO_4$ (2.5 %, w/v) & basal application of $CaCO_3$ (3 q ha^{-1})

SM_9 – Foliar application of $MgSO_4$ (2.5 %, w/v) & basal application of $CaCO_3$ (4 q ha^{-1})

SM_{10} – Control (without secondary nutrients)

Basal application of Calcium carbonate was done in single dose in the month of June. Magnesium sulphate was applied foliarly on *T. arjuna* plants in three split doses starting from May with an interval of 15 days. The effect of these treatments was studied during first (July-Aug.) and second (Sept. –Oct.) crops through leaf yield determination, bio assay and chemo assay. For bio assay studies, disease free layings of *Antheraea mylitta* were brushed and reared in three replicated batches of 100 worms each following the rearing technique suggested by Jolly *et al*., (1974). For Chemo assay, Simple Random Sampling method was followed for collecting the leaf samples excluding too tender and over mature leaves from each treatment in three replications. All the biochemical constituents of leaves except moisture were determined on oven dry basis. Moisture, total mineral, total carbohydrate and crude fibre were estimated by the method of AOAC (1955). Kjeldahl's method as described by Vogel (1978) was followed for the determination of total nitrogen. Crude protein was calculated by multiplying the estimated value of nitrogen content by 6.25.

RESULTS AND DISCUSSION

The leaf yield and percent increase in leaf yield of two crops have been presented in Table 1. It is evident from the table that there has been significant increase in leaf yield over control in case of all the secondary nutrients combinations, the highest being 27.45% over control for treatment SM_5 (foliar application of Magnesium sulphate, 2%, w/v & basal application of Calcium carbonate 3 q ha^{-1}) followed by SM_6. In treatment SM_6 (foliar application of Magnesium sulphate, 2%, w/v & basal application of Calcium carbonate 4 q ha^{-1}) leaf yield increased by 17.64% over control. The increase in leaf yield due to application of Magnesium sulphate and Calcium carbonate may be due to the fact that Magnesium sulphate is involved in the formation of Chlorophyll and activation of enzymes (Gunther, 1981 and Tandon, 2002). Similar trends of increased yield of potato (21.00 to 41.60%) and tea (20.20%) have been reported by Sarkar and Singh (2003) by the application of Magnesium sulphate and Sulphur respectively. Calcium carbonate provides Calcium to the soil in available form to plants. Calcium is extremely important mineral in plant nutrition. It increases the uptake of nutrient. It is required for the growth of the meristematic tissues and for the functioning of the root tip. It also maintains the shape of the cells. Our findings also corroborates with the findings of Sarkar and Singh (2003) who also reported that basal application of 2- 4 q ha^{-1} of Calcium carbonate increased the yield of Soya bean to the tune of 26.70%.

Effect of different treatments on the commercial characters of *Antheraea mylitta* Drury has been presented in Table 2. It is evident from the table that feeding silkworm with leaves of secondary nutrients treated plants has a favourable effect on the full grown larval weight, effective rate of rearing (E.R.R.), cocoon weight, shell weight and silk ratio (S.R.) percent. This result corroborates with the findings of Shankar *et al.,* (1994). They reported that secondary nutrients play an important role in silkworm larval growth, cocoon weight and silk quality. Among the ten treatments under study, combination SM_5 is the most effective in increasing the larval weight, effective rate of rearing, cocoon weight, shell weight and silk ratio percentage followed by combination SM_6. Under treatment SM_5 *i.e.,* foliar application of Magnesium sulphate, (2%, w/v) and basal application of Calcium carbonate (3 q ha^{-1}), larval weight, effective rate of rearing, cocoon weight, shell weight and silk ratio percent increased by 10.29%, 27.59%, 20.17%, 35.71% & 13.01% respectively as compared with control. Bose *et.al*., (1995) reported that mineral contents stimulate the metabolic activities in silkworm resulting in quantitative improvement of cocoon and silk. Gunther

Table 1: Effect of different combinations of secondary nutrients on the leaf yield of *T. arjuna*

Treatment	Leaf yield of *T. arjuna* (kg/ha)			% Increase over control
	Crop I	Crop II	Average	
SM_1	27248.40	31285.20	29266.80	6.62
SM_2	28257.60	30948.80	29603.20	7.84
SM_3	29603.20	32428.96	31016.08	12.99
SM_4	29603.20	31217.92	30410.56	10.78
SM_5	32967.20	37004.00	34985.60	27.45
SM_6	30948.80	33640.00	32294.40	17.64
SM_7	28930.40	30948.80	29939.60	9.07
SM_8	30276.00	32967.20	31621.60	15.20
SM_9	28930.40	30545.12	29737.76	8.33
SM_{10} (control)	25566.40	29334.08	27450.24	-
C.D. at 5%	1782.80	1703.71	1743.26	-

Table 2: Influence of different combinations of secondary nutrients on the commercial characters of cocoons reared on *T. arjuna*

Treatment	Wt of late 5th stage larva (g)		E.R.R. (%)		Cocoon weight (g)		Shell weight (g)		Silk Ratio (%)	
	Crop I	Crop II	Crop I	Crop II	Crop I	Crop II	Crop I	Crop II	Crop I	Crop II
SM_1	38.73	39.55	33.00	36.67	12.58	12.80	1.54	1.66	12.25	12.97
SM_2	38.91	39.71	33.00	37.00	12.68	12.92	1.56	1.68	12.30	13.01
SM_3	39.63	40.45	34.00	40.00	13.34	13.56	1.58	1.70	11.84	12.55
SM_4	39.32	40.14	34.00	38.00	13.00	13.40	1.57	1.69	12.09	12.61
SM_5	41.66	42.54	40.33	43.33	14.18	14.42	1.83	1.97	12.91	13.66
SM_6	40.29	41.11	37.00	39.67	13.75	14.05	1.64	1.76	11.93	12.53
SM_7	39.08	39.90	34.00	36.67	12.80	13.00	1.57	1.69	12.26	13.00
SM_8	39.94	40.78	36.00	39.00	13.60	13.80	1.59	1.71	11.71	12.39
SM_9	38.97	39.79	34.00	36.00	12.79	13.01	1.54	1.64	12.04	12.61
SM_{10} (control)	37.80	38.60	30.00	34.00	11.80	12.00	1.35	1.45	11.44	12.08
C.D. at 5%	1.83	1.31	3.15	2.99	0.74	0.72	0.09	0.09	0.43	0.38

Table 3: Effect of different combinations of secondary nutrients on the chemical constituents of *T. arjuna*

Treatment	Moisture (%)		Total mineral (%)		Crude fibre (%)		Crude Protein (%)		Total carbohydrate (%)	
	Crop I	Crop II	Crop I	Crop II	Crop I	Crop II	Crop I	Crop II	Crop I	Crop II
SM_1	71.60	70.70	7.93	7.41	9.85	11.10	12.31	12.75	15.18	15.40
SM_2	71.71	70.81	8.01	7.49	9.90	11.20	12.44	12.88	15.29	15.51
SM_3	72.18	71.27	8.35	7.80	10.00	11.25	12.88	13.25	15.74	15.98
SM_4	71.98	71.07	8.21	7.67	10.20	11.30	12.69	13.06	15.54	15.78
SM_5	73.50	72.58	9.30	8.70	10.40	11.65	14.06	14.37	17.00	17.30
SM_6	72.61	71.69	8.66	8.09	10.35	11.50	13.25	13.63	16.14	16.41
SM_7	71.83	70.92	8.09	7.56	10.15	11.40	12.50	12.94	15.39	15.63
SM_8	72.38	71.47	8.50	7.94	10.30	11.35	13.00	13.44	15.93	16.18
SM_9	71.75	70.85	8.05	7.52	9.95	11.30	12.44	12.87	15.33	15.56
SM_{10} (control)	71.00	70.10	7.50	7.00	9.80	11.00	11.75	12.25	14.60	14.80
C.D. at 5%	0.56	0.74	0.25	0.32	NS	NS	0.35	0.28	0.67	0.61

(1981) concluded that about 300 enzyme reactions are influenced by Mg ions. When Magnesium is passed on to the silkworms, it accelerates the growth of silkworms through orientation of physiological activities. Moreover, Sulphur is known to have an important role in the synthesis of amino acids, proteins and vitamins. This may be the reason for improvement in commercial characters of cocoons due to the application of Magnesium sulphate. Further, results of Viswanath and Krishnamurthy (1982) is similar to our findings who have reported that silkworm larvae fed with Mg sprayed leaves resulted in better cocoon yield and cocoon weight. Results of Loknath and Shivshankar (1986) also support our findings. They observed that when leaves fortified with Magnesium (1.25 kg/ha) were fed to mulberry silkworms, it favourably influenced the cocoon yield and shell quality. These findings are in agreement with the findings of Subburathinam and Chetty (1991). Subburathinam *et. al.,* (1993) reported that enrichment of mulberry leaves with Calcium results in improvement of the commercial characters of cocoons.

Table 3 shows the average chemical composition of *T. arjuna* leaf under different combinations of secondary nutrients. It is evident from the table that application of secondary nutrients combinations has improved the quality of leaf. Except crude fibre, contents of moisture, crude protein, total carbohydrate and total mineral were significantly higher in treated plant leaves than control. Maximum increase in chemical constituents of leaves was observed in combination SM_5. The increase in chemical constituents may be due to the beneficial role of secondary nutrients in plant metabolism. Magnesium activates enzymes and Sulphur is involved in the formation of amino acids essential for protein synthesis (Pasricha and Sarkar, 2002). Calcium is an important mineral for plant nutrition. It enhances the uptake of nitrogen in the form of nitrates and helps in protein synthesis (Das and Chaudhary, 2007). This may be the reason for increase in chemical constituents of leaves.

From the present study it is, therefore, inferred that among all the treatments of secondary nutrients under study, combination SM_5 is the best for boosting the production of tasar crops. This treatment brings improvement in quality and quantity of leaves of *T. arjuna* as well as the commercial characters of cocoons of *A. mylitta*. Thus, it functions as a booster of tasar crops.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 304-309

BIODIVERSITY OF ERI SILKWORM AND ITS HOST PLANTS IN INDIA

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ABSTRACT

Eri silkworm has a few wild counterparts apart from the domesticated eco-races. Under the genus *Samia*, 19 species are so far identified from tropical and temperate region of South East Asia. The Seri biodiversity of North East India possess two species of eri silkworms, namely, the domesticated *Samia ricini* Donovan and its wild progenitor *Samia canningi* Hutton. *Samia fulva* JORDAN, is another wild species reported from the evergreen low land forests of Andaman islands. We have found six homozygous strains on the basis of larval colour and body markings, namely, Yellow plain (YP), Yellow spotted (YS), Yellow Zebra (YZ), Greenish blue plain (GBP), Greenish blue spotted (GBS), Greenish blue zebra (GBZ). These strains produced different attractive coloured cocoons *i.e.* snow white, cream white, off white, deep brick red and light brick red when maintained in GPB of Central Muga Eri Research and Training Institute, Central Silk Board, Lahdoigarah, Jorhat, Assam. *Samia canningi* Hutton collected from the foot hills and plain forests of the NE India and maintained in GPB, and two strains, *i.e.* Greenish Blue Plain (GBP) and Greenish Blue Spotted (GBS) were observed with in the species. Both the strains produced grey to dark brown coloured compact cocoons with prominent peduncle. Hybridization between *S ricini* and *S canningi* were conducted in captive condition. The hybrid worms were more vigorous and found to be covered with more powdery substance and mostly prefer the leaves of Kessaru *Heteropanax fragrans* Seem. *Samia ricini* is polyphagous, feed on a wide range of food plants, where Castor *Ricinus communis* Linn. ranks as the primary food plant suitable for all time rearing. The wild eri silkworm *Samia canningi* were mostly collected from Kesseru *Heteropanax fragrans* Seem and Kadam *Anthocephalus cadamba.* The food plants of wild eri silkworm, *Samia fulva* is mainly *Heteropanax fragrans* Seem and *Picrasma javanica*.

Key words: Biodiversity, Eri silkworm, Host plant, *Samia ricini*, *S. canningi, S. Fulva*

INTRODUCTION

Biodiversity refers to the variability of organisms in all its manifestations. India owing to its varied topography and climate possess a diversified ecosystem consisting of a reservoir of different bio- resources and identified as one of the 12 mega diversity centres in the world. North East (Eastern Himalayas) and Western Ghat area of the country are considered as the richest mega biodiversity 'hotspots' of the world (Chaudhuri and Sarkar, 2003) based on the existence of variety of species and endemism. North Eastern India forms the natural habitat of Eri and their wide range of food plants. The sericigenous insect fauna along with their food plants forms a separate habitat known as 'Seribiodiversity' (Chakravorty, 2004) in the region.

Various authors provided valuable information on seribiodiversity in Indian sub-continent (Arora and Gupta, 1979; Chinnaswmay, 2001; Thangavelu *et al*., 2002; Singh and Chakravorty, 2005; Kakati and Chutia, 2009). Despite the availability of sporadic documentation of the different eco-races of eri silkworm and their host plants (Debraj *et al*., 2001; Chakravorty and Neog, 2008; Chaudhury, 2008; Jayaprakash *et al*., 2008; Quadri and Krishnamoorthi, 2008; Bajpai *et al*., 2008; Chutia and Kakati, 2008; Bindroo *et a*l., 2008), comprehensive details on the diversity of eri

Table 1: The distribution of different species under the genus Samia in the world

Sl. No.	Species	Distribution
1	*Samia cynthia* (DRURY, 1773)	Peoples Republic of China, Korea & Russia
2	*Samia canningi* (HUTTON, 1859)	South East Asian mainland
3	*Samia pryeri* (BUTLER, 1878)	Japan
4	*Samia watsoni* (OBERTHÜR, 1914)	China and North Vietnam
5	*Samia vandenberghi* (WATSON, 1915)	Central Indonesia
6	*Samia insularis* (SNELLEN VAN VOLLENHOVEN, 1862)	Indonesian islands of Java & Sumatra
7	*Samia luzonica* (WATSON, 1913)	Philippines
8	*Samia peigleri* (NAUMANN & NÄSSIG, 1995)	Central Indonesia
9	*Samia treadawayi* (NAUMANN, 1998 WS)	Philippines
10	*Samia naumanni* (PAUKSTADT, PEIGLER & PAUKSTADT, 1998)	North Central Indonesia
11	*Samia abrerai* (NAUMANN & PEIGLER, 2001)	Java and Bali
12	*Samia naessigi* (NAUMANN & PEIGLER, 2001)	Eastern Indonesia
13	*Samia kohlli* (NAUMANN & PEIGLER, 2001)	South East Asia
14	*Samia wangi* (NAUMANN & PEIGLER, 2001)	South East China and North Vietnam
15	*Samia tetrica* (REBEL, 1924)	Singapore, Brunei and Indonesia
16	*Samia yuyukae* (PAUKSTADT, PEIGLER & PAUKSTADT, 1993)	Sunda islands of Indonesia
17	*Samia fulva* (JORDAN, 1911)	Andaman Islands of India
18	*Samia ceramensis* (BOUVIER, 1927)	Central Moluccas of eastern Indonesia
19	*Samia ricini* (DONOVAN, 1798)	Eastern Gangetic Plain, Assam and adjacent sections, Bangladesh.

silkworm and its host plants are yet to be accrued. In the present paper deals with the diversity of eri silkworm and its host plants together with the strategies for conservation of seri-biodiversity in North East India.

Eri culture enjoys a unique position among other sericulture activities like mulberry, tasar and muga for its typical white soft yarn with thermal properties. It is a traditional and agro-based small scale industry of North East India consisting of multifarious activities like food plant cultivation, silkworm rearing, spinning of yarn and weaving. Being basically a leisure time occupation, it is limited to meet partly the family's clothing and food needs. Due to its thermal property, eri fabric is used as an alternative to wool and the pupae as food for protein source. Eri silkworm rearing and eri silk weaving activities have become an inseparable part of the socio-economic activities of the rural folk of North East, as a whole. About 1.5 lakh families are directly or indirectly associated with ericulture, wherein involvement of women (about 65%) and weaker sections of the society (52.4%) is predominant. NE India alone contributes the lion's share of 95% to the national production of eri raw silk (1410 MT out of 1485 MT in 2007-08). Ericulture as a additional income generating avocation, has presently spread to some non-traditional states in tropical region like Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, Gujarat, Jharkhand, Chattisgarah, *etc*. and thus contributing to the increased productivity.

Biodiversity of eri silkworm

Apart from domesticated eco-races, Eri silkworm has a few wild counterparts. Under genus *Samia*, 19 species are so far identified from tropical and temperate region of South East Asia (Peigler and Naumann, 2002). The nomenclature and distribution of the species under genus *Samia* are listed in Table 1.

Among these, three species, namely, *Samia ricini* (Donovan, 1798), *Samia canningi* (Hutton, 1859) and *Samia fulva (*Jordan, 1911) are reported to be found exclusively in India (Peigler and Naumann, 2002).

North East India is a natural abode for distinctively diversified wide range of flora and fauna including eri silkworm. The seribiodiversity system of North East India possess two species of eri silkworms, namely, the domesticated *Samia ricini* (Donovan) and its wild progenitor *Samia canningi* (Hutton) (Lepidoptera: Saturniidae), which are the permanent inhabitants of North East India. Their predominance is attributed to the availability of distinctive ecological requirements for their sustenance in the region. Besides them, *Samia fulva*, another wild species is reported from the evergreen low land forests of Andaman islands (Mohanraj *et al*., 1998). Wild eri silkworms are polyphagous in nature having a wide range of host food plants.

Details of the eri silkworm species available in NE

Table 2: The morphological characters of different eco races Samia ricini maintained at CMERTI

Sl. No.	Accn. No.	Larval body colour	Cocoon colour
1	SRI-001	Plain & Zebra on yellow and blue	White
2	SRI-002	Plain & Zebra on yellow and blue	White
3	SRI-003	Plain yellow and blue	White
4	SRI-004	Plain yellow and blue	White
5	SRI-005	Plain blue	White
6	SRI-006	Plain yellow and blue	White
7	SRI-007	Plain yellow	White & brick red
8	SRI-008	Plain & Zebra on Yellow and blue	White
9	SRI-009	Plain & Zebra on Yellow and blue	White & brick red
10	SRI-010	Plain & Zebra on Yellow and blue	White
11	SRI-011	Plain yellow and blue	White
12	SRI-012	Plain & spotted on yellow & blue	White
13	SRI-013	Plain & Zebra on Yellow and blue	White & brick red
14	SRI-014	Plain yellow and blue	Brick red
15	SRI-015	Plain yellow and blue	White
16	SRI-016	Plain yellow and blue	Brick red
17	SRI-017	Plain yellow and blue	White & brick red
18	SRI-018	Plain yellow and blue	White
19	SRI-019	Spotted on yellow	White
20	SRI-020	Plain yellow	White
21	SRI-021	Plain yellow	White
22	SRI-022	Plain yellow	White
23	SRI-023	Plain yellow	White
24	SRI-024	Plain yellow and blue	Brick red
25	SRI-025	Plain yellow	White
26	SRI-026	Plain yellow and blue	Brick red

India are elaborated below:

Samia ricini (Donovan)

Samia ricini (Donovan) is the commercially cultivated multivoltine species of eri silkworm, which is derived from the wild eri silkworm *Samia canningi* (Hutton) found in the forests of North East India (Peigler and Naumann, 2002). Cultivated eri silkworm is the only saturniid species reared completely indoor among the non-mulberry silk moths.

Six homozygous strains were classified from *S. ricini* (Donovan) on the basis of larval colour and body markings, namely, Yellow plain (YP), Yellow spotted (YS), Yellow Zebra (YZ), Greenish blue plain (GBP), Greenish blue spotted (GBS), Greenish blue zebra (GBZ) (Sarmah *et al.*, 2002). These strains produce different cocoons of attractive colours like snow white, cream white, off white, deep brick red and light brick red.

Further, hitherto 26 eco-races of *S. ricini* have been identified from different potential eri growing pockets of NE India and are morphologically characterized (Chakravorty *et al*., 2008) and maintained at Central Muga Eri Research and Training Institute (CMERTI), Central Silk Board, Lahdoigarah, Jorhat. The morphological characters of the eco races are detailed in Table 2.

Among these, the accessions bearing No.001, 002, 003, 004, 005, 006, 011, 015, 018 and 025 are considered as productive (Chakravorty *et.al.,* 2008). At present, the accession no. 001 (Baruduar), 014 (Kokrajhar) 002 (Titabar) and 010 (Diphu) are reared commercially. In order to improve the productivity through the development of productive hybrids, silkworm breeding programmes are under progress at CMERTI, Lahdoigarah, Jorhat.

Samia canningi (Hutton)

Samia canningi (Hutton) is the wild species of eri silkworm mostly collected from the foot hills and plain forests of the NE India, and found in Himachal Pradesh and peninsular India (Chowdhury, 2005; Singh and Suryanarayana, 2003). It is bi- or trivoltine in nature. It exhibits irregular termination of diapause and stray moth

Table 3: The host plant range of *Samia ricini* (Donovan) and their distribution in India

Sl. No	Host plant species	Vernacular name	Family	Distribution
01	*Ricinus communis* Linn	Castor	Euphorbiaceae	Throughout India
02	*Heteropanax fragrans* Seem	Kesseru	Araliaceae	North East India, South Andaman
03	*Manihot utilissima* Phol	Tapioca	Euphorbiaceae	Northeastern and southern India
04	*Evodia fraxinifolia* Hook	Payam	Rutaceae	Nagaland & some parts of NE India
05	*Ailanthus grandis* Rox	Barpat	Simaroubiaceae	Northern and Eastern India
06	*Ailanthus excelsa* Rox	Barkesseru	Simaroubiaceae	Northern and Eastern India
07	*Ailanthus integrifolia*	Barkesseru	Simaroubiaceae	West Bengal
08	*Ailanthus malabarica*	China-sumac	Simaroubiaceae	Western and Southern India
09	*Ailanthus altissima* Mille	Paradise tree	Simaroubiaceae	Kashmir, Himachal Pradesh
10	*Plumeria acutifolia*	Gulanch	Apocynaceae	Throughout NE India
11	*Carica papaya*	Amita	Euphorbiaceae	Throughout India
12	*Gmelina arborea* Rox	Gamari	Verbenaceae	Throughout NE India

Table 4: The host plant range of *Samia canningi* (Hutton) and their distribution in India

Sl. No.	Host plant species	Vernacular name	Family	Distribution
01	*Heteropanax fragrans* Seem	Kesseru	Araliaceae	North eastern India
02	*Zizy phus jujuba*	Bogori	Rhamnaceae	NE India, some part of North India
03	*Anthocephalus cadamba*	Kadam		North eastern India
04	*Zanthoxylum alatum* Rox	Bajramoni	Rutaceae	Throughout India
05	*Ailanthus altissima* Mille	Paradise tree	Simaroubiaceae	Kashmir, Himachal Pradesh
06	*Coriaria nepalensis*Wallich		Coriariaceae	Northern India
07	*Berberis asiatica* Rox	Ber	Berberiaceae	Throughout India
08	*Ailanthus integrifolia*	Barkesseu	Simaroubiaceae	West Bengal
09	*Evodia fraxinifolia* Hook	Payam	Rutaceae	Nagaland & some parts of NE India
10	*Ailanthus excelsa* Rox	Barkesseu	Simaroubiaceae	Northern & Eastern India

emergence. *Samia canningi* is generally bivoltine and pupal dormancy is recorded up to 6 -7 months. It is highly polyphagous and has a wide range of food plants. Two strains, *i.e.* Greenish Blue Plain (GBP) and Greenish Blue Spotted (GBS) are generally found with the species. Both the strains produced grey to dark brown colour compact cocoons with prominent peduncle. The cocoons are smaller but with stronger moths, compared to those of cultivated species. The moths of wild species can fly to high elevation and it is difficult to maintain them under indoor condition. Therefore, it is more suitable to rear *S. canningi* in outdoor condition owing to its wild nature.

Hybridization between *S ricini* and *S canningi* were conducted in captive condition (Sarkar *et al*, 2009). The hybrid worms are more vigorous and found to be covered with more powdery substance and mostly prefer the leaves of Kessaru (*Heteropanax fragrans* Seem).

Samia fulva (Jordan)

Samia fulva is reported to be found in the evergreen low deciduous forests of Andaman islands. The species is difficult to rear in captivity.

Biodiversity of eri silkworm food plants

Food plants of *Samia ricini* (Donovan)

Being polyphagous, worms of *S. ricini* feed on a wide range of food plants, where castor (*Ricinus communis* Linn) ranks as the primary food plant suitable for all rearing seasons. Kesseru (*Heteropanax fragrans* Seem), which is an evergreen plant, ranks as the second primary food plant. Cassava (*Manihot utilissima* Phol) is also considered as the second major food plant for eri silkworm. The range of other host plants for *Samia ricini* are listed in Table 3.

Food plants of *Samia canningi* (Hutton)

The food plants for this species are l are listed in Table 4.

Food plants of *Samia fulva* (Jordan)

The wild eri silkworm, *Samia fulva* (Jordan) thrives on different food plants, namely, *Zanthoxylum rhesta* (Rutaceae), *Heteropanax fragrans* (Araliaceae) and *Picrasma javanica* (Simaroubiaceae).

Need for conservation of Seribiodiversity

Considering the potentiality of eri culture as an additional income generating avocation, it is fast spreading in non-traditional states apart from its natural home of North East India. This necessitates the development of productive silkworm breeds/hybrids. Towards this, exploration, collection, identification, characterization and ultimate documentation of the eco-races become must as it forms the backbone of any breeding programme. While doing so, importance should be given to conservation of biodiversity and maintenance of the natural environment. It is predicted that next few decades will be the period of maximum danger as 40% of world's present species are likely to be extinct within next 50 years. To minimize this eventual loss, the long term *ex-situ* and *in-situ* conservation of the natural resources call attention of the conservationists and biologists.

Strategy for conservation of Seribiodiversity

With regard to the depletion of seribiodiversity of India, many reasons can be attributed which include:

- Loss of natural habitat due to deforestation.
- Urbanization and exploitation of natural eco-system.
- Introduction of pervasive agro-technology.
- Over exploitation of commercial flora and fauna.
- Lack of awareness and non-involvement of masses in conservation of seribiodiversity.

To overcome the above bottlenecks, the conservation of existing seribiodiversity including eri silkworm and its host plants, needs an exclusive national strategy and suitable action plan. The strategies could comprise the following:

- Survey and indexing of existing biodiversity of sericigenous insects and their food plants.
- Identifying/ mapping of the important eco-systems/ habitats, bio-reserves, etc. for in situ conservation and developing ex situ back up.
- Developing national database on various components of the seri-biodiversity along with associated traditional knowledge and innovations.
- Developing an integrated approach for conservation and sustainable utilization.
- Creating awareness and educating stakeholders about the importance, sustainable use and also sharing pattern of the benefit.
- Development of a legal framework as a strong back up for enforcement.
- Funding mechanism and monitoring of implementation.
- Establishment of Germplasm Bank and wild silk reserve forest or sanctuary for sericigenous insects.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 310-311

VARIETAL PREFERENCE OF CASTOR IN ERI SILKWORM *PHILOSAMIA RICINI* HUTT.

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ABSTRACT

Leaves of castor are used as food for rearing of eri silkworm, *Philosamia ricini.* For determining varietal preference of castor in eri silkworm, six varieties of castor *viz.,* GAUCH-1, GCH-2, GCH-4, GCH-5, GCH-6 and JI-96 were evaluated. The larvae of white plain eri silkworm breed (Boaurdar), were reared in the laboratory on leaves of the six castor varieties grown at College farm, N.M. college of Agriculture, Navsari under irrigated conditions during 2004, 2005, 2006 2007 and 2008. Different parameters *viz.,* effective rate of rearing by percentage, single cocoon weight, single shell weight, shall ratio percentage, larval weight, larval survival percentage *etc*., were recorded. The results revealed that there was no significant difference among varieties on all the parameters except larval duration, single cocoon weight and fecundity. Higher single cocoon weight (2.438 g) was recorded in GCH-4 and GCH-5. Higher fecundity of 359 eggs was recorded in GCH-5. From the overall performance it was observed that the castor varieties GCH-4 and GCH-5 were more suitable for the rearing of eri-silkworm.

Key words: Castor, Fecundity, Single shell weight, Varietal performance

INTRODUCTION

India is the largest producer of Eri silk in the world contributing to 96 per cent of Eri silk produced in India of the total eri silk produced. The eri silkworm feeds on leaves of Castor, Kesseu, Tapioca, Barkesseru, Payam, Barpat, Jatropha, Papaya, *Ailanthus altissima*, Gulanch, Gamari *etc*. Castor *(Ricinus communis),* the primary food plant of eri silkworm (*Samia Cynthia ricini*) is cultivated abundantly in the state of Gujarat with 3.5 lakh hectares. According to Dayashankar (1982) and Devaiah *et al*., (1985), out of four different host plants (Castor, Tapioca, White plumeria and Red plumeria), castor was the most preferred followed by Tapioca. Castor plant grows as shrubs or small trees in tropical and temperate regions and finds a place of importance in the cropping systems of dry land farming in semiarid zones. To know the preference of eri silkworm to different varieties of castor in south Gujarat, the present study was carried out.

MATERIALS AND METHODS

For determining varietal preference of castor to eri silkworm, six varieties of castor *viz.,* GAUCH-1, GCH-2, GCH-4, GCH-5, GCH-6 and JI-96 were evaluated. The larvae of white plain eri silkworm breed (Boaurdar) were reared in the laboratory on leaves of these six castor varieties grown at College farm, N. M. college of Agriculture, Navsari under irrigated conditions during 2004, 2005, 2006 2007 and 2008. Different parameters *viz.,* effective rate of rearing by percentage, single cocoon weight, single shell weight, shall percentage, larval weight, larval survival percentage *etc*., were recorded.

RESULTS AND DISCUSSION

The pooled data of five years are presented in Table 1. Among different parameters of eri silkworm, reared on different varieties of castor, single shell weight, fecundity and larval duration were found significantly different. The highest single shell weight (0.277g) was recorded in GCH-5 and it was statistically at par with GCH-4 (0.275 g) and GAUCH-1 (0.270 g). The interaction between variety and Year (V×Y) was non-significant, indicating consistent performance of varieties over the years. The highest fecundity (357) was recorded in GCH-5 and it was statistically at par with GCH-4 (351). The interaction between variety and Year (V×Y) was non-significant,

Table 1 Performance data of ERI silk worm against different varieties of castor (Pooled 2004 to 2008)

Castor Variety	ERR %	Larval survival %	Single larval wt.(g)	Single cocoon wt.(g)	Single shell wt. (g)	Shell ratio (%)	Fecundity	Larval Duration (days)
GAUCH-1	82.17	87.38	6.131	2.153	0.270	12.56	346	25.53
GCH-2	81.59	87.31	6.072	2.160	0.261	12.23	344	25.50
GCH-4	82.27	87.76	6.198	2.166	0.275	12.58	351	25.52
GCH-5	82.21	87.33	6.200	2.198	0.277	12.65	357	25.63
GCH-6	81.95	87.38	6.253	2.128	0.266	12.56	347	25.47
JI-96	82.76	86.73	6.070	2.124	0.265	12.51	345	25.52
SEM ±	0.363	0.316	0.078	0.021	0.003	0.107	3.16	0.03
CD @ 5%(V)	NS	NS	NS	NS	0.008	NS	8.87	0.09
SEM ±(VxY)	0.828	0.731	0.078	0.046	0.006	0.228	7.67	0.04
CD @ 5%	NS	NS	0.218	NS	NS	NS	NS	0.10
C.V. %	2.02	1.67	2.52	4.25	4.80	3.64	4.40	0.28

indicating consistent performance of varieties over years. Significantly, the minimum larval duration (25.47 days) was recorded in GCH-6. The interaction between variety and Year (V×Y) was significant, indicating inconsistent performance of varieties over year.

CONCLUSION

There was no significant difference among varieties in respect of all the parameters except larval duration, single cocoon weight and fecundity. Higher single cocoon weight (2.438 g) was recorded in GCH-4 and GCH-5. Higher fecundity of 359 eggs was recorded in GCH-5. From the overall performance it was observed that the castor varieties GCH-4 and GCH-5 were found more suitable for the rearing of eri silkworm. These two varieties can be well utilized for economic production of eri silk.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 312-314

GENETIC VARIABILITY AND ASSOCIATION OF YIELD TRAITS IN CASTOR *(RICINUS COMMUNNIS* L.) VARIETY RG2824 - A PROMISING FOOD PLANT FOR ERI SILK WORM

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ABSTRACT

Castor based ericulture, has started gaining popularity in West Bengal since the last decade. Since castor is not a cultivated oilseed crop in West Bengal, eri farmers are dependent on stray castor flora with inconsistent leaf yield. RG2824 is identified as a promising castor food plant for Eri (*Samia ricini* Donovan) silkworm rearing at CSRTI, Berhampore after 4 years of trials since 2005. Variability in yield and yield attributing traits have been observed through selfed generations. A comprehension of variance and its components with respect to leaf lamina yield/plant and 5 associated traits like height up to primary raceme, mean height, number of nodes, branches and petiole yield as well as their extent of association became imminent for selecting parents towards carrying forward the generations. All the traits have significant, fairly wide ranging variability but narrow difference between phenotypic and genotypic coefficient of variations implying that they may be fixed through selection due to presence of additive genes. Except for the trait, height up to primary raceme, all others have high heritability coupled with moderately low genetic advance suggesting intra- and inter-allelic interaction towards expression of these traits. In furtherance, correlation studies divulge that strong positive association exists between leaf lamina yield and yield attributing traits: mean height, number of nodes and petiole yield. These correlated components are indicative of a selection criterion to choose parents among RG2824 towards improvement of lamina yield.

Key words: Castor, Correlation, Leaf yield, Variance components, Yield attributing traits

INTRODUCTION

Eri silk accounts for 11% of the total raw silk produced in India. There has been a 12-fold increase in eri silk productivity during the last five decades with an impressive 8.27% annual growth rate in productivity during last five years. These are unique indicators of growth in research and development efforts in the eri silkworm as well as food plant sectors.

In West Bengal, ericulture is exclusively castor (*Ricinus communis* L.) based although castor is not a cultivated oil seed crop. In absence of any recommended variety, eri farmers depend mostly on naturally thriving castor flora (Chaudhuri. *et al*., 2009). Efforts on systematizing the castor food plant sector at CSRTI, Berhampore from 2005 2009 resulted in identification of the genotype RG 2824, originally collected from Directorate of Oilseeds Research, Indian Council of Agricultural Research, Hyderabad, as the most promising food plant for eri silkworm rearing at Berhampore conditions (Chakravarty, 2008; Chaudhuri, 2010). While carrying forward the selfed generations of this genotype, significant variations in lamina yield and yield-components were observed. This led to the necessity of selection of parents on the basis of underlying genetic relationships of yield traits for improving lamina yield. In self-pollinated crops too there is ample scope of improvement amongst the transgressive segregants (Chahota *et al*., 2007). The success of any crop improvement programme depends primarily on nature, magnitude of genetic variability and trait association and these genetic analyses have been extensively utilized in an array of crops (Robinson *et al.,* 1951; Burton, 1952; Patro and Ravishankar, 2004; Ibrahim and Hussein, 2006).

Attempts on genetic study at CSRTI, Berhampore encompassing leaf yield traits of castor thus far have been very limited and it was initiated by Chakravarty *et al.*(2009).

Table 1: Analyses of variance

Trait	Generational variation	F-Statistics	Significance
Lamina yield (g)	Between generations	21.7	**
	Within generation	10.95	**
Height up to primary raceme (cm)	Between generations	3.15	ns
	Within generation	12.97	**
Mean height (cm)	Between generations	32.75	**
	Within generation	413.19	**
Number of nodes (No)	Between generations	61.24	**
	Within generation	103.86	**
Number of branches(No)	Between generations	22.63	**
	Within generation	11.14	**
Leaf petiole yield (g)	Between generations	27.53	**
	Within generation	33.24	**

Table 2: Mean estimates of traits and components of variation

Trait	Mean	S E	Minimum	Maximum	Coefficient of variation (%)			H	GA
					Phenotypic	Genotypic	Environmental		
Lamina yield (g)	466.60	39.27	192.50	671.67	44.91	41.91	15.97	0.93	12.88
Height up to primary raceme (cm)	223.73	23.45	139.00	410.00	27.09	17.04	19.62	0.63	6.74
Mean height (cm)	393.33	32.46	170.00	537.67	9.79	9.03	2.76	0.92	5.95
Number of nodes (No)	27.76	4.10	6.33	58.00	45.73	44.02	9.67	0.96	13.41
Number of branches (No)	264.46	36.13	71.67	540.33	49.76	48.42	16.26	0.97	14.14
Leaf petiole yield (g)	5.84	0.24	4.17	7.33	22.05	20.23	7.49	0.92	8.87

Table 3: Correlation between yield and attributing traits

Trait	Lamina yield (g)	Height up to primary raceme (cm)	Mean height (cm)	Number of nodes (No)	Number of branches (No)	Leaf petiole yield (g)
Lamina yield (g)	1					
Height up to primary raceme (cm)	0.204	1				
Mean height (cm)	0.757	0.620	1			
Number of nodes (No)	0.770	0.467	0.561	1		
Number of branches (No)	-0.073	0.337	0.253	0.345	1	
Leaf petiole yield (g)	0.806	-0.056	0.783	0.823	-0.158	1

The present study was conducted to elucidate the variance with respect to the most important economic trait -leaf lamina yield/plant and 5 associated traits like height up to primary raceme, mean height, number of nodes, branches and petiole weight as well as their extent of association for selecting parents towards carrying forward the generations.

MATERIALS AND METHODS

Rg2824 was raised from selfed seeds annually in 3 replications for 3 generations during 2007, 2008 and 2009 at Central Sericultural Research and Training Institute, Berhampore, West Bengal (88 15′E: 246′N; 19 m. MSL),

during the month of March. Primary data, on per plant basis were recorded on leaf yield and associated growth parameters during 5 harvests during June, August, September, November and February. Analyses of variance, mean estimates, genotypic and phenotypic coefficient of variations, broad sense heritability, genetic advance and correlation of lamina yield (ly) with 5 most important growth parameters namely (i) height up to primary raceme in cm, (ii) mean height in cm, (iii) number of nodes, (iv) number of branches and (v) leaf petiole yield in were derived following Falconer (1981).

RESULTS AND DISCUSSION

Analyses of variance expounds that all the yield and growth traits studied have significant ($p<0.01$) variation between as well as within the generations except the trait-height up to primary raceme (hur) having inter generational variation of no significance (Table 1). Intra-generational variations with respect to all the traits studied appeared to have responded to the seasonal variations within each generation. Inter generational variations, which did not follow any definite inheritance pattern, may be ascribed to the presence of transgressive segregants as is prevalent in many other self pollinated field crops (Snape, 1982; Chahota *et al*., 2007; Yadav *et al.,* 2008).

Mean estimates of yield and yield components of all the traits are enumerated in Table 2. Wide range of variations prevailed in respect of all the traits except in case of number of branches. Narrow differences between genotypic and phenotypic co-efficient of variation with respect to leaf yield, mean height, number of nodes, number of branches and petiole yield coupled with low environmental co-efficient of variation indicate that these traits are least influenced by environment and may be fixed through selection due to presence of additive gene action. Other than height up to primary raceme all the traits have high heritability ($H> 90\%$) coupled with moderately low genetic advance is suggestive of intra- and inter-allelic interaction towards expression of these traits and they may respond to recurrent selection.

The degree of association of lamina yield with yield attributing traits is detailed in Table- 3. Strong positive correlation exists between the lamina yield and mean height, number of nodes and petiole yield as evident from high, positive correlation coefficients ($\geq +0.8$). This is suggestive of presence of linked genes in respect of these 3 traits towards expression of the yield. Weak positive and negative correlations between yield and height upto primary raceme and number of branches, respectively, indicative of epistasis of different genes upon these traits.

Therefore, while selecting parents amongst the population of RG 2824, plants with greater mean height, number of nodes and petiole yield is expected to be useful in raising offsprings with high lamina yield.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 315-317

STUDIES ON THE RELATIONSHIP BETWEEN LAMINA YIELD AND YIELD COMPONENTS OF SOME HIGH FOLIAGE YIELDING CASTOR (*RICINUS COMMUNNIS* L.) SUITABLE FOR ERICULTURE

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ABSTRACT

Castor enjoys a unique distinction of being a foliage yielding crop in addition to producing non-edible oil seeds of great importance. More than 90% of eri silk produced in India is derived from castor foliage fed eri silkworm and naturally thriving castor flora serves as the major source of foliage. Ericulture, a popular vocation in northeastern India is now encouraged as a source of supplementary income to rural and semi urban folks belonging to 16 Indian states. For sustainable ericulture in eastern India, 10 annual castor genotypes superior in quality and productivity wise studied to draw a comprehensive numerical relationship between lamina yield and yield attributing parameters. Lamina yield was regressed logistically over 7 independent variables. A basic yield yield components equation is developed from the initial prediction model. The final model elucidates that mean height, number of nodes, petiole weight and crop seasons are the most important predictors towards lamina yield. This equation can be utilized for projecting lamina yield of castor food plants for determining the size of eri silkworm crops towards effective resource utilization and income generation.

Key words: Castor, Leaf yield, Regression analysis, Yield attributing traits

INTRODUCTION

Ericulture - a traditional vocation involving Eri silkworm (*Samia ricini* D**.)** rearing was confined to the northeastern India till recently. But it has gradually started gaining foothold in non traditional states too. Presently, it is encouraged to be practiced for supplementary income to the rural and semi urban folks belonging to 16 states of India. More than 90% of the eri silk produced in India is derived from castor food plant-based ericulture and is mostly dependent on naturally thriving castor flora (Chaudhuri *et al*., 2009). To address the dearth of region-specific castor genotypes for sustainable ericulture in eastern India, 10 annual castor genotypes- superior in leaf quality and productivity were studied at Central Sericultural Research and Training Institute, Berhampore, West Bengal for 4 years since 2006-07 (Chakravarty, 2009). But relative contribution of yield components to lamina yield in castor food plant for working out a crop schedule has not been reported as of now. Stepwise multiple regression analysis provided an estimate of the net effect of yield components on economic yield and is a widely accepted contrivance for evolving a numerical relationship between any yield and yield attributing parameter resulting in formulation of a prediction model in various crops (Wiley and Heath, 1969; Chaudhuri, 2003; Kaya *et al*., 2007). A basic yield model with differentiated yield components is generally utilized for economic yield prediction (Worley *et al*., 1974; Chaudhuri *et al*., 2010) which is reported herein for the first time pertaining to foliage yield from castor plants utilized in Eri silkworm rearing.

MATERIALS AND METHODS

Ten high yielding castor accessions were raised in RBD with 3 replications successively for 4 years since March, 2006 at Central Sericultural Research and Training Institute, Berhampore, West Bengal (8815$^{/}$E: 246$^{/}$N; 19 m. MSL), durin the month of March. Primary data on per plant basis were recorded on lamina yield and associated growth parameters during 5 crop seasons namely June (1) , August (2), September (3), November (4) and February (5). Backward stepwise multiple regression analysis over lamina yield in g (ly) as dependent variable with 7 independent variables namely castor accessions (ca: 1 to10), crop seasons (crop:1 to 5), height up to primary raceme in cm (hur), mean

Table 1: Descriptive statistics of variables

Variables	No of observations (N)		
Crop (Crop 1 to 5)	450		
Castor accession (ca:1 to 10)	450		
	Mean	SD	N
Lamina yield in g (ly)	348.63	154.64	450
Ht. upto primary raceme in cm (hur)	184.82	86.83	450
Mean ht.in cm(mh)	363.74	120.59	450
No. of nodes (nn)	29.93	14.22	450
No. of branches (nb)	7.12	1.82	450
Petiole yield in g(py)	152.13	121.71	450

Table 2: Model summary of logistics of multiple regressions

Model	Multiple Correlation Coefficient (R)	Coefficient of Determination (R^2)
1	0.835(a)	0.698
2	0.835(b)	0.698
3	0.835(c)	0.698
4	0.836(d)	0.699

a Predictors: (Constant), py, nb, ca, nn, mh, hur, crop
b Predictors: (Constant), py, ca, nn, mh, hur, crop
c Predictors: (Constant), py, ca, nn, mh, crop
d Predictors: (Constant), py, nn, mh, crop
Dependent Variable: ly

Table 3: Regression ANOVA

Model		Sum of Squares	df	Mean Square	F
1	Regression	7494725.28	7	1070675.040	145.921**
	Residual	3243120.91	442	7337.378	
	Total	10737846.19	449		
2	Regression	7494620.64	6	1249103.441	170.618**
	Residual	3243225.55	443	7321.051	
	Tota1	10737846.19	449		
3	Regression	7494128.41	5	1498825.683	205.159**
	Residual	3243717.78	444	7305.671	
	Total	10737846.19	449		
4	Regression	7474382.21	4	1868595.554	254.798**
	Residual	3263463.98	445	7333.627	
	Total	10737846.19	449		

Equation I. Initial equation :

Lamina yield = 375.08 85.32 X crop + 2.50 X ca + 0.02 X hur + 0.54 X mh + 1.74 X nn + 0.32 X nb + 0.43 X py

Equation II. Final equation :

Lamina yield = 379.61 88.69 X crop + 0.58 X mh + 1.45 X nn + 0.44 X py

height in cm (mh), number of nodes (nn), number of branches (nb) and petiole yield in g (py) was worked out using SPSS 11.5 software.

RESULTS AND DISCUSSION

The descriptive statistics of 450 observations on each variable spanning 3 years through 5 crop seasons as enumerated in Table 1 indicated that mean ± standard deviation of lamina yield was 348.63 g ±154.64, that of height up to primary raceme and mean height were 184.82 cm ± 86.93 and 363.74 cm ± 120.59, respectively; number of nodes and branches were 29.93±14.22 and 7.12±1.82 respectively; petiole yield being 152.13 g ±121.71 suggesting prevalence of variability within the traits.

The backward multiple step regression worked through 4 steps in formulating a final yield- yield component model resulted in as high output of multiple correlation coefficients (R) and coefficients of determinations (R^2) as 0.835 to 0.836 and 0.698 to 0.699, respectively. The coefficients improved with the final model, which excluded the impact of independent variables namely number of branches (nb), height up to primary raceme and castor accessions (ca) as evidenced in Table 2. The exclusion of castor accessions at the final step is indicative that differences of castor accessions do not influence the contribution of the rest of the yield components towards the lamina yield. Equation 1 reveals the relationship between the lamina yield and yield components. Equation 2 projects the final model elucidating that lamina yield is expected to increase with greater mean height, petiole weight and number of nodes but with the advancing crop seasons, reduced yield is expected. The significant F statistics of regression coupled with relatively low residuals at each step of Anova (Table 3) as well as stepwise high output of multiple correlation coefficients (R) and coefficients of determination (R^2) justify the fitness of this prediction.

The final equation thus developed deciphers the basic yield and yield component relationship prevailing among castor plants. This equation can be utilized for projecting lamina yield of castor food plants for determining the size of eri silkworm crops. This in turn is expected to lead to effective resource utilization and better income generation.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 318-320

REACTION OF DIFFERENT MORPHOTYPES OF MUGA FOOD PLANT SOM TOWARDS MAJOR FOLIAR DISEASES

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ABSTRACT

Som (*Persea bombycina*), the principal food of the muga silkworm (*Antheraea assamensis*). Loss of foliae due to diseases is a major constraint in raising Som plantations for Muga silkworm rearin. Various chemicals that have been recommended for the control of these diseases are known to be toxic to silkworm. Screening and evaluation of Som morphotypes for tolerance to pathogens attack showed that morphotype III is resistant to leaf spot and red rust diseases (2.2 and 3.6 PDI) and morphotypes V (11.3 PDI) and VI (17.9 PDI) are moderately resistant. On the other hand, morphotypes IV (21.4 PDI), VII (23.3 PDI) and VIII (21.4 PDI) showed moderately susceptible reaction to leaf spot disease. Morphotype III showed resistant reaction to Leaf spot as well as Red rust diseases (Table-4.1 and 4.2). This morphotype, however, was moderately resistant to Grey blight disease. The morphotype VI showed moderate reaction to all three major foliar diseases of som..

Key words: Disease, Morphotype, *Persea bombycina,* Resistant, Screening, Som

INTRODUCTION

Som is the principal food of the muga silkworm. Loss of foliage due to diseases is the most important production constraint in Som plantations of Assam. Leaf spot (*Phyllosticta persae*), red rust (*Cephaleuros parasiticus*) and grey blight (*Pestalotiopsis disseminate*) are the common and destructive foliar diseases of muga food plant in the entire muga growing areas. (Bharali, 1969; Thangavelue *et al.,* 1988; *Das et al., 2007).* The estimated loss in productivity due to leaf spot and red rust diseases were estimated at 1070 kg and 938 kg hectare^{-1} year^{-1}, respectively. Grey blight disease is reported to cause upto 18 % loss in productivity (Das and Benchamin, 2000). Besides, these diseases also reduce the total consumable portion in affected leaves. Feeding silkworms with diseased leaves results prolonged larval duration and deterioration of cocoon characters (Noamani et al., 1970; Sulisa and Padma, 1987). Consequently, there is a shortage of quality leaves for rearing of muga silkworm. This results in severe economic loss to muga farmers. Hence, management of muga host plant diseases is one of the pre-requisites for muga culture. Though various chemicals have been recommended (Padule and Hande, 1980) these chemicals are known to be toxic to silkworm (Narasimhanna, 1988: Singh *et al.,* 2002). The resistant varieties therefore, have important role to play in combating these diseases. This is not only environment friendly but also convenient to be adopted at farmers' level (Dutta *et al.*, 2005). Thus screening and evaluation of Som cultivars for improving tolerance to pathogens attack is an invaluable tool in muga host plant breeding programme to increase crop protection against microbial pathogens. The present study, therefore, was undertaken to screen commonly grown Som morphotypes to isolate a morphotype that is resistant to different foliar diseases encountered commonly in som growing areas of Assam.

MATERIALS AND METHODS

The experiment was conducted under field conditions for a period of two years in the field of Central Muga Eri Research And Training Institute, Lahdoigarh, Jorhat, Assam. Six morphotypes of *Persea bombycina viz*., Morphotype-III, Morphotype-IV, Morphotype-V, Morphotype-VI, Morphotype-VII and Morphotype-VIII were used for this experiment. These morphotypes were planted in the experimental field of Central Muga Eri Research and Training Institute, Jorhat, Assam in randomized block design (RBD) in 3 × 3m spacing.

The morphotypes were screened against leaf spot, red rust and grey blight diseases during the study period. As there was heavy incidence of leaf spot, red rust and grey blight diseases during the study period, the cultivars were scored for the diseases under natural field conditions

without artificial inoculation. Data were recorded at regular intervals of fifteen days by randomly selecting the plants. In each plant, the total number of diseased and healthy leaves was recorded from five selected branches. The diseased leaves infected by different pathogens were studied separately for each disease and were categorized into 5 grades as suggested by Dubey and Dwivedi (1991).

Grading of infection

Grading	Description
0	Leaves free from infection
1	Disease covering < 5% leaf area
2	Disease covering 5.1-10% leaf area
3	Disease covering 10.1-25% leaf area
4	Disease covering 25.1-50% leaf area
5	Disease covering >50% leaf area

The Percent Disease Index (PDI) was calculated using the following formula as suggested by Mc Kinney (1924).

$$PDI = \frac{SNV}{TLO \times MG} \times 100$$

PDI - Percentage disease Index
SNV - Sum of numerical value
TLO - Total no. of leaves observed
MG - Maximum grading

Numerical values were obtained by multiplying the number of diseased leaves with their respective grading.

Mean of 24 observations were recorded as annual PDI of each morphptypes. Two years pooled mean PDI was used to find out resistant reaction of different morphptypes on a 0-5 scale (Baker, 1961).

Grade		Severity
No disease	=	Immune
1--5%PDI	=	Resistant
5.1--20%PDI	=	Moderately resistant
20.1--50%PDI	=	Moderately susceptible
Above 50%PDI	=	Highly Susceptible

RESULTS

Reaction to Leaf spot

Out of six morphotypes of Som screened against leaf spot disease (Table- 1), morphotype III showed resistant reaction showing grade-2 with < 5% disease incidence and 2.2 PDI. Morphotypes V (11.3 PDI) and VI (17.9 PDI) showed moderately resistant reaction. On the other hand, morphotypes IV (21.4 PDI), VII (23.3 PDI) and VIII (21.4 PDI) showed moderately susceptible reaction to leaf spot disease. No morphotypes was recorded either as immune or highly susceptible.

Reaction to Red rust disease

Morphotype III showed resistant reaction to Red rust disease. The PDI recorded for this morphotype was 3.6 (Table- 2). The PDI recorded for morphotype VI was 8.5 and this morphotype was placed under grade 3 (6%) and was categorized as moderately resistant. Two morphotypes such as VII and VIII showed moderately susceptible reaction with 23.5 and 31.3 PDI. Morphotypes IV and V were recorded as highly susceptible to Red rust disease with >50 % severity or disease incidence.

Reaction to Grey blight disease

Amongst the morphotypes studied, two morphotypes viz. morphotype III and morphotype VI were found moderately resistant to Grey blight disease with 10.8 and 14.6 percent disease index. Screening of different morphotypes for Grey blight disease under the natural conditions revealed that the other remaining four morphotypes were highly susceptible to the disease as their PDI varied from 52.4 to 61.4%. No morphotype was recorded showing immune and resistant reactions to the disease. (Table-3).

Morphotype III showed resistant reaction to Leaf spot as well as Red rust diseases (Table-1 and 2). This morphotype, however, was moderately resistant to Grey blight disease. The morphotype VI showed moderate reaction to all three major foliar diseases of Som.

DISCUSSION

Disease intensity in any crop is dependent upon the virulence of pathogens, susceptibility of host and the environmental conditions. The results of this study clearly indicated that different morphotypes of Som behaved differently as regards to their reaction to different foliar diseases. Morphotype III showed resistant reaction against Leaf spot and Red rust diseases and moderately resistant reaction against Grey blight disease. Das *et al.,* (2005) also obtained similar results with S-3 morphotype against Leaf spot disease. They also reported that none of the Som morphotypes studied by them were immune to *Phyllosticta persae* infection. The results of the present study revealed that none of the morphotypes showed immunity to different foliar diseases.

The mulberry genotypes tolerant to leaf rust disease have been reported to posses thicker surface layer and lesser infection sites (Philip *et al.,* 1991). Rajaram *et. al.* (1993) also reported that the morphotype III and VI have lower stomatal frequency. The morphotype VI has thicker surface (Raja Ram *et al*., 1993). The resistant reaction of morphotype VI is due to thicker epidermal layer of leaves. The resistant reaction of morphotype III to leaf spot and red rust diseases during the present study may be due to less number of stomata, the natural opening for penetration of germ tube of pathogens, and thickness of the leaf surface.

Siddiqui *et al.* (2000) reported that the morphotype III, which recorded higher leaf yield and higher palatability, was superior for sustainable yield of muga cocoons over other morphotypes. From the present study, morphotype III was found to be resistant to Leaf spot and Red rust and moderately resistant to Grey blight.

Table 1: Reaction of different som morphotypes to Leaf spot disease

Reaction	Morphotypes
Immune (0 %)	Nil
Resistant (0-5%)	III (2.2)
Mod. resistant (5.1-20 %)	V (11.3) & VI (17.9)
Mod. susceptible (20.1-50%)	IV (21.4), VII (23.3) & VIII (21.4)
High. susceptible (> 50.1%)	Nil

Table 2: Reaction of different som morphotypes to red rust disease

Reaction	Morphotypes
Immune (0 %)	Nil
Resistant (0-5%)	III (3.6)
Mod. resistant (5.1-20 %)	VI (8.5)
Mod. susceptible(20.1-50%)	VII (23.5) & VIII (31.3)
High. susceptible(> 50.1%)	IV (52.6) & V (58.6)

Table 3: Reaction of different som morphotypes to Grey blight disease

Reaction	Morphotypes
Immune (0 %)	Nil
Resistant (0-5%)	Nil
Mod. resistant (5.1-20 %)	III (10.8) & VI (14.6)
Mod. susceptible(20.1-50%)	Nil
High. susceptible(> 50.1%)	IV (52.4),V (57.6) , & VII (53.9) & VIII (61.4)

Mod. = Moderatly ; High. = Highly

Figures in parentheses are percent disease index

From the above study it can be concluded that the Som morphotypes III and VI are the most suitable cultivars for muga silkworm rearing in Assam .The other morphotypes *i.e.* VII and VIII may also be cultivated in upper Assam due to their moderate resistance to the leaf spot and red rust diseases. The morphotypes III and IV thus selected may be used directly in the field or it can be utilized as a source of breeding material for the development of disease resistant varieties of muga food plant for the effective management of the foliar diseases.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 321-326

EVALUATION OF SOM MORPHOTYPES FOR RESISTANCE TO LEAF SPOT CAUSED BY *PHYLLOSTICTA PERSAE* IN FIELD ENVIRONMENT

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ABSTRACT

The leaf spot caused by a necrotroph Phyllosticta persae affects commercial cultivars of the primary host plant of muga silkworm Som (Persea bombycina) during June to September causing a foliage loss up to 16%. The disease severity index (DSI) varied 2.8 fold (16.1-44.0) in six locations of Kamrup and Goalpara districts of Assam during Aherua (June-July), which warrants control of the Phyllosticta leaf spot (PLS). Consequently, eight som morphotypes were evaluated multi-parametrically for resistance to PLS pathogen in field condition under natural inoculum. The disease reaction was assessed from 80th to 125th days after pruning in each season. The variations in DSI, disease incidence (DI%), area under disease progression curve (AUDPC) and apparent infection rate (AIR) among morphotypes were significantly different. Morphotype M-5 had useful resistance to PLS pathogen on the basis of DSI. The DI and AUDPC values were 5.1 fold and 4.2 fold higher in most susceptible accession M-8 than the least responsive M-5. Plants were also evaluated for lesion diameter, lesion frequency and leaf area at the final disease scoring stage. High broad sense heritability (h2:0.80) of DSI values showed additive nature. The DSI values showed high significant correlation with DI ($r = 0.91$; $P < 0.001$) and AUDPC ($r = 0.86$; $P < 0.001$), and moderate correlation with AIR ($r = 0.55$; $P < 0.05$). Further, high positive correlation of DSI and AUDPC with lesion diameter ($r = 0.76$; $P < 0.01$) and lesion frequency ($r = 0.79$; $P < 0.01$) confirmed the consistency of obtained results. Finally, morphotypes were partitioned into three clusters based on multivariate analysis of 6 best classification variables. Euclidian distance showed that morphotype M-5 moderately resistant to PLS, was also the most diverse accession among the lines. Cluster analysis showed good agreement among obtained disease reactions and correlative morphological features. The overall data support the potential of M-5 for PLS resistant breeding programme of Som.

Keywords: Disease resistance, Leaf spot, *Persea bombycina*, *Phyllosticta persae*, Som morphotypes

INTRODUCTION

Since time immemorial, muga silkworm (Antheraea assamensis) culture is virtually endemic to Assam, Meghalaya and adjoining areas of Brahmaputra valley. Though the muga worm is polyphagous, rearers mainly depend on Som, (Persea bombycina), an evergreen tree for better silk yarns (Das *et al*., 2003; Das and Das, 2003). In spite of immense potential of muga culture and considerable thrust on the expansion of activities, muga silk production is extremely fluctuating since last two decades due to recurring failure of seed crop rearings and inadequate supply of silkworm eggs for rearing commercial crops. Seed crops are mainly reared in the Kamrup and Goalpara districts of Assam and Garo hills of Meghalaya. Among these, Aherua (June-July) and Bhodia (August-September) crops are considered most difficult due to prolonged rainfall, higher temperatures and recurrence of diseases to silkworm and its host (Bindroo *et al*., 2008).

The Phyllosticta leaf spot (PLS) caused by a necrotroph Phyllosticta persae (Coelomycetes) adversely affects cultivation of Som during June to September causing foliage loss of up to 16% (Das and Das, 2008). The loss in quality

foliage also impacts silkworm rearing. Som is generally cultivated in Assam as a monoculture by the poor and marginal growers dominated by different ethnic groups, usually with a very small land holding. However, record of PLS incidence from the seed crop areas of Assam during Aherua and Bhodia are very limited (Anonymous, 2004). Development of disease resistant accession(s) is considered as most sustainable and economic mode of disease control (Davidson *et al.*, 2004). Such approach seems to be extremely important considering the economic status of the muga rearers. Research in this direction needs proper impetus. As a prerequisite, efforts to search the 'source of resistance' for major pathogens /pests in available genetic resources of Som are also not properly documented.

Therefore, the practical study was undertaken with twin objectives to evaluate the degree of severity of PLS in the seed rearers' fields of Kamrup and Goalpara districts and fields of RMRS Assam and to screen available morphotypes of Som at RMRS for sources of resistance.

MATERIALS AND METHODS

Survey of Phyllosticta leaf spot severity at farmers' fields of Kamrup and Goalpara districts and RMRS, Boko

Natural open pollinated hybrid seed orchards of Som of uniform age (8-10 years) with similar cultural practices and 3m 3m spacing were selected in three villages each of Kamrup (Singra, Bolkona and Khatolpara) and Goalpara (Agia, Baida and Durapara) districts of Assam along with three distinct patches of trees (0.5 acre each) at RMRS, Boko. Three farmers' fields per village (twenty trees per field) were surveyed. PLS severity were measured twice during June and August (major seasons of PLS incidence) of 2010. The timing coincided with the ´Aherua` and 'Bhodia' schedule of muga silkworm seed rearing.

Screening of som morphotypes for resistance to Phyllosticta leaf spot in field

Eight Som morphotypes were evaluated in the experimental garden of RMRS Boko (92m above msl; 25°5'31"N and 91°24´ 00"E). Plants were maintained in randomized block design with 3m ×3m spacing. The soil was alluvial (entisol) and sandy clay loam in texture, pH: 7.6, with organic carbon 0.72%, available N: 230 kg/ha, available P: 30.2 kg/ha and available K: 210.7 kg/ha at the time of initiation of the experiment. The recommended doses of inorganic N as urea (87g/plant), inorganic phosphorus as P_2O_5 (125g/plant) and inorganic potassium as K_2O (33g/plant) were applied in two splits after each commercial harvest (June and November) and a solitary dose of farm yard manure was applied @ 10kg Unit .plant^{-1} during May applied (Chakravorti et al., 2007).

Disease assessment

Twenty plants of each morphotype were visually scored for percentage of leaf area covered by PLS on a 0 (resistant) to 10 (susceptible) scale four times between 80th and 125th after ground-level pruning. For analysis, disease scores were converted using the modified logarithmic scale of Horsefall-Barrett (Horesfall and Cowling, 1978). The scale was 0=0%, 1=03%, 2=$^{+}$36%, 3=$^{+}$612%, 4=$^{+}$1225%, 5=$^{+}$2550%, 6=$^{+}$5075%, 7=$^{+}$7588%, 8=$^{+}$8894%, 9=$^{+}$9497% and 10=$^{+}$97100%. Disease incidence (DI) was calculated as the number of leaves of main branch with necrotic spot on a percent basis (Gawande and Patil, 2003). Disease severity index (DSI) was calculated for each accession according to Chattopadhyay et al. (2010). The DSI of the accessions falling in the grades 1 and 2 to 3 were considered as highly resistant and moderately resistant classes; while, those falling in 4 and ≥ 5 were classified as intermediate and susceptible classes, respectively.

PLS development over time was assessed as the area under a disease progression curve (AUDPC) and apparent infection rate (AIR) were calculated according to the methods of Chattopadhyay et al., (2011) and Rao et al., (2008), respectively using following formulae:

$$AUDPC = \sum_{i=1}^{n} [(x_i + x_{i+1}) / 2] (t_{i+1} - t_i)$$

Where, n is the number of evaluation times, x_i is the disease intensity at evaluation time i and t_{i+1} is the time between two disease scores.

$$AIR = \frac{1}{t_2 - t_1} \log_e \left[\frac{n_2 (1 - n_1)}{n_1 (1 - n_2)} \right]$$

Where, t_1= time during 1st observation; t_2= time during 2nd observation; n_1= DSI at time t_1 and n_2 = DSI at time t_2.

Lesion sizes and lesion frequency of PLS infection were given in units of mm^2 (length x width) and per leaf, respectively and measured 125 days after pruning from the 8-12th leaf positions from the top according to Chaerani et al., (2007).

Data analysis

Analysis of variance was performed on obtained data by using Microsoft Excel version 8.0. Heterogeneity in the variances was observed in the data from disease screening methods. Therefore arcsine-square root transformation was applied before analysis. Recorded data were averaged across the replicates and resulting mean scores were used for analysis. When F values were significant ($P < 0.05$), Fisher's

Table 1: Estimates of Phyllosticta Leaf spot severity (DSI), mean sum of square (MS), variance components (VC) at different areas of lower Assam during Aherua and Bhodia seed crops.

Season	Location[1]	DSI	VC	df	MS	P < F
Aherua (June –July)	Kamrup	29.8	5.3	2	298.57	0.001
	Goalpara	20.1	3.2			
	RMRS	16.3	2.1			
	LSD (P0.05)	3.2				
Bhodia (August- September)	Kamrup	23.2	4.1	2	154.7	0.01
	Goalpara	18.6	2.6			
	RMRS	12.3	1.9			
	LSD (P0.05)	2.1				

Data are mean of nine field observations collected from three villages per location.

Table 2: Mean responses of som morphotypes to Phyllosticta leaf spot disease reactions, lesion diameter (LD) and lesion frequency (LF) at field environment of RMRS, Boko, Assam

Morphotype	DS*I*	DI	AUDPC	AIR	LD	LF
M-1	25.9	46.9	752.3	0.030	37.1	6.7
M-2	30.4	56.3	823.9	0.034	43.4	8.6
M-3	22.3	41.0	580.8	0.037	19.9	4.2
M-4	30.9	58.1	868.4	0.036	41.3	7.2
M-5	9.8	17.0	287.2	0.026	14.8	2.9
M-6	14.2	21.9	411.4	0.035	19.0	4.0
M-7	31.8	59.2	909.0	0.038	45.6	9.1
M-8	36.0	68.9	920.4	0.037	47.4	10.1
$LSD_{(0.05)}$	3.1	5.2	60.1	0.007	4.5	1.1
h^2	0.80				0.76	0.61

cv%= 15.3

Average of twenty values per morphotype with a total df = 160 for each parameter; values are back transformation of arcsine [√(x/100]. DSI (disease severity index) and DI (Disease incidence; %), AUDPC = area under disease progression curve (accumulative %), AIR = Apparent infection rate (unit progress.day^{-1}), LD (mm^2) and LF (no.50cm^2 of 7-10 positioned leaf from the top after 125 days of pruning).

Table 3: Pearson correlation coefficients among qualitative and quantitative parameters of Phyllosticta leaf spot assessment.

	DSI	DI	AUDPC	AIR	LD
DI	0.91**				
AUDPC	0.86**	0.79**			
AIR	0.56*	0.44ns	0.54*		
LD	0.76**	0.67**	0.68**	0.43ns	
LF	0.79**	0.76**	0.70**	0.49ns	0.86**

**, * and ns Indicates significant at p> 0.01, p> 0.05 and non-significant, respectively.

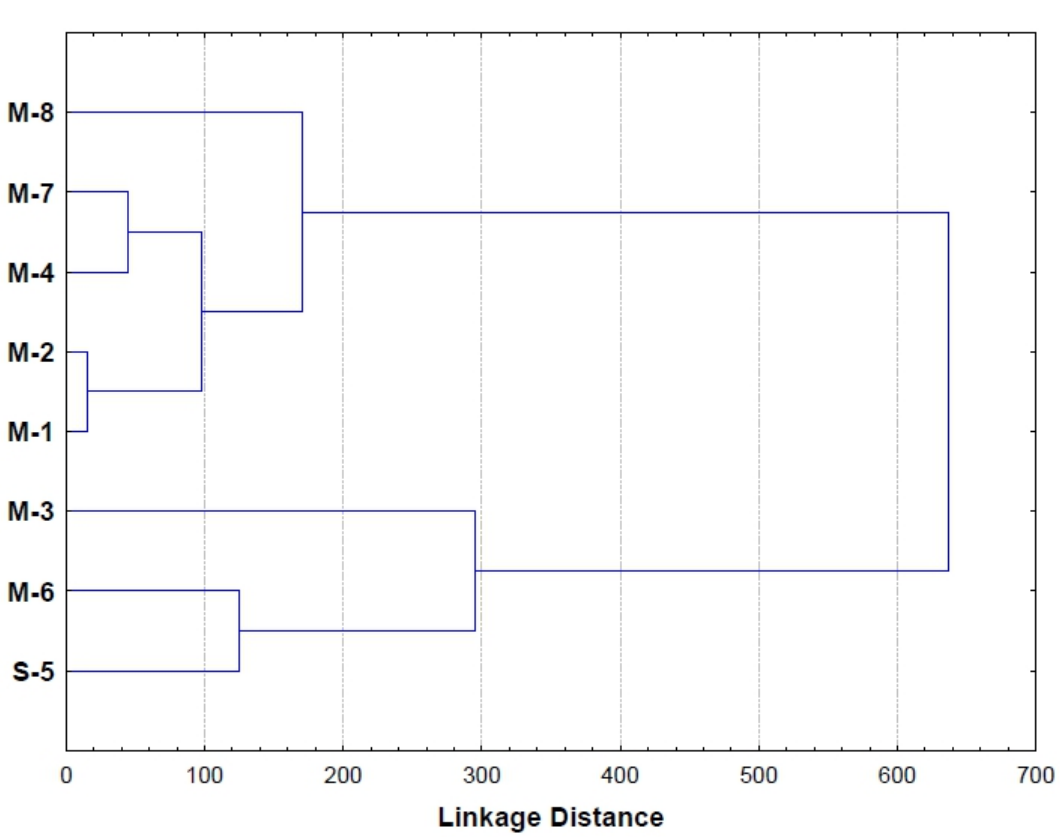


Fig.1: Dendrogram of eight som morphotypes obtained by analysis of DSI, DI, AUDPC, AIR, lesion diameter and lesion frequency values during leaf spot infection at field environment of RMRS, Boko.

Least Significant Differences (LSD), correlation matrix and broad sense heritability (h^2) were calculated in appropriate cases according to Gomez and Gomez (1984) and Jhonson et al., (1955), respectively. Further, mean values of tested parameters of morphotypes from the leaf spot screening were clustered using 'Statistica' version 8.0 software (Statsoft Inc., Tulsa, USA). The Euclidean distance based on complete amalgamation rule was used to construct dendrogram using hierarchical clustering. A linkage distance of 100 was arbitrarily chosen to separate the morphotype into two major clusters and 4 sub clusters in the dendrogram (Berdahl et al., 1999).

RESULTS AND DISCUSSION

High incidence of PLS was recorded in Kamrup and Goalpara spanning over six villages, as well as in the fields of RMRS Boko during Aherua and Bhodia seed crop seasons (Table 1). However, PLS severity was significantly high during Aherua than the Bhodia crop period. The DSI variation amongst survey locations was also significant in both seasons.

Compared to other plants, little information is available on the source of disease resistance in Som. The need to locate resistance has instigated several germplasm-screening programmes worldwide (Bubici and Cirulli, 2008) and many workers advocated multi-parametric assessments (Raghuchander et al., 2001). Both qualitative and quantitative resistances for various diseases from different host parasite systems have been reported. The former type of resistance is usually monogenic in nature. On the other hand, quantitative resistance is based on the assumption of multiple gene control and collectively confers divergent levels of resistance (Agrios, 1998). Therefore, multi-parametrically screening was restricted to using two qualitative (DSI and DI) and two quantitative (AUDPC and AIR) parameters. Though disease reaction was scored four times between 80 to 125 days after pruning (DAP) at intervals of 15 days, magnitude of symptom variations in the 4th stage (125 DAP) allowed sufficient discrimination at the level of disease reactions. Therefore, final disease scores were used to estimate qualitative parameters. A grossly uniform trend of PLS infections was observed in all four parameters. The mean DSI to leaf spot was 25.2, compared to severity index of 9.8 for M-5 and 40.1 for M-8, moderately resistant (H-B scale: 3) and susceptible (H-B scale: 5) morphotypes, respectively (Table 2).

Moderate resistance or slow disease progress is a unique phenomenon observed in various host leaf spot pathogen systems. It delays the onset and severity of symptom development. Such slow disease progress is often found more durable than complete resistance and gained attention from breeding point of view (Calenge et al., 2004). Slow progress of leaf spot and leaf rust were evaluated quantitatively as a function of disease progress over time as AUDPC and AIR (Cambell and Madden, 1990; Raju and Anilkumar, 1990). The leaf spot morphotypes showed sufficient variation of DI (4.1 fold) and AUDPC (3.2 fold) values while the variation of AIR values (1.4 fold) was least across the morphotypes (Table 2). The morphotype M-5 appeared moderately resistant to leaf spot. Overall results showed a gross agreement of trend of all qualitative and quantitative disease reaction parameters, indicating the importance of measuring disease progress, for the first time in muga host plant diseases. Besides, high broad sense heritability (h^2 :80.6 to 60.1) of DSI and quantitative disease assessment parameters like LD and LF indicated the additive nature of the resistant trait(s) and provided a scope for further utilization in breeding programes.

Identification of a moderately resistant source (M-5) to PLS through disease reaction features compelled us to elucidate the correlation among the studied parameters (Table 3). It was found that DSI was strongly correlated with the obtained values of DI ($r = 0.91$; $P > 0.01$), AUDPC ($r = 0.86$; $P < 0.01$) and AIR ($r = 0.55$; $P < 0.05$). Highly positive correlation of DSI especially with DI and AUDPC values indicates that the leaf spot screening could be confirmed by any of the three disease reaction tests. Further, highly significant positive correlations of qualitative (DSI) and quantitative (AUDPC) disease screening parameters with LD ($r = 0.76$; $P < 0.01$) and LF per leaf ($r = 0.79$; $P < 0.01$) confirmed obtained results.

Strong association of all disease reaction values with LD and LF were further partitioned through hierarchical cluster analysis (Fig. 1). Euclidian distance showed that the morphotype M-5 moderately resistant to PLS was also the most diverse accession among the tested lines. Cluster analysis largely showed good agreement among obtained disease reactions and correlative morphological features. Significant variability among the morphotypes to PLS with identification of a moderately resistant accession M-5 through multi-parametric features of high heritability and sufficient genetic divergence suggests the potential of the said resource for the use in leaf spot breeding program.

ACKNOWLEDGEMENT

The authors acknowledge the assistance provided by Mr .T. C. Boro, throughout the study.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 327-331

MANAGEMENT OF GALL INSECT, *TRIOZA FLETCHERRI MINOR* CRAWF, A MAJOR PEST OF PRIMARY TASAR FOOD PLANTS THROUGH ECOFRIENDLY TECHNIQUES

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ABSTRACT

Population dynamic studies of gall insect, *Trioza fletcheri minor* (Homoptera: Psyllidae), a major pest of primary tasar food plant *Terminalia tomentosa* W & A were carried out during gall infestation period with an object to work out suitable pruning strategies for its suppression. Changes in gall infestation percent, number of galls per leaf, number of branches per plant and leaf yield per plant were recorded in different pruning schedules commencing from first week of March to last week of April at 15 days intervals. The results indicated that gall infestation was minimum (8.45%) in plants pruned on 30th April and maximum (19.09%) in plants pruned on 15th March as compared to control (12.91%) where plants were pruned on 1st March. The number of galls per leaf was compared to control (0.74). However, the leaf yield per plant and number of branches per plant were not found significant by different treatments as compared to control. The results also indicate that in *T. tomentosa* plants, pruning influenced the gall infestation (14.41%) as compared to un-pruned plants (3.42%). In pruned and un-pruned plants, number of galls per leaf was 0.83 and 0.10 respectively. The interaction between pruning and months showed maximum gall infestation during July (32.62%) and minimum during September (0.44%). However, in un-pruned plants, the corresponding values were 10.48% in July and nil in September, respectively. In addition to the pruning strategies, neem products were also tested against gall insect. Results reveal that foliar spray of azadirachtin (15 ppm) and soil application neem cake @ 150 kg per hectare were found effective in controlling the gall insect population.

Key words: Azadirachtin, Gall infestation, Homoptera, Leaf yield, Population dynamics, Psyllidae, *Trioza fletcheri minor*

INTRODUCTION

Psyllids, *Trioza fletcheri minor* Crawf. and *Phyllopleacta hirsuta* Crawf. Are serious pests causing 40-50% crop loss during peak period (August) in *Terminalia arjuna* Bedd. and *Terminalia tomentosa* W & A., the primary food plants of tasar silkworm, *Antherea mylitta* D. (Thangavelu and Singh, 1991). The gall induced by the nymph of these pests cause foliar damage to the host plants, rendering the leaves unsuitable for silkworm feeding (Mathur, 1975). Pruning and training of tasar food plants have become an integral part of tasar culture. Pollarding of T. arjuna and T. tomentosa at 180 240 cm height resulted in higher yield of quality foliage and cocoon production (Jolly et al., 1974). Various agro-climatic conditions and agronomical practices like plant spacing, nitrogen application and irrigation, harvesting and pruning methods were reported to influence the occurrence of pests and diseases in various crops (Sharma and Govindaiah, 1991). Sharma et al., (2002) carried out extensive studies on the effect of pruning schedule on the incidence of T. fletcheri on T. arjuna.

Presently, gall insects are being controlled by insecticides. Indiscriminate use of insecticides for the control of gall insect leads to "ecological backlash" in the form of environmental pollution as well as development of resistance to insecticides and resurgence (Sundararaj et al., 1995).

Further, insecticides cannot be used during silkworms rearing, as the silkworm do not tolerate even the sub-lethal doses of toxic compounds (Thangavelu and Singh, 1991). This has led to investigations on the possibility of utilizing plant-derived chemicals. It has been well documented that, neem an extremely potent one among all the plants, has pronounced and exemplary bio-pesticide properties (Sundararaj et al., 1995). The potential neem seed oil and seed extracts against several crop pests has been demonstrated (Jotwani and Srivastava, 1984). In the present study emphasis has been given to minimize the gall incidence through eco-friendly techniques such as pruning strategies and use of neem products for reducing the load of insecticides in the forest ecosystem.

MATERIALS AND METHODS

Experiment was designed using 20 years old T. tomentosa plantation grown with 180 cm x 180 cm spacing. There were four treatments and one control with five replications in randomized block design. From each replication, ten healthy plants were considered for periodical observations. Plants of *T. tomentosa* were subjected to pruning (180 cm) at 15 day intervals commencing from 1st March (C), 15th March (T1), 30th March (T2), 15th April (T3) and 30th April (T4). First March was considered control, because it is the general practice. Separate un-pruned plots with similar replications were maintained in order to compare gall infestation on unpruned plants with that of pruned plants. Observations were recorded on gall infestation percent and number of galls per leaf at one month interval, commencing from 15th May to 15th September. Gall infestation percent and number of galls per leaf were calculated as per formula given below (Sharma *et al.,* 2002).

$$\text{Gall infestation (\%)} = \frac{\text{No. of gall infested leaves}}{\text{Total no. of leaves considered}} \times 100$$

$$\text{No. of galls/leaf} = \frac{\text{Total no. of galls in the infested leaves}}{\text{no. of leaves considered Total}} \times 100$$

For the estimation of gall infestation, ten leaves of each branch were considered and only active galls were taken into consideration. Biomass characters such as number of branches and leaf yield per plant were estimated during the month of October. Meteorological data on maximum and minimum temperature, relative humidity and rainfall were recorded. The moth-wise observations for all parameters in pruned and un-pruned plants were analysed using one-way and two-way analysis of variance (Kempthrone, 1952). The correlation analysis between gall infestation percent and number of galls per leaf with that of abiotic factors such as temperature, relative humidity and rainfall was carried out for establishing the relation between them.

For evaluating the effect of azadirachtin and neem cake against nymphs of gall insects, another set of experiment was laid down in randomized block design. Each treatment had five replications with 250 healthy plants in 180 cm × 180 cm spacing. Plants were pruned on 30th April at 180 cm height. Different concentrations (5,10, 15, 20 and 25 ppm) of aqueous solution of azadirachtin were sprayed thrice (at an interval of 15 days) on the leaves of *T. arjuna* after the sprouting of the buds. The control plants were sprayed with water. Cumulative mortality of gall insect was recorded after 168 hours. Dried and fine meshed neem cake was applied to soil @ 50, 100, 150, 200 and 250 kg per hectare, 15 days before onset of monsoor. Cumulative mortality of gall insect was recorded after one month of the treatment.

RESULTS AND DISCUSSION

The results indicated that the maximum (19.09%) gall infestation was recorded in plants pruned on 15th March, followed by plants pruned on 15th April (17.11%). Treatment means for gall infestation percent was significantly different over control ($P<0.05$). The minimum (8.45%) gall infestation was observed on plants pruned on 30th April as compared to control (12.91%). The maximum (1.02) number of galls per leaf was found on plants pruned on 30th March followed by 0.98 on plants pruned on 15th March. However, minimum number of galls was recorded (0.54 per leaf) on plants pruned on 30th April. The mean differences between treatments over control were observed significant at $p<0.05$ for most of the parameters. On the other hand, differences in treatment means for numbers of branches per plant and leaf yield per plant were not found singnificant (Table 1). Further, it was observed that mean difference in pruned and un-pruned plants were significantly different ($P<0.05$) for gall infestation percent and number of galls per leaf in case of two-way analysis of variance. Consequently, it was also seen that month as well as interaction (package × month) were significantly different in increasing the incidence of gall percent in different pruning schedules as compared to un-pruned plants ($P<0.05$). Whereas, mean difference of pruned and un-pruned plants for the parameters such as number of branches per plant and leaf yield per plant were not found significant in case of one way analysis of variance (Table 2). The correlation analysis was carried out between gall infestation pecent and number of galls per leaf with abiotic factors such as, maximum temperature, minimum temperature, relative humidity, and rainfall. The results recorded (Table 3) revealed that gall infestation percent as well as number of galls per leaf has positive and significant association with minimum temperature, relative humidity and rainfall. Results revealed that gall infestation percent was minimum in plants pruned on 30th April (T4 8.45%) and maximum in plants proned on 15th March (T1 19.09%). The

Table 1: Gall infestation and productivity parameters of *T. tomentosa* under different pruning schedules.

Time of pruning	Gall infestation (%)	Galls/leaf (nos.)	Branches/plant (nos.)	Leaf yield/plant (kg)
Control (1st March)	12.91 (3.59)	0.74 (0.86)	3.96	4.26
T1 (15th March)	19.09 (4.37)	0.98 (0.98)	3.85	4.29
T2 (30th March)	14.47 (3.80)	1.02 (1.00)	3.88	4.08
T3 (15th April)	17.11 (4.13)	0.87 (0.93)	4.13	4.19
T4 (30th April)	8.45 (2.91)	0.54 (0.73)	4.06	4.49
CD at 5%	(0.22)	(0.18)	NS	NS

The figures in parenthesis are square root transformation

interaction between pruning and month reveals that gall infestation was highest (32.62%) in July (maximum temperature 27.36C, minimum temperature 21.78C, relative humidity 92.35% and rainfall 28.33 cm and lowest (0.44%) during September (maximum temperature 27.42C; minimum temperature 20.52C, relative humidity 86.63% and rainfall 22.98 cm). However, in un-pruned plants, the corresponding values were not found significantly different. Sharma *et al.,* (2002) reported that after pruning, the incidence of gall was maximum during July in *T. arjuna* and concluded that pruning encourages qualitative and quantitative leaf growth but unfortunately gall insect took advantages by laying eggs during April-May at the time of sprouting of *T. arjuna*. Sharma *et al.,* (2002) also reported the maximum and minimum gall infestation on plants pruned on 15th March and 30th April, respectively. The authors have also observed the maximum incidence of gall during rainy season. Abiotic factors while on one side influenced the sprouting of pruned plants, also induced laying in gall fly creating favourable conditions for gall to multiply, which adversely affect the leaf quality thereby reducing rearing capacity and consequently the cocoon production (Ram Kishore *et al.,* 1997).

The observations indicated that if sprouting of leaves in *T. arjuna* is delayed by more than a month by delaying the pruning, it would adversely affect the egg laying period of *T. fletcheri* minor and ultimately decrease the gall infestation as evident from the fact that infestation of gall was minimum (8.45%) in plants pruned on 30th April (T4). The number of branches per plant and leaf yield per plant did not vary significantly among treatments, which provide ample scope for delaying the pruning in order to minimise the gall infestation in tasar food plants. The data also revealed that gall infestation was less in un-pruned plants, as compared to pruned plants, which suggested that pruning should be avoided and if inevitable in the rearing management point of view, it should be carried out during the end of April. Singh *et al.,* (1992) reported that nymphs of *Trioza* sp. underwent diapause in winter (December-February) and if these gall infested leaves collected and destroyed, the gall population could be reduced. Gall population could further be reduced by delaying the pruning without use of chemical.

The efficacy of azadirachtin and neem cake against gall insects are presented in Table 4 to 6. Results revealed that azadirachtin (15 ppm) was effective in controlling the gall insect population. Maximum cumulative mortality (60%) of gall nymphs was observed on seventh day after its foliar spray. Further, neem cake @ 150 kg per hectare was found effective in controlling the gall insect population (49%) as compared to control. Results also revealed that first to third nymphal stages of gall are more susceptible to azardirachtin than the later stages.

Neem cake is used as organic manure and also used in the management of insect pests (Sidhu, 1995). The foliar spray of azardirachtin and soil application of neem cake checked the growth and development of nymph of gall insect (Sharma *et al.,* 2002). The neem extracts are easily biodegradable. The added advantage is that it is difficult for the insect to develop resistance to inherent combination of chemicals derived from plants than to the single synthetic compound (Sidhu, 1995).

Results also indicated that azardirachtin is effective in inhibiting nymphal growth and inducing adult deformities. The safe period for feeding tasar silkworms with azadirachtin sprayed leaves is after 5 days of its application (Sharma *et al.,* 2002).

Therefore, it is concluded that gall infesttion in *T. tomentosa* could be reduced significantly by avoiding pruning or delaying pruning and application of neem products. The findings could be used in formulating an integrated package for the management of gall insects.

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Table 2: Analysis of variance for gall infestation and productivity parameters of *T. tomentosa* under different pruning schedules

Factors	Anova (2 factors)		Anova (1 factor)	
	Gall infestation (%)	Galls/leaf (nos.)	Branches/plant (nos.)	Leaf yield/plant (kg)
Pruned (P1)	14.41 (3.15)	0.83 (0.74)	3.98	4.26
Pruned (P2)	3.42 (0.15)	0.10 (0.18)	3.75	4.08
May	0.54 (0.40)	0.04 (0.11)		
June	12.37 (3.39)	0.60 (0.70)		
July	21.55 (4.46)	1.41 (1.07)		
August	9.87 (2.22)	0.18 (0.30)		
September	0.22 (0.26)	0.03 (0.10)		
P1 × May	1.08 (0.81)	0.07 (0.22)		
P1 × June	18.13 (4.26)	1.24 (1.11)		
P1 × July	32.62 (5.71)	2.41 (1.55)		
P1 × August	19.74 (4.44)	0.36 (0.59)		
P1 × September	0.44 (0.52)	0.05 (0.20)		
P2 × May	0.00 (0.00)	0.00 (0.00)		
P2 × June	6.61 (2.51)	0.09 (3.00)		
P2 × July	10.48 (3.21)	0.41 (0.59)		
P2 × August	0.00 (0.00)	0.00 (0.00)		
P2 × September	0.00 (0.00)	0.00 (0.00)		
CD at 5%				
Package	(0.82)	(0.11)	NS	NS
Months	(1.29)	(0.18)		
Package × Months	(1.83)	(0.25)		

The figures in parenthesis are square root transformation

Table 3: Correlation between gall infestation and number of galls per leaf with abiotic factors

Parameters	Max. temp. (°C)	Min. temp. (°C)	RH (%)	Rainfall (cm)	Gall infestation (%)	Galls per leaf (nos.)
Max. temp. (°C)	1.000					
Min. temp. (°C)	-0.176	1.000				
Relative humidity (%)	-0.851	0.623	1.000			
Rainfall (cm)	-0.690	0.691	0.923	1.000		
Gall infestation (%)	-0.411	0.949	0.746	0.715	1.000	
Galls per leaf (nos.)	-0.190	0.882	0.601	0.508	0.886	1.000

Table 4: Efficacy of azadirachtin against gall insect *T. fletcheir minor*

Treatments	Azadirachtin (ppm)	CMA 168 h (%)	Reduction %
T1	5.0	33.6±2.19	32.0
T2	10.0	43.2±1.78	41.6
T3	15.0	60.0±2.82	58.4
T4	20.0	56.0±1.78	54.4
T5	25.0	57.6±1.78	56.6
Control	water	1.6±0.44	-

Table 5: Efficacy of neem cake against gall insect *T. fletcheir minor*

Treatments	Dosage (kg/ha)	CMA 168 h (%)	Reduction %
T1	50.0	9.6±2.19	8.0
T2	100.0	34.4±2.19	32.8
T3	150.0	49.6±2.19	48.0
T4	200.0	47.2±4.38	45.6
T5	250.0	45.6±5.36	44.0
Control	soil	1.6±0.44	-

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 332-337

MALE MATING HISTORY IN *ANTHERAEA MYLITTA* AND ITS EFFECT ON EJACULATION SIZE AND FEMALE REPRODUCTIVE FITNESS

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ABSTRACT

Reproductive activity in the economically important insect, *Antheraea mylitta* is very important because the female reproduces only once in her life time and the aging is very rapid and costly. It is a capital breeder and strictly a monoandrous species. To know how strategically the insect behaves and the male allocates its ejaculate resource more prudently during its successive mating with virgin females to maximize its own fitness and the fitness of the female with whom it mated, both being most important to sericulture industry. So, the present study was undertaken and the results revealed fresh and virgin females always prefer to mate with fresh virgin males (84%) and receives high dose of ejaculates leading to higher hatchability than to virgin males of one day old (13.7%) and one day old males with mating experience (2.3%). The ejaculation size (as referred eupyrene sperm count in the ejaculation) declined significantly over successive mating ($r = -0.9931$, $P < 0.001$), so also the male body weight ($r = -0.9560$, $P < 0.001$). The quantity of ejaculate passed to female also significantly declined during aging ($r = -0.9982$, $P < 0.001$). It was found that male weight contribute substantially to the quantum of ejaculate ($r = -0.9519$, $P < 0.001$), so also higher fecund females receive relatively more ejaculate than the lower group to reach higher reproductive fitness. The life time fecundity was found to be 334 ± 31.

Key words: *Antheraea mylitta*, Ejaculation size, Mating history, Reproductive fitness

INTRODUCTION

The fact that male contribute substantially to reproduction as female does was very clear from studies carried out in the past (Gwynne, 1984; Boggs, 1990; Vahed, 1998). Ejaculates serve to maximize the male fitness in several ways (Gillott, 2003), the primary function being to ensure male fertility. Males allocate its sperm in a most adaptive way among ejaculate when it mate more than once (Cook and Wedell, 1996) and in some species males are able to vary the number of sperms ejaculated according to circumstance. Male mating with large females ejaculated more spermatozoa than when mating with small females (Gage and Barnard, 1996; Gage, 1998; Wedell and Cook, 1999a; Engqvist and Sauer, 2003). The ejaculate weight decreases over successive matings is very common in insects (Eady, 1995; Lauer, 1996; Savalli and Fox, 1999 a, b; Lewis, 2004; Damiens and Boivin, 2006). Many empirical studies have indeed shown that ejaculate allocation patterns are markedly plastic within species (Eddy, 1995; Ofuya, 1995; Engqvist and Sauer, 2003; Wedell *et al*., 2002).

In *Antheraea mylitta* the aging is rapid and costly as the insect is very short-lived, and the female reproduce only once in their lifetime. The aging has an immense effect on reproduictive performance in this insect where a decline in mating success, fecundity and fertility with aging was reported (Rath *et al*., 1997; Rath, 2000; Rath *et al.,* 2002, 2007). Adult moths are sexually ripened at the time of emergence and the act of mating starts 2-3 hours after the emergence. Females have full complement of eggs and mating does not stimulate egg production; male ejaculates sufficient sperms (2570-3500 sperms per one egg personal communication of the author) during coupling to fertilize the eggs of the female and no re-mating in this insect is observed (Rath *et al,* 1997, 2007). Thus *A. mylitta* is monoandrous. It is a capital breeder too in the absence of adult feeding. Adult of this species do not need to feed to reproduce successfully as reported in other species also (Wightman, 1978; Savalli and Fox, 1999b) and the ejaculate size may therefore affect female fitness to a great extent which ultimately influence the viable egg production in this economically important insect.

The present study was under taken to understand the effect of male mating history on male reproductive fitness (production of fertile sperms and maintenance of ejaculation size) female reproductive fitness (life time fecundity and hatching) which is largely not studied in the species. This might be helpful in making strategic approach to augment the egg production to meet the ever increasing demand.

MATERIALS AND METHODS

Male mating History and ejaculation size

Male moth of weight range 3.1g to 3.3 g were used in this experiment and the females used were of 6.5 g to 7.0 g. Male moth soon after eclosion were separated and made three mating groups- repeated mating (same male was used for 4 successive mating with a resting period of 16 hours between two matings), alternate mating (the same male was used in alternate days, where the resting period was 40 hours between two successive matings) and single mating (separate male was used but of different ages, day 0 to day 4). The moths were released inside the nylon net enclosure (separate for each mating group) for mating for 8 hours (Rath *et al.,* 2002). After recording the mating success five mated females were randomly selected from each lot of the mating type for eupyrene sperm count and the rest were kept in the earthen cups for life time fecundity (Rath *et al.,* 1997) and hatching. There were 10 replications each with 100 moths of either sex.

Body weight loss during repeated mating

Ten number of male moths were weighed 2-3 hours after eclosion (2.7 to 3.5 g weight with separate identifying marks for a definite weight) and then released inside a nylon net for mating with fresh females (weighing 6.4 -6.5 g) for 8 hours (Rath *et al.,* 2002). After 8 hours of mating the mated males were weighed and then rested for 16 hours and then again released inside the net for its second mating for 8 hours with fresh females after that the weight of males were noted. Thus, male moths were mated 4 times and each time after mating the weight of males was noted.

Correlation between body weight and ejaculation size

Fresh male moths of various weights (2.65 g to 3.5 g) were mated with fresh females (2-4 hours old, fresh wt-6.4-6.5 g) for 8 hours to note any variation in the ejaculation size along the weight range of male moth. After the desired period of mating eupyrene sperm estimation in the ejaculate was made.

To find out whether the female weight has any relation to have a larger ejaculate we have performed an experiment where fresh males having particular body weight 3.30 to 3.33 were allowed to mate with fresh females of three different body weight ranges (5.8 ± 0.158 g, 6.53 ± 0.156 g and 7.34 ± 0.102 g) for a period of 8 hours. There were 10 replications each with 50 moths. Ten females were randomly selected from each body weight range for eupyrene sperm count while other samples were kept for finding out the realized fecundity and fertility.

Female mating preference

To find out female mating preference we conduct an experiment where 150 fresh females were released in side a nylon net enclosure along with 150 fresh males, 150 virgin males of 1 day old and 150 earlier mated males of 1 day old in the night. Virgin males of 1 day old and earlier mated males of 1 day old were given identifying marks so that it can be easily identified to find out whether it was mated or not. In the morning mating success with respect to different male categories were noted. After required period of mating (8 hours) mated females were kept for oviposition to find out the realized fecundity and fertility. There were 7 replications.

Eupyrene sperm count

The sperm preparation was made by opening the spermatheca and bursa copulatrix of a mated female in 1 ml of Belar's saline (Flint and Kressin, 1969; 6 g NaCl, 0.2 g KCl, 0.2 g $CaCl_2$, 0.2 g Na_2CO_3 and water to make 1 liter) which serve as the diluting medium for sperms. After thorough mixing the sperm suspension was loaded to improved Neubauer chamber to fill the volume 1/50 mm^3 (5 small squares- 4 at its corner and 1 at the center of the big central square). Sperms are then counted in the above squares.

Statistical Analysis

The data collected were subjected to one way ANOVA, correlation and regression analysis to find out the significant differences.

RESULTS AND DISCUSSION

Ejaculate allocation

Virgin males contribute more ejaculate to females than did once-, twice- or thrice mated males. The ejaculation size amounts to 8.553×10^5 eupyrene sperms during its first mating which declined drastically by 35.4%, 60.1% and 81.5% during subsequent mating. Thus, out of a total allocation of 19.074×10^5 eupyrene sperms, a major share of 44.8% were allocated during first mating; and then 28.9% during 2^{nd} , 17.9% during 3^{rd} and only 8.3% during 4^{th} mating ($r = -0.9931$, $P < 0.001$). When the males used alternatively, the ejaculation size declined to an extent of 59.2% upon second mating and 79.5% upon third mating ($r = -0.9539$, $P < 0.001$). The single mating (age-related changes) revealed 22.2% decline in ejaculation size on day 1 and further decline on day 2 (36.2%), day 3 (57.5%) and day 4 (77.0%). ($r = -0.9982$, $P<0.001$) (Table 1, Fig. 1). This reduction in ejaculation size might be due to constrains in production rate (Arnqvist and Danielsson, 1999; Moore *et al*., 2004), or, the variation in female fecundity may affect the evolution of male ejaculate allocation (Reinhold *et al*., 2002). Ejaculation size and the number of sperms it contain vary among males (Eady, 1995; Savalli and Fox, 1998) and, within individuals,

vary with age (Fox *et al*., 1995a, b) and male mated status as observed in the present investigation. The empirical evidence suggests that male indeed allocate ejaculates according to variation in female fecundity and thus the female body size affects the ejaculation size (Wedell, 1992; Simmons *et al.,* 1993, Mallard and Barnard, 2003). Our results further corroborate the prediction that males are investing more ejaculate in early copulations than the later ones, assuming the probability of achieving additional matings decreases over time (Reinhold *et al*., 2002). Alternate mating revealed that *A. mylitta* fails to replenish its sperm quantity following a mating where upon 2nd mating the quantity of eupyrene sperms delivered was *at par* with the quantity of that the male ejaculated during its third repeated mating (Table 1).

Male loses its weight during repeated mating from 3.01 g to 1.754 during its first mating; which further declined to 1.08 g, 0.743 g and 0.502 g in subsequent mating. Thus, male contributions constituted a substantial proportion of their pre-mating body mass (first mating mean ± SD= 41.53 ± 3.35 %; second mating, 22.38 ± 2.07 %; third mating, 11.34 ± 3.99 % and fourth mating, 7.99 ± 3.21 %, r= -0.9560, P < 0.001) and the changes between any two mating treatment were found to be significant. There was a close association of weight loss and ejaculation size during repeated mating which revealed that weight loss (y= -0.3382x + 1.4725, R^2 = 0.9064) and decline in ejaculation size (y= -2.3012x + 10.522, R^2 = 0.9858) was due to repeated mating in *A. mylitta* (Fig. 1). Earlier findings by Savali and Fox (1999a) and Fischer *et al.* (2009) reported the loss as a measure of ejaculation size are also in close agreement with our findings.

Male Size and sperm number

There was a positive and significant correlation between male weight and ejaculation size (y=0.0847x + 7.5424, R^2 =0.8112), which indicate that male weight contribute 81% to the ejaculation size (Fig. 2). A positive association between a male size and spermatophore mass that had been reportedly found in butterflies and other insects (Wiklund and Kaitala, 1995; Bissoondath and Wiklund, 1996; Karlsson,1998; Wedell and Cook, 1999) confirms our findings. Further, this finding corroborates previous finding that spermatophore mass and fertile sperm numbers increased with male size, while non fertile sperm numbers were unrelated to male size (Lewis and Wedell, 2007; Fischer *et al.,* 2009).

Mating preference

Fresh females prefer to mate with fresh virgin males (84%), than virgin males of one day old (13.7%), and one day old males with mating experience (2.3%). The realized fecundity and hatching of eggs were also significantly more when fresh females mated with fresh virgin males. Significant differences were observed among the treatment groups in mating success (df 2,18, F=531.7729, P< 0.0001), realized fecundity (df 2, 18; F=103.0297, P< 0.0001) and hatching of eggs (df 2,18; F=71.5481, P< 0.0001 (Table 2).

Lifetime fecundity

The life time fecundity in *Antheraea mylitta* was recorded to be 334 ± 31 and decreased as the male's number of previous matings increased (r= -0.9840, *P* < 0.001). When males were repeatedly mated during aging with virgin females the lifetime fecundity declined by 27.5%, 36.8% and 58.4% upon 2nd, 3rd and 4th mating. In alternate mating, the lifetime fecundity was also declined significantly (by 40.7% upon 2nd mating and 58.1% during 3rd mating). Single mating revealed that aging alone was responsible for a decline in lifetime fecundity of 21.2%, 43.4%, 60.5% and 70.6% on day 1, day 2, day 3 and day 4 respectively (y= -60.3 x + 323.8, F=164.802, R^2=0.9821, P< 0.001) (Table 1).

Correlation between female weight and ejaculation size

Heavier females were ejaculated with significantly more sperms by males than the less weighed females, so also the fecundity and fertility were higher in heavier females. Low weighed females (5.80 ± 0.158 g) were ejaculated with 7.62 X 10^5 eupyrene sperms, while the middle weight females (6.53 ± 0.156 g) were ejaculated with 13.5% more (8.65 X 10^5 eupyrene sperms) and heavier female (7.34 ± 0.102 g) with 16.5% more (8.88 X 10^5 eupyrene sperms). The regression equation (y= 0.63x – 1.6967, R^2=0.8815, P<0.001) revealed female weight contribute 88% to the ejaculated mass. The realized fecundity tends to increase significantly in middle weight (by 45.4%) and heavier females (by 70.1%) from 194 in low weighed females. Similarly, the hatching in middle weight and heavier females were significantly higher than the low weight females (Table 3, Fig. 2). The sperm: egg ratio also tend to decline from 3927:1 (in low weighed females) to 3067:1 (in middle weighed group) and 2692:1 in heavy weight group. Such a huge quantity of sperm ejaculation by male in to the body of female might be the reason behind monoandrous nature which ceases the receptivity of the female further in this wild species. Larger ejaculate volumes associated with low degree of polyandry that are reported in bushcricket texa, agrees with our findings (Vahed, 2006).

Earlier reports also revealed that male provided larger females with ejaculates frequently contain more sperm that have increased fecundity in many insects (Gage and Barnard, 1996; Gage, 1998; Wedell and Cook, 1999; Engqvist and Suer, 2003). That at least some male Lepidoptera seem capable of assessing female quality and reproductive potential, and adjust their ejaculate accordingly. Such strategic investment of reproductive sources *e.g*. by tailoring ejaculates in relation to female size that have been repeatedly documented (Wedell *et al.,* 2002) corroborates our present findings.

Females mated to virgin males had significant higher fecundity than those mated to previously mated males. The lifetime fecundity, hatching and total eupyrene count

Table 1: Effect of male mating history on fecundity, hatching and ejaculation size in *Antheraea mylitta.*

Mating type	Mated on day	Mating No.	Lifetime fecundity	Hatching %	Total eupyrene sperm count (x 10^5)
Repeated (same male is used successively after a rest of 16 hours)	0	1	334 ± 31 a	91.97 ± 1.91 a	8.553±0.392 a
	1	2	242±16 b (-27.5%)	74.73±4.23 b (- 18.7%)	5.521±0.311 b (-35.4%)
A combine effect of repeated mating and aging	2	3	211±14 c (-36.8%)	48.71±3.55 c (- 47.0%)	3.416±0.446 c (-60.1%)
	3	4	139±12 d (-58.4%)	7.43±1.99 d (-91.9%)	1.584±0.089 d (-81.5%)
r			-0.9840*	-0.9821*	-0.9931*
Alternate (same male was used after a rest of 40 hrs)	0	1	334±31 a	91.97±1.91 a	8.553±0.392 a
	2	2	198±14 c (-40.7%)	45.43±1.19 c (-50.6%)	3.294±0.350 c (-59.2%)
A combine effect of repeated mating and delayed aging	4	3	140±15 d (-58.1%)	8.43±1.27 d (-90.8%)	1.750±0.385 d (-79.5%)
r			-0.9741*	-0.9978*	-0.9539*
Single mating (separate male was used)	0	1	334±31 a	91.97±1.91 a	8.553 ± 0.392 a
	1	1	263±24 e (-21.2%)	79.39±3.37 e (-13.7%)	6.656 ± 0.349 e (-22.2%)
Effect of Aging	2	1	189±18 c (-43.4%)	60.31±3.05 f (-34.4%)	5.456 ± 0.387 b (-36.2%)
	3	1	132±15 d (-60.5%)	45.56±5.16 c (-50.5%)	3.631 ± 0.456 c (-57.5%)
	4	1	98±14 f (-70.6%)	7.86±1.68 d (-91.4%)	1.969 ± 0.304 d (-77.0%)
r			-0.9910*	-0.9766*	-0.9982*

[Female moth age 0 day (fresh 2-4 hours old), fresh wt-6.4-6.5 g]
Significant differences are indicated by different alphabets (One-way ANOVA at 5% level)

Table 2: Female mating preference and its effect on fecundity and fertility in *A. mylitta*. (Values are mean ± SD).

Details of mating preference	Mating success (%)	Realized fecundity (nos.)	Hatching %
FF x FM (Fresh females × fresh males)	84.1±6.47 a	291±13 a	92.56±1.13 a
FF x VM1 (Fresh females × Virgin males 1 day old)	13.71±5.71 b	258±12 b	86.60±3.31 b
FF x MM1 (Fresh females × Mated males 1 day old)	2.19±1.79 c	194±13 c	77.30±2.27 c

Significant differences are indicated by different alphabets (One-way ANOVA at 5% level)

Table 3: Relationship between female wt and ejaculation size received. (Values are mean ± SD).

Moth size (wt. in g)		Total eupyrene sperms (× 10^5)	Realized fecundity	Hatching %	Sperm : egg ratio
Male	Female				
3.33±0.134 a	5.80 ± 0.158 a	7.62 ± 0.455 a	194 ± 12 a	82.8 ± 3.3 a (161)	3927:1
3.30 ± 0.141 a	6.53 ± 0.156 b	8.65 ± 0.425 b	282 ± 9 b	93.2 ± 2.2 b (263)	3067:1
3.33 ± 0.134 a	7.34 ± 0.102 c	8.88 ± 0.450 b	330 ± 7 c	92.2 ± 4.3 c (304)	2692:1

Significant differences are indicated by different alphabets (One-way ANOVA at 5%)

declines ($P < 0.001$) as the number of mating increases in repeated mating (where the combined effect of both repeated mating and aging of male moth was observed), so also in alternate mating (where the effect of delayed aging along with repeated mating was seen) and in single mating where the effect of aging of male moth was only observed (Table 1).

Size of the ejaculate plays a significant role in female fitness which generally decreases with the number of times that its mate has mated previously. Decreasing size of the ejaculate has a deep effect on female fitness (Rönn *et al.,* 2008). Female fitness components that were affected by male mating history brings about the changes in ejaculation size

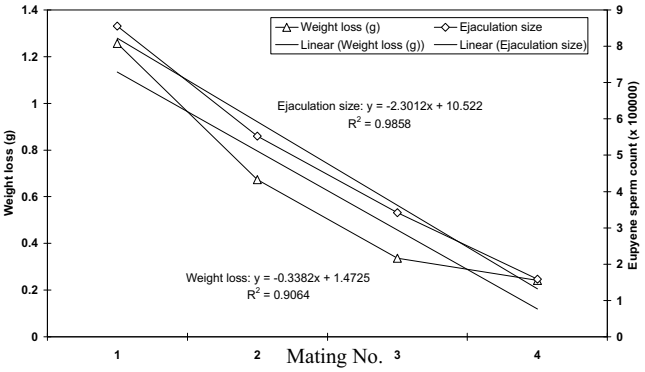


Fig. 1. Relationship of weight loss and total eupyrene ejaculated by male during repeated mating in *Antheraea mylitta*

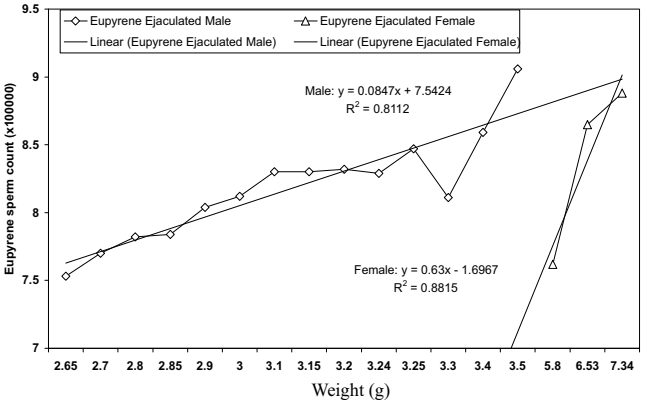


Fig. 2. Effect of body weight on ejaculation size in *Antheraea mylitta*

and composition over successive matings is the key along with effects on hatching rate of eggs (Ro¨nn *et al.,* 2008) corroborates our finding in the present study.

Our results show that male continue to mate with virgin females even beyond the point (4th in repeated and 3rd in alternate matings) where male ejaculate depletion results in female fitness being compromised. The fecundity of *C. maculates* females was significantly dependent on the male mating history, shown by Ofuya (1995) by mating with males suffering from severe ejaculate depletion, agree with our findings.

The size, quality and number of spermatophore delivered by males have been shown to be highly sensitive to factors like male age at mating, body weight, larval and adult feeding regime, mating order and the time that elapse between consecutive matings (Torres-Vila and Jennions, 2005). Male mating history strongly affects female reproductive output in Lepidoptera. Females mated to virgin males had higher fecundities than those mated to previously mated, experienced males (Torres-Vila and Jennions, 2005) further confirms our findings.

The most obvious proximate explanation for the effect of male mating history on female fecundity is that mating history affects spermatophore size as in *A. mylitta* where the virgin males produced larger number of eupyrene sperms than experienced males. This suggests that lepidopteran males suffer a depletion of spermatophore precursors after each mating.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 338-341

FIELD EVALUATION OF SEMI-SYNTHETIC DIET REARED TASAR (*ANTHERAEA MYLITTA* D) CHAWKI SILKWORM AT BILASPUR, CHHATTISGARH

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ABSTRACT

Outdoor rearing of *Antheraea mylitta* wild silkworm predisposes larvae to the pest and diseases resulting in 10-30% larval loss in young instars. Moreover there is no uniform and quality source of leaf due to rearing on forest plants. In order to provide balanced nutrition to young instar Tasar silkworms leading to stable cocoon crops, to reduce larval loss during early instar rearing, to ensure good hygiene, to avoid infection at early stages, to enhance ERR and to harvest higher number of cocoons per unit number of eggs, attempts were made to develop viable semi-synthetic diet for Tasar rearing at Central Sericultural Research and Training Institute, Mysore. In August 2010, a field trial cum demonstration & training has been conducted at Bilaspur with 50 dfls reared on semi-synthetic diet upto II instar and then shifted to outdoor host plant till spinning along with appropriate control (50 dfls brushed outdoor directly as control). 29 DOS officials of Chhattisgarh State Govt. were trained in this technology. Feed response of diet was calculated 96 %. The larval duration was 8 days up to II molt and 96% healthy larvae were shifted to outdoor. Daily growth was recorded. Diet reared larvae attained maximum growth of 0.979g in I instar and 4.193g in II instar as against 0.740 and 3.300g in I and II instar respectively of control. 62% cocoons were harvested in diet-reared batch as compared to 38% in control. Non-significant difference noticed in total larval duration, average cocoon weight, shell weight and shell % between diet-reared batch and control. With the adoption of this technology, a quantum jump in the production of Tasar silk can be expected.

Key words: *Antheraea mylitta,* Chawki rearing, Field evaluation, Semi-synthetic diet

INTRODUCTION

India is the largest consumer of silk in the world with an annual requirement of about 26,000 MT. However, the current annual silk production in India is about 16319 MT of which over 95% comprises of mulberry silk and rest is non mulberry silk. Since the domestic need of silk is more than the production, enhancement in silk production is the need of the hour. In the case of non-mulberry silk produced in India, 315 tons constitutes Tasar silk which is produced by *Antheraea mylitta* silkworm predominantly found in Chattisgarh, Madhya Pradesh, Orissa and Jharkhand. These silkworms are reared on trees of *Terminalia tomentosa* (Asan), *Terminalia arjuna* (Arjuna) found in the forests of central & north-eastern parts of India. Approximately 1.25 lakh tribal families are dependent on Tasar culture for their livelihood and employment. But these rearers encounter various problems, such as poor leaf quality, weather conditions and natural calamities. Introduction of young instar rearing centers on artificial diet therefore will be a new vista for indoor rearing to reduce the young instar loss. In tropical climatic conditions, Arjuna and Asan leaf quality is not up to the expected level for young instar Tasar rearing during the time of commercial crop production. It does not contain sufficient moisture (>75%), protein (8.163-9.956%), crude fibre (6.50-8.73%), mineral (6.94-7.84 %) reducing sugar (4.30%), sugar (5.75%) and starch (11.05%) which are essential for the optimum growth of young instar Tasar silkworms. Besides this the outdoor rearing of wild silkworm also predisposes larvae to the pest and diseases resulting in 10-30% larval loss in young instars. Further the out door rearing at young instar itself makes them more vulnerable to predators and parasites. These are the major problems to be

tackled to enhance the Tasar production.

Tasar silkworms are reared wild in nature and the survived larvae are exposed to the vagaries of nature. Due to this, the extent of loss is 90-95 % and hardly 4 to 5% cocoons are harvested. To overcome the said hurdles, several attempts were made to conduct indoor rearing with leaf and this practice is being continued to certain extent. In some places indoor rearing is conducted up to 72 hours in which case the larvae immediately after hatching are released on the branches of host plants. After 72 hours the larvae are shifted to bush plantation of food plants. This method has succeeded in reducing early loss and has improved the effective rate of rearing to a certain extent (up to 20%) but could not address the problem of poor quality of leaf.

In order to provide balanced nutrition to young instar Tasar silkworms to reduce larval loss during early instar rearing, to ensure good hygiene, to reduce early infection, to enhance ERR and to harvest higher number of cocoons per unit number of eggs, attempts were made to develop artificial diet for Tasar rearing. Only a few references are available on the development of artificial diet for *Antheraea mylitta*. First attempt was made to develop semi-synthetic diet for *A. mylitta* by Patnaik *et al.,* 1985 at CTR&TI Ranchi. They succeeded to grow larva up to 72 hours on artificial diet. Best diet was SS-11 composed of dry Arjuna leaf powder (2g) with sucrose (2g), soyabean meal (6g), cellulose powder (2g), agar-agar (1g) and other minor ingredient *viz.,* Sitosterol, ascorbic acid, citric acid, sorbic acid, riboflavin and streptomycin**.** Akai, *et al*. (1991) reared *A. mylitta* completely on an artificial diet. Thangavelu (1991) has explained the requirement of artificial diet for tropical Tasar silkworm which can open new vistas of indoor rearing. Nayak and Rao (2000) prepared artificial diet following Akai *et al* (1991) formula with Asan leaf (*Terminalia alata* -100 g), chlorella 60g, cellulose 20g, lipid free soybean flour 20g along with minor ingredients *viz.,* Calcium carbonate, potassium phosphate, magnesium phosphate, Iron phosphate and other ingredients like acrylic acid, vitamin C, vitamin B complex, chloromphenicol, sorbic acid, potassium salt, agar *etc. Antheraea paphia* (Modal and Nalia) was successfully reared from I instar to V instar and reported that cocoon quality of artificial diet reared larvae were inferior to natural leaf reared larvae. Larvae were fed four times at equal interval with fresh diet and rearing bed was cleaned twice daily and the survival recorded was 58.60-61.20%. As such the earlier attempts made to prepare artificial diet for Tasar silkworm has met with little success and till date no diet is commercially available in Indian market.

MATERIAL AND METHODS

Semi-synthetic diet (Tasar-nutrid) for tropical Tasar silkworm was prepared utilizing Arjuna /Asan leaf powder along with soya, ground nut cake, agar-agar, vitamins, minerals and preservatives. Powder mixed with 1:3 water and cooked at 120ºC and 15 lb pressure for 25 minutes. Cooled at 5ºC for 48h and cut into pieces for further use.

Field trial cum demonstration and training was conducted during August to September 2010 at Bilaspur on Tasar chawki rearing on artificial diet. 50 dfls were reared on semi-synthetic diet up to II moult and subsequent rearing was continued outdoor on Arjuna/Asan tree till spinning along with appropriate control (50 dfls brushed directly on host plant). For diet rearing, freshly hatched 200 larvae (1 dfl) of Daba eco race were fed with diet strips (2-3cm long and 2-2.5 mm thick) using kitchen grater and reared in closed plastic boxes (8" × 4" × 3"). After 24h larvae of two boxes (400 larvae) were shifted to closed plastic trays of 1½' × 2' dimension with bed area 16" × 10". Bed humidity maintained at 85 - 90 % by piling the trays one over the other and room temperature maintained at 28-29° C. After three days, larvae settled for first moult and the moulting period lasted for one day. After completion of 4th day, the larvae were resumed to second instar by providing diet as mentioned above.

RESULTS

Larval duration of 2.5-3 days was recorded in II instar and thus settled for II moult. In II instar, just before settling to II moult, all the larvae were shifted to out door for late age rearing on Arjuna tree The larval duration (7 days up to II molt), survival (96.00%) and growth parameters were observed to be better than the leaf batches brushed outdoor on the bushes. In diet rearing, no larval loss was recorded during I and II instar as there was no bed cleaning, no pest and predator attack. The feed response in diet rearing was 96%. Rearing on artificial diet allows complete prevention of various pathogenic microorganisms from food source particularly in young instar. Daily growth was recorded. Diet reared larvae attained maximum growth of 0.979g in I instar (10 nos) and 4.193g in II instar (10 nos) as against 0.740 and 3.300g in I and II instar respectively in control (Table 1). 61.68% cocoons were harvested in diet-reared batch as compared to 37.88% in control which is significantly more (Table 2). Non-significant difference noticed in total larval duration, average cocoon weight, shell weight, shell % and all the post cocoon parameters between diet-reared batch and control (Table 2). 29 DOS officials of Chhattisgarh State Govt. were trained in this technology.

DISCUSSION

Recently Dineshkumar *et al.,* (2010) composed 19 diets at CTRTI, Ranchi (D1-D19). At CSRTI, Mysore so far 50 diets were composed T1-T50. Diet T33 fared well and the formula was patented during 2010. In some of the diet compositions of CTRTI, fresh juice of leaf is used. Other formulation of CTRTI contains Chlorella/ Spirulina powder.

Table 1: Comparative performance of Tasar Silkworm rearing on diet and complete outdoor on host plant up to II instar rearing.

Sl.No.	Particulars	Diet feeding upto II instar then shifted outdoor	Complete out door rearing	t -value
1	Source of Tasar BV seed	BTSSO, Ratanpur		
2	Dfls	50	60	--
3	Fecundity	200	200	--
4	Total eggs	10, 000	12,000	--
5	Hatching %	53.50	50.00	--
6	No. of worms hatched	5350	6000	--
7	Feed response %	96	100	--
8	1st instar larval duration (days)	3	3	--
9	1st moult duration (days)	1	1	--
10	Wt. of 1st instar larvae (10 nos.) g.	0.979	0.740	293***
11	2nd instar larval duration (days)	3	3	--
12	2nd moult duration (days)	1	1	--
13	Wt. of 2nd instar larvae (10 nos.) g.	4.193	3.300	148***
14	No. of worms shifted outdoor	5136	--	--

Table 2: Comparative late age and post cocoon performance of Tasar Silkworms reared on diet upto II instar and shifted outdoor to host plant uoto spinning with complete outdoor rearing.

Sl.No.	Particulars	Diet feeding upto II instar then shifted outdoor	Complete out door rearing	t -value
1	Total larval duration (days)	24	24	--
2	No. of cocoons	3168	2273	--
3	Cocoon %	61.68	37.88	58.2***
4*	Cocoon weight (g)	8.04	7.16	NS
5*	Shell weight (g)	1.08	0.90	NS
6*	Shell %	13.43	12.57	NS
7*	Avg. cocoon filament length (m)	525.87	456.13	NS
8*	Avg. Cocoon non-breakable filament length (m)	136.23	131.69	NS
9*	Avg. Cocoon non-breakable filament weight (g)	0.55	0.53	NS
10*	Avg. Cocoon filament denier	9.43	10.45	NS
11*	Reelability %	23.90	22.86	NS
12*	Waste %	50.06	45.21	NS
13*	Raw Silk %	50.81	55.14	NS

* Data received from Zonal Office, CSTRI, CSB, Bilaspur

Since Spirulina/Chlorella is very expensive (Rs. 1000 kg) the same is totally avoided in CSRTI diet replacing with cheaper ingredients along with preservatives. Double distilled water was used for preparation of CTRTI diet and poured in sterile plates covered with sterile polythene sheets and refrigerated at 5° C. but no cooking/autoclaving procedure was adopted. Whereas CSRTI Tasar nutrid is prepared with drinking (Aquagard/ zeroB) water and autoclaved properly, which improves the keeping quality. This can be easily handled by any skilled person with little care like washing hands with 70% alcohol. In all the tasar diet rearings of CSRTI, same larval duration was recorded, whereas, changes in duration was observed only in outdoor from III instar to spinning.

Advantages of the new concept and the anticipated out come

This technology proves to be a fool-proof alternative technology to that of the conventional Tasar rearing, as it provides the requisite moisture and optimum nutrients to the young Tasar-silkworm. As the present diet rearing technology is an indoor technology, the problems such as missing larvae in early instars due to fall of larvae from tree branches will not be encountered. Besides this, this technology will also avoid the predators attack and disease infection. In the present experiment due to diet rearing technology the larval number per unit population increased resulting in higher recovery of cocoons (62.83%). Rearing of 50 dfls on tasar nutrid yielded 895 more cocoons than control, which generated extra income of Rs. 1342/- @ Rs 1.50/ cocoon. A net income of Rs. 1057 can be obtained after deducting additional expenditure of Rs.285/- on diet rearing for 50 dfls. The ultimate rearing cost will be reduced and higher returns expected due to more number of cocoon harvested. The commercial production of quality semi-synthetic diet on large scale will be of immense economic benefit in the field of young instar Tasar-rearing for raising robust Tasar chawki silkworm and in turn the full production potential can be exploited.

CONCLUSION

As the process of preparing diet and matching rearing technology of young instar Tasar rearing is standardized, it is appropriate to validate the technology in large scale through young instar Tasar rearing centres. Concept of centres for young instar Tasar rearing on artificial diet will open up a new vista for indoor rearing in Tasar culture industry. Diet rearing technology can be adopted to rear up to II instar and just before settling for II moult, larvae to be shifted and distributed to host plant (bushes) at farmer's places. This will prevent the early stage larval loss resulting in 30-40% increase in the effective rate of rearing. With the adoption of this technology, a quantum jump in the production of Tasar silk can be expected. Further, it is essential to train large number of officials / farmers in this technology which is expected to go a long way in taking up large-scale rearing in traditional areas.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 342-347

EVALUATION AND IDENTIFICATION OF CERTAIN GENOTYPES OF ERI SILKWORM, *SAMIA RICINI* DONOVAN UNDER TROPICAL CONDITIONS OF ANDHRA PRADESH

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ABSTRACT

A total of fifteen genotypes of eri silkworm, *Samia ricini* Donovan comprising of six isolated strains and nine eco-races were evaluated along with mixed population treated as control during three seasons *viz*., November-December, 2009, February - March, 2010 and June – July, 2010 to screen/identify the most suitable genotypes for tropical Andhra Pradesh conditions. Data were collected and assessed for seven economically important traits *viz*., fecundity, total larval duration and by number, effective rate of rearing per 10000 larvae by weight, cocoon weight, cocoon shell weight and cocoon shell ratio and statistically analyzed with one way classification and evaluation index methods. The analysis of variance portrayed significant differences (P<0.05) between the genotypes and replications for the traits fecundity, total larval duration, effective rate of rearing per 10000 larvae by number and weight. The genotypes were ranked based on Evaluation Index (EI) method (Mano *et al*., 1993) over the multiple traits to evaluate the best performing one. Among the genotypes evaluated, the eco-race, *Lakhimpur* ranked first with highest EI of 59.82. The genotype, Lakhimpur which showed highest performance over multiple traits of economic importance is considered as suitable and could be recommended for commercial use under tropical conditions of Andhra Pradesh.

Key words: Eri silkworm, Eco-race, *Samia ricini* Donovan, Strain.

INTRODUCTION

Ericulture enjoys an unique position among other sericultural activities like mulberry, tasar and muga for its typical quality of white soft yarn with thermal property. India is the leading producer of eri silk in the world with a production of 2038 MT during 2008-09 and bulk of the production comes from North-Eastern region of the country, the birth place of ericulture. Ericulture is predominant in North-East region and practiced as a tradition and leisure time occupation meant to meet partly the clothing and dietary needs of the sericulture families. Ericulture that proved to be a viable agro based small scale industry in North-Eastern region of the country has spread to some non-traditional states like Andhra Pradesh, Madhya Pradesh, Chattisgarh, Uttar Pradesh and Gujarat *etc*., in recent years. The potentiality of ericulture in tropical areas where the host plant cultivation *i.e*., castor (*Ricinus communis* Linn.) and tapioca (*Manihot esculenta* Crantz) is practiced for seed and tuber production respectively, is well established through various R & D schemes implemented by the Central Silk Board and other state governments. It is well substantiated that ericulture is feasible under tropical conditions as the recent advances in ericulture technologies and their dissemination have contributed in the increase in quality oriented productivity (Jayaprakash *et al*., 2005, 2006). However, the expected productivity could not be achieved primarily due to lack of suitable eri silkworm strains/eco-races for commercial exploitation. The commercially grown eri silkworm populations consisting of mixed larval types are exhibiting lower resistance to a greater extent to varying biotic and abiotic factors under fluctuating tropical conditions. It is established that there is significant seasonal variation of eri silkworm seed production and rearing performance (Sarkar *et al*., 2007) as high temperature (> 35 °C) during summer season and fluctuation in humidity adversely affect the embryonic development resulting in poor hatching and low cocoon harvest.

Unlike exhaustive research works pertaining to silkworm improvement carried out with mulberry silkworm *Bombyx mori* L., very limited research efforts are made with eri silkworm *Samia ricini Donovan in* sericulture countries of the world including India. Studies on taxonomy,

nomenclature and distribution of eri silkworm were detailed by Kar (2008). Eri silkworm *Samia ricini* Donovan is a domesticated polyphagous non-mulberry silkworm feeding on the leaves of a variety of food plants. Studies on different aspects of eri silkworms and their host plants began around mid-seventies. Sengupta *et al*., (1973) succeeded in isolating 29 sub lines of eri silkworm from five mixed stocks collected from *Nongpho*, *Diphu*, *Cachar*, *Lakhimpur* and *Dimon* and developed 12 crosses. Kakati *et al*., (1980) isolated six lines *i.e*., white plain, white spotted, white semi zebra, greenish blue plain, greenish blue spotted and greenish blue zebra from heterogenous population. Borgohain and Saratchandra (1980) established cent percent homozygocity in yellow plain, yellow spotted and greenish blue plain lines. The superiority of yellow plain for the trait fecundity (>478 eggs) and greenish blue plain for the trait ERR (>90.5%) was reported by Sengupta *et al*., (1973). Datta *et al*., (1999) established the superiority of the crosses Yellow Zebra x Greenish Blue Spotted and Greenish Blue Spotted x Greenish Blue Zebra for the traits cocoon weight and shell weight and fecundity and absolute silk yield respectively. Debraj *et al*., (2001) conducted field trials of elite crosses of eri silkworm and identified seven ecoraces *viz*., *Borduar*, *Titabar*, *Khanapara*, *Mendi*, *Sillie*, *Dhanubanga* and *Nongpho* besides six pure line strains *viz*., Yellow plain (YP), Yellow spotted (YS), Yellow Zebra (YZ), Greenish blue plain (GBP), Greenish blue spotted (GBS), Greenish blue zebra (GBZ) on the basis of larval colour and body markings. Similar studies were made on the identification of homozygous lines by Sarmah *et al.*, (2002). Twenty six eco-races of *S. ricini* collected from different potential eri growing pockets of North Eastern India have been identified based on ten descriptors and morphologically characterized (Chakravorty *et al*., 2008). All these eco-races are maintained at Central Muga Eri Research and Training Institute (CMERTI), Central Silk Board, Lahdoigarah, Jorhat and RERS, Mendipathar (Meghalaya). Among them, *Borduar*, *Diphu, Kokrajhar* and *Barpeta* eco-races are commercially being exploited. A detailed systematic eri silkworm breeding project is in progress at Regional Eri Research Station, Mendipathar. Ray *et al*., (2009) evaluated the performance of four eco-races and three strains under different seasons of Gangetic plains of West Bengal for their stability and concluded that Yellow Marked strain followed by *Borduar* eco-race performed better.

However, no work on identification of strain(s)/eco-race(s) suitable to tropical conditions in general and region specific in particular is documented so far from tropical areas. In this direction, an attempt is made in the present study in evaluating the performance of certain strains and eco-races of eri silkworm, *Samia ricini* Donovan under tropical conditions of Andhra Pradesh and identification of suitable ones for commercial exploitation in the region.

MATERIALS AND METHODS

The present study was conducted at Regional Eri Research Station, Central Silk Board, Shadnagar during November-December, 2009, February - March, 2010 and June – July, 2010 seasons. Six isolated strains of eri silkworm, *Samia ricini* Donovan *viz.*, Yellow Plain (YP), Yellow Spotted (YS), Greeninsh Blue Plain (GBP), Greenish Blue Spotted (GBS), Yellow Zebra (YZ) and Greenish Blue Zebra (GBZ) and nine eco-races *viz*., *Lakhimpur*, *Dhakuakhana*, *Kokrajhar*, *Dhemaji*, *Ambagaon*, *Sadiya*, *Mendipathar*, Diphu and *Wakhagre* constituted the experimental materials. The above materials were reared in three replications each with 200 worms retained after III moult. The mixed commercial population was treated as control. The worms were fed with castor (*Ricinus communis* Linn.) in all the three seasons under study. The general rearing technology as advocated for mulberry bivoltine silkworm (Datta, 1992) was followed in RBD design. The performance of the strains and eco-races was evaluated for the traits, fecundity, total larval duration, effective rate of rearing by number for 10000 larvae, effective rate of rearing by weight for 10000 larvae, cocoon weight, cocoon shell weight and cocoon shell ratio. The accrued data during the investigation was statistically analyzed (ANOVA) and relative ranking is assigned by following Multiple Trait Evaluation method (Mano *et al*., 1994). The strain/eco-race with highest average evaluation index value (EI) is identified as the one most suitable to the tropical conditions of Andhra Pradesh.

Statistical method followed

The data pertaining to the progenies of different mating systems over generations leading to the isolated new breeds were analyzed by employing statistical model for one way classification (Kempthorne, 1952) as described below:

$$Yij = u + Gi + eij$$

Where,

Yij = actual effect of i^{th} generation of the race

u = constant effect

Gi = effect of i^{th} generation

eij = random component effect

Multiple Trait Evaluation Index Method

Evaluation index over multiple traits was calculated as per the following formula

$$\text{Evaluation Index} = \frac{A - B}{C} \times 10 + 50$$

Where,

A = Value obtained for a trait in a breed

B = Mean value of a trait of all the breeds

C = Standard Deviation of a trait of all the breeds

10 = Standard unit

50 = Fixed value

However, for calculation of Evaluation Index for trait total larval duration the modified formula as detailed below (Goel *et al*., 2008) was applied as for the traits such as boil off loss, 5th age larval duration, total larval duration, floss % and filament size *etc*., lower values are considered as advantageous .

$$\text{Evaluation Index} = \frac{A-B}{C} \times (-10) + 50$$

Individual evaluation index values were calculated as per the above formula trait-wise for each of the breeds and average index value over seven traits under study was obtained. The average index value fixed for the selection of a genotype was above 50 and the breed showing higher average index value above 50 was considered to possess greater economic value over multiple traits and the genotype with highest average index value is ranked first and so on.

RESULTS

The morphological characteristics of larvae and cocoon of the evaluated genotypes representing both strains and eco-races are presented in Table 1. A perusal of the morphological characters shows that the larvae are basically without marked (plain), spotted, but zebra with yellow or greenish blue colour types. The cocoons of all the strains and eco-races of *Lakhimpur*, *Ambagaon*, *Sadiya*, *Mendipathar*, *Diphu* and *Wakhagre* are white in colour while both white and brick red cocoons were obtained from *Dhakuvakhana* and *Dhemaji* eco-races. Only brick red cocoons were obtained from Kokrajhar eco-race. The mean performance of the strains and eco-races over three seasons is presented in Table 2. The average evaluation index values calculated character-wise and overall evaluation index values over multiple traits are presented in Table 3. The analysis of the data character-wise is detailed as below:

Fecundity: The average number of eggs laid by a single female moth among strains and eco-races varied from a minimum of 277 (Yellow Zebra) to a maximum of 378 (*Wakhagre*) with an overall average of 330 eggs/moth. Further, the average number of eggs laid by female moth in isolated strains was lesser (306) than that of eco-races (344). The mixed population (treated as control) recorded 316 eggs/moth. Significant differences (P<0.05) were observed between the genotypes evaluated for the trait.

Total Larval Duration: The eco-race *Wakhagre* and Greenish Blue Plain varieties recorded lowest (641 hrs) and highest (665 hrs) total larval duration with an overall average of 653 hrs. It was observed that the total larval duration was longer in strains (660 hrs) compared to that of eco-races (648 hrs). The control batch recorded total larval duration of 653 hrs. The trait recorded significant differences (P<0.05) between genotypes under study.

Effective Rate of Rearing for 10000 larvae by number: The trait showed a wide range from a minimum of 5727 (*Kokrajhar*) to a maximum of 7522 observed for Yellow Plain with an overall average of 6926. The ERR recorded was found to be high (6978) among strains compared to eco-races (6895). The control batch recorded 7289 cocoons per 10000 larvae. Significant differences (P<0.05) were observed among all the genotypes for the trait.

Effective Rate of Rearing for 10000 larvae by weight: The eco-races, *Lakhimpur* and *Kokrajhar* recorded highest (22.927 kg) and lowest (16.816 kg) cocoon yield per 10000 larvae respectively compared to the overall average cocoon yield of 20.276 kg/10000 larvae. The strains showed higher ERR by weight (20.481 kg) compared to the average of 20.154 kg recorded for eco-races. The ERR by weight in control batch recorded 20.862 kg cocoons. The trait revealed significant (P<0.05) differences among the genotypes.

Cocoon weight: The trait observed to be highest in *Lakhimpur* (3.018 g) and lowest (2.734 g) in *Dhemaji*. The overall average cocoon weight recorded was 2.897 g. The analysis further present that the average cocoons weight was higher (2.933 g) in strains compared to that of eco-races (2.875 g). The control recorded 2.864 g of cocoon weight. The analysis further revealed significant differences (P<0.05) between replications and non-significant differences between genotypes.

Cocoon shell weight: The trait ranged from a minimum of 0.336 g (*Diphu*) to a maximum of 0.392 g (Yellow spotted) with an overall average of 0.364 g. The eco-races recorded higher average value (0.368 g) for the trait in comparison to that of strains (0.363 g). The average cocoon shell weight recorded for control was the lowest (0.327 g). The data further present that the trait showed non-significant differences between all the genotypes under study but significant (P<0.05) differences between replications.

Cocoon shell ratio: *Dhemaji* and Greenish Blue Zebra recorded highest (13.18%) and lowest (12.00%) values respectively for the trait that recorded an overall average of 12.54%. The eco-races recorded higher (12.80%) average value for the trait compared to that of strains (12.38%). The control batch recorded cocoon shell ratio of 11.45%. The analysis further present that the trait showed non-significant differences between all the genotypes but significant differences (P<0.05) between replications.

Table 1: Morphological characteristics of certain genotypes of eri silkworm (*Samia ricini* Donovan).

S.No.	Genotype	Larval Colour & Marking	Cocoon Colour
		Strain	
1	Yellow Plain	Yellow, Plain	White
2	Yellow Spotted	Yellow, Spotted,	White
3	Greenish Blue Plain	Greenish Blue, Plain	White
4	Greenish Blue Spotted	Greenish Blue, Spotted	White
5	Yellow Zebra	Yellow, Zebra	White
6	Greenish Blue Zebra	Greenish Blue, Zebra	White
		Eco-race	
7	Lakhimpur	Yellow & Blue ; Plain & Spotted	White
8	Dhakuakhana	Blue & Yellow Plain	White & Brick Red
9	Kokrajhar	Blue & Yellow Plain	Brick Red
10	Dhemaji	Yellow and Blue; Plain & Zebra	White & Brick Red
11	Ambagaon	Yellow, Plain	White
12	Sadiya	Yellow, Plain	White
13	Mendipathar	Blue, Plain	White
14	Diphu	Yellow & Blue; Plain & Zebra	White
15	Wakhagre	Yellow Plain	White
16	Mixed Population (c)	Yellow, Greenish Blue; Plain, Spotted & Zebra	White and few Brick red

Table 2: Performance of certain genotypes of eri silkworm, *Samia ricini* (Donovan).

Genotype	Fecun-ditiy (No.)	Total Larval Duration (Hrs)	ERR/ 10000 Larvae/ Number(No.)	ERR/ 10000 Larvae/ Weight (kg)	Cocoon Weight (g)	Cocoon Shell Weight (g)	Cocoon Shell Ratio (%)
Yellow Plain	303	658	7522	22.201	2.887	0.352	12.22
Yellow Spotted	303	657	7156	21.299	2.975	0.392	13.10
Greenish Blue Plain	333	665	6889	20.214	3.004	0.363	12.12
Greenish Blue Spotted	321	661	6833	19.638	2.868	0.353	12.32
Yellow Zebra	277	658	6433	18.604	2.901	0.366	12.56
Greenish Blue Zebra	302	662	7033	20.928	2.965	0.353	12.00
Lakhimpur	346	654	7411	22.927	3.018	0.391	12.88
Dhakuvakhana	346	655	7500	21.409	2.874	0.370	12.88
Kokrajhar	320	652	5727	16.816	2.837	0.365	12.82
Dhemaji	366	644	7033	19.313	2.734	0.361	13.18
Ambagoan	341	645	6823	21.215	2.931	0.377	12.97
Sadiya	370	647	7122	21.425	2.965	0.379	12.77
Mendipathar	331	648	6211	17.287	2.876	0.360	12.47
Diphu	329	646	6756	19.296	2.752	0.336	12.13
Wakhagre	378	641	7081	20.989	2.901	0.373	12.73
Mix.Population (c)	316	653	7289	20.862	2.864	0.327	11.45
Mean	330	653	6926	20.276	2.897	0.364	12.54
CD at 5%	23.8	4.19	724.03	3.12	0.225	0.043	1.09

Table 3: Evaluation Index values character-wise for certain genotypes of eri sillkworm, *Samia ricini* Donovan.

S. No.	Genotype	Fecun-dity	Total Larval Duration	ERR/ 10000 Larvae by Number	ERR/ 10000 Larvae by weight	Cocoon weight	Cocoon shell weight	Cocoon Shell Ratio	Ave-rage EI
1	Yellow Plain	40.02	42.36	62.46	61.43	48.72	43.22	43.15	48.76
2	Yellow Spotted	40.26	44.20	54.79	56.07	59.71	66.10	62.08	54.75
3	Greenish Blue Plain	50.99	32.85	49.22	49.63	63.37	49.48	41.08	48.09
4	Greenish Blue Spotted	46.58	38.68	48.06	46.21	46.34	43.86	45.32	45.01
5	Yellow Zebra	30.51	43.59	39.70	40.07	50.45	51.65	50.47	43.78
6	Greenish Blue Zebra	39.62	36.84	52.24	53.87	58.47	44.11	38.55	46.24
7	Lakhimpur	55.98	48.80	60.14	65.74	65.06	65.65	57.35	59.82
8	Dhakuvakhana	55.65	47.27	61.99	56.73	47.10	53.83	57.31	54.27
9	Kokrajhar	46.50	50.64	24.92	29.45	42.51	50.82	56.00	42.98
10	Dhemaji	62.94	62.76	52.24	44.28	29.71	48.39	63.75	52.01
11	Ambagoan	54.07	60.77	47.83	55.57	54.21	57.60	59.27	55.62
12	Sadiya	64.60	58.62	54.10	56.82	58.47	58.94	54.98	58.07
13	Mendipathar	50.18	56.16	35.05	32.25	47.38	47.95	48.51	45.36
14	Diphu	49.74	59.23	46.43	44.18	31.99	34.08	41.32	43.85
15	Wakhagre	67.39	66.90	53.24	54.23	50.55	55.17	54.03	57.36
16	Mix.Population (c)	44.96	50.34	57.58	53.48	45.96	29.16	26.82	44.04

Multiple Trait Evaluation Index

Individual evaluation index values calculated trait-wise for all the genotypes and average evaluation index values over multiple traits as presented in Table 3 present that out of the 16 genotypes evaluated, seven recorded values higher than 50 suggesting that they possess higher economic merit over the multiple traits studied. Out of them, *Lakhimpur* was assigned first rank (59.82) followed by *Sadiya* (58.07) and *Wakhagre* (57.36). *Kokrajhar* recorded lowest evaluation index value (42.98) whereas the control mixed population recorded evaluation index value of 44.04.

DISCUSSION

Considering the advantages of ericulture as a potential avocation providing gainful supplementary income and for poverty alleviation in rural areas through provision of additional gainful employment especially for women, it has spread out side North-East region to tropical areas including Andhra Pradesh where castor and tapioca plantations are raised commercially. To make ericulture a viable proposition through obtaining stable and successful cocoon crops in tropical areas, among various aspects, identification of suitable strain/eco-race for commercial exploitation is well realized as most of the existing strains/eco-races being reared under tropical climate are from North-East. Further, in the fluctuating tropical conditions, it is felt necessary to rear suitable genotype that shows higher viability and moderate productivity. Although, a few studies were reported in evaluation and identification of certain strains/eco-races of eri silkworm, *Samia ricini* Donovan suitable to North-East and gangetic plains in West Bengal, no work is hitherto reported for tropical areas.

The *per se* performance of all the strains and eco-races is lower compared to the original characteristics as detailed by Chakravorty *et al*., (2008) which may be attributed to the exposure of them from North-East region to typical tropical conditions in Andhra Pradesh . However, the strain, Yellow Plain that is being maintained separately over generations by the Department of Sericulture, Andhra Pradesh has recorded higher effective rate of rearing by number compared to others which may be attributed to its acclimatization to the prevailing conditions in the region. A perusal of the data for the trait fecundity as presented in Table 2 indicate the superiority of the Yellow Spotted followed by Yellow Plain among strains and Lakhimpur followed by Sadiya among eco-races. All these strains and eco-races surpassed the control mixed population except for the trait fecundity by the strains. The observation differs with that of Sengupta *et al*., (1973) who established superiority of Yellow Plain for the trait fecundity (> 478 eggs) and Greenish Blue Plain for the trait ERR (90.0)% and may be attributed to tropical conditions. The *per se* performance of all the strains and eco-races is lower compared to the original characteristics as detailed by Chakravorty *et al*., (2008) which may be

attributed to the exposure of the materials from North-East region to typical tropical conditions in Andhra Pradesh. The analysis of variance portrayed significant differences ($P<0.05$) among the breeds for the traits fecundity, total larval duration, effective rate of rearing per 10000 larvae by number and weight suggesting the profound interactions between genotype and environment. Whereas the non-significant differences among the breeds for the cocoon traits *viz*., cocoon weight, cocoon shell weight and cocoon shell ratio indicating the genetic make-up of the breeds. Further, based on the evaluation index over multiple traits (7), one strain *viz*., Yellow Plain and six eco-races *viz*., *Lakhimpur*, *Dhakuakhana*, *Ambagaon*, *Dhemaji*, *Sadiya* and *Wakhagre* recorded average Evaluation Index values above 50 and considered that they possess greater economic merit. From the study, it is concluded that the eco-race, *Lakhimpur* that ranked first is adjudjed as the best performing genotype and could be considered for commercial exploitation under tropical conditions. In addition, as no study is made hitherto as far as evaluation and subsequent identification of promising genotypes under tropical conditions, this study contribute to establish the required eri silkworm genetic base so as to use them as resource materials for future breeding programmes for development of productive and qualitatively superior genotypes suitable to tropical conditions and making ericulture a sustainable and productive enterprise in the region.

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STUDIES ON THE DOUBLE STEP PRESERVATION METHOD FOR LONGTERM LOW TEMPERATURE PRESERVATION OF SEED COCOONS OF MUGA SILKWORM, *ANTHERAEA ASSAMENSIS* HELFER

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ABSTRACT

A study was made to develop a suitable long term seed cocoon preservation method for skipping unfavorable Aherua pre-seed crop of Muga silkworm by postponing moth emergence. Muga silkworm seed cocoons of 8 days old were subjected to the low temperatures at 7.5±1°C and 10±1°C in BOD incubator for long term preservation of 32 to 52 days following the double step preservation method. The results indicated that muga seed cocoons can efectively be preserved at 10±1°C for 42 days without affecting the grainage parameters.

Keywords: *Antheraea assamensis,* Double preservation, Muga silkworm, Seed coccons

INTRODUCTION

The Muga silkworm, Antheraea assamensis Helfer is multivoltine with 6 overlapping crops, namely, Jethua (Apr May), Aherua (JunJuly), Bhadia (Aug-Sept.), Katia (OctNov), Jarua (Dec- Jan) and Chatua (Feb Mar). Among these 6 crops, Jethua and Katia are the only commercial crops, reared during favourable climatic conditions, while the remaining 4 crops, which are reared as pre-seed and seed crops, *viz.,* Aherua and Jarua pre-seed crops and Bhadia and Chatua seed crops are reared during inclement climatic conditions.

In Assam, temperature prevailing during summer crop seasons, especially in Aherua pre-seed and Bhadia seed crop, ranges from 24-36°C coupled with high humidity of 85-95%. Because of these inclement climatic conditions as well as other biotic factors viz., diseases and insect predators, the pre-seed and seed crops are low productive (14-40% crop loss) and sometimes highly uncertain and uneconomical (Chkravorty et al., 2007). However, these pre-seed and seed crops are mandatory to maintain the linkage for production of commercial seed for Katia crops.

Particularly, during the summer pre-seed crop (Aherua), muga silkworms are exposed to the extremes of temperature and relative humidity detrimental to congenial development, which results in poor crop harvest in terms of quality and quantity. The rate of multiplication of seeds from pre-seed crop cocoons is also affected due to lack of quality seed cocoons obtained from the adverse Aherua pre-seed crop, which results in high cocoon dfl ratio and low hatching. As such, the rearing vis-à-vis seed production from summer pre-seed crop (Aherua) is identified as a major constraint and critical aspect in Muga culture, which is considered as a bottleneck in augmenting Muga production.

In view of the above mentioned circumstances, this study is undertaken to tackle or to overcome the constraints of Aherua (May-June) pre-seed crop linked with the Katia (October - November) commercial seed production of Muga silkworm. An attempt is being made in this study to develop a suitable long term seed cocoon preservation method for skipping unfavourable Aherua pre-seed crop rearing of Muga silkworm by postponing moth emergence.

MATERIAL AND METHODS

Muga silkworm seed cocoons of 8 days old from commercial Jethua (April-May) crop were preserved in two lots at 7.5° and 10°C for 20 days initially followed by intermediate temperature treatment of 12.5°C for two days to allow pupae to develop to the next stage. Subsequently, treated pupae were further subjected to second step refrigeration for 10-30 days in BOD incubator and released at 10 days interval, *i.e.,* after 32, 42 and 52 days of preservation. During the time of consigning and releasing, the cocoons were passed through an intermediate temperature exposure of 15°C for 12 hrs. After releasing from BOD incubator, the seed cocoons were kept in air condition room at temperature

Table 1: Grainage performance of muga seed cocoons preserved for longer duration (32, 42 and 52 days) at low temperatures (7.5°C and 10°C).

SL No.	Parameters	Preservation Duration (Days)						Control
		LOT-I (7.5°C)			LOT-II (10°C)			
		32	42	52	32	42	52	Normal Room condition
1	Pupal period (days)	48	58	68	44	53	62	18
2	Emergence after release (days)	7	7	7	3	2	1	-
3	Emergence (%)	100	98.00	96.67	100	100	98.0	98.50
4	Coupling (%):	58	45	28	72	63	39	65.00
	Natural							
	Manual	18	15	07	19	17	08	54.8
		06	06	09	04	05	09	45.2
5	Invalid Moth							
	Male	-	-	43	-	-	21	4
	Female	-	-	35	-	-	6	3
6	Fecundity (No)	196	162	153	200	192	185	190
7	Hatching (%)	64.00	55.40	50.80	79.80	68.60	45.80	80.00

27±1°C and relative humidity 75-85% for grainage operation. The grainage performance of the preserved lots of seed cocoons in respect of total pupal period, the time taken for emergence after release, percentage of moth emergence, percentage of coupling, number of invalid moths, percentage of fecundity and hatching were studied.

RESULTS AND DISCUSSION

The recorded data of the present observations are tabulated in Table 1. Pupal period was prolonged up to a maximum of 68 days (at 7.5°C) followed by 62 days (at 10°C) in 52 days preservation as compared to 18 days in the control. Moth emergence ranged from 96.70 to 100.00% and there was not much significant difference among the treatments. However, the emerged moths were found crippled and invalid when preserved for longer duration of 52 days at 7.5°C and 10°C. Coupling percentage was recorded maximum of 72% at 10°C preserved for 32 days followed by 63% preserved for 42 days. However, 58% followed by 45% coupling was observed at 7.5°C preserved for 32 and 42 days, respectively. The crippled and invalid moths were more in number, when the seed cocoons were preserved beyond 42 days. Fecundity was recorded maximum of 200 at 10°C followed by 196 at 7.5°C in 32 days preservation as compared to 190 in the control. Hatching was maximum (79.80 %) in 32 days preservation followed by 68.60 % in 42 days preservation at 10°C as compared to 80 % in the control. However, 25 to 30% eggs were found depressed when preserved beyond 42 to 52 days both at 7.5°C and 10°C.

These results are found in contrast to the findings of earlier workers. Attempts made by earlier workers to preserve seed cocoons at 5°C beyond 30 days led to detrimental effects on economic characters in muga silkworm (Sengupta and Singh, 1974 and Bharali, 1982; Anonymous, 1999-2000).). It was also observed that tolerance of this temperature beyond 30 days was fully detrimental, but its tolerance beyond 120 days showed almost complete pupal mortality (Choudhury et al., 1987)

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 350-353

STUDIES ON *EX-SITU* CONSERVATION OF WILD SILKMOTH OF MUGA SILKWORM *ANTHERAEA ASSAMA* Ww

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ABSTRACT

The present study is an attempt for ex-situ conservation of the muga wild silkworm and its comparison with the semi domesticated race. Highly significant differences were observed in male and female larval weight, shell weight and shell ratio between wild and semidomestic races in different rearing seasons. In wild race, fecundity, hatching percentage, larval weight of both male and female, ERR%, cocoon weight, shell weight and shell ratio ranged from 132 to 147 , 60.08% to 80.62%, 6.74g to 7.96g (male), 8.96g to 11.16g (female), 12.54 to 48.50, 5.86g to 7.24g, 1.32g to 1.51g, and 18.23% to 25.77% respectively, while theses values in the semi domestic race ranged from 130 to 150, 70% to 78.8%, 4.92g to 6.02g (male) , 8.66g to 9.42g (female), 14.48 to 60.12, 5.42g to 6.84g, 0.39g to 0.49g and 6.61% to 9.04%. The present study showed that the wild muga silkmoth can be effectively utilized for commercial muga silk production.

Key words: *Ex-situ* conservation, Muga silkworm, Semi domesticated, Wild

INTRODUCTION

The muga silkworm is polyphagous in nature and feeds on a wide range of host plants.(Choudhury,1970). Among the food plants, 'som' *Persea bombycina* and 'soalu' *Litsea monoptala* Juss, are the two major primary food plants. The cultivated race of muga silkworm is multivoltine in nature and completes five to six crops in a year. The climatic conditions of North-Eastern region are congenial for the lepidopteran species and it survives up to 1370 m AMSL (Das *et. al.*, 2000). Sengupta *et.al*. 1975, collected different muga stocks from different eco pockets and named them on the basis of larval body colour. Suryanarayan and Dutta (2003) reported that wild muga silkworm is available in different pockets of Assam and Meghalaya and collected and characterized nine ecotypes. The naturally existing wild silkmoth of muga will become extinct due to deforestation, pest and predators and rapidly changing environmental conditions. Therefore, proper strategies must be taken up for the in-situ and ex-situ conservation of the important wild genetic resources of muga silk moth for utilization in future breeding programme and subsequent commercial exploitation for higher production of muga silk. The present study is an attempt for ex-situ conservation of the muga wild silkworm and its comparison with the semi domesticated race.

MATERIAL AND METHODS

One hundred and five muga wild silkworm (2nd stage larvae) were collected from the Rangrasim area of South Garo Hills, Meghalaya during the month of Oct'06 and reared them on "soalu" *Litsea monoptala* Juss till maturation. Maturation took place 32 days after date of collection. Total ninety-seven larvae were matured and put them in jali for spinning. Harvesting was done after 13 days of spinning and out of total cocoons, 92 were selected as seed cocoons. After recording their cocoon weight, cocoon shell weight and cocoon shell ratio (SR%), they were preserved till emergence. Emergence of moths started during the 1st week of April, and due to lack of synchronization of emergence between male and female moths, only 27 coupling could be obtained. The moths were allowed to couple for 10-12 hours and after decoupling, individual female moth was kept for egg laying for 72 hours on the Kharika by tying the female moth with help of a thread. The collected eggs were disinfected in 2% formaline solution and washed in plain water. After drying, the eggs were incubated at 22±2°C. The hatched larvae were reared in outdoor on the foliages of soalu *L. monoptala* in five replications in RBD in the farm of Tura, West Garo Hills, Meghalaya during four rearing seasons *viz.* 'Aherua', Early Bhodia, Late-Bhodia and Late-Kotia along

with semi-domestic stock. The rearing and grainage performance of the said wild race was compared with the general semi-domestic race to study their variation in different parameters like fecundity, hatching percentage, weight of matured larvae, effective rate of rearing (ERR%), cocoon weight, cocoon shell weight, SR%. emergence percentage, coupling aptitude, and oviposition behaviour. Data were statistically analyzed following standard statistical procedures. Student's "t" test was performed to compare the performance of the wild and semi-domestic races.

RESULTS AND DISCUSSION

Seasonal influence on rearing performances have been observed in fecundity, hatching percentage, weight of male and female matured larvae, ERR%, cocoon weight, Shell weight and Shell ratio percentage in both the races as reflected in Table 1 and 2.

Fecundity

The fecundity ranged from 132 -147 in wild race and from 130 to 150 in semidomestic race during the different rearing seasons. Significantly highest fecundity was recorded during "Baishaki" crop *i.e*. April-May and July-Aug, while, there was no significant difference in realized fecundity during June-July, Sept-Oct and Nov-Dec in wild race ($p>0.05$). In semi-domestic race, significantly higher fecundity was observed during April-May and July-August ($p>0.05$) but no significant difference was observed in other seasons ($p>0.05$). However, no significant difference was observed in the fecundity of wild and semi-domestic races throughout different rearing seasons.

Hatching

The hatching percentage ranged from 60.08% to 80.62% in wild and from 70% to 78.8% in semi-domestic race throughout different rearing seasons. The hatching percentage of wild race was significantly higher during April-May crop than the other seasons ($p<0.05$). Significant differences in hatching percentage were not observed in other crops in wild as reflected in Table 1. In semi-domestic stock, there was no significant difference of hatching percentage in all the rearing seasons ($p>0.05$). No significant difference was observed in the hatching percentage between the wild and semi-domestic races throughout the different rearing seasons.

Larval weight

The male larval weight ranged from 6.74g to 7.96g in wild race whereas in the semi-domestic race it ranged from 4.92g to 6.02g. Female larval weight in wild ranged from 8.96g to 11.16g and in semi-domestic it ranged from 8.66g to 9.42g during different seasons. In male and female larval weight, significant differences were observed in wild and semi-domestic races during different rearing seasons ($p<0.05$).

ERR%

The ERR% of wild race ranged from 12.54 to 48.50 with the highest value during L/Kotia, while in semi-domestic stock it ranged from 14.48 to 60.12 with the highest value during Baisakhi (April-May). No significant difference was observed in the ERR% between the wild and semi-domestic races during different rearing seasons ($p>0.05$).

Cocoon weight

The cocoon weight ranged from 5.86g to 7.24g in wild whereas it ranged from 5.42g to 6.84g in semidomestic race throughout all rearing seasons. However, there was no significant difference of cocoon weight between the wild and semi-domestic races during different rearing seasons ($p<0.05$).

Shell weight

The shell weight ranged from 1.32g to 1.51g in wild race without any significant variations during the different seasons ($p>0.05$). In semi-domestic race the shell weight ranged from 0.39g to 0.49g without any significant variations during the different seasons ($p<0.05$). Highly significant difference was observed in the shell weight between the wild and semi-domestic races throughout different rearing seasons ($p<0.05$).

Shell ratio

Significantly higher SR% in wild race was recorded during Sept-Oct crop ($p<0.05$) but no significant differences was observed in other seasons. In semi-domestic race, the SR% was significantly higher during Sept-Oct and Nov-Dec crop ($p<0.05$). In this character, highly significant difference was observed between wild and semidomestic races during different rearing seasons ($p<0.05$).

The wild silk moths play an important role in the conservation and utilization of biodiversity (Frankel, 1982; Peigler, 1993). The conservation links genetic diversity to utilization, protecting diverse gene pool, habitat or ecosystem for human socio-economic needs (Metzler and Zebold, 1995). The ecorace conservation is must for utilizing their valuable genes in enhancing productivity and to build variation in new population through hybridization (Mirhoseini *et al*. 2004; Kumaresan *et al*. 2004) . The studies carried out in the silkworm have shown that the characters could be pooled to suit the breeder's choice since selection for one trait has a correlation with genetic changes for other traits (Gamo, 1976; Tazima,, 1984). The stability of the characters like cocoon weight and cocoon shell ratio of the muga silkworm shows that the expression of these characters are

Table 1: Pre-cocoon characters of wild and semi-domestic (s/d) races of muga silkworm

Crops	Fecundity		Hatching		Larval wt				ERR%	
					male		female			
	wild	s/d	wild	s/d	wild	s/d	wild	s/d	wild	S/d
April-May	147*	150**	80.62**	73.8	7.96	6.02*	11.16*	9.42	12.54	60.12*
May-June	136	138	60.28	72.2	7.54	5.32	10.02	8.82	44.39*	38.48
July-Aug	143*	144**	63	70	7.88	6	9.84	9.08	29.80	14.48
Sept-Oct	132	132	62.42	71.2	6.74	5.94	8.96	8.72	20.73	34.44
Nov-Dec.	135	130	60.08	78.8*	7.14	4.92	10.78	8.66	48.50	37.04
CD 5%	8.27	10.94	11.62	45.94	0.68	0.66	1.14	0.42	20.47	21.73
CD 1%	11.39	15.06	16.00	6.33	0.93	0.91	1.58	0.57	28.20	29.93
't' value	0.03		1.89		5.67**		2.97*		0.57	

* significant at 5%., ** significant at 1%

Table 2: Cocoon characters of wild and semidomestic(s/d) races of muga silkworm

Crops	Cocoon wt(g)		Shell wt(g)		Shell ratio(%)	
	Wild	s/d	Wild	s/d	Wild	s/d
April-May	7.24	6.2	1.32	0.41	18.23	6.61
May-June	6.36	6.84	1.35	0.48	21.22	7.02
July-Aug	6.08	5.46	1.32	0.39	21.71	7.14
Sept-Oct	5.86	5.42	1.51	0.49	25.77	9.04
Nov-Dec.	6.08	6.12	1.32	0.49	21.71	8.01
CD 5%	0.72	0.79	0.36	0.07	3.01	0.78
CD 1%	0.99	0.09	0.50	0.09	4.15	1.08
't' value	0.88		21.32**		11.09**	

** significant at 1%

more of genetic nature and the genes controlling these characters can be introgressed from the wild variety to the semi domestic variety through suitable breeding method. Siddiqui & Das, (1998) have reported the high heritability of the traits-cocoon shell weight, single cocoon filament length, weight of reeled silk, reelability, reelability ratio, denier and weight of waste silk in muga silkworm.

Biodiversity conservation is increasingly recognized as a fundamental component of sustainable development of natural resources by protecting and using biological resources in the ways that do not diminish the world's variety of genes and species or destroy important habitat or ecosystem. The stability of the the different rearing parameters in all generations of the of the wild race showed that it can be successfully conserved in ex-situ condition in cilimatic condition of Tura. The present study showed that the wild muga silkmoth can be effectively utilized for commercial muga silk productioion.

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SEASONAL INFLUENCE ON GRAINAGE PERFORMANCE OF MUGA SILKWORM *ANTHERAEA ASSAMA* IN TERAI REGION OF WEST BENGAL

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ABSTRACT

The grainage performance of muga silkworm, *Antheraea assama* Ww., has been studied in the present investigation. The impact of different seasons on the adult emergence, coupling and egg laying has been studied. The correlation between the adult emergence coupling and egg laying revealed that the number of valid male and female had significant influence on natural coupling and fecundity, whereas the invalid male and female had positive and significant impact on mechanical mode of coupling. Considering the grainage parameters like good moth emergence, higher coupling in natural mode, higher fecundity, lower level of rejected layings and higher percent of good laying, it can be said that the spring (April and May) was the best season for Muga seed production and summer (August) and winter (December) was found comparatively unsuitable with higher mechanical coupling, low fecundity, higher emergence of crippled female moth. July and October was recorded to be moderately suitable for Muga seed production in this zone.

Key words: *Antheraea assama*, Coupling, Egg laying, Fecundity, Valid adult

INTRODUCTION

Muga silkworm (*Antheraea assama* Ww. Syn. *Antheraea assamensis* Helf., *Antheraea mejunkari* Moore) is a representative of the order Lepidoptera and family Saturnidae. The adult insects are large and found mainly in tropical countries; a few are also present in temperate regions. Muga culture is unique to the North eastern region of India. Over 90% of total muga raw silk production in the country is done only in Assam. The silkworm is multivoltine in nature, with six broods per year, including two crops each of pre-seed, seed and commercial respectively. Chotua and Bhodia are seed crops, Jethua and Kotia are commercial crops and Jarua and Aherua are the pre-seed crops. With the view to boost its production, Muga culture has been introduced in Coochbehar, Jalpaiguri and Darjeeling districts of West Bengal having similar agro-climatic conditions at par with that of Assam.

The quality of seed cocoon is greatly influenced by a number of factors like nutritious leaf, disease free layings, optimum temperature and relative humidity. The fecundity of muga silkworm was found to depend on the nutrient status of food plants as influenced by the seasonal weather conditions (Ghorai, 2005). The moth emergence, coupling, oviposition behavior, egg characters are fully dependent on surrounding environments (Barah *et al.*, 2001 and Ghorai, 2005). An attempt was made to study the grainage characters in different rearing seasons in the newly explored non-traditional area of muga culture, Cooch Behar, West Bengal, India.

MATERIALS AND METHODS

The Muga silkworm (*Antheraea assama,* Westwood) was reared in outdoor conditions in five different seasons during 2007-2010 at Research Extension Centre, Regional Muga Research Station, Central Silk Board, Cooch Behar, West Bengal, India. The rearing was conducted during Bhodia (August-September), Katia (October-November), Jarua (December-February), Chotua (February-March) and Jethua (April-May).

The disease free layings were collected and dipped in 2% formaldehyde solution for 5 minutes, washed in water and dried to prevent contamination of germs on the surface of egg shells. After disinfection the eggs were kept in well-aerated egg laying boxes for hatching. On the expected day of hatching the eggs were made to hatch in the Som tree (*Machilus bombycina*), in the morning. The larvae soon after hatching (in the early morning hours) crawled on the leaf and started feeding. The host plants selected for rearing were covered by nylon net before releasing of larvae. Constant watch was kept at the rearing site to protect the larvae from predators like wasps, birds and bats *etc*. Bamboo *Chaloni* was used to transfer the worms from one Som tree to another as and when required for providing continuity of leaf availability. The larvae were collected upon attaining their maturity and kept in cocooning device for spinning. After formation of cocoon they were removed carefully from the cocoonage as per recommended norms and kept in well-aerated place.

The grainage characters such as emergence of valid and invalid adults (both male and female), duration and percentage of adult emergence, total coupling (natural and mechanical), egg laying (total layings and rejected layings) were recorded in each crop schedule. Month-wise meteorological data *viz*, maximum and minimum temperature and relative humidity were recorded. Data thus obtained from different rearing seasons in three years were pooled, analyzed statistically and presented in Table 1-8.

RESULTS

The adults started to emerge from late afternoon and continued till dawn. Quantum of emergence recorded was more in the evening that morning hours. Generally male moths emerged earlier than the female (protrandry). Newly emerged adult crawls to a support to spread its wing by pumping haemolymph into the wing veins and remains motionless while the wing hardened. Under normal conditions coupling started in the evening and leave to continue till dawn and those coupled in dawn were decoupled in late afternoon. The female started laying eggs from evening and continued upto dawn.

Adult emergence

Season-wise variation in adult emergence was recorded (Table 1). The duration of emergence period was found maximum in December (8.67 days) closely and non-significantly followed by May (8.33 days) and October (8.00 days). The emergence was recorded maximum of 95.90% in October followed by 95.31% in April, the two commercial seasons, the minimum being recorded in May 82.33%. Among the adults maximum good female was in July 35.78% and minimum in August (22.41%), while for male it was maximum during April (50.70%) and October (43.25%) and minimum in August (25.02%). Reverse trend was observed in case of invalid (crippled) male and female (Maximum of 18.25% and 19.23% in August for male and female and the minimum of 9.58% and 5.23% in April for male and female respectively).

Coupling

The mode of coupling varies significantly among the seasons (Table 2). Coupling occurs mostly by natural means in higher rate in all the seasons except in the warmer month when most of the coupling occur through mechanical way. Highest coupling occur naturally in December (74.89%), followed by April (66.79%) and May (64.83%). On the other hand in the warmer months *i.e*., in July and August the coupling was done mechanically (41.47% and 53.90% respectively).

Egg laying

Egg laying performance (Table 3) depends on the mode of coupling. Good laying was recorded significantly maximum in April (93.46%) followed by October (78.18%) and the minimum was recorded in August (60.29%). Correspondingly, no laying and poor laying was minimum in April (1.98% and 1.20% respectively) and it was significantly more in August (11.09% and 28.62% respectively). It was observed that the cocoon-dfl ratio was maximum (8.00:1) in August and it was only 3.36:1 in April. In other seasons there was no significant variation.

Assessment of egg production

Average fecundity (eggs laid in first 3 days) was recorded maximum in April (143.33) closely followed by May (138.33) and the minimum in August and December (125.00 and 125.67). Though the average fecundity was found in lower scale of 134.67 and 133.67 in July and October respectively but the weight of egg was found maximum *i.e* 1.03 gm and 1.09 gm as compared to other seasons.

The percent of layings rejected in different seasons varied significantly (Table 4). It was maximum 17.78% in December followed by July with 12.40% and least being recorded in April (3.48%). The main cause of rejection was pebrine, bacteria and others. Among them, rejection due to pebrine infection was maximum during October (6.08%) followed by July (5.94%) and the infection was recorded lowest during April and August (1.68% and 1.89%). Rejection due to bacterial infection was found significantly more in cool month of December (6.48%) and the infection was absent in April.

Correlation of grainage parameters with the climatic conditions prevailing during oviposition period and the entire rearing period (Table 5) showed that the climatic condition during rearing period have significant effect on

Table 1: Seasonal influence on adult emergence behavior of muga silk moth

Months	Duration of adult emergence (Days)	% Adult emergence	Valid male %	Valid female %	Invalid male %	Invalid female %
April	6.00	95.31	50.70	34.47	9.58	5.23
May	8.33	82.33	24.05	34.04	15.36	12.53
July	6.00	85.69	34.12	35.78	14.32	15.78
August	6.50	84.51	25.02	22.41	18.25	19.23
October	8.00	95.90	43.25	29.98	14.24	12.54
December	8.67	87.94	37.51	32.51	14.50	14.48
Mean	7.25	88.61	35.78	31.53	14.37	13.30
S.Em(±)	1.5969	7.5658	10.3295	8.3692	9.1106	8.2104
CD at 5%	3.5580	16.8576	23.0155	18.6477	20.2997	18.2938

Table 2: Seasonal influence on coupling behavior of muga silk moth

Month	Mode of coupling (%)	
	Natural	Mechanical
April	66.79	33.21
May	64.83	45.17
July	58.53	41.47
August	44.61	53.90
October	51.00	49.00
December	74.89	25.11
Mean	60.11	39.89
S.Em(±)	13.7251	12.7950
CD at 5%	30.5813	28.5088

Table 3: Seasonal influence on egg laying performance of muga silk moth

Month	No laying %	Poor laying %	Good laying %	Cocoon:dfl
April	1.98	1.20	93.46	3.36:1
May	5.26	10.41	75.70	5.51:1
July	6.18	10.36	76.63	4.87:1
August	11.09	28.62	60.29	8.00:1
October	4.82	7.52	78.18	6.54:1
December	6.97	7.24	72.70	5.34:1
Mean	9.38	7.56	75.32	5.60:1
S.Em(±)	4.8355	8.8129	12.4578	2.3008
CD at 5%	10.6867	19.7238	27.7575	5.1264

Table 4: Qualitative and quantitative assessment of egg production of muga silk moth

Month	Percent layings rejected due to				Average fecundity	Wt/dfl (gm)
	Pebrine	Bacteria	Others	Total rejection		
April	1.68	0.00	1.80	3.48	143.33	0.98
May	4.99	4.25	0.67	9.91	138.33	0.97
July	5.94	3.82	2.64	12.40	134.67	1.03
August	1.89	2.16	5.88	9.93	125.00	0.90
October	6.08	3.51	1.28	10.87	133.67	1.09
December	5.34	6.48	5.96	17.78	125.67	0.99
Mean	4.32	3.37	3.04	10.73	133.44	0.99
S.Em(±)	3.2961	2.4612	2.99	2.342	6.0803	0.0844
CD at 5%	7.3441	5.4838	6.66	5.217	13.5478	NS

Table 5: Correlation coefficients of grainage parameters with the rejected layings

	Climate during	Max°C	Min°C	MaxRH%	MinRH%	No, of rainy days	No. of stormy days
Pebrine	Oviposition	-0.0174	0.0039	0.2050	0.2227	-0.2456	
	Rearing	-0.0256	-0.0649	-0.4675*	0.1243	-0.0801	0.3562
Bacteria	Oviposition	-0.3064	-0.2687	0.2676	0.2978	-0.0353	
	Rearing	-0.4336*	-0.0852	0.0967	0.5002*	-0.2612	-0.3603
Others	Oviposition	-0.2005	-0.2648	0.0979	0.2525	0.2522	
	Rearing	-0.0109	0.1100	0.1645	0.3118	-0.0731	-0.1708
Avg.	Oviposition	0.2458	0.0110	-0.3412	-0.5224*	-0.1648	
Fecundity	Rearing	0.4437*	-0.1151	-0.1950	-0.5068*	0.0684	0.0834
Wt/dfl	Oviposition	0.0771	0.0489	0.2055	0.1858	0.0228	
	Rearing	0.4679*	0.1819	-0.2632	0.0380	-0.1365	0.3539
Valid male	Oviposition	-0.2682	-0.1423	-0.2792	-0.5824*	-0.0859	
	Rearing	-0.1911	-0.3300	0.1028	-0.1085	-0.2644	0.0423
Valid female	Oviposition	-0.1337	-0.1649	-0.1586	-0.1790	0.0072	
	Rearing	-0.1926	-0.3506	-0.0268	-0.1569	-0.0488	-0.2337
Invalid male	Oviposition	0.0854	0.0432	0.1555	0.3441	-0.0641	
	Rearing	0.2120	0.1964	0.0624	0.0904	0.2212	0.2243
Invalid female	Oviposition	0.0724	0.0045	0.2718	-0.3870	-0.0637	
	Rearing	-0.2524	-0.3707	-0.1808	0.0319	-0.3406	-0.3683
Duration of	Oviposition	-0.1872	-0.0602	0.0447	0.0844	-0.1961	
emergence	Rearing	-0.4911*	-0.1733	0.0494	0.3248	-0.1958	-0.1482
Natural	Oviposition	-0.3813	-0.4440*	-0.2951	-0.3870	-0.0637	
coupling	Rearing	-0.2524	-0.3707	-0.1808	0.0319	-0.3406	-0.3683
Mechanical	Oviposition	0.4696*	0.4713*	0.3759	0.4780*	0.3495	
coupling	Rearing	0.3267	0.4001*	0.0402	0.0659	0.3647	0.3885
% adult	Oviposition	-0.2322	0.0231	-0.2315	-0.3856	-0.1738	
emerged	Rearing	-0.0962	-0.1194	0.3065	0.0115	-0.2234	0.3848
No laying	Oviposition	0.2696	0.3243	0.3731	0.2199	0.5472*	
	Rearing	-0.1324	0.3632	0.0711	0.3726	0.4214*	-0.3528
Poor laying	Oviposition	0.2863	0.1261	0.4833*	0.6106*	0.4675*	
	Rearing	0.2214	0.1363	-0.1126	0.2952	0.4104*	0.1807
Good laying	Oviposition	-0.1823	-0.2070	-0.5164*	-0.4973*	-0.4893*	
	Rearing	0.0819	-0.3291	-0.1211	-0.5293*	-0.3867	0.1875
Cocoon:dfl	Oviposition	0.1844	0.2694	0.3341	0.4534*	0.1266	
	Rearing	0.1625	0.3456	0.0642	0.2581	0.2054	0.3144

*Significant at 5% level

Table 6: Correlation coefficients of grainage parameters with the rejected layings

	Rejected layings%		
	Pebrine	Bacteria	Others
Fecundity	-0.2689	-0.2599	-0.4896*
Good laying	0.0719	0.0081	-0.6630*
Duration of emergence	0.0280	0.6967*	-0.2470
% emergence	-0.0034	-0.0233	-0.3442
Wt/dfl	0.2193	-0.1614	0.0304
Cocoon:dfl	0.2665	0.5860*	-0.5853*
Natural coupling	-0.2557	0.3414	-0.3518
Mechanical coupling	0.2291	-0.3070	0.3756

*Significant at 5% level

Table 7: Correlation coefficients of adult emergence with coupling and grainage parameters

	Laying					Coupling		
	No	Poor	Good	Average fecundity	Wt/dfl	Cocoon: dfl	Natural	Mechanical
Duration of emergence	-0.0850	-0.5689*	-0.0661	-0.2772	-0.1555	0.0067	0.1693	-0.1914
Valid male	-0.3246	-0.4288*	0.5179*	0.4049*	0.1196	-0.7288*	0.4728*	-0.4290*
Valid female	-0.4709*	-0.2664	0.4900*	0.3547	-0.0077	-0.8809*	0.5932*	-0.5115*
Invalid male	0.4020*	0.4953*	-0.5732*	-0.3535	0.0563	0.8625*	-0.5832*	0.5302*
Invalid female	0.4765*	0.5916*	-0.6766*	-0.5608*	-0.0045	0.8605*	-0.6910*	0.6703*

*Significant at 5% level

occurrence of diseases (pebrine and bacterial), duration of emergence period, fecundity and the weight of dfl ; whereas climatic conditions prevailing during oviposition period found to have significant impact on mode of coupling, emergence of valid male, cocoon-dfl ratio. The number of rainy days during both the periods had significant relation with egg laying performance.

Table 6 showed that bacterial infection had significant and positive effect on duration of emergence and cocoon-dfl ratio. The rejection due to other causes showed negative and significant relation on fecundity, good laying and cocoon-dfl ratio; bacterial infection increased with the extended emergence period, and increase in cocoon-dfl ratio; while pebrine infection was found to have no significant impact.

Correlation of adult emergence was found to have significant and negative relation with poor laying. The emergence of valid male and female showed negative and significant relation with no laying, poor laying, cocoon-dfl ratio and mechanical coupling while it was recorded positive and significant with good laying, natural coupling and fecundity. The trend was found reverse in case of invalid adults (both male and female) (Table 7).

DISCUSSION

A critical look into the result suggested that the emergence of adult was recorded higher during April (95.31%) and October (95.90%) and lowest in May (82.33%) and August (84.51%). Ghorai (2005) also recorded maximum no. of emerged adult in March-April (89.92%) and lowest in May-June (65.13%). Das and Das (2003) found 96.71% of moth emergence in Assam. In the present study it was found that the male percent was more than female. Ghorai (2005) also reported similarly. The total emergence period was longer (17.61 days) in October-November and the duration was shortest (6.54 days) in May-June as reported by Ghorai, 2005. The result of the present study also suggested that the duration of emergence was maximum in December (8.67 days) and minimum in July (6.00 days). Valid adults were found maximum in April (50.70% and 34.47% for male and female respectively) and October (43.25% and 29.98% for male and female respectively) and the crippled one was recorded maximum in the months of August (18.25% and 19.23% for male and female respectively). The minimum percent of valid adults was recorded in August (25.02% and 22.41% for male and female respectively) and for the crippled one it was April (9.58% and 5.28% for male and female respectively). The mode of coupling was occurred naturally in higher percent in all the months studied excepting August when coupling was occurred mainly mechanically. During cooler months of December coupling occur mainly naturally (74.89%) followed by April (66.79%) and May (64.83%).

During April egg laying performance was found to be the best 93.46% and the minimum being recorded in August (60.29%). The female laid no eggs and poor eggs in higher level during August (11.09% and 28.62%) and the corresponding values were found lowest (1.98% and 1.28%) during April respectively. It was found that 17.78% of layings were rejected during collection in December. Rejection due to pebrine infection was recorded maximum in October (6.08%) and lowest in April (1.68%) and in August (1.89%). Bacterial infection was recorded highest in December 6.48% and the infection was absent in April. In Assam maximum incidence of disease was recorded during Aherua, Bhodia and Jarua crops when temperature and relative humidity remain above and below the optimum ranges. Sudden fluctuation of in temperature, relative humidity and rainfall is the main cause of flacherie disease.

The average fecundity was recorded maximum 143.33 in April also recorded by Ray (2003), and the minimum being found in warmest August 125.00 and coolest December 125.67. In October fecundity was recorded in higher level (133.67). The findings of Ray et al., (2005) also corroborate the present result. Thangavelu et al., (1988) recorded minimum fecundity in summer also confirmed present results. This might be due to impairment of ovarian development leading to decreased egg production high temperature as suggested by Yocum *et al*., (1994). The average temperature during the rearing moth had negative impact on fecundity but relative humidity showed positive influence as reported by (Thangavelu *et al*., 1988; Joseph *et al*., 2000; Bora and Handique, 2003 and Ghorai, 2005).

It was also found that fecundity, good laying, valid adults and natural coupling was the maximum in April followed by May. The corresponding values were recorded in minimum level in August and December. The cocoon-dfl ratio was found significantly lowest *i.e* les no. of cocoon is required to get one dfl where there occur higher percent of valid adults and the reverse trend was found in the case of invalid ones. Similarly coupling occurs significantly naturally when there occur maximum emergence of valid adults that also increased the fecundity.

Therefore, it can be concluded that the performance of grainage parameters were varied among different seasons. Considering the grainage parameters like good moth emergence, higher coupling in natural mode, higher fecundity, lower level of rejected layings and higher percent of good laying, it can be said the spring (April and May) was the best for muga seed production and summer (August) and winter (December) was found comparatively unsuitable with higher mechanical coupling, low fecundity, higher emergence of crippled female moth. July and October was recorded to be moderately suitable for muga seed production in this zone under consideration.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 360-362

ISOLATION OF A DIAPAUSE LINE OF MUGA SILKWORM *ANTHERAEA ASSAMENSIS* HELFER

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ABSTRACT

A study was conducted for the isolation of a diapauses line in *Antheraea assamensis* Helfer and its comparative rearing performance with the semi-domestic race. Twentyfive wild muga silkworm larvae were collected from foothills of Nagaland during the month of September and reared on som foliage in ex-situ condition at the farm of CMERTI Lahdoigarh. 40% of the harvested stock underwent pupal diapause from October to March which was isolated and inbred for sixteenth generations followed by selection of the diapause line in each generation. At the sixteenth generation, pure diapause line was achieved. The isolated diapause line underwent pupal diapause during October to March. The comparative performance of the important economic characters *viz*., average fecundity, larval duration, effective rate of rearing (ERR%), cocoon weight, shell weight and shell ratio of the diapause line and non diapause line are discussed in the present paper.

Key words: *Antheraea assamensis*, Diapause line, Non diapause line, Pupal diapause

INTRODUCTION

Most insect species have evolved a period of developmental arrest (diapause) that enables them to circumvent seasonal periods of adversity. For insects in the temperate zone, winter is the season most consistently avoided. It is not at all uncommon for a species to spend 910 months in diapause, with only 23 months of summer devoted to active development and reproduction (Saunders, 1982; Tauber, *et al,*. 1986). Within a single species the potential for diapause usually is restricted to a specific developmental stage, but embryonic, larval, pupal, and adult diapauses are all well documented. Whether the insect will enter diapause usually is dictated by the day-length perceived by the insect at an earlier stage of development. Long day-lengths frequently channel the insect toward uninterrupted development during late spring and early summer, whereas the short day-lengths of late summer and autumn program the entry into diapause. Day-length thus presides over the hormonal mechanisms that direct the insect toward either diapause or nondiapause development (Denlinger, 1985). Insects in diapause are totally dependent on the energy reserves that have been sequestered during earlier active phases of the life cycle. Suppression of metabolism enables the insect to stretch its food reserves to bridge the unfavorable period. For undergoing diapause, insects having wide range of geographical variation programme for diapauses well in advance after recognizing the adversities of nature (Tauber, *et. al*., 1986, Leather *et al.,* 1993). The oak tasar silkmoths undergo facultative diapauses at the pupal stage (Singh and Singh, 2002; Mishra *et al*., 2009). Some of the wild population of the sericigenous insect, *Antheraea assamensis* Helfer also undergoes diapause at the pupal stage during certain seasons. The present paper reports the isolation of a diapauses line in *A. assamensis* and its comparative rearing performance with the semi-domestic race.

MATERIALS AND METHODS

Twentyfive wild muga silkworm larvae were collected from foothills of Nagaland during the month of September and reared on som foliage in *ex-situ* condition at the farm of Central Muga Eri Research and Training Institute, Lahdoigarh. The harvested cocoons were consigned at the grainage room. Out of the twentyfive cocoons, 40% underwent pupal diapause from October to February. The diapause lot was isolated and inbred continuously for 16 generations followed by selection of the diapause lot and rejection of the non-diapause lot. After 16th generation pupal diapause character was achieved. The rearing performance of the diapause stock was studied by rearing in four seasons

Table 1: Pre-cocoon characters of Muga Silkworm Diapause(DL) and non –Diapause (NDL) lines

Season	Fecundity		Larval duration		ERR%	
	DL	NDL	DL	NDL	DL	NDL
Apr-May	215	146	23	23	58	55
Jun-July	195	125	19	19	28	35
Aug- Sept.	187	140	19	19	45	37
Oct-Nov	185	151	22	22	61	64
Nov-Jan	--	150	--	40	--	48
Feb-Mar	-	140	-	32	-	55
CD5%	11.01	10.79	9.50	10.53	16.52	17.39

Table 2: Cocoon characters of Muga Silkworm Diapause (DL) and non –Diapause (NDL) lines

Season	Cooon wt.		Shell wt.		Shell ratio		Pupal period	
	DL	NDL	DL	NDL	DL	NDL	DL	NDL.
Apr-May	7.21	5.48	0.65	0.45	9.01	8.21	20	20
Jun-july	6.62	5.57	0.56.	0.48	8,46	9.61	18	18
Aug-Sept	6.48	5.82	0.56	0.49	8.64	8.41	19	19
Oct-Nov	7.72	5.98	0.69	0.59	8.94	9.94	135	20
Nov-Jan	-	4.53	-	0.36	-	7.94		38
Feb-Mar	-	5.18	-	0.42	-	8.14	-	28
CD5%	0.61	0.59	0.069	0.091	0.47	0.85	65.88	9.15

Table 3: Temperature and relative humidity during the rearing period.

Season	Temperature^{o}C	Relative humidity(%)
Apr-May	20-34	64-82
Jun-July	27-37	66-98
Aug-/sept	24-36	62-94
Oct-Nov	21-33	61-83
Nov_Jan	08-19	41-73
Feb-Mar	19-30	62-85

during April-May, June-July, August-September and October-November continuously for three years and compared with the non-diapause stock. The important economic charecters *viz*., fecundity (no), larval duration (days), pupal period (days), cocoon weight (g), shell weight (g), Shell ratio (%) and effective rate of rearing (ERR%) were recorded for both diapause and non-diapause stocks during different seasons.

RESULTS AND DISCUSSION

The isolated diapause line of muga silkworm *A. assamensis* exhibited same percent of pupal diapause nature during the winter season after 16 generations. The data on the rearing performance of the diapause stock and non-diapause semi-domestic stock are presented in table 1A and 1B. Perusal of the data reveal that fecundity (no) was higher in diapause stock in all the seasons reared (185-215) than in non-diapause stock (125-151). The variations in fecundity of the diapause line during the seasons June-July, August-September and October November was insignificant ($p>0.05$). There was no significant difference ($p>0.05$) in the larval period of the diapause line during the four different rearing seasons. In the semi domestic race, the larval duration during November- January and February were significantly higher than the rest four seasons ($p<0.05$). During the four rearing seasons *viz*., April-May, June-July, August-September and October-November the larval duration of both diapause line and non-diapause semi-domestic race were almost at par.The ERR (%) of the diapause line significantly ($p<0.05$) differed during the different seasons (28%-61%) indicating the instability of this trait in this line.

The mean single cocoon weight was higher in diapause stock (6.48 to 7.72 g) than that of the non-diapause stock (4.53-5.98) during the different rearing seasons. The cocoon weight of the diapause line during October-November was significantly ($p<0.05$) higher than other seasons which may be due to the storage of more fat for undergoing diapause. However, in the non-diapause semi-domestic race the

variations in the cocoon weights during the different seasons were insignificant ($p>0.05$). The mean cocoon shell weight of the diapause line was higher in the diapause line (0.56g-0.69g) than that of the non-diapause race (0.36g-0.59). The cocoon shell weight and SR % of the diapause line during different rearing seasons differed insignificantly ($p>0.05$). The pupal period of the diapause line during October November was significantly ($p<0.05$) higher than the rest of the seasons revealing the pupal diapause nature of this line during winter season.

Diapause is a form of dormancy in insects, characterized by a suite of physiological changes that confer survival advantages during unfavorable seasonal conditions, such as the low temperatures of winter (Tauber *et al*., 1986; Denlinger, 1985; 2002). It is a major means of adaptation in insects to the seasonal changes of environment (Back, 1980; Saunders, 1982; Tauber *et al*., 1986; Danks, 1987). Diapausing insects may be highly tolerant to cold, heat, desiccation and starvation but these abilities are adaptively significant only when diapause starts at an appropriate time. The timing of diapause termination is also important for efficient utilization of resources being primarily determined by diapause intensity and secondarily regulated by seasonal cues. Similarly, some population of Muga silkworm *A. assamensis* undergo pupal diapause during November to March to withstand the adverse climatic condition and unavailability of the quality leaves during winter seasons and the pupa develops into adult moth when the favourable season approaches during March-April. The special characteristic feature of the isolated diapause line is the higher cocoon weight and higher shell weight. The diapause line of muga silkworm being superior in yield contributing characters, can be utilized for commercial production of silk and in further breeding programmes.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 363-365

IN VIVO USE OF STREPTOMYCIN SULFATE FOR BACTERIAL DISEASE CONTROL IN *ANTHERAEA ASSAMENSIS* HELFER THROUGH LEAF FRESHNESS TECHNIQUE

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ABSTRACT

Among all biotic and abiotic constrains in Muga silkworm culture, disease is the most consistent and devastating one. Bacterial flacherie is such a silkworm disease that inflects more than 42% crop loss. Antibacterial drugs like streptomycin sulfate can be used successfully through leaf freshness technique useable in indoor rearing of Muga culture. Drug solution is mixed with leaf sap as absorbent by Som plant twigs that larvae feed on and, targeted disease causing bacteria in larval gut are exposed to streptomycin action. In vivo use of streptomycin sulfate resulted complete control of flacherie disease caused by Bacillus bacteria up to fourth instars. Being bacteria free in gut, larval feeding was more that was directly reflected in larval body weight and indirectly increases vurvivality of larvae. In this experiment with in vivo use of streptomycin sulfate 42% more survivality up to fifth instars of Muga larvae was achieved over 92% mortality in control rearing.

Key words: Flacherie, Leaf freshness, Mortality, Streptomycin sulfate, Survivability

INTRODUCTION

Antheraea assamensis Helfer, the golden-yellow silk producer silk moth, is semi-domesticated sericigenous insect species endemic to North East India particularly Brahmaputra valley of Assam. This silk moth is semi-domesticated owing to the fact that only cocooning and grainage operations are conducted indoor and, reared on outdoor host plant trees. It is polyphagous, multivoltine reared in six different seasons throughout the year. Out of these six seasons two seasons *viz.*, May-June and October-November are commercial crop season, whereas other seasons are seed crop season. Again, the seed crops during December-January and June –July are called pre-seed crop. Thus, each commercial crop is preceded by one pre-seed crop and one seed crop. Since this pattern of Muga silkworm cultivation has been an age old practice, it is obviously environment controlled and the rearing performance is quite different in each season. Being outdoor in nature Muga silkworm are exposed to various natural vagaries and thus prone to numbers of diseases and pests leading to heavy crop loss (Choudhury, 1981; Samson, 1987 and Thangavelu *et al.* 1988). Of all constrains, silkworm diseases being the most important that inflect heavy loss to the crop. The 'Flacherie' disease caused by bacteria is most important, causing serious damage to the Muga silkworm (Chakravorty *et al.* 2007). The chief disease affecting silkworm is flacherie caused by Bacillus bacteria. One casual bacillus of silkworm flacherie is *B. thuringiensis* which is widely distributed facultative entomogenous bacterium with as many as 34 varieties. It is a garm-positive spore forming bacterium widely distributed in the soils of various regions of the world. The endotoxin of *B. thuringiensis* is known to destroy the gut lining, causing paralysis and death in many insect species belonging to orders, Diptera and Lepidoptera including economically important insects such as silkworm*, Bombyx mori* (Aizawa, 1971; Nataraju *et al*. 1991). *B. thuringiensis* infected larvae lost appetite and became sluggish from 5 to 6 hours of infection, larvae vomited the green fluid, excreta were soft and stick to the rearing bed. During molting, skin was not shed properly. The infection also led to diarrhea. As the disease advanced, the larvae became extremely sluggish, showed irritability to touch as if in pain. Later the colour of the larvae started to change into dark colour and larvae became almost inactive and unable to spin cocoons. The larval body started to shrink and the larvae became completely paralyzed. Finally, larvae completely turned to brown colour. Within 30 minutes after the larvae ingested the spores of *B. thuringiensis*, the mid gut epithelial cells became disorganized compared to healthy larvae. Some of the

Table 1: Comparison between treatment and control on different parameters and their statistical analysis.

Larval Instars	Treatment with streptomycin (T)				Control without treatment (C)			
	Larval weight in g (5 nos.)	Mortality (%)	Survivability (%)	Litters Weight (g)	Larval weight in g (5 nos.)	Mortality (%)	Survivability (%)	Litters weight (g)
I instar	0.0332	0	100	1.41	0.0218	4.00	96	1.409
II instar	0.0906	0	100	5.907	0.0892	6.25	90	5.893
III instar	0.4140	12	88	20.972	0.4000	28.89	64	17.851
IV instar	2.2290	20.45	70	42.299	2.1530	37.50	40	30.14
V instar	11.8200	28.57	50	256.8	10.867	80.00	8	81.645
TREND	14.5868	61.02	408	327.388	13.531	156.64	298	136.938

epithelial cells became detached from the wall of the mid gut. There exist 34 different varieties of *B. thuringiensis*. Among the 23 varieties of *Bt* tested, only eight were reported to be pathogenic to silkworms and the rest as non-pathogenic (*Selvakumar et al.* 1999). Disease incidence may be due to the lowering of pH by the introduction of bacteria, which provides congeniality and could lead to degeneration of peritropic membrane, which blocks the absorption of nutrients that is reflected by cessation of feeding. From flacherie infected mulberry silkworm, Sridhar *et al.* (2000) isolated bacteria belonging to genus *Streptococcus.*

The biological defense against pathogens in insects included the innate *physical* barriers *viz.,* integument and intestinal wall and humeral responses such as the activation of prophenol oxidase cascade and induction of immune proteins namely, lysozymes, lectins, antibacterial proteins and antifungal proteins primarily by the fat bodies. Intestine harbor a great diversity of native microbes which promote gut maturation, and integrity, antagonism against pathogens by producing antimicrobial proteins and immune modulation (Girishkumar *et al.* 2005). An countable number of researchers made effort to control 'Flacherie' in Muga silkworm by various biological and non-biological agents as spray, including streptomycin, an antibacterial drug, and reported as effective. Streptomycin sulfate is a bactericidal antibiotic and is a water-soluble amino glycoside derived from *Streptomyces griseus*. It is marketed as the sulfate salt of Streptomycin. The chemical name of Streptomycin sulfate is D-Strep amine, O - 2 - dioxin - 2 - (methyl amino) - α - L - glucopyranosyl - (1→2) - O - 5 - dioxin - 3 - C - formyl - α - L - lyxofuranosyl - (1→ 4) - N,N1-bis(aminoiminomethyl)- ,sulfate (2:3) (salt). The molecular formula for Streptomycin Sulfate is (C21H39N7O12)2 -3H2SO4 and the molecular weight is 1457.41. It acts by interfering with normal protein synthesis. Streptomycin is considered a second-line agent for the treatment of gram-negative bacillary bacteria. In this present context of study, effort has been made to test the efficacy of this drug in vivo in controlling bacterial diseases under indoor reared Muga silkworm through a new leaf freshness technique.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 366-368

MANAGEMENT OF WILD SILK *CRICULA TRIFENESTRATA* HELFER A PEST OF SOM PLANT (*PERSEA BOMYCINA* KOST.)

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ABSTRACT

Muga culture (*Antherea assamensis* Helfer) is an exclusive prerogative of North Eastern India and mainly practiced in Brahmaputra valley and its adjoining hills of Assam State (India). The successful rearing of the silkworm depends on availability of quality food plants/leaves apart from other climatic factors. The wild silk, *Cricula trifenestrata* Helfer, a saturniid wild silk infests *Som* plant (*Persea bomycina* Kost.) causing non-availability of quality leaves during commercial rearing seasons of muga silkworm. The caterpillars devour the entire leaf blade except the midrib giving a broom like appearance. Efficacies of different chemical pesticides were evaluated and observed that Endosulfan (0.05% and 0.1%) caused the highest larval mortality of *C. trifenestrata* and also rendered the highest residual toxic effect to muga silkworm. Deltamethrin (0.0014% and 0.0028%) and Azadirachtin (0.0015% and 0.003%) were found effective against *C. trifenestrata* with the lower residual effect to muga silkworm after 15 days of treatment. Muga silkworm larvae can be brushed safely only after 15 days of plants treated with neem based pesticide *i.e.* azadirchtin. However, extensive trials should be conducted to develop the technology prior adoption in the fields.

Key words: *Cricula trifenestrata*, Muga silkworm, Pesticides, *Persea bomycina.*

INTRODUCTION

Out of four different types of silkworms available in India, Muga culture (*Antherea assamensis* Helfer.) is an exclusive prerogative of North Eastern India and mainly practiced in Brahmaputra valley and its adjoining hills of Assam State. The golden yellow silk produced by the muga silkworm is unique in its fibre characters and is an avenue for rural livelihood as well as socio-economic development of the state. The successful rearing of the silkworm depends primarily on availability of quality food plants apart from other rearing facilities and climatic factors. Som (Persea bombycina Kost.) is the primary food plants for muga culture, because it is evergreen, effective rate of rearing (ERR) is always higher, and quantitative characters such as shell weight, shell ratio, and reelability are better in cocoons produced by som fed worms.

Among several insect pests infesting the som plants, the Saturniid wild silk, *Cricula trifenestrata* Helfer. locally known as '*Amphutukoni muga*' is the most serious insect pest and has become a menace to the production of leaf yield of som plant (Choudhury, 1981; Negi and Sengupta, 1993). The higher incidence of the pest is observed during main commercial rearing seasons of Muga *i.e*. October-November and March-April affecting the silk production. In view of this the present study has been undertaken to evaluate the efficacy of some insecticides against *C. trifenestrata* which is otherwise safer to muga silkworm.

MATERIALS AND METHODS

The field experiments to evaluate the efficacy of selected pesticides (Table 1) against *C. trifenestrata* and its residual effect on muga silkworm were conducted at experimental field of Assam Agricultural University, Jorhat. The experiment was laid out in a randomized block design with three replications of eleven treatments including control.

The first instar larvae of *C. trifenestrata* were released in the field @ 50 numbers per plant which was covered with nylon net. The insecticides were diluted in water in respective concentration and sprayed @ 1.25 litres per plant.

Table 1: Effectiveness of various insecticides against *C. trifenestrata* Helfer.

Treatments	Concentrations (%)	Per cent mortality of *C. trifenestrata*			
		1 DAT *	3 DAT	7 DAT	14 DAT
Endosulfan 35 EC	0.05	46.87^{b} (43.22)	65.67^{a} (54.15)	87.67^{ab} (69.47)	98.00^{ab} (81.87)
Endosulfan 35 EC	0.1	53.33^{a} (46.89)	74.67^{a} (59.80)	89.67^{a} (71.28)	100.0^{a} (90.00)
Azadirachtin 1500 ppm	0.0015	4.00^{e} (11.54)	23.33^{f} (28.86)	45.67^{d} (42.53)	96.67^{ab} (79.53)
Azadirachtin 1500 ppm	0.003	8.67^{e} (17.15)	32.00^{f} (34.45)	52.00^{d} (46.15)	99.33^{ab} (85.20)
Cypermethrin 10 EC	0.0075	18.00^{d} (25.10)	36.00^{c} (36.87)	68.00^{c} (55.55)	96.00^{b} (78.46)
Cypermethrin 10 EC	0.015	20.67^{e} (27.06)	44.33^{cd} (41.73)	74.33^{bc} (59.54)	98.67^{ab} (83.45)
Fenvalerate 20 EC	0.005	30.33^{c} (33.40)	45.67^{bcd} (42.53)	80.67^{abc} (63.94)	92.00^{c} (73.57)
Fenvalerate 20 EC	0.01	33.67^{c} (35.40)	49.67^{bc} (44.83)	86.00^{ab} (68.03)	96.67^{ab} (79.67)
Deltamethrin 2.8 EC	0.0014	31.00^{c} (33.83)	38.00^{de} (38.06)	79.33^{abc} (62.94)	96.67^{ab} (79.67)
Deltamethrin 2.8 EC	0.0028	34.67^{c} (36.09)	55.00^{b} (47.87)	87.33^{ab} (69.12)	99.33^{ab} (85.20)
Control	-	1.33^{f} (6.55)	2.67^{g} (9.46)	3.33^{e} (10.47)	4.67^{d} (12.52)
S.E.		2.33	4.93	6.57	1.60
C.D. (P=0.05)		4.86	10.30	13.71	3.34

Data in the parentheses indicate angular transformed values.
The values followed the same letters within the treatments do not differ significantly at 5% level.
* DAT: Days after treatment.

Table 2: Residual effect of insecticides against *Muga silkworm*.

Treatments	Concentrations (%)	Per cent mortality of muga silkworm			
		5 DAT *	10 DAT	15 DAT	20 DAT
Endosulfan 35 EC	0.05	93.33^{de} (75.00)	86.67^{ef} (68.61)	76.67^{cd} (61.14)	63.33^{d} (52.71)
Endosulfan 35 EC	0.1	96.67^{e} (79.53)	90.00^{f} (71.57)	83.33^{d} (65.88)	66.67^{d} (54.76)
Azadirachtin 1500 ppm	0.0015	23.33^{b} (28.86)	6.67^{a} (15.00)	3.33^{a} (10.47)	3.33^{a} (10.47)
Azadirachtin 1500 ppm	0.003	33.33^{b} (35.24)	16.67^{a} (24.12)	3.33^{a} (10.47)	6.67^{ab} (15.00)
Cypermethrin 10 EC	0.0075	83.33^{cd} (65.88)	66.67^{cd} (54.76)	46.67^{b} (43.11)	30.00^{c} (33.21)
Cypermethrin 10 EC	0.015	93.33^{de} (75.00)	73.33^{de} (58.89)	53.33^{b} (46.89)	36.67^{c} (37.29)
Fenvalerate 20 EC	0.005	73.33^{c} (58.89)	66.67^{cd} (54.76)	50.00^{b} (45.00)	23.33^{bc} (28.86)
Fenvalerate 20 EC	0.01	83.33^{cd} (65.88)	80.00^{def} 63.43)	66.67^{c} (54.76)	33.33^{c} (35.24)
Deltamethrin 2.8 EC	0.0014	76.67^{c} (61.14)	50.00^{b} (45.00)	13.33^{a} (21.39)	6.67^{ab} (15.00)
Deltamethrin 2.8 EC	0.0028	93.33^{de} (75.00)	56.67^{bc} (48.85)	13.33^{a} (21.39)	10.00^{ab} (18.43)
Control	-	10.00^{a} (18.43)	3.33^{a} (10.47)	3.33^{a} (10.47)	6.67^{ab} (15.00)
S.E.		4.96	6.88	6.00	9.17
C.D. (P=0.05)		10.35	14.35	12.51	19.12

Data in the parentheses indicate angular transformed values.
The values followed the same letters within the treatments do not differ significantly at 5% level.
* DAT: Days after treatment.

Twenty number of second instar muga silkworms were released per plant treated with insecticides on 5th, 10th, 15th and 20th days after insecticide treatments and mortality, if any, was recorded after 24 h of release. The individual count method was adopted to estimate the percent larval mortality of *C. trifenestrata* on 1st, 3rd, 7th and 14th days after insecticide treatment and subsequently the residual effect of insecticides in terms of percent mortality of muga silkworm. The data obtained on larval mortality were subjected to statistical analysis by Fischer's method of Analysis of variance. The significance or non-significance of difference between means was ascertained by comparison with an appropriate CD value at 5 per cent and 1 per cent level of significance.

RESULTS AND DISCUSSION

It is evident from the Table 1 that all the treatments were found effective against wild silk, *C. trifenestrata*. Endosulafan (0.1%) provided the highest larval mortality of *C. trifenenestrata* as compared to other treatments. Azadirachtin (0.0015% and 0.003%) was found the least effective treatments as compared to other treatments. However, treatments with azadirachtin provided reasonable larval mortality on 14 DAT and were found at par with endosulfan (0.05%). The effectiveness of endosulfan against the caterpillar could be attributed to quick knock down effect and long lasting contact action. The effectiveness of deltamethrin might be attributed by its higher contact and stomach toxicity. Azadirachtin was not found effective till 7 DAT but showed greater efficacy on 14 DAT which was attributed by its antifeedant activity, disruption of metamorphosis and molting inhibition causing starvation to death. Deshmukh and Renapurkar (1992) reported that azadirachtin has repellent and antifeedant activity which effect feeding, development and reproduction of insects. Azadirachtin interferes with insect ecdysteroid level and acts on the neuroendrocrine control (Dorn *et al*., 1986). From numerous field trials, it appears that larvae of most lepidopterous pests are highly sensitive to neem, which blocks them from feeding; although this effect is usually less important than disruption of growth, it causes (Anonymous, 1992).

Results on residual toxicity of insecticides on muga silkworm larvae (Table 2) revealed that endosulfan (0.05% and 0.1%) caused the highest silkworm mortality upto 20 DAT. Azadirachtin (0.0015% and 0.003%) caused the lowest mortality on 15DAT as compared to other treatments and found at par with deltamethrin (0.0014% and 0.0028%) and control treatment. It is evident from Table 1 & 2 that endosulfan (0.05% and 0.1%) was the most effective treatment against *C. trifenestrata* but highly toxic to muga silkworm also. Azadirachtin (0.0015% and 0.003%) and deltamethrin (0.0014% and 0.0028%) were found effective against *C. trifenestrata* with lowest residual effect on muga silkworm on 15DAT. Therefore, muga silkworm can be reared on the som plants treated with azadirachtin and deltamethrin only after 15 days of application. However, it may be suggested to conduct multi-location trials in different agro-ecological situations prior recommendation to the field.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 369-371

PERFORMANCE OF WILD SILK MOTH *CRICULA TRIFENESTRATA* HELFER ON DIFFERENT HOST PLANTS AND ITS UTILIZATION

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ABSTRACT

The vanya silk moths are ecologically important forest based insects which are in general, grows in natural environment and not reared in captivity. The vanya silk producing insect shows marked differences in their colour. Among them, *Cricula trifenestrata* (Helfer) is very common in Assam and other states of North-eastern region. The life cycle and feeding behaviour of *Cricula* on different host plants *viz*., som, soalu, mango, black berry, cashew and Indian olive were studied and discussed in this paper. In summer season the insect completes its life cycle in 20 -22 days. After hatching, the larvae feed for 3 to 4 days during 1st instar, 3-5 days in 2nd instar, 5-7 days in 3rd instar, 7-10 days 4th instar and 10-12 days in 5th instar. The fully matured larvae attain 4.5-5.0g weight, 6.5-7.0 cm length and 0.9 -1.0 cm breadth in som plant and 5.00-5.25g, 6.50-7.0cm and 1.0 -1.1 cm respectively, in black berry. On maturity, the larvae spin golden yellow cocoon in between fresh or dry leaves on plant. The single cocoon weight ranges from 2.73 2.94 (female) and 1.16 1.50 g (male) in som plant where as 1.92- 2.52g (female) and 1.26 1.35g (male) in black berry. The C*ricula* is very hardy and can tolerate up to 38 - 40ºC temperature.

Key words: *Cricula trifenestrata,* Feeding behaviour, Host plant, Life cycle, Wild silk moth

INTRODUCTION

The variability in silk producing insects and their host plants are well documented. The vanya silk moth produces lustrous silk and exhibits wide range of variation in life cycle from egg to adult (Kakati and Chutia, 2009). *C. trifenestrata* is widely distributed in the Indian sub-continent, thriving on several host plants, especially mango (*Magnifera indica),* som (*Persea bombycina*) and cashew (*Anacardium occidentale*) and others. Recently, it has been reported that the insect is also a voracious feeder of Indian olive (*Elaeocarpus floribundus*) and Indian jujube (*Ziziphus jujuba*) plant. The wild silkworm has been domesticated /semi-domesticated and subsequently the host plants were also cultivated (Bhattacharya *et al*. 1993). North-East India is the centre of wild silk culture and eri, muga, temperate tasar silk worm are commercially exploited. The vanya silk varieties available are *Actias selene*, *Antherea roylei*, *Antherea* sp. novo, *Attacus atlas, Samia canningi* and *Cricula trifenestrata which are* not yet commercially exploited for silk production (Chutia *et. al*., 2010).

The cytological study of *Cricula* indicates that it has more chromosomes (n=31) which is higher than the other domesticated sericigenous insects (Narang and Gupta, 1975). Some reports are available that *A. pernyii* and *A. royleii* was successfully hybridized and used in Oak tasar sector. The inter-specific hybridization was conducted in tasar silkworm and successful result was obtained (Jolly *et.al*., 1969). Similar initiative is required to take in other wild silkworm for development of productive hybrids and also to know the genetics of different silk moths (Robinson, 1971).

The *Cricula* is considered as pest of muga silkworm host plants (Sarmah *et al*., 2010). The insect is termed as pest of mango (Ahmad and Alam, 1993) and cashew (Pal and Medda, 2006). The sericigenous insect is termed as harmful pest because the worm feeds voraciously on the leaves, completely defoliating them, leaving only the mid ribs. The observation on *Cricula* life cycle was recorded on different host plant and discussed in this paper.

MATERIALS AND METHODS

The present observation was recorded at Boko, Assam during May-June and July-August on different host plants like som, soalu, black berry, cashew and mango plant. The

Table 1: Cocoon characters of *Cricula* on different host plants

Plant name (English)	Plant name (Assamese)	Scientific name	Single cocoon weight (g)		Single shell weight (g)		Silk ratio (%)	
			Male	Female	Male	Female	Male	Female
Som	Som	*Persea bombycina*	1.50	2.81	0.113	0.160	7.395	5.717
Soalu	Shwalu	*Litsea monopetala*	1.25	2.37	0.096	0.103	7.723	4.354
Mango	Aam	*Mangifera indica*	1.25	2.28	0.106	0.136	8.496	6.000
Black berry	Kola Jamuk	*Syzygium cumini*	1.30	2.22	0.103	0.120	7.953	5.512
Cashew	Kaju badam	*Anacardium occidentale*	1.20	2.42	0.116	0.153	9.711	6.278
Indian Olive	Jalphai	*Elaeocarpus floribundus*	1.28	2.21	0.100	0.110	7.830	4.843
		Mean	1.30	2.39	0.106	0.130	8.185	5.451

worms were reared during the muga silkworm rearing season in April-May on different plant. The worms were observed from initial stage to adult up to cocoons, which is golden in colour. The data recorded in larval, cocoon and yarn stage are highlighted.

RESULTS

Cricula trifenestrata appears in different seasons and its moth lays eggs in a neat row along the outer edge of som/ soalu/ mango/ black berry/ cashew/ olive leaf and they can be easily collected. In the early stage, the larvae were found congregated at the under surface of leaves. Later the larvae dispersed but were restricted to feeding on leaves of a few neighbouring branches. The larvae were seen feeding voraciously on leaves, resulting in complete defoliation with only the mid-ribs of the plant remaining. The gregarious feeding by the 4^{th}-5^{th} instar larvae can cause partial or complete defoliation of mango trees. After completion of feeding in one plant, the worms come down and crawl for another plant. The larva of *Cricula* were orange with blackish transverse bands on the dorsal side. The head and ventral side of the body were deep red in colour. There were numerous raised yellow spots on the dorsal side of the body of the caterpillars. The body was covered with numerous white hairs also. Each segment is clothed in yellow brown hair and the segments are separated by dark brown ring.

Sex markings are prominent in pupae and it is comparatively easier to determine the sex in the pupae stadium than in the larvae stage (Thangavelu *et al*., 1988). The list of food plants used by *Cricula* is presented in Table 1. The data was recorded in two crops April-May and July-August, 2010. The data on cocoon parameters of *Cricula* reared on different host plants are also presented in Table 1. The larvae reared on different host plant showed variation in growth. The spinning of cocoon takes place 3 days in summer. The cocoons are found in between two leaves on the plant as well as on crop debris on the ground. The cocoon characters were recorded after harvest. The single cocoon weight of male and female were recorded from all the host plants. The single cocoon weight was maximum in som plant both for male and female. The single shell weight was higher in cashew (male) and som for female. Silk ratio is observed higher in cashew followed by mango, black berry, olive, soalu and som.

The cocoon colour also slightly varied from dark golden to light golden colour. The grainage operation conducted which indicated pupae stage lasts for 10-14 days. The moths emerge from the cocoons at dusk and continue till dawn. The male and female moths exhibit distinct sexual dimorphism. The male moths were yellowish with two pairs of wavy black markings both on fore and hind wings. The female moths were deep yellowish-brown in colour. There were three prominent transparent eye spots on each forewing and one each on hind wings in both adult moths. The antennae were bipectinate in both the sexes. The antennae of male moth were more developed with longer projections from each segment. The abdomen of the male moth is narrow and small whereas it was broad, larger and swollen in female. The male moth flies actively and copulates with the stationary female. The coupling lasts overnight and after decoupling the female moth lay eggs on the leaf of host plants. The *Cricula* cocoon is porous net-like structure with discontinuous filament. The reeling of cocoon is difficult but spinning can be done like eri cocoon. The cocoon quality differs when the *Cricula* feeds on different host plant.

The *Cricula* is reported as sporadic pest and occasionally available in certain areas and disappears. Sometimes it may become a major pest depending on the population of the insects. The insects are surviving on a large number of host plants and can cause serious problem to economic crop like cashew, muga silkworm host plants. The pest can be controlled mechanically as well as chemically and with parasitoids. The insect can be effectively controlled by spraying with contact insecticide like cypermethrin (Pal and Medda, 2006).

Utilization and conservation of *Cricula*

The wild silkworm produces natural colour cocoon and filament produces unique and highly valued silk textiles. *Cricula* golden cocoon is perhaps the most unique case. Earlier there was no idea of utilizing the *Cricula* moths, but in Indonesia separate industry initiated to utilize it and Suvahana is a company which is produce accessories and craft from wild cocoons of *Cricula trifenestrata*. The materials are so special because of its strong character, high quality, water resistance and golden colour. The wild silk is very fine fiber, very porous, soft, cool to wear, heat resistant, non allergenic and anti bacterial. A thread of *Cricula* from which most of the Rumen Sutera products are made is lighter, more water absorptive than the normal silk and having elegant luster with soft touch.

DISCUSSION

The *Cricula* worms are found from April to November which is the rearing season of muga silkworm. The *Cricula* forms natural golden colour silk but it is also called the pest of som, mango and many others. Any insect may be declared as harmful when it damages the crop above economic thresh hold level. In the case of muga host plant ((Sarmah *et al*., 2010), mango (Huq *et. al*., 1991), cashew-nut and tea, the sericigenous insect *Cricula* is termed as a harmful pest. The pest can be beneficially exploited, if it is reared for silk at large scale. Though a sericigenous insect, it is not commercially utilized may be due to wild nature, it may act as carrier of microsporidian spores besides feeding and damaging of host plant of beneficial insect. Earlier *Cricula trifenestrata* (Helfer) was reported to infest Cashew, Mango, Litchi, Ber and Pepper (Nair, 1975). It was reported to cause damage to cashew by defoliating of isolated trees in certain localities (Mandal, 2000).

The wild silkworm readily available in nature hold invaluable gene of desirable quality particularly the resistance to various biotic and abiotic factors (Tikader, 2001). The *Cricula* wild silkworm can sustain temperature up to 40ºC and make the cocoon. So, there is scope to utilize this insect due to present scenario of global warming and climate change which is a threat of domesticated and semi-domesticated sericigenous insects.

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STUDIES ON INTER AND INTRA-COCOON VARIATION IN PHYSICAL AND TENSILE PROPERTIES OF RAW SILK OF DIFFERENT VOLTINISM OF *BOMBYX MORI* L. IN WEST BENGAL

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ABSTRACT

As far as technological traits are concerned, presently, the breeders prefer to quantify the quality of cocoon by the average length of filament, average non-breakable filament length and average denier of the bave which exclusively may not be the correct option for quality assessment. Inter and intra-cocoon variations in the physical and tensile characteristics of the bave along its length may give better option for the breeders to come out with more determined findings. Single filaments of silk fibre are too thin for utilization; hence several filaments are combined together to form a single strand. In this process, a number of cocoon baves are reeled together to produce a single thread. Here lies the importance of a single cocoon to decide the quality of the ultimate yarn. In precise, the process parameters, type of machines are generally responsible for addition of irregularities in the yarn while the type of cocoons and type of silkworm breeds/foundation crosses/hybrids etc. are responsible for inherent irregularities. Addition of irregularities can be controlled by using improved machineries and by adopting proper process control measures, but the inherent irregularities in the yarn are genetically controlled. Hence, Addition of irregularities, Index of Irregularities (IOI) and essentially the Limit Irregularities are some of the most important parameters which truly reflect the degree of irregularities in true sense. IOI should be treated as one of the most important parameters for selection of breed. From the breeder's point of view, the filament size deviation test may be one of the most important tools for evaluation of the breeds / hybrids for commercial exploitation. The inter and intra-cocoon variations in Physical and Tensile Properties of raw silk of different voltinism of *Bombyx mori* L. may throw some light on the quality of cocoon and provide some initial information for the determination of IOI . Objective of this study is to provide first hand information to the breeders regarding the inherent irregularities present in the raw silk bave of particular race so as to facilitate selection of the breed with more efficient approach. The individual cocoon was subjected for single cocoon reeling analysis by using an epproveutte and each unit length of 100 meters from each cocoon were taken out and the physical parameter like denier and tensile properties like tenacity & elongation % were measured. The segmental variations were recorded.

Key Words: Index of Irregularities, Physical and tensile properties, Size deviation, Tenacity

INTRODUCTION

Single filaments of silk fibre (bave) are too thin for utilization. Appropriate reeling operations are very important to produce good quality silk. For production purposes, several filaments are combined together to form a single strand. In this process, a number of cocoon baves are reeled together to produce a single thread. This is achieved by unwinding filaments collectively from a group of cooked cocoons at one end in a warm water bath and winding the resultant thread onto a fast moving reel. Here lies the importance of a single cocoon to decide the quality of the ultimate yarn. Silk is a natural protein fibre. During the caterpillar phase, the silk worm wraps itself by a liquid

protein secreted by two large glands in its head. This secreted protein hardens upon exposure to the air. The resultant filament is bonded by second secretion, sericin, which forms a solid sheath or cocoon. Bave consists of two fibroin filaments, known as 'brins' that are agglutinated together by the help of a gum known as sericin [1]. More variation in the size of brins or bave more will be the irregularities in the resultant yarn.

Silkworm may distribute the given quantity of silk fibroin (say 'x' mg), over a length of l_1, l_2 or l_3 as depicted in fig-1, 2 & 3 respectively. The Length: Breadth Ratio for event-1, 2 & 3 are $l_1 / d_1 1 \ldots . l_1/d_1 n_1$, $l_2 / d_2 1 \ldots . l_2/d_2 n_2$ & $l_3 / d_3 1 \ldots . l_3/d_3 n_3$ respectively and had it been perfectly cylindrical in shape, for 'x' mg of silk fibroin, these ratios would have been a constant (say 'K').

Therefore, $K = l_1 / d_1 = l_2 / d_2 = l_3 / d_3$ since $d_1 1 = d_1 2 \ldots\ldots\ldots d_1 n_1$

$d_2 1 = d_2 2 \ldots\ldots\ldots d_2 n_2$

and $d_3 1 = d_3 2 \ldots\ldots\ldots d_3 n_3$ But since, it is conical in shape,

$l_1 / d_1 1 < l_1 / d_1 2 < l_1 / d_1 3 < l_1 / d_1 4 \ldots\ldots\ldots < l_1 / d_1 n_1$;

$l_2 / d_2 1 < l_2 / d_2 2 < l_3 / d_2 3 < l_2 / d_2 4 \ldots\ldots\ldots < l_2 / d_2 n_2$ &

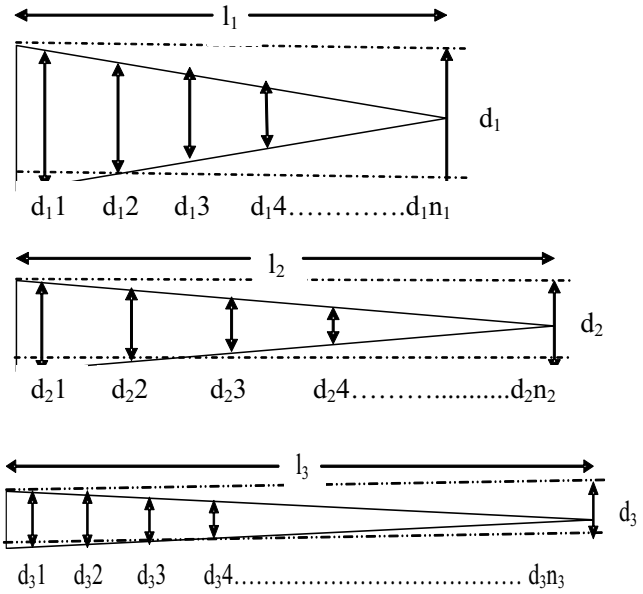
$l_3 / d_3 1 < l_3 / d_3 2 < l_3 / d_3 3 < l_3 / d_3 4 \ldots\ldots\ldots < l_3 / d_3 n_3$

However, measurement of diameter of raw silk filament is a difficult task, hence instead of diameter, linear density (wt/unit length) has been considered in this study to know the pattern of changes of linear density in every pre-decided unit length of raw silk of different voltinism thus to generate useful informations for the silkworm breeders.

As far as technological traits are concerned, presently, the breeders prefer to quantify the quality of cocoon by the average length of filament, average non-breakable filament length and average denier of the bave which exclusively may not be the correct option for quality assessment. Inter and intra-cocoon variations in the physical and tensile characteristics of the bave along its length may give better option for the breeders to come out with more determined findings. Objective of this study is to provide first hand information to the breeders regarding the inherent irregularities present in the raw silk bave of particular race so as to facilitate selection of the breed with more efficient approach.

MATERIALS AND METHODS

The experiment has been designed to conduct with three breeds / hybrids of silkworm *Bombyx mori* L of different voltinism *viz.,* Multivoltine, Multi X Bi and Bivoltine. 10 (ten) number of cocoons have been taken from each variety and



1. Each cocoon was unravelled at the equal length of 100 meters. 2. Unravelling was continued to the extent of availability of reelable length. 3. The last available length may be < 100 metres. 4. Physical & tensile properties of raw silk bave of each 100 meters available from a particular cocoon were determined and the changes in the characteristics along the advancement of the length were recorded. 5. Physical & tensile properties of raw silk bave of each 100 meters available from different cocoons were also determined and compared.

The individual cocoon was subjected for single cocoon reeling analysis by using an epproveutte and each unit length of 100 meters from each cocoon were taken out and the physical parameter like denier and tensile properties like tenacity & elongation % were calculated. The segmental variations were noted down.

RESULTS

Data on the intra-coon size deviation reveals from all the records (Table-1A, 1B, Table-2A, 2B, Table-3A, 3B) that irrespective of voltinism the size of filament in the outermost layer of cocoon are the coarsest and gradually decreases along its length leaving the finest size of the filament at pelade layer or core layer of the cocoons. It has been recorded that:

Higher the size deviation in individual filament, more will be the irregularities in the resultant yarn. Though size is decreasing along the length, the average standard deviation of denier of multivoltine ($M_{12}W$) raw silk ranges from 0.291 and 0.389 while that of Nistari from 0.378 and 0.750. The average standard deviation of denier of multivoltine x Bivoltine ($M_6DPC \times SK_4C$) raw silk ranges from 0.329 and 0.707 while that N x NB_4D2 from 0.298 and app. 0.375 The intra-coon size deviation of bivoltine ($NB_{18} \times P_5$) raw silk ranges from 0.658 and 0.277 while that of SK_7 from 0.369

and 0.731. Deviation is lower to higher in all the cases except in case of NB_{18} x P_5. It reveals that the standard deviation between the cocoons is lowest in outer surface and highest in inner surface.

Similarly, the average inter-cocoon size deviation of multivoltine ($M_{12}W$) raw silk ranges from 0.055 and 0.550 while that of Nistari from 0.052 and 0.928. The average inter-cocoon size deviation of multivoltine x Bivoltine (M_6DPC x SK_4C) raw silk ranges from 0.390 and 1.052 while that N x NB_4D2 from 0.452 and 0.936 The average inter-cocoon size deviation of bivoltine (NB_{18} x P_5) raw silk ranges from 0.686 and 1.219 while that of SK7 from 0.372 and 1.091.

As far as tensile properties are concerned, tenacity and elongations are supposed to have immense importance to determine the quality of yarn being produced. As the size of filament gradually decreases from outermost layer of cocoon to the innermost layer, tenacity goes on increasing along the length. From the graph in regard to intra-cocoons strength variations, we find that for multivoltine cocoons strength increases from 3.6 to 4.25 g/d while elongation decreases from 24 to 18% from outer surface of cocoon to inner surface. Similar is the case of other cocoons where the values of strength and elongation were recorded as 3.8 to 4.28 g/d & 23 to 14% for multi x bi cocoons and 4.0 to 4.5 g/d & 24 to 13% for bivoltine cocoons respectively.

Table 1A: Multivoltine ($M_{12}W$)

Cocoon No. / Segment	1	2	3	4	SD
C_1	2.78	2.70	2.61	2.34	0.191
C_2	2.52	2.43	2.25	--	0.137
C_3	2.43	2.34	2.16	1.89	0.238
C_4	2.57	2.43	2.34	--	0.116
C_5	2.70	2.70	2.52	--	0.104
C_6	1.89	1.80	1.62	1.70	0.114
C_7	2.43	2.34	2.33	--	0.055
C_8	2.52	1.80	1.44	--	0.550
C_9	2.16	2.07	1.80	1.80	0.186
C_{10}	2.88	2.79	2.71	2.61	0.115
SD	0.291	0.355	0.427	0.389	

Segment (Each segment = 100 metres)

Table 1B: Multivoltine (Nistari)

Cocoon No. / Segment	1	2	3	4	SD
C_1	2.88	2.61	1.98	--	0.462
C_2	2.97	2.52	1.98	0.82	0.928
C_3	1.98	2.16	1.98	2.07	0.086
C_4	2.97	2.52	1.30	--	0.864
C_5	2.79	2.43	1.98	--	0.406
C_6	2.34	2.34	2.25	--	0.052
C_7	2.16	2.25	1.71	1.89	0.248
C_8	2.61	2.07	1.26	--	0.679
C_9	3.06	2.61	1.98	--	0.542
C_{10}	2.88	2.79	2.71	2.61	0.115
SD	0.378	0.224	0.424	0.750	

Segment (Each segment = 100 metres)

Table 2A: Multivoltine × Bivoltine (M6DPC × SK4C)

Cocoon No. / Segment	1	2	3	4	5	6	7	SD
C_1	4.14	3.42	2.97	2.70	2.34	1.45	--	0.921
C_2	3.24	2.88	2.52	2.34	2.07	1.58	--	0.588
C_3	3.15	2.79	2.70	2.61	2.43	1.98	--	0.390
C_4	3.69	3.33	3.15	2.97	2.61	2.16	--	0.541
C_5	3.33	2.70	2.52	2.52	1.71	1.71	1.99	0.590
C_6	3.87	2.97	2.43	2.25	1.89	1.35	0.99	0.975
C_7	3.69	2.79	2.16	1.80	1.26	--	--	0.937
C_8	3.51	2.88	2.70	2.34	2.16	1.80	--	0.602
C_9	3.15	2.79	2.61	2.34	2.25	1.89	--	0.442
C_{10}	3.69	3.06	2.70	2.43	2.07	0.60	--	1.052
SD	0.329	0.242	0.276	0.309	0.388	0.458	0.707	

Segment (Each segment = 100 metres)

Table 2B. Multivoltine X Bivoltine (N X NB_4D_2)

Cocoon No. / Segment	1	2	3	4	5	6	7	8	9	10	SD
C_1	3.69	3.15	2.88	2.61	2.34	2.25	1.62	1.53	1.43	--	0.777
C_2	4.05	3.33	2.88	2.79	2.43	2.16	1.53	1.17	--	--	0.936
C_3	3.96	3.24	2.61	2.34	2.43	1.71	1.35	1.35	1.44	1.35	0.907
C_4	3.60	2.97	2.97	2.88	2.88	2.70	2.34	1.43	--	--	0.628
C_5	3.69	3.60	3.51	3.33	3.06	2.88	2.43	--	--	--	0.452
C_6	3.87	3.15	2.52	2.61	2.25	1.71	1.62	1.26	1.50	--	0.856
C_7	3.78	3.42	3.78	3.87	3.42	3.06	1.80	--	--	--	0.721
C_8	3.06	3.15	3.15	3.06	2.34	1.80	1.53	--	--	--	0.693
C_9	3.51	3.15	3.24	3.42	2.88	2.97	2.34	2.25	1.71		0.606
C_{10}	3.33	3.33	3.15	3.33	2.61	1.89	1.71	1.18	--	--	0.862
SD	0.298	0.177	0.385	0.465	0.382	0.543	0.394	0.375	--	--	

Segment (Each Segment = 100 metres)

Table 3A - Bivoltine (NB_{18} x P_5)

Cocoon No. / Segment	1	2	3	4	5	6	7	8	9	10	11	SD
C_1	3.51	3.24	3.15	2.97	2.79	2.61	2.07	1.62	1.13	--	--	0.799
C_2	3.69	3.33	3.06	2.79	2.7	2.43	2.25	1.80	1.60	--	--	0.686
C_3	3.33	3.42	3.15	2.88	2.61	2.34	1.89	1.80	1.44	0.96	--	0.841
C_4	4.14	3.78	3.69	3.15	2.61	2.25	2.34	1.98	1.53	1.44	1.05	1.034
C_5	2.61	2.97	3.24	3.24	3.06	2.52	2.43	2.16	1.98	1.44	0.96	0.739
C_6	3.15	3.60	3.60	3.42	2.97	2.52	2.07	1.14	--	--	--	0.860
C_7	4.56	4.32	3.96	3.78	3.33	2.61	1.67	--	--	--	--	1.020
C_8	4.68	4.68	4.68	4.05	3.15	1.65	--	--	--	--	--	1.219
C_9	4.05	3.96	3.78	3.33	2.70	2.16	1.44	0.88	--	--	--	1.201
C_{10}	3.24	3.24	3.24	3.06	2.88	2.61	1.80	1.08	--	--	--	0.798
SD	0.658	0.535	0.502	0.398	0.244	0.298	0.325	0.467	0.306	0.277	0.064	

Segment (Each Segment = 100 metres)

Table 3B: Bivoltine (SK_7)

Cocoon No. / Segment	1	2	3	4	5	6	7	8	9	10	11	→ SD
C_1	3.51	3.24	3.24	3.06	2.34	2.07	1.08	--	--	--	--	0.866
C_2	3.06	2.88	2.88	2.61	2.61	2.61	2.43	1.80	1.80	2.33	--	0.428
C_3	3.60	3.33	3.06	3.06	2.79	2.16	1.80	1.08	0.39	--	--	1.091
C_4	3.15	2.88	2.79	2.61	2.61	2.52	1.98	1.71	0.96	--	--	0.685
C_5	2.34	2.52	2.25	2.34	2.43	2.25	1.98	1.35	--	--	--	0.372
C_6	3.33	3.24	2.97	2.88	2.79	2.52	2.34	1.80	1.35	1.35	--	0.732
C_7	3.24	2.88	2.88	2.43	2.34	1.71	1.35	0.39	--	--	--	0.949
C_8	3.60	3.51	3.33	2.97	3.24	2.61	2.25	1.89	1.35	0.90		0.941
C_9	3.42	2.97	2.97	2.79	2.70	2.70	2.07	1.36	--	--	--	0.634
C_{10}	3.33	2.70	2.52	2.52	2.52	2.16	1.80	1.35	1.16	--	--	0.689
SD	0.369	0.307	0.319	0.262	0.268	0.313	0.426	0.472	0.472	0.731		

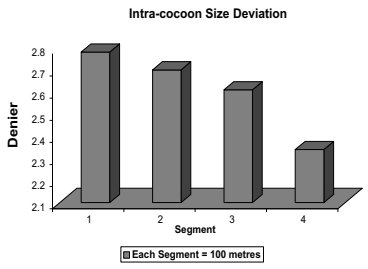
Segment (Each Segment = 100 metres)

Graphs

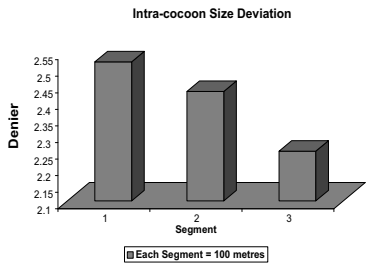
Intra-Cocoon Size Deviation

Multivoltine ($M_{12}W$) — **Each Segment = 100 metres**

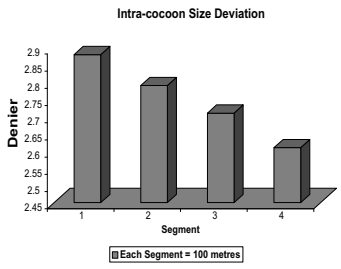
FL = 400 mtrs



FL = 300 mtrs

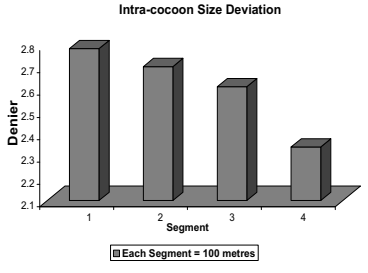


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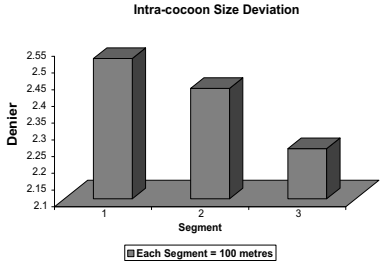


Multivoltine (Nistari) — **Each Segment = 100 metres**

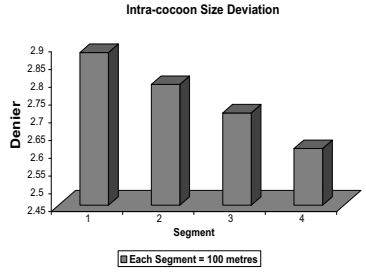
FL = 400 mtrs



FL = 300 mtrs



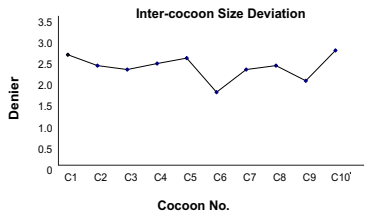
FL = 400 mtrs



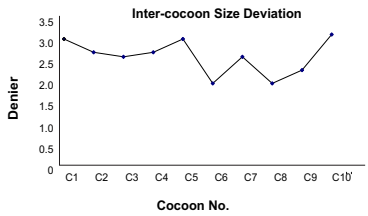
Inter-Cocoon Size Deviation

Multivoltine ($M_{12}W$)

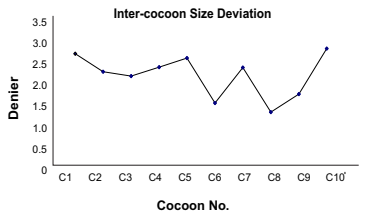
Outer layer SD = 0.291



Middle layer SD = 0.355

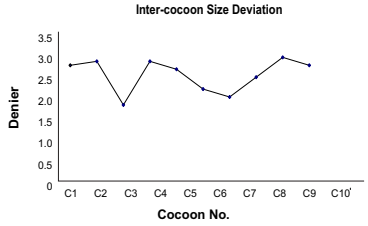


Inner layer SD = 0.427

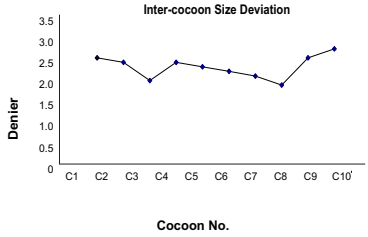


Multivoltine (Nistari)

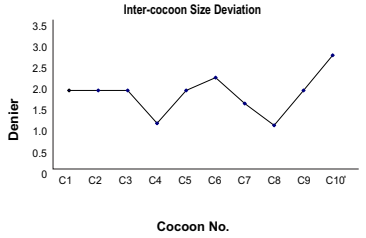
Outer layer SD = 0.424



Middle layer SD = 0.378



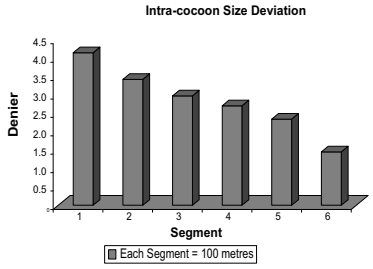
Inner layer SD = 0.224



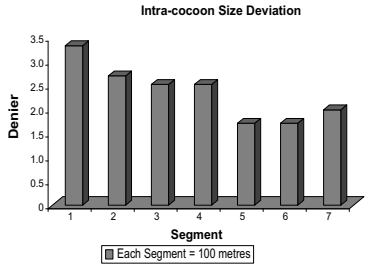
Intra-Cocoon Size Deviation

Multi x Bi (M6DPC X SK4C) — Each Segment = 100 metres

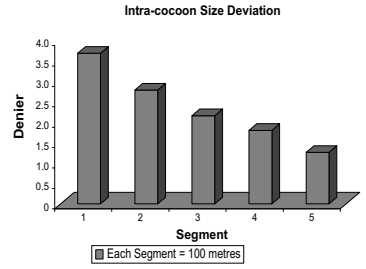
FL = 600 mtrs



FL = 700 mtrs

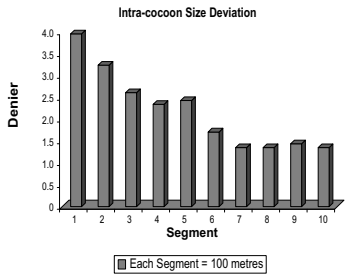


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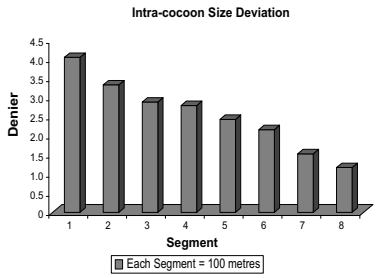


Multi x Bi (N X NB_4D_2) — Each Segment = 100 metres

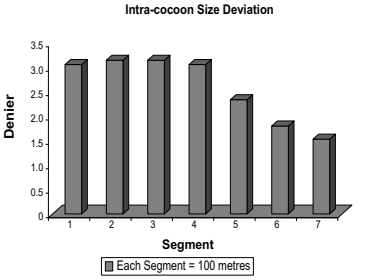
FL = 1000 mtrs



FL = 800 mtrs



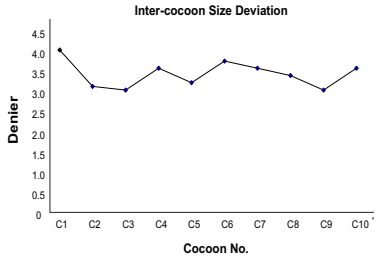
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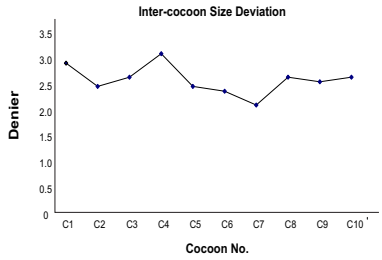
Inter-Cocoon Size Deviation

Multi x Bi (M6DPC X SK4C)

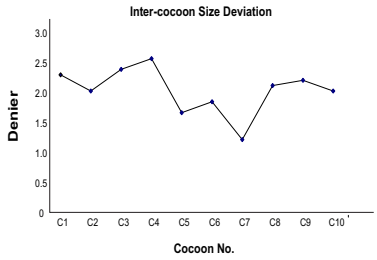
Outer layer SD = 0.329



Middle layer SD = 0.276

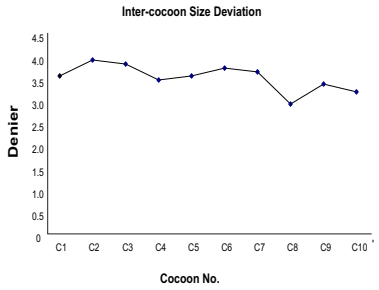


Inner layer SD = 0.388

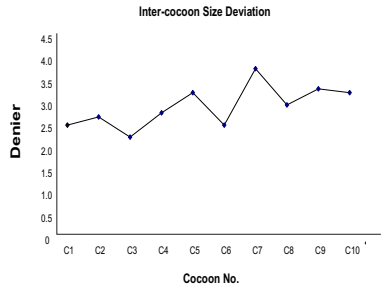


Multi x Bi (N X NB_4D_2)

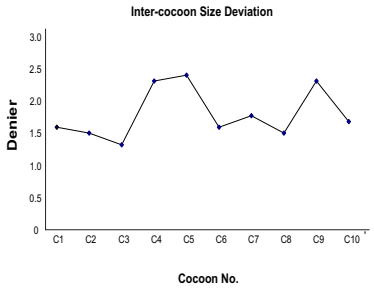
Outer layer SD = 0.298



Middle layer SD = 0.465



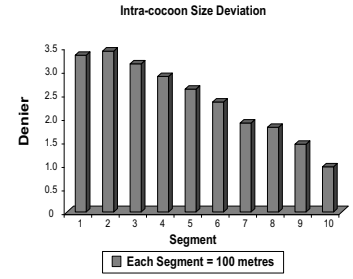
Inner layer SD = 0.394



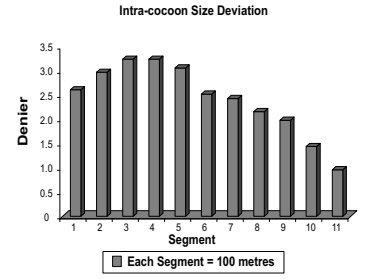
Intra-Cocoon Size Deviation

Bivoltine (NB_{18} X P_5) — Each Segment = 100 metres

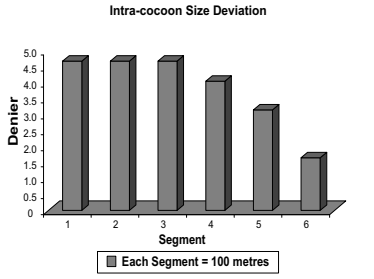
FL = 1000 mtrs



FL = 1100 mtrs

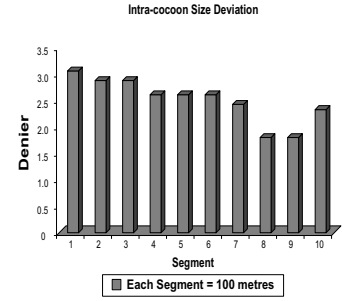


FL = 600 mtrs

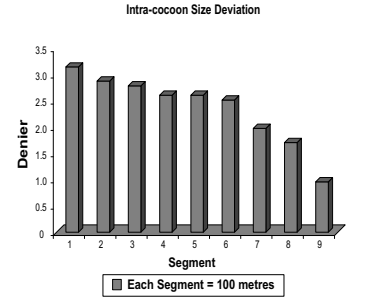


Bivoltine (SK_7) — Each Segment = 100 metres

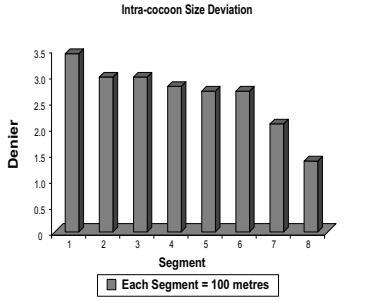
FL = 1000 mtrs



FL = 900 mtrs



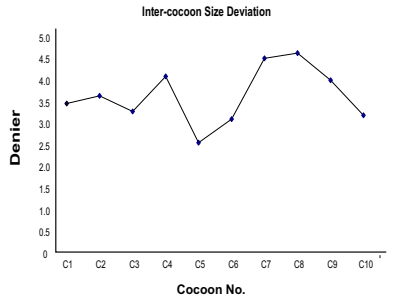
FL = 800 mtrs



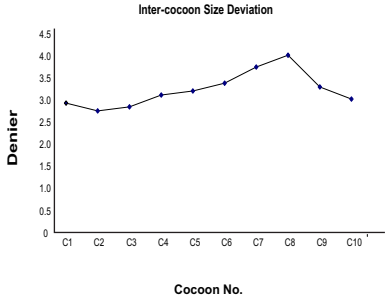
Inter-Cocoon Size Deviation

Bivoltine (NB_{18} X P_5)

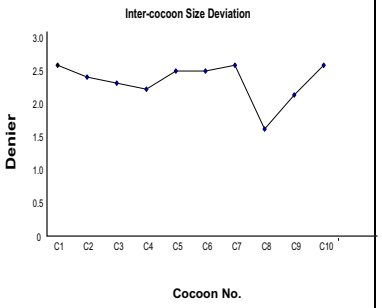
Outer layer SD = 0.658



Middle layer SD = 0.398

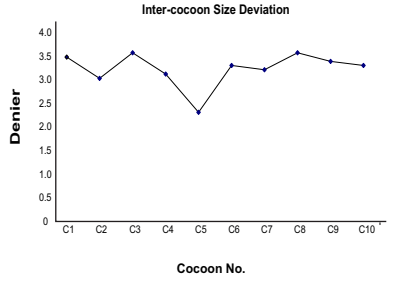


Inner layer SD = 0.298

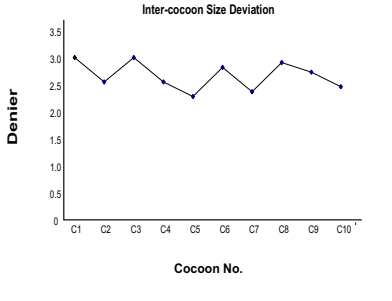


Bivoltine (SK_7)

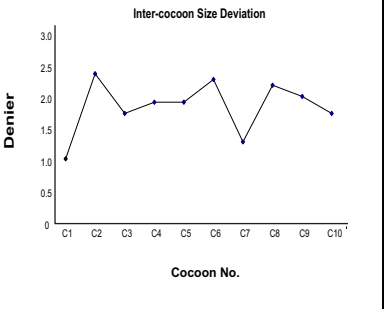
Outer layer SD = 0.369



Middle layer SD = 0.262

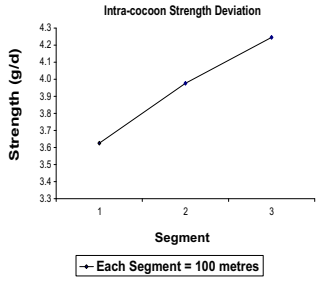


Inner layer SD = 0.426

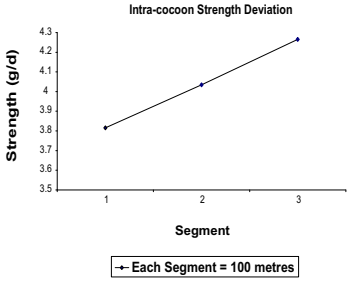


Intra-Cocoon Strength Deviation

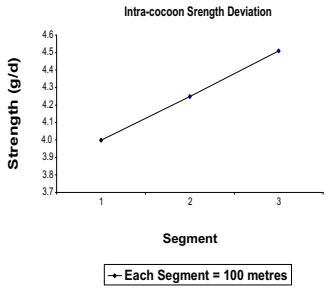
Multivoltine



Multi x Bi

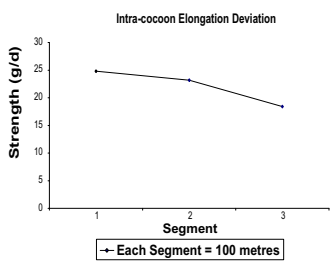


Bivoltine

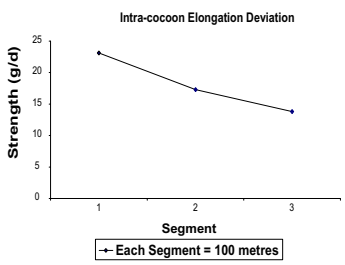


Intra-Cocoon Elongation Deviation

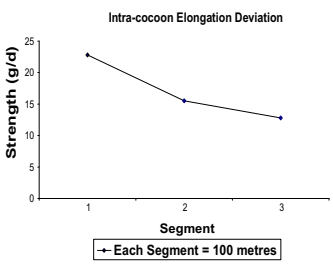
Multivoltine



Multi x Bi



Bivoltine



DISCUSSIONS

The findings of gradual loss of diameter or linear density along the length of raw silk is substantiated by the findings of Izuka, (1965) and Sureshkumar *et al*., (2002) who also observed that silkworm *Bombyx mori* L produces raw silk bave of conical shape pointing towards pelade layer possibly due to gradual loss of concentration of aqueous protein solution resulting in decreasing shear rate at and above which silk fibroin crystallises to form fibre, which in turn, suggests that filament become more crystalline or ordered along its length with the advancement of spinning. Iizuka also observed that generally when the cocoon filament size is finer, the raw silk size deviation is lower and the strength of the raw silk is higher. According to Iizuka, 1983, some physical properties of *Bombyx mori* L are linearly related to the size of thread. Iizuka *et al*, 1993*,* also studied that dynamic elastic modulus and tenacity show a negative correlation and the elongation, a positive correlation. All these findings are supported by the outcome of this study. It can be surmised that at the initiation of spinning, when the concentration of aqueous protein solution is high, the ejection pressure also remains high causing the delivery of some amorphous solution in a coarser configuration. As the spinning advances, the ejection pressure reaches to equilibrium state and thus produces filament of less variation in the middle layer of the cocoon. And finally, when the same pressure reaches to minimum, it delivers the finest filament but with wide variation. The inter-cocoon size deviation amongst the cocoon is also found to be higher in the outer and inner layer of the cocoon while it is minimum at the middle layer. The size deviation is quite sharp between the two layers at the innermost layers. These variations at different places of raw silk filament along its length are very much important to decide the ultimate quality of yarn as one raw silk filament is composed of several number of individual filament. For example, the size of filament is highest at the outermost layer, lowest at the innermost layer and intermediate at the middle layer. Hence, for a reeler, maintenance of equal number of cocoons of equal condition at all stage of reeling is not warranted to produce particular size of raw silk. The combination of full cocoon, half-reeled cocoon and almost-reeled cocoons are suitably adjusted in different phase of reeling. Interestingly, the reelers are well versed with this phenomenon and thus they choose the combinations of cocoons in accordance with the stage of reeling.

As stated by Penava and Orešković (1997) Prendžova (2000), Cybulska *et al*., (2001), Nanjundaya (1966), yarn strength decreases at the regions where yarn diameter decreases with consequent decrease in the number of fibres at the cross section. Statistically significant relationships between yarn diameter variation and strength variation can be accepted as expected results.

Since the aqueous protein solution becomes more or more ordered / crystalline with the time of spinning, strength goes on increasing. Elongation being inversely proportional to strength, it goes on decreasing along the length of spinning. It can, therefore, be narrated that Irrespective of voltinism, silkworm *Bombyx mori* L. produces raw silk bave of conical shape pointing towards pelade layer. There is a drop off of denier from the outer most layer to the inner most layer of cocoons. Hugar *et al*, 1999 found that decreased denier value suggests the increased fineness of the silk filament. And finally, tenacity shows a negative correlation and the elongation, a positive correlation. So, the dry strength in terms of tenacity (gms/denier) naturally increases as the fibre become more crystalline and similarly, elongation varies inversely with increasing crystallinity. However, as observed by Qader *et al.*, (1999), quality characteristics of raw silk *viz.,* size deviation, winding break, tenacity and elongation are strongly influenced by the variation of cocoon size in the given lot. Significant seasonal variation is also observed in reeling performance and yarn characteristics. Vasumati *et al.*, (1994), had the opinion that the skill of the reeler and other factor like quality of cocoons also happen to be the varying factor.

It is also revealed from the observations that the denier deviation between the first layer and last layer of cocoons can be minimized by increasing the filament length *i.e.,* by producing raw silk bave of finer denier for a given quantity of silk gland available in a particular genotype. As the resultant raw silk filament is a combination of number of raw silk bave that can accommodate in its cross section, so by minimizing the irregularity or size deviation in the bave raw silk of minimum irregularity can be produced. More number of bave can be accommodated in the cross section of the resultant yarn if the denier of individual bave is lower. If the number of fibres in the cross section are not in conformity with that required to form the simple structure of ideally packed yarn, either a partially filled layer must be present on the surface or the layers must pack on a simple core giving an irregular shape to the yarn. Thus, packing fraction (Ø) which is determined by Fibre Volume (v_f) ÷ Yarn Volume (v_y) is very much important and largely depends upon the volume / linear density of the fibre. In case of raw silk, packing fraction can be brought down by increasing the number of bave in the cross section which is only possible by lowering down the linear density of the constituent baves. There is a simple theory that an irregularity in the individual fibre is compensated by the increased number of fibres in the cross section of the resultant yarn and thus the resultant yarn becomes more regular. This phenomenon may be defined by the 'Index of Irregularity' (IoI). Index of irregularity expresses the ratio between the measured irregularity and the so-called limiting irregularity of an ideal yarn. In calculating the limit irregularity, the assumption is made that, in the ideal

case, fibre distribution in a yarn is completely random and a practical yarn can never improve upon this situation. Thus, the measured irregularity will be an indication of the extent to which fibre distribution falls short of complete randomness. Referring cotton, if all fibres are uniform in cross-sectional size, it can be shown that the limiting irregularity expressed in terms of C.V is given by:

$C.V_{lim} = 100 / \sqrt{n}$ where "n" denotes the mean number of fibres in the cross section.

Let,

$C.V_{lim}$ = the calculated limit irregularity

C.V = the actual irregularity

Then, Index of Irregularity (IoI) = C.V / C.V.lim

But for silk this limit irregularity value is yet to be ascertained

As discussed earlier, single filaments of silk fibre are too thin for utilization, hence several filaments are combined together to form a single strand. In this process, a number of cocoon baves are reeled together to produce a single thread. Here lies the importance of a single cocoon to decide the quality of the ultimate yarn. In precise, the process parameters, type of machines are generally responsible for addition of irregularities in the yarn while the type of cocoons and type of silkworm breeds/foundation crosses/hybrids etc. are responsible for inherent irregularities. Addition of irregularities can be controlled by using improved machineries and by adopting proper process control measures, but the inherent irregularities in the yarn are genetically controlled. Hence, Addition of irregularities, Index of Irregularities (IOI) and essentially the Limit Irregularities (bench mark values) are some of the most important parameters which truly reflect the degree of irregularities in true sense. IOI should be treated as one of the most important parameters for selection of breed. From the breeder's point of view, the filament size deviation test may be one of the most important tools for evaluation of the breeds / hybrids for commercial exploitation. The inter and intra-cocoon variations in Physical and Tensile Properties of raw silk of different voltinism of *Bombyx mori* L may throw some light on the quality of cocoon and provide some initial information for the determination of IOI and further study is required in this line.

Hence, breeders should have an endeavour to produce such cocoons where NBFL tends to FL and ICSD (Intra-Cocoon Size Deviation) has a propensity to reach to the lowest possible value respectively. Quality can't be achieved by any short cut method. Once, breeders are ready to accept the valuable traits for selection in breeding programme, reelers will be benefited automatically.

ACKNOWLEDGMENT

The authors are highly grateful to Sri A. T. Pramanik, Technical Assistant and Sri Bijoy Sarkar, Assistant Technician, Reeling Division of CSR&TI, Berhampore for their active involvement in the study and all support. The authors also pay tribute to the departed soul of Dr. A. K. Bajpai, Director, CSR&TI, Berhampore, one of the authors.

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STUDIES ON FIBRE CHARACTERISTICS OF POLYVOLTINE BREEDS AND POLYVOLTINE × BIVOLTINE HYBRIDS OF THE SILKWORM *BOMBYX MORI* L.

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Central Sericultural Research and Training Institute, Mysore-570 008, Karnataka

ABSTRACT

In silkworm breeding programmes, more emphasis is being given to the fibre quality improvement. The main quality parameters for high grade silk are Size Deviation, Evenness, Cleanness, Neatness, Tenacity, Elongation and Cohesion and Winding Breaks. Among these, some are breed / hybrid specific. Size deviation of the yarn mainly depends on the individual silk filament size variation from outer to the inner layer and filament size. In the present investigation, some of the new improved polyvoltine breeds and polyvoltine × bivoltine hybrids have been studied and assessed for their fibre characteristics. Present study aimed at investigating the importance of fibre characteristics in silkworm breeding programmes. Special emphasis was given to study the impact of early generation selection in respect of cocoon size variation, neatness and filament length in fibre quality improvement programmes.

Key words: Fibre characteristics, Fibre quality, Quality parameters, Silkworm breeding, Silkworm hybrids

INTRODUCTION

Cocoon production in India is mostly from cross-breeds with filament length ranging from 500 to 700 m and renditta of 8 to 9. Efforts in promoting the production of bivoltine cocoons has not gained the expected momentum. The strategies towards raw material improvement would have to address mainly the quality improvement (Somashekar, 2000) of cross-breed cocoons. Good quality cocoons is an important prerequisite for the production of high quality silk. The existing cross-breed Pure Mysore (PM) × CSR2 has a few limitations like high renditta, low cocoon weight, shell weight and silk content. Besides, the quality of silk produced from these cocoons is very low. In the recent conventional breeding programmes more emphasis is being given to the fibre quality improvement. From the silkworm breeding point of view, parameters considered for grading of silk yarn are 1) reelability, 2) neatness, 3) filament size and size variation in the single cocoon filament, 4) lousiness, 5) boil-off-loss ratio, 6) winding breaks, 7) evenness, 8) tenacity and 9) cohesion.

In the present investigation, fiber characteristics of the improved polyvoltine breeds and polyvoltine × bivoltine hybrids have been studied. Further, the impact of early generation selection during the breeding process in respect of filament size variation, neatness and filament length in fiber quality improvement programmes has been discussed.

MATERIALS AND METHODS

In the present investigation the following polyvoltine breeds and polyvoltine × bivoltine hybrids of the silkworm *Bombyx mori* L developed at Central Sericultural Research and Training Institute, Mysore have been utilized.

Polyvoltine breeds		Polyvoltine × bivoltine hybrids
Pure Mysore (PM)		PM × CSR2
ND7	AGL3	L14 × CSR2
ND5	AGL5	L15 × CSR2
NP1	L14	
NDV6	L15	

All the polyvoltine breeds and polyvoltine × bivoltine hybrids were reared under optimum conditions. After cocooning, 300 cocoons were selected and assessed for their reeling parameters. The new promicing hybrids L14 × CSR2 and L15 × CSR2 have been further analyzed for their yarn traits. Impact of early generation selection in respect of neatness, filament length and raw silk %. Impact of early generation selection in respect of cocoon size variation, neatness and filament length in fibre quality improvement programmes has also been studied. Neatness is estimated based on the standard panels by comparison.

For studying cocoon filament size variation, thirty cocoons from each breed randomly selected and individually reeled using mono cocoon reeling machine developed by Japan. Each cocoon was reeled in consecutive sections of 50m, numbered serially (from outer to the inner most layer) and weighed by using an electronic balance. The denier of each section was calculated by the following formula :

$$D = \frac{W}{L} \times 9000$$

Where, D is denier

W is weight of the filament in g.

L is the length of the filament in m.

Filament size of all the sections in each cocoon were recorded serially from outer most to inner most section. Filament size of 50m sections from outer to inner layer for all the breeds were plotted, as shown in Fig. 1 3, to know the slope of the denier curve. Slope of the denier curve was calculated by regression analysis by the following formula :

$$b = \frac{\Sigma xy - \frac{\Sigma x \times \Sigma y}{n}}{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}$$

Where b = slope,

× = filament length,

y = filament size and n = number of observations.

RESULTS AND DISCUSSION

Reeling performance of the new polyvoltine breeds and the polyvoltine × bivoltine hybrids is presented in Tables 1 to 6. Data indicated significant ($P<0.01$) variation among the breeds and also among the F1 hybrids for various reeling and fabric parameters studied. Filament length in the breeds ranged from 415 (PM) to 696 m (NDV6), reelability ranged from 72 (PM) to 87 (L15), raw silk % ranged from 9.2 (PM) to 14.86 (l14), raw silk recovery ranged from 55 (PM) 78.9 % (L14), neatness ranged from 86 (PM) to 90p (L14 & L15). Boil-off-loss ratio is ranged from 23.8 to 28.4. Filament size ranged from 2.1 to 2.7 d.

In the three polyvoltine × bivoltine hybrids studies, filament length ranged from 785 (PM × CSR2) to 1008 m (L14 × CSR2), filament size ranged from 2.57 to 2.73 d, raw silk percent ranged from 13.54 to 16.58, neatness ranged from 88 to 91p, reelability ranged from 74.48 to 78.88 %, boil-off-loss ratio ranged from 25.36 to 16.12, yarn size deviation ranged from 1.45 to 1.59 (2A Grade). Renditta ranged from 7.5 to 6.05 (L14 × CSR2).

Bulk of the cocoon production in India is crossbreeds. Even the best of the crossbreed cocoons have certain inherent limitations for producing good quality raw silk. Efforts in propagating bivoltine cocoons had not gained the expected momentum. Strategies towards raw material improvement would have to address mainly the quality improvement of cross breed cocoons. Good quality cocoons are an important prerequisite for the production of high quality raw silk. Studies have shown that cocoon quality contributes almost 80% towards the quality of raw silk (Somashekar, 2003).

Following are the important parameters considered for grading of silk yarn i) Reelability, ii) Neatness, iii) Filament size and size variation, iv) Raw silk %, v) Boil-off-loss ratio, vi) Lousiness, vii) Winding breaks, viii) Evenness, ix) Tenacity and x) Cohesion. Of the ten parameters mentioned above first six are considered to be influenced mainly by the races used in F1 hybrid preparation which can be improved through selection during the breeding and the latter four parameters are considered to be influenced mostly by the reeling method/machines used during reeling process.

Reelability is a qualitative character. Humidity effects reeling. It is a low heritable trait. We can hardly estimate the reelability of F1 hybrid because of large deviations caused by different environments and low percentage of genetic effect. Bad ventilation in the cocooning environment is liable to decrease the reelability making the cocoon layer too thick.Reelability is considered to be controlled by polygenes and easily fluctuated by the environmental conditions such as temperature, humidity and air current during spinning.

Raw Silk percent related to silk percentage and this character can be easily improved by the selection of cocoon shell percentage. But cocoon weight and cocoon yield fluctuate with negative correlation. Cocoon shell percent is a relative character cocoon and shell weight. Cocoon shell percent itself and cocoon shell weight or pupal weight can be the subject of selection to improve the cocoon shell percent. As selection is done attending to the cocoon shell percent, cocoon shell weight and cocoon shell percent are increased but single cocoon weight as a whole decreases. If selection is done based on cocoon shell weight and cocoon shell percent,

pupal weight is increased as cocoon shell weight increases.

Raw silk thread contains 20-30% of soluble protein (sericin), used for the cementing of cocoon filament, fibroin. Sericin is removed by boiling with alkaline solution before or after weaving. Sericin content is one of the important commercial parameter in the fabric manufacturing sector and 26% Boil-off-loss ratio **(**BOR) is the upper limit for the F1 hybrids.

BOR is controlled by polygenes and shows high response to selection. According to Gamo and Hirabayashi (1984) lower BOR is manifested by dominant genes while, recessive genes act towards the opposite direction. Epistatic and maternal effects were observed in this trait, and the value of BOR was significantly differed by reciprocal crossing. However, this trait is closely related with cocoon shell weight and positively correlated. It is difficult to breed the inbred showing low value without reducing the cocoon shell weight. F1 values are usually higher than the MPV, because the cocoon shell weight is also increased by hybridization.

During the development of L14 and L15 breeding lines generation wise data of filament length, raw silk percent and neatness were recorded from F1 and presented in Table 7. Data indicated that early generation selection for these traits has given significant results in stabilizing the traits in the later generations. Neatness is an important qualitative parameter, caused mainly by the habits when the silkworm puffs off the fiber in the course of cocooning. And it is considered to be controlled by a single gene (n^e) and the high grade are inherited as dominant. Neatness shows high heritability. High graded strain of neatness to be used as one of the breeding resources material. Selection usually carried out only in its early generations (F1 to F3). Neatness is also dependant on the conditions of rearing and mounting. Higher temperature and higher humidity during cocoon formation increases the neatness defects.

One of the fascinating problems in the silk reeling technology is the determination of the denier of the silk filament and size variation in the single cocoon filament. The applied importance of denier variation to the silk reeling industry is at par with the evolution of new silkworm races. The size of the bave varies greatly depending on the strain of the silkworm (Narayanan et al., 1967 and Rama Mohana Rao et al., 1998). Size of the cocoon filament has negative correlation with the length of filament and size of the cocoon filament has positive correlation with cocoon weight. Slender larvae usually have fine cocoon filament (Mano 1994). Cocoons superior in several traits can be of no help to the filatures in producing quality silk yarn if the size deviation is very high (Sonwalker, 1987, Naik et al., 1994,

Table 1: Reeling Performance of polyvoltine breeds selected

Breed	Filament Length(m)	Reel. %	Raw Silk %	Raw Silk Recovery	Neatness (P)	Boil-off Loss Ratio %	Filament Size
NDV6	696	80	13.80	77.50	87	23.8	2.6
ND7	642	84	12.42	69.50	87	25.7	2.2
ND5	609	83	13.58	74.65	86	28.4	2.6
NP1	605	85	13.64	76.33	86	23.8	2.3
L14	674	86	14.86	78.9	90	25.2	2.1
L15	670	87	14.62	76.3	90	25.4	2.4
PM	415	72	9.20	55.00	86	25.7	2.7
CD @ 5%	52.44**	1.95*	0.44**	2.67**	1.41**	-	0.22**

Table 2: Details of fibre characteristics in the multivoltine breeds of the silkworm

Breed	Maximum Filament size	Minimum Filament size	Average Filament Size	Slope (b)
NDV6	3.511	1.199	2.43	-0.00312
ND7	3.596	0.999	2.23	-0.00363
ND5	2.985	0.980	2.43	-0.00310
NP1	3.625	0.999	2.47	-0.00470
L14	3.425	1.105	2.12	-0.00391
L15	3.643	1.112	2.41	-0.00391
PM	2.920	1.202	1.97	-0.00377
SD	0.3433	0.2906	0.20	-
CV%	10.32	26.98	8.96	-

Table 3: Regression analysis in the Multivoltine breeds of the silkworm

Variable	n	d.f.	S.E. of y est.	r^2	r
Filament length vs filament size	66	64	0.208	0.027	0.1658
Filament size vs Slope	66	64	0.001	0.155	-0.3933**
Filament length vs slope	66	64	0.001	0.080	0.2837*

* P< 0.05, ** P <0.01

Table 4: Reeling performance of new hybrids

Hybrids	Filament length (m)	Denier	RS %	Neatness (P)	Reel. (%)	RS Rec. (%)
L14 × CSR2	1008	2.62	16.58	91	88	78.88
L15 × CSR2	985	2.68	16.09	91	88	77.32
PM × CSR2 (C)	785	2.57	13.54	88	85	74.48
ND7 × CSR2	915	2.73	15.06	90	87	75.68
SE	3.2815	0.0234	0.02062	0.2546	0.6009	0.1784
CD at 5%	11.355**	0.081**	0.0713**	0.88**	2.079**	0.617**

Table 5: Reeling performance of new hybrids

Hybrids	Biol off loss ratio	Size Deviation	Cohesion	Renditta
L14 × CSR2	25.36	1.45	89	6.05
L15 × CSR2	25.55	1.59	78	6.25
PM × CSR2	26.12	1.49	78	7.50
ND7 × CSR2	25.55	1.58	76	6.60

Table 6. Improvement in quality parameters in the new hybrid

Trait	PM × CSR2	Grade/Class (19d – 22d)	L14 × CSR2	Grade/Class (19d – 22d)
Size deviation	2.15	A	1.48	2A Grade
Maximum size deviation	4.7	A	1.9	2A Grade
Tenacity (g/d)	3.4	2A	3.8	2A
Cohesion	65	2A	61	4A
Cleanness (%)	86	B	99	4A
Avg. Neatness (p)	87	A	94	2A
Low neatness (p)	78	A	88	2A
Elongation (%)	23	4A	22	I Class
Winding breaks	6	A	0	4A
Grading		B	2A	

Table 7: Generation wise fiber characteristics in the newly developed polyvoltine breeds

L14				L15			
Generation	Filament length (m)	Neatness (p)	Raw silk %	Generation	Filament length (m)	Neatness (p)	Raw silk %
F1	770	91	15.80	F1	770	91	15.80
F2	599	90	14.70	F2	599	90	14.70
F3	673	89	13.90	F3	673	89	13.90
F4	580	92	14.10	F4	660	90	14.40
F5	673	92	14.30	F5	680	92	14.70
F6	687	92	14.51	F6	636	91	14.16
F7	628	90	14.59	F7	608	91	14.85
F8	649	91	14.93	F8	640	92	15.14
F9	685	90	14.72	F9	659	92	14.47
F10	692	89	14.35	F10	645	91	14.64
F11	665	90	14.45	F11	660	89	14.75
F12	680	91	14.20	F12	670	91	14.51
F13	697	90	14.94	F13	653	90	14.98
F14	690	90	14.80	F14	660	90	14.75
F15	677	90	14.87	F15	614	90	14.80
F16	690	91	14.50	F16	665	90	14.56
F17	675	90	14.48	F17	670	90	14.50

and Rama Mohana Rao et al., 2008).

Regression analysis (Table 3) indicated significant negative correlation between filament length and slope of the curve and is positive correlation between slope of the denier curve and maximum filament size and mean filament size. Hence, during selection of parents for breeding programmes, filament size and length can be used an indicator of single cocoon filament size variation. Filament size and size variation should be selected from F2 on wards and it may take 10 to 13 generation to fix these traits.

Owing to the field constraints, economic and social compulsions and geographical conditions cross breed cocoons would continue to hold a place of importance. There is a general feeling in the industry that the lusture and stiffness of cross breed silk is superior to that of bivoltine silk, which is specially preferred by the handloom sector. Thus the strategies towards raw material improvement would have to address mainly the quality improvement of cross breed cocoons.

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COMPARISON OF PHYSICAL AND THERMAL PROPERTIES OF MULBERRY, WHITE ERI AND RED ERI SPUN SILK YARN WOVEN FABRICS

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ABSTRACT

In this paper, mulberry, white eri and red eri pierced cocoons have been successfully degummed, spun on worsted system of spinning produced 2/60sNm, 2/80 sNm and 2/120 sNm spun silk yarns. Plain fabrics were woven on power loom using the above yarns in weft with 2/60 sNm yarn in warp. These fabrics were tested for mechanical properties as per International standard testing methods. The results have been compared and analyzed. From this study, it is revealed that white and red eri spun silk fabrics are durable, soft, have better crease resistance, good aesthetics, tactile and thermal comfort property than Mulberry spun silk fabrics.

Key words: Abrasion resistance, Breaking strength, Red Eri, White eri, Spun silk

INTRODUCTION

Silk is the Queen of Textiles and spells luxury, elegance, class and comfort. It withstood many a daunting challenges from other natural and artificial fibres and yet, remained the undisputed Queen of Textiles since centuries. It is comfortable and has a very good absorbent quality and excellent drapes, etc. These properties have made the silk, irresistible and inevitable companion of the eve, all over the world. There are four major types of silk of commercial importance viz., mulberry, tasar, eri and muga. India has the unique distinction of producing all these varieties of silk. Chemically speaking, these varieties of silk are made of proteins secreted in the fluid state by a caterpillar.

There are two type of eri cocoons *viz.,* red eri and white eri. Eri cocoons are mouth opened and not suitable for reeling to produce continuous filament to get finer quality silk unlike mulberry (Kariyappa *et al.,* 2006a). The Eri worms feed on castor and tapioca plants and mulberry worms feeds on mulberry plants. Quality spun silk yarn can be produced from both types of eri cocoons on large scale. Yarn produced from eri cocoons can be woven on power loom as well as high-speed shuttle less loom (Kariyappa *et al.,* 2006b).

In this study, pierced cocoons of mulberry, white eri and red eri were degummed, spun on worsted system of spinning to produce 2/60 sNm, 2/80 sNm and 2/120 sNm spun silk yarns. The plain fabrics were woven on power loom from each variety of silk by keeping 2/60 sNm in warp and varying yarn count 2/60 sNm, 2/80 sNm and 2/120 sNm in the weft.

MATERIAL AND METHODS

The study was carried out to know the physical and comfort properties of white and red eri spun silk fabrics compared with Mulberry spun silk fabrics. The fibre specifications used for the study is given in the Table 1. White and red eri cocoons were procured from Assam and mulberry cut cocoons were taken form CSTRI, Bangalore. These cocoons were degummed and subjected to spinning to produce 2/60 sNm, 2/80 sNm and 2/120 sNm spun silk yarns at M/s Kareem silks on worsted system of spinning (Kariyappa *et al.,* 2006b). The yarn thus produced were tested for yarn unevenness and imperfection by using Uster evenness tester and also for tensile and elongation properties by using Instron tensile tester. The test results are shown in Table 2 and Anova in Table 3.

From the above yarn, the plain fabrics were woven on power loom at CSTRI, Bangalore with particulars of Reed 60, PPI 42, width 54"as given below. White eri spun silk fabrics using 2/60 sNm Warp and 2/60 sNm, 2/80 sNm &

2/120 sNm of Weft mulberry spun silk fabrics using 2/60 sNm Warp and 2/60 sNm, 2/80 sNm, 2/120 sNm & 2/140 sNm of Weft. Red eri spun silk fabrics using 2/60 sNm Warp and 2/60 sNm, 2/80 sNm & 2/120 sNm Weft. The fabrics produced were subjected to various tests as given below and the the fabric properties are given in Table 4.

- Weight per square meter as per IS 1964-2001
- Thickness of fabric as per IS 7702-1975.
- Air permeability as per IS 11056-1984
- Bursting strength as per IS 1966-1975
- Tearing strength as per IS 6489-1993
- Tensile strength and elongation as per IS 1969-1985
- Drape as per IS 8357 1977
- Abrasion resistance as per IS 12673- 1989.
- Crease recovery as per IS 4681- 1981
- Bending length and flexural rigidity as per IS 6490-1971.
- Water repellency as per IS 390 1975.
- Pilling resistance as per IS 1097-1964
- Thermal insulation value as per guarded hot plat method

Table 1: Fibre parameters of mulberry, white and red eri silk

Sl. No	Particulars	Mulberry	Red Eri	White Eri
1	Fibre fineness (micron)	14.33	16.51	15.05
2	Std. Deviation of fineness	3.95	4.31	4.26
3	Whiteness index	63.96	43.07	54.90
4	Yellowness index	5.59	10.838	7.8
5	Specific gravity of fibre	1.296	1.307	1.305
6	Fibre bundle strength (g/t)	42	29.4	31.1
7	Fibre elongation (%)	9.4	11	13.2
8	Moisture content (Wet)	10.69	9.69	10.55
9	Moisture regain (Dry)	9.66	8.83	9.54
10	Denier	1.8	2.37	2.08

RESULTS AND DISCUSSION

Analysis of yarn parameter

The Mulberry, White eri and Red eri spun silk yarn were tested for the following parameters.

Uster evenness (%)

From Table 2, it is observed that Um%, Cvm%, Cvm (1m)% are highest in Red eri spun silk yarn followed by White eri and least in case of mulberry spun silk yarn. From ANOVA Table 3, it is observed that there is significant difference among the three varieties of silk in corresponding count of yarn and three different count of yarn in each variety of silk. This is due to the fact that fibre fineness and variation of fibre fineness is least in mulberry silk followed by white eri and highest in case of red eri silk fibre as depicted in Table 1. These parameter influences the Uster evenness properties. As count of yarn increases, evenness also increases because of number of fibres in the yarn cross-section reduced.

Thin places and thick places

From table(2), it is observed that Thin places (-50%) and thick places (+50%) are highest in Red eri spun silk yarn followed by, White eri and least in case of mulberry spun silk yarn. From ANOVA table(3), it is observed that thin places (-50%) and thick places (+50%) have no significant difference among three varieties of silk in corresponding count of yarn and three different count of yarn in each variety of silk. But 2/120 $^{s}N_{m}$ spun silk yarn has Significance difference with 2/60s and 2/80 $^{s}N_{m}$ spun silk yarns in White eri and Red eri. This is due to the fact that fibre fineness and variation of fibre fineness is least in mulberry silk fibre followed by white eri and highest in red eri silk fibre as depicted in table (1). These fibre parameter influences the spun silk yarn thick and thin places. As count of yarn increases thin (-50%) and thick (+50%) also increases because of no. of fibre in the yarn cross section reduces. Thick places (+100%) have no significant difference among three varieties of silk in corresponding count of yarn and three different count of yarn in each variety of silk.

Statistical analysis

Fabric parameters were analyzed through one-way ANOVA using SPSS 11.5 and windostat package.

Table 2: Evenness, imperfection and mechanical properties of Mulberry, White Eri and Red Eri spun silk yarns

	Count 2/60 $^{s}N_{m}$			Count 2/80 $^{s}N_{m}$			Count 2/120 $^{s}N_{m}$			Count 2/140 $^{s}N_{m}$	SE ±	CDat 5%
Per / 100 km	Mulb.	White Eri	Red Eri	Mulb.	White Eri	Red Eri	Mulb.	White Eri	Red Eri	Mulb.		
Evenness properties												
Um %	7.40	8.93	10.90	8.62	10.15	11.17	9.65	14.18	14.17	10.71	0.2865	0.8219
Cv m %	9.57	11.34	13.82	11.05	12.84	14.29	12.32	17.98	18.00	13.83	0.3845	1.1030
Cvm (1m) %	5.74	6.87	7.33	6.67	8.28	10.17	7.45	11.10	10.36	7.50	0.4792	1.3746
Imperfection properties												
Thin Places (-50%)	0	0	6	0	2	6	0	66	65	2	3.1767	22.7800
Thick Places (+50%)	11	6	10	20	10	18	30	69	74	32	2.5114	18.0100
Thick Places (+100%)	1	0	0	2	2	2	3	6	4	4	0.8580	6.1500 ^{NS}
Neps (+ 140 %)	25	27	37	35	34	45	84	117	126	190	3.5464	25.4300
Neps (+ 200 %)	12	14	18	18	10	22	36	44	47	55	1.7456	12.5200
Neps (+ 280 %)	9	4	10	12	6	15	22	22	20	26	1.6000	11.4700
Neps (+ 400 %)	4	3	6	6	4	8	7	13	12	10	1.0000	7.1700 ^{NS}
Index (-)	1.27	1.62	1.75	1.32	1.66	1.86	1.4	1.86	2.09	1.4	0.0524	0.1503
Hairiness (-)	2.62	2.95	2.67	2.88	3.14	3.12	3.27	3.38	3.25	3.32	0.0698	0.1984
Sh (-)	0.77	1.01	0.92	0.83	1.00	0.95	0.83	1.15	1.00	0.92	0.0250	0.0717
Mechanical properties												
Breaking Force (gf)	878.79	870.78	677.70	590.115	622.22	462.38	377.79	359.39	277.59	309.92	12.5292	34.9760
Elongation (%)	10.89	23.33	21.26	8.62	20.75	18.36	8.15	18.93	18.13	8.12	0.0312	0.8410
Tenacity (gf / den)	2.74	2.43	2.07	2.55	2.40	2.07	2.51	2.30	1.77	2.33	0.0547	0.1527
B-Work (Kf.cm)	11.65	22.31	17.13	6.46	14.87	10.37	4.10	7.94	6.07	3.24	0.6358	1.7749
Young's modulus	58.30	21.50	27.51	69.08	39.27	37.48	71.46	40.45	47.67	80.78	0.8589	2.3976

Table 3: ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Um%	216.325	9	24.036	64.279	0.000
Cvm%	345.366	9	38.374	57.207	0.000
Cvm(1m)%	144.559	9	16.062	14.453	0.000
Index(-)	3.226	9	0.358	28.101	0.000
Thin places (-50%)	5203.680	9	578.187	11.912	0.000
Thick places (+50%)	4260.180	9	473.353	13.992	0.000
Thick places (+100%)	20.880	9	2.320	1.432	0.207
Neps (+140%)	22430.820	9	2492.313	42.545	0.000
Neps (+200%)	1961.780	9	217.976	14.899	0.000
Neps (+280%)	402.400	9	44.711	3.482	0.003
Neps (+400%)	91.520	9	10.169	2.071	0.056
Hairiness(-)	3.253	9	.361	15.864	0.000
Sh(-)	.557	9	.062	21.691	0.000
Max. load (gf)	8782287.855	9	975809.762	296.227	0.000
Tenacity (gpd)	14.166	9	1.574	24.713	0.000
Elongation (%)	6513.974	9	723.775	379.122	0.000
young's modulus	77883.308	9	8653.701	570.960	0.000
Energy-max load(kgf-mm)	6798.377	9	755.375	211.079	0.000

Significant at 5%

Neps

From table (2), it is observed that Neps counts are highest in Red eri spun silk yarn followed by White eri and least in case of mulberry spun silk yarn. From ANOVA table-3 it is observed that Neps counts have no significant difference among three varieties of silk in corresponding count of yarn and three different count of yarn in each variety of silk. But 2/120 $^{s}N_{m}$ spun silk yarn has Significance difference with 2/60 $^{s}N_{m}$ and 2/80 $^{s}N_{m}$ spun silk yarns in each variety of silk. In case of Neps (400%) have no significant difference among three varieties of silk in corresponding count of yarn and three different count of yarn in each variety of silk. But has significant difference between 2/60 $^{s}N_{m}$ and 2/80 $^{s}N_{m}$ in white eri spun silk yarns. As count of yarn increases Neps count in spun silk yarn also increases.

Hairiness (-) and Sh (-)

From the table (2), it is observed that Hairiness is highest in white eri followed by red eri and least in case of Mulberry spun silk yarn. Hairiness increases with increase of yarn count in all varieties of spun silk yarn. From ANOVA Table -3 it is observed that hairiness has significant difference among the three varieties of spun silk yarn in corresponding counts, but not in 2/120 $^{s}N_{m}$. There is significant difference among different count of yarn in each varieties of silk. In case of higher count, more fibres on surface of yarn get abraded with contact point during process which increases the hairiness (Chalamani *et al.,* 2008).

Index of Irregularity (-)

From Table 2, it is observed that Index of Irregularity (-) increases with increase of yarn count in all three varieties of spun silk yarn. Index of Irregularity (-) is highest in red eri spun silk yarn followed by white eri and least in case of Mulberry spun silk yarn. From ANOVA Table (3) it is observed that Index of Irregularity (-) has significant difference among the three varieties of spun silk yarn in corresponding counts, but in case of 2/60 $^{s}N_{m}$ spun silk yarn there is no significant difference between red and white eri. There is no significant difference between of 2/60 $^{s}N_{m}$ and 2/80 $^{s}N_{m}$ spun silk yarn in all three varieties of spun silk yarns. In case of mulberry there is no significant difference among all the four different counts of yarn. This is due to the fact that the fibre diameter, diameter variation, fibre length distribution is highest in red eri, followed by white eri and least in Mulberry silk fibre which influences the index of irregularity, beside this, yarn evenness and imperfections also influences.

Table 4: Physical and Comfort properties of Mulberry, White eri and Red eri spun silk fabrics

Fabric properties		Mulberry				White Eri			Red Eri			SE	CD at 5%
		(2/60 x 2/60)	(2/60 x 2/80)	(2/60 x 2/120)	(2/60 x 2/140)	(2/60 x 2/60)	(2/60 x 2/60)	(2/60 x 2/60)	(2/60 x 2/60)	(2/60 x 2/80)	(2/60 x 2/120)		
1. Linear Density (N_m)	warp	$2/60^s$	$2/60^s$	$2/60^s$	$2/60^s$	$2/60^s$	$2/60^s$	$2/60^s$	$2/60^s$	$2/60^s$	$2/60^s$	NA	NA
	weft	$2/60^s$	$2/80^s$	$2/120^s$	$2/140^s$	$2/60^s$	$2/80^s$	$2/120^s$	$2/60^s$	$2/80^s$	$2/120^s$	NA	NA
2. Threads (no.)	Ends/in	62	62	62	62	62	62	62	62	62	62	NA	NA
	Picks/in	44	44	44	44	44	44	44	44	44	44	NA	NA
3. Breaking strength (kgf)	Warp	104.56	103.43	110.99	110.66	82.67	95.232	97.65	72.57	79.02	82.06	18.266	5.3460
	Weft	82.78	53.6	19.9	26.97	73.53	57.57	31.16	52.54	38.52	26.65	8.578	2.5106
4. Elongation (%)	Warp	25.40	20.22	16.00	15.80	33.57	32.565	31.83	28.82	27.48	25.08	0.3524	1.0107
	Weft	18.32	15.02	9.52	7.20	25.688	25.082	23.34	25.08	23.48	21.80	0.38069	1.0919
5. Tearing strength (g)	Warp	Jaw slippage	Jaw slippage	Jaw slippage	Jaw slippage	Jaw slippage	Jaw slippage	Jaw slippage	Jaw slippage	Jaw slippage	Jaw slippage	NA	NA
	Weft	4314	4250	2560	2509	5500	4378	3354	2138	1523	998.4	58.75	168.9155
6. Crease Rec. angle (in degrees)	warp	92	93	93	95	93	92	95	96	95	94	NA	NA
	weft	90	90	91	90	89	88	93	93	92	91	NA	NA
	Total	182	183	184	185	192	190	188	189	187	185	0.8630	2.4753
7. Fabric mass (g/m2)		163.5	144.88	125.40	121.20	169.4	155.1	131.9	167	155	135	0.44842	1.3900
8. Air permeability (m3/m2/min)		20.3	23	28.6	29.6	25.64	25.8	30.3	26.47	29.64	34.63	0.9046	2.5946
9. Water permeability (rating)		0	0	0	0	0	0	0	0	0	0	NA	NA ^{Ns}
10. Pilling resistance (rating)		5	5	5	5	5	5	5	5	5	5	NA	NA ^{Ns}

Fabric properties		Mulberry			White Eri			Red Eri				SE	CD at 5%
		(2/60 x 2/60)	(2/60 x 2/80)	(2/60 x 2/120)	(2/60 x 2/140)	(2/60 x 2/60)	(2/60 x 2/60)	(2/60 x 2/60)	(2/60 x 2/60)	(2/60 x 2/80)	(2/60 x 2/120)		
11. Abrasion resistance (no of rubs)		750	622	685	866	604	475	383	538	520	429	64.472	184.915 Ns
12. Cover factor	Warp	15.03	15.03	15.03	15.03	15.03	15.03	15.03	15.03	15.03	15.03	NA	NA
	Weft	10.46	9.82	7.29	6.6	10.46	9.82	7.29	10.46	9.82	7.29	NA	NA
	Overall	19.88	19.58	18.43	18.04	19.88	19.58	18.43	19.88	19.58	18.43	NA	NA
13. Drape coefficient (%)		41.00	39.00	38.8	31.7	44.76	39.92	30.32	38.59	33.66	30.28	2.3183	6.649
14. Bursting strength (kgf/cm2)		18.3	14.3	11.6	12	17.56	16.2	12.96	14.52	12.72	11.336	1.383	3.9667
15. Thickness (mm)		0.387	0.378	0.323	0.326	0.465	0.426	0.367	0.513	0.445	0.395	0.00357	0.01023
16. Flexural rigidity Stiffness (mg-cm)	Warp	171.7	145.9	147.2	152.6	150.3	186.6	196.36	168.88	172.18	191.03	14.28937	40.98408
	Weft	237.5	156.3	49.6	51.4	200.8	152	58.18	156.04	118.28	59.9	7.8914	22.6336
	Overall	201.9	151	85.4	88.6	173.7	168.2	107.414	162.34	142.71	107.02	8.9457	25.6518
17. Thermal insulation value (Tog)		0.8576	0.8577	0.8658	0.8771	0.8767	0.8599	0.8475	0.9383	0.8716	0.7813	0.00191	0.0055

Table 5: ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Fabric Mass	13678.545	9	1519.838	1322.749	0.000
Thickness(mm)	0.152	9	.017	179.388	0.000
Air permeability	750.663	9	83.407	21.414	0.000
Bursting	268.667	9	29.852	183.054	0.000
Pilling resistance	0.000	9	.000	NA	NA
Water Repellency	0.000	9	.000	NA	NA
Crease recovery angle	5065.200	9	562.800	28.980	0.000
Warp B.L	0.589	9	.065	2.921	0.009
Warp F.R	30549.837	9	3394.426	2.884	0.010
Weft B.L	4.587	9	.510	52.545	0.000
Weft F.R	139668.587	9	15518.732	44.744	0.000
overall	31842.520	9	3538.058	7.700	0.000
Drape coefficient	1459.030	9	162.114	5.854	0.000
Tearing (Warp)	436250.000	9	48472.222	NA	NA
Tearing (Weft)	86831928.320	9	9647992.036	593.317	0.000
Abrasion esistance	301557.220	9	33506.358	1.431	0.208
Tensile (Warp)	812969.139	9	90329.904	56.313	0.000
Tensile (Weft)	1962180.75	9	218020.084	631.696	0.000
Elongation (Warp)	1812.92	9	201.436	346.56	0.000
Elongation (Weft)	2060.256	9	228.917	250.869	0.000
TIV(Tog)	451.28	9	50.142	13.63	0.000

Mechanical properties spun silk yarns

Mechanical properties of mulberry, white eri and red eri spun silk yarn were tested on Instron machine, it gives the following important parameters and these parameters are very important to decide the end uses of the yarn and fabric.

Breaking force (gf)

From Table 2, it is observed that breaking force (gf) of mulberry spun silk yarn is highest followed by white eri and least in case of red eri spun silk yarn.The Breaking force (gf) reduces with increases of yarn count because of number of fibre get reduced in the cross section. From ANOVA table (3) it is observed that Red eri spun silk yarn has significant difference with White eri and Mulberry spun silk yarn in corresponding counts, there is no significant difference between mulberry and white eri spun silk yarns. This is due to fact that Mulberry and white eri fibres are stronger and finer than red eri fibre.As a result, Mulberry and white eri spun silk yarn are stronger than red eri spun silk yarn.

Elongation (%)

From Table 2, it is observed that elongation percentage of white eri spun silk yarn is highest followed by red eri and least in case of mulberry spun silk yarn. The elongation percentage reduces with increases of yarn count because of number of fibre get reduced in the yarn cross section. From ANOVA table (3) it is observed that elongation percentage has significant difference among the three varieties of silk in corresponding counts of yarn and among different counts of spun silk yarns in each variety of silk. This is due to fact that elongation percentage of White eri silk fibre has highest elongation percentage followed by red eri and least incase of Mulberry silk fibre which influences the spun silk yarn elongation percentage.

Tenacity (g/d)

From the Table 2, it is observed that Tenacity (g/d) of mulberry spun silk yarn is highest followed by white eri and least in case of red eri spun silk yarn. The Tenacity (g/d) reduces with increases of yarn count because of number of fibre get reduced in the yarn cross section. From ANOVA table -3 it is observed that Tenacity (g/d) of Red eri spun silk yarn has significant difference with White eri and Mulberry spun silk yarn in corresponding counts of spun silk yarn, but there is no significant difference between mulberry and white eri spun silk yarn. This is due to fact that Mulberry and white eri fibres are stronger and finer than red eri fibre as a result

Mulberry and white eri spun silk yarn are stronger than red eri spun silk yarn.

B-work (gf-cm)

From the table-2, it is observed that B-work (gf-cm) of white eri spun silk yarn is highest followed by red eri and least in case of mulberry spun silk yarn. The B-work (gf-cm) reduces with increases of yarn count because of number of fibre get reduced in the cross section. From ANOVA Table -3 it is observed that B-work (gf-cm) has significant difference among all three varieties of silks in corresponding counts of yarn and among three counts of spun silk yarns in each variety of silk. This is due to fact that B-work (gf-cm) is related to area under the load elongation curve. The load elongation curve of White eri is highest followed by red eri and least incase of Mulberry silk fibre which influences B-work (gf-cm) of spun silk yarn.

Young's modulus

From the Table 2, it is observed that young's modulus of mulberry spun silk yarn is highest followed by red eri and least in case of whit eri spun silk yarns. The young's modulus increases with increases of yarn count because of number of fibre get reduced in the cross section. From ANOVA Table 3, it is observed that young's modulus has significant difference among all three varieties of silks in corresponding counts of yarn and among the three counts of spun silk yarns in each variety of silk. This is due to fact that young's modulus is related to extensibility of silk fibre, higher the extensibility lower the young's modulus visa-versa.

Mechanical properties spun silk fabrics

Mechanical properties of mulberry, white eri and red eri spun silk fabric were tested as per IS methods, it gives the following important parameters and these parameters are very important to decide its end use.

Breaking strength (kg)

Breaking strength (kg) is the maximum amount of tensile stress that it can be subjected to before failure. The definition of failure can vary according to type of a material (Pradeepa and Jayalakshmi, 2009). From table (4), it is observed that the breaking strength (g) of mulberry fabric in warp way and weft way is highest followed by white eri and least in red eri spun silk fabric irrespective of weft yarn count, Breaking strength of fabric in warp way increases with increases of weft yarn count in the fabric, this is due to fact that as weft count increases, the weft assistance in the fabric reduced as a results in higher the warp breaking strength (Pradeepa and Jayalakshmi, 2009). Increase of weft count in fabric is significantly effecting on breaking strength in case of both eri fabrics but not in mulberry spun silk fabrics. From table (4) it is observed that the breaking strength (g) of fabric weft way is reduces with increases of weft count in all three varieties of spun silk fabric because of number of fibres get reduce as count increases. From ANOVA table(5) it is observed that the breaking strength (g) of fabric in both warp way and weft way has no significant difference between Mulberry and white eri but theses have significant difference with Red eri spun silk fabrics corresponding counts of fabrics and among three varieties of spun silk fabrics each variety. This is because of tensile strength of both fibre and yarn of all varieties

Elongation (%)

Elongation percentage is the extensibility of fabric at breaking point. The definition of Elongation percentages can very according to type of a material (Kaswell, 1953). From table(4), it is observed that the Elongation percentage of white eri fabric is highest followed by red eri and least in case of Mulberry fabric in both warp way and weft way. The elongation percentage of spun silk fabric in warp way is more than weft way in all three varieties of silk. The elongation percentage decreases with increase of weft count in each varieties of silk; this is due to fact that elongation percentage of silk fibre and yarn influence the elongation percentage of fabric. From ANOVA table(5) it is observed that the Elongation percentage of fabric in both warp and weft way has significant difference among three varieties of spun silk fabrics in corresponding count as well among the three different count of spun silk yarn in each variety. This is due to fact that weft yarn and warp yarn in the fabric also assist in fabric elongation percentage in warp way and weft way (Senthil Kumar and Jambagi, 2008).

Tearing strength (g)

Tearing strength (g) is the measure of the resistance of the either the warp or weft series of yarn in the fabric. The fabric that tears easily is regarded as an inferior product. From the table-4, it is observed that there is jaw slippage noticed during warp way Tearing strength (g) testing in all three varieties of spun silk fabrics because of 2/60s spun silk yarn used in the warp in all the fabrics.

Tearing strength (g) in weft way of White eri spun silk fabric silk is highest followed by mulberry and least in red eri spun silk fabric irrespective of weft yarn count, tearing strength decreases with increases of weft count in the fabric, from ANOVA table 5 it is observed that tearing strength (g) has significanct difference between and within varieties of silk irrespective of different counts of yarns in the fabrics. This is due to the fact that white Eri fibre and yarn tensile strength and elongation % are higher than the Mulberry and red eri silk fibre and it influences fabric tearing strength as a result higher tearing strength in white eri spun silk fabrics.

Fabric mass (g/m2)

This is measure of weight of fabric in grams per square meter. The comparative results and critical difference at 5% are given in table(4) it is observed that fabric mass per square meter of white Eri spun silk fabric is highest followed by red eri and least in Mulberry, The fabric weight decreases with increases of weft yarn count in all three varieties of spun silk fabrics. From ANOVA table (5) there is significant difference

among the all the varieties of spun silk fabrics. This is due to the fact that density and fineness of the fibre play a very important role deciding the fabric weight, density of white eri is higher than red eri and mulberry as a result white eri fabric weight is at higher side.

Air permeability (m3/m2/min)

Air permeability is reciprocal of the air resistance. From the table(4), it is observed that air permeability of fabric is highest in Red eri followed by white eri and least in case of mulberry spun silk fabrics; Air permeability increases with increase of weft yarn count in all three varieties of fabrics. From ANOVA table (5) it is observed that there is significant difference among the all the varieties of spun silk fabrics. This is due to the fact that the fineness of fibre play very important role in air permeability, finer fibre of mulberry silk gives higher packing density in the yarn than coarser fibre as a result, reduce the porosity in the yarn and fabric. Hence coarse fibre of red eri has higher air permeability than finer fibre of white eri and Mulberry spun silk fabrics

Water repellency (rating)

High and uniform absorbency of water is desirable quality of the fabric. Absorbency of fabrics is influenced by their wicking ability. The absorbency is very important in quick evaporation of perspiration in under garment, absorption of water by towel, cleaning cloth, diapers, gauge and bandages. From table (4), it is observed that water repellency (rating) of all fabrics is Zero. This is due to fact that the all three varieties of spun silk fabrics are hygroscopic in nature.

Pilling resistance (rating)

Pilling is tufts of entanglement of fibers are attached to the surface of the cloth and they look like small pills. In certain fibre, pills generated during the course of wear. Testing of this property is very important especially for fabrics meant for shirts, blouse, suits, skirts, etc. From the table (4), it is observed that no pilling was observed in Mulberry, White eri and red eri spun silk fabrics.

Abrasion resistance (no of rubs)

Abrasion is just one aspect of wear and is rubbing away the component fibers and the yarn of the fabric. From table (4), it is observed that abrasion resistance of Mulberry spun silk fabric is highest followed by white eri and least in case of red eri spun silk fabrics. Abrasion resistance increases with increase of weft yarn count in Mulberry spun silk fabrics, but in case of white eri and red eri abrasion resistance decreases with increases of weft yarn count. From ANOVA table (5) it is observed that abrasion resistance has no significant difference among the all the varieties of spun silk fabrics. This is due to fact that abrasion resistance depends on fibre cross-section shape, strength and yarn fineness (Senthil Kumar and Jambagi, 2008).

Drape coefficient (%)

Drape is the ability of the fabric to assume a graceful appearance in use. It is an important factor of textiles materials, which allows fabric to orient itself into graceful folds or pleats as results of force of gravity. From the table (4), it is observed that drape coefficient of white eri spun silk fabric is highest followed by mulberry and least in case of red eri spun silk fabric. The drape coefficient decreases with increase of weft yarn count in all three varieties of spun silk fabrics. From ANOVA table (5) it is observed that is there is no significant difference in drape coefficient among all three varieties of spun silk fabrics in corresponding counts. But in case of 2/120 ${}^{s}N_{m}$ weft yarn fabric there is significant difference among all three varieties of silk fabrics, in case of white eri fabric, there is significant difference among three varieties of fabric is noticed, in case of red eri there is significant difference between 2/60 ${}^{s}N_{m}$ and 2/120 ${}^{s}N_{m}$ weft yarn fabric. This is due to the fact that a thickness and weight of the fabric affects the drape properties of spun silk fabrics.

Bursting strength (Kgf/cm2)

Bursting strength is measure of fabric resistance to multidirectional force. From the table (4), it is observed that the Bursting strength of Mulberry fabric is highest followed by white eri and least in case of red eri fabric. Bursting strength of fabric reduces with increases yarn count in each variety of spun silk fabrics. From ANOVA table (5), it is observed that there significant difference among three varieties of spun silk fabrics in corresponding counts of fabric and among the counts of yarn in each variety of spun silk fabrics. This is due to the fact that silk fibre and yarn strength influences the fabric bursting strength.

Fabric thickness (mm)

Thickness is an important factor of the fabric .The thickness has a great impact on the drape and application of the fabric. From the table (4), it is observed that thickness of Red eri fabric is highest, followed by white eri and least in case of Mulberry spun silk fabric. Thickness of fabric reduces with increase of weft yarn count. From ANOVA table-5 it is observed that there is significant difference in fabric thickness among three varieties of spun silk fabrics in corresponding counts. In case of mulberry fabric there is no significant difference between 2/60 ${}^{s}N_{m}$ and 2/80 ${}^{s}N_{m}$ weft yarn fabrics. This is due to the fact that fabric thickness is influenced by fibre finesse and density, Red eri fibre coarser than white eri and mulberry fibre. As a result Red eri fabric is thicker than white eri and mulberry fabric.

Flexural rigidity (Stiffness (mg-cm)

Fabric stiffness indicates the resistance of the fabric to bending and it is a key factor in the study of hand and drape. From the table (4), it is observed that flexural rigidity of fabric is highest in Mulberry, followed by white eri and least in case of red eri fabric. The flexural rigidity of fabric reduces with increases of weft yarn count in each variety of silk fabrics. From ANOVA table(5) it is observed that there is no significant difference among all three varieties of spun silk in

corresponding counts except in 2/80 $^{s}N_{m}$ red eri which has significant difference compared to Mulberry and white eri. In white eri fabric there is no significant difference among three different counts of weft yarn fabrics. In case of mulberry there is no significant difference between 2/60s and 2/80 $^{s}N_{m}$ and 2/120 $^{s}N_{m}$ and 2/140 $^{s}N_{m}$ weft yarn fabric, and also in case of red eri there is no significant difference between 2/60 $^{s}N_{m}$ and 2/120 $^{s}N_{m}$ fabric. This is due to the fact that Flexural rigidity of fabric is inversely proportional to the fabric weight as lesser the fabric weight higher flexural rigidity in mulberry spun silk yarn and higher the fabric weight lesser the fabric rigidity in white eri spun silk fabrics.

4.3.13 Thermal Insulation value (Tog)

Thermal insulation value is measure of the thermal properties of fabric. From the table(4), it is observed that thermal property of Red eri spun silk fabric fabric is highest, followed by white eri and least incase of mulberry spun silk fabric. The Thermal insulation value increase with increase of weft yarn count in mulberry spun silk fabrics because of mulberry fiber are finer and more or less circular cross section and gives good packing density in yarn and fabrics as a result thermal properties increases with increases of weft yarn count, while in case of red eri and white eri ,TIV value decreases with increase of weft yarn count because yarn become finer air space in fabrics increase as a result reduce the thermal insulation value. Flatness of fibre in both eri silk fabrics will cling and trap air between the fibre which results in higher thermal insulation value than mulberry fabrics (Kaswell). From ANOVA table (5) it is observed that there is significant difference among all varieties of spun silk fabrics.

4.3.14 Crease recovery angle

Crease resistance is the property of fabric which causes it to recover from folding deformation the normally occur during its use. Higher the crease recover angle the fabric is more resistance to crease visa-versa. From the table(4), it is observed that Crease recovery angle of white eri is highest followed by red eri and least in incase of Mulberry spun silk yarn fabric. The crease recovery angle decreases with increase of weft yarn count in mulberry while in white and red eri, crease recovery angle decreases with increase of weft yarn count, From ANOVA table-5 it is observed that there is significant difference among all varieties of spun silk fabrics in corresponding count and there is no significant difference between 2/60 $^{s}N_{m}$ and 2/80 $^{s}N_{m}$ weft yarn fabrics in each variety of fabrics. This is due to the fact that crease recovery of fabric is highly influenced by the fibre and yarn elongation percentage , fineness and fabric thickness.

CONCLUSION

From the study, it is revealed that Mulberry spun silk yarn is best in uniformity, followed by White Eri and Red Eri, which directly correlate with fibre quality of silk. Yarn evenness decreases with increase of Count. There is no significant difference in yarn imperfection among three varieties of silks. It means good quality Eri spun silk yarn can be produced from both eri cocoons. Mulberry spun silk yarn is strongest followed by white Eri and red Eri but there is no significant difference between Mulberry and white eri. White Eri is best suited for crease resistant fabric and toughest fabric as it has highest elongation percentage and B-work force. White eri fabric is more durable as B-work force is highest and Mulberry is more resistant to sudden shock as it has highest young modulus. The spun silk yarn Imperfections, Hairiness and Index of irregularity are highest in red eri followed by white eri and least in mulberry spun silk yarn and these values increases with increase of yarn count.

From the study, it is concluded that white Eri spun silk fabric is strong as mulberry, and it has highest mass, elongation percentage, tearing strength, drape coefficient good air permeable, resistance to wear & tear, best resistance to crease, good water absorbency, thermal properties next to red eri. Red eri spun silk fabric has highest thermal insulation value and thickness value than white eri and Mulberry fabric. Mulberry spun silk fabric is strongest and has highest bursting strength than both eri silk fabrics. There is no significant difference in pilling resistance, abrasion resistance, flexural rigidity and water repellency among these three varieties of spun silk fabrics. These fabric properties are significantly influenced by yarn fineness. From this, it is concluded that both eri spun silk fabrics are durable, soft, better in crease resistance and have good aesthetic, tactile and thermal comfort property than Mulberry spun silk fabrics. Because of these properties, both Eri spun silk fabrics are most suitable for ladies and gents dress material as well as for under garments in all seasons.

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PRESENT STATUS OF MUGA SILK TECHNOLOGY AND INNOVATION PROSPECTS

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ABSTRACT

The golden *Muga* silk is produced in Assam and other states of North East India by wild silk worm *Antheraea assamensis*. Present production of *Muga* silk is around 100 metric tones per year. This is most expensive commercial natural textile fiber and 1 kg of Muga raw silk fetches a price of 200 US$. The two commercial cocoon crops are : (i) *Jethua* (April-Jun) and (ii) Kotia (October-December). In absence of hybridization or *heterosis* commercial characters of *Muga* cocoon are stagnant with some of the characters like average shell weight 0.45-0.60 g., average filament length 300-450 m., non-broken filament length 75 -150 m., single cocoon filament denier 4.0-5.0 and raw silk recovery on reeling (RSR) 45 -60 (%). Since 1996 many new innovations have been introduced in Muga silk technology sector. Regular export demand for Muga yarn and fabric has been generated and presently about Rs. 15.00 crores worth Muga yarn and fabrics are being exported per year. Innovations and research is necessary in improving cocoon quality, cocoon cooking - deflossing techniques and in twisting and weaving of Muga silk fabrics.

Key words: *Antheraea assamensis,* Innovations, Muga silk, Waste spinning, Weaving process

INTRODUCTION

The first documentary evidence of the use of golden yellow Muga silk fabric in North Eastern India dates back to around 100-250 AD. The uniform of 'Kirat' warriors living in 'Morangs' was made of Muga silk fabrics. The commercialization of Muga silk fabric was also pioneered by Chand Saudager with the support of his daughter in law Bihula during 300-450 AD. Muga silk fabric established itself as an aristocratic costume during the region of Bhaskar Verman, the king of Kamrupa (600- 650 AD). Silk weaving as a custom was developed as a state subject by Ahom, Koch and Kachari Kings (1200-1500 AD). Queen Lakhima a Koch princess popularized 'Mekhala' , a traditional lady's attire made from Muga silk with floral designs. Around 1600-1750 AD, weavers from Varanasi were invited by Ahom queens Phuleswari Devi and Sarveswari Devi for enriching the local weaving tradition. Since 1996 many technologies in muga sillk reeling sector were introduced such as:

- Hot air stifling of cocoon in place of prolonged sun drying or expensive smoke stifling.
- Mechanized reeling device has replaced Bhir reeling and Reeling speed has increased from 15 meter per minute to 30 meter per minute.
- Reeling Cum Twisting system has been introduced for reeling warp yarn and Cottage reeling system has been introduced in weft yarn reeling.
- Mechanized winding with 20 g package and sectional warping with warp length of 120 -135 meter has become popular
- Cone winding of 60-75 g has been successfully commercialized for exportable yarn packages
- Twisted warp yarn in weaving has improved the reed density from 72 to 80 counts.
- Traditional fabric width of 30" and 42" inches have been further increased to 48" and 60" inches with innovation in looms by increasing loom width and slay size to 60" and 72" inches
- Computer aided textile designs (CATD) has been absorbed by Muga weavers and Jacquard of 120 hooks are being replaced with 200 240 hooks
- Traditional products of *Mekhla*, *Chadder* and *Shirting*

has been added with *Muga Sari* and *Scarves*.

MATERIALS AND METHODS

The study has been concentrated on commercial characters of Muga cocoons, Stifling process adopted in the region, Skill adopted in Muga cocoon cooking, Muga Silk Reeling & Spinning Systems. The developments in sectors like Winding, Twisting, Warping and weaving has also been studied. Efforts in areas of Marketing, Product Development, Design, Patenting and Geographical Indication has also been touched.

The potential areas for future innovation and improvement like, Muga cocoon quality, Cocoon cooking, Deflossing, Twisting and Weaving has also been identified in this study.

RESULTS AND DISCUSSIONS

Present status of Muga silk technology

Cocoon Quality

In Assam an estimated 50 crore number of Muga cocoons are harvested every year, of which only around 10% is used for multiplication of eggs and breeding. The remaining 90% goes for commercial reeling. Availability of commercial Muga cocoons are highest during October-December. The annual distribution of Muga cocoon production is indicated in Fig. 1.

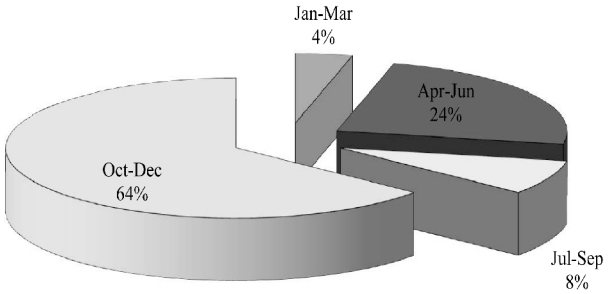


Fig. 1 : Annual Distribution of Muga cocoon Harvest

Commercial quality of Muga cocoons are depending on seasons and crops and it has been found from the cocoon testing results of last ten years that there is no major improvement or depression in these qualities. Reeling quality of cocoon is determined by pressing stifled Muga cocoons with fingers. When pupa inside gives hard feeling cocoon is treated good for reeling, if pupa is crushed easily cocoon is considered defective. Length of rudimentary peduncle and firmness of shell are also part of visual and tactual cocoon test. Average commercial qualities of these cocoons are indicated below in Table 1.

Stifling Methods

Muga cocoons were stifled either by Sun Drying or by Smoke Stifling. However since year 1996 onwards Electrical Hot Air Stifling of Muga cocoon is being adopted on commercial scale in Assam. Comparative economics of popular Muga cocoon stifling system is indicated below in Table-

Cocoon Cooking

Generally fresh Muga cocoon is transported in bamboo baskets, while stifled cocoons are transported in gunny bags. Presently 1000 Muga cocoons are costing Rs 750 -900. In a room size of 5 x 4 sq mt size about 3.0 - 4.5 lakh Muga cocoons can be stored for 1 year without any major degradation in reeling.

Muga cocoon shell is softened by cooking in single open pan. A pan of 10 liter capacity is used to cook 500 cocoons. Cocoons are boiled in about 7.50 liter water for 15-30 minutes with 2.0 -3.0 gpl washing soda. Cooked cocoons are individually deflossed by hand and end of continuous filament is searched. About 120 Muga cocoons are deflossed by a skilled reeler per hour.

Reeling System

Muga cocoons are reeled in hot water bath at about 60°C. Well cooked Muga cocoons give a raw silk recovery of 40 - 45 % in term of shell weight (absolute silk content). About 4000 - 5000 quality muga cocoon is required to produce 1 kg reeled silk yarn. Well cooked cocoon shell are converted into reeled yarn on reeling devices. Muga yarn is reeled on the principle of unwinding, combining by twist and winding. As optimum unwinding speed for Muga cocoon is limited to around 20 -30 meter per minute, due consideration has been given to low unwinding speed while designing reeling devices. Since 1951 attempts are being made to improve reeling devices and develop reeling machines on twisting principle. Reeled Muga yarn is re-reeled in hank of 1.50 meter circumference and 20-25 g weight. Comperative reeling performance of various Muga reeling machines are given below in Table 3.

Waste Spinning

Muga silk wastes are broadly classified as soft wastes and hard wastes. Cut cocoons, pierced cocoons, burst open cocoons of cooking basin and dropped cocoons of reeling basin are soft wastes. Wastes generated in process of deflossing and entangled mass of wastes generated in reeling basin are hard wastes. In addition to various pre spinning operation, the three essential operations in spinning are: Drafting, Twisting & Winding. Spinning performance in various popular spinning systems are indicated in Table 4.

Table 1: Commercial Characters of Muga Cocoons

Crop	Month	Cocoon size (cc)	Cocoon wt (g)	Shell Wt (g)	SR (%)	Filament Length(m)	Filament Denier
Aghonia	Dec-Jan	12.00	5.00	0.25	5.00	225	5.00
Jarua	Feb-Mar	15.00	6.00	0.35	5.83	275	4.50
Jethua	Apr-May	21.00	7.00	0.45	6.42	350	4.00
Akharua	Jun-Jul	15.00	5.50	0.30	5.45	250	4.00
Bhadia	Aug-Sep	18.00	6.50	0.45	6.92	350	4.50
Kotia	Oct-Nov	24.00	7.50	0.60	8.00	450	5.00

Table 2: Economics of Various stifling systems for Muga cocoons

Stifling	Heat Source	Operation Capacity	Time Taken	Loss Damage	Space Required	Product Coverage	Stifling Cost
Unit		Coc. Nos.	Hrs.	%	Sq Mtrs.	%	Rs/1000
Sun Drying	Sun Rays	50,000	360	6	50	26	3.00
Smoke Stifling	Wood - Husk	16,000	8	2	4	52	4.50
Hot-air Stifling	Electric Power	80,000	8	0	12	22	1.50

Table 3: Reeling Performance of Various Muga Silk Reeling Devices
(60/66 denier yarn)

SN	Device	Feature	Ends	Coverage (%)	Reeling Speed (meter/minute)	Production(g) (8 Hours)
1	Bhir	Arm Friction	1	71	20	96.00
2	CMERTI	Cottage Reeling	4	1	30	204.00
3	CSTRI	Ring Spindle	4	28	15	154.00
4	Multiend	Reeling - Twisting	8	--	45	286.00

Table 4: Performance of popular Muga Spinning system

SN	Device	System	Ends/ Spindle	Recov (%)	Unit Cost (Rs)	Count (nm)	Production 8 hr (kg)
1	Ghicha	Surface friction	1	90	-	6 s	0.120
2	Flyer	Flyer spindle	1	75	5000.00	15 s	0.240
3	Takli	Muel	1	60	-	30 s	0.040
4	CSTRI	Ring spindle	1	60	5000.00	30 s	0.160
5	Amber	Ring spindle	36	45	48000.00	30 s	1.800
6	SpunMill	Ring frame	840	30	24000000.00	60/2	60.000

Table 5: Specification of Handloom used for Muga silk weaving

Particulars	Specifications
Loom type	Fly shuttle frame loom
Timber	*Bongsum / Hallok*
Loom Length	7 ft
Loom Width	6 ft
Front Post	5”x5”x 6.50 ft
Middle Post	4”x4” x6.50 ft
Back Post	5”x5”x3.50 ft
Warp & Cloth Beam	Pull Bar Type
Treadle	3 Nos
Heald	2 Nos - Cotton Heald
Reed	78 count –Iron Reed
Sley (shuttle box 18”x2)	108 “(Including shuttle box)
Mounting	120 Hook Jacquard
Design Device	Extra Weft (Rayon-Jari)
Design Creation	CATD (75% Coverage)

Table-6 Specification of Muga Silk Products in commercial Use

Product	Length (meter)	Width (inches)	Ends/ inch	Picks/ inch	Piece-Muga Weight (g)
Mekhla	2.50	33	78	92	120 -180
Chadder	3.00	42	78	92	240 -300
Shirting	12.00	36	78	92	720 -840
Saree	6.00	48	78	92	540 -630
Stoles	2.00	18	80	102	75 -90
Shawl(Spun Muga)	2.50	36	42	36	300 -360

Table-7 Major Exports From North East India (Year 2009-2010)
(Source- EXIM Bank Guwahati Branch)

Products	Export (Rs Crores)
Tea	225.00
Coal	205.00
Plant Products - Aromatic	30.00
Muga silk products	15.00
Handicrafts	10.00
Others	15.00

Weaving Process

For the purpose of weaving Muga silk yarn is winded on plastic bobbins package with 20-25 silk content each. These bobbins are converted into warp by sectional warping on a drum of 5 meter circumference. Popular warp length on a beam is 120 -150 meter.

Muga silk weaving is done on wooden fly shuttle frame loom made out of *Bangsum or Hallok* timber. Muga fabrics are having 78 ends & 92 picks per inch density. Muga silk weaving is practiced on about 1500 commercial handlooms with annual consumption of 45kg reeled Muga yarn per looms.Size specification for handloom used for Muga silk weaving as in Table 5.

Muga Silk Products

Muga *Mekhla , Chader & Shirting* are local tradition products woven since long. Muga Sari weaving started around 1975 in Sualkuchi, while commercial production of Muga Stoles and Shawl have started by start of year 2000. Specification of various Muga silk products are in Table 6

Marketing & Innovations

At present in domestic market a Muga plain shirting fabric of 36 inches width costs about Rs 600.00 per meter. Muga Mekhla & Chadder accounts for about 69% of the total market share in traditional market.

Process of Muga silk weaving on Power loom has been Patented by an entrepreneur in Assam but it has not been tested on commercial scale. Assam Science Technology & Environment Council has been awarded with Geographical Indication for Muga.

Muga silk products have significant contribution in export earning for North East India. Japan and South Korea are main buyers of Muga silk products. Muga plain fabrics, Muga yarn hanks and Muga yarn in Cone Package are major export items from the region.The export of leading products from NE region during year 2009-2010 is as in Table-7.

Innovation prospects in Muga silk technology

Cocoon quality improvement

Cocoon test results of last 10 years have revealed that there is stagnation in commercial qualities of Muga cocoons and the danger of inbreeding depression can not be ruled out. In past there was a practice of shifting seed cocoons from Lower Assam to Upper Assam and vice versa, which was resulting in natural heterosis, however this practice has been abandoned after 1975. It is necessary to improve Muga cocoon quality like shell weight, filament length and raw silk recovery.

Cooking & Deflossing

It has been found that about 3 -6 % Muga cocoons are damaged in course of cooking and deflossing due to bursting of cocoons during cooking or damage of shell during deflossing. Cocoon deflossing process is also time taking and in 1 hour only about 90 -120 Muga cocoons are deflossed by a reeler. Generation of waste in reeling is also high and this is rendering a raw silk recovery of only around 45%. Hence more innovations are required in areas of Muga cocoon cooking and deflossing.

Knitting & Weaving

It has been known that Muga package in cone form exported to Japan are used in Knitting and shuttle less weaving sector, however this is yet to be commercialized in India.

ACKNOWLEDGEMENT

The author is thankful to Executive Manager EXIM Bank (Guwahati Regional Office) for providing statistical information about export of various products from North east India.

Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 403-410

STUDIES ON NON-MULBERRY SILK REELING: EFFECT OF COMMERCIALLY EXPLOITED ECORACES OF TROPICAL TASAR COCOONS

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ABSTRACT

Daba, Sukinda and Sarihan are commercially exploited eco races of tropical tasar silkworm, *Antheria mylitta* Drury for silk production in India. Larvae of each eco-race are reared in different eco-pockets for production tasar cocoons. In present study experimental cocoons were procured from Dumka (Jharkhand), Chaibasa (Jharkhand) and Bhadrachalam (Andhra Pradesh) for Daba bivoltine; Baripada (Orissa), Purulia (West Bengal) and Bhadrachalam (A.P.) for Daba trivoltie; Baripada, Sundergarh and Sukindagarh (Orissa) for Sukinda and Madhuban, Panchpara and Dumka (Jharkhand) for Sarihan eco-race. Reeling performance of these cocoons was studies in term of cocoon weight (g), shell weight (g), shell ratio (%), filament length (m), filament denier (d), silk recovery (%) and silk yield (g). Significant difference was observed in cocoon weight, shell weight, Non breakable filament length (NBFL) and silk yield parameters among the cocoons produced in three different eco-pockets of Daba BV and Daba TV eco-races. Similarly SR % differed significantly among the cocoons produced in three different ecopockets of Daba TV and Sukinda. Significant difference was also observed in case of NBFL in Sukinda and silk yield in Sarihan cocoons procured from different eco- pockets. Influence of eco-pockets was more pronounced in Daba BV and TV as it was reflected in five parameters each. In case of Sukinda and Sarihan the significant influence was observed in two and one parameter respectively.

Key words: Eco-pocket, Reeling parameters, Reeling performance, Tasar cocoon

INTRODUCTION

Indian tropical tasar silkworm, *Antheraea mylitta* Drury (Lepidoptera: n) is a sericigenous insect that produces silk (tasar silk) of high commercial importance. It is wild and polyphagous and feeds mainly on a forest trees *viz*., Arjun, *Terminalia arjuna, Asan, T. tomentosa and Sal, Shorea Robusta*. Daba BV and TV, Sarihan and Sukinda ecoraces of the most commercially exploited races among 44 ecoraces of *A. mylitta*. It is distributed from latitude of 16°N to 24° N and longitude of 80°E to 89°E (Suryanarayana and Srivastava, 2005). Tasar culture is a forest-based industry uniquely suited to the economy and social structure of developing countries because of its minimum investment requirements, high employment and foreign exchange earning potential. Raw silk production enjoys rapid growth mostly in the developing countries. This is largely due to their low level of economy, suitability of sericulture to family labour, favourable weather conditions and less investment.

Cocoon characteristics such as the physical properties of the cocoon, filament length of Daba ecorace was studied by Chattopadhyay *et al.,* (1997) and Iizuka, (1994). The genetic traits of tasar cocoon quality, nature and magnitude of gene action in tasar silkworm, *A. mylitta* was reported by Siddiquai *et al.,* (1996). A recent study on the index score analysis of commercial characters in various ecoraces of *A. mylitta* was showed that Raily is best in terms of commercial characters followed by Daba and Modal (Sinha *et al.,* 1995). Nayak and Guru (1998) also studied the biometry of Daba BV tasar cocoons reared at Bangiriposi and Sundergarh area in Orissa state of India. Moon (1995) studied on tasar silk technology in relation with post cocoon silk technology. The information on non-broken filament length of tasat silk for a

reeler in maintenance of require number of cocoons for a particular denier described by Das, Subrata and Ghosh, Anindya (2009). In *Bombyx mori,* qualitative traits and post cocoon characters were studied by Gowda and Reddy, 2006; Malik and Reddy, 2007. As the quality and productivity of raw silk depends on the quality of cocoons, cooking method, reeling water and reeling machine and skill of the reeler (Vijayender *et al.,* 1999). It is importance mentioning here that cocoon quality depends on fibrion and sericin which are also controlled by atmosphere conditions. The effect of different food plant on the cocoon crop performance of silk worm Antheraea mylitta D. was shown in a study (Das *et al.,* 1992). Some of ecoraces of tasar cocoon shows superiority for cocoon weight, shell weight, shell ratio, whereas other give better results in terms of effective reeling characteristics such as filament length, raw silk recovery and silk yield. The previous work was highlighted on reeling characteristics (post cocoon technology) in a limited manner especially cocoons of various ecoraces of *A. mylitta*. Therefore, it is essential to determine on the reeling performance (characteristics) for reeler's to perform better tasar silk reeling with higher productivity from cocoons of different ecoraces of *A. mylitta.* Present study is undertaken to comparative performance of the commercial and technological reeling characteristics of cocoons of Daba BV and TV, Sukinda and Sarihan produced in different ecopockets of Jharkhand, Orissa, west Bengal and Andhra Pradesh.

MATERIALS AND METHODS

In present study, cocoons were produced during 2007-08 and collected from different ecopockets *viz.,* Daba Bivoltine 2nd crop (November December) cocoons from Dumka, Chaibasa (Jharkhand) and Bhadrachalam (Andhra Pradesh). Daba Trivoltine 3rd crop (January- February) cocoons were collected from Baripada (Orissa), Purulia (West Bengal) and Bhadrachalam (Andhra Pradesh). Sarihan 3rd crop cocoons were collected from Madhuban, Panchpara and Dumka (Jharkhand). Sukinda and Daba Trivoltine 3rd crop cocoons were collected from three places Bangiriposi, Sundergarh and Sukindagarh, (Orissa) and utilize for the study. These different locations/ecopokcets were selected for comparing the cocoon quality and tasar silk productivity. Dumka is a district of Jharkhand state under Santha Pargana and located at 86 16" North latitude and 87 15" East longitudes. It is situated at the height of 472 ft from the sea level. It the District has an area of 3716.02 Sq.KM. The fertility of soil is poor due to extensive erosion, acidic character and low retaining capacity. The climate of Madhuban and Panchpara is nearly similar to the Dumka (wwwjharkhand.gov.in). In Chaibasa Rainy monsoon generally breaks in the second week of June. December-January are the coldest months while April-May are the hottest. On account of the barrier of hills in the southeast, the atmosphere is generally dry. The Rainfall is the highest in July and August. The annual average rainfall in the district is about 1422 mm. The district is situated at a height of 244 Meter above the sea level and has an area of 5351.41 Sq. Kilometers (www.chaibasa.nic.in).

Bhadrachalam is situated in Khammam, Andhra Pradesh state in India, its geographical coordinates are 17° 40' 0" North, 80° 53' 0" East and it has an average elevation of 50 metres (164 feet). The place experiences maximum temperature up to 47°C in summer (March to June). minimum temperature of 20°C in winter(November to February. Monsoons (July to October) are the main rainy season in Bhadrachalam and it makes atmosphere humid (www.mapsofindia.com). Baripada lies in north eastern Orissa state in east India. It is located at a 21.94A°N 86.72A° E and has an average elevation of 36 meters. Baripada is a major center for its textiles including handloom products. Bagiriposi, Sundergarh and Sukindagarh are famous for production of tasar silk cocoons (www.orissaonline.in. Purulia lies between 22.60° and 23.50 ° north latitude and 85.75 ° and 86.65 ° east longitude. The geographical area of the district is 6259 sq. kms. About 60 % of the total cultivated land is upland. Average annual rainfall varies between 1100 and 1500 mm. The relative humidity is high in monsoon season, being 75% to 85%. But in hot summer it comes down to 25% to 35%. Temperature varies over a wide range from 7° Celsius in winter to 46.80° Celsius in the summer (www. westbengalonline.in).

Cocoons of all ecoraces and ecopockets were analyzed at Post Cocoon Technology division, Central Tasar Research and Training Institute, Ranchi, India. The presence of defective cocoons affects raw silk yield and raw silk quantity and quality. Total 300 reelable tasar cocoons were selected from each lot of Daba, Sukinda and Sarihan according to their sizes/shapes, colours and shell thickness to ensure uniform softening of cocoons. To achieve the optimum results in reeling the defective cocoons (double, urinated, malformed, flimsy, pierced/cut and loose shell cocoon), which are unreelable for reeling quality yarn silk, are to be sorted out. Three hundred reelable cocoons in six replications having 50 cocoons in each were taken from each ecorace to determine cocoon weight, cocoon shell weight, shell ratio and reeling parameters. The cocoons were tested of each race for cocoon weight, shell weight, shell ratio by use of digital balance and other parameters by the use of wrap reel. The reeling was conducted using motorized reeling cum twisting machine in randomly with six replications for each ecorace. The data were statistically analyzed for comparative reeling performance of three ecoraces in respect of cocoon weight, shell weight, shell ratio, filament length, non-breakable filament length (NBFL), raw silk recovery, denier and silk yield. Mean value of all the parameters ± standard deviation were calculated.

Drying conditions

The cocoons were spread on perforated shelves/trays in batch type hot air drier and stifled at 80-100^{0}C for 4-5 hours. The cocoons were conditioned at room temperature for two days and then taken for test reeling.

Cooking of cocoons

The sorted and dried cocoons were cooked by using soft water and neutral soap and hydrogen peroxide in pressure cooker according to number of cocoons and capacity of cooker. The cocoons were tied in a netted cloth and boiled in a solution of 1 % H_2O_2 (30 % w/w) and 1 % soap for 10 minutes. Then, the cocoons were subjected to a steaming with same solution for 30-45 minutes depending on the compactness and shell weight of tasar cocoons. Steamed cocoons were allowed to cool and deflossed for reeling.

Reeling of cocoons

Deflossed tasar cocoons were subjected to reeling as per the standard technique (Jolly *et al.,*.1987; Manna *et al.,.,* 2004). The CSTRI reeling -cum-twisting machine at medium reeling speed, used to produce tasar reeled yarn is based on the principle of the ring spindle system The machine is provided with vertical traverse mechanism for distributing reeled thread uniformly on the bobbins. 150 good cocoons were used for conducting test reeling maintaining four ends by keeping six to seven cocoons per reeling end. Continuous ends from 6-7 numbers of cocoons are brought together and passed through a thread guide, and then through tension roller, then, after traveling through another thread guide, they are passed through the ring and wound around on a bobbin mounted on a spindle.

RESULTS

The cocoon assessment and reeling performance of Daba BV 2nd crop reared at Dumka, Chaibasa (Jharkhand) and Bhadrachalam (Andhra Pradesh) ecopockets is presented in Table 1. The result revealed that significant difference was observed in mean cocoon weight, shell weight, non-breakable filament length (NBFL), recovery and raw silk yield in different of different ecopockets whereas, shell ratio, filament length and denier were not differ significantly. The best performance was observed in cocoons produced in Chaibasa ecopockets in respect of shell weight (1.475±0.081g), shell ratio (12.744±0.521%), filament length (868.600±45.027 m), NBFL (458.400±72.124 m), silk recovery (62.400±0.452%) and raw silk yield per 1000 cocoons (764.800±17.443g). The cocoon weight (11.783±0.414g) and single filament's denier (10.200±0.133) were recorded to be highest in cocoons collected from Dumka ecopockets.

The data of Daba TV 3rd crop reared at Baripada (Orissa), Purulia (W.B.) and Bhandara (Maharastra) ecopockets is illustrated in Table 2. Highly significant differences were observed on cocoon weight, shell weight, shell ratio, non-breakable filament length and raw silk yield in different ecopockets. The cocoons of Baripada ecopockets showed better results on single cocoon weight (10.534±0.266g), filament length (800.000±57.349 m), silk recovery (62.000±1.453%) and raw silk yield/ 1000 cocoons (726.600±35.513g) where as shell weight (1.331±0.088 g), shell ratio (14.589±1.051 %), non-breakable filament length (449.800±96.026 m) were noticed to be maximum in the cocoons of ecopockets of Purulia. The highest denier (9.600±0.340) was recorded in cocoons of Bhandara ecopockets.

The cocoons analysis and reeling performance of cocoons of Sukinda ecorace 3rd crop was recorded to be differ significantly in different ecopockets except silk ratio and non-breakable filament length (Table 3). The better results were obtained in cocoons collected from Sundergarh in respect of shell weight (1.549±0.096 g), filament length (984.000±29.794m) and raw silk yield/1000 cocoons (856.400 ±35.726 g) whereas mean cocoon weight (12.908±0.775 g), non-breakable filament length (411.700±37.802 m) was recorded to be maximum in cocoons of Sukindagarh ecopockets. The highest cocoon and reeling assessment was observed in cocoons of ecopockets of Bangiriposi in respect of silk ratio (14.088±0.048 %) and denier (9.300±0.396).

The results of Sarihan 3rd crop cocoons of Madhuban, Panchpara and Dumka ecopockets is presented in Table 4. The data revealed that no significant difference was observed in all the parameters tested for different ecopockets except raw silk yield/1000 cocoons. The cocoons of Dumka ecopockets showed better performance in case of shell weight (0.798±0.035 g), shell ratio (13.173±0.555 %), filament length (716.500±43.231 m) and non breakable filament length (262.700±17.241 m). Panchpara ecopockets cocoons performed better in respect of denier (7.800±0.200) and yield (551.300±18.326 g) whereas cocoons of Madhuban ecopockets was observed highest in in cocoon weight (6.512±0.421 g) and recovery (62.300±1.476%).

DISCUSSION

The variation in the size of silk filament depends mainly on the uniformity of cocoons used and which in turn will ultimately determine the uniformity and the quality of the silk reeled. The earlier studies carried out on different seasons effects for cocoon weight, shell weight, silk ratio, filament length and sericin content on characteristics Muga cocoons of *Antheraea Assama* (Barah *et al.,* 1988)., the nature of variability available in *A. mylitta* ecoraces at different level (Sengupta *et al.,* 1993; Singh and Srivastava, 1997), Index score of seven acclimatized ecoraces of *A. mylitta* was analyzed for different commercial characters

Table 1: Analysis of reeling performance of tasar cocoons of Daba bivoltine 2nd crop reared in different ecopockets.

Parameters	Eco-pockets	Mean ±SE	F value	C D at 5 %
Cocoon weight (g)	Dumka	11.783 ±0.414	11.513**	3.845
	Chaibasa	11.546 ±0.290		
	Bhadrachalam	9.544 ±0.373		
Shell weight (g)	Dumka	1.399 ±0.072	6.784**	0.704
	Chaibasa	1.475 ±0.081		
	Bhadrachalam	1.145 ±0.038		
Shell ratio (%)	Dumka	11.952 ±0.648	0.489^{NS}	6.267
	Chaibasa	12.744 ±0.521		
	Bhadrachalam	12.143 ±0.596		
Filament length (m)	Dumka	713.600 ±58.096	1.615 ^{NS}	664.922
	Chaibasa	868.600 ±45.027		
	Bhadrachalam	759.000 ±79.919		
NBFL (m)	Dumka	361.300 ±20.335	5.296**	489.099
	Chaibasa	458.400 ±72.124		
	Bhadrachalam	246.400±27.633		
Denier	Dumka	10.200 ±0.133	0.550 ^{NS}	5.777
	Chaibasa	10.900 ±0.458		
	Bhadrachalam	10.200 ±0.814		
Recovery (%)	Dumka	58.800 ±1.083	20.779**	11.160
	Chaibasa	62.400 ±0.452		
	Bhadrachalam	52.900 ±1.394		
Yield/1000 cocoons (g)	Dumka	620.600 ±13.069	16.977**	228.345
	Chaibasa	764.800 ±17.443		
	Bhadrachalam	603.200 ±30.255		

**: Significant at $p< 0.01$, $^{NS:}$ Non significant

(Sinha , A.K. *et al.,* 1995). Genetical studies in *A. mylitta* D have been made by Siddiqaui *et al.,* (1996) and Firdose Ahmad *et al.,* (2007) reported that the manifestation of cocoon and post cocoon characters is dependent both on silkworm race and mulberry nutrition in mulberry silkworm race and mulberry nutrition in mulberry silk worm, were based on the silkworm rearing under optimal conditions. Cocoon production and post cocoon characters are influenced by plant's leaf nutrition.

In present study, the mean cocoon weight among all the ecoraces and ecopockets was the highest in Sukinda trivoltine 3rd crop (12.908 g) received from Sukindagarh, Orissa followed by Daba bivoltine 2nd crop (11.783 g) from Dumka, Jharkhand, Daba trivoltine 3rd crop (10.534 g) from Baripada, Orissa and Sahrihan trivoltine 3rd crop (9 6.512 g) received from Madhuban, Jharkhand.

The mean shell weight among all the ecoraces and ecopockets was relatively highest in Sukinda trivoltine 3rd crop (1.549 g) received from Sundergarh, Orissa followed by Daba bivoltine 2nd crop (1.475 g), from Chaibasa, Jharkhand, Daba trivoltine 3rd crop (1.331 g) from Baripada, Orissa and Sahrihan trivoltine 3rd crop (0.798 g) received from Dumka, Jharkhand.

Malik and Reddy (2007); Reddy *et al.* (2009); Srivastava *et al.,* (2004) indicated that the optimal genotype environment relation with longer larval feeding period on better quality leaf under friendly climate might be the one of the reason for elevated performance.

The mean shell ratio (%) among all the ecoraces and ecopockets was relatively highest in Daba trivoltine 3nd crop (14.589 %) received from Purulia, West Bengal followed by Sukinda trivoltine 3rd crop (14.088 %) received from

Table 2: Analysis of reeling performance of Daba Trivoltine III crop tasar cocoons reared in different places

Parameters	Eco-pockets	Mean ±SE	F value	C D at 5 %
Cocoon weight (g)	Baripada	10.534 ±0.266	15.333**	3.372
	Purulia	8.081 ±0.361		
	Bhandara	9.679 ±0.320		
Shell weight (g)	Baripada	1.331 ±0.088	4.581**	0.842
	Purulia	1.157 ±0.068		
	Bhandara	0.991 ±0.081		
Shell ratio (%)	Baripada	12.040 ±0.350	13.484**	7.193
	Purulia	14.589 ±1.051		
	Bhandara	9.608 ±0.392		
Filament length (m)	Baripada	800.000 ±57.349	1.430 ^{NS}	646.228
	Purulia	734.200 ±62.470		
	Bhandara	654.500 ±62.807		
NBFL (m)	Baripada	258.800 ±33.441	4.504**	655.478
	Purulia	449.800 ±96.026		
	Bhandara	198.600 ±33.433		
Denier	Baripada	10.100 ±0.433	0.500 ^{NS}	3.774
	Purulia	9.900 ±0.277		
	Bhandara	9.600 ±0.340		
Recovery (%)	Baripada	62.000 ±1.453	0.264^{NS}	13.518
	Purulia	61.500 ±1.447		
	Bhandara	60.700 ±0.817		
Yield/1000 cocoons (g)	Baripada	726.600 ±35.513	7.783**	282.434
	Purulia	721.600 ±24.498		
	Bhandara	595.500 ±16.304		

* Significant at $p< 0.01$, ^{NS} Non significant

Bangiriposi, Sahrihan trivoltine 3nd crop (13.173 %) received from Dumka and Daba bivoltine 2nd crop (12.744 %), from Chaibasa, Jharkhand.

Chattopadhyay *et al.* (1997) reported that progressive change in characteristics of the filament along its length in mulberry and tasar cocoons. The filament denier of all the variety of the cocoons decreases from the outer layer to the inner layer and tenacity remains constant for Daba and rises marginally for oak tasar but show a definite increasing trend for bivoltine mulberry cocoons. The residual sericin content decreased marginally for Daba and oak tasar cocoons.

There was no significant difference in the mean filament length among all the ecoraces and ecopockets. The mean filament length was relatively more in Sukinda trivoltine 3rd crop (984 m) received from Sundergarh, Orissa followed by Daba trivoltine 2nd crop (868 m) received from Chaibasa, Daba trivoltine 3rd crop (800 m) received from Baripada and Sahrihan trivoltine 3rd crop (716 m) received from Dumka.

The mean denier was relatively highest in Daba bivoltine 2nd crop (10.90 d) received from Chaibasa, followed by Daba trivoltine 3rd crop (10.10 d) cocoon 's lot received from Baripada, Sukinda trivoltine 3rd crop (9.90 d) received from Sundergarh and Sahrihan trivoltine 3rd crop (8.30 d) received from Madhuban.

The mean raw silk recovery among all the ecoraces and ecopockets was relatively highest in Daba bivoltine 2rd crop (62.40%) received from Chaibasa, followed by Sahrihan trivoltine 3rd crop (62.30 %) received from Madhuban, Daba trivoltine 3rd crop (62.00 %), from Chaibasa, Sukinda trivoltine 3rd crop (61.40 %) received from Bangiriposi, Orissa.

Table3: Analysis of reeling performance of Sukinda Trivoltine III crop tasar cocoons reared in different places

Parameters	Eco-pockets	Mean ±SE	F value	C D at 5 %
Cocoon weight (g)	Bongriposi	10.620 ±0.474	2.760 ^{NS}	7.347
	Sundergarh	11.547 ±0.783		
	Sukindagarh	12.908 ±0.775		
Shell weight (g)	Bongriposi	1.482 ±0.048	0.191 ^{NS}	0.860
	Sundergarh	1.549 ±0.096		
	Sukindagarh	1.495 ±0.090		
Shell ratio (%)	Bongriposi	14.088 ±0.463	6.984**	5.270
	Sundergarh	13.571 ±0.596		
	Sukindagarh	11.599 ±0.413		
Filament length (m)	Bongriposi	852.000 ±33.864	2.667 ^{NS}	440.410
	Sundergarh	984.000 ±29.794		
	Sukindagarh	945.000 ±56.016		
NBFL (m)	Bongriposi	267.800 ±20.411	6.454**	312.628
	Sundergarh	303.800±27.581		
	Sukindagarh	411.700 ±37.802		
Denier	Bongriposi	9.300 ±0.396	0.637 ^{NS}	4.056
	Sundergarh	9.900 ±0.407		
	Sukindagarh	9.500 ±0.342		
Recovery (%)	Bongriposi	61.400 ±2.468	0.505 ^{NS}	20.892
	Sundergarh	59.200±1.896		
	Sukindagarh	58.800 ±1.397		
Yield/1000 cocoons (g)	Bongriposi	823.800 ±24.385	1.002^{NS}	327.965
	Sundergarh	856.400 ±35.726		
	Sukindagarh	794.500 ±31.580		

** Significant at $p< 0.01$, ^{NS}Non significant

The mean silk yield among all the ecoraces and ecopockets was relatively more in Sukinda trivoltine 3nd crop (856 g) received from Sundergarh, Orissa followed by Daba bivoltine 2nd crop (764 g) received from Chaibasa, Jharkhand; Daba trivoltine 3rd crop (726 g), from Baripada, Orissa and Sahrihan trivoltine 3rd crop (551 g) received from Panchapara, Jharkhand.

The results of present study clearly indicated that the effect of different ecoraces of *A. mylitta* Drury cocoons viz. Daba bi and trivoltine, Sukinda and Sarihan from different ecopockets on the majority characteristics such as average cocoon weight, shell weight, shell ratio, filament length, non-breakable filament length, single filament's denier, recovery (%) and silk yield/ 1000 cocoons.

Based on the above study, it is observed that Sukinda trivoltine 3rd crop' cocoon received from Sundergarh (Orissa) performed the best taking into consideration followed by Daba bivlotine 2nd crop' cocoon lot due to tropical climatic condition suitable at these ecopockets. On the other hand, Sukinda trivoltine perform better in respect of cocoon weight, shell weight, filament length and silk yield. In the back ground of the above discussion, it may be concluded that eco-pocket/location also plays an important role in producing quality cocoons due to the effect of atmosphere which creates condition for growth of food plants of Antheraea mylitta D. However, the data indicated the scope of improvement in cocoon characteristics of different ecoraces and in the need of improvement in rearing practices.

Table 4: Analysis of reeling performance of Sarihan Tri-voltine III crop tasar cocoons reared in different places

Parameters	Eco-pockets	Mean ±SE	F value	C D at 5 %
Cocoon weight (g)	Madhuban	6.512 ±0.421	0.382NS	3.829
	Panchpara	6.167 ±0.395		
	Dumka	6.094 ±0.239		
Shell weight (g)	Madhuban	0.774 ±0.074	0.321NS	0.545
	Panchpara	0.740 ±0.035		
	Dumka	0.798 ±0.035		
Shell ratio (%)	Madhuban	11.975 ±0.671	1.415NS	5.788
	Panchpara	12.140 ±0.368		
	Dumka	13.173 ±0.555		
Filament length (m)	Madhuban	657.500 ±38.953	1.014NS	402.192
	Panchpara	645.000 ±30.450		
	Dumka	716.500 ±43.231		
NBFL (m)	Madhuban	248.700 ±21.811	0.123NS	221.192
	Panchpara	251.900 ±23.059		
	Dumka	262.700 ±17.241		
Denier	Madhuban	8.300 ±0.213	1.235NS	2.524
	Panchpara	7.800 ±0.200		
	Dumka	8.200 ±0.291		
Recovery (%)	Madhuban	62.300 ±1.476	2.753NS	13.346
	Panchpara	61.900 ±1.090		
	Dumka	58.500 ±1.176		
Yield/1000 cocoons (g)	Madhuban	426.000 ±23.158	9.872**	235.579
	Panchpara	551.300 ±18.526		
	Dumka	435.400 ±24.503		

** Significant at $p< 0.01$, ^{NS} Non significant

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ERI SILK FOR FASHIONABLE KNITTED GARMENTS

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ABSTRACT

Eri silk is eco-friendly and glamorous. This paper reports the pioneer work done by NIFT-TEA KFI, Tirupur and Central Silk Board, Bangalore under collaborative project on the development of Eri silk knitted Garments in circular weft knitting machines and quality requirements of the Eri silk mill spun yarn. Varieties of knit structures were made from Eri silk mill spun yarn and converted in to men, women and kids garments. The knit structures have better geometrical and mechanical properties which evidence that the fabric is suitable for garment making. The Eri silk garments inspire and stimulate the creative minds of the fashion world. Eri silk garments are suitable for both summer and winter wear. Eri silk knitwear has added one more dimension to the range silk products; offers immense possibilities for product diversification and better value realization for the primary tribal producers. This paper reveals the yarn parameters suitable for knitting to enhance the knitting performance consistency. It also deals on the production process, potentiality of eri knitwear for high fashion garments, kids wear, under wear *etc.* Catering to the requirements of domestic and export markets.

Key words: *Ahimsa* silk, Eri silk, Knitted garments, Physical parameters, *Vanya* silk

INTRODUCTION

India is the only country in the world producing all four varieties of commercially known silks viz Mulberry, Tasar, Eri and Muga. While mulberry silk is produced on larger scale as an important commercial venture, the other three varies of silks *viz* Tasar, Eri and Muga are produced mainly by the tribal people inhabiting the forests. Therefore these silks are popularly known as Vanya Silks. The Vanya Silk production which was considered as a limited tribal craft has of late received commercial importance due to its eco friendly production process and natural colour. These silks have good demand now both in domestic and export markets. Mulberry, Tasar and Muga cocoons are reelable to produce quality raw silk yarn but Eri cocoons are mouth opened and are not suitable for reeling to produce continues filament to get finer quality silk. The word "eri" seems to be derived from "Era" or "Eranda", the Assamese local name of "castor" the primary food plant of eri silkworm. Eri silkworm, *Philosamia ricini,* a domesticated multivoltine silkworm belonging to Order Lepidoptera and Family Saturnidae is polyphagous in nature feeding primarily on leaves of Castor (*Ricinus communis*) and Kesseru (*Heteropanax fragrans*) and secondarily on Tapioca (*Manihot utilessima*), Payam (*Evodia flaxinifolia*), Barkesseru (*Ailanthus excelsa*), Gulancha (*Plumeria acutifolia*), Gamari (*Gmelina arboria*), Papaya (*Carica papaya*) *etc.* The Eri silkworm produces open ended cocoons and spun silk. The silk can be taken out without killing the pupae / insect. Therefore, Eri silk can be promoted as non violent (Ahimsa) silk. This property of eri silk can create a special market niche in the global market. About 2460 metric tones of eri yarn is produced in India and yarn spun through hand spinning and machine also. The Eri spun yarn produced from worsted system of spinning ranges from $2/10^s$ Nm to $2/140^s$ Nm.

The table below indicates some of important parameters of eri silk in comparison with mulberry

Table 1: Fibre Parameters of mulberry and eri silk

Parameters	Mulberry	Eri
Staple Length (MM)	48.5	57
Fine Ness (Microns)	13.33	13.15
Strength (Gram / Tex)	42.00	30.00
Elongation (%)	9.4	9.2
Whiteness	42.27	43.31
Yellowness	14.55	13.90
Dye Absorption	Normal	Darker

Table 2: Yield Percentage of mulberry and eri silk

Process	Mulberry	Eri
Degumming	50	92
Dressing	15	30
Comber	15	63
Preparatory	96	95
Spinning	92	92
Gasing	84	84
Yarn Yield %	22	51

Table 3: Eri yarn specifications

Characteristics	Actual Value		Required values for Knitting
Yarn count	2/100s Nm	2/120s Nm	
Actual count	29.5	35.0	
Count CV%	6.5%	8.0%	2.5%
CSP	2850	3200	2600
Single Yarn strength	397gms	347gms	350 gms
Single Yarn strength CV%	14%	11%	5%
Mean elongation	11.9	12.2	11
Tenacity (RKM)	14.8	14.8	14
U%	14	14.5	11
Total Imperfection	261	166	150
Thin (-50%)	56	46	20
Thick (+50%)	120	60	6
Neps(+200%)	85	60	70
Hairiness index	4.72	4.12	5

Among the Vanya Silks, Eri yarn is more suitable for knitting a huge range of structures in circular and flat knitting machine. The Eri knit structures were found to be dimensionally more stable. Eri knitted fabrics can also be used for different surface ornamentation techniques. Eri knit products improve in sheen and luster with subsequent washes. Three Eri Spun Silk Mills recently established in different parts of India with high end machines is now producing good quality Eri yarn suitable for Eri knitwear.

The fashion world is constantly seeking and latching onto new materials. Organic products have actually been showing up in department stores and botiques.Sustainable eco-textile for both consumerist and manufacturer satisfaction and well being are the need for today. By considering the above facts and the positive role of value added products and need of organic eco friendly knitted garments in the fashion world new vibrant garments are produced using Eri silk yarns

MATERIALS AND METHODS

For the development of weft knitted fashion garment, Eri yarn with linear density of 2/100s Nm & 2/120s Nm were used to produce single and Double Jersey structures. The yarn specifications used for the development is given in the table.

Fabric development

Knitting

Knitting is one of the main aspects of this project work. So, more attention was given for the knitting prerequisites such as waxing and winding to make the knitting programme trouble free one. For successful production of a knitted fabric the following things has to be taken care during knitting.

1. Selection of appropriate machine gauge is important one according to the yarn count and yarn type and the fabric structure to be knitted.
2. Yarn with negligible count variation (Less CV %), soft / low twist, optimum strength, minimum 5 % elongation, high degree of uniformity, free from knots, slubs and neps less hairiness, low co-efficient of friction *etc.,*
2. Selection of optimum stitch length and set the machine accordingly.

The Structures developed by using eri Yarn and the specification of knitting machine on which the samples of fabric were produced as given in the table.

Wet processing of fabrics

The processing is done for all the knitted fabric structures in Soft flow Dyeing machines. The fabric samples were dyed with acid dyes as per the following recipe.

Particulars of Finishing and Drying

The fabrics finished with SKI 2 to3% on weight of material in tubular relax Padding and dryer machine and curing was done at 150°C for3min. This can be done in soft flow machine and curing in separate heat setting instrument.

Compacting

Compacting is a mechanical finishing process carried out for the knitted fabrics. The purpose of compaction is to bring the fabric into dimensionally equilibrium state or dimensionally stable state and to remove the crease marks from the fabric surface and to make it flat. It is done with the help of a machine called “tube tex” compaction calendar under high temperature (100°c 110°c) and steam pressure. In this machine, fabric is stretched width wise and, during that time, it over feed lengthwise. Then it shrunk in length wise in the compressive shrinkage unit.

Product Development

The design were developed mainly targeting on women fashion able wear, Kids wear, and men wear. (Fig. 1-4)

Measurement of Physical Parameters of fabric

Bursting Strength

The bursting strength test was carried out according to the available literature[1] using hydraulic diaphragm bursting tester for which the test method has been withdrawn from ASTM D 3786test. The hydraulic tester employs glycerine as liquid medium and screw driven piston for increasing the pressure. Five tests were carried out for each specimen and the average had been taken for analysis purpose.

Pilling Resistance

Pilling resistance of the samples were measured using ICI pill box Tester using IS:10971-1984 test method with standard abrading surface. The samples were asssed the pilling rating by using standard photographs.

Fabric Thickness

The thickness of the fabrics was measured according to ASTM D1777 standard with the MAG thickness gauge at a pressure of 4.14Kpa with pressure foot width of 28.70 mm.

Air Permeability

Air permeability of the fabric has been measured using TEXTEST FX III 3300 air permeability tester at a pressure of 125 Pa; test area 38 cm^2; ASTM D737 has been followed.

Measurement of Geometrical Parameters of fabric

Dry Relaxed State

The samples were kept for conditioning for a period of minimum of 24 hours at a temperature of 25°± 2°c and RH 65%. This removes the stress from the fabric imparted during knitting.

Table 4: Specifications of knitting machines and eri fabric details

Machine Particulars	Machine Values		
Fabric Structure	Single Jersey	Lycra Single Jersey	1x1 Rib
Type of Machine	Single Jersey		Double Jersey
Make	Pailung	Orizo	Terrot
Dia (inches)	24	24	30
Gauge	24	20	16
Feeders	72	72	54
Cam tracks	4	4	4
Number of Needles	1800		
Speed (RPM)	12	20	08

Table 5: Dyeing recipe

Pre -treatment		Dyeing With Acid Dyes	
M: L	1: 20	M: L	1: 20
Soap	15% OWM	Dye	x %
Soda Ash	1.5 % OWM	Glaubour salt	10 % owm
Sodium Silicate	4.5 % OWM	Acetic acid	4 – 6 %
Hydrogen Peroxide	20 Ml /Litre	Temperature	85 – 90° C
p^H	10-11	Time	30 – 45 mins
Temperature	85 –90° C	Ph	4 – 6
Time	45 Mns		

Table 6: Particulars of Finishing Machine

Make	Nagai / Taiwan
Type	Tubular Relax dryer with single Dip Padding
Softener	Non – Ionic Silicone 2015
Time(in min)	2
Temperature (°C)	Room



Fig. 1: Kids wear-Single Jersey



Fig. 2: Kids wear-Single Jersey



Fig. 3: Ladies Wear - 1X1 Rib



Fig. 4: Men's Polo Neck T Shirt

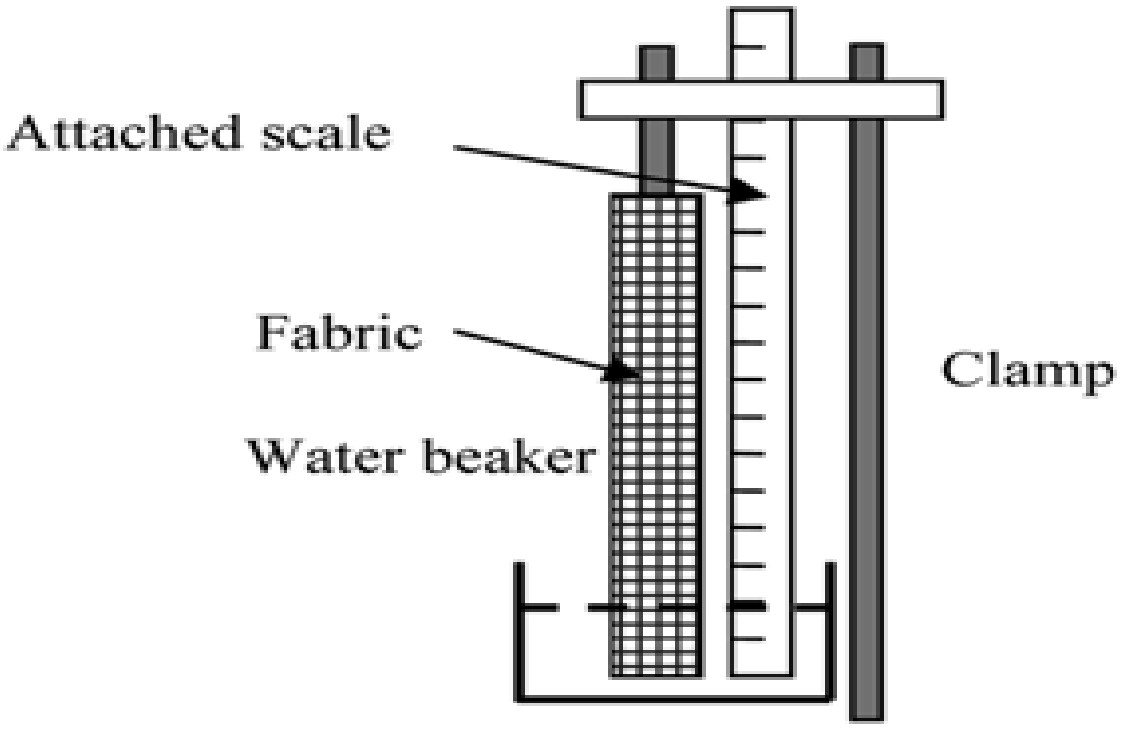


Fig. 5: Vertical Wicking Test

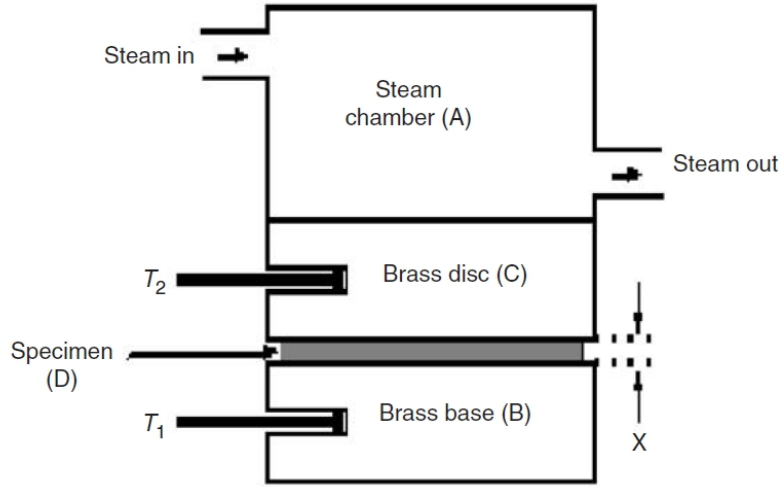


Fig. 6: Lee Disk

Table 7: Fabric particulars

Fabric Structure	Yarn Count	LL Cm	CPI	WPI	Fabric Tightness factor	Fabric mass (g/m2)
Single Jersey-Red	2/100s Nm	.30	49	37	14.66	144.8
Lycra Single Jersey	2/120s Nm	.34	65	44	11.78	183.8
1x1 Rib	2/120s Nm	.38	24	21	10-82	161.6
Single Jersey-Navy	2/100s Nm	.30	49	37	14.66	155.0

Physical Properties

Table 8: Mechanical properties of fabric

Fabric Structure	Fabric thickness (mm)	Bursting Strength (lb/sq.in)	Pilling Resistance (Rating)	Air Permeability (C.C /Cm^2/Sec)
Single Jersey-Red	0.51	73	4	99.1
Lycra Single Jersey	0.55	84	4	32.0
1x1 Rib	0.73	110	4	65.8
Single Jersey-Navy	0.52	75	4	95.2

Table 9: Color fastness of particulars fabric

Fabric Structure/Color	Rubbing		Perspiration						Light	Wash		
			Acid			Alkali						
	Dry	Wet	CC	SS	SC	CC	SS	SC	CC	CC	SS	SC
Single Jersey-Red	4-5	4	3	4-5	4	3	4-5	4	3	3-4	4-5	4-5
Lycra single Jersey-Pink	4	3-4	3	4-5	2-3	3	4-5	3-4	3-4	3	4-5	3-4
1x1 Rib-Yellow	4-5	4-5	3-4	4-5	4-5	3-4	4-5	4-5	2-3	4	4-5	4-5
Single Jersey -Navy	4-5	4-5	4	4-5	4-5	4	4-5	4-5	3	4	4-5	4-5

(CC-Color Change, SS-Staining on Silk, SC-Staining on Cotton)

Study of Geometric Properties of Eri Fabrics

Table 10: Geometric properties of eri fabrics

Fabric	State	CPCm	WPCm	LL in mm	Kc	Kw	Ks	Kc/Kw
	DRS	18.1	12.6	3	6.0	4.2	25.4	1.4
Single Jersey	WRS	18.5	13.4	3	6.2	4.5	27.5	1.4
	FRS	19.3	13.8	3	6.4	4.6	29.5	1.4
	DRS	11.8	8.7	3.6	3.3	2.4	7.9	1.4
1X1Rib	WRS	12.6	10.2	3.6	3.5	2.8	10.0	1.2
	FRS	13.4	10.2	3.6	3.7	2.8	10.6	1.3
	DRS	22.4	11.8	3.4	6.6	3.5	22.9	1.9
Lycra Single Jersey	WRS	22.8	15.0	3.4	6.7	4.4	29.6	1.5
	FRS	23.6	17.3	3.4	6.9	5.1	35.4	1.4

Moisture Transmission Properties

Table 11: Moisture transmission properties of fabric

Fabric Structure	Single Jersey	Lycra Single Jersey	1x1 Rib
Moisture Absorbency, in Seconds	8	10	10
Moisture Content% of Fabric	9.02	8.87	9.5
Wick ability in mm after 5 minutes	180	70	150

Thermal Properties

Table 12: Thermal properties of fabric

Fabric Structure	Thermal Conductivity (K) Value (W/m/K)	
	Eri Silk	Cotton
Single Jersey	16.62	28.12
1X1Rib	29.45	35.42

Wet Relaxed State

Fabrics that were wet processed and conditioned at 25°± 2°c and RH 65% are considered as wet relaxed samples. The knitted loops of the fabric samples are not reached fully stable level in this state and the fabric may undergo dimensional changes when washed.

Fully Relaxed State

Fabrics in which the stress present is removed and is at minimum energy level is said to be in fully relaxed state. This can be achieved by subjecting the fabric to compacting or repeated cycled of washing and drying. The dimensional changes while washing will be minimal when the loops are arrested.

Measurement of Moisture and Thermal properties of fabric

Vertical Wicking Test

The effects of fibre parameters on the vertical wicking of the fabrics have been determined by measuring the wicking height against gravity. The test has been conducted using a vertical wicking tester according to DIN 53924 method [6]. The schematic diagram of the instrument is shown in Figure 5.

A strip of fabric (200 mm×25 mm) was suspended vertically with its lower end (30 mm) immersed in a reservoir of distilled water. At a regular interval, the height reached by water in the fabric was measured by the clamped scale.

Moisture Absorbency Rate

Moisture absorbency rate was measured by drop test method. In which, Drop of 0.5g/l methylene blue solution is placed on the fabric surface from a height of 2.5cm with the help of pipette. A stop watch is started as soon as the drop falls on the fabric and stopped no sooner the image of the reflected light disappears at the edge of the drop i.e. the water drop is completely absorbed by the fabric. This is termed as 'drop absorbency time'. A drop absorbency of about 5sec is generally considered satisfactory for well-prepared Cellulosic materials.

Thermal Conductivity

Thermal conductivity (K) is intensive property of the material that indicates its ability to conduct heat. It is defined as the quantity of heat,Q, transmitted through a thickness L, in a direction normal to a surface of area A; due to temperature difference T, under steady state conditions and when heat transfer is dependent only on the temperature gradient.

Thermal conductivity = heat flow rate X distance/(area X temperature difference)

Figure 5 represents the simple form of Lee's Disc, which has used for determining the thermal conductivity of jute/cotton blended knitted fabric. The knitted fabric sample (D) is placed in between a brass base (B) and a Thermal Conductivity Behavior of Eri Silk Knitted Fabric (D) is placed between brass disc (C), the whole arrangement is suspended by means of strings attached to hooks in brass disc (C)

RESULTS AND DISCUSSION

Knittability

The Eri silk yarn contains slubs and bigger size knots and its affects the knitting performance. The lack of yarn quality is due to the technological gap in the ERI silk sector. For improving knitting performance, Circular machine speed reduced to less than 10rpm whereas Cotton knitting we could able to run above 30rpm. To reduce fabric defects, coarser gauge machine was selected and Loop length of ERI yarn were maintained 10% more than same cotton count. Yarn feeding and the take-up tension were reduced less than 3 CN.

Fabric Particulars

The fabric samples were analysed after knitting. The fabric details measured were: Course and Wale count, fabric weight per unit area and fabric thickness. Wales and Course densities were measured according to the ASTM D3775 standard, using the counting glass. Fabric weight per unit area was determined according to ASTM D-3776 standard using electronic weighing balance. The fabric parameters have also been mentioned in the table - 7. The table shows the mechanical properties of Eri silk knitted fabric. The Bursting strength and Pilling Resistance of Eri Silk knitted fabrics are better when compared cotton fabric. The air permeability of fabric also found better except Lycra Single Jersey fabric and its due higher closeness between adjacent loops.

Colour fastness test

The fabric colour-fastness were evaluated as per IS methods. The Rubbing fastness and Perspiration fastness were evaluated according to the IS: 266-1988 and IS: 971-1983.Color Fastness to Light and Wash were evaluated according to the IS: 2454-19885 and IS: ISO-105, C-10. Table 9 shows the Rubbing, Light, Wash and Perspiration fastness grades of the fabric. Except the perspiration fastness, fastness at all stages is better.

(WPI - Wales per Inch, CPI Courses per Inch, LL - Loop Length. DRS Dry Relaxed State, WRS Wet Relaxed State, FRS Finished Relaxed State)

Geometrical values are shown in Table 10. The loop Shape values are determined at three stages i.e. Dry relaxed state, Wet relaxed state and fully relaxed state. The difference between loop shape values are Minimum and it indicates Eri knit structures were found dimensionally more stable even after successive washing. Table 11 shows the Moisture transmission properties of fabric. The Moisture Absorbency Rate is found to be higher when comparing cotton fabrics. The rate absorbency for cotton fabric is around 5 sec. The wickability of fabric is found to be better except the lycra Single jersey fabric and its and its due more closeness between adjacent loops. Table 12 shows the Thermal Properties of Eri silk knitted Fabric. The Thermal Conductivity of the fabric was compared with equillent thickness of Cotton fabric of same Structure. The Thermal insulation values of Eri silk fabric found to be better and its evidence that it can be used as lightweight winter wear.

CONCLUSION

The studies revealed that the ERI spun yarn fabric has good Physical, Dimensional Properties and thermal insulation. The working performance of fabrics was good at the time of cutting and sewing. It confirms the suitability of ERI silk knit materials for garmenting. The knitting performance not upto the satisfactory level and it's due to presence more no. of slubs, Thick and thin places, bigger size knots. If the above problem rectified, this yarn can be used to produce all kinds of lighter to heavy fabrics like inner wear, dress material, sweaters, ornamental fabrics, fancy wear etc. The Knitted fabric produced from these yarns has good demand in international market because Eri spun silk fabric is produced by non violence and is stiffer, has luster, water permeable, stronger, durable, warmth is soft to wear, has good air permeability and is good in all season. Production of Eri Knit Wear and other fashion products out of Eri silk provides a better value addition which ultimately increases the price of eri cocoon and yarn; thereby improve the income of poor tribal producers. Eri Silk is skin friendly and it can be used for production of inner garments and kids wear.Eri silk can be used in temperate area because of its higher thermal property. Eri Silk can be blended with wide range of other natural fibres such as ramie, wool, cotton, jute, banana fibre *etc.*

Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 421-423

PEST AND DISEASE INCIDENCE IN SILKWORM REARINGS OF SC/ST SERICULTURISTS: KNOWLEDGE LEVEL ON INCIDENCE AND MANAGEMENT

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ABSTRACT

The SC / ST sericulturists in Chintamani, Sidlaghatta and Kolar taluks were personally interviewed through structured schedules to assess their knowledge level on silkworm pest and disease incidence as well as their management. A total of 581 SC and ST silkworm rearers were personally interviewed. All the SC and ST silkworm rearers expressed that Uzi fly was the only pest affecting the silkworm crops from third instar onwards. None of the SC and ST silkworm rearers had noticed the incidence of pebrine disease. However, 92.40 per cent of the rearers in Chintamani taluk, 89.10 per cent in Sidlaghatta taluk and 96.60 per cent in Kolar taluk were aware of grasserie disease incidence in fourth and fifth instars. The awareness about the management of silkworm diseases revealed that 93.40 per cent of the SC and ST rearers were aware of using bed disinfectants for the management of grasserie disease, 80.70 per cent for the management of flacherie disease and only 58.70 per cent for the management of muscardine disease, in all the three taluks.

Key words: Knowledge level, SC and ST, Silkworm disease, Silkworm pest

INTRODUCTION

Sericulture occupies the place of pride in the rural economy of India, since it is one of the important cash crop with frequent attractive returns throughout the year. However, the major challenges the silk producing nations all over the world confront are the damage caused by diseases and pests of silkworms. In spite of concerted efforts made by the government for transfer of technology the sericulturists do not adopt the technologies to the desired extent (Dolli *et al*., 1993). In this context an extensive survey was undertaken to know the knowledge level of SC / ST sericulturists on incidence and management of pests and diseases of silkworm in Chintamani, Sidlaghatta and Kolar taluks.

MATERIALS AND METHODS

The SC / ST sericulturists in Chintamani, Sidlaghatta and Kolar taluks of Karnataka state were personally interviewed through structured schedules to assess their knowledge level on silkworm pest and disease incidence as well as on their management. A total of 581 SC and ST silkworm rearers were interviewed through structural schedules and the data collected were classified and the knowledge level of the selected respondents was presented as per cent to the total.

RESULTS AND DISCUSSION

All the SC and ST silkworm rearers expressed that Uzi fly was the only pest affecting the silkworm crops from third instar onwards (Table 1) . However, they all opined that the incidence of other pests like rat, ants, *etc*., was insignificant.

None of the SC and ST silkworm rearers had noticed the incidence of pebrine disease (Table 2). However, 92.40 % of the rearers in Chintamani taluk, 89.10 % in Sidlaghatta taluk and 96.60 % in Kolar taluk were aware of grasserie disease incidence in fourth and fifth instars. The flacherie disease incidence was reported by 90.50 % of the rearers in Chintamani, 73.80 % in Sidlaghatta and 78.90 % in Kolar taluks. Similarly, 52.50 % of the rearers in Chintaman, 43.30 % in Sidlaghatta and 71.40 % in Kolar taluks had observed muscardine disease incidence.

Table 1: Awareness of SC / ST sericulturists on the incidence of silkworm uzi fly

Uzi fly Incidence	Proportion of SC / ST Farmers					
	Chintamani Taluk		Sidlaghatta Taluk		Kolar Taluk	
	No	%	No	%	No	%
I instar	0	0.00	0	0.00	0	0.00
II instar	0	0.00	0	0.00	0	0.00
III instar	158	100.00	157	2.12	266	100.00
IV instar	158	100.00	157	100.00	266	100.00
V instar	158	100.00	157	100.00	266	100.00

Table 2: Awareness of SC / ST sericulturists on disease incidence in silkworm rearing

Diseases	Proportion of SC / ST Farmers					
	Chintamani Taluk		Sidlaghatta Taluk		Kolar Taluk	
	No	%	No	%	No	%
Pebrine	0	0.00	0	0.00	0	0.00
Grasserie	146	92.40	140	89.10	257	96.60
Flacherie	143	90.50	116	73.80	210	78.90
Muscardine	83	52.50	68	43.30	190	71.40
Total respondents	158	-	157	-	266	-

Table 3: Adoption of Uzi fly management practices by SC / ST sericulturists

Management practices	Proportion of SC / ST Farmers					
	Chintamani Taluk		Sidlaghatta Taluk		Kolar Taluk	
	No	%	No	%	No	%
Nylon / iron mesh to door and windows	158	86.83	157	94.01	266	93.01
Uzitrap	10	6.33	05	3.18	20	7.32
Uzicide	15	9.50	05	3.18	0	0.00

Table 4: Adoption of silkworm disease control measures by SC / ST sericulturists.

Diseases	Proportion of SC / ST Farmers applying lime and bed disinfectants	
	No	%
Grasserie	543	93.40
Flacherie	469	80.70
Muscardine	341	58.70

Uzi fly management practices adopted by the SC and ST silkworm rearers included fixing of nylon/ iron mesh to doors and windows (86.83% of rearers in Chintamani, 94.01% in Sidlaghatta and 93.01% in Kolar taluks) and use of Uzitrap (6.33 %, 3.18 % and 7.32 % farmers in Chintamani, Sidlaghatta and Kolar taluks, respectively) (Table 3). However, the awareness on dusting of Uzicide was noticed only among the SC and ST silkworm rearers of Chintamani (9.50 %) and Sidlaghatta (3.18 %) taluks.

The awareness about the management of silkworm diseases revealed (Table 4) that 93.40 % of the SC and ST rearers were aware of using bed disinfectants for the management of grasserie disease, 80.70 % for the management of flacherie disease and only 58.70 % for the management of muscardine disease, in all the three taluks.

Lack of knowledge about disease control measure was perceived as the most important reason for non-adoption of disease control measures by sericulturists in Mysore district (Singhvi *et al*., 1994). Lakshshmanan *et al*. (1998) have reported a low rate of Uzi control among the sericulturists of Dharmapuri district in Tamil Nadu. It has also been found that equal proportion of small farmers in Mandya district have either fully or partially adopted IPM for Uzi fly management, whereas 80 % of the large scale farmers had fully adopted IPM for Uzi fly management (Vijaya Prakash and Dandin, 2005). Mani *et al*. (2006) have also observed that the adoption of IPM in Uzi fly management and rearing house disinfection was at a lower rate among the sericulturists of Erode district in Tamil Nadu.

Even in the present study the use of biological control agents and other ecofriendly methods for Uzi fly management is totally unknown to all the SC and ST silkworm rearers, though majority of them used the bed disinfectants for the management of silkworm diseases. It could be thus, concluded that there is a need to train SC and ST silkworm rearers of the three taluks studied in adopting integrated pest and disease management practices in silkworm rearing for successful cocoon crop harvest.

ACKNOWLEDGEMENT

The authors are grateful to the Department of Biotechnology, Government of India, New Delhi, for funding the study.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 424-428

IMPACT OF EXTENSION *VIS-À-VIS* NEED OF STRENGTHENING EXTENSION SYSTEM FOR SUSTAINABLE SERICULTURE IN EASTERN UTTAR PRADESH

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ABSTRACT

Production of quality and quantity cocoons commercially at farmer's level, services of effective extension is very much essential. The new technologies evolved by research bodies are transferred to field in lab to land programme for adoption by the target group through technical demonstration in various means, exposure visit and training in different activities and adequate infrastructure build up through extension. But gains from new technologies still remains to be realized because of non-adoption of technologies fully (Anonymous, 1974; Puttaswamy *et al.,* 1978; Prakash Kumar, 1986; Aswathanarayan, 1989 and Gopala, 1991). The reasons for non-adoption of technology were lack of awareness about the technologies and to make the sericulture a success adoption of recommended sericultural practices is essential (Jaiswal and Kumar, 2005). In the present paper authors have discussed the impact of extension and further need of strengthening of extension mechanism for sustainable sericulture in U.P.

Key words: Impact of extension, Technology adoption, Technical demonstration, Training

INTRODUCTION

Sericulture has become the most important rural industry playing a dominant role in rural development in various states because, it keeps the rural population employed in villages itself and helps in preventing migration to towns. The employment is remunerative and utilizes family labour effectively. It can be operated successfully on small, medium and large scale. It is a low investment high output occupation with low gestation period. It provides raw material for cottage and large scale textiles industry. Most importantly, it goes well with the life style of rural people without affecting the environment.

Mulberry sericulture status in U. P.

The rearing of silkworm is an age old practice in Uttar Pradesh (U.P.). The pre cocoon activities are spread over in almost all districts of U. P. Presently mulberry sericulture is confined to 14 potential districts of which 11 districts are rearing multivoltine silkworms (majority in Tarai region) and 3 districts bivoltine in western area. Post-cocoon sector is maily confined in Varanasi and Mubarakpur area of Azamgarh. There were more than 1.0 lakh hand looms and around 2.0 lakh power looms operational till 1998-1999 and the consumption of silk was around 11000 MT (8000 MT in Varanasi & 3000 MT in Mubarakpur) but due to various reasons *viz.,* non-availability of raw silk throughout the year, outdated hand looms/power looms, uneven colour dyeing, non value addition, outdated system of fabric finish and insufficient support for marketing and training to weavers the consumption of silk reduced to 5000- 5500 MT likewise the number of hand looms and power looms have come down to the tune of 50% simultaneously, dyeing machines also reduced to 150-200 from 650 units, printing units from 50 to 8-10 units and calendar units from 20 to 2-3. Moreover, the raw silk production of the state is only 50 MT.

Constraints

Certain reasons identified for the low production and productivity of cocoons and raw silk in the state are :

- ☞ Farmers are fully dependent on the leaf production of Govt. Sericultrure Farms and most of the time they face scarcity of leaves during final stage of rearing.
- ☞ Most of the mulberry varieties in the farms are not high yielding and also 20 to 25 years old Hence, the leaf yield is low.

- ☞ Inadequacy of rearing space, as most of the farmers rear silkworms in their dwelling units.
- ☞ Non availability of latest rearing equipments including improved mountages.
- ☞ Non availability of marketing avenues particularly for green cocoons.
- ☞ Sericulture is less profitable in this area due to low rate of cocoons.
- ☞ Non availability of season specific and region specific silkworm races and suitable mulberry varieties and various improved technologies.

Profile of sericultural districts under REC, Gorakhpur

In eastern U.P. eight major districts viz., Bahraich, Gonda, Balrampur, Gorakhpur, Basti, Kushinagar, Mahrajganj and Deoria are producing mulberry cocoons predominantly Multi x Bi in three seasons i.e. Summer, Monsoon and Autumn and Bi x Bi in Spring season. Five districts namely Gorakhpur, Basti, Kushinagar, Deoria and Mahrajganj are under Gorakhpur division.

The Gorakhpur district is situated on N.H.-28, 279 Kms. away from the capital Lucknow lies between latitude 26^0 46'N and longitude 83^0 22'E covers the geographical area of 3483.8 Sq.Km.. It is bounded by district Mahrajganj in the north. Ambedkar Nagar, Azamgarh and Mau in the south. Kushinagar and Deoria in the east and Sant Kabir Nagar in the west. District Kushinagar situated at 53 Kms. east from Gorakhpur on the N.H.-28 lies between latitude 26^0 45'N and 83^0 24'E. The district headquarter is Padrauna 71 Km. from Gorakhpur covering the geographical area of 2873.5 Sq.Km.. It is bounded by district Mahrajganj in west, Gorakhpur in south west, Deoria in the south and Bihar in the east.

Similarly Basti is situated on N.H.-28, 70 Km west from Gorakhpur covering geographical area of 7309 Sq.Km.. District Mahrajganj is situated at Indo-Nepal border, its boundary touches Nepal in north, Gorakhpur in south, Padrauna in east, Siddharth Nagar and Sant Kabir Nagar in west and total area of district is 2952 Sq.Km. The details of these districts are given in Table 1. The details of mulberry sericulture status of districts Gorakhpur, Kushinagar, Mahrajganj and Basti are given in Table 2.

Table 1: Profile of Sericultural districts of Gorakhpur Division

Particulars	Gorakhpur	Kushinagar	Mahrajganj	Basti
Area(sq.km.)	3483.80	2873.50	2952.0	7309.0
Tahsil (No.)	07	04	04	03
Block (No.)	19	14	12	14
Population Density(Sq.km.)	1140	778	763	682
Total Population (lakh)	37.79	22.45	21.73	27.51
Rural Population (lakh)	30.30	21.36	20.63	20.75
S.C. (lakh)	8.31	3.63	4.24	5.70
S.T. (No.)	898	91	2564	23541
Agricultural Labourer (lakh)	2.49	1.60	1.75	2.02
Agricultural Area(lakh ha)	3.36	2.94	2.09	2.11
Area under Forest (ha)	5905	2870	180	2752
Irrigated Area(lakh ha)	1.95	1.15	1.33	1.31

Table 2: Sericulture Status of District Gorakhpur, Kushinagar, Basti and Mahrajganj

Particulars	Gorakhpur	Kushinagar	Mahrajganj	Basti
Mulberry area (acre)	40.0	265	62.18	63.74
Block covered(No.)	02	08	05	06
Sericultural Villages	17	122	34	27
Sericultural families	186	1385	758	709
DFLs reared(No.)	46000	144900	96500	87500
Cocoon Production(Kg)	17000	53781	36200	32800
Raw Silk Production(Kg)	1700	5378	3620	3280
Raw Silk Production(MT)	1.700	5.378	3.620	3.280

Extension approach of REC, Gorakhpur

In effective extension management/services following protocol is being followed for quality & quantity cocoon production:

- The incubation of silkworm eggs at three Chawki Rearing Centres operating in Kusamhi,Gorkhpur, Gazipur in Kuishinagar and Kajrikund in Basti districts is being carried out in each crop according to the suggested norms.
- The chawki rearing of silkworm was ensured in each crop as per the technology at three CRCs. The distribution of chawki reared silkworm of authorized bivoltine hybrids viz., NB4D2 x SH6 and CSR2 x CSR4 and its reciprocals during Spring crop and multivoltine hybrids Nistari x NB4D2 during Monsoon and Autumn crops respectively. Beside, under Provincial Race Authorization and in other programme the chawki reared worms of ATR16 x ATR29 and RSJ15 x NB4D2 along with SH6 x NB4D2 and Dun6 x Dun22 is being reared in Autumn and Spring crops.
- Monitoring, supervision of late age rearing, in addition provide technical inputs pertaining to rearing like proper preservation of mulberry leaves, spacing in bed, use of bed disinfectants, lime, handling of moulting condition of larvae in every moult, cleaning of bed, maintenance of temperature, humidity and hygienic conditions, disposal of dead and diseased larvae, proper aeration during mounting and cocooning stage. Proper mounting, proper harvesting of cocoons and sorting of cocoons was demonstrated through Field-Days, Group-Discussions, Film-Shows, Kisan Vichar Goshthies, visit and contact (Table-3).
- The crop wise data of DFLs reared, cocoon production, cocoon productivity were recorded. The details are given in Table 4.

Table 3: Details of events conducted in extension communication programme since inception

Year	Group-Discussions	Film-Shows	Field-Days	Vichar Goshthi
1999-00	16	01	11	00
2000-01	19	00	10	12
2001-02	11	03	08	05
2002-03	07	01	06	03
2003-04	05	00	10	03
2004-05	12	03	05	03
2005-06	12	03	04	03
2006-07	12	03	04	02
2007-08	6	03	03	01
2008-09	6	03	03	01
2009-10	6	03	03	01
2010-11	6	03	03	01

Strengthening of extension system

The Sericulture in Uttar Pradesh is predominantly practiced by small and marginal farmers with low land holdings and landless hard working labourers. These groups have own mindset and feel apprehension to adopt new technologies in fear of crop loss. Obviously, the average literacy rate and knowledge level of the farmers are not very satisfactory. As such, they suffer from traditional mind-set, reluctant to take/adopt new technologies.

These problems of sericulturists can be addressed by conducting regular awareness programmes and demonstrations, explanation of technologies in simple language by the extension workers etc.

For effective expansion of the industry in terms of increase in production and productivity, following points are essential in development of beneficiaries and popularization of technologies :

Requirement of Extension Worker: The extension worker plays an important role in extension work. The extension network in relation to number of districts, blocks, villages and rearers under REC, Gorakhpur is really inadequate and as such, needs to be strengthened. Similarly staff strength of the implementing agency i.e. State Sericulture Department should also have sufficient staff. NGOs may also be encouraged in the on farm segment of the activity.

Facility of Mobility: Extension centre has to cover vast area and in absence of approachable roads and due to Kachha roads, villages remain out of reach, neglected and devoid of the benefits of improved technologies particularly during

Table 4: Details of rearing and cocoon production of farmers adopted by REC, Gorakhpur

Year	DFLs reared (No.)	Farmers covered (No.)	Villages covered (No.)	Cocoon produ ction (kg)	Cocoon yield/ 100Dfls (kg)	Raw silk production (kg)
1998 -99	2725	80	07	685.650	25.16	68.57
1999 -00	3090	67	06	604.340	19.55	60.43
2000 -01	2780	69	06	542.800	19.52	54.28
2001 -02	2240	54	05	550.050	24.55	55.00
2002 -03	1150	29	03	348.800	30. 33	34.88
2003 -04	2250	50	05	553.525	24.60	55.35
2004 -05	3350	68	07	1006.740	30.05	100.67
2005 -06	2400	63	05	784.400	32.68	78.44
2006 -07	1955	49	06	661.150	33.81	66.11
2007 -08	4100	88	07	1392.400	33.96	139.24
2008 -09	4700	94	09	1709.450	36.37	170.94
2009 -10	3800	72	10	1496.300	39.37	149.63
2010 -11	4250	76	06	1704.700	40.11	170.47

and after monsoon season. To encounter these problems Vehicle(4 Wheeler) must be provided to the extension centre.

Technological and communication skill: The technological knowledge of improved technologies as well as the skill to communicate the technologies effectively has a vital role in transfer of technologies. As such, training of extension worker on above aspects accompanied with periodical interaction between the farmers and extension scientist is very much essential.

Aptitude and empathy: It is equally important to understood the view point of farmers, modifying steps of a technology depending upon the situation without altering its main objective and provide appropriate and required information in a given situation. The extension workers should be unbiased in their approach.

Facility of marketing: Lack of marketing facilities for the end products which finally tax the farmers. In the absence of adequate market facilities in the vicinity for green cocoons, the cocoon growers have to suffer as they did not get much price in selling of dry cocoons. Hence, organisation of cocoon market for green cocoons will facilitate the farmers not only to get higher rate but just after the harvest of cocoons. With this effort farmers encourage to produce both quality and quantity cocoons.

Benchmark survey & Sensitization: Before taking up any extension work a baseline survey should be conducted to ascertain prevailing conditions and practices like mulberry plantation, availability of foliage, DFL intake, cocoon production, productivity etc. which would help devise the parameters and also sensitize the farmers about the improved technologies to be introduced through interaction and group meetings with the farmers.

SUGGESTIONS

For effective extension, following measures towards propagation of technologies may be taken :

- Identify the area and make a benchmark survey to ascertain the socio-economic condition and the prevailing cultural practices.

- Sensitize the farmers well in advance about the technologies including their economic and environmental aspects.
- Demonstrate the technology and interact with the farmers to get the feedback.
- Identify the progressive farmers who are ready to take the risk and apprise them about the technologies and with their help demonstrate the results to other farmers.
- Mulberry demo plots could be preferably nearer the approachable side.
- Monitor the entire demonstration programmes regularly.
- Dissemination of information should be step by step and relevant to that particular phase of activity.
- Conduct regular group-discussions with the farmers. Try to understand the problems from their point of view and help them to overcome.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 429-432

RETROSPECT AND PROSPECT OF SSPC, DAKSHINBHOWANIPUR - THE HIGHEST COMMERCIAL SILKWORM SEED PRODUCER IN EASTERN ZONE

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ABSTRACT

Silkworm Seed Production Centre, Dakshinbhowanipur is one of the oldest seed production centre of West Bengal, rather of Eastern India. During 1978, it was germinated as a small unit under the control of CSR&TI, Berhampore to promote sericulture activity in West Bengal. After more than three decades, SSPC, Dakshinbhowanipur has steadily, rather firmly established its lead for sustainable production both in terms of quality and quantity of multivoltine hybrid and cross breed layings in eastern zone of India through its stabilized/standardized production process. Its annual raw silk contribution to the nation is 18 MT/Yr that improves the socio-economic status of large weaker section of society through increased productivity as well as return. As recognition of sustainable quality seed production this unit, SSPC, Dakshinbhowanipur has covered up under prestigious ISO 9001 : 2008.

Key words: Cocoon yield, Process standardization, Seed production, Sustained improvement, Technologies

INTRODUCTION

In West Bengal, the major silk producing state, rearing of productive silkworm highbreed is restricted due to prevailing high temperature and humidity, particularly during April to September, when huge leaf biomass is produced. However, from November to March, the climatic conditions remain favourable for rearing and to exploit the climatic gift, multi x bi hybrids are reared by farmers (Das, 1994).Thus, total of five commercial crop rearings are carried out, out of which, multi x bi hybrids can successfully be reared during two-three seasons, *i.e.,* Autumn (Oct.-Nov.), Spring (Feb.-March) and Early summer (Mar.-Apr.) and other two seasons, *viz,* Dry summer (June-July) and Wet summer (Aug.-Sept.). Both Dry summer and wet summer crops are considered as the most unfavourable for silkworm rearing as well as seed production. Considering the seasonal constraints, indigenous multivoltine breeds and limited quantities of multi x multi hybrids are reared.

Since long time back, Central Silk Board has been continuously providing support to this state by supplying disease free layings (Dfls) through its Silkworm Seed Producing Centres (SSPC), amongst which SSPC, Dakshinbhowanipur is the oldest unit situated in the northern part of the state and adjacent to Bangladesh. The climatic condition is congenial to some extent than southern part of the state for silkworm rearing as well as seed production. During its long journey, since 1978, the nomenclature of the production unit as well as controlling authority have been changed like NSSP, ISDP, NSP, NSSP, NSSO. Initially, its main function was to produce P1 and commercial dfls of indigenous multivoltine breed, Nistari at the tune of 0.25 lakh. Up to nineteen centuries, the unit increased its seed production up to the tune 12.0 lakh/annum without paying attention to standardize the process of production and major contribution was Nistari x Nistari dfls. As a result, the production unit passed through unstable egg recovery with less cocoon yield both in terms of quality and quantity. In early 2002, the NSSO decided to stop production of indigenous multivoltine breed, *i.e.,* Nistari x Nistari in its units in West Bengal to increase the productivity with quality of both production unit and end user. Thus, traditional Nistari x Nistari was replaced by productive multivoltine hybrid, Nistari x M12W and its reciprocal. An attempt has been made by the authors to review the past and present practice and results like P1 rearing performance, quantum of dfls

produced with egg recovery, cocoon yield performance against this pioneer silkworm seed production unit for its vital contribution to achieve the sustainable growth of sericulture in West Bengal.

Grainage seasons

In West Bengal, indigenous multivoltine breed, Nistari is reared commercially throughout the year and farmers preferred multi x bi during favourable season for better cocoon yield and return. Previously, the farmers practiced four commercial crops per year namely, Jaistha (May), Bhaduri (July-August), Aghrayani (Oct.-Nov.) and Chaitra (Jan.-Feb.). During Bhaduri, farmers reared exclusively multi x multi hybrids (NxN, NxG/NxOS616) and in other seasons, their preference was multi x bi (NxNB4D2) hybrids. However, due to non-availability of sufficient bivoltine component from West Bengal , farmers were forced to rear multi x multi hybrid along with less quantities of multi x bi/bi x multi hybird dfls, inspite of favourable climate for rearing of cross breed .The average annual share % of multi x multi and multi x bi dfls were 75 and 25% respectively.

During late nineties, two major changes in crop pattern occurred. The Jaistha crop was replaced by optional commercial crop, Shravani (Jun.-July) considering the utility of foliage before yearly bottom pruning usually done after Bhaduri crop in Malda district and another additional crop, Baishaki (March-April) was introduced. The details of crop seasons with silkworm breeds prevailed in Malda district before and after late nineties are shown in Table 1.

Table 1: Details of Silkworm hybrids reared in Malda district of West Bengal in different seasons.

Crop season	Combination (Pre- 2000)	Combination (Post- 2000)
Jaistha (May)	NxN / NxG / NxOS616/ NxBi	Nil
Shravani (June-July)	Nil	NxM12W / M12WxN
Bhaduri (July-August)	NxN / NxG / GxN / NxOS616	NxM12W / M12WxN
Aghrayani (Oct.-Nov.)	NxN / NxBi / BixBi / BixN	NxBi
Chaitra (Jan.-Feb.)	NxN / NxG / GxN / NxOS616/ NxBi / BixBi / BixN	NxBi
Baishaki (March-April)	Nil	NxM12W / M12WxN / NxBi

For preparation of multi x bi hybrid dfls since time immemorial indigenous Nistari breed has been used as prime mother component. Usually NB4D2 is used as male component and for multi x multi hybrid both ruling Nistari and M12W (White coloured cocoons developed by CSR&TI, Berhampore and exposed to grainage during 2002) are being exploited for preparation of N x M12W and its reciproca. Matching the commercial rearing schedule, there are total five P1 rearing conducted in different seasons. Only P1 Shravani, Bhaduri and Aghrayani rearings are conducted in worst season,*i.e.,* dry summer and wet summer respectively, whereas, P1 Chaitra & Baishaki are marked as favourable in terms of grainage operation.

In terms of performance, Baishaki P1 rearing and grainage operations conducted during February and March respectively are the best which followed by Chaitra, Bhaduri, Aghrayani and Shravani. The Shravani is the optional crop for rearers and practiced by very less farmers in patches in Malda due to dry and hot weather prevailing during June. As a result indigenous multivoltine breeds and limited quantity of multi x multi hybrids are reared. However, both P1 Shravani crop and its grainage operations sporadically give better performances excepting when early downpour starts. In case of Bhaduri, there are huge demand of dfls due to luxurious mulberry growth due to rain. But P1 Bhaduri crop suffered heavily due to high temp. and high humidity. This enforces the grainages to reduce their production owing to lack of quality seeds.

Due to systematic adoption of technology through the time span both in mulberry and silkworm sides, *viz.* raising high yielding varieties of mulberry replacing crowded local variety with wider spacing, use of vermicompost and compost, application of fertilizers as per recommendation, thorough pre- and post- crop disinfection with Sanitech/bleaching powder, use of season specific silkworm race, use of electrical appliances (fan, light and room heater) and use of recommended bed disinfectants (Labex, Bijetha), mother moth examination, the cocoon crop yield of P1 rearers increased 20-30%.The average cocoon yield /100 dfls irrespective of rearing season increased to 24-25 kg from 18-20 kg with average pupation more than 90% and average dfls recovery of 26.0% and 48.0 g/kg seed. This was possible only due to adoption of imported technologies by the seed rearers which were disseminated through IVLP, farmers

meets, farmers days, seminars and imparting skill up-gradation trainings at the Training institutes of CSB.

The procurement and supply of bivoltine seeds as male component has been streamlined and NSSO, HQ, Bangalore is monitoring and supplying the entire requirement of bivoltine P1 seeds (NB4D2/CSR2/CSR4/FC2) from southern states / Orissa during Aghrayani, Chaitra and Baishaki. In addition, a small quantity of seed cocoons of SK6 x SK7 are produced locally through ASR in West Bengal, particularly, during Chaitra & Baishaki. However, replacement of ruling NB4D2 with CSR2/CSR4/ SK6xSK7/FC2 for production of multi x bi commercial hybrid in West Bengal needs to be reviewed further (Ghosh,2010). The approximate annual requirement of bivoltine seeds is 30-40 qtl. and its average utilization (bivoltine cocoon : dfls) for the production of multi x bi hybrid was 1.90 during pre-2000 and has been reduced to 1.40 – 1.56 in post-2000.

Production and egg recovery

The overall production of hybrid dfls in post-2000 has increased sufficiently to the tune of 40.0 % due to steady improvement both in terms of quality and quantity of cocoon yield with higher return due to recovery of more raw silk. Up to 1996-97. The performance of grainage was evaluated on the basis of only recovery % (No.) irrespective of quantity of seeds processed, *i.e.,* weight (kg). The average annual recovery was around 20.0%. In addition to that, during 1997-98, another assessment criteria, *i.e.,* recovery of dfls in g. per kg of seed was introduced. Up to pre-2000 that was recorded as 35-40 g/kg seed. It was enhanced steadily ranging from 45-48 g/kg seed in post-2000 (Tabel 2). This improvement has been made particularly due to adoption of technologies in approprite manner in P1 seed sector, rational handling of seed cocoons and standardization of production process.

The utilization of seed cocoons to produce one dfls also maximized from more than five in pre-2000 to less than five in post-2000 due to advance planning and maintenance of checks and balances on input and output ratio and action in time. Therefore, there was steady improvement in quality and quantity of egg produced during post-2000.

Table 2 : Seed Production performance of SSPC, Dakshinbhowanipur during 2005-06 to 2009-10.

Year	Dfls Produced	Egg recovery in %	Egg recovery in g/kg	Cocoon : Dfls recovery
2005-06	1504980	24.95	42.65	4.92 : 1
2006-07	2133450	25.03	44.26	4.73 : 1
2007-08	2572600	26.55	47.86	4.46 : 1
2008-09	1832400	24.97	45.58	4.00 : 1
2009-10	1948850	27.34	47.46	4.46 : 1

Seasonwise egg recovery

The egg recovery in different seasons at SSPC, Dakshinbhowanipur during last five years is depicted in Table 3 to get an idea about favourable & unfavourable grainage seasons.

Table 3: Season wise dfls recovery in SSPC Dakshinbhowanipur

Grainage season	Egg recovery in %	Egg recovery in gm/kg seed
Shravani (June-July)	24.24	45.28
Bhaduri (July-August)	25.91	46.03
Aghrayani (Oct-Nov.)	24.87	44.17
Chaitra (Jan.-Feb.)	27.12	48.02
Baishaki (March- April)	27.94	49.40

In terms of egg recovery, out of five production seasons, the grainage operations conducted during Baishaki (March-April) is the best due to congenial weather for silkworm followed by Chaitra, Bhaduri, Shravani and Aghrayani. The Shravani is the optional crop for rearers and is practiced by very less farmers in some pockets in Malda district due to dry and hot weather prevailing during June. As a result indigenous multivoltine breeds and a small quantity of multi

x multi hybrids are reared. However, both P1 Shravani crop and its grainage operations sporadically give better performances when early downpour starts. In case of Bhaduri, there are huge demand for dfls due to luxurious mulberry growth. But P1 Bhaduri crops suffer heavily due to high temp. and high humidity which enforces the grainages to reduce their production owing to lack of quality seeds. In case of Aghrayani grainage season, usually every year late P1 rearings experience with a depression raised from Bay of Bengal, thus the quality as well as quantity of seed cocoons are affected greatly due to the infection of late age grasserie.

Field performance silk wormseed

The quantum of dfls (Lakh) sold through selling units (SSC/SSUs) and the average cocoon yield (kg)/100 dfls obtained irrespective of rearing season for multi x multi and multi x bi hybrids as shown in Table 4.

Table 4 : Quantity of dfls sold and cocoon yield obtained during 1990-95 and 2005-10

Quantity of dfls sold (In lakh) (1990-95)	Pre-2000		Quantity of dfls sold (In lakh) (2005-10)	Post-2000	
	Cocoon yield per 100 dfls (kg)			Cocoon yield per 100 dfls (kg)	
	Multi x Multi	Multi x Bi		Multi x Multi	Multi x Bi
51.98	18.50	35.00	90.59	25.55	45.60

The table clearly indicates that the quantity of dfls sold and the cocoon yield significantly increased over the years, which is a testimony of adoption of standard system of production in SSPC, Dakshinbhowanipur.

Considering the stable production system reflected through high egg recovery and cocoon yield per unit of dfls to support quality raw silk production, this production unit has been covered under ISO 9001 : 2008 since May,2010. The change over of production from indigenous multi x multi in pre-2000 period to improved multi x multi hybrid and multi x bi hybrids in post-2000 period was a remarkable decision in right direction. That decision with the progress of time has made SSPC,Dakshinbhowanipur a leader in quality dfls production in eastern zone contributing around 18 MT raw silk annually to the nation and serves as a pillar of faith by improving the socio-economic status of large weaker section of society through increased productivity as well as return. From above observation, it is well established that SSPC, Dakshinbhowanipur has acquired the potentiality to produce silkworm seeds both in terms of quality and quantity.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 433-435

AN OVER VIEW OF THE MULBERRY SERICULTURE IN ORISSA: PROSPECT OF BIVOLTINE SEED COCOON PRODUCTION TO MEET THE DEMAND OF SEED COCOON OF WEST BENGAL

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ABSTRACT

The present study was undertaken with an objective to find out the suitable silkworm bivoltine breed/hybrid for rearing during August-September season in southern part of Orissa. SK6 × SK7 was reared as a foundation cross (FC) as seed instead of commercial rearing consecutively for 3 years in the southern part of Orissa, both at farm and farmers' level. The yield per 100 dfls ranged from 25 kg to 60 kg. The farmers income for their product increased about 2 folds thereby improving their socio-economical status.

Key words: Bivoltine, Foundation cross, Seed cocoon

INTRODUCTION

Silk is traditionally the heritage of Orissa from the age old times. But Orissa is a non-traditional state in mulberry sericulture. Sericulture is practiced in 12 districts mostly by the weaker and backward section of the society. A total of 1094 SC/ST families are involved in mulberry sericulture activities. The climate and topography in some of the areas of the state is suitable for mulberry sericulture. There is scope for developing the mulberry sericulture in Orissa. About 90% of mulberry cultivation is under rainfed condition in Orissa. (Sarangi *et al.*, 2010)

Four commercial crops are reared in the state. Out of four crops, August-September and October-November are the major crops in the state. But August -September is adverse for mulberry silkworm rearing due to heavy and continuous rain due to depression. Thus, this is a much risky crop. As per the records available, it was either failure or wash-out due to rain, if any bivoltine pure race was reared during the period.

The silkworm provides one of the best examples of hybrid vigour. F1 silkworm hybrids are in many respects superior to their parents (Toyama, 1906; Hirobe, 1956; Sengupta *et al*., 1971, 1974; Jolly, 1983; Subba Rao *et al*., 1989, 1992; Das *et al*., 1994, 1997; Sen *et al*., 1996; Ghosh *et al*., 1993, 1995, 1996; Sengupta *et a*l., 1997). The evaluation and choice of parents is an important part of heterosis breeding programmes for any crop improvement. When the germplasm collection is large, it becomes difficult to identify parental stocks (Holden, 1984) and compare all possible breeds and crosses in the laboratory or in the field level. We selected bivoltine F1 hybrid as the male parent in our experiments for several reasons. The first reason is their better tolerance and increased vigour in comparison to pure bivoltine parents, as suggested by Das *et al*., 1994 and Pal *et al.,* 2010. Secondly, it is easier for farmers of the tropical belts to rear a bivoltine F1 foundation hybrid than a pure bred bivoltine as male parent for the seed crop to produce a commercial multivoltine × bivoltine hybrid. Thirdly, the hybrid (FC) cocoons will be sold as seed cocoons and the price will be two fold higher than commercial cocoons.

In the year 2008, we planned to rear hardy bivoltine hybrids (foundation cross) to utilize them as male parent for the preparation of multivoltine × bivoltine commercial hybrid for rearing in the commercial season (Agrahyani (November) in West Bengal. Accordingly, the rearing was undertaken.

There is heavy demand of Agrahyani P1 bivoltine seed cocoons in West Bengal. To meet the demand of Agrahayani P1 bivoltine seed for West Bengal P1 rearing was undertaken at farm and farmers' level.

MATERIALS AND METHODS

Two bivoltine races *viz*., SK6 and SK7 were selected following the technique advocated by Chattopadhyay *et al*. (1994); Ghosh *et al*., (1995), (1996) (2000) and Sen *et al*., (1996) and their cross SK6 x SK7 was reared during August-September, in 2008, 2009 and 2010 at Centre for Sericulture Development, Ramagiri, Orissa. During August-September, 2010, a large scale rearing was undertaken with 11,300 dfls at both farm and farmers' level in Ramagiri, Chandragiri, Koraput and Kashipur areas of Orissa following the standard rearing technology (Krishnaswamy, 1978, 1979). 11,300 dfls was reared upto second moult and supplied to the farmers on the 2nd day of third instar as per capacity of respective farmer.

Observations were recorded for fecundity, hatching %, larval period, survial percentage, yield per 10,000 worms brushed by no. and weight (kg), single cocoon and shell weight (g.), S.R. % and pupation percentage, actual no. and weight and no. of cocoons per kg.

RESULTS AND DISCUSSION

The performance of SK6 × SK7 was recorded during August-September (Agrahayani P1 of West Bengal) rearing season at Centre for Sericulture Development, Ramagiri, Mulberry Demonstration Farms Patangi and Naranga and RSRS, Koraput. The data is presented in Table 1. The results revealed that maximum dfls reared (300) at the Centre for Sericulture Development, Ramagiri for all the three years. During 2010, three other centres *viz*., mulberry demonstration farms Patangi and Naranga and RSRS, Koraput, the rearing was undertaken along with CSD, Ramagiri. The highest ERR No. (9302), ERR Wt. (14.535 kg), yield per 100 dfls (60.00 kg) were recorded at RSRS, Koraput followed by MDF, Naranga with ERR No. (7832), ERR Wt. (11.921 kg), yield per 100 dfls (47.00 kg) during August-September, 2010. But the pupation % was 90 in all cases and highest no. of cocoon per kg. of 708 was recorded in 2009 at CSD, Ramagiri.

Table 1: Rearing performance of SK6 × SK7 (P1 seed crop) at farm level

Season	Farm	Dfls	Fecundity	Hatching %	Yield/100 dfls	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Pupation rate	Cocoons/ kg
Aug.-Sep. 2008	CSD, Ramagiri	300	400	75.00	25.33	1.420	0.247	17.39	90.00	706
Aug-Sep. 2009	CSD, Ramagiri	300	403	74.00	24.93	1.480	0.269	18.18	90.00	708
Aug-Sep. 2010	CSD, Ramagiri	300	400	73.00	30.33	1.592	0.282	17.71	90.00	628
Aug-Sep. 2010	MDF, Patangi	200	420	91.00	34.63	1.650	0.302	18.30	90.00	591
Aug-Sep. 2010	MDF, Narenga	50	415	95.00	47.00	1.500	0.285	19.00	90.00	657
Aug-Sep. 2010	RSRS, Koraput	50	430	96.00	60.00	1.560	0.296	18.97	90.00	640

Table 2: Rearing performance of SK6 × SK7 (P1 seed crop) at farmers' level

Season	Dfls	Fecundity	Hatching %	Yield/100 dfls	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Pupation rate	Cocoons/ kg
Aug-Sep. 2009	1050	425	90.00	38.86	1.410	0.250	17.73	90.00	708
Aug-Sep. 2010	10100	400	89.00	23.36	1.592	0.282	17.71	90.00	628

The results of the trials given at farmers level at Ramagiri, Chandragiri and Koraput of Orissa during AugustSeptember season for the year 2009 and 2010 are presented in Table 2. In 2009, yield per 100 dfls of 35.857 kg with 90% pupation and maximum no. of cocoon per kg. (708) were recorded. During 2010, the trial was conducted with 10,100 dfls among the 231 farmers during the same season but the average yield per 100 dfls was recorded as 23.356 kg, which was a bit less than the previous year due to tremendous adverse climatic condition. But pupation rate was recorded above 90 percentage.

The cocoons produced during above mentioned years were procured as seed cocoon and supplied to SSPCs, DOS and LSPs of West Bengal as P1 bivoltine seed for Autumn (Agrahayani) commercial crop of West Bengal. Thus farmers of Orissa earned more than two fold income for their cocoons.

ACKNOWLEDGEMENTS

The authors express sincere thanks to the Director, Directorate of Textiles & Handloom, Govt. of Orissa for taking lead for arrangement of the entire programme. The authors also express thanks to the Technical Officers/Staff of DOT, for their sincere involvement in conducting and recording rearing data.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 436-440

ADOPTION OF IMPROVED TECHNOLOGIES BY BIVOLTINE SILKWORM REARERS OF BANGARPET TALUK OF KOLAR DISTRICT

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ABSTRACT

Considering the importance of increasing the production of bivoltine cocoons both sericulture scientists and extension workers have been advocating a good number of practices (mulberry cultivation and bivoltine silkworm rearing) for general adoption by the farmers. The present study was carried out in Bangarpet taluk of Kolar district during 2008-09 to analyze the adoption level of improved technologies by bivoltine silk worm rearers. The results revealed that 74 % of the respondents belonged to high/medium overall adoption levels. Education, mass media exposure, participation in training programme, extension agency contact and extension participation of the respondents had highly significant association with the adoption level of improved sericulture practices. Susceptibility of silkworm to the diseases (98%), difficult to manage rearing compared to existing conventional cross breed (98%), high risk involved in practising bivoltine silkworm rearing (90%), required more bed disinfectants resulting in health hazard (86%), non-availability of quality disinfectants (82%) and non-availability of quantity silkworm seeds (76%) were important constraints faced by the farmers in the adoption of improved bivoltine technologies.

Key words: Adoption, Bivoltine Sericulture, Improved technologies

INTRODUCTION

The Government of India has taken several steps to increase the production of superior quality bivoltine silk by promoting several schemes, especially with the assistance of Japan International Collaborative Agency (JICA) by implementing 'Bivoltine Sericulture Technology Development Project' during 1991 to 1997. This project has resulted in development of comprehensive package in bivoltine sericulture technology through research institutes of Central Silk Board. Project for 'Promotion of Popularizing the Practical Bivoltine Sericulture Technology' was implemented during the second phase of the project from 1997 to 2002. The third phase of the project (Project for Strengthening Extension System for the Qualitative Bivoltine Sericulture) was implemented in states of Karnataka, Andhra Pradesh and Tamil Nadu from August 2002 to July 2007. This project emphasised on qualitative and quantitative production of bivoltine silk which depends mainly on intensive cultivation of mulberry, quality seed production, care during early and late ages of silkworm rearing , management of pests and diseases, etc.

The introduction of bivoltine sericulture technology will not only result in increasing the silk production in the country, but also helps in improving the quality and standard of living of rural population. It is proven fact that adoption of recommended sericultural technologies gives good returns to the farmers. In spite of all the educational efforts made by the Karnataka State Department of Sericulture and Central Silk Board, farmers are facing the problem in adopting the scientific bivoltine sericulture practices. In this background,

the present study is undertaken with the following specific objectives

- To study the adoption level of improved technologies by bivoltine silkworm rearers.
- To find out the association between the personal and socio-psychological characteristics of bivoltine silkworm rearers with their adoption level.
- To identify the constrains faced by bivoltine silkworm rearers.

MATERIALS AND METHODS

The research study was conducted in five villages of Bangarpet taluk in Kolar district of Karnataka State during 2008-09. Bangarapet taluk was selected for the research study because the taluk is first in bivoltine cocoon production in the Kolar district and more number of bivoltine rearing farmers is present in the taluk. A total of 50 bivoltine silkworm rearers who have completed two crops of bivoltine silkworm rearing were selected randomly for the study.

Measurement of dependent variable (Adoption level)

The procedure followed by Sengupta (1967) for calculation of adoption quotient was used to measure the adoption level of the respondents in this study. Accordingly to this method, the adoption quotient was calculated by using the following formula.

$$\text{Adoption Quotient} = \frac{\text{No. of scores obtained}}{\text{No. of scores that could be obtained}} \times 100$$

To find out the extent of adoption by sericulturists, a total of 34 recommended practices in mulberry cultivation (13 practices) and bivoltine silkworm rearing practices (21 practices) were selected for the study after reviewing the literature, consulting sericulture scientists of University of Agricultural Sciences, Bangalore and Central Silk Board and officials of Karnataka State Department of Sericulture. Out of 21 bivoltine silkworm rearing practices, eight practices were related to chawki rearing practices and the remaining 13 practices were related to late age rearing practices.

For each of the recommended practices score of two was assigned for full adoption of the practices. One score and zero score were assigned to partial adoption and non-adoption of practices, respectively. The minimum and maximum score one could get was 0 and 100, respectively. The raw adoption scores were converted to adoption quotient, based on the adoption quotients obtained. Later, the respondents were classified into low, medium and high adoption levels based on mean (76.70) and standard deviation (12.60) as a measure of check.

Categories	Adoption quotient
Low (Below mean ½ SD)	Upto 70. 40 score
Medium (Mean + or ½ SD)	70.41 to 83.00 score
High (Above mean + ½ SD)	Above 83.00 score

Measurement of ten personal and socio-psychological characteristics (independent variables) (Table 4) of bivoltine sericulturists were measured using a structured schedule with suitable scales (Lakshminarayan, 1997). A pre-test interview schedule was used to collect the relevant data. The collected data were tabulated and analysed using mean, frequency, percentage and chi-square test.

RESULTS

Adoption level of mulberry cultivation and bivoltine silkworm rearing practices

The study results revealed that about 40 % of the bivoltine sericulturists belonged to low level of overall adoption levels, whereas 36 % and 24 % of them belonged to medium and high overall adoption levels, respectively with respect to mulberry cultivation and bivoltine silkworm rearing practices. It can be concluded that as high as 60 % of bivoltine sericulturists belonged to high / medium overall adoption levels. Similar kind of findings were observed by Meenal and Rajan (2006).

Adoption of mulberry cultivation, chawki rearing and late age rearing practices by bivoltine sericulturists

Adoption of specific mulberry cultivation practices

Table 1 reveals that the a majority of respondents had fully adopted the mulberry cultivation practices such as drip irrigation (98%), improved variety (96%), wider spacing (94%), quantity of farmyard manure (82%), stump formation (64%) and fertilizer application as per recommendation (54%). Table 1 also indicates that over three-fourth of the respondents had not adopted liquid fertilizers (96%), good maintenance of chawki garden (88%) practising chawki in the same garden (86%) and vermicomposting (76%) in the cultivation of mulberry. An equal percentage of respondents (54% each) had not adopted growth regulators and plant protection chemicals. More or less similar findings were observed by Meenal and Rajan (2008)

Adoption of specific practices in chawki rearing practices by bivoltine sericulturists

As 86 % of the respondents were depending on Chawki Rearing Centres' for chawki worms (Table 2). The practice of disinfection was highly adopted by 14 % of the respondents only. Over 75 % of the respondents had not-adopted chawki rearing practices such as wrap-up method of chawki rearing

(90%), practicing the chawki rearing on own (86%) and possessing a separate chawki rearing room (78%) .

Adoption of specific practices in late age rearing by bivoltine farmers

All the respondents fully adopted the practice of shoot rearing (Table 3), while 74 % of the respondents had separate rearing house. The respondents partially adopted the Integrated Pest Management (IPM) of uzi fly. Whereas, a majority of respondents had partially adopted practices such as use of plastic mountages (88%), recommended disinfection (86%), care during moulting (86%), cocoon deflossing (84%), using of bed disinfectants (78%) and bed cleaning practices (62%). Majority of the respondents (over 70 %) have not followed same late age rearing practices, namely maintaining separate mounting hall (76%), burning of contaminated material (76%) and practicing of proper bed cleaning (72%). The above findings are in line with the findings of Meenal and Rajan (2006).

Association between the adoption level and selected personal and socio-psychological characteristics of bivoltine sericulturists

Age, family size, value orientation, cosmopoliteness and social participation of bivoltine sericulturists had no significant association with the adoption level (Table 4). Whereas, education and mass media use had significant association with the adoption level. Variables such as participation in training programme, extension agency contact and extension participation of the respondents had highly significant association with the adoption of improved sericulture technologies.

Constraints faced by bivoltine sericulturists in the adoption of improved technologies

Table 5 reveals that over 70 % of the respondents had faced the constraints of susceptibility of silkworm to diseases (98%), difficult to manage rearing compared to existing traditional crossbreed (98%), high risk involved in practicing bivoltine silkworm rearing (90%), use of require more bed disinfectants resulting in health hazardous (86%), non-availability of quality disinfectants (82%) and non-availability of quantity silkworm seeds (76%). Less than 50 % of the respondents faced the problems of lack of skill in stump formation (48%), lack of knowledge regarding quantity of fertilizer to be used as per dosage (34%), labour intensiveness (24%), lack of separate rearing house (26%) and difficulties in marketing of cocoons (24%).

CONCLUSION

It is disheartening to note that as high as 76 % of bivoltine silkworm rearers belonged to low / medium overall adoption levels of improved sericulture technologies. The farmers' knowledge need to be increased by providing ample opportunities to participate in training programmes and extension activities like demonstrations, discussions, field visits, exhibitions, krishi melas, farmers field schools, farm schools, etc. Frequent contacts with formal extension workers (sericulture extension workers of Karnataka State Department of Sericulture officers and sericulture scientists) would also increase the knowledge of farmers on improved bivoltine silkworm rearing practices leading to the adoption of the same by them. There is also a need to present useful and

Table 1: Adoption level of specific practices followed by the bivoltine silkworm rearers in mulberry cultivation

Mulberry cultivation practices	Adoption level					
	Full Adoption		Partial Adoption		Non - Adoption	
	Number	%	Number	%	Number	%
Improved variety	48	96	02	04	00	00
Wider spacing	47	94	03	06	00	00
Quantity of manure	42	84	08	16	00	00
Vermi -composting	00	00	12	24	38	76
Fertiliser application	27	54	18	36	05	10
Growth regulators	11	22	12	24	27	54
Plant protection chemicals	11	22	12	24	27	54
Removal of weak shootlets	10	20	19	38	21	42
Drip irrigation	49	98	00	00	01	02
Stump formation	32	64	05	10	13	26
Liquid fertiliser	00	00	02	04	48	96
Separate chawki garden	00	00	06	12	44	88
Chawki in the same garden	00	00	07	14	43	86

Table 2: Adoption level of specific practices followed by the bivoltine farmers in chawki rearing practices

Chawki rearing practices	Adoption level					
	Full Adoption		Partial Adoption		Non - Adoption	
	Number	%	Number	%	Number	%
Practicing the chawki rearing on own	07	14	00	00	43	86
Depending on CRCs for chawki	43	86	00	00	07	14
Possessing the separate chawki rearing room	09	18	02	04	39	78
Wrap up method of chawki rearing	00	00	05	10	45	90
Use of plastic trays for chawki rearing	05	10	00	00	45	90
Maintenance of temperature and humidity	05	10	02	04	43	86
Practice of disinfection	07	14	43	86	00	00
Disinfection as per package	02	04	05	10	43	86

Table 3: Adoption level of specific practices followed by bivoltine silkworm rearers in late age rearing practices

Late age rearing practices	Adoption level					
	Full Adoption		Partial Adoption		Non Adoption	
	Number	%	Number	%	Number	%
Separate rearing house	37	74	13	26	00	00
Disinfection as per package	07	14	43	86	00	00
Practice of shoot rearing	50	100	00	00	00	00
Maintenance of temperature and humidity	18	36	21	42	11	22
Proper bed spacing	02	04	12	24	36	72
Proper bed cleaning	02	04	31	62	17	34
Care during moulting	07	14	43	86	00	00
Use of bed disinfectants	11	22	39	78	00	00
Integrated management of uzi fly	00	00	50	100	00	00
Separate mounting hall	07	14	05	10	38	76
Use of plastic chandrikes	06	12	44	88	00	00
Cocoon deflossing	08	16	42	84	00	00
Burning of the contaminated materials	04	08	08	16	38	76

Table 4: Association between the adoption level and personal and socio- psychological characteristics of bivoltine silkworm rearers

Personal and socio-psychological characteristics	Degrees of freedom	Chi-square value
Age	4	1.268 NS
Education	4	12.277*
Family size	4	0.999 NS
Value orientation	4	5.629 NS
Cosmopoliteness	4	4.692 NS
Social participation	4	7.162 NS
Mass media use	4	12.002*
Participation in training programme	4	14.620**
Extension agency contact	4	15.260**
Extension participation	4	17.169**

* Significant at 5 % level of probability
** Significant at 1 % level of probability
NS = Non significant

Table 5: Constraints faced by the bivoltine silkworm rearers

Constraints*	Respondents	
	Number	%
Lack of knowledge regarding the fertiliser application	17	34
Lack of skill in stump formation	24	48
Non-availability of quality silkworm seeds	38	76
Lack of separate rearing house	13	26
Silkworm rearing is expensive	15	30
Difficult to manage rearing compared to existing traditional crossbreed	49	98
Non availability of quality disinfectants	41	82
More use of bed disinfectants which cause health hazardous	43	86
More susceptible to diseases	49	98
Labour intensive in complete operation	12	24
Difficulties in marketing of cocoons	12	24

*Multiple responses is possible

necessary applicable messages on improved bivoltine silkworm rearing practices through mass media like television, radio, newspaper, farm magazines *etc*.

Non-availability of quality silkworm seeds and quality disinfectants and lack of separate rearing house are some of the dominant reasons for non-adoption of improved bivoltine silkworm rearing practices. Therefore, it is necessary to develop suitable strategy by the Department of Sericulture and other major Sericulture Research Institutes for providing good quality silkworm seeds and disinfectants and technical services.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 441-444

TRANSFER OF TECHNOLOGY FOR SERICULTURE DEVELOPMENT IN 'MALENADU' AREA OF KARNATAKA - AN EVALUATION

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ABSTRACT

The adoption of technological packages in sericulture attained greater importance in the wake of enhancement of productivity and income to keep pace with the existing competing crops in 'Malenadu' region of Karnataka. In this regard the farmers were exposed to sericulture technologies through awareness programmes, group discussions followed by personal visits. The survey of the sample farmers prior to the exposure of a set of technologies in sericulture revealed a technological gap index of 40.57, which indicated that more than half of the technologies were not adopted at the farmers' level. Later when exposed to various technology practices, it was found that the level of adoption technologies was highest with respect to mulberry spacing (77.00 per cent) followed by irrigation (75 per cent), use of bed disinfectants (68.50 per cent), disinfection of rearing house (65.00 per cent), control of uzi fly (64.00 per cent), shoot rearing (62.00 per cent), improved mulberry variety (52.00 per cent), farmyard manure application (51.00 per cent) and separate rearing house (43.00 per cent). The level of knowledge and skills acquired by the respondents was found to be significant.

Key words: Adoption of technologies, Knowledge and skill, Technology gap index, Transfer of technology

INTRODUCTION

In sericulture, the level of productivity increased considerably due to the evolution of superior silkworm hybrids and development of robust mulberry varieties along with improved mulberry cultivation and silkworm rearing practices. Sericulture in 'Malenadu' region of Karnataka gained momentum with the introduction of region specific technologies in the recent years.

'Malenadu' in Karnataka is a non-traditional belt for sericulture which falls under transitional agro-climatic zone, with heavy showers of rains likely to occur between June to September followed by warm and humid summer. Sericulture in this region is in a take off stage. The region provides ample scope for crop diversification with a large extent of area covered under forest. The major crops grown are arecanut, banana, paddy, spice crops, besides sericulture in small units. Sericulture, in this area has now been considered as one of the important enterprise contributing to income and employment in the rural economy. Farmers however area are still using conventional methods of raising mulberry and rearing silkworm. Predominance of migrant farmers from the neighboring traditional districts has been the key feature for introduction of sericulture in the region.

The earlier phase of development in sericulture had the threat of prevalent constraints in production of good quality mulberry leaves as well as silk cocoon, due to traditional practices being adopted by the farmers. However, with the efforts of the extension personnel and dynamic process of transfer of technology, now there is a continuous thrust on technology dissemination in this area. The adoption of technological packages attained greater importance in the wake of enhancement of productivity and income to keep pace with the existing competing crops in the region.

The present study was conducted for imparting essential skills to the untrained and new farmers and to effectively bridge the gap in knowledge and adoption of sericulture technologies in this region using skill teaching methodology

MATERIALS AND METHODS

A sample of 120 farmers were selected at random from Sagara, Soraba and Shimoga taluks of Shimoga district. These farmers were exposed to important sericultural practices by extension communication programmes through farm and home visits, group discussions, method demonstrations and film shows. Besides awareness programmes and filed days were conducted to delineate the importance of technologies in sericulture. The programmes were conducted through the year 2009-10. Data from the farmers were collected prior and after the imposition of the treatment and analysed using appropriate statistical techniques.

Seventeen important practices in sericulture, seven of the mulberry cultivation technology practices and ten of the silkworm rearing technology practices were considered for evaluation of knowledge and adoption. The level of knowledge and adoption of different technological practices by all the respondent farmers was analysed using scoring technique (Kapse *et al*., 2000). The adoption coefficient was computed for each farmer followed by computation of Technological Gap Index (TGI):

$$\text{Technolgical gap index} = \frac{R - A}{R} \times 100$$

Where;

R = Recommended technology
A = Technology actually adopted by the famers

RESULTS AND DISCUSSION

Before the initiation of the exposure programmes, the bench mark survey of the sericulturists revealed that there is a considerable amount of constraints existing in the field. These were ascertained and ranked in order.

Table 1: Perceived Constraints of Sericulturists in the Sample Area

Perceived constraints	Extent (%)
Lack of technical knowledge and essential skill	51.00
Lack of availability of skilled labour	48.00
Lack of rearing house facility	38.00
Incidence of pest and diseases	21.63
Non availability of quality DFLs / Chawki worms	17.73
Reeling & marketing problems	16.13
Non availability of rearing inputs	6.20

The farmers perceived that the constraints like lack of technical knowledge about the skills (51.00 %), followed by lack of availability of skilled labour (48.00 %), lack of rearing house facility (38.00 %) and incidence of pests and diseases (21.63 %) as important (Table 1). This necessitated the teaching of skills necessary for practicing sericulture, which was found to be an essential component in the technology dissemination process. Hence the farmers were exposed to series of programmes to teach them the necessary skills. While exposing the farmers to various technologies, they were explained about the importance of adopting the technology in sericulture. As the farmers were new learners of technology, it was easy for this end group to understand and adopt the technologies on priority basis. A series of method demonstration techniques were employed to expose them to important sericultural practices. Besides, farmers were also educated through extension methods such as Group Discussion, Personal Visits, Film Shows and Awareness Programmes.

The survey of the farmers prior to the exposure to a set of technologies in sericulture revealed a technology gap index of 46.03 in case of moriculture technologies and 53.22 in case of silkworm rearing technologies, which indicated that more than half of the technologies in sericulture were not adopted at the farmers' level.

Further, with the introduction of farmers on the mulberry cultivation practices through the extension communication programmes on knowledge and adoption revealed a significant level of improvement (Table 2). It was found that the knowledge level of technologies on mulberry cultivation practices, prior to the exposure to extension communication programmes, was highest with respect to mulberry leaf harvest (87.88 per cent) followed by improved variety (70.83 per cent), mulberry plant spacing (78.89 per cent) and irrigation (75.56 per cent). Similarly, the adoption level of sericulturists with respect to mulberry cultivation practices was high in case of mulberry spacing (76.67 per cent) followed by irrigation (75.56 per cent) and improved mulberry variety (61.67 per cent). There was an increase in the level of knowledge and adoption rate with the imposition of treatments. The level of knowledge improved from 69.80 per cent to 81.15 due to imposition of the treatments at the farmers' level. The overall rate of adoption of mulberry cultivation practices which was 55.32 per cent to 69.60 percent.

Similarly the impact of extension communication programmes on knowledge and adoption of Silkworm rearing practices was also studied (Table 3). There was an increase in the level of knowledge and adoption of technologies with the imposition of treatment. The knowledge level prior to the exposure to extension communication programmes with respect to silkworm

Table 2: Impact of Extension Communication Programmes on Knowledge and Adoption of Mulberry Cultivation Practices

Sl. No.	Technology	Extent of knowledge			Extent of adoption		
		Before Exposure	After Exposure	Difference t-value	Before Exposure	After Exposure	Difference t-value
1	Improved mulberry variety	70.83	91.11	**	61.67	82.22	**
2	Spacing	78.89	87.78	**	76.67	81.11	*
3	Use of FYM/Compost	68.89	81.67	**	51.11	64.17	**
4	Fertilizer application	63.33	72.50	**	41.11	51.67	*
5	Plant protection measures	41.11	51.67	**	23.33	32.50	**
6	Irrigation	77.78	88.89	**	75.56	86.67	**
7	Leaf harvest	87.78	94.44	*	57.78	88.89	**
	Overall	69.80	81.15	**	55.32	69.60	**

Table 3: Impact of Extension Communication Programmes on Knowledge and Adoption of Silkworm Rearing Practices

Sl. No.	Technology	Extent of knowledge			Extent of adoption		
		Before Exposure	After Exposure	Difference t-value	Before Exposure	After Exposure	Difference t-value
1	Disinfection of rearing house	74.44	80.00	**	51.67	65.56	**
2	Maintenance of hygiene	62.22	82.22	**	48.89	60.83	**
3	Shoot rearing	74.44	80.00	*	62.22	71.11	**
4	Bed spacing	64.44	67.78	*	47.78	62.22	**
5	Bed cleaning	48.89	61.11	**	42.22	54.44	**
6	Maintenance of temperature and humidity	47.78	57.78	**	22.22	52.22	**
7	Moulting care	48.89	65.56	**	37.78	64.44	**
8	Bed disinfection	73.33	75.56	*	55.56	68.89	**
9	Mounting & harvesting	60.00	65.56	*	49.17	64.44	**
10	IPM of uzifly	68.89	72.22	*	48.33	67.50	**

** - Significant at 1 per cent and * - Significant at 5 percent

rearing practices was high in case of disinfection of rearing house (74.44 per cent) as well as shoot rearing (74.44 per cent) followed by bed disinfection (73.33 per cent). The overall knowledge rate was 69.80 per cent prior to the exposure to the method demonstrations, which was improved to 81.15 per cent after the exposure. Similarly the rate of adoption of silkworm rearing technologies was found to be only 46.58 per cent and there was an improvement in the rate of adoption to 63.16 per cent, indicating an improvement of 16.58 per cent. The level of adoption of technologies prior to the exposure to extension communication programmes, was highest with respect to shoot rearing technology (62.22 per cent) followed by disinfection of rearing house (51.67 per cent). However there was a drastic improvement in terms of adoption of these technologies with an exposure to demonstrations. The level of knowledge improved from 62.33 per cent to 70.78 per cent due to imposition of treatments at the farmers' level.

The Technological Gap Index, after the imposition of the treatment was found to be 30.40 per cent in case of mulberry cultivation practices and the same was 36.84 per cent in case of silkworm rearing practices. The findings of the study are in comparison to the earlier studies conducted on knowledge and adoption of technologies in sericulture (Geetha *et.al.,* 2005 and Shankar, *et al.*, 2000) .

CONCLUSION

The evolution of technologies has led to vertical growth in sericulture. However, the adoption remains unexplored unless there is a clear acceptance by the farmers. Prevailing constraints at the farmers' level also play a major role in affecting the rate of adoption. The above analysis has clearly indicated that the extension communication programmes in the 'Malenadu' region have been effective in technology transfer at the farmers' level. In this regard suitable methodologies for imparting appropriate training and skill development to the farmers has to be devised in future.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 445-448

KNOWLEDGE AND ADOPTION LEVELS OF ORGANIC FARMING IN MULBERRY CULTIVATION WITH THE FARMERS OF CHITTOOR DISTRICT OF ANDHRA PRADESH

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ABSTRACT

The present study was conducted to apprise the knowledge and extent of adoption pattern of recommended organic manures in Chittoor district of Andhra Pradesh. The findings revealed that all the farmers had the required knowledge and 67.50 72.00% farmers had fully adopted the technologies like application of farm yard manure (FYM) and tank silt. Knowledge levels, though, was more on composting technologies (60%), organic cakes (65%), vermi-composting (76%) and green manuring (63%), their adoption levels were poor (21.5-26%). Most of the farmers did not adopt the practices like composting, application of bio-fertilizers and use of panchagavya.

Key words: Adoption, Constraints, Knowledge, Organic farming, Socio-economic factors

INTRODUCTION

The application of organic manures helps to increase the soil characters besides converting the nutrients into available form. Though organic manures such as farm yard manure (FYM), sludge, compost, press mud, oil cakes, green manures *etc*., contain comparatively smaller quantities of plant nutrients, this helps to improve the soil physical properties and increase the moisture holding capacity of the soil (Shivaprakash and Narayanagowda, 2006). They also help to increase the biological activity of the soil and thereby increase the useful microbial load in the soil.

However, many farmers are reluctant to adopt the recommended organic manures fully due to various reasons *viz*., economic and biological factors (Lakshmanan *et al.,* 1998; Vijayaprakash, and Dandin, 2005). In view of the above, an attempt has been made in the present study to analyse the knowledge and adoption pattern of organic technologies related to organic farming in sericulture, with the following specific objectives:

- To appraise the knowledge levels and extent of adoption pattern of recommended organic manures in Chittoor district of Andhra Pradesh;
- To find out the relationship between the socio-economic factors with knowledge and adoption levels; and
- To identify the constraints for adoption of technologies related to organic farming in sericulture in the study area.

MATERIALS AND METHODS

The study was taken up in Chittoor district of Andhra Pradesh in 2005-06, five mandals namely, V.Kota, Shanthipuram, Gudipalli, Palamaner and Chittoor were selected randomly in Chittoor district. From each mandal five villages were selected and from each village again five farmers were selected randomly for the study. Thus, a total of 125 farmers were selected for the study. All the sericulturists were interviewed using a pre-tested interview schedule. The data collected include the information regarding mulberry cultivation practices with organic manures and the profile of the farmers namely age, education, family size, experience, total land holding, area under mulberry cultivation. The compiled data were subjected to tabulation, per centage and correlation analysis.

Table 1: Knowledge and adoption levels on recommended organic manures with the farmers in Chittoor district of Andhra Pradesh

Sl No.	Name of organic manure	Knowledge level (%)			Adoption level (%)		
		Full	Partial	Nil	Full	Partial	Nil
1	Farm Yard Manure	100	--	--	62.5	37.5	--
2	Compost	60	40.0	--	21.5	15.2	63.3
3	Seri residue composting	16.5	12.2	71.3	5.6	1.5	92.9
4	Green manuring	63.0	17.6	19.4	22.5	12.2	65.3
5	Bacterial Biofertilizers (N fixing)	12.5	5.6	81.9	1.5	1.0	97.5
6	VAM	3.5	--	96.5	--	--	100
7	PSB	--	--	100	--	--	100
8	Vermicompost	76	24	--	26	18.5	55.5
9	Organic cakes (Neem/Castor/Ground nut)	65.0	12.6	22.4	--	22.6	77.4
10	Tank silt	100	--	--	72.5	27.5	--
11	Panchagavya	1.5	28.5	70.0	--	--	100

Table 2: Correlation between socio-economic characteristics of farmers and level of their knowledge and adoption of technologies on organic farming.

Characteristics	Knowledge	Adoption
Age	-0.1356	-0.0192
Education	0.4335*	0.2556*
Family size	-1.2058	-0.1589
Experience	-0.5328*	-0.4852*
Total land holding	0.2558	1.0550
Area under mulberry	0.0958	0.0655
Extension contact	0.08587*	0.7588*
Social participation	0.1547*	0.0987*
Cocoon yield	0.3554*	0.2556
Cattle population	0.8225*	0.7553*

* Significant at 5 percent

Table 3: Constraints/Reasons for partial/ non adoption of the recommended organic manures

Sl. No.	Constraints	Farmers (%)
1	Lack of proper knowledge	63
2	Lack of technical guidance (Training)	74
3	Lack of finance	64
4	Traditional practice	56
5	Non availability of organic fertilizers	67
6	High costs	58
7	Lack of credit facilities	75
8	Negligence	33

RESULTS AND DISCUSSION

All the sample farmers had full knowledge on application of farm yard manure (FYM) and tank silt to mulberry garden (Table 1). More than 60% of farmers had full knowledge on composting, green manuring (sowing and mulching of diancha, sunhemp and other leguminous crops), application of oil seed cakes (neem, castor, groundnut) and vermicomposting. Majority of farmers had no knowledge on application of N-fixing biofertilizers *(Azotobacter* and *Azospirillum),* Vesicular Arbuscular Micorrihiza (VAM) and phosphate solubilising bacteria (PSB). The knowledge on preparation and use of panchagavya was also very negligible (1.5%).

With regard to adoption of technologies with the farmers, it was found that majority of the farmers had fully adopted the technologies like application of FYM and tank silt. Green manuring, composting of seri-residues, vermin-composting and application of oilcakes like neem, castor, groundnut were not adopted by majority of the farmers. None of the sample farmers used bio-fertilizers like VAM and PSB.

Relationship between knowledge and adoption and socio-economic factors

The socio-economic variables such as education, extension contact, social participation and cattle population and cocoon yield were positive and significantly associated with knowledge and adoption levels (Table 2). However age, family size and experience of respondents had shown negative relationship with knowledge level. Total land holding and area under mulberry had shown non-significant relationship with knowledge and adoption.

It was observed in the present study that most of the farmers were not aware of organic farming either in sericulture or in other agricultural crops. Majority of the farmers were in the age group of 45-55. As a result, they had not shown much interest on organic farming though government extension agencies and voluntary organizations have taken up promoting organic farming in sericulture and also in other agricultural crops.

Constraints for partial/non-adoption of organic manures

Lack of technical guidance (74%), non-availability of organic manures (67%), lack of finance (64%), traditional practice (56%), lack of credit facilities (75%) and negligence of rearer (33%) were the major reasons attributed by the sample farmers for non-adoption of technologies related to organic farming. The reasons for non-adoption of technologies like biofertilizers like *Azotobacter* and *Azospirillum*, Vesicular Arbuscular Micorrihiza (VAM), phosphate solubilising bacteria (PSB) and panchagaya were lack of proper knowledge (63%), lack of technical guidance (74%), high cost and non-availability of biofertilizers/ materials in time (58-67%). The above constraints are partially in agreement with the studies of Mallikarjuna *et al*., (2004) and Dhane and Dhane (2004).

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 449-452

CLUSTER PROMOTION PROGRAMME - AN EFFECTIVE APPROACH FOR PROMOTION OF BIVOLTINE SERICULTURE

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ABSTRACT

Sericulture being a long chain industry with backward and forward linkages ranging from egg producers to farmers in cocoon production, to reelers, to twisters, to weavers, to dyers, to garment makers and to traders before reaching the consumers, requires a holistic appraoch for the overall development of the industry. Any weak link in the chain may affect the the growth and prospects industry adversely. For pursuing the goal of sericulture development systematically and meeting the current and future demand of the sericulture industry, a well-organized/planned extension system is very much essential for and to achieve the targeted production. In this direction, many extension approaches have been followed in the transfer of sericultural technologies to the farmers from time to time. Among them, cluster development approach is one such approach using the participatory extension mode with Research-Extension-Farmer (R-E-F) linkage and yielded fruitful results.

Key words: Cluster promotion, Bivoltine sericulture, Linkages, Extension system, Sericulture technologies.

INTRODUCTION

In the cluster promotion approach, a cluster of villages and families located nearby are selected and adopted so as to have area/mass effect of the improved technologies introduced under the programme and the programmes are manageable by the limited scientists and extension workers jointly with the active involvement of local stakeholders. Under this programme, contiguous villages (if more than one village) within the radius of around 20 km in order are selected to save time and money on transport and to facilitate closer interactions of scientists with the adopted families. This would help in effective supervision and guidance by the scientists. One village or a cluster of villages located nearby is selected in such a way that as far as possible all eligible families of village/cluster of villages are covered under the programme. Attempt should be made to select at least 100 to 200 families (beneficiaries) from such village /villages. Adopted village/villages are regarded as a field operational unit and all eligible farm families including big, medium and small farmers irrespective of caste and creed are the beneficiaries of the programme. The inputs such as training and guidance are given to all farmers of the field operational unit.

Advantages of cluster approach

1. The cluster approach ensures an integrated thematic response, drawing upon the comparative advantages of all the agencies working for sericulture development, fund and programme and leveraging resources through inter-agency partnerships.
2. The cluster approach ensures coordination among different agencies, joint programming, information sharing, knowledge sharing on technical and policy issues, joint formulation of sectoral/thematic strategies, promote implementation synergies by combining support and common services.
3. In cluster approach, effective R-E-F linkage is maintained and the technology spread is effected from farmer to farmer.
4. As the ratio between farmer and extension worker is widening, the cluster approach can be implemented with the limited number of scientists and extension workers.
5. The cluster approach is a need based and target based

approach, unlike the traditional approach. Here the technologies are provided to farmers as a module based on the requirement unlike individual technologies provided to the farmers in the traditional approach.

6. The needs of the farmers vary from area to area in terms of the agro-climatic conditions, social and economic conditions, availability of infrastructure facilities etc. Hence, the cluster approaches are preferable to address the constraints and satisfy the needs of the local farmers.
7. Experience sharing and lead farmer's interaction builds confidence and ensures mistake correction in the cluster promotion programme.
8. Resource augmentation and sharing of resources or implements such as power sprayers, mountages are facilitated in the cluster approach.
9. Orderly development of different segments of the industry in a particular cluster with proper infrastructure facilities.

Basic requirements of a cluster

Each sericulture cluster should have adequate facilities with adequate forward and backward linkages covering all the activities at least up to the production of raw silk. An ideal cluster should have the following:

1. Farmers numbering 100-200 in nearby villages as a cluster to start with and at least 300 farmers covering 300-400 acres at the end of the programme.
2. Assured supply of planting materials and quality silkworm seed.
3. Commercial CRC with the production capacity of 1.25 lakh dfls/year and compulsory supply of chawki worms to the farmers.
4. One farmers' filed school, one mobile disinfection unit, one seri-polyclinic and one bio-control agent multiplication unit to provide input support and services to the farmers.
5. Vehicles, computer and communication facilities are provided for the extension centers for effective functioning. Two scientists/extension staff are provided for conducting and monitoring the programme
6. Provision of financial assistance for the farmers and for establishment of CRCs, separate rearing houses, sprayers, mountages, vermi-composting units and reeling units in the cluster areas
7. Strengthening of marketing system for the sale of cocoons for the farmers and purchase of adequate quantity of quality cocoons by the reelers. Ensuring quality based remunerative price to the farmers
8. Marketing support or facilities for processing of cocoons (reeling unit) in the cluster.

Cluster Promotion Programme in sericulture under XI Plan

Under Cluster Promotion Programme being implemented during XI Plan, Central Silk Board and State Sericulture Departments have jointly organized 50 sericulture clusters covering both mulberry and vanya sectors spread over 17 states (Table 1) for the promotion of sericulture. In the peninsular India (Karnataka, Andhra Pradesh, Tamil Nadu and Maharshtra), which comprises the major silk producing states, the programme was launched in 2008-09 in 14 clusters. Then 8 more clusters were added in 2009-10. As given in Table 2, currently, the programme is totally implemented in 22 clusters (7 clusters in Karnataka, 6 clusters each in Andhra Pradesh and Tamil Nadu and 3 clusters in Maharashtra) covering 5682 farmers with 8622 acres of mulberry.

Methodology for implementation

The clusters, which have congenial agro-climatic conditions and ideal conditions (such as labour) for silk production, are identified. Soon after the identification of the clusters, a benchmark survey is done jointly by CSRTI and DOS staff to assess the existing status of sericulture with farmers and also his requirement for equipment, rearing house etc. Based on the survey, the assistance is provided to the farmers through Catalytic Development Programme to strengthen their facilities.

Each cluster is directly attached to the nearest Research Extension Centres (REC) of CSR&TI, Mysore and in case there is no REC an exclusive Cluster Promotion Centre is established. The scientists and technical staff of REC / CPC look after the implementation of CPP programme with close co-ordination with extension officers and staff of state sericulture department. A Joint Level Cluster Promotion Committee (JLCPC) is constituted for each cluster. The Scientist In-charge of local CSB unit is the Chairman of JLCPC. The members of JLCPC include local DOS officers, technical staff working in nearby CSB unit and two progressive farmers of the cluster. The JLCPC meets once in fortnight regularly and draw action plan and programmes for conducting the activities. It also reviews the performance of the silkworm crops regularly and takes remedial measures if there is any problem.

As a technology transfer intervention, a Chawki Rearing Centre (CRC), Farmers Field School (FFS), mobile disinfection unit, seri-polyclinic and bio-control agent multiplication units are established in each cluster under CDP to provide input support and services to the farmers. For each crop, the chawki worms can be reared and supplied to the farmers. The subject matter specialists can regularly visit the farmers and provide technical guidance. The bivoltine hybrids are reared in this programme. However, in the high

temperature regions, bivoltine (single/double) hybrids are reared during favourable seasons and cross breed during the summer season. After completion of each crop, the results of the crop are collected.

The farmers are trained through lead farmers under FFSs. Besides, awareness programmes, group discussions, enlightenment programmes, demonstrations, study tours, field days etc are conducted in each cluster to educate the farmers on various improved technologies.

Crop review meetings are conducted once in a quarter at CSRTI, Mysore, in which all the chairpersons of clusters, DOS officers, silkworm seed suppliers, scientists of CSRTI, Mysore and CSTRI, Bangalore attend the meeting to review the overall crop performance and solve the problems related to technical in nature. The entire programme is conducted with research-extension-farmers (R-E-F) linkage. Hence, the research institutions, Government agencies involved in sericulture development and farmers are involved in all the stages of the programme namely, planning, implementation and monitoring stages.

Crop performance under Cluster Promotion Programme

Under Cluster Promotion Programme, 75.40 lakhs bivoltine dfls were brushed in 22 clusters in the period between 2008-09 and 2011-12 (up to July 2011) and an average cocoon yield of 63.52 kg/100 dfls was obtained. It is also evident from the Fig. 1 to 3 that there was a consistent improvement in dfls brushing, bivoltine cocoon production and yield/100 dfls in all the four states over the last three years under the programme.

The success of CPP can be attributed to meticulous planning, dedicated implementation, and the efforts of R&D and extension personal of CSRTI with prompt and timely support of Central Silk Board and Dept. of Sericulture authorities. Regular review of crop performance and technical guidance by CSR&TI, Mysore were also a catalyst for this grand success. It was proved beyond doubt that by the close interaction and guidance of the scientists and extension staff, the traditional cross breed rearers could successfully practice bivoltine sericulture in South India.

Table 1: Details of Clusters Organized under CPP in India

Sl. No	Sector	No of clusters
1	Mulberry	31
2	Non-mulberry	
a	Oak tasar	4
b	Tasar	3
c	Muga	4
d	Eri	3
3	Post-cocoon	5
	Total	50

Table 2: Number of Farmers and Mulberry Acreage Covered under CPP in South India and Maharashtra

State	No of clusters	No. of Farmers	Mulberry area (acres)
Karnataka	7	1578	2248
Andhra Pradesh	6	1546	2302
Tamil Nadu	6	2009	3395
Maharashtra	3	549	677
Total	22	5682	8622

Table 3 Crop Performance under CPP in South India and Maharashtra (Up to July 2011)

No of Clusters	22
No. of farmers	5682
Mulberry area (acres)	8622
No. of dfls (in lakhs)	75.40
Yield (kg)/ 100 dfls	63.52
Cocoon price (Rs./kg)	221.70

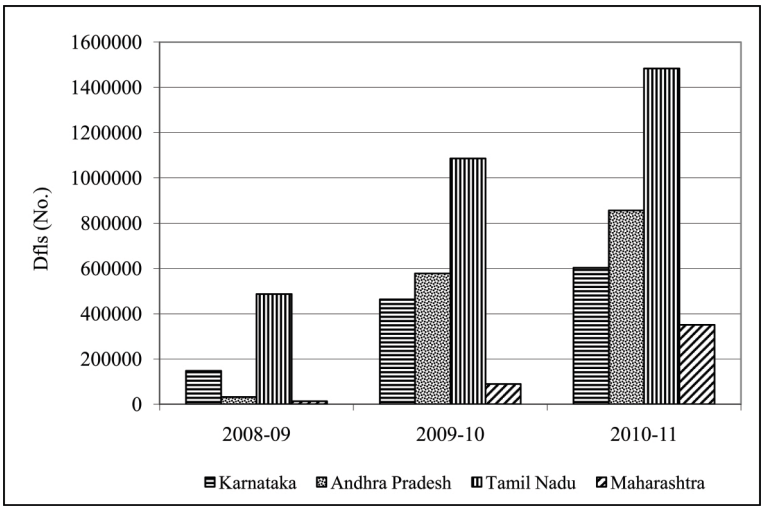


Fig.1: Dfls consumption under CPP over the years

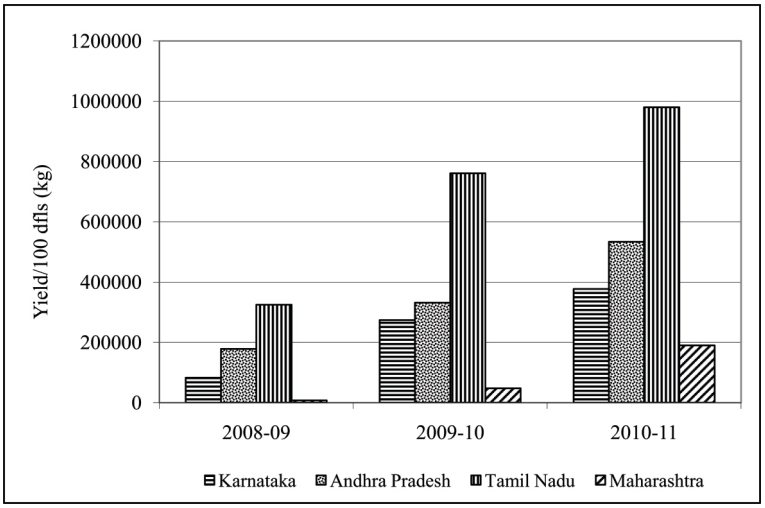


Fig.2: Bivoltine cocoon production under CPP over the years

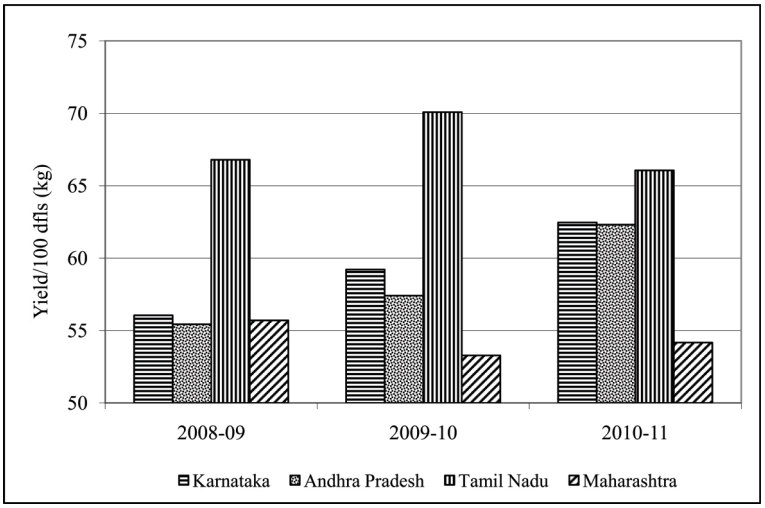


Fig.3: Yield per 100 dfls under CPP over the years

Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 453-455

IMPACT OF INSTITUTE VILLAGE LINKAGE PROGRAMME (IVLP) IN DEOGARH, KEONJHAR AND MAYURBHANJ DISTRICTS OF ODISHA UNDER RAINFED CONDITIONS

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ABSTRACT

A field trial was conducted for three years in 2007-08, 2008-09 and 2009-10 with 5, 15 and 20 farmers respectively covering Deogarh, Keonjhar and Mayurbhanj districts of Odisha. Plots having mulberry variety S1635 with 3' × 3' spacing was selected for the purpose. FYM@ 10 mt/ha/yr in single dose, Nitrofert (Azotobacter) @ 10 kg/ha/yr in two equal split doses, Phosphofert (VAM) @ 40 kg/ha once in four years and N:P_2O_5:K_2O @ 75:10:50 kg/ha/yr with N in two equal split doses (15 days after application of bio-fertilizers) were applied. Plant Growth Regulator (Morizyme-B) @ 0.01% was sprayed 15 and 30 days after pruning during Autumn and Spring seasons (first spray 340 ml PGR + 340 ltr water /ha/ crop and 2nd spray 680 ml PGR+ 680 ltr water / ha/ crop). Disinfection of rearing houses and appliances with 5% bleaching powder solution was carried out. Multi x Bi hybrid dfls during Aug-Sept and Bi × Bi hybrids during Oct-Nov and Feb-Mar were reared. Bed disinfectant *i.e.*, Labex @ 3.5 kg / 100 dfls was also used during the rearing period. The average leaf yield over three years due to imposition of improved 'package of practices' was 11,778 kg /ha/ yr with 15.2% increase over control (10,224 kg/ha/yr). Cocoon yield data over three years indicated that during Aug-Sept it was 30.89 kg / 100 dfls with 19.96% gain over control (25.75 kg / 100 dfls). During Oct-Nov rearing season the cocoon yield was 32.45 kg/100 dfls with 5.97% increase over control (30.62 kg/100 dfls) while in Feb-March rearing season, it was 34.94 kg/100 dfls with 7.94% gain over control (32.38 kg/100 dfls).

Key Words: Crop performance, Field trial, IVLP Programme, Rainfed condition

INTRODUCTION

Deogarh, Keonjhar and Mayurbhanj districts of Odisha situated between 84° 28' to 87° 11' East longitude and 20° 1' to 22°34' North latitude enjoy congenial agro-climatic conditions for mulberry sericulture, the average annual rainfall in these districts being 1527mm, 1534.5mm and 1648.2mm respectively. The soils of the area are poor in fertility status. In general, the leaf yield of mulberry at farmers' level in Odisha under rainfed conditions is within the range of 5000-6000 kg/ha/yr leading to low production of cocoons. To make the sericulture industry viable, the cocoon production has to be increased to its optimum level which is linked with the mulberry leaf output per unit area. Thus, to enhance and stabilize the production at farmers' level the Central Silk Board implemented Institute Village Linkage Programme (IVLP) through Technology Assessment and Refinement (TAR) under rainfed conditions. For this purpose, integrated package of practices for rainfed mulberry and silk worm rearing recommended by CSR&TI, Berhampore was imposed in farmers' field in Deogarh, Keonjhar and Mayurbhanj districts during the years 2007-10 and a comparative study was conducted *vis-à-vis* the conventional farmers' practice.

MATERIALS AND METHODS

A field trial was conducted for three years in 5,15 and 20 farmers' fields during 2007-08, 2008-09 and 2009-10 respectively covering Deogarh, Keonjhar and Mayurbhanj districts of Odisha. Farmers' fields having mulberry variety

S1635 with 90 × 90 cm spacing were selected for the purpose. FYM @ 10 mt/ha/yr in a single dose, bio-fertilizers- Nitrofert (Azotobacter) @ 10 kg/ha/yr in two equal split doses, Phosphofert (Vesicular Arbuscular Mycorrhiza) @ of 40 kg/ha once in four years and N : P_2O_5: K_2O @ 75:10:50 kg/ha/yr with N in two equal split doses(15 days after application of bio-fertilizers) were applied. Plant Growth Regulator (Morizyme-B) @ 0.01% was sprayed 15 and 30 days after pruning during Autumn and Spring seasons (first spray 340 ml PGR + 340 ltr water/ ha/ crop and second spray 680 ml PGR + 680 ltr water/ ha/ crop). Disinfection of rearing houses and appliances with 5 % bleaching powder solution was carried out. Multi × Bi-hybrid dfls during Aug-Sept and Bi × Bi hybrid during Oct-Nov and Feb-March were reared. Bed disinfectant-Labex @ 3.5 kg/100 dfls was used during the rearing period. Data on leaf yield was recorded selecting 10 plants randomly and the yield data values were converted into one hectare. A total of three leaf harvests were made every year during September, November and March. The bio-assay studies were conducted during Aug-Sept, Oct-Nov and Feb-March every year with silk worm races N × NB4D2 and CSR2 × CSR4 .

RESULTS AND DISCUSSION

It is observed that in all the crop seasons there were 14.5 to 19.8 % increase in leaf yield in TAR package applied plots *vis-à-vis* control plots (Table 1). Average annual leaf yield over three years was enhanced by 15.2% over control (10224 kg/ha/yr). Simultaneously 50% chemical N fertilizer and 80% chemical P_2O_5 fertilizers could be saved by applying Azotobacter and VAM bio-fertilizers which corroborates the findings of Das *et al.,* (1992) and Setua *et al.,* (1996). This indicates the increase in nutrient use efficiency of mulberry due to application of integrated nutrient through TAR package. Jayaraj *et al.,* (2005) also found very good impact of integrated nutrient management package at farmers' level in South India.

The increase in cocoon yield by feeding silk worms on leaves from TAR package treated plots ranged from 5.97% to 19.96% in three rearing seasons (Table 2). This indicates that leaves from TAR package applied plots have more nutrient value than those from control plots, and thereby influence the cocoon quality.

Average of three years' data revealed that during Aug-Sept rearing season N × NB4D2 hybrid dfls yielded 30.89 kg cocoons/ 100 dfls with 19.96% increase over control (25.75 kg/100 dfls). In Oct-Nov rearing season dfls of CSR2 × CSR4 combination were reared which produced 32.45 kg cocoons/100 dfls *vis-a-vis* 30.62 kg/ 100 dfls in control registering 5.97% increase. During Feb-March season also CSR2 × CSR4 hybrid dfls were reared which recorded 34.94 kg cocoons / 100 dfls compared to 32.38 kg in control thereby recording 7.94% increase over control. The overall increase in cocoon yield was 9.5% (Table 2) due to which the farmers could earn more income.

Economics was calculated taking family labour into consideration and the prices of inputs, cost of dfls, cocoon prices, etc prevalent during the period of investigations. The cost of production of cocoons with adoption of TAR package was Rs. 10864.00 / ha/yr *vis-à-vis* those with control plots (Rs.10726.00) (Table 3). The return through sale of cocoons worked out to be Rs. 46184.00 from TAR package applied plots and Rs.36421.00 from control plots with a calculated net income of Rs. 35320.00 /ha/yr and Rs. 25695.00 /ha/yr respectively leading to an additional net income of Rs. 9625.00 /ha/yr.

The TAR package comprising FYM, bio-fertilizers, reduced chemical fertilizers, spraying of 0.01% Morizyme-B apart from improving soil structure and fertility and improving leaf and cocoon yield and quality is economical for the marginal and small farmers of Deogarh, Keonjhar and Mayurbhanj districts of Odisha. As such, 10 mt FYM/ ha/ yr,

Table1: Effect of TAR package on S1635 mulberry leaf yield (kg/ha)

Year	September			November			March			Total		
	TAR	Control	Gain%	TAR	Control	Gain%	TAR	Control	Gain%	TAR	Control	Gain%
2007-08	4272	3736	14.3	5170	4341	19.0	3350	2917	14.8	12792	10994	16.35
2008-09	3385	2870	17.9	3959	3482	13.69	3680	3208	14.7	11024	9560	15.31
2009-10	3715	3302	12.5	4058	3528	15.0	3746	3288	13.9	11519	10118	13.85
Average	3957.3	3302.6	19.8	4395.6	3783.6	16.17	3592	3137	14.5	11778	10224	15.20

Table 2: Effect of TAR package on cocoon yield (kg/ 100 dfls)

Year	Aug-Sept. Race: N × NB4D2			Oct.-Nov. Race: CSR2 × CSR4			Feb-March Race: CSR2× CSR4			Average		
	TAR	Control	Gain%	TAR	Control	Gain%	TAR	Control	Gain%	TAR	Control	Gain%
2007-08	38.59	26.59	45.13	31.50	29.05	8.43	37.26	36.40	2.36	35.78	30.68	16.6
2008-09	25.24	24.33	3.74	29.52	28.41	3.90	31.3	30.32	3.23	28.68	27.68	3.60
2009-10	28.86	26.32	9.65	36.33	34.40	5.61	36.25	33.41	8.50	33.81	31.37	7.80
Average	30.89	25.75	19.96	32.45	30.62	5.97	34.94	32.38	7.90	32.75	29.91	9.50

Table 3: Economics of TAR package *vis-à-vis* control from one hectare rainfed mulberry

Treatments	Average annual leaf yield (kg/ha)	No.of dfls can be brushed	Cocoon yield (kg)	Total cost of production of cocoons (Rs.)	Return through sale of cocoons (Rs.)	Net Income (Rs.) (6-5)	Additional net income (Rs.)
Control	10224	330 (M×B) 691 (B×B)	84.975(M×B) 217.665(B×B)	10726.00	36421.00 (5948+30473)	25695.00	--------
TAR package	11778	395 (M×B) 798 (B×B)	122.0(M×B) 268.886(B×B)	10864.00	46184.00 (8540+37644)	35320.00	9625.00

10 kg Azotobacter /ha/yr along with NPK @ 75:10:50 kg/ha/yr and 0.01% Morizyme-B is recommended to obtain optimum leaf yield in S_{1635} mulberry at farmers level in Odisha.

ACKNOWLEDGEMENTS

The authors thank the Director, CSR & TI, Berhampore for providing bio-fertilizers needed for the field trial and the Joint Director, RSRS, for encouragement and for providing necessary facilities.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 456-461

CLEAN DEVELOPMENT MECHANISM THROUGH RAISING HOST PLANTS OF TASAR SILKWORMS

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ABSTRACT

Clean Development Mechanism (CDM) is one such initiative through which developing countries would receive the capital investment and clean technology or beneficial change in land use to earn Certified Emission Reduction (CER) credits as part of Kyoto Protocol. CDM Projects include small and large scale energy projects, afforestation and reforestation projects, designing of which shall invariably cover social, economic, environmental and technological well being of the poor. Out of total 1769 CDM Projects registered, major share of 1297 are of energy industries and only six are of afforestation/ reforestation category indicating the unexplored opportunity in this sector. While afforestation Projects can be carried out on lands that has not been forested for a period of at least 50 years, reforestation projects can be carried out on land that was forested but that has been converted to non-forested land. As the Indian definition for these CDM projects include tree crown cover of 15%, land area value of 0.05 ha and tree height value of 2 meters, fits most for raising host plants of tasar silkworms in private lands, which also addresses the creation of alternative livelihoods amongst tribal populations besides many other social benefits. Possibility of this is proved beyond doubt with raising of more than 5000 ha. of block plantations of tasar host plants in private degraded lands under various developmental initiatives including Special Swarnajayanti Gram Swarozgar Yojana (SGSY) projects, Integrated Tribal Development Projects with NABARD assistance, Tribal Welfare Commission and NREGS funded Projects etc. Further, in case of host plants of tasar silkworms, biomass would be consumed only once in a year which would be compensated by the silkworm litter as the rearing is carried out on the trees. Methodology of project implementation along with brief review of the progress made under various components of plantation, regeneration and conservation of tasar host plants, its impact on improvement of tasar silkworm rearing, earning levels of the tribal beneficiaries, steps taken for continuation of the activities including the maintenance of plantation etc., are detailed besides those areas need to be addressed to take up these initiatives effectively.

Key words: Afforestation, Clean development mechanism, Degraded lands, Tasar host plants

INTRODUCTION

India shares the global concern of climate change by becoming a Party to the recent Kyoto Protocol which imposes binding targets to reduce combined Green House Gas (GHG) emission by 2012, 5.2 % below their 1990's level. Carbon Emission Reduction (CER) unit or carbon credit is defined as a reduction of 1 tonne of carbon dioxide emission into the atmosphere and one CER earned is directly proportional to volume of CO2 equivalent emission reduced. Carbon credits can be acquired through Joint Implementation (JI), Clean Development Mechanism (CDM) and International Emissions Trading (IET).

While under CDM, a developed country can 'sponsor' a greenhouse gas reduction project in a developing country where the cost of greenhouse gas reduction project activities is usually much lower, but the atmospheric effect is globally

equivalent, under IET, the developing countries can trade in the international carbon credit market to cover their shortfall in allowances, under this. As on date, 1769 projects are registered and total 4200 CDM Projects are in pipeline through which over 290 crore CERs are expected until the end of 2012, of which India has over 400 projects to its credit. Transactions include equity investment in projects and receiving CERs in return (bilateral), Purchasing CERs through sale agreement (weak unilateral) and purchasing CER through on the spot market trade (unilateral).

CDM Executive Board is the Regulating Body which issues CERs supported by validating and verifying Body and other National Authorities. CDM Projects include small scale (less than 15 MW) and large scale (more than 15MW) energy projects and afforestation and reforestation projects. Under the alternate option of CDM Projects through afforestation and reforestation programmes, no much action has been initiated yet. While afforestation Projects can be carried out on lands that has not been forested for a period of at least 50 years, reforestation projects can be carried out on land that was forested but that has been converted to non-forested land. According to Indian definition for these projects include tree crown cover of 15%, land area value of 0.05 ha and tree height value of 2 meters, are the main criteria.

Vegetation in the forests or block plantations raised under various developmental programmes have the potential to earn substantially more from carbon trading, which could be a source for afforestation programmes. As result of Bali climate summit, traders in the emerging European carbon market are buying the carbon credits (one-ton reduction in carbon) at about $35. Though afforestation has potential for earning revenues through carbon trading, forest-based carbon market would be complicated keeping in view of the various Forest Acts in force. The per capita availability of forestland in India is one of the lowest in the world, 0.08 hectares, against an average of 0.5 hectares for developing countries and 0.64 hectares for the world. The right of deforestation in the country has been considerably reduced during the last few years. The average annual rate of deforestation fell from about 1.3 million hectares in the 1970s to 339,000 hectares in 1980s and to about 129,000 hectares during 1990-95. However, considering that important objective of the National Forest Policy, 1988 is to increase the forest/tree cover to 33 per cent from the present level of 19.27 per cent, even the reduced level of deforestation is a negative achievements, though of a lesser intensity.

Sericulture Industry & Clean Development Mechanism: Two Silk industries viz., M/s Garden Silk Mills Ltd., Surat, and the Palsana Industrial cluster, Gujarat have been involved in small scale (13.5 MW) natural gas based package cogeneration system for power generation and steam generation using the exhaust waste heat, CDM projects in India with crediting period of ten years and estimated credits of 5,86,124 units.

Further, TERI developed a gasifier suitable for silk reeling industry under Swiss Development Corporation funded SERI-2000 project, which is now commercially marketed by two manufactures. The main goal of the project was to improve the productivity and profitability and reduce environmental impact of post-cocoon processing in the silk industry. Biomass gasifiers developed for the silk industry allow fuel savings of about 70%, representing 822 tons of fuel wood per year. This reduces CO2 emissions of the silk factory and decreases the pressure on the local forests. In addition these systems also reduced the water consumption of silk reelers. However, the above effort could not commercially sustain due to various practical reasons.

Tasar host plant cultivation as an option for CDM: However, the alternate option of CDM Projects through afforestation programmes, can well be utilized in sericulture sector. Agro-forestry like raising tasar host plants not only has the potential to store carbon, it also addresses the need for alternative livelihoods amongst tribal populations who currently benefit from deforestation. Tropical tasar silkworm Antheraea mylitta Drury is polyphagus and rearing is carried on nature grown forest plantation belonging to genus Terminalia, viz., T.arjuna, T.tomentosa (arjuna and asan) and also Shorea robusta (sal). Production of tasar cocoons largely depends on the availability of food plants in the forest. In India, though tasar flora is available in about 111.68 lakh ha., it is mainly dominated by Sal, while arjuna and asan are mostly used for tasar rearings at farmers level. The farmers generally do not raise their own plantation and solely depend upon nearby forest patches. Details of extent of tasar host plants in forests and tribal families conducting rearing are appended at Table-1, above.

Of late, indiscriminate felling of tasar food plants from village forest for fuel purpose has posed great hindrance for extension of tasar cocoon production, besides objections raised by local forest department officials. Though, under Inter State Tasar Project (ISTP) over 7500 ha. of land was brought under Arjun./ Asan plantation in different traditional and non-traditional states, but much of the plantations have not been properly maintained after the project, due to lack of accountability on part of tasar rearers. It is therefore, necessary that economic plantation should be raised in private lands, as land resources are better managed and utilized under private ownership to avoid conflict, which may arise with respect to ownership and income sharing. In case of private wastelands / fallow lands, the major challenge before the intervention is to create a vision of long term livelihood opportunity for the land owner through the utilization of waste/fallow lands. Since tasar silkworm

rearing is a family avocation, hence the landowners would always value host tree plantation raised in their private lands as an asset and the family will tend to invest efforts and resources to maintain the plantations in better ways. Moreover, the income from this asset would always be fully retained by the landowners.

Table 1: Tasar food plants and rearers in different states

State	Available forest area (lakh ha.)	Area under tasar food plants (lakh ha.) *	No. of tribal families in tasar rearing (in lakh)	Plantation available for exploitation (ha.)
Jharkhand/ Bihar	34.9 (27.73/7.17)	9.18	0.600	1270 70
M.P./ Chattisgarh	146.32 (62.72/ 83.6)	50.48	0.200	5600 2300
Orissa	67.46	20.24	0.320	400
West Bengal	11.48	3.55	0.050	120
Andhra Pradesh	65.18	13.02	0.030	910
Maharashtra	66.96	10.04	0.020	1200
Uttar Pradesh	35.10	5.21	0.015	30
Total	427.40	111.68	1.235	11900

Source: State of Forest Report, 2003. *CSB estimates

MATERIALS AND METHODS

Though, Central Silk Board, the Apex body for promotion of sericulture has supported the concept of raising block plantations of tasar host plants, it was limited to village common lands, revenue and forest lands that too with meager financial assistance not sufficient for maintenance after establishment. In view of the above, a collaborative initiative was taken up under the Special Swarnajayanti Gram Swarojgar Yojana (SGSY) Projects in the States of Bihar and Jharkhand with the financial assistance from the Ministry of Rural Development, Govt. of India executed by CSB and implemented by a Non-Governmental Organization, Professional Assistance for Development Action (PRADAN) to promote economic plantations of tasar host plants in private wastelands of tribals. The beneficiaries were from the below poverty line (BPL) families of rural poor mostly belonging to scheduled tribes, Schedule Castes and other weaker sections of the society who are traditionally involved in tasar culture.

The idea of promoting arjuna plantation was based on the concept of creating sustainable livelihoods by using hitherto idle assets like wastelands. This idea had relevance in the southern part of Bihar (now Jharkhand) as the average landholding of even poor households was 1.7 hectares and 40% of the landholding was either fallow or uncultivable. Initially, it was difficult to get a positive response from the people, as most of them did not believe that plants could grow in wastelands. A cluster-based approach was followed in plantation activities to attain scale of economy in a compact area (comprising of 1-2 panchayats). In most of the clusters the overall area of plantation was around 100-150 hac involving 100-200 families. This ensured equitable sharing of benefits by the participants and participation of the majority.

Selection and motivation of tribal groups: Concept of plantation and its benefits were shared with small groups of poor tribals preferably in hamlets owning a contiguous patch of lands (at least 5 ha. of land) suitable for tasar host plant cultivation. Exposure visits were organized to economic plantation promoted under other schemes in which rearers have already started commercial cocoon production. Interaction between the tasar rearers and the group was facilitated to understand the economic returns and the various factors like managing and protecting plantations at least for 4 years before it fetches returns and labour contribution they need to make.

Selection of plantation site: A compact geographical area covering 1-2 panchayats having a minimum of 35% of the private land holdings coming under the category of fallow / wastelands was identified. The wastelands / fallow lands without continuous stone layers with in 3 feet depth and soils interspersed with loose bolder or soil with loose morrum layers up to 4 feet depth were selected. Special land husbandry measures were taken up to check run-off of water

and soil erosion, where slope was more than 25%. Fallow / wastelands belonging to poor people looking for livelihood activity was only selected.

Opportunity cost analysis: A hamlet-based meeting was organized to assess the economic benefits of the idle lands such as from cattle grazing, or from fuel wood gathering from the bushes growing on the land. Investment and returns from the same land were discussed if Tasar plantations are raised on it, besides economics of other competitive agriculture crops like minor pulses or millets, which can be grown on the land.

Formation of Tasar Vikas Samity: Tasar Vikas Samity (TVS) is an informal village level group responsible for raising and maintenance of plantations. TVS's role begins with selecting the nursery farmer. It then plans, implements and monitors the entire range of activities including pits and trenches, land husbandry, transplantation, etc. The TVS meets once in 15 days to plan and budget for various activities. It has its own bank account. TVS maintains its accounts and maintain stock book for material transactions, which are audited. By forming TVS, increased tribal participation was sought at every stage of plantation activities starting from site selection, planning, budgeting, nursery raising and transplantation to regular intercultural operations and protection of plantations against grazing. All the financial and material transactions with individuals in the villages are carried out through the respective TVSs. If the owners of the land, earmarked for plantation, comprise of majority of the SHG members, then the SHG in the village has played the role of TVS.

At the start of the work, the TVSs are facilitated to prepare a detail work plan and budget based on their abilities to contribute labour and material. The work plan and the budget of the TVSs are submitted to PRADAN office through the functionary of PRADAN operating in the area. Once the work starts in the village, PRADAN functionary assesses the progress of the work and monitors the expenditure details and recommends release of the next indent directly to the bank account of the TVS.

Land Husbandry and Plantation Maintenance: Tasar host plantations are raised in the unbunded / unterraced uplands or medium uplands that remain mostly fallow or sporadically cultivated. These lands in undulating topographical terrain facilitate rapid water run off to cause soil erosion. Considering this, land husbandry measures viz., staggered trench, 30' x 40' model and field bunding, water harvesting structures etc., were planned to check water run off and prevent soil erosion to enhance moisture retention capacity of the land.

Survival of over 90% is ensured by proper pit digging, timely transplantation of robust seedlings so that they receive at least 500 mm of rains in the first year. To promote uniform and vigorous growth of the plants in the subsequent years was ensured through intercultural operations such as hoeing, fertilizer application and pruning for 3 years subsequent to the year of transplanting.

Intercropping: To sustain the interest of the tribal rearers during the gestation period, they were encouraged to take up intercropping leguminous crops that fix nitrogen in their roots and add the same to the soil. As the farmers start attaching value to the short-term returns from intercropping, hence, their own interest in protection of the plantations from grazing animals improves significantly. Moreover, cattle are generally not released in the cropped land. Ploughing across the slope at the time of intercropping turns the soil of the entire field and checks water run-off, which promotes vigorous growth of the plants. Leguminous plants like moong (Vigna mungo) and urad (Vigna radiata) were utilized for intercropping. Rapid growth of tasar host plants is thus triggered by increased soil loosening, higher percolation of rainwater and biologically added nitrogen.

Performance Indicators of Raising Tasar Host Plants: Survival percentage of over 95% after one year and over 90% after two years with average height of plants of more than 8 ft. after 2nd hoeing in 3rd year and at least 80% of the plants will mature in 4th year ready for tasar silkworm rearing were fixed as checklist for extending the assistance under the Projects.

Sequence of activities under the Special SGSY Projects was adopted by incorporating all the technological inputs from the Central Tasar Research & Training Institute (CTR&TI), Ranchi in raising of kisan nursery and establishment of block plantations and their maintenance. Besides, SHGs were encouraged to produce vermicomposts which was utilized in maintaining the plantations besides application of inorganic fertilizers to upkeep the soil health.

RESULTS AND DISCUSSION

Block plantations of tasar host plants viz., arjun and asan were raised in the project area by the members of TVSs and maintained for three years as per recommended package of practices. While, the block-wise and district-wise area covered under the projects is indicated at Table 2, the targets vis-à-vis achievements are furnished at Table 3.

Table 2: Tasar host plants raised under Special SGSY Projects

Sl. No.	State	Districts	Blocks	Plantations raised (ha.)
1	Bihar	Banka	Bounsi, Chandan & Katoria	511.80
2	Jharkhand	Godda	Godda, Sundarpahari & Poraiyahat	360.00
		Dumka	Jarmundi, Saraiyahaat, Sikari para, Kathikund & Dumka Sadar	527.00
		West Singhbhum	Jagannathapur, Kumardungi, Manjgaon & Jhinkpani	171.00
	Total	4 districts	15 Blocks	1569.80

Table 3: Economic plantations raised and maintained under Special SGSY Projects

State	Bihar			Jharkhand		
Partic ulars	Target	Achie-vement	% of achie - vement	Target	Achie-vement	% of achie - vement
Extent of tasar host plants raised (ha.)	275	268.76	97.73	750	743.09	99.08
Extent of host plants maintained (ha.)	550	586.26	106.59	1250	1125	90.00
Chawkie garden units raised (0.1 ha.)	225	243.00	108.00	300	314.4	104.80
Chawkie garden units maintained (0.1 ha.)	675	598.00	88.59	600	710.6	118.44

Besides raising economic plantations of arjun and asan, the Projects helped in rejuvenation of over 10000 ha. of natural forests with tasar host plants with annual income potential of over Rs. 10.0 crores.

Impact of the initiative: All the block plantations and chawkie gardens raised under the Projects have become ready for rearing tasar silkworms by fourth as envisaged under the Project with more than 90% survival and better quality foliage. Further, the crop duration was considerably reduced because of quality foliage resulting in better growth of tasar silkworms. Suitability of leaf quality and increased uptake of dfls (disease free layings) per unit area was evident with increase in cocoon productivity of 60 per dfl from 35 per dfl under natural forest plantation. In some of the clusters, cocoon yields were as high as 100-110 cocoons/ dfl. The increase in cocoon yield was due to better management practices of tasar silkworm rearing on plantations raised in private lands as they were in the vicinity of villages. Further, the crop duration was considerably reduced from 75 days in forest plantation to 60 days in these economic plantations due to quality foliage resulting in better growth of tasar silkworms (Table 4).

Table 4: Impact of economic plantations of tasar host plants raised under the Special SGSY Projects

Particulars	Forest plantation	Economic plantation
Cocoon Productivity (per dfl)	35	60
Crop duration (Days)	75	60

Future Opportunities: Studies by Paul et. al. (2002) emphasized on the quantifying changes in soil C, which may be an important consideration under large-scale afforestation or reforestation. It was felt that the accumulation is maximised by maintaining longer forest rotations. Furthermore, inclusion of litter reversed the decrease in soil C, so that amount of C in soil and litter layer was greater than under preceding pasture. This attains importance with respect to tasar host plants, which biomass would be consumed only once in a year, but compensated by the silkworm litter as the rearing is carried out on the trees.

When agricultural land is no longer used for cultivation and allowed to revert to natural vegetation or replanted to perennial vegetation, soil organic carbon can accumulate. This carbon sequestration essentially reverses some of the effects responsible for soil organic carbon losses from when the land was converted from perennial vegetation. Though, there is a large variation in the length of time for and the rate at which carbon may accumulate in soil, related to the productivity of the recovering vegetation, physical and biological conditions in the soil, and the past history of soil organic carbon inputs and physical disturbance, soil carbon sequestration rates would get enhanced with changes in land-use and soil management (Wilfred and Kwon, 2000). Out of total 1769 CDM Projects registered, major share of 1297 are of energy industries and only six are of afforestation/ reforestation category indicating the unexplored opportunity in this sector.

Management of soil health is the priority for these tasar rearers as these plantations would help them to rear tasar silkworms with annual returns of over Rs. 25,000/- per ha. for over fifty years with minimum maintenance, better management practices due to the vicinity of the plantations to the villages etc., which would bring in sustenance of the activity besides expansion. These plantations also have unexplored potential to generate carbon credits based on the Clean Development Mechanism (CDM). This attains importance as the developed countries and economies in transition can acquire carbon credits generated through such projects to abate part of their greenhouse-gas emission-reduction commitments ratified in the Kyoto Protocol. It is established that highest carbon sequestration rates (0.1 - 0.25 MT/ha) are associated with the trees than those from herbaceous crops and consequently can cause marked increases in the level of soil carbon.

Issues to be addressed: Though there is vast potential to utilize the plantations of tasar host plants in private lands of tribals, some of the major issues to be addressed in these projects are demarcation of the project boundaries, permanence (temporary credits), quantification of CERs, validation and verification and environmental and social sustainability. Due to these issues, while only one project is registered from China under this category, two projects have been submitted from India to the CDM Executive Board.

Of the above demonstration of land Eligibility becomes a very important criterion and under afforestation projects, the proposed land should be of non-forest category for 50 years before the project start and land use change from non-forest to forest defined through tree crown cover, tree height and land area. Further, the complex methodology involved, difficulty in proving land eligibility and establishing baseline, expensive and limited data and maps, limited expertise available in this field etc., are the some of the areas need to be looked into for bringing in additional and recurring income avenues to these poor tribals besides other social and economic benefits like migration to urban areas, checking pollution through enhanced green cover, soil erosion etc. Keeping in view the above benefits, these issues needs attention of policy makers and environmental activists.

With the present initiative through active tribal participation in raising tasar host plants in systematic way following recommended technologies in raising and maintenance by involving NGOs would bring in social inclusion and empowerment of tribals.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 462-466

CONTRIBUTION OF BSM&TC KHARSWAN IN THE SUCCESS OF SGSY PROJECT IN JHARKHAND WITH SPECIAL REFERENCE TO SINGHBHUM

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ABSTRACT

Jharkhand is the rank one among the tasar producing states, with a contribution of about 50-65 % of country production. Tasar culture is concentrated mainly in the tribal areas of the state such as Santhal praganas and Chottanagpur regions. The seed sector in tasar needed special attention to ensure supply of quality commercial seed in field. Therefore, the special SGSY (Swarnjayanti Gram Swarojgar Yojana) project was formulated and implemented by Basic Tasar Silkworm Seed Organization (CSB) and PRADAN. The project aimed to meet about 66% of total requirement of the commercial seed for which three-tier system of seed multiplication was done in place of seed rearers and adopted seed rearers. During the project period a total of 44,150 Dfls were reared by BSM & TC, Kharsawan and harvested 29,51,330 cocoons with an average of 66.85 cocoons per Dfl. A total of 31, 80,774 cocoons were produced and 7, 63,924 dfls were prepared out of which 7, 46,574 dlfs were supplied in the project area. On an average 4.16:1 cocoons:Dfl ratio was obtained. A total 212 silkworm rearers were adopeted in Kuchai area and supplied 32,250 dfls to them. 14, 52,052 cocoons were harvested by them with an average of 45 cocoons per dfls. Under the adopted seed rearers programme 411 farmers were adopted for seed crop rearing. A total of 57,330 dfls were supplied to them and harvested 23, 17,561 nucleus seed cocoons with an average of 40.42 cocoons per dfl. A total 1117 persons were trained at BSM&TC, Kharsawan out of which 221 were private graineurs, 133 seed rearers, 140 commercial rearers, 411 adopted seed rearers and 212 adopted rearers.

Key words: Adopted rearers, Seed crop rearing, Seed multiplication, Tasar

INTRODUCTION

India is the only country in the world producing all the five varieties of commercially exploited natural silks *viz*., mulberry, Tasar, Oak Tasar, Eri and Muga. India is the second largest producer of Tasar Silk after China and earns abount Rs 40 crores in foreign exchange annually which amount to 2 -3% of India's total earnings from Silk export. Tasar culture is practiced by nearly 1.25 lakh tribal families in different states, *viz*., Andhra Pradesh, Bihar, Chattishgarh, Jharkhand, Madhya Pradesh, Maharashtra, Orissa, Uttar Pradesh & West Bengal. Tasar culture provides gainful employment and remunerative supplementary income to the tribal population. Tasar culture in recent time has opened up several avenues for establishing profitable rural enterprises, especially in the area of seed production, yarn production and also diversified products from this unique silk.

Tasar silkworm *Antheraea mylitta* Druy (Indian Tropical Tasar) is polyphagous and wild in nature and is reared on nature grown trees in the forest and block plantation raised in waste land, denuded forest areas *etc*. The tasar silkworm feeds on leaves of Arjuna, Asan and Sal tress. The tribals of Jharkhand rear tasar eco-races like Daba and

Sukinda on Asan and Arjun plantations. The Tasar cocoon crop is always open to natural vagaries. The tasar culture for its sustained developement needs to be supported with adequate market support, effective linkages amongst various activity groups in the production process and design/product development inputs to meet the demands for quality finished products.

Present status of Tasar silk industry in Jharkhand

Jharkhand is rank one among the tasar producing states, with a contribution of about 50-65 % of country production. Tasar culture is concentrated mainly in the tribal areas of the state such as Santhal praganas and Chottanagpur regions particularly in the districts of west Singhbhum, Ranchi, Dumka, Godda, Giridhi, Seraikella *etc*. An estimated 65,000 families are engaged in tasar silkworm rearing but only 50-60% of them are active and conduct tasar silkworm rearing every year. West Singhbhum, Ranchi, Dumka, Pakuar, Godda & Seraikella districts accounts for over 65% of the reares. Tasar silk production accounts for sizeable contribution to the state domestic product and thus assumes special importance in the economy of the state .

Beneficiaries

The project beneficiaries were mostly from the below poverty line (BPL) families of rural poor mostly belonging to scheduled tribes, scheduled castes and other weaker sections of the society who are traditionally involved in tasar culture with a special emphasis on women.

Seed Organisation

The seed sector in tasar needed special attention to ensure supply of quality commercial seed in field. Therefore, the special SGSY project was formulated and implemented by BTSSO (CSB) and PRADAN. The project aimed to meet about 66% of total requirement of the commercial seed for which three- tier system of seed multiplication was done in place of seed rearers and adopted seed rearers.

Basic seed supply

It is largely the responsibility of the Central Silk Board to meet the entire requirements of Basci seed of the state for multiplication and further production and supply of commercial Dfls to the rearers. There are four basic tasar seed multiplication and training centres (BSM&TC) in the state located at Kharsawan (West Singhbhum), Kathikund (Dumka), Madhupur & Deoghar with a supply capacity of 32000 Dfls each. However, the demand is much more than their supply capacity and hence additional facilites have to be created to almost double their production capacity.

The concept of Adopted Seed Rearers (ASR) is introduced in the project to conduct rearing of nucleus seed and produce quality seed cocoons, the activity hitherto undertaken wholly by BSM & TCs, of Central Silk Board. This has been introduced to strengthen the efforts of BSM & TCs, and meet the entire basic seed requirement by the BSM & TCs located in the project area.

Objectives and critical areas

Main objectives of the project were to augment income of tribals, poverty alleviation, check migration to urban areas besides conserving biodiversity, environmental protection and utilizing private degraded waste lands for raising tasar host plants in a systematic and sustainable manner. Through addressing the following critical areas of socioeconomic development for empowerment of tribals with equity and sustainable growth were made possible.

1. Raising of block plantation and chawki gardens of tasar food plants in private lands.
2. Organization of the beneficiaries into serviceable groups like SHGs, women groups, rearers groups, reelers groups, Tasar Vikas Samitis (TVS), Mutual Benefit Trusts (MBT) *etc*.
3. Establishment of back ward and forward linkage from plantation to silk reeling with substantial assistance from the project funds.
4. Concepts of Adopted seed rearers (ASRs) to strengthen the efforts of BSM&TC in rearing and nucleus seed production of entire basic seed.
5. Cultivation of tassar and castor (for eri silkworm rearing) and inter crop during gestation period of tassar host plants.
6. Utilization of the facilties created under UNDP projects viz., seed rearers, private graineurs, reelers, spinners *etc*.
7. Creation of additional private grainages for assured supply of commercial tasar silkworm seed and common facilities for rearers, reelers and spinners.
8. Motivation of graineurs groups to preserve nucleus seed cocoons for basic seed preparation.
9. Adoption of recommended technologies, creation of marketing facilities and human resources development.

Contribution of BSM &TC, Kharsawan in SGSY project area

1. Selection of adopted rearers (ARs)
2. Selection of adopted seed rearers (ASRs)
3. Selection of private graineurs

- During the project period a total of 44,150 Dfls were reared by BSM & TC, Kharsawan and harvested 29,51,330 cocoons with an average of 66.85 cocoons per Dfl (Table 1).

- A total of 31, 80,774 cocoons were produced and 7, 63,924 dfls were prepared out of which 7, 46,574 dlfs were supplied in the project area (Table 2). On an average 4.16:1 cocoons:Dfl ratio was obtained.
- A total 212 silkworm rearers were adopeted in Kuchai area and supplied 32,250 dfls to them. 14, 52,052 cocoons were harvested by them with an average of 45 cocoons per dfls (Table3).
- Under the adopted seed rearers programme 411 farmers were adopted for seed in Hatgamharia, Kuchai, Kharsawan and Chakradharpur Project area. A total of 57,330 dfls were supplied to them and harvested 23, 17,561 nucleus seed cocoons with an average of 40.42 cocoons per dfl (Table 4).
- A total 1117 farmers were trained at BSM & TC, Kharsawan out of which 221 were private graineurs, 133 seed rearers, 140 commercial rearers, 411 adopted seed rearers and 212 adopted rearers (Table 5).

The concept of Adopted seed rearers (ASRs) was introduced successfully under the project to conduct rearing of nucleus seed cocoons.

Nucleus seed cocoons preservation and productions of basic seed was taken up by the progressive graineur groups. Basic seed reared by the seed rearers, who supplied seed cocoons to unemployed educated tribal youth / women, progressive seed rearers and commercial rearers *etc.,* who were identified as private graineurs.

Productions of nucleus seed, seed cocoons and commercial dfls was achieved more than target set. It is evident that the activities of BSM&TC, Kharswan were encouraging for scaling up the private intervention in tasar seed sector in Singhbhum area.

Future strategy

To sustain the achievements:-

1. Continue such activities which ensures quality seed production.
2. Define and demarcate seed zones for different areas.
3. Develop a policy for procurement of seed cocoons to avoid pressure of traders who lure the farmers by offering higher price.
4. Uniform price for tasar seed so that tasar seed production becomes a remunerative proposition for the private entrepreneurs.

Table 1: Departmental rearing performance under SGSY project for the period from 2003-04 to 2008-09

Year	Crop	No. of Dfls Brushed	No. of Cocoons Harve sted	Yield / Dfls
	I	3600	216000	60.00
2003-04	II	4175	217500	52.10
	TOTAL	7775	433500	55.76
	I	3000	199200	66.40
2004-05	II	5000	248755	49.75
	TOTAL	8000	447955	60.00
	I	3450	262500	76.07
2005-06	II	5000	385500	77.00
	TOTAL	8450	648000	76.68
	I	3000	226200	75.00
2006-07	II	3025	200500	66.28
	TOTAL	6025	426700	70.82
	I	3500	260700	74.48
2007-08	II	3000	190415	63.47
	TOTAL	6500	451115	69.40
	I	3000	280000	96.66
2008-09	II	4400	264060	60.00
	TOTAL	7400	544060	73.52
GRAND TOTAL		44150	2951330	66.85

Table 2: Departmental rearing performance under SGSY project for the period from 2003-04 to 2008-09

Year	Crop	Seed Cocoons Processed	Dfls Production	Cocoon Dfl Ratio	Dfls Supplied
	I	269988	60285	4.48	60285
2003-04	II	216000	61525	3.51	61525
	TOTAL	485988	121810	3.99	121810
	I	209534	45129	4.64	42729
2004-05	II	218300	51235	4.26	51235
	TOTAL	427834	96364	4.42	93964
	I	252546	53740	4.70	53290
2005-06	II	226500	50500	4.48	45500
	TOTAL	479046	104240	4.60	98790
	I	338500	50505	6.70	47505
2006-07	II	226000	52650	4.29	52650
	TOTAL	564500	103155	5.47	100155
	I	338626	91465	3.71	87965
2007-08	II	260700	65690	3.91	65690
	TOTAL	599326	157155	3.81	153655
	I	347980	109600	3.18	106600
	II	276100	71600	3.86	71600
2008-09	TOTAL	624080	181200	3.44	178200
GRAND TOTAL		3180774	763924	4.16	746574

Table 3: Adopted rearers rearing performance under SGSY project for the period from 2003-04 to 2008-09

Year	Crop	No of Adopted Rearers	No. of Dfls Brushed	No. of Cocoons Harvested	Yield / Dfls
	I	15	3000	164155	55.00
2003-04	II	15	3000	100000	33.00
	TOTAL	30	6000	264155	44.00
	I	18	3150	84600	27.00
2004-05	II	28	3500	111600	32.00
	TOTAL	46	6650	196200	30.00
	I	13	1550	66680	43.00
2005-06	II	12	2050	67650	33.00
	TOTAL	25	3600	134330	38.00
	I	18	2000	80500	40.00
2006-07	II	10	2000	101000	51.00
	TOTAL	28	4000	181500	45.00
	I	14	2300	115200	50.00
2007-08	II	23	4700	290100	62.00
	TOTAL	37	7000	405300	58.00
	I	16	2000	118032	59.00
2008-09	II	30	3000	152535	51.00
	TOTAL	46	5000	270567	54.00
GRAND TOTAL		212	32250	1452052	45.00

Kuchai area (Seraikella- Kharswan) Jurisdiction, PPC, Kharswan

Table 4: Adopted seed rearers rearing performance under SGSY project for the period from 2003-04 to 2008-09

Year	Crop	No of Adopted Seed Rearers	No. of Dfls Brushed	No. of Cocoons Harvested	Yield / Dfls	Name of Villages	Area	Under Which PPC
2003-04	II	50	7000	212350	30.33	Kusmita, BaraKusmita, Jaldiha & Bichaburu.	Hatgamaria	PPC, Hatgamharia.
2004-05	II	50	10000	182890	18.29	Puniburi, Damadiri, Maranghatu & Champad.	Kuchai	PPC, Kharswan.
2005-06	II	61	10025	255370	26.00	Champad, Potlore, Bandi & Bara Bandi	Kuchai	PPC, Kharswan.
2006-07	II	79	10000	585721	59.00	Kurjuli, Tenda, Jonko & Tentaipoda.	Chakradharpur	PPC Chakradharpur
2007-08	II	97	10265	678230	66.00	Kurjuli, Tenda, Jonko & Tentaipoda.	Chakradharpur	PPC Chakradharpur
2008-09	II	74	10040	403000	40.14	Motugora, Gerupani, Rugurdih & Siyadi h	Kuchai	PPC, Kharswan.
Grand Total		411	57330	2317561	40.42			

Table 5: Number of persons trained under SGSY project by BSM & TC, Kharswan for the period from 2003-04 to 2008-09

Year	Private Graineurs	Seed Rearers	Commercial Rearers	Adopted Seed Rearers	Adopted Rearers	Total
2003-04	5	20	25	50	30	130
2004-05	22	20	39	50	46	177
2005-06	90	45	0	61	25	221
2006-07	70	28	60	79	28	265
2007-08	14	0	16	97	37	164
2008-09	20	20	0	74	46	160
Grand Total	221	133	140	411	212	1117

Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 467-471

INTERVENTION OF IMPROVED TECHNOLOGIES IN MUGA AND ERI CULTURE THROUGH CLUSTER APPROACH

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ABSTRACT

In order to increase the production and productivity through effective technology absorption in the potential pockets of sericulture, Central Silk Board has initiated Cluster Development Programme during XI Plan. In the present paper, impact assessment of the different Cluster Development Programme being implemented under CMER&TI, Lahdoigarh is discussed. The assessment has shown a considerable increment of cocoon production in different muga and eri cluster after intervention of improved technologies through cluster approach. In the muga clusters, cocoon production has increased by 30.0 % in seed crops and 39.0% in commercial crops over benchmark in the initial year. In the subsequent year, cocoon production has increased by 65.0% in seed crops and 43.0% in commercial crops over benchmark. Similarly, cocoon production has increased by 6.7% in the initial year and 10.8% in the subsequent year over benchmark in the eri cluster. From the present assessment, it could be inferred that the recommended technologies of muga and eri culture are effective for enhancing production and productivity. As the socio-economic conditions of the farmers are very poor, they need financial support for infra-structure development as well as input cost. The technology intervention through cluster approach and financial support is also found to be effective in sericulture.

Key word: Cocoon productivity, Cluster approach, Eri culture, Muga culture, Technology intervention

INTRODUCTION

Muga and eri culture are traditional practices in the North Eastern region of India and believed to be originated in the Brahamputara valley of Assam. The congenial climate and indigenous food plants have made the region a natural abode of muga and eri silkworm. Since time immemorial, both the culture is being practiced by the rural folk of the region. Apart from muga and eri, mulberry is also practiced by the people of North Eastern region. In ancient days, the Ahom kings patronized sericulture as a rural industry in Assam and made it an obligatory household work (Thangavelu, *et a*l 1988). This provides evidence that sericulture has immense potentiality for socio-economic development with sustainable income generation of the rural poor. Keeping this in view, the department of sericulture was established long back in the region for development of the industry as well as up-liftment of the weaker section of the society. To support the industry, Central Silk Board also intervened in muga and eri culture through establishment of Central Muga Eri Research Station (CMERS) at Titabor, Jorhat, Assam in the year 1972. Presently, it has developed to a full-fledged institute and renamed as Central Muga Eri Research & Training Institute situated at Lahdoigarh, Jorhat in Assam.

With the establishment of different units of Central Silk Board, continuous efforts were made for growth and development of the muga and eri industry. As a result, various improved technologies were developed in muga and eri sectors in the recent past. Continuous efforts are also being made for popularization of the technologies among the farmers through various extension programmes. The increasing trend of raw silk production of muga from 108 MT in 2000-01 to 118 MT in 2008-09 and eri from 731 MT in 2000-01 to 1996 MT in 2008-09 is probably due to intervention of the improved technologies and collective efforts made by both central and state goverments. In order to

further increase in production and productivity through effective technology adoption in the potential pockets of sericulture, Central Silk Board has implemented Cluster Promotion Programme in collaboration with the Department of Sericulture of the respective states during XI Plan. Keeping this in view, muga and eri Cluster Development Programmes have been implemented under CMER&TI, Lahdoigarh since 2008-09. The scientists associated in the clusters attended frequent monitoring and supervision for providing of technical inputs timely to the farmers. In the present paper, cocoon production in different muga and eri clusters during the project period of 2008-09 and 2009-10 is discussed.

MATERIALS AND METHODS

Four muga Cluster Promotion Programmes (CPP) being implemented at Golaghat and Lakhimpur in Assam, West Garo Hills district of Meghalaya and Coochbehar district of West Bengal and one eri Cluster Promotion Programmes in Udalguri, BTC were considered for present assessment. Inventory of the recommended technologies intervened in the muga and eri clusters are given below.

I. Improved technologies of muga culture

- Pruning & pollarding of host plants
- Application of manure and fertilizer to the host plants
- Pre brushing care at the rearing field
- Early stage silkworm rearing technique
- Late stage silkworm rearing technique
- Disease Free Laying (DFL)
- Prophylactic measures against pest and diseases of silkworms
- Improved spinning device

II. Improved technologies of eri culture

- Raising of systematic plantation of perennial food plants
- Intercropping of castor plants
- Application of manure and fertilizer to the host plants
- Disinfection of rearing house and rearing appliances
- Disease Free Laying (DFL)
- High yielding silkworm races
- Early stage eri silkworm rearing technique
- Late stage eri silkworm rearing technique

The cocoon productions of the farmers under different clusters during 2008 -09 and 2009-10 were recorded to compare the percentage increased over the benchmark cocoon production.

RESULTS AND DISCUSSION

Data presented in the Tables 1 to 6 indicate that by intervention of improved technologies through cluster approach, overall cocoon production in muga and eri clusters was increased over the benchmark. It was also observed that cocoon production has not only increased over benchmark during the initial year but also found to increase in the subsequent year of implementation. It is evident from the Table -1 that during 2008-09, average number of muga seed cocoons production was 24.2 per dfl against benchmark production of 20.0 cocoons per dfl. In the subsequent year 2009-10, it has been recorded that average production has been increased to 33.0 cocoons per dfl against the same benchmark (Table 2). The production gain over benchmark has registered to be 30.0 % in the year 2008-09 and 65.0% in the year 2009-10. Similarly, data presented in the Table -3 indicates that production of reeling cocoons was 41.8 per dfl against benchmark production of 30.0 cocoons per dfl during 2008-09. In the subsequent year, the production has been recorded 42.9 cocoons per dfl (Table 4). The production increased over the benchmark has recorded to be 39.0 in the year 2008-09 and 43.0 in the year 2009-10. Study made by Mech *et al.,* (2004) also revealed that the farmers who fully adopted the recommended technologies of muga culture could produce 50-60 muga cocoons per laying against 30-40 cocoons per laying of partial adopters and below 20 cocoons per laying of non adopters. Barah *et al.,* (2006) reported that integration of improved technology packages of muga culture has increased the production up to 52 cocoons from the benchmark production of 29 cocoons per dfl at farmer's level which registered 79.3% increase in cocoon production.

In the same manner, data presented in the Table 5 indicates that average eri cut cocoon production in Udalguri Eri Cluster was 6.4 kg against the benchmark of 6.0 kg per 100 dfls in the year 2008-09 with 6.7% increase over the benchmark. In the subsequent year, cocoon production was 6.7 kg per 100 dfls with 11.7 % increase over benchmark (Table 6).

The socioeconomic conditions of the farmers associated in sericulture are usually not much improved. Most of the farmers are not able to meet the expenses of the improved technologies. As a result, they are not able to adopt the improved technologies fully. Sometimes, the farmers are not aware about the recommended technologies and in some extent traditional ideas or belief keep them away from the improved technologies. Among the various constraints, non-

awareness about the technologies, high cost of technology adoption and strong inclination towards traditional practices were identified as the major constraints for non adoption of technologies in muga culture (Mech *et al.,* 2004). Study conducted by Barah *et al.* (2004) also found that high cost of technologies is the major impediment for adoption of improved technologies at farmers' level followed by their strong inclination towards traditional practices and lack of awareness. In mulberry sericulture, the constraints for non-adoption of technologies are the farmers strong attitude towards traditional practices, non-awareness of technologies, high cost of inputs and non-availability of inputs in time (Geetha *et al.,* 1997). Rao *et al.* (2000) documented the reasons for partial adoption and non-adoption of improved technologies that were lack of awareness, non-availability of inputs in time and high cost of inputs in mulberry sericulture.

Under the cluster development programme, the farmers were provided financial assistance for implementation of the recommended technologies. They were also provided technological inputs through imparting training under the provision of Cluster Promotion Programme. Every cluster in-charges are attending supervision of the different activities of the farmers regularly. The scientists associated in implementation of the CPP are providing appropriate technical guidance at their doorsteps. As a result, the farmers are comfortably coming forward to adopt the recommended technologies which have ultimately increased cocoon production over benchmark.

Table 1: Dfls brushing and seed cocoons production in different Muga Cluster during 2008-09

Cluster location	Dfls brushed	Cocoon production (Number)	Cocoon production / dfl (Number)	Benchmark cocoon Production / dfl ((Number)	Gain over bench -mark (%)
Golaghat	1000	32000	32.0	20.0	60.0
Lakhimpur	550	8000	14.5	20.0	0
Tura	1000	26000	26.0	20.0	30.0
Average			24.2	20.0	30.0

Table 2: Dfls brushing and seed cocoons production in different Muga Cluster during 2009-10

Cluster location	Dfls brushed	Cocoon Production (Number)	Cocoon production/ dfl (Number)	Benchmark cocoon Production / dfl (Number)	Gain over bench -mark (%)
Golaghat	9000	256000	28.4	20.0	42.0
Lakhimpur	9000	254500	28.3	20.0	41.5
Tura	9000	233500	25.9	20.0	29.5
Coochbehar	3614	178700	49.4	20.0	147.0
Average			33.0	20.0	65.0

Table 3: Dfls brushing and reeling cocoon production in different Muga Cluster during 2008-09

Cluster location	Dfls brushed	Cocoon production (Number)	Cocoon production / dfl (Number)	Benchmark cocoon production / dfl ((Number)	Gain over bench -mark (%)
Golaghat	7000	293700	42.0	30.0	40.0
Lakhimpur	2000	84500	42.2	30.0	40.0
Tura	5000	206585	41.3	30.0	37.0
Average			41.8	30	39.0

Table 4 : Dfls brushing and reeling cocoon production in different Muga Cluster during 2009-10

Cluster location	Dfls brushed	Cocoon production (Number)	Cocoon production / dfl (Number)	Benchmark cocoon production / dfl ((Number)	Gain over bench -mark (%)
Golaghat	7300	367300	50.3	30.0	67.6
Lakhimpur	7000	293400	41.9	30.0	39.6
Tura	7500	356250	47.5	30.0	58.3
Coochbehar	20000	640000	32.0	30.0	6.66
Average			42.9	30.0	43.0

Table 5: Dfls brushing and cocoons production in Eri Cluster during 2008-09

Cluster location	Dfls brushed (Nos)	Total cut cocoon production (Kg)	Cut cocoon production /100 dfl (Kg)	Benchmark cut cocoon production /100 dfl (Kg)	Gain over bench -mark (%)
Udalguri	7140	455	6.4	6.0	6.7

Table 6: Dfls brushing and cocoons production in Eri Cluster during 2009-10

Cluster location	Dfls brushed (Nos)	Total cut cocoon production (Kg)	Cut cocoon production /100 dfl (Kg)	Benchmark cut cocoon production /100 dfl (Kg)	Gain over bench -mark (%)
Udalguri	48240	3221	6.7	6.0	11.7

CONCLUSION

From the study, it could be inferred that the recommended technologies are undoubtedly effective for enhancing production and productivity in muga and eri culture, which in turn helps the farmers to enhance income generation. It is possible that necessary support for infrastructure development and cost of technology encourage the poor farmers for adoption of improved technologies effectively. Besides, monitoring and supervision of the different activities and timely technical advice give confidence to the farmers for further involvement in sericulture and thereby more income generation. Continuity of technology intervention through cluster approach in different potential pockets is also pivotal.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 472-477

PHENOTYPIC VARIABILITY IN PLUS TREES OF SOM, *PRESEA BOMBYCINA* KOST. IN NORTH EASTERN INDIA

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ABSTRACT

Thirty nine plus trees of Som, *Persea bombycina* (King ex. Hook f.) Kost identified using Point Grading Methods in different locations in Northeast India showed distinct variation in height, girth, number of branches, crown height, leaf biomass and disease tolerance. Amongst plus trees, PT-12 showed maximum improvement (62.84%) in height and the same was minimum in PT-7 (1.05%). Girth of plus trees ranged from 26.4 (PT-23) - 37.3 cm (PT- 29) with maximum improvement in PT-6 (56.76%) whereas minimum improvement was observed in PT-29 (8.57%). Maximum improvement in number of branches was found in PT-15 (95.65%). Among the different plus trees, the crown height ranged from 6.67 (PT-20) - 81.24% (PT-2). Leaf biomass was recorded maximum in PT-18 (87.64%) followed by PT-5 (84.17%) it was minimum in PT-32 (1.04%). Moreover, plus trees showed resistance in various leaf diseases ranging from 77.66% (PT-4) to 99.22 % (PT-2) over companion tree.

Keywords: North East India, Phenotypic variability, Plus tree, *Presea bombycina,* Som

INTRODUCTION

Persea bombycina (King ex. Hook f.) Kost. locally known as Som (Assam), is an economically important, principal food plant of muga silkworm, *Antheraea assamensis* Helfer. It is an evergreen, perennial and medium sized tree. It grows up to an elevation of 500 m AMSL and is widely found in Assam, Khasi and Jaintia Hills (Kanjilal *et al*., 1984), Garhwal and Kumaun hills (Sengupta and Srivastava, 1995) and western Nepal (Hooker, 1885). The species shows wide variability in natural habitats. Information is available on this species especially on m**o**rphology and propagation (Jolly *et al*., 1979; Choudhury, 2005 and Seth, 2000), floral biology (Yadav *et al*., 1985), diseases (Das, 2005), cytology (Gogoi *et al*., 2005) and silkworm palatability (Siddique, 2000; Gogoi *et al*., 2005). However, identification of plus trees and its distribution in natural habitat are not yet done unlike in other forest tree species (Kumar *et al*., 2003; Sindhu, 1996; Sindhu, 1987; Zobel and Talbert, 1984). Generally, plus trees are selected for obtaining immediate genetic gain in terms of better quality, wide adaptability, higher productivity and maintaining broad genetic base for continued improvement of species for selection of elite genotypes .

The current holdings of genetic resources of P. bombycina are small and likely to represent a fraction of the available genetic diversity (Ram *et al.,* 1993). Further development of P. bombycina would require a greater and better documentation of genetic resource base. The wide distribution of plus trees of P. bombycina across the North East India and their occurrence provides an opportunity for targeted collections to regions most likely to yield adapted germplasm. This is only possible through the extensive survey. The study was undertaken to identify the plus trees of Som in natural habitats through assessing yield attributing quantitative and disease tolerance traits for using in future breeding programme.

MATERIALS AND METHOD

Survey was conducted to identify plus trees of Som in five different states of North East India *viz*., Assam, Arunachal Pradesh, Meghalaya, Mizoram and Nagaland in its natural habitats. Som was found scattered along

roadsides, grazing fields and forest peripheries. Its occurrence inside big forests and national sanctuaries was rare.

Comparison (Point Grading Method) tree method of Zabal, (1993) was adopted to evaluate the candidate plus trees. Quantitative characters like height, diameter at breast height (DBH), number of branches, crown height, pest and disease incidence and leaf biomass were compared with 5 trees (Check trees) growing in the first circle of candidate plus trees (CPT). The extent of superiority of CPTs over the average check trees was assessed by awarding a maximum point as per standard Performa (Table 2). Other characteristics namely, leaf yield, diseases and pest incidence and number of branches were assessed for CPTs and comparison trees. Pest infested trees were not selected. Candidate plus trees that scored above 90 out of 100 points were selected as plus trees or phenotypically desirable tree.

RESULTS AND DISCUSSION

Thirty-nine plus trees of Som were identified in different locations of Northeastern region of India. However, plus trees showed wide variation in height, diameter, number of branches, crown height, leaf biomass and disease tolerance in natural habitats (Table 3). In case of height (Fig.1), of plus trees maximum PT-12 and PT-36 (62.84%) followed by PT-15 (58.98%) over companion trees and the lowest was found in PT-7 (1.05%). Girth at breast height revealed wide variation (Fig. 1) and maximum was found in PT-6 (56.76%) while the lowest was found in PT-29 (8.57%). Similarly, plus trees showed wide variation in number of branches (Fig. 3). Maximum was recorded in PT-15 (95.65%) followed by PT-34 (71.87%) and minimum was found in PT-18 (5.26%). These plus trees showed variation in crown height (Fig. 4) which ranged from 6.67 % (PT-20) to 81.24% (PT-2) over companion trees. Among the different plus trees, PT-18 showed maximum improvement in leaf biomass (87.64%) followed by PT-5 (84.17%) whereas it was minimum in PT-32 (1.04%) (Fig.5). Moreover, plus trees showed resistance to various leaf diseases *viz*., leaf spot, leaf rust and leaf blight (Fig. 6) ranging from 77.66% (PT-4) to 99.22 % (PT-2) over companion tree.

Selection based on single traits may not be very effective to screen elite genotypes in many forest species (Cotterill and Dean, 1986). However, selection based on leaf yield and yield-attributing characteristics result in higher expected response (Baker, 1986).

In multi traits selection method, each trait plays an important role and all the individuals are ranked according to one scoring system. Genotypes selected by this method are expected not only to have desired qualities but will also have genetically divergent base for future breeding programme.

Since the success of a genetic improvement programme largely depends on the existence of variability in the base population, selection methodology for identifying plus trees of P. bombycina has been evolved so that significant improvement can be achieved in yield and other traits of economic importance. In the present study, a total of 39 plus trees and 195 companion trees were selected from different study sites. These genotypes will have immense use when multiplied and established in the clonal seed orchards to meet the immediate demand for seed and provides further opportunities to select the elite P. bombycina genotypes by subsequent evaluation.

Table 1: Statewise Geographical location wise No. of plus trees

State	District	Locations	Nos. of Plus trees	Geographical locations			Hill slope/ Valley
				Altitude (m)	Longitude	Latitude	
Assam	Golaghat	Bogidhola	7	58	93.9	26.4	Valley
	Jorhat	Jogdowar	5	55	94.2	26.6	Valley
	Sibsagar	Borahibari	5	58	95	26.8	Valley
	Dibrugarh	Bordubi	5	55	95.6	27.5	Valley
	Tinsukia	Tingrai,	7	55	95.5	26.5	Valley
	Lakhimpur	Dhakuakhana	2	54	94.5	27.4	Valley
	Cachar	Thaligram	1	55	93.1	24.8	Valley
Arunachal Pradesh	Lohit	Namsai	1	182	96.2	27.5	Hill slope
	Changlang	Bordumsa	1	185	96.3	27.4	Hill slope
Nagaland	Mokokchung	Mokokchung,	2	1832	94.8	26.5	Hill slope
Meghalaya	East Garo Hills	Rompara	3	350	91.1	25.9	Hill slope

Table 2: Scoring for different characteristics of trees of *Persea bombycina*

Characteristic	Description	Points
Leaf biomass (40 points)	Less than average	5
	Equal to average tree	10
	More than average but less than biggest check tree	30
	More than largest check tree	40
Health	Infection (Percent Disease Index)	
(a)Leaf disease infection (15 points)	0-1	15
	2-5	12
	6-25	10
	26-50	8
	51-75	4
	75-100	2
(b) Pest infestation (15 points)	Infection (%)	
	0-1	15
	2-5	12
	6-25	10
	26-50	8
	51-75	4
	75-100	2
Height (5 points)	Less than average	1
	More than average	2
	More than average but shorter t han largest check tree	4
	Taller than tallest check tree	5
Girth at breast height (5 points)	Less than average	1
	Equal to average	2
	Between average and largest check tree	4
	More than largest check tree	5
Crown height (10 points)	Shorter than average	2
	Equal to average	4
	Between average and tallest trees	6
	More than tallest tree	10
No of branches (10 points)	Less than average	2
	Equal to average	4
	More than average	6
	More than largest check tree	10

Table 3: Morphological characters of plus trees of som in natural habitats

Accession	Height (m)	Diameter (cm)	No of branches	Crown height (cm)	Leaf disease incidence (PDI	Leaf biomass (kg)
PT1	9.5	31.64	14	7.65	0.23	24.8
PT2	9.5	30.2	8	8.5	0.10	19.8
PT3	9.8	29.82	12	7.6	0.23	26.4
PT4	9.7	28.92	14	7.95	2.08	26.9
PT5	10.2	31.67	9	7.45	1.09	25.6
PT6	8.9	34.64	22	8.6	2.08	35.4
PT7	4.8	29.22	14	2.5	0.22	32.4
PT8	9.4	30.5	24	8.6	1.02	32.4
PT9	10.5	31.58	18	7.9	1.94	22.8
PT10	10.2	29.16	8	7.6	1.84	20.6
PT11	8.5	28.9	10	8.4	0.24	24.6
PT12	12.5	29.64	8	8.2	1.24	20.6
PT13	9.5	30.76	14	7.8	1.64	26.5
PT14	9.3	28.78	10	7.9	1.92	19.5
PT15	13.8	32.8	18	9.6	0.21	28.8
PT16	10.6	29.22	10	8.6	1.52	20.6
PT17	9.5	29.48	12	8.1	1.72	22.6
PT18	8.9	30.5	8	7.2	1.64	32.8
PT19	10.2	27.9	8	8.2	2.08	20.6
PT20	7.8	27.69	12	4.8	1.21	20.6
PT21	10.2	28.9	12	7.6	0.94	22.4
PT22	8.25	30.06	8	5.2	1.25	22.2
PT23	10.5	26.42	13	8.6	1.62	19.6
PT24	9.5	29.32	12	8.6	1.24	20.6
PT25	10.2	27.95	14	8.2	1.82	21.8
PT26	12.6	30.62	24	8.2	1.09	36.8
PT27	14	30.8	24	9.2	1.12	34.5
PT28	11.5	34.8	18	7.5	1.5	29.5
PT29	9.8	37.3	22	7.8	1.75	33.5
PT30	10.5	28	23	8.2	1.9	38.6
PT31	11.2	30.2	26	8.6	1.56	41
PT32	11.8	28.5	27	9	1.24	28.9
PT33	12	28.6	31	9.5	1.03	29.8
PT34	8.2	30	22	5.6	1.05	32.5
PT35	14	34.8	24	9.2	0.95	34.5
PT36	12.5	29.64	8	8.2	1.24	20.6
PT37	9.5	30.76	14	7.8	1.64	26.5
PT38	9.3	28.78	10	7.9	1.92	19.5
PT39	8.3	32.2	18	6.2	1.92	34.2
Mean	10.18	30.30	15.46	7.80	1.31	26.96
SD(±)	1.82	2.19	6.52	1.35	0.59	6.23

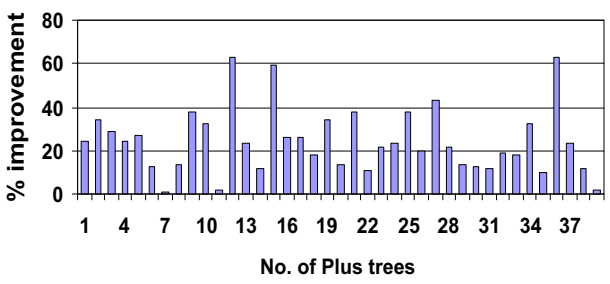


Fig. 1. Height of Plus trees of Som in natural habitats

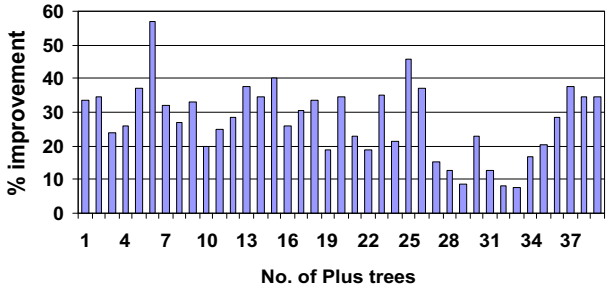


Fig. 2. Girth at breast height of Plus trees in natural habitats

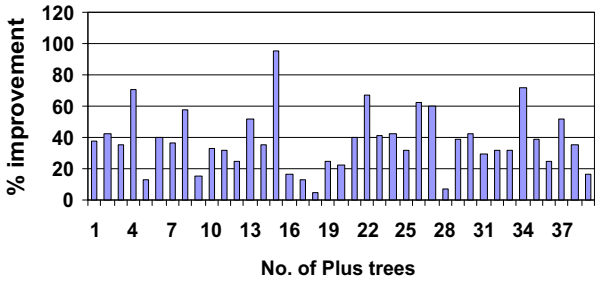


Fig. 3. No. of branches of Plus trees of Som in natural habitats

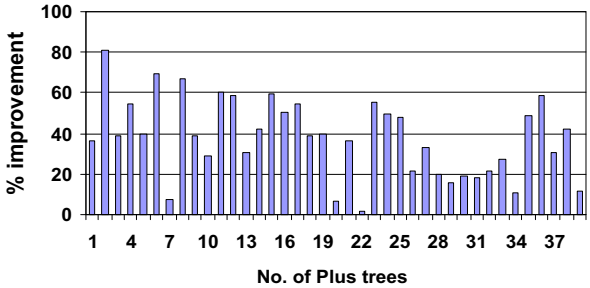


Fig. 4. Crown height of Plus trees of Som in natural habitats

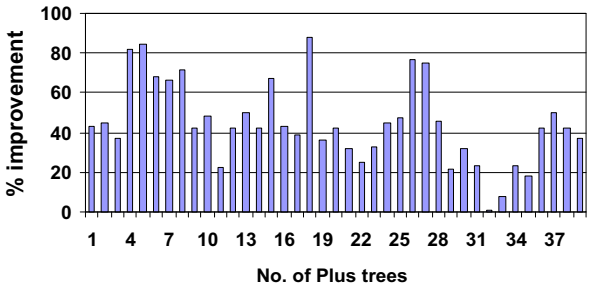


Fig. 5. Leaf biomass of Plus trees of Som in natural habitats

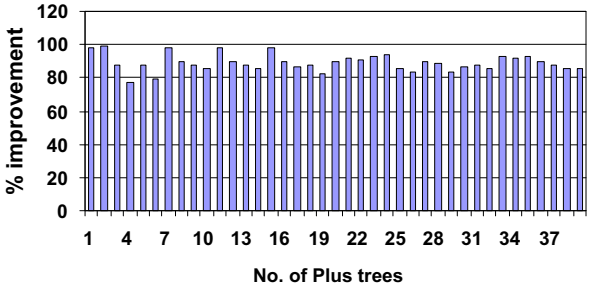


Fig. 6. Disease tolerance in Plus trees of Som in natural habitats

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 478-480

DETERMINATION OF SUITABLE COMBINATION OF NPK FERTILIZER FOR APPLICATION IN SOM PLANTATION BASED ON SOIL TEST VALUE

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ABSTRACT

Muga silkworm, *Antheraea assamensis* Helfer is endemic to the state of Assam and one of major component of *Vanya,* the wild silks of India, since it is reared. But due to outdoors different abiotic and biotic factors, have adversely influenced the muga cocoon production, resulting in a decline in golden raw silk production in the last couple of years. Further, the diversified geological conditions, topographical characteristics, climatic situations and vegetation types have also resulted in variation in muga cocoon production areas. Soil being as major component that influences in quality and quantity of leaf biomass directly affects Muga cocoon production. Hitherto, there was a blanket recommendation for NPK application in Som plantations, irrespective of different geographical zones of Assam. The present study was undertaken to study the soil fertility status in certain potential muga growing areas in 3 districts of Assam covering 60 farmers' fields and evaluate combinations of NPK fertilizers for Som based on soil test value. In all areas the requirement of NPK was found higher than existing recommended dose *i.e.*150:50:50 kg/ha/year.

Key words: *Antheraea assamensis,* Muga, NPK fertilizer, Som plantation, Soil test,

INTRODUCTION

Assam gets an important place in the sericulture map of India, due to its rich sericultural flora and fauna. The congenial climatic feature favours the luxuriant growth of enormous host plants thus about 19 sericigenous insect species of the world which are included in *Vanya* silk are available in this region. Among the *Vanya* silkworms, Muga, *Antheraea assamensis* Helfer is endemic to the state. Assam contributes lion's share of 110 MT of muga raw silk. Over the last ten years, production of muga silk yarn in the region is ranging from 86-110 MT. The trend indicates steady increase in muga silk production. However, the production is not uniform in different years and in different regions of the state. Different biotic as well as abiotic factors are influencing in the production of Muga cocoon. Soil is one of the major factors, which influences the qualitative and quantitative production of leaf biomass. The diversified geological conditions, topographical characteristics, climatic situations and vegetation types have resulted in different types of soil in the state of Assam, which also affecting muga cocoon production. The soils of Assam can be broadly classified into the following categories (Environmental Information System, Assam, 2010).

Forest and hilly lateritic soil: Deep reddish in colour, developed over the geological formations belonging to Archaean, Precambrian and Upper Tertiary age. The soil is characterized by low nitrogen, low phosphate and medium to high potash and pH is acidic.

Low level terrace, red and yellow soil: Formed due to laterisation process of Upper Pleistocene fluvial sediments under favourable climatic conditions. Soil pH is acidic due to intensive leaching of bases and formation of clay minerals and ferric hydroxides.

Alluvial plain soil: Light grey to dark grey of recent age occurring along the major river valleys. Earlier there was a blanket recommendation for NPK application irrespective of different geographical zone of Assam. The present study was undertaken to study the soil fertility status in the potential muga growing areas in 3 districts of Assam

covering 60 farmers' fields and evaluate combinations of NPK fertilizer for application in Som plantations based on soil test results.

MATERIALS AND METHODS

Survey, Identification of farmers as well as collection of leaf and soil samples from the selected 60 farmers of muga growing pockets in three districts of Assam *viz.,* Jorhat, Golaghat and Lakhimpur was done following sampling method. Reckoner of Nitrogenous, Phosphatic and Potassic fertilizer recommendation chart for muga growing areas of Assam prepared on the basis of Mitscherlich-Bray concept was utilized in the study with little modification (Majumder *et al*., 2009). Soils were collected from the surface layer (0-30 cm depth) from each of the locations. The samples were processed and used for physical characterization and analyzing various soil fertility parameters *viz*., available N (kg/ha), available P_2O_5 (kg/ha) and available K_2O (kg/ha) following the methods as described by Jackson (1973). Total nitrogen was estimated by the method of Willits and Ogg (1950). The Kel plus nitrogen analyzer assembly was utilized for estimation of available nitrogen. All estimations were done on dry weight basis. Nutrient status was determined based on the available reports (Anonymous, 2010).

RESULTS AND DISCUSSION

The fertility parameter of NPK status in different muga growing areas was determined based on the level of NPK status in low, medium and high level. Variable range of available nitrogen, available P_2O_5 and available K_2O were recorded in three districts. According to similar soil test values, the areas were grouped in to different clusters. In Jorhat district, available nitrogen was found in the medium range 250-500 kg/ha in all areas except Chenijan area. Similarly, in Golaghat district except Bogorijan other area showed medium level of available nitrogen. In Lakhimpur district, nitrogen status was medium in all areas. Available P_2O_5 was high in all districts. In Jorhat and Golaghat districts, available K_2O was recorded as medium to high, whereas in Lakhimpur district it was low. Based on the maximum potential targeted leaf yield, 20 MT/ha/year of nitrogenous fertilizer, 19.50 MT/ha/year of phosphatic fertilizer and 19 MT/ha/year for potassic fertilizer was suggested for muga growing areas of Assam and following Mitscherlich-Bray concept, the combinations of NPK fertilizers were determined. In Jogduar area, since the available nitrogen level was high, application of nitrogenous fertilizer was not recommended. In all areas, the requirement of NPK was found higher than existing recommendation dose of

Table 1: NPK fertilizer recommendation in different muga growing areas based on soil test value

Area	NPK status of soil			Recommended dose NPK based on soil test value (kg/ha/year)
	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	
Jorhat District				
Borahom, Borhola Gorajan areas	300.00	70.00	300	360: 190: 100
Chenijan area	200.00	80.00	260	400: 190: 100
Balijan Titabar area	250.00	60.00	200	380: 220: 100
Jogduar area	500.00	60.00	250	000: 220: 100
Koliapani area	290.00	70.00	230	360: 220: 100
Bamunpukhuri area	250.00	80.00	220	380: 190: 100
Golaghat District				
Chalangini area	260.00	100.00	250	380: 160: 100
Bogorijan area	200.00	80.00	260	400: 190: 100
Padumoni & Dulakasaria areas	260.00	85.00	280	380: 190: 100
Lakhimpur District				
Balipur Sonowal & Rangati areas	288.00	80.00	200	360: 190: 100
Japisajia & Kamalabari areas	240.00	80.00	200	380: 190: 100

150:50:50 kg/ha/year (Table-1). Thus it is very possible that, muga farmers are not getting the potential leaf biomass production in their plantations due to low nutritive value of soil. Hence, it is very essential to find out actual requirement of application of NPK on the basis of soil test value to get potential leaf yield per unit area.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 481-485

A NOVEL APPROACH TO SILKWORM LITTER MANAGEMENT

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ABSTRACT

Silkworm litter in combination with paddy straw was evaluated for its bio-efficacy in button mushroom (*Agaricus bisporus* Lange) production. Mushroom yield, bio-efficacy, microbial counts, cellulose, lignin, nutritive values of button mushroom, NPK before and after cropping period were studied. Higher mushroom yield (914.0 g / 5 kg substrate) with a bio-efficacy of 62.13 per cent was observed in the standard substrate, followed by the other treatments. The crude protein content varied much among the mushroom fruiting bodies (24.61 to 29.83 %). The total sugar content was high (61.20%) in control and it ranged from 52.90 to 55.30 per cent among the treatments. The fat content was also high in control at 5.94 per cent, but less than 5 per cent in the treatments. The fibre content ranged from 8.46 to 9.63 per cent. The microbial counts like bacteria, fungi and actinomycetes increased upto 21st day of composting and decreased there after. The cellulose and lignin contents also decreased as the process of composting progressed. The NPK contents increased in the compost after the cropping period.

Key words: *Agaricus bisporus,* Button mushroom, Novel approach, Silkworm litter

INTRODUCTION

Sericulture offers a wide range of by-products, which have diverse utility either directly or indirectly in agriculture as well as rural cottage industry. Mulberry shoots are used as fuel source and for paper making while, fruits are used for making jam, juice and wine preparation. Components like chlorophyll, carotene, phytol and pectin are extracted from the silkworm faeces for use in the manufacture of edible colours, candy, wine, ice-creams and medicines for gastric, ulcer, liver and blood diseases. Silkworm litter is used as feed for cattle, sheep and goats and the excreta for bio-gas production (Somanna, 1995). Silkworm pupae are utilized in the extraction of oil, which finds use in soaps, paints, *etc*. The pupal powder has amino acids, vitamins, *etc.,* which is used as feed for poultry, fish, swine, cattle and as manure (Aruga, 1994). The dead pupae along with larvae and moths are used in organic composting. Excreta and silkworm litter is used in vermiculture (Das *et al*., 1997).

MATERIAL AND METHODS

The method outlined by Pandey and Tewari (1993) was followed for the mushroom cultivation. The composts were processed by autoclaving at 121°C for 30 min and allowed to cool by spreading over polythene sheet. Individual composts were packed separately into polythene bags of 15 × 20 cm with 150 gauges, with interspread layers of spawn at 5 cm and 10 cm from top of the cover at the rate of 50 g / 5 kg compost. The bags were arranged on the iron racks by covering with news paper on top. Watering was done on the news paper. The relative humidity of 80 – 85 per cent and temperature of 26±2°C were maintained. After two weeks of spawn run period, when compost was fully covered by mycelium, the news paper was removed and casing was done. The temperature was lowered to 16 - 19°C and fresh air with 85 – 90 per cent relative humidity was maintained. The changes resulted in initiation of pin heads. During this period mist watering was done. When mushrooms were at pea size, rate of watering was slightly increased. Mushrooms appeared in flushes at 3 – 5 days duration at an interval of 7 – 10 days. Likewise, 4 – 6 harvests were done for 4 – 8 weeks. The yield of sporophores was expressed as g /5 kg dry substrate and bio-efficiency of the substrate was calculated by the following formula:

$$\text{Bio-efficiency(BE)} = \frac{\text{Weight of fresh flush}}{\text{Dry weight of the compost}} \times 100$$

The substrate combinations exploited for the purpose of compost making in the experiment are as follows:

T_1 : Paddy straw + Chicken manure + Gypsum + wheat bran (Control)

T_2 : Paddy straw (75%) + Silkworm leaf litter (25%) + Gypsum + wheat bran

T_3 : Paddy straw (50%) + Silkworm leaf litter (50%) + Gypsum + wheat bran

T_4 : Paddy straw (75%) + Silkworm leaf litter (25%) + Silkworm excreta + Gypsum + Spent silk moths

T_5 : Paddy straw (50%) + Silkworm leaf litter (50%) + Silkworm excreta + Gypsum + Spent silk moths

T_6 : Paddy straw (75%) + Silkworm leaf litter (25%) + Silkworm excreta (25%) + Chicken manure (75%) + Wheat bran (50%) + Spent silk moths (50%)

T_7 : Paddy straw (50%) + Silkworm leaf litter (50%) + Silkworm excreta (50%) + Wheat bran (50%) + Spent silk moths (50%)

T_8 : Paddy straw (75%) + Silkworm leaf litter (25%) + Gypsum + Silkworm excreta (75%) + Chicken manure (25%) + Wheat bran (25%) + Spent silk moths (75%)

Finally the NPK before and after cropping; microbial counts like bacteria, fungi and actinomycetes, cellulose and lignin contents in the compost at different stages of composting, yield and nutritional status of mushrooms produced in the above mentioned treatments were estimated.

Nitrogen was determined by Kjeldhal method as outlined by Bremmener (1979). Phosphorus and Potassium was estimated by the procedure given by Jackson (1973). Cellulose by calorimetric method using anthrone reagent. Lignin by acid- detergent method as outlined by Sadasivam and Manickam (1996). The nutritional status of mushroom was estimated by Microkjeldhal method as detailed by Jackson (1973) for protein; phenol – sulphuric acid method as outlined by Sadasivam and Manickam (1996) for carbohydrates, fibre and fat.

RESULTS AND DISCUSSION

Nitrogen was found to be significantly highest in the treatment T_2 with 6.78 per cent followed by T_3 (6.39%), T_4 (6.17%) and was least in control *i.e.,* T_1 (3.37%) before cropping. After cropping the nitrogen content increased slightly in the treatments, being highest in T_2(6.88%) followed by T_3 (6.82%), T_4 (6.60%) and least in T_1 (3.35%). The phosphorus content in the treatments did not vary much but it was least in control T_1 (2.61%) and ranged from 3.01 to 3.72 per cent in treatments. After cropping, the phosphorus slightly increased in the substrates. The potassium ranged from 1.56 to 2.88 per cent and 1.75 to 2.81 per cent before and after cropping, respectively. The potassium content did not vary much but slightly increased after the cropping (Table 1).

The increase in NPK content in compost may be due to the accumulation of mycelial growth in the strata. Similar results were reported by Chang (1990), Ramalakshmi (1995), Reddy (1999 & 2006) and Reddy *et al*. (2000).

The microbial counts like bacteria, fungi and actinomycetes were least on zero day and increased in population upto 21st day of composting. But by 28th day of composting these was decrease in their number in all the treatments (Table 2). These results are in agreement with the results of Krishnamoorthy (1981), Rainey *et al*. (1990), Ramalakshmi (1995), Nugaeva (2000) and Reddy (2006).

The cellulose and lignin context in the substrates decreased drastically from 0 to 28th day of composting (Table 3). This decrease may be attributed to the utilization of the materials as food by the micro-organisms. These findings are in line with the observations of Cortez *et al.* (1996) and Kadalli (1999).

The yield of button mushroom and bio-efficiency varied considerably among different strata. They were higher in T_1 (914 g and 62.13%, respectively) and lowest T_5 (792 g and 52.82%, respectively) (Table 4). The other treatments yielded on par with the control implying that those substrates could be used for mushroom cultivation. Differences in respect of both yield and bio-efficiency might be attributed to inherent capacity of the composts to release nutrients, present in the respective substrates. The results fall in line with the observations of Madan *et al*. (1987), Madan and Vasudevan (1989), Poppe (2000), Baruah *et al.* (2000) and Reddy (2006).

Nutritive value of mushrooms was significantly influenced by the type of composts used for their cultivation. Proteins were higher in T_3 (29.83%) and least in T_1 (24.61%) *i.e.,* control. In other treatments proteins ranged from 27.57 to 29.62 per cent which were higher than the control. The total sugars, fat and fibre contents were less in the treatments compared to the control. The total sugar in control was 61.20 per cent which was highest and in treatments it ranged from 52.90 to 55.30 per cent. Fat in treatments ranged from 3.64 to

Table 1: NPK contents of compost before and after cropping

Treatments	Before cropping (%)			After cropping (%)		
	N	P	K	N	P	K
T_1	3.37	2.61	1.62	3.35	3.02	1.75
T_2	6.78	3.72	2.64	6.88	4.78	2.81
T_3	6.39	3.71	2.61	6.82	4.62	2.58
T_4	6.17	3.36	2.11	6.60	4.04	2.46
T_5	5.98	3.31	2.48	6.28	4.22	2.43
T_6	5.68	3.37	2.17	6.00	3.90	2.46
T_7	3.91	3.01	2.88	4.45	4.14	2.19
T_8	3.81	3.05	1.56	4.40	4.17	2.08
CD at 5 %	0.756	0.335	0.284	0.692	0.241	0.383

Table 2: Microbial counts in the compost at different stages of composting

Days / Treatments	Bacteria ($\times 10^5$ / g)					Fungi ($\times 10^3$ / g)					Actinomycetes ($\times 10^2$ / g)				
	0	7	14	21	28	0	7	14	21	28	0	7	14	21	28
T_1	3.90	5.80	7.40	12.70	9.90	4.20	5.80	7.00	10.40	7.40	2.60	4.80	6.40	11.90	8.30
T_2	4.90	6.70	8.10	13.00	9.90	3.80	5.00	7.20	11.60	7.90	3.00	5.00	6.80	10.90	7.90
T_3	4.10	6.90	8.70	14.20	9.58	3.70	5.40	7.20	11.50	8.30	4.00	5.20	7.10	11.00	7.90
T_4	3.40	6.20	8.40	13.00	8.50	4.20	5.60	7.50	11.00	8.50	2.70	4.70	6.80	10.80	7.80
T_5	3.50	5.50	7.50	12.80	9.80	3.90	5.70	7.70	10.80	7.90	3.00	5.20	7.20	11.00	7.90
T_6	3.70	5.70	7.60	13.60	9.90	3.90	5.80	7.70	11.40	8.30	2.50	4.60	6.70	10.60	7.30
T_7	3.40	5.90	8.30	13.20	9.20	4.60	5.60	7.50	11.00	8.00	4.50	6.20	8.00	12.30	8.70
T_8	4.30	6.60	8.30	12.50	9.70	5.00	6.10	8.30	11.50	8.60	3.70	5.20	6.70	11.20	8.80
CD at 5 %	1.17	1.15	1.42	1.73	1.45	1.10	1.03	1.05	1.38	1.05	1.16	1.03	1.06	1.66	1.27

Table 3: Cellulose and lignin contents in the compost at different stages of composting

Days Treatments	Cellulose (%)					Lignin (%)				
	0	7	14	21	28	0	7	14	21	28
T_1	28.09	25.72	23.57	20.72	19.39	34.30	30.35	26.98	25.24	21.51
T_2	29.21	27.45	24.28	21.25	17.92	33.74	29.74	26.14	22.98	19.86
T_3	29.70	27.16	24.32	18.53	16.92	35.31	30.83	26.99	34.04	20.36
T_4	29.67	27.29	25.06	20.99	18.13	34.79	30.00	27.63	24.15	21.50
T_5	29.90	27.22	23.98	20.91	18.15	35.67	29.94	26.40	23.78	20.88
T_6	29.83	27.04	23.81	21.17	18.36	34.23	29.59	25.49	23.87	21.19
T_7	28.56	26.34	24.96	21.41	17.60	35.90	31.47	25.95	24.36	21.79
T_8	28.52	26.12	23.71	21.03	18.14	35.56	31.82	28.52	24.62	21.09
CD at 5 %	1.37	1.09	1.47	2.51	1.74	1.78	2.30	2.40	1.45	1.60

Table 4: Button mushroom yield and nutrition status as influenced by the strata

Treatments	Button mushroom yield (g)	Bio-efficiency (%)	Proteins (%)	Total sugars (%)	Fat (%)	Fibre (%)
T_1	914.56	62.13	24.61	61.20	5.94	9.63
T_2	906.33	60.40	29.62	53.90	4.43	8.84
T_3	858.71	57.20	29.83	54.00	4.52	8.72
T_4	836.90	56.73	27.57	54.20	4.78	8.62
T_5	792.83	52.80	27.90	54.70	4.46	8.47
T_6	806.11	53.73	29.35	54.00	3.64	8.49
T_7	809.72	59.33	28.91	52.90	4.19	8.46
T_8	864.58	58.80	28.17	55.30	4.16	9.05
CD at 5 %	20.43	2.23	1.01	1.75	0.21	0.43

4.78 per cent and highest (5.94%) in control. In control, fibre content was recorded to be highest (9.63%) while in other treatments it ranged from 8.46 to 9.05 per cent (Table 4). The variation exhibited with respective values of button mushrooms grown on different composts might be due to the varied composition of nutrients in different substrates, which might have contributed to the nutritional profile of mushrooms. The above results fall in line with the results of Chang *et al.*(1981), Chang and Miles (1989), Madan *et al*. (1987), Madan and Vasudevan (1989), Poppe (2000) and Reddy (2006).

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 486-491

ECONOMIC IMPACT OF A MULBERRY BASED FARMING SYSTEM - AN EMPIRICAL STUDY

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ABSTRACT

The present study was conducted to ascertain the impact of mulberry based farming system at the farmers' level in Kolar and Bangalore (Rural) districts. The distribution of costs in production, returns associated with sericulture and other associated crops in the existing farming system were studied. The net farm income from sericulture was found to be highest compared to all the other crop enterprises. While the net farm income derived from sericulture was Rs. 75,907 per hectare per year in Kolar district, the same was Rs. 59,113 per hectare per year in case of Bangalore (Rural) district. It was found that the net income derived from the integration of mulberry sericulture with other crops yielded higher net returns.

Key words: Cost concepts, Farming system, Net farm income, Productivity, Risk in production, Value addition

INTRODUCTION

Resources of production will come under extreme pressure for consumption as a result of growing demand from the farm sector. Under the conventional farming system which mainly focuses on the growing of traditional crops for sustenance will no longer benefit the mass of rural population because of lack of market price. With the predominant small size holdings, in India, traditional agriculture has limited role to play in eradicating poverty and hunger. Possibility of increased size of holding being less, diversification in the farming sector to high value crops and enterprises may hasten farmers' income and livelihood. In this regard integrating activities which can effectively utilize the available resources at the farm level would be beneficial.

Farming system is an integrated set of activities, that farmers perform in their farms with their resources under the prevailing circumstances to maximize the productivity and net farm income on a sustainable basis. The main characteristics of the farming system involves four basic elements:

i) farm resources – land, labour & capital

ii) consumption needs – food, clothing, social obligations and other needs

iii) farm enterprises – crops, livestock, and off-farm activities

iv) the environment – physical and socio-economic.

Nagaraja *et. al*., (2001) defines farming system as an integrated set of activities that farmers perform in their farms under their resources and circumstances to maximize the productivity and net farm income on a sustainable basis. The present study has been made to identify types of farming system and to assess the potentialities for increasing farm income through reallocation of resources in farming system

Integrated farming systems are probably as old as farming itself if the broadest definition of integrated farming is accepted. According to this, integration occurs when outputs (usually by-products) of one production sub-system are used as inputs by another, within the farm unit (Imre Csavas, 2002).

Value addition in sericulture: The concept of value addition emanates as a result of continuous changes that take place in the process of production. In sericulture, the value addition is experienced right from the mulberry leaf production, silk cocoon rearing, raw silk reeling and finally silk dyeing, twisting, weaving for silk fabrics besides the utilization of by-products generated at each cycle of

production. In each of these stages, the transformation of each of the intermediary products confines to the process of utilization under different factors of production at various stages. The concept of integrated farming gains importance from the point of view of effective resource utilization and higher risk coverage for the crop enterprises. The enterprises involved in a mixed farming system, emanate as one standard or main followed by two or more subsidiaries. These subsidiary enterprises being complementary, adds incremental net gain to the economy.

The present study was conducted in order to analyse the economic impact of the mulberry based farming system in terms of performance of sericulture as compared to other economic enterprises within the farm in a mulberry farming system, at the farmers' level.

MATERIALS AND METHODS

Under the study Kolar and Bangalore (Rural) districts of Karnataka were selected purposively as these districts have major area share under mulberry. The selected districts put together constitute more than 50 percent of the area under mulberry in Karnataka, thereby revealing the importance of mulberry sericulture on the livelihoods of the people. A survey was conducted in the farmers' fields by selecting the farmers (n = 120) at random followed by an interview with a designed questionnaire. Data on important technological inputs, the impact on productivity, income and employment were elicited. The enterprise budgets were prepared using the various cost concepts for all the major enterprises.

Simple tabular analysis was used to estimate the costs, returns and employment generation in mulberry cultivation and silkworm rearing. For determining the cost structure, of the farms, a method similar to the farm management studies (Sadhu and Mahajan, 1985) has been adopted. There are a few important cost concepts such as Cost A_1, Cost A_2, Cost B_1, Cost B_2, Cost C_1 and Cost C_2 (Singh, 1993), which have been worked out in the current study. The input items included under each category of cost are indicated below:

Accounting costs and returns: The variable costs include wages for owned and hired human labour, owned and hired bullock power, cost of farmyard manures and fertilizers, interest on working capital, maintenance charges, land revenue, cost of DFLs or chawki worms, hiring charges of mountages, disinfection, marketing, maintenance and other miscellaneous expenses used in mulberry cultivation and silkworm rearing. The fixed costs include apportioned costs of establishment of mulberry garden, depreciation on farm implements, equipments, rearing house and appliances and interest on fixed capital. The gross income was valued at total value of cocoons sold in the market plus returns from by-products namely, the stems, left over leaves and litter, which is the rearing bed refuse.

Cost concepts and procedure for evaluation

Type of cost		Inputs
Cost A1	=	Hired human labour, hired and owned bullock labour, hired and owned machine labour, value of Farm Yard Manure (FYM), value of chemical fertil isers, Irrigation, value of plant protection, land revenue, depreciation charges, Disease Free Layings (DFLs) including chawki silkworms, materials for disinfection of rearing house, bed disinfectants, marketing & transport cost, interest on working capital, other miscellaneous cash expenses
Cost A2	=	Cost A1 + rental value of leased in land
Cost B1	=	Cost A2 + interest on fixed cost
Cost B2	=	Cost B1 + rental value of owned land
Cost C1	=	Cost B1 + imputed value of family labour
Cost C2	=	Cost B2 + imputed value of family labour

On the basis of these concepts, total costs of inputs per acre were worked out for sericulture as well as other important crop enterprises in the selected districts. The cost computation was done for the individual groups of adopter and non adopter categories of technologies in sericulture.

The estimates of gross income per acre for the sericulture and other important crops were also estimated based on the prevailing market price and presented. The important measures of farm profit are net farm income, farm investment income, family labour income and farm business income. These different income concepts are defined and used in the present analysis is as follows:

The estimates of gross income per acre for the sericulture and other important crops

Gross Farm Income	=	Gross value of output, including by-product
Net Farm Income	=	Gross Income – Cost C2
Farm Investment Income	=	Net Income + Rental value of owned land
Family Labour Income	=	Gross Income – Cost B2. Also refers to return to family labour and management.
Farm Business Income	=	Gross Income - Cost A1 and A2

RESULTS AND DISCUSSION

The distribution of costs and returns from major crops from the selected two districts were studied. It indicated that, the enterprise sericulture was found to be economically feasible when compared to other crops grow at the farmers' field (Table 1). It was found that the mulberry production cost was as high as Rs. 42,852.21/ha/year in case of Kolar district followed by Rs. 32,558.57 /ha/year in case of Bangalore (Rural) district. Similarly the silkworm rearing cost was as high as as Rs. 60,740.34/ha/year in case of Kolar district followed by Rs. 55,498.55 /ha/year in case of Bangalore (Rural) district.

Table1: Production Cost of Mulberry and Silk Cocoon at the farmers' level (Value in Rs/ ha/year)

Item	Bangalore (Rural)	Kolar	Overall
A. Mulberry production			
Human labour (Hired)	6043.88	2981.69	4512.79
Human labour (Owned)	6290.57	3952.48	5121.53
Bullock labour (both owned & hired)	1489.62	2073.56	1781.59
Farm Yard Manure	5271.24	12655.12	8963.18
Fertilizers	6353.7	8784.71	7569.21
Plant protection	144.34	0	72.17
Irrigation	805.51	2423.57	1614.54
Miscellaneous	783.49	1826.85	1305.17
Land revenue	79.85	82.11	80.98
Apportioned cost of establishment of garden	1069.22	2065.93	1567.57
Rental value of land	3399.78	4789.98	4094.88
Mulberry production cost	32558.57	42852.21	37705.39
B. Silkworm Rearing:			
Human labour (Hired)	13104.68	9898.41	11501.55
Human labour (Owned)	10722.02	14244.06	12483.04
DFLs	9576.65	6748.74	8162.7
Material	4857.52	7022.26	5939.89
Hiring charges for mountages	2574.98	4321.09	3448.04
Marketing	2690.04	1323.69	2006.87
Miscellaneous	516.19	2159.18	1337.68
Depreciation cost of rearing house & equipments	9514.98	12738.88	11126.93
Interest on fixed cost (@ 12 per cent per annum)	1141.8	1528.67	1335.23
Interest on working capital (@ 12 per cent per annum)	799.69	755.35	777.52
Silkworm rearing cost	55498.55	60740.34	58119.45

Table 2: Costs Associated with Sericulture

Costs associated	Cost components	Bangalore (Rural)	Kolar	Overall
Cost A1	Value of all the inputs including hired human labour, hired and owned bullock labour, hired and owned machine labour, land revenue, depreciation charges, interest on working capital, other miscellaneous cash expenses	66502.9	79077.4	72790.2
Cost A2	Cost A1 + rental value of leased in land	66502.9	79077.4	72790.2
Cost B1	Cost A2 + interest on fixed cost	67644.7	80606	74125.4
Cost B2	Cost B1 + rental value of owned land	71044.5	85396	78220.3
Cost C1	Cost B1 + imputed value of family labour	84657.3	98802.6	91730
Cost C2	Cost B2 + imputed value of family labour	88057.1	103593	95824.8

Table 3: Measures of Profit in Sericulture

Type of Income	Components	Bangalore (Rural)	Kolar	Overall
Gross Farm Income	Gross value of output, including by-product	147170.5	183978.8	165574.6
Net Farm Income	Gross Income – Cost C2	59113.39	80386.23	69749.81
Farm Investment Income	Net Income + Rental value of owned land	62513.17	85176.21	73844.69
Family Labour Income	Gross Income – Cost B2. Also refers to return to family labour and management.	76125.99	98582.77	87354.38
Farm Business Income	Gross Income - Cost A1 and A2	80667.57	104901.4	92784.49

Table 4: Costs and Returns from Major Crops in Kolar District

Particulars	Paddy (Rs/ha/crop)	'Ragi' (Rs/ha/crop)	Tomato (Rs/ha/crop)	Mango (Rs/ha/year)	Sericulture (Rs/ha/year)
Total cost C2	38340.00	25125.60	41837.00	39710.00	103592.55
Income from main product	61560.00	30495.60	59430.00	70686.00	172031.78
Income from by-product	9200.00	7100.00	2125.00	700.00	11947.00
Total Income	70760.00	37595.00	61555.00	71386.00	183978.78
Net Farm Income (Gross Income – Total Cost)	32420.00	12469.40	19718.00	31676.00	80386.23

Table 5: Costs and Returns from Major Crops in Bangalore (Rural) District

Particulars	Paddy (Rs/ha/crop)	'Ragi' (Rs/ha/crop)	Pulses (Rs/ha/crop)	Coconut (Rs/ha/year)	Sericulture (Rs/ha/year)
Total cost C2	41062.80	27880.16	24915.77	33225.00	88057.12
Income from main product	57376.00	32376.00	32376.00	57200.00	141283.73
Income from by-product	12000.00	5520.00	5520.00	4450.00	5886.82
Total Income	69376.00	37896.00	37896.00	61650.00	147170.55
Net Farm Income (Gross Income – Total Cost)	28313.20	10016.00	12980.23	28425.00	59113.43

Table 6: Integration of mulberry sericulture with other economically important crops

Particulars	Net Farm Income(Rs/ha/yr)	Employment (Mandays/ha/yr)
Agril. crop + Sericulture	76725.95	894
Agril. crop + Sericulture + Livestock	70515.18	809
Agril. crop + Sericulture +Plantation	67315.18	769
Agril. crop + Sericulture + Vegetable	78515.18	861
Agril. crop + Sericulture + Livestock + Plantation	65564.68	746
Agril. crop + Sericulture + Livestock + Vegetables + Plantation	70581.18	778

The various costs associated in sericulture in the two sample districts were studied (Table 2). It was found that the cost A1 was as high as Rs. 79077.40 /ha/year in case of Kolar district followed by Rs. 66502.90 /ha/year in case of Bangalore (Rural) district. Similarly the Costs A2, Cost B1, Cost B2, Cost C1 and Cost C2 were also worked out assigning the requisite cost component. It was found in all the cases the costs associated were high in Kolar district than Bangalore (Rural) district. The cost C2 which associates all cost components including the imputed value of family labour also was as high as Rs. 103593.00 /ha/year in case of Kolar district followed by Rs. 88057.10 /ha/year in case of Bangalore (Rural) district.

The measures of farm profit using the income concepts was worked out (Table 3) and it was found that the Gross farm income from sericulture was found to be Rs. 1,65,574.60 /ha/year, followed by the net farm income of Rs. 69749.81 /ha/year. In case of Kalor district, the gross farm income was as high as 183978.80 /ha/year followed by Bangalore (rural) district at Rs. 147170.50 /ha/year. The net farm income from sericulture was highest in case of Kolar district at Rs. 80,386.23 /ha/year followed by Bangalore district at Rs. 59,113.39 /ha/year.

The costs and returns associated from other major crops of the districts was also worked out on the similar grounds and it was found that, paddy was the next best alternative crop compared to sericulture in Kolar district (Table 4). The net farm income from paddy was found to be Rs. 32,420 /ha/year followed by mango (Rs. 31,676/ha/year), tomato (Rs. 19,718/ha/year) and ragi (Rs. 12,469.40/ha/year). The net farm income from sericulture in Kolar district was highest with Rs. 80,386/ha/year as compared to other economically important crops in the district.

The costs and returns associated from other major crops of Bangalore (Rural) district also was worked out on the similar grounds and it was found that, coconut was the next best alternative crop compared to sericulture (Table 5). The net farm income from coconut was found to be Rs. 28,425 /ha/year followed by paddy (Rs. 28,313 /ha/year), pulses (Rs. 12,980 /ha/year) and ragi (Rs. 10,016/ha/year). The net farm income from sericulture in Bangalore (Rural) district was highest at Rs. 59,113.43 /ha/year as compared to other economically important crops in the district.

The integration of mulberry sericulture with other economically important crops was studied and the net farm income derived for an unit of one hectare was worked out (Table 6). It was found that the net income derived from the integration of mulberry sericulture with other crops, yielded higher net returns. With the combination of sericulture with enterprises like field crops and vegetable crops, the net farm income was highest (Rs. 78,515 per hectare per year) followed by the combination of sericulture with field crops (Rs. 76,725 per hectare per year). The combination of sericulture with livestock (Rs 70,515/ha/year), plantation crops (Rs. 70515 /ha/year) also yielded highest net farm income than the income derived from mono cropping. The mandays employed enhanced considerably with combination of sericulture with other farm enterprises.

CONCLUSION

Based on the results obtained from the study indicated that the mulberry sericulture based integrated farming system can effectively bring about enterprise diversification for sustainability and additional benefits, thereby reducing risk in production. Mulberry sericulture in the study area was found to be a successful enterprise for any crop combination. The study brought out that effective combination of enterprises in mulberry can aid in increasing farm income. This however increases the entrepreneurial ability of the sericulture farmers. Thus the efficiency of production can be increased at the farmers' level, with effective combination of enterprises, thus enhancing the managerial efficiency and decision making capacity of the farmers. The mulberry based farming system also was found to hasten better management of farm resources, as could be seen from the results of the study.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 492-496

SERICULTURE SCENARIO – CHINESE DOMINANCE AND INDIAN STRATEGIES

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ABSTRACT

Silk is precious commodity with high value and low volume. Globally over 30 countries are engaged in the production and processing of the silk, but it is consumed by almost all countries in the world. India and China are the two major players at the global platform as far as silk production, processing and trade are concerned. The share of China and India in total world raw silk production is 82% and 15.50% respectively. The average growth of raw silk production of last 10 years in case of China is more than 8%, compared to India's growth rate of around 5.50%. In view of its major share, China dominates the sericulture industry internationally. Though India is second largest silk producing country, the gap between China and India is very wide. However, India plays major role at international silk scenario despite the Chinese dominance. The standard of the Indian Sericulture Training Institutes is well recognized globally. These Training Institutes render advanced training and consultancies in different areas of the sericulture to the sericultural countries. India is the leading exporter of the quality silkworm seed to the silk producing countries. Besides it is an active and founder member of International Sericulture Commission (ISC). At national level, sericulture is practiced in India in 27 states and it plays a major role in Indian economy in terms of providing employment to the rural people, earning foreign exchange and flow of money from rich to poor. Sericulture is a major venture of remunerative income for more than six million people. Many key sectors of Indian silk industry are at par with the China and in some cases it has upper hand over latter.

Key words: Chinese sericulture, Economy, Growth rate, Indian strategies, Silk trade

INTRODUCTION

Sericulture industry enjoys the prominent place at international level in spite of its meager production. The silk fibre constitutes 0.39% in total global natural fibre production whereas it shares 0.18% in global natural and man made fibre production. However, actual trading value of silk and its products is much more impressive. In fact, it is a multi billion dollar trade with unit price for raw silk roughly 20% that of raw cotton and much more of man made fibre. In silk sector, India and China are the two major players at global platform. The share of these two countries in total world raw silk production is in order of 81.89% and 15.51% respectively. Globally, over 30 countries are engaged in production of silk of which, 16 are from the Asian continent accounting more than 95% of the total world silk production. The major countries are China, India, Brazil, Uzbekistan, Thailand, Vietnam, Korea Republic, and Indonesia. Sericultural countries are classified into three categories *viz*., silk producing, silk consuming and silk exporting country. Country-wise raw silk production and their share in total production are given in Table 1.

Table 1: Raw silk production in major silk producing countries [Unit MT]

Country	2002	2003	2004	2005	2006	2007	2008	2009	% share
China	68600	94600	102560	105360	130000	108420	98620	104000	81.89
India	16319	15742	16500	17305	18475	18320	18370	19690	15.51
Japan	394	287	263	150	150	105	95	90	0.07
Brazil	1607	1563	1512	1285	1387	1220	1177	811	0.64
Korea Republic	154	150	150	150	150	150	135	135	0.11
Uzbekistan	1260	950	950	950	950	950	865	750	0.59
Thailand	1510	1500	1420	1420	1080	760	1100	665	0.52
Vietnam	2200	750	750	750	750	750	680	550	0.43
Others	3814	1500	1500	1500	1000	500	350	304	0.24
Total	95858	117042	125605	128870	153942	131175	121392	126995	100

The China's annual growth rate of the silk production during 2002 to 2009 was 6.45% whereas in case of India, it was 2.58% compared to 4.06% of annual growth of total global raw silk production. Ironically, the annual growth rate of raw silk production of the rest of the silk producing countries had negative trend (-8.72%). It would be worthwhile to mention that, Japan was the leading silk producing country till 1970. Chinese silk industry is well organized and unlike India, their production is at large scale. Therefore, their cost of production is 30-40% less compared to us. However, the Chinese silk industry is also passing through some basic problems like increasing labour cost. Because of the giant size of the industry, China plays prominent role in global silk scenario and also dictates the industry directly or indirectly.

India's total raw silk production has increased significantly from 886 MT during early 1950s to 19,690 MT during 2009 registering an annual growth rate of more than 5.5 %. The basic difference of the Chinese and Indian silk industry is that former has the export oriented industry and consumes hardly 15-20% of its total raw silk production indigenously whereas India depends upon the import to meet out the domestic demand. A comparison of silk industry between China and India is shown in Table 2.

The comparative analysis shows that the size of the industry of China is many times bigger than India. Besides, the China has an edge over India in respect of productivity and other parameters. Undoubtedly, quality-wise also China is ahead of India.

India plays a major role at international silk scenario despite the Chinese dominance. India is an active founder member of the International Sericulture Commission (ISC) having its headquarters in Lyon France. ISC is the only international forum of silk and is an inter-governmental organization. China is not the member of the ISC. Moreover, India enjoys the creditability at international sericulture forum, because of its commitment towards the industry, transparency, cooperative attitude and democratic set up of governance. The Indian sericultural research and training institutes are globally well recognized and quality of the Indian silkworm seed and training is of par excellence. India plays an active role in providing training, supply of quality silkworm seed and consultancies to other sericulture countries. Moreover, India is a traditional sericulture country, cultivator of all four commercially known varieties of silk and enjoys monopoly in Muga silk production. China considers India as its main competitor and has industrial rivalry.

Sericulture Industry in India

At national level, sericulture has an important place in India's economy. It is a labour intensive industry which requires nominal capital investment. Sericulture is practiced as a cottage industry in 25 states covering more than 50,000 villages and providing remunerative employment to around 6 million people at their door steps. The industry is eco-friendly and helps to check the migration of the people from village to cities in search of employment. It can be inferred from Table 3 that the total raw silk production of the country during 2009-10 was 19,690 MT, of that non-mulberry silk accounted for 17.10% (3368 MT).

Sericulture industry is instrumental for socio-economic reform as 60% of the beneficiaries are women and from the weaker section of the society and money flows from the rich people to the poor in transaction of the silk.

Table 2: Comparative picture of sericulture industry in India and China

Particular/Parameter	Unit	China	India
Output value (estimated)	US$ Bn.	31.25	0.60
Exports	US$ Bn.	5.50	1.00
Nature of the industry		Organized and global market oriented	Unorganized and domestic market oriented
Silk producing states	No.	26	25
Area under mulberry	Lakh ha	7.36	1.84
Mulberry leaf yield	MT/ha/year	25 to 30	30 to 50
Race reared		All Bivoltine	Mostly cross breed
Egg production	Crore dfls	51.94	9.84
Supply system		Majority chawki reared	Majority as egg
Time of supply		Batch wise	Throughout the year
Crops per year	No.	6-8 tropical (staggered) 2 – 3 temperate	8-12 Tropical (split spot system) 1-2 temperate
Dfls brushed	No./ha/yr.	1050	1492
Cocoon yield	kg./100 dfls	84.00	52.85
Raw silk productivity	kg/ha./yr.	96.4	88.82
Leaf cocoon ratio		16-18	20-22
Cocoon weight	g	1.9-2.0	1.6-1.8
Shell %		21-23	CB = 17-19 BV = 20-22
Filament length	m	> 1000	< 1000
Renditta		6.4	8 (BV-6.7)
Grade of silk		A – 5A	Ungraded to A g r.
Prevailing cocoon price	Rs./kg	138.00	BV: 205.00 CB: 175.00
Average crop loss	%	3 - 5	6 – 8
Demand and supply position		90% export	Self consumption. 30% deficit.

Table 3: Variety wise silk production in India during 2009-10

Variety	Raw silk (MT)	%
Mulberry (CB)	15122	76.80
Mulberry (BV)	1200	6.10
Tasar	803	4.08
Eri	2460	12.49
Muga	105	0.53
Total	19690	100

The industry has also the good employment potential. It is estimated that sericulture can generate employment of 6,402 mandays or 26 manyear from one hectare of mulberry sericulture activities right from mulberry cultivation and silkworm rearing to reeling of cocoon, twisting, weaving, printing, dyeing *etc*.

Employment generation through sericulture is showing increasing trend (4.37%) during 2009-10 over previous year. Export earnings from silk are growing steadily because of increasing demand of silk goods. During 2009-10, the country's total export of silk was US$ 605 million (Rs.2871.79 crore). The Indian silk good have high export potential because of its distinctiveness and low production cost.

In India, sericulture is a state subject. The management of sericulture sector has been broadly entrusted to followings:

- Govt. of India (Through Administrative Ministry)
- Central Silk Board
- State Govts.(through respective SDD)
- NGOs/Co-operative societies
- Universities
- Indian Silk Export Promotion Council (ISEPC)

The major constraints of the Indian silk industry are its

domestic market oriented nature, highly unorganized and many implementing agencies, dominance of inferior quality and availability for market for the same, poor/moderate financial status of stakeholder, inappropriate extension and marketing system, low credit, taking up of the quality improvement programme as a complementary, dominance of the rainfed nature of the host plant cultivation, low land holdings etc. However, R & D sector is making the sincere efforts so as to increase the production and productivity but the same is not being translated in the field because of the inappropriate transfer of technology due to obvious reasons.

In our country, consumption of the dfls per unit area is much higher (>25 %) compared to China whereas Cocoon yield, raw silk productivity, leaf cocoon ratio are less by 37.08%, 7.86% and 20%, respectively. These lacunae can be dealt very well by strengthening the extension system covering training, proper disinfection, rearing facilities etc. with effective management supported with innovations both at government and farmers level. Central Silk Board is making the best efforts in this direction by implementation of the Catalytic Development Programme in the country from IX plan onward in association with the State governments.

Approach and strategy

Now the question arises whether India can really compete with China in quantitative and qualitative terms. With the present sericulture scenario in both countries, it can be admitted honestly that quantity-wise it would not be possible for India to surpass the China. However, with perfect policy and efficient management, India can very well compete with China in terms of the quality and establish its effective existence at international platform. In this endeavour, India has to act both at international and national level right from R&D, extension, trade sector. Following approach and strategies would be useful to take up the above mission:

a. At international level

- More bilateral agreement/cooperation in the field of sericulture with the silk producing countries like Japan, Vietnam, Israel, Indonesia, Bulgaria, Sri Lanka, Nepal, Bangladesh etc. to improve the sericulture relation with them. The agreement should be in the field of R&D sector, training, supply of the silkworm seed, providing of consultancy services and taking up of the sericulture programme in these countries.
- Active participation and role in the programmes of International Sericulture Commission (ISC), Lyon (France).
- Efforts for introduction and development of sericulture in African countries like Uganda, Ghana *etc*., as these countries enjoys good potential for sericulture.
- Promotion and branding of **Indian Silk** with quality assurance through **Silk Mark Organization of India**. Active participation in international exhibitions so as to establish Indian Silk globally.
- Geographical identification (GI Tag) for well-known silk produced in India with the Ministry of Commerce & Industry for promotion in international market.

b. At national level

Govt. of India

- Approach should be oriented towards international market but without ignoring the domestic market.
- Formulation of the National Sericulture Policy in view of the tough competition from China, capability of sericulture industry, provide remunerative employment to rural people and enhance trade value of the silk and export potential.
- Formulation of laws/rules and regulations for effective and friendly transaction of silk business.
- Effective coordination and inter-ministerial linkages particularly among Ministry of Agriculture, Forest & Environment, Rural Development etc.

Central Silk Board

- Strengthening the extension, training, marketing and management.
- Approach should be vertical as land and water are precious.
- Strengthening of the research institutes particularly CSR&TI, Pampore (J&K), Berhampore (West Bengal) and CTR&TI, Ranchi (Jharkhand).
- Product diversification and adding value to the by-products commercially.
- Concentration on development of rainfed sericulture and making sericulture less labour intensive.
- Stabilization of 2nd and 3rd crop of mulberry sericulture in temperate and sub-temperate regions so as to make the industry more lucrative.
- Non-mulberry or Vanya silk has the vast potential. Moreover, India does not face significant challenges/competition from China in Vanya sector. Therefore, thrust should be on Vanya silk production.
- For bivoltine, Himachal Pradesh, Manipur, Uttarakhand, J&K and Tamil Nadu have vast potential. Therefore, a forum for these states be created to formulate and execute the bivoltine programme. Bivoltine activity should not be complementary.
- Besides the R&D activities, thrust should be on innovations as innovation requires low investment,

less infrastructure and time. Therefore, CSB institutes should formulate a road map of Research and Innovation Programme (RIP) to deal with the problem of the industry.

- Substantial infrastructures both at government and private level have been developed through Catalytic Development Programme (CDP) during IX, X & XI Plan (upto 2009-10) in the country.
- A large numbers of beneficiaries have been covered under CDP in the country. Effective monitoring of the CDP is prime need so as to ensure maximum outcome in term of quality, quantity and productivity.
- Sericulture is an unorganized activity in the country. People are not aware about the sericulture programmes and procedure involved therein to take up these programmes. Therefore, a single window system approach should be adopted through which all information right from soil to silk trade be made available to the people in one place.
- Setting up of Special Sericulture Zone (SSZ) in the new and existing potential areas on the pattern of ongoing Special Economic Zone (SEZ).

State governments

- Sericulture should be on priority list.
- Maximum utilization of Centrally Sponsored Schemes like CDP, RKVY and MNREGA etc.
- Steady replacement of the local mulberry varieties and strengthening of the field extension management.
- Recruitment process should be gear up.
- Maximum use of vermicomposting and use of organic manure particularly in non-traditional states
- Creation of independent Sericulture Department in those states where it does not exist.
- States having similar background, topography and common problems, should be clubbed together for discussing their problems and making common strategy for sericulture development. These states should have close rapport among them.
- Promotion of the NGOs in sericulture development but selection of the NGOs should be done carefully.

Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 497-499

ECONOMICS OF SERICULTURE *VIS-À-VIS* COMPETING CROPS IN ANANTHAPUR DISTRICT OF ANDHRA PRADESH

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ABSTRACT

Sericulture has become one of the prime occupations, as it requires less water for mulberry cultivation and minimum gestation period. Ananthapur is one of the important districts on the sericultural map of Andhra Pradesh. The district has 35% of the total mulberry plantation of the state. One of the major reasons for the decline in mulberry area and thereby reduction in cocoon production in recent years in Andhra Pradesh is the competition from other cash crops. The stability and sustainability of sericulture enterprise highly depends on its economic viability vis-à-vis other competing crops. Therefore, the profitability from sericulture in Anantapur district of Andhra Pradesh was compared with that of other agricultural crops.

Key words : Andra Pradesh, Competing crops, Economic viability, Sustainability

INTRODUCTION

Ananthapur district is one of the backward regions of Andhra Pradesh. Due to recent problems of drought and lack of permanent water resources, sericulture has become one of the prime crops. The district is having about 35% of the total mulberry acreage of the state. About 29750 farmers in 4700 ha cultivate mulberry (Anonymous, 2007). Sericulture provides continuous income throughout the year. Recent fluctuations in the price of raw silk have drastically affected the prices of cocoons (Kumaresan and Vijayaprakash, 2001 and Purushotham and Rama Mohana Rao, 2009).

The stability and sustainability of sericulture enterprise highly depends on its economic viability vis-à-vis other competing crops mainly paddy, groundnut and sunflower in the study area. Hence, an attempt has been made to study the comparative economics of sericulture with the other major crops cultivated in six villages which have the highest area under mulberry in the district.

MATERIALS AND METHODS

Six villages namely Beedanapalli, Sanipalli, C.H. Palli, Gopurampalli, Peddipalli and Mahadevapalli of Ananthapur district in Andhra Pradesh were purposively selected for the study as sericulture is practiced by a large number of farmers along with other major agriculture crops such as groundnut, paddy and sunflower. Data from fifteen farmers from each village were collected, analysed and presented.

RESULTS AND DISCUSSION

Major agricultural crops cultivated in Ananthapur sistrict are presented in Table 1. Groundnut is the major oilseed crop cultivated in the district with 8,99,035 ha followed by bengalgram (49,105 ha), sunflower (48,477 ha) and paddy (48,150 ha). redgram, fresh fruits, maize, jowar, vegetables and mulberry are the other main crops cultivated in the district. Sericulture is practiced in an area of 4707 ha. The economics of sericulture and other major crops namely, paddy, groundnut and sunflower cultivated in the study area of Ananthapur district was worked out. The crops cultivated other than mulberry are annual crops with life duration of 3 to 4 months. In the study area generally farmers cultivate only one crop per year because of scarcity of water resources. Sericulture activities are entirely different from other agriculture crops cultivated in the area. Sericulture involves mulberry cultivation and silkworm rearing.

Economics of sericulture (cocoon production) is presented in Table 2. Labour was the main input in the production of mulberry leaf (Rs. 7505.35/acre/year) followed by farmyard manure and fertilizers, which were estimated to Rs 6150.40 and Rs 2893.25 per acre per year,

respectively. Economic life of mulberry garden was approximated for 15 years and calculated as Rs. 1595.15 per acre. The total leaf production cost was worked out to Rs. 22518.10 per acre per year. Labour was the main input in silkworm rearing also, which amounted to Rs. 18250.0. The cost incurred for silkworm seed was Rs. 3490.10. Depreciation cost on rearing building and equipment was estimated to Rs. 6234.40. The total cost incurred for silkworm rearing worked out to Rs. 33090.15. From silkworm rearing, revenue is generated from sale of cocoons and by-products as silkworm litter and leaf wastes, which can be used as manure after decomposing. The total revenue worked to Rs 1,07,513.00. The net revenue was estimated as Rs. 51904.75. The cost and return structure of major competitive crops in the area namely, groundnut, paddy and sunflower is presented in Table 3. Paddy is the major food crop and groundnut and sunflower are important oilseed crops cultivated in the area. Paddy in Ananthapur district is grown under varied agro-climatic conditions. Paddy requires more irrigation water compared to other food crops. The cost of irrigation for paddy was Rs. 1250.50. The expenditure made on labour was higher with Rs. 2827.70. The total cost of production was worked out to Rs. 11072.26. Paddy grains worth Rs. 20150.50 and the straw which is used as cattle feed, having a value of Rs.1547.70 were produced from one acre per year. Thus, the total revenue was worked out to Rs. 10623.94.

In Andhra Pradesh, groundnut is the dominant oilseed crop among major oilseeds. Groundnut cultivation requires fewer inputs compared to paddy and groundnut is cultivated as rainfed crop in the area. The cost of production worked out to Rs 5735.33 per acre per year. Total revenue was estimated at Rs 12420.25/acre/year. The net return was worked out to Rs. 4511.51.

Sunflower has become another popular oilseed crop in the recent years. The overall performance of sunflower is not encouraging as the productivity growth showed negative trend. The yield of oilseed such as sunflower is affected by the vagaries of monsoon. Sunflower requires less financial inputs and mostly cultivated as rainfed crop. The cost of production of sunflower was the least with Rs. 1802.26. Total revenue of Rs. 4455.00 was earned from the production of grains. The net returns were worked out to Rs. 2653.00.

Farmers in the area followed different crop rotations depending on the prevailing market rate of the produce, water availability, soil type and season. Overall results indicated that the revenue obtained fro sericulture was higher than all other crops cultivated in the area. The major strengths and advantages of sericulture over other crops are low capital investment with long crop stand, shorter gestation period, quick and frequent returns, easy marketing of the produce and high employment for family members. Sericulture can be integrated with other agriculture and animal husbandry activities.

Table 1: Area under major crops in Ananthapur district of Andhra Pradesh 2005-06

Sl. No.	Crop	Area (ha)
1	Groundnut	8,99,035
2	Bengal gram	49,105
3	Sunflower	48,677
4	Paddy	48,150
5	Red gram	35,013
6	Fresh fruits	26,284
7	Maize	7,393
8	Jowar	6,690
9	Vegetables	5,879
10	Mulberry	4,707

(Source: Handbook of Statistics 2005-06, Ananthapur District, Andhra Pradesh)

Table 2: Cost and return structure of cocoon production in the study area (Rs./acre/year)

Item	Cost (Rs)
I. Mulberry leaf production cost	
Bullock power	1,099.50
Farmyard manure	6,150.40
Chemical fertilizers	2,893.25
Labour	7,505.35
Plant protection chemicals	579.40
Other costs	1,145.20
Interest on working capital	1,549.85
Total cost A	20,922.95
Apportion cost of establishment of mulberry garden B	1,595.15
Total leaf production cost (A+B)	22,518.10
II. Rearing cost	
Fixed cost	
Interest on working capital	1,965.65
Equipment cost (depreciation and interest on fixed cost)	6,234.40
Recurring expenditure	
Dfls cost	3,490.10
Materials	2,850.00
Labour	18,250.00
Transportation and marketing	300.00
Total rearing cost	33,090.15
Total cost (cost of mulberry and silkworm rearing)	55,608.25
III. Revenue	
Income from cocoons	1,03,250.00
Income from by-products	4263.00
Gross income	1,07,513.00
Net returns	51,904.75

Table 3. Cost and return structure (Rs./acre/year) of crops competitive to sericulture.

Item	Cost (Rs.)/acre/annum		
	Paddy	Groundnut	Sunflower
I. COST			
Bullock power	432.10	635.40	438.50
Tractor power	1,821.8	374.60	-
Seed	368.75	819.60	270.25
Labour	2,827.70	2,011.16	515.25
Farm yard manure	935.60	790.12	190.25
Chemical fertilizers	1,496.65	936.16	233.76
Plant protection chemicals	579.25	493.45	79.25
Irrigation	1,250.50	-	-
Machine power	352.95	-	-
Other costs	275.50	300	75.00
Interest on working capital	780.96	424.84	
Total cost	1,1072.26	5,735.33	1,802.26
II. REVENUE			
Main product	2,015.50	12,420.25	4,455.00
By product	1545.70	-	
Total revenue	21,696.00	12,420.25	4,455.00
Net revenue (II – I)	10,623.94	4,511.51	2,653.00

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 500-506

AN ECONOMIC ANALYSIS OF REARING SOME PROMISING NEW MULTIVOLTINE × BIVOLTINE HYBRIDS OF THE SILKWORM *BOMBYX MORI* L. UNDER IN-HOUSE LARGE SCALE EVALUATION

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ABSTRACT

The stability and sustainability of sericulture highly depends on its economic viability vis-à-vis other competing crops of the area. Unlike other agricultural crops sericulture involves mulberry cultivation and also silkworm rearing. In the present investigation, the cost and return structures were worked out separately for each hybrid for rearing ten silkworm crops in a year at the rate of 350 dfls/crop. The new hybrid NDV6 × CSR2 exhibited the lowest cost of cocoon production (Rs. 87.23/ kg), the highest cocoon production (2,732.10 kg/ha/year), the highest average cocoon price (Rs. 163.00 /kg), the highest net profit (Rs. 2,19,519.50 /ha/year) and the highest cost benefit ratio of 1: 1.92 compared to other hybrids evaluated.

Key words: Cocoon production, Cost and benefit ratio, Economics, Inputs, Leaf production

INTRODUCTION

Sericulture is highly suitable to small and marginal farmers, who constitute a major portion of rural population, because of its nature of generating high income with comparatively less investment. More than 90 % of the mulberry raw silk production in the country depends only on multivoltine × bivoltine hybrids. The stability and sustainability of sericulture highly depends on its economic viability vis-à-vis other competing crops (Nadadur, 2000; Kumaresan and Vijaya Prakash, 2001). The prices and productivity significantly affect the profitability in cocoon production (Saratchandra, 2000; Dandin and Kumaresan, 2003). In spite of increase in production cost of commercial silkworm cocoons as well as raw silk, a downward trend in their selling prices has been observed in the last few years. This is the direct consequence of large imports of silk yarn at low prices (Oomen, 2002). Earlier a few studies were made to find out the economic prospects of sericulture in southern India at the farmers' level during different period (Lakshmanan *et al.,* 1997; Balasaraswati *et al.,* 2006; Dandin *et al.,* 2008; Lakshmanan *et al.,* 2008; Balasaraswati *et al.,* 2010) They were mostly focused on estimation of income and return profile of farmers based on the primary data but such studies failed to address economic appraisal of new silkworm hybrids in the field. Though many productive polyvoltine x bivoltine hybrids were developed and demonstrated in the field by various research institutions (Rayar *et al*., 2000; Narayanaswamy *et al*., 2002; Rao et al., 2004 a & b; Ragavendra Rao *et al.,* 2005; Umadevi *et al.,* 2005; Nazia Choudhary and Ravindra Singh, 2006; Ravindra Singh *et al., 2004 &* 2006; Dandin *et al.,* 2007; Nirupama *et al.,* 2008; Premalatha *et al.,* 2010) but their economic benefits under large scale adoption was not analyzed critically before taking them in to the field. Therefore, it is imperative to study and analyze the cost and return structure of cocoon production with the new productive hybrids before recommending them for commercial exploitation in order to appraise the economic merits of them in the field. In the present study efforts were made to investigate the cost of mulberry and cocoon production and returns per unit area of mulberry in rearing new promising multivoltine x bivoltine silkworm hybrids under large-scale evaluation.

MATERIALS AND METHODS

The present study is aimed at assessing the economic feasibility of the new multivoltine x bivoltine silkworm hybrids. One hectare of mulberry garden planted with V1 mulberry variety under paired row system and as per the package of practices recommended for irrigated condition and meant for large-scale validation of new silkworm hybrids at Technology Validation and Demonstration Center (TVDC) of CSTRI, Mysore was selected for the present study. A model of rearing ten silkworm crops in a year at the

rate of 350 dfls per crop by dividing one hectare of mulberry garden in to two equal plots was followed in the present study to utilize the resources more intensively to increase returns. Loose eggs were utilized in the study in order to maintain standard unit of egg number irrespective of the hybrid and season (A unit of 50,000 eggs are considered as 100 dfls). Since there is uniformity in the egg number, the assessment of the hybrid is more accurate and scientific. Two newly developed productive multivoltine × bivoltine hybrids namely, NDV6 × CSR2 and NP1 × CSR2 along with the control hybrid, PM × CSR2 were utilized in the study. The hybrids under the study were reared thrice during the study period covering all the seasons of a year and data were pooled together in order to avoid the seasonal variations.

The cost economics was worked out for mulberry leaf production and silkworm rearing with the hybrids under the study individually by adopting shoot rearing technique of Dandin and Giridhar (2010) under farmers simulated conditions.

RESULTS AND DISCUSSION

Cost of mulberry leaf production

Table 1 reveals the costs incurred towards establishment of one hectare of mulberry garden, which worked out to Rs. 39,580.32. Among the cost components, the highest cost was incurred for farmyard manure (Rs.10,000.00) accounting 25.27 % of the total cost followed by the man power amounted to Rs.7,600 (19.20 %) and cost of saplings amounted to Rs.7,500.00 (18.95 %). Out of the total establishment cost, human, animal and tractor power formed the major share (36.25 %). Among the inputs, farmyard manure and chemical fertilizer formed the major share (38.42 %). Laxmanan *et al.*, (1997) and Balasaraswati, (2006) also reported the similar observations. Mulberry being a perennial crop, the cost incurred on establishment of mulberry garden was apportioned to the economic life span of mulberry garden (15 years) in the straight-line method and considered as fixed cost. The fixed cost was thus, worked out to Rs. 2,638.69 /ha/year.

The costs involved for maintenance of mulberry garden for continuous leaf production are presented in Table 2. The total leaf production cost was estimated to Rs.97,381.85 and the leaf production was estimated to 60,000 kg/ha/year. Thus, the mulberry leaf production cost worked out to Rs.1.62 per kg in the present study. The present findings are in conformity with the earlier findings of Lakshmanan and Geethadevi (2005). Of the total cost of leaf production, the variable cost for the maintenance of mulberry garden was Rs.94,743.16, which accounted to 97.29% of the total cost and the remaining cost of Rs.2,638.69 was the fixed cost which accounted to 2.71% of the total cost. Among the variable cost components, man power and cost of chemical fertilizers were the major inputs amounting to Rs.45,280.00 and Rs.29,820.15 per year representing 46.49% and 30.63 % of the total cost respectively, followed by the cost of farmyard manure with Rs.10,000.00 accounting to 10.27 % of total cost.

Cost structure for silkworm rearing

Requirement of the rearing building and equipments as well as their costs for rearing 350 dfls at a time is depicted in Table 3. Its cost was worked out to Rs. 3,60,600.00 and its depreciation was Rs. 15,750.00 per year.

Like mulberry leaf production, the cost concepts of cocoon production during one-year period for rearing three multivoltine x bivoltine hybrids were also worked out and are presented in Table 4. The variable cost except the cost of leaf and fixed cost was same for all the three hybrids as the quantum of dfls reared was same. Leaf was the major input used in silkworm rearing. The lowest leaf cost of Rs. 92,080.80 was accounted for NDV6 × CSR2 followed by NP1 × CSR2 (Rs. 94,575.60) and PM × CSR2 (95,482.80) representing 38.64%, 39.27% and 39.50 % on their total cost, respectively. Manpower was the next major item that worked out to Rs. 70,000.00 for all the hybrids tested which accounted for 29% of their total cost of production. The total variable cost were estimated to Rs. 2,21,302.80 for NDV6 × CSR2, Rs. 2,23,797.60 for NP1 ×CSR2 and Rs. 2,24,704.80 for PM x CSR2 representing 92.86%, 92.94% and 92.96 % share on their total production cost. The fixed cost was estimated to Rs. 17,010.00 for all the hybrids accounting to around 7 % on their total cost of production. The total cost involved on cocoon production was Rs. 2,38,312.80 for NDV6 × CSR2, Rs. 2,40,807.60 and Rs. 2,41,714.80 for NP1× CSR2 and PM × CSR2, respectively. The total cost of production involved for NDV6 × CSR2 was less than that of other two hybrids, which was due to less consumption of mulberry leaf during rearing. The cost of production of one kg of cocoon of different hybrids was also estimated for better understanding of the cost structure. The lowest production cost per kg of cocoon was noted for NDV6 × CSR2 (Rs.87.23) followed by Rs. 91.54 (NP1 × CSR2) and Rs. 96.17 (PM × CSR2).

Profitability in cocoon production

The return structure for rearing ten crops in a year @ 350 dfls per crop with different hybrids under the study is depicted in Table 5. The highest average cocoon production per year and sale price per kg of cocoon was 2,732.10 kg and Rs. 163.00 respectively was recorded for NDV6 × CSR2 followed by NP1 × CSR2 (2,630.6 kg and Rs.159.10) and PM × CSR2 (2,513.35 kg and Rs.141.30). Thus, the highest income from sale of cocoons of Rs.4, 45,332.30/ha/year was recorded for NDV6 × CSR2 followed by NP1 × CSR2 (Rs.4,18,528.46) and PM × CSR2 (Rs.3,55,136.36). The income from by-

products such as silkworm litter and leaf waste, which can be used as organic manure after decomposition estimated to Rs.12,500.00/ha/year. The total revenue, hence, worked out to Rs. 4,57,832.30, 4,31,028.46 and 3,67,636.36 /ha/year for NDV6 × CSR2, NP1 × CSR2 and PM × CSR2 respectively. The highest net revenue was accounted to be Rs.2,19,519.50 for NDV6 × CSR2 followed by NP1 × CSR2 (Rs.1,90,220.86). PM × CSR2 recorded the least net revenue of Rs.1,25,921.56. The highest net revenue was obtained in NDV6 × CSR2 as a result of higher cocoon yield and price of cocoons. Input-output co-efficient ratio was found to be better for NDV6 × CSR2 with the cost benefit ratio of 1: 1.92 compared to 1:1.79 and 1:1.52 in NP1 × CSR2 and PM × CSR2, respectively.

CONCLUSION

The analysis clearly indicated that the cocoon price and productivity significantly affect the profitability of cocoon production. Any crop loss or significant reduction in cocoon price would adversely affect the profitability of the silkworm rearing. High productivity with low cost of production registered in the new hybrids would help the farmers to sustain even under distress conditions. Hence, the need of the hour is to educate the farmers on the economic merits of productive new silkworm hybrids to increase the productivity per unit area and also to increase the profitability in the sericulture. Besides, emphasis should be given to adopt proven technologies to cut down the cost of production thereby to increase the profit margin.

Table 1: Establishment costs of mulberry garden (duration - 6 months)

(Cost in Rs. for 1 ha)

Sl. No.	Particulars	Requirements	Value (Rs.)	% of total
1	Tractor power for tilling (10 hrs/ha), harrowing (5 hrs/ha) and making trenches (5 hrs/ha) @ Rs. 300/hr.	20 hrs.	6000.00	15.16
2	Bullock power for final land preparation (5 pairs/ha) @ Rs. 150/pair	05 pairs	750.00	1.89
3	Farmyard manure (20 MT/ha) @ Rs. 500/tonne	20 tonnes	10000.00	25.27
4	Cost of saplings (15000/ha) @ Rs. 0.50/sapling	15000 Nos.	7500.00	18.95
5	Cost of chemical fertilizers (50:50:50 kg NPK/ha after 2 months of planting)			
	• Ammonium sulphate (20% N) @ Rs. 14.50/kg.	250 kg	3625.00	9.16
	• Single super phosphate (16% P) @ Rs. 3.85/kg.	312 kg	1201.20	3.03
	• Murate of potash (60% K) @ Rs. 4.60/kg.	83 kg	381.80	0.96
		Total	5208.00	13.15
6	Man power) @ Rs. 80/manday for			
	• Planting (30 man days/ha)	30 man days	2400.00	6.06
	• Fertilizer application once after two months of planting (5 man days/ha)	5 man days	400.00	1.01
	• Irrigation (Once in a weak for 6 months @ 1 man days per ha/ irrigation)	24 man days	1920.00	4.85
	• Weeding (3 times @ 12 man days /ha/weeding)	36 man days	2880.00	7.28
		Total	7600.00	19.20
7	Miscellaneous expenditures @ Rs. 1000/ha		1000.00	2.53
8	Interest on variable costs for six months @ 8% per annum		1522.32	3.85
9	Total establishment cost		80937.43	100.00
10	Apportioned cost		2638.69	

*: On total cost

Table 2: Cost of mulberry leaf production

(Cost in Rs. for 1 ha/year)

Sl. No	Particulars	Requirement	Value (Rs.)	% share*
A	Variable costs			
1	Cost of farmyard manure (20 tonnes/ha in 2 equal splits) @ Rs. 500/tonne	20 tonnes	10000.00	10.27
2	Cost of chemical fertilizers (350:140:140 kg NPK/ha/year in 5 equal dose			
	• Ammonium sulphate (20% N) @ Rs. 14.50/kg.	1750 kg	25375.00	26.06
	• Single super phosphate (16%P) @ Rs. 3.85/kg.	875 kg	3368.75	3.46
	• Murate of potash (60% K) @ Rs. 4.60/kg.	234 kg	1076.40	1.11
		Total	29820.15	30.63
3	Man power @ Rs. 80/ man day for			
	• Farm yard manure application – 2 times in a year (10 man days/ha/ application)	20 man days	1600.00	1.64
	• Chemical fertilizer application – 5 times in a year (5 man days/ha/ application)	25 man days	2000.00	2.05
	• Irrigation (Once in a weak for 9 months in a year @ 1.0 man days/ ha/irrigation)	36 man days	2880.00	2.96
	• Inter cultivation for 5 times in a year (12 man days/ ha/ cultivation)	60 man days	4800.00	4.93
	• Mulberry shoot harvest (250 kg shoot/man day)	400 man days	32000.00	32.86
	• Pruning and cleaning of plants (5 man days/ha/crop)	25 man days	2000.00	2.05
		Total	45280.00	46.49
4	Bullock power for ploughing - 5 times in a year (02 pair/ha/plough) @ Rs. 150/ pair	10 pair	1500.00	1.54
5	Land revenue @ Rs. 125/ha/yr		125.00	0.13
6	Miscellaneous expenditure @ Rs. 1000/ha/yr		1000.00	1.03
7	Interest on variable costs @ 8% per annum		7018.01	7.21
	Total variable cost (A)		94743.16	97.29
B	Fixed cost i.e. Apportioned cost of establishment of mulberry garden (B)		2638.69	2.71
C	Total leaf production cost (A+B)		97381.85	100.00
D	Leaf yield (kg/ha/year)		60000	
E	Production cost per kg of leaf		1.62	

*: On total cost

Table 3: Investment on building and equipments for rearing 350 dfls/crop

Sl. No	Items	Quantity	Rate (Rs.)	Value (Rs.)	Life Span (years)	Depreciation (Rs.)
A	Buildings					
1	Rearing house with AC sheet (sq. ft.)	1600	200.00	320000.00	30	10666.67
B	Equipments					
1	Power sprayer (No)	1	6000.00	6000.00	10	600.00
2	Mask (No)	1	1000.00	1000.00	5	200.00
3	Flame gun (No)	1	750.00	750.00	10	75.00
4	Litter baskets (No)	1	500.00	500.00	5	100.00
5	Plastic basins (No)	5	70.00	350.00	2	175.00
6	Shoot rearing stands (32' x 5.5', 4 tier), (No)	4	3000.00	12000.00	20	600.00
7	Plastic mountages (No)	500	40.00	20000.00	6	3333.33
	Total			360600.00		15750.00

Table 5: Return structure in multivoltine x bivoltine cocoon production (for rearing 10 crops in a year @ 350 dfls/crop)

(Cost in Rs. for 1 ha/year)

Sl. No.	Particulars	T1	T2	C
1	Cocoon yield/100 dfls (kg)	78.06	75.16	71.81
2	Total cocoon production (kg/ha/yr)	2732.10	2630.60	2513.35
3	Average cocoon rate/kg (Rs.)	163.00	159.10	141.30
4	Revenue from cocoon sale	445332.30	418528.46	355136.36
5	Revenue from by products	12500.00	12500.00	12500.00
6	Total revenue	457832.30	431028.46	367636.36
7	Cost of production	238312.80	240807.60	241714.80
8	Net revenue	219519.50	190220.86	125921.56
9	Cost benefit ratio	1:1.92	1:1.79	1:1.52

T1: NDV6 × CSR2; T2: NP1 × CSR2; C- PM × CSR2; 100 dfls = 50,000 eggs.

Table 4: Cost structure in multivoltine x bivoltine cocoon production (for rearing 10 crops in a year @ 350 dfls/crop)

(Cost in Rs. for 3500 dfls/year)

Sl. No.	Particulars	T1	T2	C
	Leaf consumed/100 dfls (kg)	1624	1668	1684
	Qty. of leaf consumed by 3500 dfls (kg)	56840	58380	58940
A	Variable costs			
1	Cost of leaf @ Rs. 1.62/kg	92080.80 (38.64)	94575.60 (39.27)	95482.80 (39.50)
2	Cost of Chawki worms @ Rs. 600 per 100 dfls	21000.00 (8.81)	21000.00 (8.72)	21000.00 (8.69)
3	Disinfectants			
	• Chlorine dioxide (20,000 ppm) -7.5 lt. /crop @Rs.70/lt.	5250.00 (2.20)	5250.00 (2.18)	5250.00 (2.17)
	• Bleaching powder (36%chlorine) – 20 kg/crop @ Rs. 20/kg	4000.00 (1.68)	4000.00 (1.66)	4000.00 (1.65)
	• Vijetha – 6 kg/100 dfls @ Rs. 40/kg	8400.00 (3.52)	8400.00 (3.49)	8400.00 (3.48)
	• Lime powder – 50 kg/crop @ Rs. 3/kg	1500.00 (0.63)	1500.00 (0.62)	1500.00 (0.62)
4	Man power – 25 man days/100 dfls @ Rs. 80/man day	70000.00 (29.37)	70000.00 (29.07)	70000.00 (28.96)
5	Transportation and marketing	5000.00 (2.10)	5000.00 (2.08)	5000.00 (2.07)
6	Miscellaneous expenditure like old news paper & etc.	4500.00 (1.89)	4500.00 (1.87)	4500.00 (1.86)
7	Interest on variable costs @ 8% per annum	9572.00 (4.02)	9572.00 (3.97)	9572.00 (3.96)
	Total variable cost (A)	221302.80 (92.86)	223797.60 (92.94)	224704.80 (92.96)
B	Fixed costs			
1	Depreciation on building and equipments	15750.00 (6.61)	15750.00 (6.54)	15750.00 (6.52)
2	Interest on fixed costs @ 8% per annum	1260.00 ((0.53)	1260.00 (0.52)	1260.00 (0.52)
	Total fixed cost (B)	17010.00 (7.14)	17010.00 (7.06)	17010.00 (7.04)
C	Total cost (A + B)	238312.80	240807.60	241714.80
D	Total cocoon production (Kg)	2732.10	2630.60	2513.35
E	Cost of production per kg of cocoon (Rs.)	87.23	91.54	96.17

Figures in the parenthesis are the percent share on the total cost.
T1: NDV6 x CSR2; T2: NP1 x CSR2; C- PM x CSR2; 100 dfls = 50,000 eggs.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 507-510

COMPARATIVE ADVANTAGE IN INDIA'S TRADE IN SILK GOODS

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ABSTRACT

The prime objective of the study is to explore the structure of comparative advantage enjoyed by India and China in the global silk goods market by using Basala's Revealed Comparative Advantage (RCA) index. The results revealed that that while China remained competitive in all the silk products during 1992-2007, India could maintained its RCA in the finished goods such as silk fabrics, silk blouses and shirts, handkerchiefs and shawls, scarves, mufflers, mantillas and veils.

Key words: Exports, Revealed Comparative Advantage (RCA), silk goods

INTRODUCTION

India has a long history of production, tradition of wearing silk clothes, and trade of silk by developing its own weave and texture, which are very popular all over the world. It has natural comparative advantage in silk production on account of the availability of huge human resources, abundant availability of weaving and designing skills, low level of cost and existence of diverse agro-climatic conditions. Nonetheless, the market share of Indian silk exports in the global silk trade is only 4-5 % and this is quite insignificant considering the fact that India is the second largest producer of raw silk.

With the textile quota phased out and withdrawal of price restrictions from 2005 under WTO agreements, India now has unrestricted access to global market for the trade in silk goods. However, it may face tougher competition from China and European countries, which are the traditional traders in silk goods to expand its market share. Indian silk goods should remain to be competitive in the international markets for improving its trade in silk goods.

The competitiveness of Indian silk goods in the global markets has not received great interest in the literature. A study was, therefore, undertaken to explore the structure of comparative advantage enjoyed by India and China in the global silk goods market in a comparative framework.

MATERIALS AND METHODS

The present study is based on the time series secondary data pertaining to the period between 1992 and 2007 compiled from COMTRADE database of United Nations.

The disaggregated data obtained under the chapters of 50 (silk) and 62 (articles of apparel, accessories, not knit or crochet) of HS1992 were used for analyzing the performance of silk goods exported from India and China. Only the major silk items traded in the world market and available in the COMTRADE database were used in the present study. The silk goods considered for the study accounted for about 92 % of the total value of Indian silk goods exports.

The Revealed Comparative Advantage (RCA) approach uses *ex post* specialization patterns to infer comparative advantage patterns; *i.e*., a country's actual high specialization in an activity implies that it has strong comparative advantage in that activity. Based on the basic concept of revealed comparative advantage, many different RCA indices have been suggested (Bowen, 1983; Yeat, 1985; Vollrath, 1991; Lafay, 1992). Yet the one most widely adopted in empirical studies remains to be the standard Balassa's RCA index (Balassa, 1965):

$$RCA_{xki} = (X_{ki}/X_i)/(X_{kw}/X_w) \quad \ldots\ldots (1)$$

Where,

X_{kj} = Value of ith country's exports of commodity k

X_{kw} = Value of world exports of commodity k

X_i = Value of total exports of country i

X_w = Value of total world exports (of all commodities)

The RCA index greater than one reveals a comparative advantage of the country with respect to the particular product.

To compute an index, which takes into account the time dimension of the export performance, Balassa (1989) suggested a method called Dynamic Revealed Comparative Advantage (DRCA) index for the products, which presumes that the past trend in relative shares is expected to continue. It has been worked out by taking the current year and its normalized value. For normalization, the RCA in the current year has been multiplied by the ratio of RCA in the current year and in the base year. The dynamic RCA is estimated using the following relationship symbolically:

$$DRCA_{Xij} = ½ [(X_{ki}^{t}/X_{i}^{t}) + (X_{ki}^{t}/X_{i}^{t}) * (X_{ki}^{t}/X_{i}^{t}) * (X_{ki}^{0}/X_{i}^{0})] \ldots. (2)$$

Where the variables have been defined as follows

$$X_{ki}^{t}/X_{i}^{t} = (X_{ki}/X_{i}) / (X_{kw}/X_{w}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where ^{0} represents the base year; t represents the current year and X_{ki}/X_{i} represents RCA of commodity k. The numerical value of DRCA would range between zero and infinity with 100 as a cut-off mark. A value above 100 would show the country's comparative advantage in the world in kth commodity. It may be added that DRCA has an edge over RCA which reveals comparative advantage at a point of time while the DRCA takes into account change over time, *i.e.,* the changes in the relative share between the current year and the base year.

RESULTS AND DISCUSSION

Commodities showing RCA_x in static framework generally do not take into account of changing pattern of comparative advantage. Since a change in these indices is intrinsically linked with change in their factor endowment structure, it would be more realistic if trade cooperative is considered on dynamic rather than on traditionally employed static indices basis. Hence, both static and dynamic RCA indices were computed in both cross-sectional as well as inter-temporal framework to determine the competitiveness of India's and China's silk goods exports in the global market. The results can then be used to indicate whether India can increase its silk goods exports by sacrificing the exports of products in which the other country has a greater advantage.

RCA Analysis for Indian Exports of Silk Goods

By comparing the RCA_x values for four different time periods, the volatility of RCA indices was assessed and subsequently the stability of the comparative advantage of different products was determined. It can be observed from Table 1 that India did not have any comparative advantage in raw silk (not thrown) throughout the period. Since the demand for raw silk is higher than that of the domestic production, India imports a huge quantity of raw silk every year. As a result, India has emerged as one the largest importers of raw silk, which puts India in comparative disadvantageous position in the product. Moreover, the Government of India has also restricted the free exports raw silk with the support of various policy measures.

India did not have comparative advantages in silk waste and yarn spun from silk waste in 1992. However, it gained comparative advantage in the subsequent periods. There was spurt in the exports of silk wastes from the country in the period between 1997 and 2001 and it became competitive over the years. The RCA_x values of silkworm cocoons suitable for reeling, which were less than unity during 1992 and 1997, became more than unity during 2002 and 2007. This implies that this product gained comparative advantage in the recent years. It should be noted that the global trade in silkworm cocoons is very meager and India is not producing the cocoon or raw silk in the exportable surplus quantity.

The RCA_x values were more than unity for silk yarn and yarn spun from silk waste, women's/girls' blouses, shirts and shirt-blouses, handkerchiefs and shawls, scarves, mufflers, mantillas, veils and the like in all the four periods, which implies that the comparative advantage was maintained in these products. The RCA_x values of silk yarn and yarn spun from silk waste, however, reduced over the years, which implies that the comparative advantage has been reducing consistently. This may be due to increase in the direct exports of silk wastes in the recent years. Woven fabrics of silk or of silk waste had lost comparative advantage during 1997 but regained during 2007. The Indian exports of ties, bow ties and cravats of silk/silk waste did not have comparative advantage in the global markets.

As far as Dynamic Revealed Comparative Advantage ($DRCA_x$) is concerned, Table 1 reveals that the products in which India's comparative advantage exists are, shawls, scarves, mufflers, mantillas, veils and the like, handkerchiefs of silk/silk waste, woven fabrics of silk or of silk waste and women's/girls' blouses, shirts and shirt-blouses. These products have displayed a higher (more than 100) index value of $DRCA_x$ during 1992-2007. Shawls, scarves, mufflers, mantillas, veils and the like and handkerchiefs of silk/silk waste had the index value of greater than 100 during all the time periods that is during 1992-97, 1998-2002 and 2003-07. The $DRCA_x$ of women's/girls' blouses, shirts and shirt-blouses increased consistently over the period and reached the maximum during 2003-07. Similarly, woven fabrics of silk or of silk waste became highly competitive in the period between 2003 and 2007. India's dynamic comparative advantage in silk yarn and yarn spun from silk waste dropped heavily in 1998-2002 but recovered in the ensuing period. India did not have any dynamic comparative advantage in raw silk (not thrown), silk waste, silk yarn (other than yarn spun from silk waste), yarn spun from silk waste and ties, bow ties & cravats of silk/silk waste.

Table 1: India's Comparative Advantage (Static and Dynamic) in Silk Goods

HS code	Commodity Description	Revealed Comparative Advantage (RCAx)				Dynamic Revealed Comparative Advantage (DRCAx)			
		1992	1997	2002	2007	1992-97	1998-2002	2003-07	1992-07
500100	Silkworm Cocoons Suitable for Reeling	0.00	0.00	5.82	11.03	0.00	32.77	902.60	5.51
500200	Raw Silk (Not Thrown)	0.24	0.32	0.30	0.26	0.17	0.17	0.15	0.14
500300	Silk Waste	0.20	5.19	2.50	5.49	5.34	14.27	14.36	5.82
500400	Silk Yarn (Other Than Yarn Spun from S ilk Waste)	0.24	0.47	1.25	0.37	0.26	1.32	0.25	0.20
500500	Yarn Spun from Silk Waste	0.26	0.33	2.48	2.85	0.18	3.75	9.39	2.49
500600	Silk Yarn and Yarn Spun from Silk Waste	18.43	4.85	4.15	3.22	219.38	88.79	129.97	97.00
500700	Woven Fabrics of Silk or of Silk Waste	11.82	0.24	0.52	13.23	0.45	0.30	264.98	1041.04
620610	Women's/Girls' Blouses, Shirts & Shirt-Blouses	3.53	2.34	6.05	7.66	10.79	37.64	182.33	107.25
621310	Handkerchiefs, of Silk/Silk Waste	58.19	12.00	4.79	44.78	4197.14	176.27	2268.45	58375.96
621410	Shawls, Scarves, Mufflers, Mantillas, Veils and the like	13.67	6.94	12.55	17.25	333.03	700.08	2186.22	2042.11
621510	Ties, Bow Ties & Cravats of Silk/Silk Waste	0.80	0.10	0.02	0.02	0.05	0.01	0.01	0.01

Table 2: China's Comparative Advantage (Static and Dynamic) in Silk Goods

HS code	Commodity Description	Revealed Comparative Advantage (RCAx)				Dynamic Revealed Comparative Advantage (DRCAx)			
		1992	1997	2002	2007	1992-97	1998-2002	2003-07	1992-07
500100	Silkworm Cocoons Suitable for Reeling	28.73	28.62	11.96	2.25	2348.26	196.15	20.90	129.30
500200	Raw Silk (Not Thrown)	39.33	22.69	22.07	11.94	7343.53	3544.32	738.84	1910.02
500300	Silk Waste	22.35	15.19	15.76	8.04	1728.23	657.78	247.02	546.95
500400	Silk Yarn (Other Than Yarn Spun from Silk Waste)	13.65	10.34	13.00	5.23	565.25	413.25	50.03	94.40
500500	Yarn Spun from Silk Waste	20.35	18.13	15.84	10.57	2815.97	1222.56	332.84	561.97
500600	Silk Yarn and Yarn Spun from Silk Waste	4.50	6.70	12.54	6.25	1062.93	423.51	80.62	51.16
500700	Woven Fabrics of Silk or of Silk Waste	18.54	9.79	5.80	4.40	478.05	78.99	30.52	125.57
620610	Women's/Girls' Blouses, Shirts & Shirt-Blouses	32.20	14.57	12.06	3.99	3206.58	486.85	26.98	112.82
621310	Handkerchiefs, of Silk/Silk Waste	21.18	9.48	5.85	4.95	201.02	60.00	16588.99	118629.55
621410	Shawls, Scarves, Mufflers, Mantillas, Veils and the like	10.45	3.60	3.41	2.90	65.26	18.64	5.58	20.31
621510	Ties, Bow Ties & Cravats of Silk/Silk Waste	2.75	1.30	2.29	3.41	131.49	28.75	17.09	14.87

RCA Analysis for Chinese Exports of Silk Goods

China maintained comparative advantage in all the silk goods exported from the country as evident by RCA_x index value of more than unity for these products (Table 2). The RCA_x values have been coming down consistently in the recent years for the products such as raw silk (not thrown), silk waste, woven fabrics of silk or of silk waste, women's/girls' blouses, shirts and shirt-blouses, handkerchiefs of silk/silk waste and shawls, scarves, mufflers, mantillas, veils and the like. This may be due to the imposition of quota system by the United States of America and the European Union on the exports of finished silk goods from China.

It should be noted that both India and China are exporting similar products as apparent from static RCA_x values. However, China had higher RCA_x values for raw silk (not thrown), silk yarn (other than yarn spun from silk waste), yarn spun from silk waste, woven fabrics of silk or of silk waste and ties, bow ties and cravats of silk/silk waste. But India's advantage over China is visibly lying in value added products like women's/girls' blouses, shirts and shirt-blouses, handkerchiefs, of silk/silk waste, shawls, scarves, mufflers, mantillas, veils and the like.

As far as Dynamic Revealed Comparative Advantage ($DRCA_x$) is concerned, the values were very high for raw silk (not thrown) all the periods for China, which indicates that

China has reminded highly competitive in the product. As China accounts for almost 82% of the global silk production and is the dominant exporter of raw silk with a share close to 75% of the world market remains competitive in the trade in raw silk.

China was competitive in silk yarn (other than yarn spun from silk waste) and silk yarn and yarn spun from silk waste during 1992-97 and 1998-2003, but these products lost their comparative advantage in the ensuing period. The reason may be that China reduced the exports of primary products and concentrated on exports of value added products. The rapid decline in the silk weaving activities in Europe also would have reduced the demand for the import of silk yarn from China.

The $DRCA_x$ value considerably reduced for the products like woven fabrics of silk or of silk waste and women's/girls' blouses, shirts and shirt-blouses after 1997. China lost the dynamic comparative advantage in handkerchiefs of silk/silk waste in the period between 1998 and 2002. Nonetheless, the comparative advantage of the product increased significantly in the subsequent period. China could not maintain the dynamic comparative advantage in shawls, scarves, mufflers, mantillas, veils and the like and ties, bow ties and cravats of silk/silk waste due to continuous decline in the RCA_x in the products over the years. However, the global trade in these products is not very high.

SUMMARY AND CONCLUSION

It can be concluded from the study that while China remained competitive in all the silk products during 1992-2007, India could maintained its RCA in the finished goods such as silk fabrics, silk blouses and shirts, handkerchiefs and shawls, scarves, mufflers, mantillas and veils. Various measures may be taken up for increasing competitiveness of Indian silk goods in the international market.

The competitiveness of Indian silk can be improved only by increasing the quality of silk with concomitant improvement in productivity. Hence, it is necessary to develop highly productive silkworm hybrids along with improved rearing practices and through research and development and popularize with the farmers. Modernization of reeling facilities in the country is also essential for the production of quality raw silk in the country.

The Indian silk industry can explore Foreign Direct Investment (FDI) for technology upgradation/ modernization, product innovation, penetration into new markets, marketing channels, brand promotion and retailing. The Indian exporters should concentrate on fashion, technology, quality and services and actively participate in trade fairs, conduct personal visits and concentrate on Customer Relationship Management (CRM) with the buyers for promoting their products in the major silk consuming markets. Generic promotion of the image of 'Indian silk' in the global market is also essential for promoting the competitiveness of Indian silk goods.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 511-514

VALUE CHAIN IN SILK INDUSTRY

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ABSTRACT

The performance of silk industry is expected in such a way that, the market margins should be equivalent to the chain of value addition in enhancing the efficiency and quality in the production of silk fabrics. While, price spread alone does not indicate the share of different intermediaries and their contributions. The study implies a maximum of 40 per cent of price spread by the rearers adding 32 per cent of value with highest market margins of 47 per cent is meaningfully justifiable. Followed by weavers, 23 percent price spread with 26 per cent value addition and market margins were 19 per cent indicating inefficiency and quality deterioration. The price spread for traders was 13 per cent with only 10 per cent value addition and market margins of 21 per cent was unjustifiable due to the excess margins. Reelers were the most important and the riskiest entrepreneurs with 10 per cent price spread and 14 per cent of value addition with lower market margins of five per cent showing sub-optimal use of resources. The share of dyeing in price spread was eight per cent with 12 per cent value addition and least market margins of two percent. Further, the main problem lies with reelers, weavers and dyers with lower market margins, as the skilled labour is shifting to other activities because of wage rate stagnation.

Key words: B:C Ratio, Costs, Market Margins, Price Spread, Returns, Value Addition

INTRODUCTION

The current scenario of global production of 1,30,000 tonnes of raw silk in 2009-10 of which china contributed one lakh tonnes. India is the world's second largest producer and exporter of silk with 20,000 tonne contributing 15 per cent of total production, while the consumption was 27,341 tonnes, so 7,341 tonnes i.e around (6 per cent)of shortage in raw silk was out sourced from china. The imports were 7,341 metric tonnes valued at RS 1810.27 crores, while the total exports from the country was Rs 2872.00 crores for all silk products constituting 2.74 per cent of total textile exports. Thus enhancing both domestic and international demands for silk goods. Despite temporal increase in raw silk production in the country there has been growth in the imports and the domestic and international markets continued to show signs of enhanced demand. Thus implying lot of potential for expanding sericulture industry through backward linkage in terms of mulberry and cocoons production and expands through forward linkage with the raw silk reeling, twisting ,dyeing ,weaving and marketing.

Silk industry in India is traditional and has existed as an important agro-based cottage industry. The silk cocoons produced by the farmers are processed at different stages to arrive at silk fabrics. The technical process involves production of mulberry and cocoons from which raw silk by reeling , twisted silk by twisters, dyeing by dyers, production of fabric by the weavers and marketing by the traders. More than 50 percent of silk is processed through charaka, and 100 per cent twisted, dyed and weaved locally by hand looms. Presently, the studies on value chains in silks were out dated. Therefore this study was under taken to estimate contemporary value chains in the commodity like silk in eastern dry zone of Karnataka.

MATERIALS AND METHOD

The study was undertaken in eastern dry zone of Karnataka as it occupies a pre eminent position in mulberry silk production. An effort is made to know the economy of silk value chain. For this, a stratified three tier randomised sampling block design was used. So, a sample of 30 rearers,

34 reelers, 30 twisters, 30 dyers, 30 weavers and 5 traders were selected from these areas. The data from these respondents were collected for a period of one year (1st April to 31st of March, 2009-10) through a pre -tested questionnaire on different aspects of costs, returns and marketing. The data were collected during the months of August and September 2010. The estimation of variables which constitutes the total costs, variables costs, fixed costs, total returns and profits were computed by using the formulae TC=TVC+TFC, π= TR-TC and Price Spread = Basic material cos [leaf +dfl's] +Value addition + market Margins.

RESULTS AND DISCUSSION

Cost, returns and B:C ratios

Table 1 indicates the cost, returns and B:C ratio for the enterprises in the value chain of Silk commodity for eastern dry zone of Karnataka. Firstly, rearers incurred a variable cost of 85 per cent particularly on the mulberry leaves, dfl's and human labour which are considered as the drivers of silk industry. The profit earned by rearers was Rs.66563.00 per year per acre with a return of Rs.1.55 per rupee of investment.

The reelers were the second stakeholders, who were considered to be most risky entrepreneurs in the silk chain processing. There are 24 cycles of reelings dominated by 99 percent of variable cost, the net return was Rs. 249823.00 with a second least return of B:C ratio 1:1.052 i.e. 5.20 percent. This enterprise converts the perishable cocoons into non-perishable raw silk yarn. The twisters were the third stake holders with 52 cycles of variable cost contributing 99 per cent of variable cost. It is the most important value addition of production of warp and weft with imparting strengths through different twists. The quality of silk will be based on the type of twist imparted on the yarn. The net return was Rs. 312300 with 6.40 per cent annual return *i.e.* the B:C ratio is 1:1.064.

The dyeing is the fourth and very effective and cognisable enterprise performed only by specialists in colouring techniques and hobby oriented avocation people. This activity also has 52 cycles. The main variable cost was on fuel, colour, acid and labour which brings about value change in the silk processing particularly the reduction of the weight of the silk through degumming by 25 per cent, with a net return of Rs.268272.00 (1.30 per cent) least return in value chain with B:C ratio of 1:1.013.

Weaving is the fifth intermediary in the value chain of silk particularly handlooms requires tremendous skill and perseverance with patience. This also includes 48 to 52 cycles with net returns of Rs. 116123.00 and B:C ratio of 1:1.10 i.e. 10 per cent earning was observed per rupee of investment. The weavers are not happy with the wage rate because of greater increase in wages of other sectors .Many weavers have quit the job due to lower returns. Main drivers of weaving were weaver, silk yarn and the design.

The last and the final stakeholder is trader in the silk value chain operating nearly 52 cycles with 99 percent variable cost. The net returns of Rs.147250.00 was the second highest market margins with second least value addition. These results are in conformity of Raveendra *et.al.* (1997) with a change in less margin to traders from the earlier 50 per cent to present 10 per cent with a B:C ratio of 1:1.10.

Price Spread, Value addition and market margins

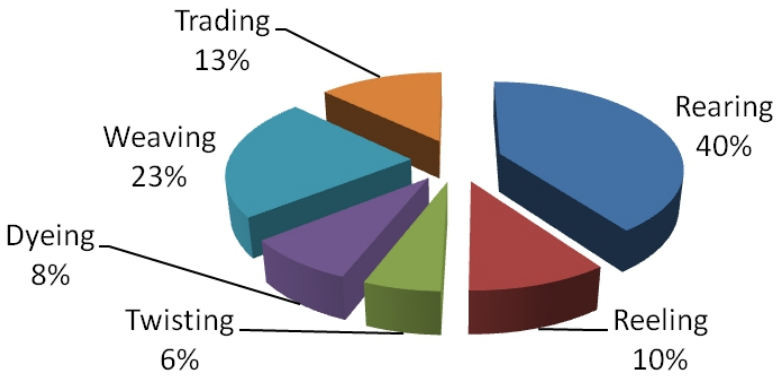
The value addition, market margin and price spread were worked out for ten meters of soft silk fabric weighing 60 grams per Meter. The share of different enterprises (Such as rearers, reelers, twisters, dyers, weavers and traders) in price spread, value addition and market margins were worked out and presented in the form of Table 2.

It can be noticed that the market (Whole sale) price of ten meters of fabric was rupees 6016.52. This price was distributed to different intermediaries as represented in Fig a. Out of the total price spread, rearers get a share of 40.07 per cent followed by weavers (22.75 per cent), traders (12.96 per cent), reelers (10.27 per cent), dyers (8.32 per cent) and twisters got a meagre share of (5.63 per cent) in the price.

The price spread alone cannot indicate the share of different enterprises and their contribution to the silk industry. The price is further split into basic material *i.e.* Leaf + dfl's (disease free layings) cost, value addition and market margins were also worked out. The basic material considered for the study was (Leaf + dfl's) which accounted for Rs. 308.41 in order to produce 10 meters of soft silk fabric. The value addition in converting the Leaf + dfl's to fabric was to the extent of Rs.3872.69. The contribution of different enterprises in value addition is presented in Figure b and Table 2. The rearers share was the highest in the total value addition accounting for 32.11 per cent followed by the weavers (26.36 per cent), reelers (13.56 per cent), dyers (12.10 per cent), traders and twisters contributed 10.37 per cent and 5.50 per cent, respectively.

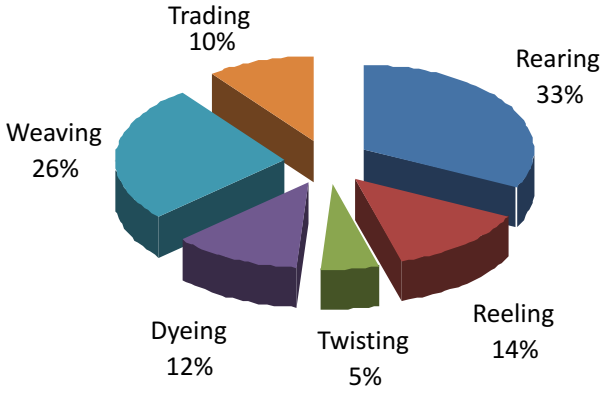
The share of different enterprises in total market margins is presented in Table 2 and Figure c. The share of rearers in the market margins was highest of 46.79 per cent was observed. The traders realising 20.57 per cent, followed by weavers 18.94 per cent, twisters 6.96 per cent, reelers 5.05 per cent and dyers 1.74 per cent of total market margins respectively.

Thus the share of the rearers in price (40.07 per cent) is highly justifiable when looked at their contribution to value addition (32.11 per cent). While on the consonance the share of the rearers in the market margins was highest (46.79 per cent). The traders had a higher share of 20.59 per cent in market margins, while contributing only 10.37 per cent to the value addition, followed by the weavers contributing 18.94 per cent. Similarly twisters, reelers and dyers got less share i.e 6.91 per cent, 5.05 per cent and 1.74 per cent ,respectively in the market margins.



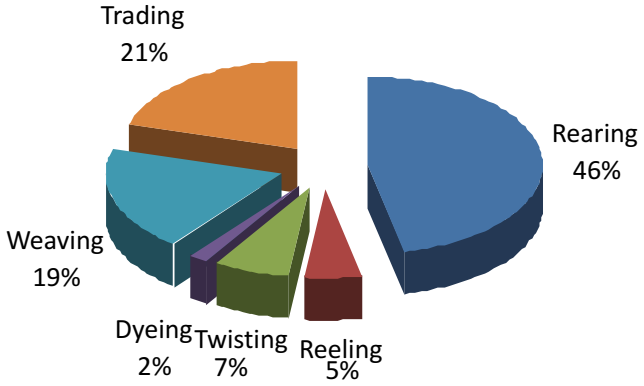
The wholesale price of 10 m soft silk fabric of 60 grams/m = Rs. 6016.52

Fig. A : Price Spread



The total value addition = Rs. 3872.69

Fig. B : Value addition



The total Market margins = Rs. 1835.42

Fig. C : Market Margins

Table 1: Enterprise wise average Costs, Returns, profits and B:C Ratio for the value chain of silk Industry for the year 2009-10 In Eastern Dry Zone of Karnataka.

Sl. No.	Particulars	Rearers (per acre)	Realers (6 charakhas)	Twisters (300 spindles)	Dyers (4 chullas)	Weavers (5 Handlooms)	Marketers (1 Shop)
1	Kgs of silk	77.52	2694	2463	8418	334	3900
2	Variable cost	103081	4751309	4865193	20588463	1150964	15022850
3	Fixed cost	17201	14136	13475	21765	8113	80000
4	Total cost	1120282	4765445	4878668	20610228	1159077	15102850
5	Total returns	186845	5015268	5790968	20878500	1275200	16575000
6	Profits	66563	249823	312300	268272	116123	1472150
7	B:C ratio	1:1.55	1:1.052	1:1.064	1:1.013	1:1.10	1:1.10

Table 2 : The shares of different silk enterprises in value addition, Market margins and Price spread during 2009 – 10. In eastern dry zone of karnataka

Sl No	Category	Total cost per kg	Value Addition per kg	Per cent value addition	Market margins per Kg	Per cent market margin	Price spread per Kg	Per cent price spread
1	Rearers	308.41	1243.61	32.11	858.88	46.72	2410.90	40.07
2	Reelers	1768.91	525.30	13.56	92.73	5.05	618.03	10.27
3	Twisters	1980.79	211.87	5.50	126.80	6.91	338.67	5.63
4	Dyers	2449.35	468.73	12.10	31.87	1.74	500.60	8.32
5	Weavers	3470.29	1020.94	26.36	347.67	18.94	1368.61	22.75
6	Traders	3872.53	402.24	10.37	377.47	20.57	779.7	12.96
	Total		3872.69	100.00	1835.42	100.00	6016.52	100.00

(Price Spread = Basic material cost [leaf +dfl's] +Value addition + Market Margins)
(6016.52 = 308.41 + 3872.69 + 1835.42)

Policy issues

- The study draws the attention of the policy makers to formulate efficient marketing system especially during and after weaving stage having better distribution price.
- Economising the cost and margins through better infrastructure, price and quality control at international market.
- Improving efficiency of silk production and processing.
- Strengthening linkages between stakeholders.
- Development of value added products.
- Support to quality control, standardization, marketing services and development.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 515-519

TELECONFERENCING – AN EFFECTIVE EXTENSION TOOL FOR TRANSFER OF SERICULTURAL TECHNOLOGIES

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ABSTRACT

A teleconference or teleseminar is the live exchange and mass articulation of information among several persons remote from one another through a telecommunication system. In general, teleconferencing can bring people together under one roof even though they are separated by hundreds of kilometres. It is useful in reaching the technologies effectively to a large or sparsely populated areas, providing broader access to farmers' meetings as well as widening the reach of public involvement, providing immediate response to concerns, issue or problems, reduction for holding several meetings in different geographical areas thereby decreasing the involvement of cost, staff and time, besides reaching more people in one session at a time than in several sessions over several weeks. The scope, objectives and requirements of teleconferencing are discussed in this paper.

Key words: Extension tool, Sericulture, Teleconferencing, Transfer of technology

INTRODUCTION

The words 'tele' means distance and 'conference' means consultations or discussions. Through teleconferencing, two or more locations situated at a distance are connected so that they can see and communicate each other. It allows the distant sites to interact with each other and the interactions occur in real time. This means that the learners/participants and the resource persons are present at the same time in different locations and are able to communicate with each other.

Functions of Teleconferencing

The functions of teleconferencing in education and training are to:

- Impart information, build attitudes, provide role models, etc
- Up-grade skills
- Share experiences
- Facilitate problem solving
- Offer counselling
- Supervise/conduct/guide project work

The learner and participant groups could vary from students, teachers, grass root level functionaries, community groups, farmers, housekeepers, experts, administrators to high level executives.

Uses of Teleconferencing

Teleconferencing has many uses. Teleconferencing is essentially a means for communication and training. It can be used for information dissemination, guidance in response to policy, consultations with experts, focused group discussions, interviews, etc. As a technology, it has broad applications in education, training and development, business/corporate communication, governance and professional and medical courses/services including telemedicine.

Education: In the academic area, many professional training institutes are using the teleconferencing mode to provide quality teaching support to widely dispersed student community.

Training and development: Teleconferencing is used to provide training and staff development for capacity building in agriculture, health, nutrition, family welfare, etc. in remote rural areas. It reaches out to a large number of groups such as community workers, farmers, functionaries, etc. for extension activities, sharing of experiences, raising of issues,

introducing government schemes, projects, mobilizing for activities and conducting campaigns. Teleconferencing has been effectively used for empowerment of women and local self-government bodies and training of grass root workers spread over in large geographical areas.

Business/corporate communication: In the business and corporate sector, teleconferencing has been used for a variety of purposes such as organizing conferences, interviews for recruitment, project supervision, problem solving, consultations, information dissemination and training of the personnel.

Governance: Using teleconferencing facilities, planners, administrators and executives can directly and simultaneously interact with people at all levels for speedy dissemination of policy, execution, monitoring and implementation of projects, addressing problems and providing expert consultations.

Medical services: Medicine is an area in which teleconferencing is being increasingly used. Hospitals can provide medical services to remote areas with expert diagnosis and medical advice.

Strengths of Teleconferencing

Teleconferencing offers a number of advantages to organizers, administrators, educators and learners.

- It provides learning to large groups, which are geographically dispersed.
- For organizations, delivery costs are reduced with resultant cost benefit in terms of time, travelling and spread of resources over large groups.
- It can be designed to meet local specific requirements of training in terms of content, language and conditions.
- Training is of high quality and consistent.
- There is greater appeal, motivation and retention of information as a variety of teaching methodologies are used.
- By using animation, graphics and other techniques, teleconferencing is good at showing processes for demonstrations and experiments, thereby concretizing learning.
- By conveying sights, sounds, and the spirit of the subject, it provides a more rounded view of an issue.
- It provides uniformity of training, which is interactive.
- For the field functionaries in remote rural areas, it reduces the sense of isolation, encourages sharing of concerns and ideas, and helps to solve their problems.

Teleconferencing activities

Before teleconferencing, the following aspects have to be meticulously planned:

- Assessment of information needs / identification of objectives
- Selection of the topic
- Relevance of the topic
- Topic and session planning and duration
- Selection of the resource persons
- Preparation of reading material or slides

Assessment of information needs/identification of objectives: The broad learning objectives of the teleconference are determined on the basis of an assessment of information needs of the learner group. For the purpose, form a team of teachers / extension functionaries / subject experts, communication specialist and researchers to discuss the following:

- Current status of information, knowledge, skills, motivation and attitude of the learner group.
- Nature of job/task to be done and the type of information, knowledge, skills, motivation and attitudes needed by the workers/researchers for better understanding of the subject.
- Areas of interest and information needs, which other learning resources are not meeting or are unable to meet adequately.

The identification of themes/topics for the teleconferencing session is on the basis of the well-considered recommendations of the team. The key questions to be addressed here are:

- The profile of the target audience
- Client specific needs
- Training and learning tasks
- Objectives of the teleconference session
- Strategies and media resources which can be built into the teleconference
- Architecture to achieve the objectives
- Experts/teachers/scientists available on the selected subject

Selection of the topic: Selection of topics can be made on the following criteria:

- It should be need based.

- It should be important and relevant to the target group.
- It should generate interaction. The topic should have the potential to make the learners enquire, discuss, enter into a dialogue, reflect on their existing knowledge and experience and motivate them to think of ways they can apply what they are learning.

Relevance of the topic: Effective teleconferencing requires planning and effective use of media resources and experts. Having selected the topic, the next step is to do content research, consult experts and identify problem areas:

- Break up the topic in segments and explore the visualization through a variety of resources, demos, graphics, actuality, etc.
- Build in question and answer session and provide stimulus for response,
- Ensure that the key points are covered and opportunity given for analysis, synthesis and application.
- Topic should be stimulating & interesting
- Bring in case studies for better understanding

Session planning and duration: Enhance learning and create interest through visualization and treatment such as inputs of video excerpts, charts, posters, graphics, audio recordings, etc. While developing content, the principle challenge is how to keep the learner motivated, interested and actively involved throughout. Some teleconference formats are illustrated lectures, interviews, panel discussions, case studies, field visits, demonstrations, etc. The duration of the conference depends on the objectives and complexity of the content and the nature of problems to be discussed by the participants. Teleconference may be a single session or it may be spread over several sessions in a progressive manner, each session taking off from the previous one, recapitulating what was done earlier and linking it to the next one. Each session should be of 2-2½ hours.

Selection of the resource persons: The resource person should:

- Be an expert in the subject
- Have good communication skills (verbal clarity, pleasant voice, correct pronunciation, pauses and inflexions at the right places)
- Generate enthusiasm
- Have good listening skills
- Be familiar with the equipment and aware of its capabilities/limitations
- Alter teaching strategy to suit learners' needs
- Anticipate difficult areas and make advance preparation for responding to questions
- Have a pleasant personality and follow a particular style, whether serious, chatty, humorous or witty
- Act as a guide and a friend.
- Be familiar with the background of participants and understands their needs, hopes and aspirations

Components of Teleconferencing

The satellite communication (SATCOM) is found handy in addressing agriculture related problems directly from "Expert Centre" to the grass-root people / farmers through "Village Resource Centres" (VRCs), which enable two-way interactions (Fig 1).

Village Resource Centre

The Village Resource Centre (VRC) or Village Knowledge Centre (VKC) is a place to render variety of services from a single window to remote rural mass in a given geographical area through moderninformation and satellite communication technology *viz*., Very Small Aperture Terminal (VSAT)/GRAMSAT/Leased line. The VRC is an information kiosk that connects village level communities to the Expert Centers which are located in strategic places. The objective of this programme is focused on reaching the benefits of satellite based information technology directly to the communities at the grass-root level as a single window delivery system on agriculture, health and variety of other livelihood needs of rural mass.

VRC has special advantage over other mass media channels like radio and television where it has both audio and video opportunity with two way conferencing. The farmers participating in the programme can directly interact with the experts through two way audio video conference and get more details as well as solutions to questions. Therefore, this information support system will provide the services of the experts directly to the end users which take care of the distortion of the messages, inadequacy of grass root level extension workers, credibility of messages and necessity of timeliness. Generally, VRCs are placed at Hobli level while VKCs at Panchayat level. The VKCs at present are existing in the union territory of Pondicherry

In Karnataka, two NGOs and University of Agricultural Sciences, Bangalore (UAS-B) have been identified to take up this challenging task of reaching the space technology to rural community through their network of 51 VRCs. They are Mysore Resettlement and Development Agency (MYRADA) with 14 VRCs and Karuna Trust with 19 VRCs.

University of Agricultural Sciences, Bangalore (UAS-B) is another associating institute with 15 VRCs established in each KVKs under its jurisdiction.

MYRADA is an NGO working towards the development of rural India and is taking part in establishing the VRCs in various parts of Karnataka. Presently there are 14 VRCs under MYRADA. MYRADA Head Office, Domlur is the Expert node for these 14 VRCs. These 14 VRCs will cover around 5,50,000 population in 403 villages and 1158 Community Based Organisations (CBOs).

Karuna Trust, an NGO with focus on Public Health has identified nineteen (19) locations as listed below. These locations are Primary Health Centres/Units (PHC/PHU) maintained and managed by Karuna Trust. VRCs under Karuna Trust will cover around 3,46,218 population in 430 villages. Expert node for these 19 VRCs is located at Mysore and is named as Technology Resource Centre. Telemedicine component is rendered by two specialty hospitals viz. Narayana Hrudayalaya, Bangalore and Amrita Institute of Medical Sciences, Kochi.

University of Agricultural Sciences, Bangalore (UAS-B) has included 15 Krishi Vigyan Kendras incliding one Operational Research Project (ORP) in Pavagada (Tumkur district), one Extension Education Unit (EEU) in Nagenahally (Mysore district), one Extension Unit (EU) in Kathalagere (Davanagere district) and one Forestry College at Ponnampet (Coorg district) as VRCs under its jurisdiction. Other two KVKs are privately managed by (JSS), Suttur (Mysore) and Sri Taralabalu Krishi Vigyan Kendra, Tholahunase (Davanagere). The Expert node for these 18 VRCs is located at GKVK campus, Bangalore.

Performance of VRCs in Karnataka

MYRADA is conducting programmes in two slots, 9.00-10.00 h for Children and 11.30 to 13.00 h for public/women. GKVK brings out tele-agriculture advisory on every Monday between 11.00 and 13.30 h. Karuna Trust operates during 14.00 to 16.30 h slot mainly dealing with health awareness and medical activities for children, women, livestock *etc*. Weather Information generated by Agrometeorology Division of GKVK, UAS, Bangalore is being made available online for users of VRCs on Karnataka nodes. As many as 224 tele-education/tele-agriculture programmes were conducted during April 2007 to March 2008 from three Karnataka VRC Expert nodes benefiting 32,089 participants.

Thus, VRC programme is the synergy of different space technology applications and services to meet the developmental needs at grassroots. VRC is a unique platform addressing the different dimensions of societal needs, social education, healthcare etc. and natural resources related land and water resources management, watershed development, agrometeorology, disaster warning etc. The success of the programme depends on the contents and services provided at VRCs to meet the requirements of individuals at grassroots.

Expert Centre

The Expert Centres are established in different states to provide information support to the VRCs. In the ECs opportunity is provided for two way audio video conferencing. One individual or group of individuals of VRCs can directly interact with the expert(s) in the Expert Centres. The expert can directly provide information to large number of rural people simultaneously through VRCs. Generally, the ECs are located in places where large number of experts are easily accessible. One such centre is located at the University of Agricultural Sciences, GKVK, Bangalore, which has started functioning from 5th April 2007 and had conducted 171 Expert Programmes till date covering crop production and protection aspects, harvest and post harvest techniques, value addition of crops, weather forecast information etc. which was found very much useful by farmers at the receiving end. Two more Expert Centres one at MYRADA, Bangalore and another at KARUNA Trust, Mysore are functioning in Karnataka.

Overall objective of the initiative is to leverage technologies to reach the rural communities. The VRCs have wireless or satellite connectivity with the nodal Knowledge Centers or Expert Centers. The Expert Centres provide information support to VRCs. The main aim of this Village Resource Centers is to empower rural farming families to make better choices and achieve better control of their development through building skills and capacities for enhancing their livelihood opportunities.

While inaugurating the Village Resource Center in 2004, Prime Minister Manmohan Singh noted that "Mass Poverty can be removed only if Science and Technology reaches Villages". The first VRC was established by ISRO in collaboration with MSSRF on 18th October 2004. As on today there are 380 VRCs established in the country in association with universities, NGOs, Trusts, State and Central Institutes. At present ISRO works in close liaison with the following agencies for the establishment of VRCs:

- Amrtia Vishwa Vidya Peetam, Ettimadi, Coimbatore, Tamil Nadu.
- Karuna Trust, Biligiri Ranga Hills, Chamarajanagar District, Karnataka
- MS Swaminathan Research Foundation (MSSRF), Chennai.
- Self-Employed Womens' Association (SEWA), Ahmedabad, Gujarat.

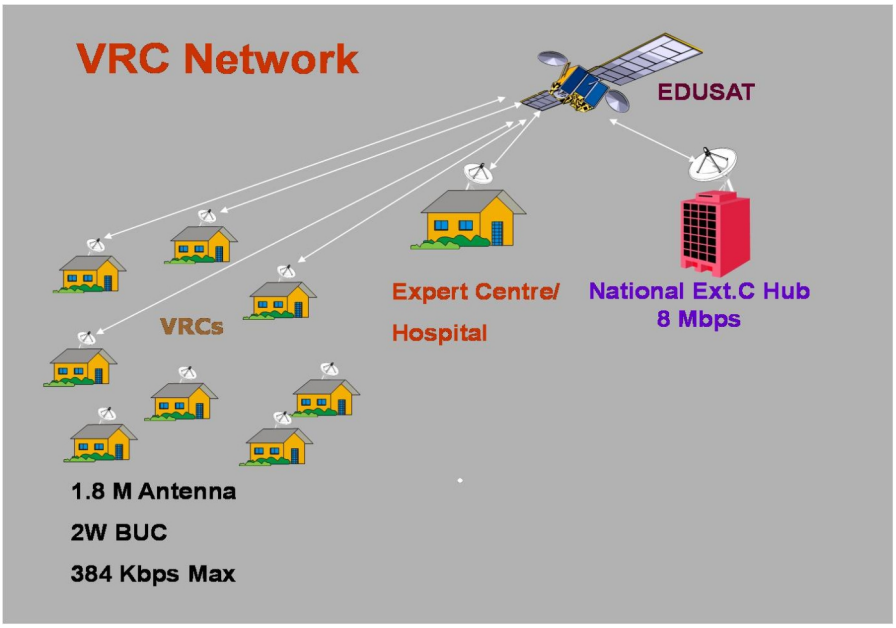


Fig 1: VRC Network functioning concept

- Kutch Nav Nirman Abhyan, Bhuj, Kutch District, Gujarat,
- Mysore Resettlement and Development Agency (MYRADA), Bangalore, Karnataka
- Kerala State Planning Board, Government of Kerala.
- University of Agricultural Sciences, Bangalore (UAS, GKVK)

CONCLUSION

The Indian farmers have suffered over the years partly due to lack of timely comprehensive information support for taking rational decisions. In this context, VRCs have great role to play in providing timely reliable information at a reasonable cost to the farmers in particular and rural people in general for their development. Therefore, it is appropriate to establish one VRC in each Hobli in the initial stage and thereafter for all the panchayats in the country. The VRC can provide timely needed information to the farmers of the area. Involvement of representatives of the group members of the local institutions such as SHGs, MPCSs, Gram Panchayats, School children, Teachers and local extension personnel in the concerned programme, enhances the effectiveness of this system. It is a challenge for the extension researchers to explore how to enhance the system in terms of reaching every clientele with required effectiveness as well as benefit over other communication methods.

Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 520-524

TRAINING NEEDS OF SERICULTURISTS AND EXTENSION PERSONNEL IN KOLAR DISTRICT OF KARNATAKA

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ABSTRACT

In order to disseminate the technological innovations to the grassroots, various training programmes are conducted for extension personnel and sericulturists in different organizations. Training programmes in the field of sericulture are very much essential to reduce the yield gaps that exist between the potential and actual yield in the field. Based on the feedback provided by extension personnel and farmers, both the felt and unfelt training needs were estimated separately for the two groups. The important felt training needs of farmers include, usage of mountages (56%), mulberry pest and disease control (76%) and deflossing techniques (67%) and that of the extension personnel were shoot rearing technology (92%), using improved mountages (68.50%), water saving technology (67.50%) on quality parameters (67.50%). The major unfelt training needs of farmers include information on quality club/SHG formation (97%), deflossing using machine (66%) and cocoon marketing rules & regulations (75%). The important unfelt training needs of officials were statistical analysis (93.75%), mechanization in sericulture (91.50%) and farm management (91.25%).

Key words: Extension Personnel, Field Staff, Training Needs

INTRODUCTION

Sericulture is practiced in many states of the country. Karnataka is the major silk producer and accounts for 55% of national production. Though the other crops are grown in the state, mulberry occupies prominent position in the cropping pattern of the state. The technologies generated at the research institutes and universities should reach the sriculturists for realizing the benefit of the technologies. Even though extension network is a must for effective transfer of technology from laboratory to field level (Dolli *et al.,* 1995), training efforts are essential towards improving the productivity of farm resources by improving the technical capability of sericulture farmers. The skill training is considered as an effective tool for speedy transfer of technological information to the grassroot level. Even though many organizations are involved in transfer of the state-of-art technologies in sericulture, there is a huge gap between the practices recommended and that practice by the farmers. This gap raises doubt about the understanding and practice of technology by the stakeholders. A thorough investigation on the training needs of the farmers and extension workers will provide an insight into the areas in which the farmers need support. Thus, it will direct the training organization to frame their curriculum. Hence, the present investigation was planned to take up with an objective to identify the training needs of sericulturists and extension staff and give suitable suggestions for the effective training and dissemination of technology in sericulture.

MATERIALS AND METHOD

The study was conducted in Kolar district, which is the largest cocoon producing district in Karnataka. As per the requirement of the study, both officials and sericulturists operating in Siddlaghatta, Chintamani and Srinivasapura taluks were listed village wise. A total of 34 extensions official and 80 farmers were selected at random for the study. Further, An interview schedule was prepared to collect data from the farmers and officials. The primary data were collected by personal interview method by contacting the extension official and farmers individually. The opinion of the respondents and constraints for non-adoption of

Table 1: Felt training needs of farmers in the study area

Sl. No.	Technology	Siddlalghatta		Chintamani		Srinivaspura		Overall	
		No.	(%)	No.	(%)	No.	(%)	No.	(%)
1.	Soil reclamation	3	9.68	2	6.67	1	5.00	6	7.50
2.	Mulberry varieties and their Package of practices	8	25.81	13	43.33	6	30.00	27	33.75
3.	Vermi -composting	5	16.13	3	10.00	4	20.00	12	15.00
4.	Mulberry pest & disease control	16	51.61	22	73.33	8	40.00	46	57.50
5.	Intercropping in the mulberry	11	35.48	11	36.67	7	35.00	29	36.25
6.	Drip irrigation technology	20	64.52	23	76.67	11	55.00	54	67.50
7.	Transportation, incubation and black boxing	2	6.45	3	10.00	1	5.00	6	7.50
8.	Maintenance of hygiene in rearing house	5	16.13	2	6.67	5	25.00	12	15.00
9.	Maintenance of temperature and humidity in rearing house	2	6.45	2	6.67	1	5.00	5	6.25
10.	Brushing of loose eggs	5	16.13	4	13.33	6	30.00	15	18.75
11.	Worms spacing in shoot rearing	14	45.16	16	53.33	12	60.00	42	52.50
12.	Shoot rearing	23	74.19	27	90.00	16	80.00	66	82.50
13.	Identification of worms under moult	7	22.58	4	13.33	12	60.00	23	28.75
14.	Visit to different Sericulturists	3	9.68	0	0.00	5	25.00	8	10.00
15.	Discussion with successful entrepreneur	20	64.52	0	0.00	3	15.00	23	28.75

technology by farmers were also recorded and documented wherever necessary to support the findings of the study.

RESULTS AND DISCUSSION

Felt training needs of sericulturists

It can be inferred from the Table 1 that, 74.19% of the respondents in Sidlaghatta taluk felt, shoot rearing concept and maintenance of cocoon quality (74.19%) as the crucial technologies which require training, followed by the interaction with successful entrepreneurs (64.52%), drip irrigation (64.52%), mulberry pest and disease control (51.61%), silkworm bed spacing (45.16%), use of mountages (45.16%), intercropping in mulberry (35.48%), mulberry varieties (25.81%), identification of worm under moult (22.58%), vermi-composting (16.31%), soil reclamation measures (9.68%), visit to different sericulturists (9.68%), and transportation of eggs (6.45%).

In the case of Chintamani taluk, shoot rearing concept (90.00%), use of improved mountages and harvesting (83.33%), drip irrigation (76.67%), maintenance of cocoon quality (73.33%), mulberry pest and disease control (73.33%), interaction with successful entrepreneurs (64.52%), silkworm bed spacing (53.33%), mulberry varieties (43.33%), inter cropping in mulberry (36.67%), identification of worm under moult (13.33%), vermin-composting (10.00%), soil reclamation measures (6.67%) and transportation of eggs (10.00%) were the technologies considered to be the important to be trained.

In the case of Srinivasapura taluk, shoot rearing concept (80.00%), use of montages (80.00%), identification of worm under moult (60.00%), silkworm spacing (60.00%), maintenance of cocoon quality (45.00%), interaction with successful entrepreneurs (15.00%), drip irrigation (55.00%), mulberry pest and disease control (40.00%), intercropping in mulberry (40.00%), mulberry varieties (30.00%), visit to different sericulturists (25.00%), vermicomposting (20.00%), soil reclamation measures (5.00%) and transportation of eggs (5.00%) were the technologies considered to be the important to be trained. Thus it revealed that, there is a great level of significance attached to these areas where the farmers need training to hasten the level of knowledge and adoption.

Unfelt training needs of sericulturists

The unfelt needs were largely divided into four distinctive areas *viz.,* moriculture technologies, silkworm rearing technologies, supporting information and other areas. Among very important moriculture technologies, unfelt training needs were relatively high in the case of mulberry varieties (67.74%), fertilizers (58.06%), sapling (51.61%) and spacing followed (51.61%) in Sidlaghatta (Table 2). Similarly in Chintamani taluk, the unfelt training

Table 2: Unfelt training needs of farmers in the study area

Sl. No.	Technology	Siddlaghatta		Chintamani		Srinivasa-pura		Overall	
A	*Moriculture technologies*	No.	(%)	No.	(%)	No.	(%)	No.	(%)
1	Importance of soil sample	11	35.48	12	40.00	11	55.00	34.00	42.50
2	Soil reclamation	3	9.68	4	13.33	0	0.00	7.00	8.75
3	High yielding mul. varieties	21	67.74	20	66.67	12	60.00	53.00	66.25
4	Sapling/acre	16	51.61	16	53.33	11	55.00	43.00	53.75
5	Spacing	16	51.61	11	36.67	10	50.00	37.00	46.25
6	Fertilizer quantity	18	58.06	20	66.67	11	55.00	49.00	61.25
7	Bio-fertilizer quantity	7	22.58	5	16.67	0	0.00	12.00	15.00
8	FYM quantity	14	45.16	18	60.00	13	65.00	45.00	56.25
9	Leaf quantity/100dfl	15	48.39	14	46.67	11	55.00	40.00	50.00
10	Plant protection	14	45.16	23	76.67	9	45.00	46.00	57.50
11	Pruning schedule	12	38.71	6	20.00	11	55.00	29.00	36.25
B	*Rearing technologies*								
1	Bivoltine silkworm races	16	51.61	16	53.33	10	50.00	42.00	52.50
2	Care at chawki stage	18	58.06	15	50.00	14	70.00	47.00	58.75
3	Shoot rearing	15	48.39	20	66.67	13	65.00	48.00	60.00
4	Spacing	20	64.52	8	26.67	7	35.00	35.00	43.75
5	Identification of disease	18	58.06	20	66.67	8	40.00	46.00	57.50
6	Silkworm disease mngt.	7	22.58	14	46.67	10	50.00	31.00	38.75
7	Uzi management	13	41.94	6	20.00	2	10.00	21.00	26.25
8	Mountage and mounting	13	41.94	17	56.67	8	40.00	38.00	47.50
9	Cocoon quality parameter	11	35.48	19	63.33	11	55.00	41.00	51.25
10	De-flossing technique	18	58.06	20	66.67	15	75.00	53.00	66.25
C	*Supporting information*								
1	Extension agencies	8	25.81	10	33.33	6	30.00	24.00	30.00
2	Research organization	10	32.26	14	46.67	8	40.00	32.00	40.00
3	NGOs	20	64.52	19	63.33	8	40.00	47.00	58.75
4	SHG/ Quality club	30	96.77	28	93.33	20	100.00	78.00	97.50
5	Input agencies	8	25.81	12	40.00	11	55.00	31.00	38.75
6	Financial agencies	9	29.03	14	46.67	9	45.00	32.00	40.00
7	Chemical supplier	7	22.58	19	63.33	8	40.00	34.00	42.50
8	Inter cropping in mulberry	12	38.71	13	43.33	8	40.00	33.00	41.25
D	*Other areas*								
1	Economics	0	0.00	4	13.33	0	0.00	4.00	5.00
2	Basic farm management	3	9.68	10	33.33	5	25.00	18.00	22.50
3	Investment technique	4	12.90	10	33.33	6	30.00	20.00	25.00
4	Mechanization in seri.	15	48.39	17	56.67	13	65.00	45.00	56.25
5	Account and book keeping	1	3.23	2	6.67	1	5.00	4.00	5.00
6	Cocoon market I the state	20	64.52	24	80.00	14	70.00	58.00	72.50
7	Training organization	20	64.52	23	76.67	9	45.00	52.00	65.00

Table 3: Felt training needs of extension workers in the study area

Sl. No.	Technology	Siddlaghatta		Chintamani		Srinivasa-pura		Overall	
		No.	(%)	No.	(%)	No.	(%)	No.	(%)
1	Soil sampling method	9	64.29	2	11.76	1	25.00	12	15.00
2	Soil reclamation	7	50.00	2	11.76	2	50.00	11	13.75
3	Mulberry varieties and their package	7	50.00	7	41.18	1	25.00	15	18.75
4	Nursery technology	2	14.29	10	58.82	2	50.00	14	17.50
5	Vermicompost pre paration	3	21.43	10	58.82	0	0.00	13	16.25
6	Mul. pest & disease mngt.	6	42.86	10	58.82	2	50.00	18	22.50
7	Intercropping in mulberry	10	71.43	5	29.41	2	50.00	17	21.25
8	Drip irrigation technique	8	57.14	9	52.94	1	25.00	18	22.50
9	Vermicompost preparatio n	3	21.43	10	58.82	1	25.00	14	17.50
10	Disinfection & hygiene	3	21.43	8	47.06	1	25.00	12	15.00
11	Maintenance of temp. and humidity in rearing house	5	35.71	6	35.29	1	25.00	12	15.00
12	Brushing of loose eggs	3	21.43	12	70.59	1	25.00	16	20.00
13	Chawki rearing	2	14.29	9	52.94	3	75.00	14	17.50
14	Spacing of worms in shoot rearing	5	35.71	8	47.06	1	25.00	14	17.50
15	Shoot rearing	6	42.86	7	41.18	3	75.00	16	20.00
16	Identification of worms under moult	2	14.29	4	23.53	2	50.00	8	10.00
17	Silkworm pest & disease control	2	14.29	10	58.82	1	25.00	13	16.25
18	Visit to successful sericulturist / research organization	3	21.43	2	11.76	2	50.00	7	8.75
19	Discussion with successful sericulturist	4	28.57	7	41.18	2	50.00	13	16.25
20	Using improved mountages and harvesting	7	50.00	9	52.94	2	50.00	18	22.50
21	Mechanization	10	71.43	8	47.06	2	50.00	20	25.00
22	Sericulture economics	4	28.57	9	52.94	1	25.00	14	17.50

needs were high in the case of plant protection (76.67%), mulberry variety that yield maximum (66.67%), quantum of fertilizer to be applied (66.67%), FYM quantity (60.00%) and sapling per acre (53.33%). In the case of Srinivasapura, it was high in the case of FYM quantity (65.00%) mulberry varieties (60.00%), fertilizers (55.00%), sapling (55.00%) and spacing followed (50.00%).

The silkworm rearing technologies, which need attention for improving knowledge through training were silkworm spacing (64.52%) followed by deflossing technique (58.06%), identification of diseases (58.06%), care at chawki stage (58.06%), shoot rearing method (48.39%), uzi-control (41.94%), mounting practices (41.94%) and cocoon quality parameter (35.48%) in Sidlaghatta. Similarly, the unfelt training needs in Chintamani regarding silkworm rearing practices were identified as deflossing technique (66.67%), identification of disease (66.67%), shoot rearing method (66.67%), cocoon quality parameter (63.33%) mounting practices (56.67%), care at chawki stage (50.00%), silkworm spacing (26.67%), and uzi-control (20.00%). In Srinivasapura taluk, deflossing technique (75.00%), care at chawki stage (70.00%), shoot-rearing method (65.00%), cocoon quality parameter (55.00%), mounting practices (40.00%), identification of disease (40.00%), silkworm spacing (35.00%) and uzi-control (10.00%).

Felt training needs of extension officials

The DOS officials at Chintamani, felt the package of practices of mulberry (42.65%), quality of leaf (55.36%) by pest management in the mulberry (41.18%), disease management in mulberry (41.18%), soil testing methods (39.71%) and paired row system of planting (39.71%) were considered to be the most important areas for training. In case of silkworm rearing, they felt that the training was required in the areas such as chawki rearing (51.47%), shoot rearing (50.00%), basic statistical analysis (44.12%), silkworm races (42.65%), programme planning (42.65%), disease prevention (47.06%), farm management (42.65%), management of microclimate (41.18%), and cocoon quality assessment (36.76%) (Table 3).

Table 4: Unfelt training needs of officials in the study area

Sl. No.	Technology	Sidlaghatta		Chintamani		Srinivasapura		Overall	
		No.	%	No.	(%)	No.	(%)	No.	(%)
1	Soil testing methods	28	50.00	27	39.71	13	81.25	68	85.00
2	Interpretation of soil tests result	22	39.29	28	41.18	11	68.75	61	76.25
3	Vari ety and mulberry package of practices	25	44.64	29	42.65	10	62.50	64	80.00
4	Paired row system	28	50.00	27	39.71	11	68.75	66	82.50
5	Intercropping & mixed cropping	25	44.64	27	39.71	11	68.75	63	78.75
6	Chemical fertilization & fertility mngt.	24	42.86	28	41.18	11	68.75	63	78.75
7	Biofertiliser	26	46.43	22	32.35	12	75.00	60	75.00
8	Mulberry disease & their mngt.	29	51.79	28	41.18	12	75.00	69	86.25
9	Pest of mulberry & their mngt.	30	53.57	28	41.18	10	62.50	68	85.00
10	Quality parameter of leaf	31	55.36	23	33.82	10	62.50	64	80.00
11	Growth regulator in mulberry	27	48.21	25	36.76	10	62.50	62	77.50
12	Silkworm races & their characteristics	31	55.36	29	42.65	11	68.75	71	88.75
13	Chawki rearing	29	51.79	35	51.47	11	68.75	75	93.75
14	Shoot rearing	31	55.36	34	50.00	12	75.00	77	96.25
15	Management of micro climate	31	55.36	28	41.18	10	62.50	69	86.25
16	Disease prevention	30	53.57	32	47.06	11	68.75	73	91.25
17	Silkworm pest mngt.	27	48.21	30	44.12	11	68.75	68	85.00
18	Usage of sampoorna	27	48.21	29	42.65	11	68.75	67	83.75
19	Mountage and cocoon harvesting	31	55.36	26	38.24	8	50.00	65	81.25
20	Cocoon quality parameter	33	58.93	25	36.76	8	50.00	66	82.50
21	Mechanization in sericulture	32	57.14	30	44.12	12	75.00	74	92.50
22	Extension in Programme planning	31	55.36	29	42.65	10	62.50	70	87.50
23	Farm management	31	55.36	29	42.65	13	81.25	73	91.25
24	Basic statistical analysis	33	58.93	30	44.12	12	75.00	75	93.75

Similarly, the DOS officials at Srinivasapura felt, the areas such as farm management (81.25%), basic statistical analysis (75.00%), shoot rearing method (75.00%), silkworm races (68.75%), disease prevention (68.75%), chawki rearing (68.75%). Programme planning (62.50%), and management of microclimate (62.50%) and cocoon quality assessment (50.00%) as their training needs.

The DOS officials at Sidlaghatta felt, the areas such as cocoon quality assessment (58.93%), basic statistical analysis (58.93%), silkworm races (53.36%), shoot rearing methods (55.36%), management of microclimate (55.36%), programme planning (55.36%), farm management technique (55.36%), disease prevention (53.57%) and chawki rearing (51.79%) needed training.

Unfelt training needs of extension officials

Among the unfelt needs of DOS officials, in Sidlaghatta, the quality of leaf (55.36%), pest management in the mulberry (53.57%), disease management in mulberry (51.99%), soil testing methods (50.00%) and paired row system of planting (50.00%) were considered to be the most important areas for training (Table 4).

For the DOS officials at Chintamani, the package of practices of mulberry (42.65%), quality of leaf (55.36%, pest management in the mulberry (41.18%), disease management in mulberry (41.18%), soil testing methods (39.71%) and paired row system of planting (39.71%), were considered to be the most important areas for training.

For the Srinivasapura, DOS staff, the important areas where the training required were, soil testing methods (81.25%), bio-fertilizer (75.00%), mulberry disease management (75.00%), pest management in the mulberry (62.50%), disease management in mulberry (75.00%) and paired row system of planting (68.75%).

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 525-528

TRAINING IMPACT: AN ANALYSIS OF SERICULTURE FARMERS IN KOLAR DISTRICT, KARNATAKA

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ABSTRACT

The present study was taken up with an objective of understanding the knowledge and adoption of technologies involved in mulberry cultivation and cocoon production by the farmers in Karnataka. Kolar district was purposively selected for the study as it represents an important area for sericulture in the state. A total of 80 trained sericulturists form the sample of the study. The results indicated that arranging field study tours and refresher training programmes to gardens of innovators and early adopters will stimulate and build confidence in the farmers, which would result in technology adoption and have a spread effect in the study area.

Key words: Impact of training, Knowledge and adoption, Kolar district, Training programmes

INTRODUCTION

Sericulture has made a clear impact on the farmers of southern states especially Karnataka, Andhra Pradesh and Tamil Nadu in the last two decades. Further, efforts are made to develop the industry in non-traditional areas like north-eastern states to improve the economic status of the farmers. In spite of efforts made by Central Silk Board, the state department of sericulture and the non-government organizations, the practice of bivoltine sericulture is not picking up in India in general and Karnataka in particular. Various studies conducted in this direction indicated that the farmers training play an important role in adopting bivoltine sericulture. In this context, the present study was taken up with an objective of understanding the impact of training on knowledge and adoption level of bivoltine cocoon production by the farmers in Karnataka.

MATERIALS AND METHODS

The study was conducted in Karnataka state. Kolar district was purposively selected for the study as it represents the district with high proportion of area under mulberry. Shiddlaghatta, Chintamani and Srinivasapura taluks were selected in the district and from each taluk, three villages were identified based on the number of trained sericuturists. Thirty trained farmers each from Shiddlaghatta and Chintamani and 20 farmers from Srinivasapura taluk were selected for the purpose of collecting data. Thus, a total of 80 trained sericulturists form the sample of the study. The required information for the study were collected from the selected farmers with the help of a structured interview schedule by using personal interview method both before and after the training. The data were analysed by using percentages.

RESULTS AND DISCUSSION

Impact of training on level of knowledge of sericulturists in Kolar district

Table 1 reveals that the knowledge level about the importance of sericulture practices improved among farmers due to training. The knowledge level was found to be 54.84% in case of incubation and loose egg brushing followed by disinfection (35.48%), mounting care (32.26%), bed cleaning (32.26%) and uzi control (32.26%) and cocoon harvesting (32.26%). The impact of training on the level of knowledge of different sericultural technologies was studied. The study revealed that there was a considerable change in the level of knowledge due to the exposure to training in sericulture.

Table 1: Impact of training on knowledge level of sericulturists in different taluks of Kolar district

Technologies	Sidlaghatta (N=30)				Chintamani (N=30)				Srinivasapura (N=20)				Pooled (N=80)			
	BT	AT	CG	CG in %	BT	AT	CG	CG in %	BT	AT	CG	CG in %	BT	AT	CG	CG in %
Mulberry variety	4	7	3	9.68	4	15	11	36.67	4	15	11	55.00	12	37	25	30.86
Nursery bed size	2	6	4	12.90	3	13	10	33.33	1	11	10	50.00	6	30	24	29.63
Planting material selection	1	2	1	3.23	2	4	2	6.67	1	3	2	10.00	4	9	5	6.17
Paired row sys. of plantation	0	1	1	3.23	1	6	5	16.67	1	4	3	15.00	2	11	9	11.11
FYM Quantity	2	10	8	25.81	3	17	14	46.67	1	15	14	70.00	6	42	36	44.44
Fertiliser	2	10	8	25.81	3	14	11	36.67	3	4	1	5.00	8	28	20	24.69
Plant protection	1	5	4	12.90	2	10	8	26.67	1	9	8	40.00	4	33	29	35.80
Pruning	0	4	4	12.90	1	10	9	30.00	1	9	8	40.00	22	35	13	16.05
Bofertiliser	0	3	3	9.68	1	4	3	10.00	1	3	2	10.00	2	10	8	9.88
Weedicide	0	2	2	6.45	1	3	2	6.67	1	2	1	5.00	2	7	5	6.17
Growth promoter	0	0	0	0.00	1	2	1	3.33	3	3	0	0.00	4	5	1	1.23
Disinfection	11	12	1	3.23	12	12	0	0.00	2	12	10	50.00	25	36	11	13.58
Incubation	17	19	2	6.45	17	17	0	0.00	8	18	10	50.00	42	54	12	14.81
Loose egg brushing	17	18	1	3.23	17	17	0	0.00	7	13	6	30.00	41	48	7	8.64
Wrap up method	11	11	0	0.00	12	12	0	0.00	7	7	0	0.00	30	30	0	0.00
Temp. & RH at chawki	4	4	0	0.00	3	3	0	0.00	1	1	0	0.00	8	8	0	0.00
Temp. & RH at late age	4	4	0	0.00	2	2	0	0.00	1	2	1	5.00	7	8	1	1.23
Bed disinfectant	6	6	0	0.00	7	7	0	0.00	1	1	0	0.00	14	14	0	0.00
Moulting care	10	10	0	0.00	11	11	0	0.00	1	11	10	50.00	22	32	10	12.35
Bed cleaning	10	11	1	3.23	11	11	0	0.00	1	11	10	50.00	22	33	11	13.58
Shoot rearing	9	9	0	0.00	1	1	0	0.00	1	9	8	40.00	11	19	8	9.88
Uzi control	10	31	21	67.74	2	29	27	90.00	1	1	0	0.00	13	44	31	38.27
Mounting	3	7	4	12.90	3	7	4	13.33	11	11	0	0.00	17	25	8	9.88
Cocoon harvesting	10	16	6	19.35	8	16	8	26.67	5	7	2	10.00	23	39	16	19.75
Rearing space/100 dfls	6	16	10	32.26	5	16	11	36.67	14	14	0	0.00	25	46	21	25.93
Leaf size for difft. stages	2	8	6	19.35	1	6	5	16.67	15	15	0	0.00	18	29	11	13.58

BT: before training; AT: after training; CG: change

Table 2: Impact of training on level of adoption of sericultural technologies in different taluks of Kolar district

Technologies	Sidlaghatta (N=30)				Chintamani (N=30)				Srinivasapura (N=20)				Pooled (N=80)			
	BT	AT	CG	CG in %	BT	AT	CG	CG in %	BT	AT	CG	CG in %	BT	AT	CG	CG in %
Mulberry variety	12	13	1	3.23	6	17	11	36.67	6	16	10	50.00	24	46	22	27.16
Nursery bed size	3	3	0	0.00	7	14	7	23.33	5	12	7	35.00	15	29	14	17.28
Planting material selection	4	4	0	0.00	3	4	1	3.33	2	3	1	5.00	9	11	2	2.47
Paired row syst. of plantation	16	19	3	9.68	2	6	4	13.33	1	4	3	15.00	19	29	10	12.35
FYM Quantity	14	15	1	3.23	11	20	9	30.00	9	18	9	45.00	34	53	19	23.46
Fertiliser	10	13	3	9.68	11	15	4	13.33	10	14	4	20.00	31	42	11	13.58
Plant protection	10	10	0	0.00	6	13	7	23.33	5	12	7	35.00	21	35	14	17.28
Pruning	4	4	0	0.00	5	10	5	16.67	4	9	5	25.00	20	35	15	18.52
Bofertiliser	3	6	3	9.68	3	4	1	3.33	2	3	1	5.00	8	13	5	6.17
Weedicide	1	2	1	3.23	3	4	1	3.33	1	2	1	5.00	5	8	3	3.70
Growth promoter	8	8	0	0.00	1	3	2	6.67	1	1	0	0.00	10	12	2	2.47
Disinfection	12	18	6	19.35	13	13	0	0.00	12	12	0	0.00	37	43	6	7.41
Incubation	8	8	0	0.00	7	8	1	3.33	16	16	0	0.00	31	32	1	1.23
Loose egg brushing	0	0	0	0.00	15	15	0	0.00	16	17	1	5.00	31	32	1	1.23
Wrap up method	0	0	0	0.00	2	2	0	0.00	10	11	1	5.00	12	13	1	1.23
Temp. & RH at chawki	0	0	0	0.00	1	1	0	0.00	2	2	0	0.00	3	3	0	0.00
Temp. & RH at late age	0	0	0	0.00	2	2	0	0.00	2	2	0	0.00	4	4	0	0.00
Bed disinfectant	0	0	0	0.00	1	1	0	0.00	7	7	0	0.00	8	8	0	0.00
Moulting care	0	0	0	0.00	1	1	0	0.00	11	11	0	0.00	12	12	0	0.00
Bed cleaning	0	0	0	0.00	1	1	0	0.00	1	1	0	0.00	2	2	0	0.00
Shoot rearing	23	28	5	16.13	1	1	0	0.00	1	1	0	0.00	25	30	5	6.17
Uzi control	7	12	5	16.13	29	30	1	3.33	0	16	16	80.00	36	58	22	27.16
Mounting	16	18	2	6.45	5	5	0	0.00	0	5	5	25.00	21	28	7	8.64
Cocoon harvesting	17	22	5	16.13	14	15	1	3.33	0	12	12	60.00	31	49	18	22.22
Rearing space/100 dfls	14	14	0	0.00	15	16	1	3.33	0	14	14	70.00	29	44	15	18.52
Leaf size for different stages	12	18	6	19.35	8	8	0	0.00	0	7	7	35.00	20	33	13	16.05

BT: before training; AT: after training; CG: change

In Sidlaghatta taluk, the improvement in knowledge level was seen with respect to technologies like uzi control (67.74%), followed by rearing house (32.62%), farmyard manure and fertiliser application (25.81%), cocoon harvesting methods (19.53%), leaf size for different instars (19.53%), plant protection (12.90%), nursery bed size (12.90%) and weedicide (6.45%). However, there was no significant change in other important technologies required for silkworm rearing.

In Chintamani taluk the training impact was seen in technologies like uzi control (90.00%), FYM quantity (46.67%), fertiliser (36.67%), rearing house (36.67%), nursery bed size (33.33%), pruning (30.00%), cocoon harvesting methods (26.67%), leaf size for different instars (16.67%), mounting (13.35%), planting material selection (6.67%), weedicide (6.67%) and growth promoter (3.33%).

The impact was seen in Srinivasapura taluk on the knowledge level of technologies such as mulberry variety (55.00%), nursery bed size (50.00%), plant protection (40.00%), pruning (40.00%), shoot rearing (40.00%), loose egg brushing (30.00%), paired row (15.00%), cocoon harvesting methods (10.00%) and planting material selection (5.00%).

The pooled data revealed that the knowledge level was increased after training for the technologies *viz.,* FYM quantity (44.44%), uzi control (38.27%), plant protection (35.80%), mulberry variety (30.86%), nursery bed size (29.63%), rearing house (29.63%), pruning (30.00%), fertiliser (36.67%), incubation (14.81%), disinfection (13.08%) and leaf size for different instars (13.58%). However, there was no change in the level of knowledge for technologies like bed disinfectant, wrap-up method, maintenance of temperature and relative humidity at chawki, usage of growth promoter (Srinivasa *et al*., 2005).

Impact of training on level adoption of Sericultural technologies in Kolar district

The impact of training on the level of adoption of different sericultural technologies was studied. The impact of exposure to training was studied prior to training and after the training. The study revealed that there was a considerable change in the level of adoption due to training in sericulture. The technology wise impact of training on adoption showed that there was a significant improvement in technology adoption after the training.

In Sidlaghatta taluk, the technologies which were adopted after imparting training included disinfection (19.35%), leaf size for different instars (19.35%), cocoon harvesting methods (16.13%), uzi control (16.13%), shoot rearing (16.13%), bio-fertiliser (9.68%), paired row system of plantation (9.68%), mounting (6.45%), mulberry variety (6.45%) and weedicide (3.28%) (Geetha *et. al*., 2003) (Table 2),

In Chintamani taluk, the technologies which were found adopted after imparting training included mulberry variety (36.67%), FYM quantity (30.00%), nursery bed size (23.33%), plant protection (23.33%), pruning (16.67%), paired row system of plantation (13.33%), growth promoter (6.67%), uzi control (80.00%), rearing house (70.00%), cocoon harvesting methods (60.00%), mulberry variety (50.00%), nursery bed size (35.00%), plant protection (35.00%), leaf size for different instars (35.00%), pruning (25.00%), fertiliser application (20.00%) and planting material selection (5.00%).

In Srinivasapura taluk, the technologies, which were adopted after the training included uzi control (80.00%), rearing house (70.00%), cocoon harvesting methods (60.00%), mulberry variety (50.00%), paired row system of plantation (45.00%), nursery bed size (35.00%), plant protection (35.00%), leaf size for different instars (35.00%), pruning (25.00%), fertiliser application (20.00%) and planting material selection (5.00%) (Chikkanna, *et al*., 1995).

To conclude, the farmers' training programmes have helped to improve the farmers' knowledge level and adoption of certain technologies in sericulture in Kolar district of Karnataka.

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DEVELOPMENT OF NEW AND DIVERSIFIED PRODUCTS OF SILK TO ENHANCE THE INDIAN SILK IN INTERNATIONAL MARKET

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ABSTRACT

Indian silk industry is catering its silk products to both domestic market and export market. The domestic market for silk is quite substantial and even though silk continues to be in demand for many traditional end uses, new applications are constantly being developed for this fibre. Product diversification in to casual wear and focus on bringing the growing upper middle income group along with high income group into the fold of silk products is leading to greater value addition in domestic silk production. In case of Export market, the base requires to be widened by offering new range of products with quality and perhaps exceeding customer's expectation. This can happen only when silk industry has new range of products to offer all the time and newness would make the products appear to be custom made to suit individual preferences. At this point the product diversification and development has been a pressing need of the Indian silk industry for which the inherent strength of the industry needs to be projected in right perspective way and also to be harnessed effectively. In the emerging silk scenario, the industry needs to have silk which covers products of comfort and pleasure which communicates certain values such as harmony, security and sensuality, culture silk that re-injects sense into the products that are becoming old fashioned and finally a sense of glamour into the products with discreet luxury. To meet all these requirements, Central silk board has established a product development cell for silk so as to empower the Indian silk industry with the right strategy for enhanced market share in the international trade. Now the center is actively involved in development of new and diversified products out of all major varieties of silks produced in India viz., mulberry, tasar, eri and muga silk. The new varieties of silk products developed by Central silk board has abundant scope for commercially exploiting the market demand and has to widen the possibility of providing fashion apparel to the market.

Key words: Diversified products, Fashion apparel, Indian silk, International market

INTRODUCTION

India is the second largest producer and first largest consumer of silk and is the only country that produces all the four varities of silk. Since time immemorial, silk has been a export material. Skilled art, colour combinations, unique traditional designs, and usage of natural dye in printed goods produced by traditional printing clusters etc. have carved a niche for the Indian silks in the international market.

Basically Indian silk industry has certain inherent strength thanks to the availability of four varieties of silk, skilled labour and also the traditional art. Perhaps, till recently, the industry had not realized its own strength. The need of the hour was to consolidate the research out put and to convert the traditional products in to contemporary designs suitable for outer world. Further, it is required to widen the export market base, to provide quality products according to customer expectations.

Bringing market awareness

Indian silk goods are being exported to both traditional and non-traditional market. The foreign trade in the silk is attaining greater importance year after especially in the non-traditional markets

From a humble beginning of export of traditional items, India today exports high fashion item and its export earnings worth millions! Indian silk industry is on the threshold of discovering a new identity (Venkatakrishna, 2000; Datta and Nanavathy, 2005). The industry has resurging through various interventions. Now it is time for consolidating such developments and realizing them in the form of better market share. This can happen when we have a new range of products to offer. Sometimes traditional manufacturer may not have the idea of new market and its potential. Besides, the diversified silk products of CSTRI of CSB are not being fully realized by the beneficiaries due to lack of exposure and communications.

P3D Approach

In view of the above, Central Silk Board established a special cell *i.e.*, P3D - design, development and diversification of silk products at CSTRI, Central Silk Board. The main purpose of establishing P3D is to empower the Indian silk industry with the right strategy for enhanced market share in the international trade besides making wide choice of silk product for domestic market. Hence the product development cell (P3D) is showcasing the new products for visualizing the end product and providing technical information for developing the same. Apart from show casing the unique products, P3D under CSTRI is also working in the area of development of new and diversified product out of all major varieties of silk produced in India.

Approaches of P3D are -

- Revival of traditional products
- Development of new products

Taking a cue!

India is known for its traditional weaving, dyeing and printing heritage. Many clusters have distinct traditions and skills. These products are restricted to limited end uses. However, it has been possible to look at alternate end uses for these products breaking the monotony. The famous designs of Bagh, Bagru, Ujain and Kalahasti were printed on different varieties of silk fabrics which were then converted in to western apparel. Similarly, the famous design of Mekhala and chadar of Muga silk have given a cue for unique muga silk garments. Apart from reviving traditional products, CSTRI have brought out a nge of new products of silk in terms of its design, construction and end uses. The development of silk stretch fabric and silk knitted fabrics silk denims with soft touch, light weight, comfortable, blended with luxury and smooth feel have been developed. An attempt has also been made for production of light weight denim fabrics using mulberry and eri silk &its blends as warp and weft combinations to cater to the needs of ladies wear and kids wear.

Diversification to infuse newer design sense in to the traditional saree by replacing golden zari with muga silk have added variety to the range of silk products and has also widened the possibility of providing fashion apparels to the market. The situation is no different in case of handloom industry. The hand loom cluster needs to be exploited in the area of Tapestry weaving, Jala techniques and multi shuttle techniques to create exclusive designs suitable for garment. Demand for diversified sarees undoubtedly exists. Usage of Indian art like *Kasuthi, Fulkari, Kuch* work, *Zardosi, Chicken* work, *Kanta* work, *Kashmere* work on silk materials has enhanced their value and beauty. Silk industry also needs to be stabilized in terms of finishing such as Aroma finish, Anti wrinkle finish and fire retardant finish *etc*.

Now a day's export of Indian silk garments is gaining importance. Even though garment export is increasing, there is an increase in import of high end garment (Somashekar, 2003). However, to compete in international market, stabilizing of silk garment sector in terms of raw materials, selection of appropriate thread, stitch accessories, new designs and equipping ourselves with high end finishing techniques are essential. Further the silk products are to be ensured for their purity thro silk mark logo identity and ultimately the silk industry has to participate in national and international exhibition to highlight and popularize Indian silk.

CONCLUSION

Indian silk industry is on the threshold of discovering a new identity wherein the world is looking up to us. The industry has evidenced resurgence through various interventions thanks to the development agencies. Now it is time for consolidating the improvements and realize it in the form of better market share. This can happen when we have a new range of products to offer all the time and the newness would make the products appear to be custom made to suit the individual preferences (Koshi, 1993).

It is in this context the textile ministry has set up a product development cell at CSB to provide the necessary impetus for this momentum, which has been gathered thus far, to reach farther. The manufacturing and export community is therefore invited to interact with the cell, make use of this infrastructure to benefit in the long run. The synergy we can establish among the various players in the value chain becomes vital for fostering each others growth since inter dependence of the various sectors of the industry is a foregone conclusion.

To summarize, we need to have silk, which covers products of comfort and pleasure, that communicates certain values like harmony, security, tenderness and sensuality and finally a sense of glamour into the silk products with discreet luxury.

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SERICULTURE EXTENSION IN THE STATE OF JAMMU AND KASHMIR - A CSB EXPERIENCE

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ABSTRACT

Undertaking R&D, economic and human resource development activities research in sericulture and extending accrued research benefits to the farming community *vis-à-vis* silk industry as a whole has been the prime responsibility of Central Silk Board [CSB]. Sericulture extension plays a vital role in enhancing production, productivity and quality of silk. The first unit of CSB in the State of J&K was established in the year 1958 at Pampore (Kashmir) with the objective of maintaining univoltine/bivoltine silkworm races and supply of silkworm seed to northern States of India. Although, the unit was a mere seed station up to 1980, nevertheless, it also engaged in need based research in silkworm breeding and agronomical practices. The extension backup during the early period was provided by periodical camp extension, whereby the silkworm rearing villages would be adopted and the technologies tested. The role of CSB in this direction can well be understood by evaluating the progress achieved in sericulture research and development and resultant increase in cocoon productivity and production during 1970–1980 (Phase I), 1981–1990 (Phase II), 1991–2000 (Phase III) and 2001–2010 (Phase-IV), besides taking in to cognizance the development of promising productive bivoltine silkworms lines/breeds during these years and there field use thereof. The paper evaluates in detail the periodic progression achieved through extension during each phase of development as envisaged above in the state of J&K, development of extension mechanism, popularization of improved technologies, establishment of various extension centres by CSB and their accomplishments.

Keywords: Cocoon productivity, Extension mechanism, Improved technologies Silkworm seed

INTRODUCTION

Extension is well recognized as a tool for development of sericulture and increasing cocoon and raw silk production. To keep pace with the brisk change in technologies, farmers need to learn new practices and in turn transmit the real field problems back to the research workers (Reddy, 1993). Extension activity at the farmers' field attains significance as much as research in a research station. Hence the main objective of extension is to solve the practical problems of the farmer. Adoption of technology by the farmers essentially is a decision making process. The rate of adoption of technologies at the farmer level can be attributed to a dynamic process of effective Transfer of Technology (TOT) programmes adopted by the extension agencies (Ray, 1991). In this regard the contribution of Central Silk Board (CSB) in disseminating the sericulture technologies to the field through the plan periods is commendable.

Undertaking research in sericulture and extending the accrued research benefits to farming community and to silk industry as a whole has been the prime responsibility of CSB. The first unit of CSB in J&K at Pampore was established in the year 1958 with the objective of maintaining univoltine/ bivoltine silkworm races and temperate mulberry varieties besides production of parental silkworm seed and its supply to northern States of India. The role of Central Silk Board in this direction, in the State of Jammu & Kashmir, can best be understood by evaluating the periodic progression achieved in sericultural research and development, extension and the resultant increase in cocoon productivity and production in a phased manner from the year 1970 onwards.

Phase I: 1970-1980

Even when the CSB unit at Pampore was a mere seed station (up to 1980), it took up need based research in silkworm breeding and agronomical practices. The extension backup during the early period was provided by periodical camp-extension, whereby the silkworm rearing villages would be adopted and the technologies tested. This practice continued till 1975 in Kashmir and till 1979 in Jammu province. The silkworm hybrids that were propagated during this period included PL-F x KY-1, BL-1 x SS-4A, SS-17 x SS-4A and SS-17 x SS-17. These hybrids excelled over the ruling hybrids of the day in terms of productivity and quality parameters. However, since extension units were temporary and would last for the specific rearing / planting seasons, continuous interaction with the rearers was lacking. Besides, the extension workers would also change often affecting the efficacy of the person and confidence levels among the rearers. The rearers took time to adjust and accept the new extension personnel.

In the year 1975, the first ever extension centre of Central Silk Board was established and with it's headquarter at Pampore. This marked the beginning of a new era in scientific and logical management of effective extension to reach the research benefits to rearers. Subsequently, with the establishment of Extension Centres at Sunderbani in Jammu (1980), Sujanpur in Punjab (1981) and Tral in Kashmir (1982), the extension management entered a new phase.

Phase II: 1980-1990

The role of extension in disseminating the evolved technologies among rearers is best illustrated by the impact of the activities of the Research Extension Centre [REC], Sunderbani, established in December, 1980 and commenced functioning in the year 1981. Previous to 1981, the average yield of cocoons in Sunderbani area was in the range of 17 to 24 kg per oz of seed. With popularization of improved rearing technologies, introduction of superior silkworm hybrids and ensuring effective supervision of rearings, the average yield in the area steadily increased over the years (Table-1) and touched a high of 52 kg/oz during 1987-1990. Also the most remarkable feature of the period was emergence of a new silkworm hybrid viz., SH6 x NB4D2, which was introduced in the State by the REC in the year 1982. In spite of initial ups and downs, the hybrid stabilized and established itself in the field. The hybrid continues to rule even today with convincing replacements hard to find.

During the same period new and superior mulberry varieties, Chinese white, Chak Majra and later S146 were popularized in the area and mulberry wealth increased many fold with their multiplication and plantation in other areas as well. Moreover, multiple cocoon cropping system with four crops comprising of two bivoltine cocoon crops (spring & autumn) and two Multi x Bi crops (April to July) were introduced and practiced vigorously in the area.

The REC at Tral in Kashmir during the same period did not lag behind and did equally well in increasing cocoon production and mulberry wealth and the resultant productivity in the Batnoor, Mundura and Kahlil zones remarkably went upto 80 kg/oz of seed.

Phase III: 1990-2000

This phase could be considered the golden period in the development of sericulture through the efforts of CSB in the State as the extension services further proliferated and far-flung rural areas were covered for increased cocoon production through RECs and Technical Service Centres [TSC] established under the National Sericulture Project. Benefits of Extension guidance reached to new as well as far off areas such as Kishtwar (Doda District), Solki & Rajouri (Rajouri District), Arnas/Panasa/Gordhi (Udhampur District) and Plassi/Mahanpur (Kathua district) in Jammu Division. In the valley of Kashmir, the extension guidance through establishment of TSCs (now RECs/SRECs) was extended to rearers in distant areas in North Kashmir (Langet area), Central Kashmir (Pattan area) and South Kashmir (Y. K. Pura).

In the year 1995, silkworm hybrids evolved by Central Sericultural Research & Training Institute [CSR&TI], Pampore, its affiliated RSRSs and other Institutes of CSB were authorized for rearing in J&K State. Some of these hybrids for spring and summer crops included SH6 x KA, SH6 x NB4D2, YS3 x SF19 and CA2 x NB4D2. Similarly, for autumn/ early winter crops, Pam101 x NB4D2, CC1 x NB4D2, Pam11 x SF19 and SH6 x NB4D2 were recommended. As a result, in the Jammu division rearing of JAM hybrids was gradually replaced and ultimately totally stopped.

Further, concerted efforts were made to stabilize the second cocoon crop with greater thrust. Sub-REC of CSB located at Tikri (Jammu) took the initiative from its very first year of establishment in 1998. The year-wise performance of the autumn crop under this unit is illustrated in the Table-2, which depicts an overwhelming progression with increased potential for productivity in the area for autumn crop. Similar progress was achieved in the area under REC at Kathua during the last three years of phase III. In the valley, on account of agricultural and horticultural crops during Autumn, advancing the second crop to late Summer season gave encouraging results.

High sericigenous CSR series of silkworm hybrids reared in J&K showed a reduction in renditta from 10-11 kg to about 7-8 kg, besides production of high quality silk. These hybrids are still being popularized by the RECs.

In their study Trag et al. (1991) reported that the on an average 68.95 kg per ounce of seed was obtained from the high yielding breeds and by adoption of package of practices The reason for lower productivity in the past performance was attributed to low yielding silkworm breeds and crude traditional rearing techniques. Hence this phase was primarily important from the point of view of vertical growth in sericulture in Jammu & Kashmir.

Phase IV 2001-2010)

The RSJ series of silkworm hybrids evolved at RSRS, Miran Sahib in the year 2000 have been seen to be more promising than the CSR hybrids (Table-3), in the field trials conducted in the Tikri area during spring season. The productivity of the evolved hybrid RSJ14 x RSJ11 was invariably over 70 kg/oz across the years.

Among the mulberry varieties, S146 and Chak Majra continued to be most popular in sub-tropical areas and Chinese White together with S 146 in intermediate areas. Among the new mulberry varieties that were popularized in field were Tr-10, S-1 and S-13. The period also saw the emergence of extension in the areas of post cocoon technologies, which benefited both the rearers and the entrepreneurs. Large scale demonstrations of use of black cloth for cocoon drying, drying in Ushnakothis, demonstrations and training of reelers to upgrade their skills, assistance in marketing etc., by the Demonstration-cum-Technical Service Centres [DCTSC] of CSB have immensely helped in improving cocoon quality and thereby make the practice more remunerative. Technologies for mulberry grafting, raising mulberry nurseries, Package of practices for cultivation of mulberry under rainfed conditions, pruning of plants, introduction of region and season specific silkworm hybrids viz., YS3 x NB4D2; SH6 x KA; SH6 x NB4D2 and CA2 x NB4D2 for spring and PAM101 x NB4D2; CC1 x NB4D2; PAM111 x SF19 and SH6 x NB4D2 for autumn through extension were the major contributions during the period. Establishment of the Cluster Development Centres [CDC] at Nowshera and Tikri in Jammu Division and Bandipora and Tral in Kashmir division has opened new vistas to strengthen extension and facilitate percolation of sericulture technologies through cluster mode. As a result, around 500 rearers were provided with infrastructure support by way of rearing accommodation, rearing appliances, mulberry plantation blocks, disinfectants, cash incentive and more importantly assured marketing support for their produce. The introduction of multiple cropping in the State through state agencies and its due dissemination through various RECs spread across the State has been appreciable and the action plans for taking up 3rd crop were drawn and was executed. The progress made during this decade to popularize multiple cropping by conducting summer field rearings by CSR&TI, Pampore has been overwhelming with an average productivity of 38.62 kg of cocoons/oz in Y. K. Pora and 35.70 kg of cocoons/oz in Pattan area of Kashmir region. The cocoon productivity, during autumn season, in REC, Tikri area has gone up to 40 kg/ounce. This improvement has been possible by planning and exploiting available technologies specific to autumn including rearing of robust season specific hybrids.

Table 1: Average cocoon yield during 1981-1990 in area under REC, Sunderbani, Jammu division

Year	Qty. of seed reared (ozs)	No. of rearers	Cocoon yield (kg/oz)
1981	50	45	32.00
1982	65	70	34.00
1983	425	410	38.00
1984	440	425	43.00
1985	445	450	45.00
1986	453	460	48.00
1987-1990	425-460 oz/year	500-550	48-52

Table 2: Performance of Autumn crop in area under Sub-REC, Tikri during 1998-2003

Year	Qty. of seed reared (oz)	No. of rearers	Cocoon yield (kg)	Av. yield (kg/oz)
1998	4.00	10	132.000	33.000
1999	4.80	13	176.740	36.820
2000	5.50	17	195.600	35.560
2001	7.00	20	315.000	45.000
2002	10.00	26	435.200	43.520
2003	16.25	37	677.800	41.710

Table 3: Relative performance of spring crop of RSJ14 X RSJ11hybrid in area under Sub-REC, Tikri during 2001-2003

Hybrid	Average yield (kg/oz)		
	2001	2002	2003
RSJ14 X RSJ11	70.500	74.000	75.895
CSR2 X CSR4	-	58.120	58.475
CSR2 X CSR5	54.190	49.720	51.486
SH6 X NB4D2	61.175	62.070	64.029

CONCLUSION

From the foregoing account it is clear that CSB has been a role model in disseminating the benefits of R & D efforts for increasing production, productivity and quality of silk in J & K. The strategies adopted are worth emulating by the State government agencies, NGOs etc., functioning in the area of sericulture development. Though, the sericulture industry in the State has been put on a sound pedestal as is evident by the steady and sustained growth in the production levels over the last decade, especially in Jammu division, it is essential that the State of J&K thrives to enhance the level of adoption of new technologies developed by Central Silk Board and switch over to improved methods of mulberry cultivation, silkworm rearing, silk reeling and spinning.

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SERICULTURE FOR LIVLIHOOD DEVELOPMENT IN KATHUA DISTRICT, JAMMU AND KASHMIR

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ABSTRACT

Sericulture is an ancient agro-based cottage industry that provides ample employment opportunities irrespective of gender and age.. Its returns are assure, regular and substantial. The profit margin can be increased substantially by generating value added products from its wastes such as fuel wood and fodder. Kathua district in Jammu and Kashmir is rich in mulberry wealth. As per statistical data of Kathua district (2009) the number of nurseries are 15 (26 hectare), producing about 7-8 lakh saplings of improved genotypes annually. About 10.81 lakh mulberry trees are presently available in about 600 hectare. While the leaf from these trees is utilized by landless sericulturists, the twigs are used for the production of saplings. In addition, Sericulture Development Department Kathua is also supplying saplings to other districts of Jammu and Kashmir on demand. More than 3500 sericulturists from 222 villages are involved in producing cocoons. During spring 2010, Kathua district produced about 1.05 lakh kg of cocoons (green), out of 3200 oz seed distributed. Farmers sold their cocoons in the cocoon auction markets within the district at an average rate of Rs.422per kg (dry cocoons) and earned an average income of about Rs.4500=00 per family. An income of Rs.1.48 crore was earned by the silkworm rearers by sale of their cocoon crop (spring-2010) in different cocoon auction markets of Kathua District organized by the Sericulture Development Department.

Keywords: Livelihood development, sericulture, value added products, watershed development

INTRODUCTION

Sericulture is an ancient agro-based cottage industry that provides ample employment opportunities irrespective of gender and age. It is a boon to rural farmers. Its returns are assumed regular and substantial. The profit margin can be increased substantially by generating value added products from its wastes such as fuel wood, and fodder. The mulberry plant also has been selected for agro-forestry in waste land and watershed development as a foliage and horticultural plant.

Kathua, the gateway of J&K state is known for prominent sericultural activities. It has a geographic area of 2440 sq. km and situated at an altitude of 370 MASL. It lies between lat 32º 17′ N to 32º 55′ N latitude and 75º 7′ E to 76º 17′ E longitudes (Map 1). The maximum average temperature is recorded in the month of June (42ºC) and minimum in the month of January (6ºC). The moderate temperature was recorded during autumn (33 ºC to 19ºC) and spring (26ºC to 17ºC). The climatic condition of district ranges from sub tropical to temperate, with an average rainfall of about 1500 mm.

The total population of Kathua is 5.50 lakhs (2001 census) with a population density of 207 persons per sq. km. Out of the total population 119235 belong to Schedule Caste and 33969 to Schedule Tribe. With a total geographical area of 264729 hectares, about 72732 hectare (2007-2008) is covered under forest and 128055 hectare area under cultivable land area. The district has a cultivable waste of 13190 hectare, which can be used for raising mulberry plantation and for rearing silkworm.

The State Sericulture Department, Jammu and Kashmir and Research Extension Centre (REC), Barnoti, Kathua are working together for the development of Sericulture in the district. The REC is working under the direct control of RSRS, Miransahib, Jammu.

The soil ranges from alluvial to sandy loam in plains to gravelly in rainfed (Kandi) areas. Organic content of the soil is usually less in sub tropics and medium to intermediate in temperate areas. The soils in the hilly areas are fertile and ideal for cultivation of high yielding varieties of mulberry. There is no assured irrigation facility in the region, with most of the farmers are practicing sericulture under rainfed conditions. The agriculture crops cultivated in the area are rice, wheat, maize, millets, pulses and oil seeds, along with fruits, vegetables & spices, fodder etc.

The salient features of mulberry sericulture in Kathua district can be explained as follows:

- Mulberry is adaptable to the extreme conditions of the wasteland areas.
- Provide a permanent land cover resulting in eco-conservation of tree lands.
- Significant leaf yield, which is nutritionally rich for silkworms.
- Ensure sustainable income to the people by providing insurance against recurrent crop failures and losses common in these areas.
- Once established, require little maintenance care.
- Generate employment not only from sericulture but also by developing ancillary cottage industries like, basket, silkworm rearing tray and sports goods manufacture.

Mulberry in the region is usually grown in the form of bushes of different sizes varying up to small trees depending on the suitability of the situation under the cultivation. The moderate agro- climatic condition and slightly acidic soil available in the hilly areas of Kathua are advantageous for good growth of mulberry. The important mulberry varieties such as S-146, TR-10, Chinese white, Chak Majra and Local are cultivated.

Advance techniques of mulberry cultivation

Mulberry is being cultivated for Sericultural activities and also in Agro Forestry, Wasteland development, Watershed management, horticulture and cottage industry. The quality of silk depends on the quality of leaf and hence the advance techniques of mulberry cultivation are essential to produce qualitative and quantitative mulberry leaf. Several factors are involved for the success of rearing in silkworm; the role played by mulberry leaf is about 38.2% (Miyashita, 1986). Shashtri (1983) states that 60% of expenditure of the total cocoon production is incurred for the mulberry leaf production. The good quality of mulberry leaf can be produced with the help of proper investment, new evolved varieties, proper use of fertilizers and irrigation etc. The details of bush cultivation at government farms and the benefit of intercropping are given below.

1. Time of plantation	:	June/July and December/January
2. Genotypes	:	S146, S1635, Chak Majra, Chinese white and TR10
3. Spacing	:	3’ x 3’
4. Compost/FYM	:	4 Ton/Acre/Year
5. Chemical fertilizer	:	60:30:30 Kg. NPK/acre/year (two split doses)
6. Method of plantation	:	Through sapling
7. Intercrop	:	Rabi: Berseam, Pea, Lentil, Kharif: Chari, Moong, Urad, Cow pea
8. Irrigation method	:	Canal, Bore well. (During dry spell)
9. Weeding method	:	Inter cultivation or use of herbicide
10. Harvesting	:	Leaf or Shoot
11. Pruning	:	1. Bottom pruning (30 cm from stump, July)
	:	2. Middle pruning (3 feet from the ground December/January)
12. Leaf Production	:	6-7 ton/acre/year (2 crops)

Tree cultivation is also in practice in hilly and plain areas of Kathua under rain fed condition, particularly on sloppy land, wasteland and bund plantation as agro forestry. The TR 10, S 146 and S 1635 mulberry genotypes are suitable for tree plantation. It is planted at the time of onset of monsoon with a spacing of 8′ X 9′ in pit (size 2′ X 2′ X 2′) with one year old sapling. The compost/FYM is applied at the rate of 6-7 kg per pit. Pyriban (anti termite) 10 gm per pit should

be applied at the time of plantation. The amount of chemical fertilizer should be applied at the rate of 50:50:50 kg. in February and 50 kg/ N/ha in August. Thus, 100-150 DFLS can be reared in a year (2 crops) from hundred plants (5 year old).

Contribution of Sericulture in the economy of Kathua farmers

Sericulture is one of the important economic activities in sub tropical and temperate areas of the state. Jammu and Kashmir is traditional Sericultural state of the country. It was introduced on commercial scale in the state by the Royal family of Jammu and Kashmir. Kathua district is very rich in Mulberry wealth. As per the statistical data available the district has 15 (26 hectare) number of nurseries producing 7-8 lakhs saplings of improved genotypes annually. About 10.81 lakhs Mulberry trees presently exist in the field spread over an area of about 600 hectare. The leaf from these trees is utilized mainly by the landless sericulturists. There are more than 3500 Sericulturists from 222 villages of the district are involved in the production of silk cocoons. The most famous silkworm breeds of the area are SH6 x NB4D2, Dun6 x Dun21, RSJ 14 x RSJ11, and CSR2 x CSR4.

During the spring season of 2010-11, the production of green cocoons in the district was about 1.05 lac kg, out of 3200 ozs seed distributed. The average price obtained by the sale of cocoons was Rs.422=00 per kg (dry cocoons) through which the income earned per family was found to be Rs. 4500=00 per family. Overall during the Spring season of the year 2010, it was estimated that an income of Rs. 1.48 crore was earned by the silkworm rearers of the district (Table .1)

Table 1: Green Cocoon Production and income against Silkworm Seed Distributed In Kathua (2006-2010)

Year	Silkworm Seed Distributed (oz)	Green Cocoon Harvested (Lac kg)	Amount earned by rearers (Rs. in Lac)
2006-07	2994	1.09	107.10
2007-08	3172	0.92	81.35
2008-09	3057	1.01	77.34
2009-10	3203	1.07	103.42
2010-11*	3011	1.05	147.79

* spring crop

It was estimated that on an average one hectare of mulberry could provide employment at the rate of 3 persons for engaging in different activities like, mulberry cultivation, silkworm rearing and silk reeling etc. (figure 3). Quality bivoltine cocoon is basically produced in temperate and sub tropical regions of the Kathua. A well-managed mulberry garden generates a net income of about Rs. 24000/- annum per acre with intercrop (Berseam, Chari, Pea, Cow pea, Lentil, Urad, and Moong).

Infrastructure of Sericulture in Kathua District: The existing infrastructure for sericulture in the district include a) 12 number of Chawki rearing centers b) Cocoon Ware House at Dangara (Billawar.) c) Cocoon auction market at Dangara d) F1 Breeding Hall at Dangara, e) 15 Mulberry Nurseries (26 hectare) f) 55 Mulberry Farms (50 hectare), g) 4 Hot air driers (100 kgs. capacity) Malda type are installed with one each at Barnoti farm and Tharakwal, with remaining two at Dangara farm.

Infrastructure Development under CDP during 2010-11(Targets)

Under the Cluster Development Programme it is targeted to provide the following infrastructures in the district:

- Construction of 183 rearing houses @ Rs. 50000=00 per house.
- Construction of 220 Tin shed rearing houses @ Rs. 17000=00 per house
- Supply of 240 rearing kits to sericulturists.
- 297 women sericulturists will be covered under Women health Insurance scheme along with their husbands and two children less than 18 years of age.

Mulberry as fodder and fuel: In hilly areas of Kathua fodder and fuel is a limiting factor. Mulberry can grow as a tree on the wasteland of the village to meet the demand of fodder and fuel. The requirement of fodder and fuel is progressively increasing with the increase in population. Information available with respect to availability of green fodder in the selected villages of Kathua indicates that fodder is mostly extracted from forest area. In order to meet the requirement of fodder, mulberry trees grown on bunds and terraces of agricultural lands could also contributed to supply of green fodder in village.

The rearing waste (bed refuse) of silkworm rearing activity is used as a cattle feed, faecal matter as organic manure, pupae for extraction of oil/feed for poultry and fisheries etc. During the silkworm rearing about 20% left over leaf can be ideally used as fodder. The whole leaf produced in non-rearing season can also be used as fodder. Apart from this, around 50% of the mulberry leaves that are unsuitable for rearing due to over maturity can be used as fodder. Rearing of cattle along with silkworm rearing will meet the FYM requirement. However, excessive mulberry leaf feeding is injurious for pregnant cow and hence prevention may be taken.

Fuel is an essential need of household for cooking food. Farmers are dependent on forest for meeting the requirement. A limited quantity of fuel wood is also utilized from trees, available in private lands. Cow dung is not used as fuel, as the same is utilized for making farmyard manure. The farmers can not afford alternate fuel sources like biogas, LPG cooking gas etc. due to poor socio-economic conditions. Mulberry green shoots can be produced to the extent of 2 – 2.5 tons/year in two crops from hundred trees (15 years old tree)

Use of Mulberry in wasteland development: Owing to constraints in their utilization, these lands remained abandoned from productive use. However, adoption of modern scientific approaches can make this area usable. Per capita land availability has already shrunk to as low as 0.25 ha and hence the use of these land can help the poorest of the poor. Obviously, the technology for utilization of the wasteland must ensure not only ecological security by putting a check to degradation processes but also provision of sustainable income and nutritional security. Mulberry could form major component of vegetation cover on this land. Being a hardy in nature mulberry in Kathua can be planted in wasteland area. It prevents the soil erosion, implies the wise use of soil and water resources within a geographical area so as to enable sustainable production.

Use of mulberry shoot in Cottage industries: Pruning is one of the most important steps to improve the quality and quantity of mulberry leaf production. Straight shoots without leaf are being used by landless labourers in North Punjab for the preparation of tokry (Basket) and rearing trays, after pruning during the month of December and July. One labour can prepare 20 to 25 tokry (basket) per day and earn Rs.250=00 to Rs.300=00 after meeting the cost of raw material (figure. 5-6).

Central Silk Board is also giving technical and financial help to develop silk production in Jammu and Kashmir. However, Sericultural technologies developed by Central Silk Board for boosting silk production in the area are not found to have fully percolated to the farmers. Therefore, extension network is required to be strengthened for proper and effective technology transfer and its percolation for making sericulture more attractive and economical avocation. It will help to improve economic conditions of poor landless farmers of Kathua district.

Thus, it can be concluded that economically deprived farmers can be effectively engage themselves for their livelihood requirement through sericulture. Sericulture can be practiced as a subsidiary enterprise for value addition and income generation along with agriculture and dairy for earning returns mainly during the months of April to October.

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TECHNICAL SESSIONS AND RECOMMENDATIONS

To celebrate the Institute's Golden Jubilee year (2011-12) a two days National Conference on **Sericulture Innovations: Before and Beyond** was organized at CSRTI, Mysore on 28-29th January 2011. Smt. Panabaka Lakshmi, Union Minister of State for Textiles, Govt. of India graced the occasion as the chief guest while Sri. H. Hanumanthappa, Hon'ble Chairman, CSB presided over the function. A total number of 484 research papers were presented on various aspects covering entire gamut of sericulture during the conference. Four new silkworm hybrids were released for commercial use during the conference in addition to two CD's and three books.

During these two days, eleven technical sessions were conducted covering various topics related to sericulture. A brief report on these sessions is presented hereunder:

SESSION I: MULBERRY IMPROVEMENT

Chairperson: Dr. C.K. Kamble, Director, CSGRC, Hosur

The lead paper on *Major contributor for sustainable cocoon productivity in India* highlighted the research work carried out in India over the last five decades on various aspects of mulberry improvement and emphasized the role played by the high yielding mulberry varieties in boosting the silk productivity per unit area in the country. It stressed on the need for future strategies in the areas of productivity, quality, adaptability and resistance to diseases.

The session dealt with a total of 22 research papers of which 6 were selected for oral and 11 for poster presentation. The Chairperson briefed the audience the session highlights:

Oral session

Six papers were presented in this session, which emphasized certain areas of research, that would help the farmers to improve sericulture like:

- Development of low temperature stress tolerant mulberry varieties for North East India.
- Varieties amenable to propagation by stem cuttings in Kashmir region.
- Evaluation of chawki mulberry variety for CRCs.
- Performance of improved mulberry varieties under rainfed conditions of Odisha
- Preliminary evaluation of mulberry genetic resources for growth and yield
- Plant regeneration from leaf explants.

Poster session

Eleven posters were displayed; various research findings were discussed during this session. Some of the interesting areas of research presented were:

- Parameters for selection of alkaline tolerant varieties.
- Varieties suitable for problem soils

- Genetic divergence in germplasm accessions.
- Identification of key physiological parameters for drought resistance in mulberry.
- Techniques for propagation through bud grafts useful for rainfed areas.
- Identification of promising genotypes for semi-arid areas of Andhra Pradesh

Recommendations

It was recommended that research in following areas need more emphasis.

- Development of productive and region specific varieties with emphasis on leaf quality.
- Development of mulberry varieties tolerant to water stress, alkalinity and salinity stress.
- Development of genotypes resistant to root diseases.
- Utilization of bio-technological approaches through Marker Assisted Selection for making breeding programmes more directional and for reducing the time taken in evolving a mulberry variety.
- Development of suitable mulberry varieties for low temperature tolerance, with characters like frost resistance, low dormancy, fast growth and regeneration.
- Screening of varieties suitable for mechanized cultivation.
- Screening of mulberry varieties for non-sericultural purposes for value addition in sericulture.

SESSION II: MULBERRY PRODUCTION & PROTECTION

Chairperson: Prof. Nazir Khan, Former Head, Dept. of Plant Pathology, UAS, GKVK Bangalore

In this session two lead papers were presented. (1) *Present status and future strategies in research and development* highlighted the R&D achievements in mulberry production during the past five decades. (2) *Mulberry protection - An overview of the research done before and beyond* brought out a comprehensive account of the research done over the last five decades and future strategies and prospects. After the deliberations, the Chairperson suggested to attempt development of meta-genomic control of soil borne plant diseases, which is a new frontier area of research.

Oral session: During the session, three papers were presented in mulberry production, four in mulberry protection.

The highlight of this session was new design and development of multipurpose harvesting and pruning machine for mulberry plantation, raising of mulberry saplings using polythene sheets over the conventional nursery beds for higher rate of survival, water conservation and higher income.

With regard to mulberry protection, a new viral disease in mulberry and need for its management and search for resistance was discussed. '*Glucosinolate*' - containing plants as a source of bio-fumigants against soil borne disease was discussed. This was identified as a new area for future research. The development of mulberry diseases and pest database as part

of the National Sericulture database, population dynamics of native predator (*Micraspis discolor*) and white fly forewarning system for pest and diseases, emerged as important recommendations.

A total of 16 posters were presented in the session. Interaction with the delegates on the subject gave an insight into the present status of work carried out at various Institutes and universities. The main focus was observed to be on field problems related to improvement of soil health and management of pests.

SESSION III: SILKWORM IMPROVEMENT

Chairperson: Dr. H. K. Basavaraja, Former Scientist-E, CSB

The lead paper entitled *Present status and future prospects of utilization of silkworm breeds/hybrids for Indian sericulture* emphasized that to realize the dream of producing large quantity of high quality raw silk at competitive price, sustainable tropical bivoltine sericulture technology has to be popularized besides continuous improvement of breeds. The silkworm-breeding scenario from 1960's through 2010 was highlighted. The conventional silkworm breeding techniques in the past have moved to a more scientific approach now and the results were noteworthy. The paper also enumerated the new breeding strategy utilizing amylase enzyme based selection by transferring amylase genes and subsequent development of the new bivoltine hybrid Gen3 x Gen2, and the introduction of double hybrid (CSR6 x CSR26) x (CSR2 x CSR27). The improvement achieved in new multivoltine x bivoltine hybrids ND5 x CSR2, ND7 x CSR2 and NDV6 x CSR2 in productivity and silk quality was highlighted. Further, a recently developed new multivoltine x bivoltine hybrid L14 x CSR2 producing >2A grade silk by CSRTI, Mysore was highlighted.

Oral Session

During the course of the session, five research papers dealing with the evaluation of bivoltine foundation cross SK6 x SK7 ; polyvoltine breeds L14 and L15 and the hybrids L14 x CSR2 and L15 x CSR2 ; Dun 17 x Dun 18-a new bivoltine silkworm hybrid with high silk content ; MH1 x CSR2 from KSSRDI, *Swarnandhara* from APSSRDI were presented. Other 29 papers were presented as posters. Of these, six were on the performance of the newly evolved breeds/hybrids, eight on the evaluation of the hybrids, eight on silkworm breed development, four on breed maintenance and the rest on other related topics.

A paper on *Bivoltine foundation cross SK6 x SK7 - A breakthrough in bivoltine seed crop stabilization in Eastern and North Eastern India* highlighted the difficulties in rearing of bivoltine parents during seed crop season for preparation of multi x bi eggs owing to unpredictable and fluctuating harsh climatic conditions prevailing during the season. To overcome this, a sustainable bivoltine foundation cross (FC) namely SK6 x SK7 was identified.

The second paper on *Development of new polyvoltine x bivoltine hybrids of the silkworm Bombyx mori* L. *with quality silk* dealt on breeding methodology and rearing and reeling performance of new polyvoltine breeds L14 and L15, their hybrids like L14 x CSR2 and L15 x CSR2. For the first time, these new hybrids yielded silk of 2A grade and above.

The third paper *on Dun 17 x Dun 18 a new bivoltine silkworm hybrid with high silk content* explained the method of breeding and selection during the development of this new bivoltine breeds.

The fourth paper on *Superior crop stability of the authorized silkworm hybrid MH1 x CSR2*

dealt with its performance consistency in different test centers by registering higher average cumulative index values for various economic traits, compared to control.

The last paper of the session on *Introgression of sex-limited marker trait to the parents of a commercial crossbreed of silkworm* (*Bombyx mori* L.)*, Swarnandhra* concluded that sex-limited strains assume a special significance in Indian sericulture as the bulk of silk production is derived from polyvoltine x bivoltine cross breeds at reduced cost of production.

Poster session

A total of 29 posters were showcased in the session. Of which six were on the performance of the newly evolved breeds/hybrids in respect of different economic traits such as egg yield in double hybrid; performance of *Nistari* at Denkinikottai*,* T.N.; the importance of heritability estimates on bivoltine breeds *viz.,* MG406, KA-1 for 6 traits; performance of single and double hybrid evolved by amylase marker assisted selection; egg hatching and moulting behavior in CR2 x CSR4.

Eight posters dealt with the evaluation of the hybrids**;** Screening of promising multivoltine silkworm breeds for leaf silk conversion efficiency; manifestation of heterosis for survival parameters under BmNPV stress; genetic diversity in some multivoltine silkworm genotypes; testing of new silkworm hybrids in different agro climatic conditions of Odisha, evaluation of bivoltine parental breeds for utilizing them for hybridization programme; evaluation and identification of suitable bivoltine silkworm hybrids for hilly regions of West Bengal; field efficacy evaluation of the juvenile hormone analogue SB-515 for crop yield improvement and heterosis on the economic traits of foundation hybrids.

The posters on the silkworm breed development comprised of subjects like development of thermo-tolerant bivoltine silkworm hybrid, HTO5 x HTP5 suitable for tropical areas; synthesis of bivoltine silkworm breeds with longer filament and thin denier; development of bivoltine pure strains of silkworm to rear exclusively on artificial diet during young instar; development of a productive multivoltine x bivoltine hybrid Line4 x CSR2 tolerant to high temperature and humidity; evolution and evaluation of single and double hybrids developed through amylase marker assisted selection; new promising robust bivoltine hybrid BRO-2 x NP4 for summer season; evolution of new multivoltine x bivoltine hybrids for rearing on semi-synthetic diet; breeding for the development of sericin rich bivoltine silkworm breed/ hybrid.

Four posters were on maintenance of racial characters by adopting systematic breeding programme in multivoltine Pure Mysore; role of conservation and utilization of bivoltine silkworm genetic resources in silkworm crop improvement; maintenance of bivoltine breeds and crop stability at P4 and P3 centers; and status of exotic and indigenous silkworm races maintained under temperate conditions of Kashmir.

The remaining posters were on eclosion behaviour in new multivoltine breed ND7; comparative biochemical studies on CSR2, PM and PM x CSR2; and one on studies on sex determination based on moulting and spinning behavior in the silkworm *Bombyx mori* L

Recommendations

- Breeding programmes to evolve breeds / hybrids with resistance / tolerance to high temperature, high humidity should be taken up.
- The authorized breeds/hybrids should be utilized in different agro-climatic zones.

- Development of breeds for special traits.
- Breeding programmes should be based on the requirements of the sericulture industry.

SESSION IV: SILKWORM PRODUCTION AND PROTECTION

Chairperson: Dr. B. Saratchandra, Director (Tech.), CSB, Bangalore

Three lead papers entitled (1) *Silkworm rearing technology - today and tomorrow* (2) *Present status and future research studies in silkworm crop protection* and (3) *Mechanization in Sericulture* were presented. The papers enlightened the audience about the transition of old and traditional technologies into new improved technologies and future strategies. Briefed about the role of machines/ equipments in reducing drudgery in sericulture.

Oral session

26 papers were presented in the session, out of which 8 were concerned with silkworm crop production and protection and the remaining dealt with the following :

Silkworm crop production: Out of eight, six were on egg preservation technology, segregation of cocoon colour, selection through ultra violet rays, and on the effect of organic inputs in mulberry cultivation on egg production.

Silkworm crop protection: The paper dealt with a vide range of topics like silkworm disease management, silkworm pest management, microsporidia, grasserie, new bed disinfectants, silkworm crop losses, pest management, biological control of uzi fly, sex pheromonal control of uzi fly, chemical control of white fly, bio-intensive management of papaya mealy bug and simplified method to raise mealy bug colony on sweet pumpkin.

Poster session

Thirty posters were received for this session. Under Silkworm Production 8 posters were presented.

Role of embryonic tools in silkworm egg handling: The importance of embryonic stage identification helps in understanding the status of preserved silkworm eggs, which enables decide on the appropriate time for release of eggs. Preserved eggs can be certified based on the merits of embryonic development. By conducting series of embryonic studies, an efficient egg handling system has been developed wherein relationship between embryonic stage and egg handling is established. This also helps in proper egg preservation.

Studies on unseasonal hatching in bivoltine eggs under north west Indian conditions: In North India, maximum egg production is done under government sector and the production of seed cocoon and egg is confined only to the spring season. Attempts made to produce seed cocoons during the other seasons has resulted in un-seasonal hatching to the tune of 22-25% under natural preservation. However, the silkworm seed preserved in spring-to-spring schedule has revealed that the loss due to unseasonal hatching is reduced significantly. So the proper protocol of egg preservation in cold storage helps in successful crop and also brings down the cost.

Effect of humidity on hatching of bivoltine silkworm Bombyx mori L. *eggs during black box condition:* The commercial bivoltine hybrids, both single and double and their parental breeds were subjected to constant temperature of 25±1°C and varied relative humidity regimes *viz.,* 40 ± 5, 50 ± 5, 60 ± 5, 70 ± 5, 80 ± 5 and 90 ± 5%. The study revealed that at < 70 % RH, parental breeds and single hybrids show reduced hatching while in double hybrids the

hatching percentage reduced only at < 60 % RH.

*Effect of different egg management techniques on quantitative characters in bivoltine silkworm Bombyx mori***.** L. The egg management techniques like hot acid, cold acid, short term and long term chilling and different hibernation schedules indicated no significant difference in cocoon yield and shell percentage among the different egg management methods. However, significant differences were noticed in hatching percentage, survival, cocoon and shell weight.

Development of long term preservation technology for Nistari cross breed eggs of silkworm, Bombyx mori L.: A long term preservation technology for Nistari cross breed eggs wherein the eggs can be stored for 80 days without any adverse effect on hatchability and crop performance is developed. This technology helps in management of seed supply without any hindrance.

Use of ultraviolet light for cocoon colour segregation in Bombyx mori L: Use of ultraviolet light for cocoon colour segregation is very helpful for the breeders in fixing the breeds based on colour variation among the breeds. The cocoon colour is a heritable character and responds to selection. However, to the naked eye the cocoon colour appears more or less uniform but under UV light, distinct variations in colour can be observed. Based on the cocoon colour variation, they can be segregated which helps in fixing the white colour cocoon trait.

Studies on refrigeration of polyvoltine silkworm eggs, Bombyx mori L. *for tropics*: Silkworm eggs of pure races can be stored for longer periods by adopting a two-step refrigeration method. Early age eggs (24 to 30 hours) can also be cold stored for longer durations. The safest period of cold storage is between 30 and 45 days. The MH1, MU303, Sarupat, Nistid and Thai have higher cold tolerance than Nistari (w), Nistari (gy), MYN and PN. The hatching performance was found *on par* with control (PM).

Role of integrated organics in quality improvement in mulberry leaf for silkworm seed cocoon and egg production: The seed cocoons produced under organics, reduced chemical fertilizer inputs and recommended dosage of fertilizer has yielded 58 gm, 54 gm and 50 gm of egg per kg of cocoon, respectively.

Recommendations

Future research should emphasise on :

Development of molecular markers in silkworm for resistance.

Development of transgenic silkworms with resistance to virus.

Characterization, dissemination and detection of microsporidia using molecular probes.

Cryo preservation of germplasm resources for biodiversity conservation.

Application of nano technology for crop improvement and protection.

Production of Bio materials particularly from fibroin and sericin.

SESSION V: POST- COCOON TECHNOLOGY

Chairperson: Dr. T.N. Sonwalkar, Former Director, Central Silk Board.

In the opening remarks, the Chairperson narrated the setting up of reeling section at CSRTI,

Mysore and then its elevation to CSTRI, Bangalore exclusively for post cocoon- technology and its achievements.

The lead paper on *Sericulture Yesterday, today and tomorrow* presented. During 1964 the Reeling division at CSRTI was established. Basic studies on cocoon size, shape, denier, filament neatness, driage etc., together with industrial level of mass reeling studies were undertaken and vast amount of data were generated. Few recommendations were made in respect of cocoon drying, open pan cooking, 3 pan cocoon cooking, reeling device right from Charkha system to automatic reeling technique, fresh cocoon reeling, utilization of cocoon waste, defective cocoons, silk waste, degumming of cocoon waste, defective cocoons, silk waste, time and motion study on multiend silk reeling were taken up. Based on these experiments, the post cocoon division was made independent and CSRTI was established during 1983-84 in Bangalore. It consisted of various sections such as cocoon assessment, cocoon drying, cooking, reeling, re-reeling, testing, weaving preparatory, weaving and wet processing. Achievements of CSTRI since inception were highlighted

Reeling section

The section developed improved charaka together with economic oven, designed and developed ingenious gadgets for Multiend end reeling machine, denier detecting device, button system, conveyor cooking, complete package for Multivoltine and bivoltine reeling etc. As of now, over 3000 basins are in operation.

Some of the reeling technologies developed for Non-mulberry reeling sector were as below:

- Development of Tasar/Muga Motorised cum pedal operated reeling cum twisting machine (6 spindles)
- Development of Tasar / Muga Motorised cum pedal operated reeling cum twisting machine (4 spindles). About 8500 nos machines are in the field
- Development of Tasar / Muga / Eri Motorised cum pedal operated Spinning machine. About 15000 nos machines are in the field.
- Development of Tasar/ Muga / Eri Re-Reeling machine. About 1000 nos machines are operational in the field.
- BISU plant was developed for separation of pelade from the pupae
- Development of low cost Flyer type spinning machines for spinning of Tasar/Muga /Eri waste.
- Development of cooking recipe for Tasar cocoon for wet reeling.
- Development of cooking recipe for Muga cocoon to produce quality silk.
- Development of Degumming recipe for Degumming of Eri cocoons for Hand spinning.
- Development of Degumming recipe for Degumming of White & Brick red Eri cocoons, Muga and Tasar waste for both Mill spinning and Hand spinning.
- Technology for spinning of Eri, Muga & Tasar spun silk yarn in spun silk mills and characterization of yarns.
- Technology for spinning of Eri Noil yarn in woolen, cotton and open-end system of spinning and characterization of yarns.

- Technology for spinning of Eri wool blend for producing blended yarn.
- Technology for spinning Eri cocoons (with pupae) developed.
- Eri Blankets were developed and mechanical, low stress, thermal and shrinkage properties were characterized.
- Eri denim fabric developed from which, Jacket, vest, pants and shirts were made. Same fabric was subjected to various finishing treatments i.e. Enzymatic, Denim, tint, blue and yellow finish.
- Various fancy yarns developed (Feather, chenille, flag and slub yarns).
- Development of equipment to maintain constant basin temperature.
- Development of two in one system of reeling machines for reeling of Tasar and Muga cocoons.
- Established 3 spun silk mills for eri spinning one each in Andhra Praesh, Kokkrajhar (Assam) and another at Upper Assam

Fabric division:

The division was created to study silk garment quality for seam slippage, seam performance, accessories for new diversified silk garments.

Weaving division:

- Developed electronic jacquard system for handlooms
- Pneumatic lift system to over come the pay load of jacquard system and to reduce drudgery
- Twin shuttle looms for north east
- Warp and weft knitted fabrics and union fabrics
- Development of non -woven silk.
- Weaving of tasar reeled fabric on shuttle less loom.

Wet processing division

- Development of formulae for softening the water
- Standardization of recipe for degumming mulberry raw silk
- Development of standing bath method for degumming
- Extraction of pupa oil and its characterization
- Stain guard finish to silk yarn to create new generation silk fabrics
- Optimization of fire retardant finish to silk fabrics
- Wrinkle resistance finish to silk fabrics
- Studies on application of natural dye, printing on silk fabrics
- Sericin extraction by HTHP method

- Preparation of silver Nano using sericin as a stabilizer
- Silk carbon material and its characterization

Oral Session

Totally six research papers were presented, the details of presentation made and the interaction held during the presentation are as follows;

First paper dealt with *evolving process norms for silk reeling on cottage basin, multiend and domestic basin reeling units*.

Second paper was on the *studies on inter and intra cocoon variation in physical and tensile properties of raw silk of different voltinism of Bombyx mori available in West Bengal.*

Third paper *Comparison of physical and comfort properties of Mulberry, White eri and Red eri spun silk yarn woven fabrics* brought out that eri cocoons can be degummed and spun on worsted system of spinning to produce international quality yarn. These fabrics were compared with mulberry spun silk fabrics, it was revealed that both eri spun silk fabrics are durable, soft, better crease resistance, better aesthetic, tactile and thermal comfort property compared to mulberry spun silk fabrics.

Fourth paper on *Present status of Muga silk technology and innovation prospects* gave the present status of muga silk industry including the quality of cocoons, reeling process parameters and new equipments developed, their influence on the productivity and quality, new products developed were briefed.

Fifth paper on *Studies on non-mulberry silk reeling Effect of commercially exploited ecoraces of tropical tassar cocoon* briefed about post cocoon parameter for different eco-races of tasar cocoons available in different region, it was found that there is a significant difference in post cocoon parameters in all eco-races.

The last paper *Colour fastness and fabric properties of natural pink colour yarn and fabric* dealt with colour fastness to light and concluded that it needs to be improved for natural colour silk for better acceptance by the consumer. However, the economics need to be are to be worked out for processing natural colour silk and dyeing process in the industry for its comparisons.

Poster session

In all five posters received were displayed :

The poster *Evaluation of eight races silkworm (Bombyx mori):* Germplasm *for post cocoon traits,* highlighted the 20 elite silkworms for special post- cocoon characteristics.

The poster *on Impact of implementation of CDP programme on quality of dying and economy of silk yarn* confirmed that the scheme benefited dyers in the cluster.

The poster *Eri silk for fashionable knitted garments* gave an account of Eri knit products for internal consumption and for export market. It revealed that final results are encouraging for future product development.

The poster *Studies on effect of sizing agent on tasar silk fabrics* suggested the use of PVA as sizing material for tasar on high speed loom.

The poster on *Studies on dimensional stability of eri silk fabrics* observed that shrinkage is an

inherent problem of eri spun silk. Treated yarn that was later converted into fabric has solved the problem along with improvement in aesthetic properties.

Recommendations

The panel recommended further studies on :

- Comparison of physical and comfort properties of various spun silk yarn woven fabrics
- Post-cocoon reeling parameters for different eco-races of non-mulberry silks of different regions.

SESSION VI: BIOTECHNOLOGICAL BREAKTHROUGH IN SERICULTURE

Chairperson: Dr. V. Sivaprasad, Director, NSSO, Bangalore

A lead paper on *Biotechnology research in sericulture, its status, approach and road ahead* was presented by Dr. N.B. Vijaya Prakash. In the paper, current status of biotechnology and the future needs of biotechnology support/intervention in sericulture research for improving silk quantity, quality and disease resistance were discussed.

Oral session

Under the session, six papers were presented. A Paper on *Characterisation of Nosema spp. infecting tasar silkworm Antheraea mylitta* dealt with characterization of fourteen *Nosema* isolates for the sequence variation in 16S rRNA primer and found that N14 isolate was distinct. The infectivity of various isolates differed in infection to different tissues. This is a first report on 16S rRNA sequence of *Nosema mylitta* isolates.

The second paper *Concept paper on cryopreservation of silkworm genetic resources* dealt with importance of cryo preservation for conservation of valuable silkworm germplasm stocks was discussed in length especially of mulberry silkworm genetic resource and the possibility of cryopreserving sperm, ovary, embryo as well as eggs of silkworm. The silkworm egg cryopreservation requires dechorionation and identification of suitable stage for cryopreservation. The cryo preservation techniques were successfully employed in greater wax moth *Galleria mellonela* and *Drosophila*

The third paper *Molecular characterisation of densonucleosis virus isolated from flacherie diseases silkworms* informed that DNV-2 as one of the causative agent for flacherie disease in southern states of India screened the silkworm germplasm for the presence of DNV-2 resistance gene.

The fourth paper on *Pegylated tasar sericin self assembled nano particles* described the pegylated sericin particle analysed and confirmed proper assemblage of PEG with sericin protein. It was emphasized that this would be useful for drug delivery system and cosmetics applications.

The fifth paper on *Identification / development of markers for resistance to BmNPV and marker assisted breeding programme for development of silkworm races with NPV resistance* dealt with. Four cDNA and one SSR markers associated with NPV resistance, introgression of NPV resistance character from Sarupat to CSR2 through backcrosses. Segregation of these markers was found in F2 population and these markers were found

introgressed in susceptible lines, which showed improved tolerance to NPV.

The sixth paper on *Development of linkage map in mulberry for rooting characters* shortlisted two contrasting parents *ie.,* Dhudia white and UP from more than 800 germplasm collections and QTL mapping carried out using different RAPD and ISSR markers.

Poster Session

Totally six posters were presented in this session.

The poster *DNA fingerprinting of multivoltine silkworm breeds using EST markers* dealt with screening of two RFLP derived STS markers among 30 multivoltine stocks of diverse origin and different yield potential. The analysis led to the identification of two markers showing significant association with five yield traits.

Immunity in insects against parasites and pathogens - recent developments in silkworm: Immune mechanism against uzi infection on silkworm was studied, which showed induction of proteolytic activity on integumental epithelium followed by induction of PPO cascae in the silkworm. Under humeral mechanism, transcription factors that regulate expression of immune-associated genes play a significant role. Signalling pathways and the role of immunoglobullins discussed.

Detection of Single Nucleotide Polymorphism (SNP) DNA marker linked to cocoon traits in the mulberry silkworm, Bombyx mori: The paper described the screening of 240 EST SNP primers between parents showing contrasting features for cocoon traits. 20% of the primers showed distinct polymorphism between the parents. Bulked segregant analysis indicated linkage of SNP primer No.124 of 4th linkage group with cocoon traits which was also confirmed by screening the BC progeny.

Construction of core collection of mulberry germplasm using dominant DNA marker systems a preliminary attempt: The study involved construction of core collection of 850 mulberry accessions from CSRTI, Mysore and CSGRC, Hosur using RAPD markers. By application of maximization strategy using MSTRAT, the core representatives from each group were identified and high marker polymorphism of 96% recorded, thus indicating the diverse nature of pre-core entries. By re-application of MSTRAT, the size of the core collection was reduced to 100 numbers.

Molecular characterization of popular and evolved silkworm genotypes Bombyx mori of India using RAPD markers: DNA profiling using 22 RAPD markers was studied among 23 silkworm genotypes with diverse yield potential. The analysis revealed 89% polymorphism among the breeds and genotype specific amplified products were identified. The UPGMA based on RAPD profiles showed clustering of these breeds into two distinct groups.

The poster *Evolutionary analysis of Beta fructo-furanosidase of mulberry* dealt with In-silico analysis of the gene controlling Beta fructo-furanosidase enzyme production in silkworm which enables the silkworm to feed solely on mulberry. The phylogenetic analysis of this gene using BLAST and PHYLIP showed unique conserved domains with higher similarity with that of diverse organisms such as Bacillus, Weissella and honey bees.

Recommendations

The future research programmes should consider studies on :

- Cryo preservation techniques for conservation of silkworm germplasm

- Use of nano particles in sericulture research
- Construction of core collection of germplasm using DNA markers
- Molecular characterization of silkworm genotypes using RAPD markers

SESSION VII: *VANYA* SILK HOST PLANT

Chairperson: Dr. N.B. Vijaya Prakash, Director, SBRL, Bangalore

The Lead paper ***Tropical tasar silk industry in India: status and challenges ahead*** **evoked the following**:

- Under utilization of *Sal* should be addressed properly at various levels.
- Commercial seed production should be properly addressed.
- Diapause manipulations can be thought off to minimize the erratic emergence and to solve the problem in seed preparation.
- Strategies for quality silk production, eco-friendly management of diseases and improvement in the yarn quality should be properly chalked out to address the field problems.
- Ecorace conservation programme should be initiated immediately to exploit genetic resource.
- Basic Seed Organization to be thought of.

Oral session

A total of six papers were presented in the oral session.

Paper on *Phenotypic variability in plus trees of Som, Presea bombycina* Kost*. in North East India*: 39 plus trees were identified out of which 18 showed improvement in stem, girth, crown height, no. of branches and leaf biomass. It was suggested to go for bio-molecular approaches to identify duplication in genotypes.

Paper on Determination of suitable combination of NPK fertilizer for application in Som plantation based on soil test value: It was suggested to find out the actual combination for application of NPK on the basis of soil test value for Som plantations for Assam.

Paper on *Prospects for improvement of oak tasar culture through innovations in Quercus species* dealt with the development of pruning and propagation technologies, selection of morphotypes and early and late sprouting varieties, clonal propagation through air layering, stem cutting, approach grafting, establishment of clonal orchards, bioassay and future strategies for improvement of species. Suggested to carry out the studies further for selection of superior genotypes of *Quercus serrata* and *Q. grifithii* and their multiplication and propagation through stem cutting and tissue culture and bio-molecular studies for isolation of superior genotypes for spring and autumn crops.

Paper on *Shoot induction from cotyledonary node* explants of *Terminalia tomentosa W&A plantlets*: It was suggested to try multiplication through auxiliary & nodal explants for selected genotypes

New tree hosts of eri silkworm Samia cynthia ricini Boisd : It was suggested to identify new variety suitable for Eri silkworm.

Poster Session

In the poster session nine posters were displayed. The observations made are as follows:

Genetic viability and association of yield traits in RG2824 a promising castor (Ricinus communis I.) food plant for eri silkworm: Castor variety RG2824 is identified as a promising castor food plant for Eri (*Samia ricini* Donovan) silkworm rearing in non traditional eri growing areas at Berhampore, West Bengal. Correlation studies divulged strong positive association between leaf lamina yield and yield attributing traits such as mean height, number of nodes and petiole yield. These correlated components are indicative of a selection criterion to choose parents among RG 2824 towards improvement of lamina yield.

Studies on the relationship between leaf lamina yield and yield components of some high leaf yielding castor (Ricinus communis I.) food plants suitable for ericulture: Leaf lamina yield of 10 high yielding castor genotypes during five crop seasons has been regressed backwardly over 5 independent variables. Thus, they developed a basic leaf lamina yield components equation from the initial prediction model. The final model showed that mean height, number of nodes, petiole weight and crop seasons are the most important predictors of lamina yield.

Management of gall insect, Trioza fletcheri minor Crawf a major pest of primary tasar food plants through ecofriendly techniques: In *T. tomentosa* plants, pruning has influenced the gall infestation (14.41%) as compared to un-pruned plants (3.42%), whereas in pruned and un-pruned plants, number of galls per leaf was 0.83 and 0.10, respectively. Results reveal that foliar spray of Azadirachtin (15ppm) and soil application of neem cake @ 150 kg per hectare were found effective in controlling the gall insect population as compared to control. Eco-friendly techniques for the suppression of gall population were highlighted.

Clean development mechanism through raising host plants of tasar silkworms: Clean Development Mechanism (CDM) is one such initiative through which developing countries would receive the capital investment and clean technology or beneficial change in land use to earn Certified Emission Reduction (CER) credits as part of Kyoto Protocol. Methodology of project implementation along with brief review of the progress made under various components of plantation, regeneration and conservation of tasar host plants, its impact on improvement of tasar silkworm rearing, earning levels of the tribal beneficiaries, steps taken for continuation of the activities including the maintenance of plantation *etc.,* are detailed besides those areas need to be addressed to take up these initiative effectively.

Reaction of different morphotypes of muga food plant Som towards major foliar diseases: Variation in tolerance of different morphotype of Soalu to grey blight disease. The findings shows that the morphotype III is resistant to leaf spot and red rust diseases (2.2 and 3.6 PDI) Morphotypes V (11.3 PDI) and VI (17.9 PDI) showed moderately resistant reaction. On the other hand, morphotypes IV (21.4 PDI), VII (23.3 PDI) and VIII (21.4 PDI) showed moderately susceptible reaction to leaf spot disease. Morphotype III showed resistant reaction to leaf spot as well as red rust diseases. This morphotype, however, was moderately resistant to grey blight disease. Morphotype VI showed moderate reaction to all the three major foliar diseases of S*om*.

Recent advances and management in oak tasar host plants discussed the different aspects of oak tasar host plant, recent trends and development from nursery propagation to maintenance through agronomical practices.

Estimation of leaf yield and rearing capacity of eri silkworm on two popular tapioca

varieties in Tamil Nadu: Emphasized on foliage availability for eri silkworm rearing on two popular varieties (H226 & MVD-1) cultivated under irrigated and rain fed conditions in Tamil Nadu.

Evaluation of Som morphotypes of resistance to leaf spot caused by Phyllosticta persae in field environment: The leaf spot caused by *Phyllosticta persae* affects commercial cultivars of the primary host plant Som (*Persea bombycina*) of muga silkworm during June to September and responsible for foliage loss up to 16%, study supports the potential of M-5 for leaf spot resistant breeding program of *som*.

Nutritive value of castor varieties and their impact on economic parameters of eri silkworm Samia cynthia ricini (Boisduval)*:* To evaluate the rearing performance of eri silkworm, *Samia cynthia ricini* (Boisduval) fed on different castor varieties *viz.,* Local green, local red and GCH4. The relationship between nutritive value of castor varieties and economic parameters of eri silkworm was investigated and the possible role of nutritive value of castor leaf with economic parameters discussed.

Recommendations

- Greater emphasis to be laid on utilization of ruling as well as introduced high oil yielding varieties of castor for eri silkworm rearing in West Bengal as well as in non traditional states of India.
- Emphasis should be given to introduction of IPM strategy including pruning for tasar host plant and other *Vanya* host plants.
- In the breeding programmes on muga host plant, screening for both pests and disease resistance should be a priority.
- Micro-propagation and macro-propagation techniques should be developed for multiplication host plant of tasar silkworm using biotechnology tools.
- Evaluate suitable strain of tapioca predominant in southern region of India for exploitation in eri silkworm rearing in Tamil Nadu.
- Evaluate nutritious castor genotype for eri silkworm rearing in Karnataka.
- The Basic seed organization like P3 and P4 should be added to the benefit of tasar research.

SESSION VIII: *VANYA* SILKWORM

Chairperson: Dr. B. B. Bindroo, Scientist-D, RSRS, Jammu.

During the session, a lead paper on *Vanya silkmoth and host plant germplasm resources and their conservation, was presented.* Six oral papers and 20 posters were presented. After the discussions on various topics on *Vanya* silkworms, the following recommendations were drawn.

Poster session

The poster *Performance of wild silk moth Cricula trifenestrata Helfer on different host plants and its utilization*" described the life cycle of *Cricula trifenestrata* (Helfer), and its host plants. It was inferred that Cricula can tolerate up to 38-40°C and there is a need for post-cocoon studies.

Socio economic development of tribes through tasar culture in Odisha : The paper indicated that a Socio-economic survey is essential for remote areas of tasar practicing zones for cataloguing the beneficiaries.

The poster *Comparative life cycle study of wild silkmoth Acteus seleni Hubner (lepidoptera : Saturniidae) on Terminalia arjuna and Terminalia tomentosa* reported *Acteus seleni* in Similipal Biosphere reserves in Odisha. The studies inferred that *Acteus seleni* is a diapausing genus and has three cycles per year.

Conservation and protection of bioresources for employment, empowerment and entrepreneurship through Vanya silk (oak tasar) industry in Uttarakhand state, India : Out of 220 entrepreneurs engaged in different sectors in Uttarkhand, only 74 entrepreneurs contribute to 33.67% silk industry in state. More and more entrepreneurs need motivation in future.

The poster *Varietal preference of castor to eri silk worm Philosamia ricini Hutt* indicated that castor varieties GCH-4 and GCH-5 were more suitable for the rearing eri-silkworm in laboratory. These two varieties can be well utilized for harvesting better cocoon production of eri silkworm. Further, quantum of leaf available needs to be studied. Reeling parameters have to be studied.

The poster *Biodiversity of eri silkworm and its host plants in India* reported another wild species of eri silkworm *Samia fulva* Jordan, from the forests of Andaman Islands. Six homozygous strains were found on the basis of larval colour and body markings, which produced different attractive coloured cocoon Hybridization between *S.ricini* and *S. canningi* were conducted in captive condition. The hybrid worms were more vigorous and prefered the leaves of Kessaru (*Heteropanax fragrans*). Only one hybrid was prepared. However, possibility of preparing more hybrids may be tried with all possible combinations.

The poster *Evaluation and identification of certain genotypes of eri silkworm, Samia ricini Donovan under tropical conditions of Andhra Pradesh* : Fifteen genotypes of eri silkworm, *Samia ricini* Donovan comprising of six isolated strains and nine eco-races were evaluated during three seasons *viz.,* Nov-Dec., Feb March and June July to identify the most suitable genotypes for tropical Andhra Pradesh conditions. Data were subjected for Evaluation Index method (Mano *et al*., 1993) to evaluate the best performing one. Among the genotypes evaluated, the eco-race, Lakhimpur ranked first with highest EI of 59.82. The genotype, Lakhimpur which showed highest performance over multiple traits of economic importance was considered as suitable and could be recommended for commercial use under tropical conditions of Andhra Pradesh. Post cocoon parameters may be studied.

The poster *Evaluation of some oak tasar silkworm breeds under different seasons in Manipur* : Out of ten oak tasar silkworm lines tested for their performance in respect of seven yield attributing traits, the line C27, PRP5 and RPP4 showed better performance for commercial exploitation for spring crop rearing. Whereas, C27, PRP12 and RPP4 in summer crop rearing. Whether the developed lines are breeding true to be further studied and confirmed.

The poster *Application of Jeevan Dhara for containment of virosis in tasar silkworm, Antheraea mylitta* D. dealt with use of *Jeevan Dhara* (a plant extract) which was found effective in suppressing virosis and was found to check polyhedral infestation. The cost involved in production of *Jeevan Dhara* for 100 dfls rearing was estimated at Rs.40.00. The cost benefit ratio calculated at 1:15

The poster *Comparative studies on the rearing and grainage performance of eri silkworm*

Samia ricini (Donovan) on two different host plants viz., Ricinus communis and Manihot utilissimia in Hosur conditions of Krishnagiri district of Tamil Nadu dealt about an experiment conducted to study the performance of rearing and grainage aspects of Eri silkworm *Samia ricini* on two different host plants *viz*., Castor *Ricinus communis* and tapioca *Manihot utilissimia.*. The experiments were conducted in four different crops, the results showed superior and better performance in rearing and grainage parameters in the eri silkworm reared with the food plant castor compared to that of eri silkworm fed on leaf of tapioca.

The poster *Effect of juvenile hormone (JH-III) and 20 Hydroxyecdysone (20-HE) on rearing performance of muga silkworm, Antheraea assamensis Helfer (lepidoptera: saturniidae)* indicated that among the three different concentrations of Juvenile hormone (JH-III) and 20 hydroxyecdysone (20-HE) @ 5, 10,15 □g/g body weight formulation was applied, and it is observed that application of Juvenile hormone results in the prolongation of larval period up to 7.5 days where as in 20 hydroxyecdysone, the larval period is shortened to 6.25 days compared to untreated control (9.0 days). Fecundity in *A. assama* is high *i,e.,* 162 in JH-III

The poster *Recent advances in management of quality seed production in eri silkworm seed production centers* indicated that for quality seed production, effective selection is required, generation of quality P-1 seed cocoons through ASRs, purchase of seed cocoons and following production norms including quality linked pricing system need to be followed. Further, use of innovative devices for rearing and grainage shall improve the quality and productivity of eri silkworm seed by the ESSPCs.

Recommendations

The future research should include :

- Survey, collection, conservation and documentation of muga and eri germplasm resources in both host plant and silk moth sectors need top most priority. It is suggested to take up characterization of all host plant genotypes.
- Strengthening of seed multiplication chain in tasar seed sector.
- Evaluation of suitable management strategies for minimizing the muga silkworm diseases
- Validation of juvenile hormone (JH-III) claimed to increase fecundity in *A. assama.*
- Popularization of disinfection in oak tasar rearing for prevention of *Tiger Band disease*.
- Fine tuning of semi-synthetic diet for tasar silkworm to make it more economical.
- Development of suitable oviposition device for eri silkworm for mass multiplication in non-traditional states of India.
- Popularization of Castor varieties GCH-4 and GCH-5.

SESSION IX: PRODUCT DIVERSIFICATION & BIOMATERIALS

Chairperson: Dr. R. K. Datta, Former Director, CSRTI, Mysore

A lead paper on *Product diversification of various silk material since first world in Europe, Japan and China* detailed how China has of late captured the world market with various types of processed silk fibre and fabric design. Now silk materials are available in the world

market at a cheaper price due to Chinese entrepreneurship. At the end of the 70's, Japan started diversification of silk fibroin and sericin protein by processing fibroin and sericin powder for commercial use in cosmetics, nutraceuticals and pharmaceuticals. Now silk waste materials including silkworm and mulberry leaf are processed for medicinal purposes like controlling diabetes II, cancer. Following this, South Korea and China too have initiated many commercial ventures to produce silk biomaterials useful in surgery, medical care, neutraceutical, culture of stem cells for repairing damaged tissue. Thus, a new frontier of silk-based biomaterial production has been initiated in many research institutes followed by commercial applications.

It was informed that use of silkworm litter with paddy straw had improved mushroom yield (914.0 g / 5 kg substrate) with a bio-efficacy of 62.13%. Mulberry fruit raw juice extract can be exploited for food and pharmaceutical application due to its high phenol content and higher antioxidant activity. Details about thirteen edible products from mulberry leaves and fruits, *Spoorthi*-mulberry health drink effective in controlling diabetes and hypertension, value added products from fibroin of silkworm were displayed as posters.

Oral Session

The following papers were presented in the session.

The first paper presented a novel approach to silkworm litter management. They used silkworm litter in combination with paddy straw and evaluated for its bio-efficacy in button mushroom (*Agaricus bisporus* Lange) producing. Higher mushroom yield (914.0 g / 5 kg substrate) with a bio-efficacy of 62.13 per cent was observed in the standard substrate, but non-significant to other treatments tried. Nutritive value viz., crude protein, total sugar and fibre content were determined.

The second paper dealt with usage of fungal and bacterial protease for degumming of silk. The conventional method by boiling-off with soap and alkaline solution often damage the surface of silk fibre and makes it a non-eco friendly process, causes serious pollution to the receiving waters. Fungal protease that gave 22-24% weight loss equivalent to that of conventional method was found to be best among the proteases tested.

The third paper described that out of two cultivars (S-36 & MR-2) of mulberry fruit raw juice extract MR-2 cultivar exhibited higher value of IC50 and can be exploited for food and pharmaceutical application due to its high phenol content and higher antioxidant activity.

The fourth paper explained the development of new and diversified products of silk from mulberry, tasar, eri & muga silk to reposition Indian silk in the international market

Poster Session

The following posters were presented in the session.

The poster from KSSRDI attempted to promote 13 edible products from mulberry leaves and fruits and grouped into two types, *viz*., saleable products (commercial products) and edible products for domestic consumption (kitchen recipes). The commercial products were: Mulberry black gram *papad,* rice *papad*, *khakra, chilli* biscuits, sweet biscuits, *poustika chapathi* mix, tomato soup mix, corn soup mix, fruit syrup and fruit preserve. The recipes identified for domestic consumption were: Mulberry fruit pickle, *pakoda* and rice *roti* from mulberry leaves. To popularize mulberry as a food plant for human consumption and to create awareness, 100 women sericulturists belonging to self-help groups were trained in two batches at B.R.Hills, and Krishnarajapet.

A poster on mulberry health drink detailed about *Spoorthi* which is effective in control of diabetes and hypertension; reducing gastric and constipation problems and revitalizing the body as an energy source. The extraction of LPC and its preservation techniques were standardized for different mulberry varieties. Processes were standardized for preparation of juice, jam, jelly and wine from fruits of *Morus laevigata, M. nigra* and *M. alba* cultivars.

Poster on *Value added products from fibroin of silkworm, Bombyx mori* has indicated that purified silk fibroin has become a novel, promising biomaterial and found rapidly increasing application in biomedical fields including tissue engineering of bone, cartilage, tendon, skin, ligament and blood vessels. Fibroin cream, hydrogel, film, powder and scaffold preparation have been standardized and discussed.

Recommendations

- Research on product diversification of silk and other silk based materials especially that related to production of biomateirals and their commercial use in the industry may be initiated in different research institutes of CSB.
- Research on use of sericin and fibroin powder for developing neutraceutical and pharmaceutical products may be initiated.
- Popularization of biotechnologial research products in the field is required.

SESSION X: SERICULTURE ECONOMICS, MARKETING AND FINANCE

Chairperson : Dr. M. A. Khan, Director, CSRTI, Pampore

The session included a lead paper, four oral and two poster presentations. The lead paper entitled *Sericulture industry in India retrospect and prospect* highlighted the stagnation of silk production in the recent years due to decline in mulberry area in the major silk producing states. Further, the paper indicated increasing imports of raw silk and fabrics in the recent years as a worrying factor for the development of Indian sericulture industry. The paper also indicated decline in *per capita* consumption of silk goods in the last one decade.

Oral session

The paper *entitled Economic impact of mulberry based farming systems An empirical study* by H. Jayaram indicated that mulberry based integrated farming system with agriculture and vegetable crops was found more profitable than solo crop of mulberry and other cropping systems. The house recommended that the synergy between the various enterprises should be considered while suggesting the farming system models for the farmers.

The paper entitled *Sericulture scenario Chinese dominance and Indian strategies* compared the sericulture production system of India with that of China and stressed that the Chinese sericulture is better than in India in quality and productivity levels. The paper suggested to improve the bilateral relationship with other silk producing countries and revamp Indian sericulture to face the competition from Chinese sericulture. It was also felt to improve the silk processing sector in India, in order to make it more competitive.

The paper on *Contribution of sericulture in the economy of poor farmers of Kathua district of Jammu and Kashmir* indicated that sericulture is more profitable than wheat for the small farmers of Kanthua district in Jammu and Kashmir. The farmers earned an average income of Rs.4,500/- per family from sericulture.

A paper on *Economics of private chawki rearing centres in southern India,* indicated that the

owners of CRCs were able to earn a net income of Rs.180/- to Rs.200/- per 100 dfls. The cost benefit ratio of the CRCs ranged from 1: 1.72 to 1: 1.83. The study revealed that the CRCs are economically viable and commercially feasible besides improving the crop yield of the farmers.

Poster session

In the session, two posters were presented. The poster on *Studies on economics of sericulture in the non-traditional area of south India and Maharashtra* indicated that in spite of low technology adoption level along with higher input cost, the sericulturists of the area opined that sericulture is remunerative. The author suggested increased training programmes including establishment of Farmers Field Schools.

The second poster on *Commercial production of biocontrol agents of mulberry and silkworm pests through private entrepreneurs* indicated that establishment of biocontrol agents production units is economically viable and will provide employment and income generation opportunities to the rural entrepreneurs, besides acting as eco-friendly measure to control the pests of mulberry and silkworm. It is observed that additional income could be earned from residue of culture of *Nesolynx thymus.*

SESSION XI: TRANSFER OF TECHNOLOGY, HRD AND SOCIETAL DEVELOPMENT

Chairperson: Prof. Chinnaswamy, K.P., UAS, Bangalore

A total of 73 papers were received. Out of that, three were lead papers, eight oral, 16 poster and 46 abstracts.

- All the three lead papers concentrated on methodology and programmes for TOT in CSRTI in collaboration with DOS of concerned states. From the papers presented, it was inferred that sericulture provides substantial income ranging from 1 lakh to 5 lakh / year. It also generates employment to the extent of 26 man years and 6431 man days

Oral session: In addition, HRD programmes offered by CSRTI, Mysore and other centers were presented and it mainly concentrated on capacity building of farmers as well as extension functionaries.

Recommendations

- There were many suggestions from the learned participants for better fine tuning of TOTs *viz.,* integrated approach could be followed and need based/tailor made approaches can be adopted region wise.
- Special programmes need to be drawn in addition to the existing programmes for empowerment of women.
- All the IVLP programmes which have been implemented throughout India found viable and needed to be continued in future with fine-tuning.
- Cluster approach in TOT has appeared to have positive effect and this needs to be expanded to newer areas.
- Tele-conferencing being tried at UAS, Bangalore along with ISRO is found very useful and effective in TOT. CSB should take the advantage of these facilities to transfer the knowledge to the farming community.

- ICAR / NABARD are involved in training technical graduates for establishment of agri-clinics as an agency for providing services to the agriculture / farmers as a whole. So CSB can also exploit this, in addition to their seri-polyclinics under CPP for effectively to reach the *unreached* in a collective manner.

PLENARY SESSION

The Plenary session was held during the afternoon of 29.01.2011 wherein the details of the deliberations made over the two day National conference, the interactions had during the sessions on various topics, and the recommendations emerged for taking up future research programmes were discussed. The session was chaired by Dr. M. Mahadevappa (the recipient of *Padmashree* Award), Former Vice-Chancellor, University of Agricultural Sciences, Dharwad. The chief guest was Dr. R.J. Rabindra, Director, NABII, Bangalore.

Dr. M. Mahadevappa speaking as the Chairperson of the session congratulated Dr. S. M. H. Qadri, Director, CSR&TI, Mysore for the grand success of the conference. Recalling his association with the CSR&TI, Mysore, he said that hailing from a sericulture family, he learnt the basics of sericulture at home but learned the science of sericulture at this institute. "As a member and Chairperson of RAC of the Institute for two terms, I learnt a lot about sericulture" he said. He hoped that all the aspects of sericulture and silk industry have been covered in this seminar including the contemporary issues. While mentioning about the farmers gathering at the *Suttur Jathra* he briefed how this *Jathra* has become a forum for the farmers to discuss agriculture. He advised CSR&TI, Mysore to take part in such events. "With new technologies CSR&TI has developed, sericulture can become a highly profitable venture" he felt.

Speaking about the role of women in sericulture, he called on the concerned to involve more women in this *women-friendly* activity. Patting the women's role in sericulture, he mentioned that Dr. Swaminathan's report indicates that the participation of women in agriculture is 64% and that of men is only 36%. The trend is more or less same in sericulture too.

Stressing on Dr. Ayyappan's (Director General, ICAR) concern about the convergence, he felt that unfortunately it is not happening to the expected level. He informed that in one of the meetings, while discussing about the NRLM (National Rural Livelihood Mission redesignation of SGSY), his thoughts about sericulture were well received. Incidentally, our scientists strive hard to develop a new technology but do not follow it up till its adoption and acceptance in the field he said. "A scientist needs to be a good extension worker also" he felt strongly. He opined that the economic impact analysis is required to be properly made which he was sure, will confirm that sericulture is a safe and beneficial activity. "Further, there are no reports of sericulturists commiting suicide", he added. He therefore, called on the scientists concerned to take up economic analysis in sericulture and also make publicity campaigns highlighting the success stories of sericulture more intense. Incidentally, he mentioned about SEETA (Pune based) which brings out publications in seven languages and also about *Krishi Kayaka* for which he is the Chief Editor. He advised scientists to share their knowledge through such magazines.

Speaking about ICAR, he expressed that all the technologies developed even by this esteemed organization have not reached the field. So, he requested the scientists to put their best efforts so that the research findings reach the farmers. However, while doing so, he cautioned about the fake scientists / sericulture / *agriculture pundits* who mislead the farmers. Therefore, such people be kept at bay and appealed the scientists to draw more and more programmes to educate farmers to benefit silk industry.

Dr. R.J. Rabindra**,** sharing his reflections as the chairperson at the session said that he started with a small project sponsored by CSB and then worked as a Professor and Head of Sericulture in TNAU, Coimbatore for some time. Later, he was nominated to RAC as its member and so on. But with all this exposure, he said he still is a student of sericulture. Appreciating the theme of the seminar *i.e., Sericulture innovations, before and beyond* he said that it is the right time to act and innovate. Incidentally, he remembered the contributions of the previous Directors of the institute like Dr. R.K. Datta and Dr. S.B. Dandin. His association with present Director, Dr. Qadri particularly in successfully addressing the Papaya mealybug problem in mulberry is unforgettable. "Of the enormous technologies available one has to filter the suitable ones and how best we can focus these technologies for the use of mankind. Mentioning about the Dr. Kasturi Rangan's repeated question that if your research findings are so vibrant, why our agriculture growth rate is still at 4% and some other crops like oil seeds and pulses with negative growth rate? Where is your contribution to the agriculture GDP? Dr. Rabindra said that now the farmer's mentality has changed and his needs are increasing. Therefore, we have to rise up to the occasion and provide technologies to suit the needs of farmers in the field and have to be pragmatic in our approach. He added that innovations come only from patriotic minds. "If one is patriotic then he thinks about the current status. Why we should be second to China? If we have fertile lands and labour why not overtake China? We should dream and innovate" he added.

Dr. Satish Verma, Scientist E, SED of the Institute proposed vote of thanks.

Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 78-81

LABORATORY EVALUATION OF GLUCOSINOLATE CONTAINING PLANTS FOR THEIR BIOFUMIGATION POTENTIAL AGAINST SOILBORNE PATHOGENS OF MULBERRY (*MORUS* SPP.)

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ABSTRACT

The study was undertaken to know the effectiveness of biofumigation using glucosinolate containing plants against various soil borne pathogens causing root rot disease in mulberry under in vitro. The residue of seven plants viz., Brassica oleraceae, B. rapa, B. oleraceae var. botrytis, B. juncea, Lectuca sativa, Rhaphanus sativus and Daucus carota were selected for conducting the experiment. Cultures of root rot pathogens such as *Fusarium solani, Botryodiplodia theobromae and Rhizoctonia bataticola* (=*Macrophomina phaseolina*) were exposed individually to isothiocyanates released by these Brassica cultivars during decomposition. After 14 days, the pathogens were tested for their viability. Residue of B. juncea and R. sativus were found highly effective by completely arresting growth of all the three root rot causing pathogens. Further experiments conducted on mulberry grown in earthen pots confirmed effectiveness of these plant residues, suggesting their potentiality for developing the IDM package against soilborne pathogens of mulberry.

Key words: Biofumigation, Isothyocyanate, Soil borne diseases

INTRODUCTION

Mulberry (Morus spp.), cultivated in various parts of the country for commercial silkworm rearing is susceptible to diseases caused by various pathogens. The quality of mulberry leaf fed to the silkworm is important determinant of the quality of silk produced. The diseases cause considerable of loss in terms of quality (Teotia and Sen, 1994; Pratheesh Kumar *et al*, 2003) and quantity leading to poor economic return (Qadri *et al*, 1999). Unlike foliar diseases the root rot caused by various pathogens such as *Fusarium solani, Botryodiplodia theobromae* and *Rhizoctonia bataticola* (=*Macrophomina phaseolina*) are very vital since it is diagnosed after appearing symptoms on the aerial part of the plants by the time disease have attained in severe condition. During recent years, many methods for management of soil borne diseases are suggested (Govindaiah *et al*., 2005; Sharma *et al*., 2009). However, use of chemicals for disease control may harm beneficial faunae and flora of rhizosphere. Also, prolonged use of chemicals may lead to development of resistant strains. Due to these economical and environmental considerations as well as negative public perception, chemical control measures are not desirable for management of root rot disease of mulberry. Therefore, an alternate farmers' friendly management method is very essential. Biofumigation especially using *Brassica* cultivars is a sustainable agronomic technique exploiting some plants' defensive myrosinase-glucosinolate enzymatic systems for management of soilborne pathogens, nematodes, insects and weeds in various agricultural crops.

This biocidal activity is frequently attributed to isothiocyanates (ITCs) released by disintegrating tissues (Delaquis and Mazza, 1995).When incorporated into the soil, biofumigants, are reported to suppress populations of pathogenic fungal species such as *Sclerotium, Rhizoctonia, Phytium, Botrytis cinerea, R. solani, F. oxysporum, Didymella lycopersici,* and *Cladosporium fulvum*, nematodes, weeds and certain insect species (Charron and Sams, 1999: Harvey, 2002). It is reported that, black mustard

Table 1: Effect of plants residues on radial growth of root rot pathogens

Name of the plant	Radial growth (mm)		
	Rhizoctonia bataticola	*Botryodiplodia theobromae*	*Fusarium solani*
	Mean	Mean	Mean
Dacus carota	16.9 ± 2.10	26.9 ± 2.90	27.4 ± 2.01
Brassica rapa	21.3 ± 2.02	23.1 ± 1.98	29.3 ± 1.98
Lectuca sativa	23.6 ± 2.19	24.1 ± 2.20	28.6 ± 2.02
B. oleraceae var. *capitata*	20.1 ± 1.90	34.2 ± 1.20	32.4 ± 1.22
B. oleraceae var. *botrytis*	19.6 ± 1.87	21.1 ± 2.01	21.1 ± 2.11
B. juncea	0.00 ± 0.00	1.10 ± 0.01	1.24 ± 0.01
Raphanus sativus	2.10 ± 0.01	2.20 ± 0.01	2.24 ± 0.02
Control	35.5 ± 2.91	36.2 ± 2.86	35.2 ± 2.66
CD P<0.05	5.62	4.98	4.59

In the experiments conducted with mulberry plants grown in earthen pots, the least disease was found in case of plants treated with mustard plant residue followed by treatment with mustard oil cake and residue of *Raphanus* plant. The root rot incidence was higher in the control (87%). The percent of disease control was found higher in case of mustard oil cake and mustard plant residue followed by *Raphanus* residue (Fig 2).

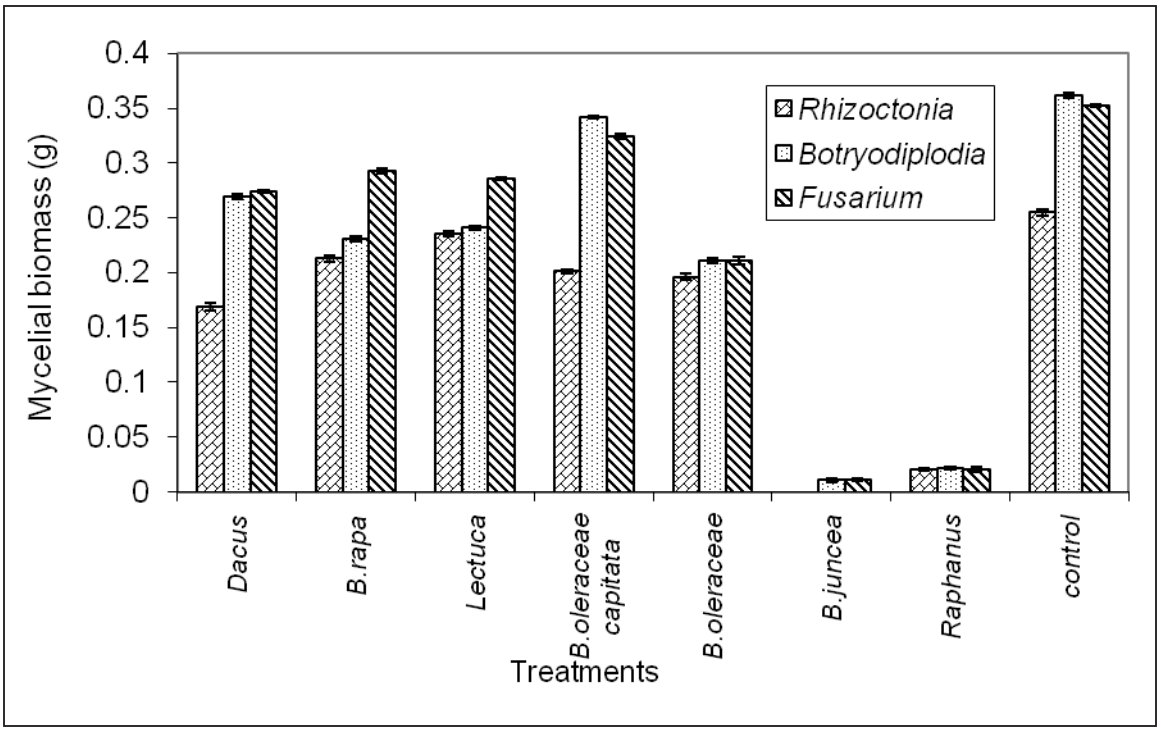


Fig. 1: Impact of plant residues on root rot pathogens of mulberry

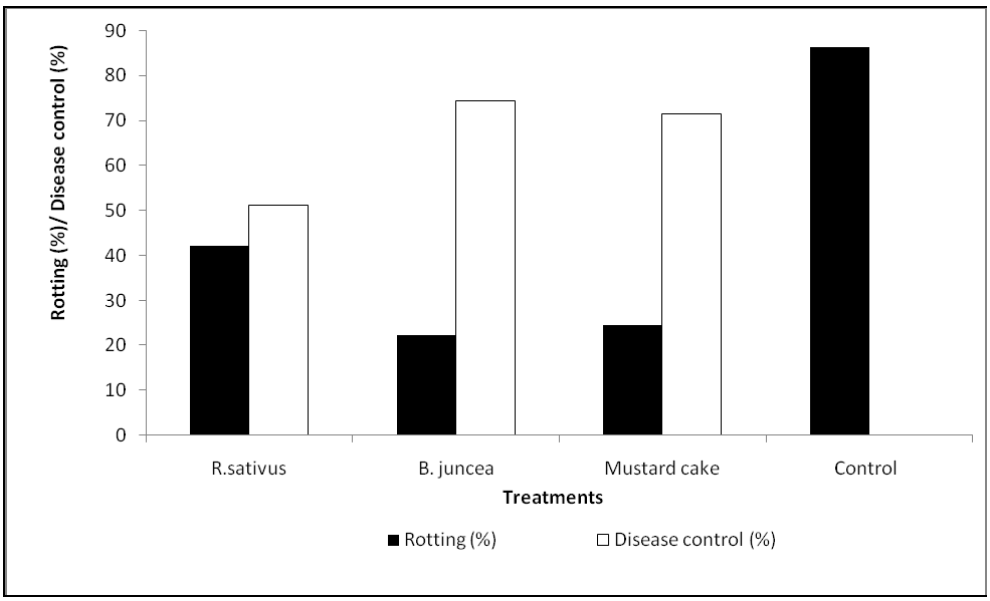


Fig. 2: Impact of selected plant residues on root rot incidence of mulberry

(*B. nigra* L.) and Indian mustard (*B. juncea* L.) produce high levels of isothyocyanates (Tollsten and Bergstrom, 1988) and could be utilized in a biofumigation cropping system. Subbarao *et al*. (1996) reported control of *V. dahliae* by *Brassica* residues comparable to plots fumigated with methyl bromide + chloropicrin along with significant decreases in the incidence of southern blight of tomato and increases in fruit yield, when integrating biofumigation into a sustainable production system. The present study has been conducted to evaluate potential of certain *Brassica* plants to suppress the fungal pathogens causing root rot disease of mulberry.

MATERIALS AND METHODS

Laboratory assay of biofumigants was conducted using seven plant species, *Brassica juncea*, *B. rapa*, *B. oleraceae* var. *capitata*, *B. oleraceae* var. *botrytis*, *Raphanus sativus*, *Lectuca sativa* and *Dacus carota,* which are reported to contain glucosinolate were planted in the experimental field. After two months, leaves of these plants were harvested and brought to the laboratory. These leaves were cut in to small pieces of 1sq cm and 50 g were transferred to a 250 ml polyurethane container. Seven days old culture of *Rhizoctonia bataticola* (=*Macrophomina phaseolina*), *Botryodiplodia theobromae* and *Fusarium solani* causing root rot disease, were cut in to 0.5 mm diameter discs and kept on inner part of the lid of polyurethane container under aseptic condition. The bottles were closed airtight and incubated at 28 ± 2C° for 14 days so as to expose the fungi to the isothyocyanates released by the decomposing plant materials. The laboratory assay of the plants for suppression of fungi was done in solid and liquid medium. After 14 days incubation, the fungal discs were collected and transferred in to plates containing Potato Dextrose Agar (PDA) medium and Erlenmeyer flasks containing PDA broth for testing their viability. Both the sets were incubated at 28 ± 2C° for 14 days. Radial growth of the fungi was measured from the Petri plates. Similarly, after 14 days the fungi were harvested from the liquid medium by passing the culture through a filter paper. The fungi were dried and the fungal biomass was recorded from each treatment and control.

The *in vivo* studies were conducted using mulberry plants grown in earthen pots. Three fungal pathogens were grown in sorghum (*Sorghum vulgare* L.) were mixed the upper layer of the soil around the collar region of plants were removed and inoculated with 100g mix of the fungal inoculum and covered with soil. After 10 days, 100 g chopped leaf of selected plants i.e. *B. juncea* and *R.sativa* as well as mustad oil cake were applied separately on the basin of the plant removing the top soil and then covered. A control was kept without applying the treatment. Five replications were kept against each treatment and control. The data on wilting and root rot were collected after one month following standard methods (Govindaiah *et al*., 2005).

RESULTS AND DISCUSSION

There was a significant different in biomass production of all three fungal pathogens causing root rot disease in various treatments. The biomass production of all the test fungi was significantly less when they were exposed to the degrading *B. juncea* and *R. sativus* plant tissue. The growth was negligible in both the cases with higher suppression of fungal growth. Followed by growth in *B. oleraceae*. The

highest biomass production was observed in case of control (Fig.1).

Three fungi were tested for their viability and growth after exposing them in the decomposing tissues of test plants. There was a significant ($P<0.05$) variation in the growth of fungi in the solid agar medium due to various treatments. Maximum suppression of growth of all the fungi was found due to exposing them in the decomposing tissue of *B. juncea* followed by *R. sativus*. The growth of all the fungi in other treatments also significantly less compared with control. Even there was complete suppression of *R. bataticola* when exposed to *B. juncea* residue (Table 1).

The process of Brassica degradation includes hydrolization of glucosinolates via the enzyme myrosinase. The products of the decomposition are a variety of sulfur containing compounds, which are classified into groups based on specific chemical structures. The products of the decomposition of glucosinolates include nitriles, epithionitriles, isothiocyanates, thiocyanates, and oxazolidinethiones (Bending and Lincoln, 1999; Lazzeri and Manici, 2001). Isothiocyanates and other compounds from decomposition are thought to interact with proteins, inhibiting a variety of organisms (Brown and Morra, 1997). Isothiocyanates are the active compounds in the commercial fumigants Vapam and K-pam. While isothiocyanates and aromatics are thought to be crucial to the suppression of plant pathogens, other compounds such as carbon-disulfide, dimethyl-disulfide, dimethyl-sulfide, and methanethiol are also suspected to have beneficial effects when brassica break crops are used as a biofumigant (Bending and Lincoln, 1999; Smith *et al*., 2004). The suppression of the test fungi is due to the effect of volatile compounds produced by the decomposing plant tissue. The study shows that *B. Juncea* plant, its oil cake or *R.sativa* sativus can be used as eco-compactable material for control of soil borne fungal disease of mulberry. Further detailed studies along with field implication of biofumigation are required in the mulberry cropping system.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 82-85

IMPACT OF INTERACTION OF NEMATODE AND ROOT ROT PATHOGENS ON SEVERITY OF ROOT DISEASE COMPLEX IN MULBERRY (*MORUS* SPP.)

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ABSTRACT

A green house study was conducted to know the effect of root knot nematode (*Meloidogyne incognita*) and root rot pathogens (*Botryodiplodia theobromae* and *Fusarium solani*) at different series of inoculations *viz*., individual, concomitant and sequential (inoculation of nematode four weeks prior and later to root rot pathogens) on severity of root disease complex in mulberry. The maximum mulberry growth parameters were reduced (72.5 - 92.7 %) with respect to the control (without pathogens) in sequential inoculation of nematode four weeks prior to both the root rot pathogens, and the disease severity was extremely high due to the presence of all the three pathogens *viz*., *M. icogninta*, *B. theobromae* and *F. solani* (89.5-93.8 %) resulting in the mortality of a maximum number of plants (72.2 %) compared to the disease severity due to individual inoculation of pathogens. (29.8-47.5 %), concomitant inoculation of root rot pathogens and nematode (69.5-74.8 %) as soon as nematode inoculation later to root rot pathogens (76.8-80.3 %). Thus the present study indicates that *M. incognita* provided a good site for rapid entry and penetration of of *B. theobromae* and *F. solani* into the roots of mulberry, which considerably increased severity of disease and reduced the mulberry growth parameters.

Key words: Disease complex, Mulberry, Root knot nematode, Root rot pathogens

INTRODUCTION

Mulberry (*Morus* spp.) is cultivated for several years as a mono crop. Continuous cultivation and repeated harvesting makes the crop vulnerable to soilborne diseases *viz*., stem canker, collar rot, root rot and root knot. Among them, root rot caused by *Fusarium solani* and *Botryodiplodia theobromae* is the most dangerous and potential to kill the plants completely. Whereas, root knot disease (*Meloidogyne incognita*) causes 15 % yield loss and provides a good site for easy entry of root rot pathogens resulting root disease complex (Sharma *et al*., 2003; Ramakrishnan and Senthilkumar, 2003; Nishitha, 2006). Bhagyarathy *et al.* (2000) reported that the interaction between *M. incognita* and *Rhizoctonia bataticola* causes disease complex in mulberry and reduce the mulberry growth and increase the disease severity rapidly. The interaction effects between root knot nematode (*M. incognita*) and root rot pathogens (*Fusarium solani* and *Botryodiplodia theobromae*) have not been reported so far. The present study was undertaken to know the effect of root knot nematode and root rot pathogens on severity of root disease complex and individual, concomitant and sequential inoculation and its impact on mulberry growth.

MATERIALS AND METHODS

The experiment was conducted on effect between the root knot nematode (*M. incognita*) and root rot pathogens (*B. theobromae* and *F. solani*) to assess the severity of root disease complex and mulberry growth parameters at different series of inoculations such as individual, concomitant and sequential (inoculation of nematode four weeks prior and later to that of the root rot pathogens) at green house. The trial was conducted using three month old mulberry saplings (V1) in earthern pots with 3 kg sterile soil mixture of soil, sand and farmyard manure at 2:1:1 ratio. The nematode was inoculated @ 1000 larvae/pot and root rot pathogens @ 6.25 % based on soil weight; having colony forming units (CFU) of 3.2 3.6 10^7/g fungal biomass (Nishitha, 2006). After thorough mixing, the initial load was determined as 160 larvae/250 cc soil for nematode, CFU of 3.1 10^6/g soil for *F. solani* and 3.0 10^6/g soil for *B. theobromae*, while 3.6 10^6/g soil for mixed inoculation of

root rot pathogens. A control without nematode or root rot pathogen was maintained for comparison. The experiment comprised of 14 treatments and 12 replications. The pots were kept in the green house in a completely randomized block design and irrigated thrice in a week. Ninety 90 days after inoculation, data on plant growth, nematode population and root rot infection as well as along with survival of plants were recorded. The reproductive factor of nematodal fungi (Rf) was calculated dividing the final population (pf) (for nematode per 250 cc soil and root rot pathogens CFU/g soil) with initial population (Pi). The data were subjected to ANOVA using statistical software, INDOSTAT to know the significant differences among the treatments.

RESULTS

There was no mortality of mulberry due to incidence of inoculation of nemetodes. Maximum plant mortality (72.2 %) was recorded when nematode was inoculated 4 weeks prior to root rot pathogens (Table 1). The symptoms of root disease complex such as wilt on foliage, rotting of roots and presence of galls on root system was significantly higher. This resulted in foliar infection: 93.8 %, rotting of root: 89.5 % and number of galls/plant: 27.8. However, the intensity was significantly less in the treatments, where the nematode and root rot pathogens were inoculated individually (Table 2). Similarly, highly significant reduction in plant growth parameters were recorded in the treatment where nematode inoculation was made four weeks prior to inoculation of root rot pathogens. The leaf yield, length of shoot and root were reduced by 91.8, 82.5 and 86.7 % respectively. Similarly, fresh weight of shoot and root was reduced to an extent of 90.9 and 89.7 %, while reduction in dry weight of leaves, shoot and root was recorded as 72.5, 88.4 and 92.7 %, respectively over the uninoculated control (Table 1).

The multiplication rate of nematode in soil was 7.9 times higher than the initial population, when nematode was inoculated individually. Significant reduction in multiplication rate of nematode was observed when root rot pathogens were inoculated separately or concomitant with nematode. However, nematode multiplication was least with 2.4 times more from initial population when nematode was inoculated four weeks prior to root rot pathogens while nematode population was reduced to an extent of 69.2 % over the treatment when nematode was inoculated separately. On the other hand, the multiplication rate of root rot pathogens was increased in the presence of nematode. The significantly maximum multiplication rate of root rot pathogens was recorded in the above said treatments with Rf: 20.6 times higher from initial population and the population of root rot pathogens was increased to maximum (Table 2).

DISCUSSION

In the present investigation, maximum reduction of mulberry growth parameters, higher disease severity and maximum mortality of plants in four weeks prior to root rot pathogens might be due to the synergistic effect of the nematode and root rot pathogens. Since the nematode causes wounds in roots, which facilitate the fungal pathogens to penetrate rapidly and establish rapidly, resulting in higher severity. These observations also reflect on the role played by the nematode in predisposing the mulberry plants to fungal pathogens. Overall, presence of all the three pathogens together resulted more deleterious effect to mulberry due to positive interaction among them causing maximum disease severity.

The present work is in agreement with the findings of Pathak *et al*. (1999) on significant increase in banana wilt when nematode (*M. incognita*) was inoculated 10 days prior to wilt causing pathogens, *F. oxysporum* f. sp. *cubens* and *Pseudomonas solanacearum*, as compared to the disease severity when the three organisms were inoculated individually or together. They also observed a positive interaction among all the three pathogens in respect to increase in wilt severity with heavy damage of the crop. Bhagyarathy *et al.* (2000) also reported easy entry of *Rhizoctonia bataticola* hyphae and increased the severity of root rot disease in mulberry in presence of *M. incognita*.

Nematode multiplication, number of galls and egg production were high when nematode was inoculated individually. However, the nematode multiplication reduced considerably when root rot pathogens were inoculated along with the nematodes individual, concomitantly or sequentially. This suggests that *B. theobromae* and *F. solani* were having an inhibitory effect on nematode multiplication. This may be due to the accumulation of mycotoxins and portions around portal of entry of the fungi which get suberised and preventing the entry of nematodes. Similar observations on reduced population of nematode and root knot index in the presence of wilt and root rot causing fungi have been reported (Powell, 1971; Zaidi and Tiyagi, 1989; Pathak *et al*., 1999) in onion crops.

The present study confirms that the nematode, *M. cognita* provided a good portal for easy entry of *B. theobromae* and *F. solani* into the roots of mulberry, which rapidly increases the severity of disease and turn to root disease complex leading to more deleterious effect on mulberry plants with maximum disease severity due to the presence of all the three pathogens.

Table 1: Effect of *M. incognita* and root rot pathogens on mulberry growth

Treatment	90 days after inoculation									
	Dead Plants out of 36	Mortality of plants (%)	Length (cm)		Leaf Yield/ plant (g)	Fresh weight (g)			Dry weight (g)	
			Shoot	Root		Shoot	Root	Leaf	Shoot	Root
Control	0	0	77.0	29.4	76.6	75.5	29.1	22.2	22.4	8.5
Individual inoculation										
Nematode (N)	0	0	66.2 (14.0)	27.4 (6.8)	59.4 (22.5)	57.0 (24.5)	21.3 (26.8)	16.7 (24.8)	15.3 (31.7)	6.2 (27.0)
B. theobromae (Bt)	10	27.7	37.8 (50.9)	19.4 (34.0)	36.3 (52.6)	36.4 (51.8)	16.4 (43.6)	10.9 (50.9)	11.0 (50.8)	5.0 (41.2)
F. solani (Fs)	9	25.0	41.4 (46.2)	20.9 (28.9)	39.4 (48.6)	39.3 (47.9)	20.4 (29.9)	11.9 (46.4)	11.9 (46.9)	5.9 (30.6)
Concomitant inoculation										
Bt + Fs	14	38.9	32.2 (58.2)	17.1 (41.8)	32.2 (57.9)	32.5 (56.9)	12.0 (58.7)	10.3 (53.6)	9.1 (59.3)	3.5 (58.8)
N + Bt	14	38.9	29.4 (61.8)	12.1 (58.8)	30.6 (60.0)	28.3 (62.5)	10.2 (64.9)	9.6 (56.8)	8.3 (62.9)	4.1 (51.8)
N + Fs	11	30.5	35.8 (53.5)	14.5 (50.7)	35.6 (53.5)	35.0 (53.6)	11.4 (60.8)	11.4 (48.6)	11.2 (50.0)	4.7 (44.7)
N + Bt + Fs	16	44.4	26.2 (66.0)	9.8 (66.7)	20.9 (72.7)	21.6 (71.4)	8.9 (69.4)	8.5 (61.7)	6.8 (69.6)	2.4 (71.8)
Sequential inoculation (nematode 4 weeks prior to fungus)										
	15	41.7	22.3 (71.0)	8.8 (70.0)	15.5 (79.8)	15.5 (79.5)	6.6 (77.3)	8.3 (62.6)	6.0 (73.2)	1.8 (78.8)
N → Fs	12	33.3	25.6 (66.8)	10.7 (63.6)	23.9 (68.8)	22.6 (70.0)	7.0 (75.9)	9.4 (57.7)	7.2 (67.8)	2.5 (70.6)
N → Bt + Fs	26	72.2	13.5 (82.5)	3.9 (86.7)	6.3 (91.8)	6.8 (90.9)	3.0 (89.7)	6.1 (72.5)	2.6 (88.4)	0.62 (92.7)
Sequential inoculation (nematode 4 weeks later to fungus)										
Bt → N	14	38.9	26.3 (65.8)	10.9 (62.9)	26.0 (66.0)	23.5 (68.9)	8.8 (69.8)	9.6 (56.8)	7.4 (66.9)	2.7 (68.2)
Fs → N	12	33.3	31.7 (58.8)	12.8 (56.5)	31.0 (59.5)	29.8 (60.5)	10.2 (64.9)	10.8 (51.4)	9.1 (59.2)	3.4 (60.0)
Bt + Fs → N	19	52.8	19.3 (75.0)	8.4 (71.4)	15.2 (80.2)	15.3 (79.7)	5.7 (80.4)	7.7 (65.3)	5.4 (75.9)	1.9 (77.6)
	-	0.56	0.52	0.43	0.50	0.48	0.44	0.45	0.41	0.29
CD at 5 %	-	1.58	1.45	1.20	1.41	1.34	1.23	1.28	1.15	0.82
CV %	-	5.4	5.1	10.1	5.4	5.3	12.5	14.4	14.9	26.8

Figures in parentheses indicate the percent reduction over the control

Table 2: Effect of population of *M. incognita* and root rot pathogens on disease severity

Treatment	90 days after inoculation									
	Nematode					Root rot pathogens				
	Galls/ plant	Egg masses/ 25g root	Multiplication factors (larvae/ 250 cc soil)			Foliar infect-ion (%)	Rotting of root (%)	Multiplication factors (CFU/g soil $\times 10^7$)		
			Pf	*Red. (%)	Rf = Pf/Pi			Pf	*Inc. (%)	Rf= Pf/Pi
Control	0	0	0	0	0	0	0	0	0	0
Individual inoculation										
Nematode (N)	292.5	209.7	1266.5	-	7.9	-	-	-	-	-
B. theobromae (Bt)	-	-	-	-	-	47.5	43.8	3.2	-	10.6
F. solani (Fs)	-	-	-	-	-	35.5	29.8	2.6	-	8.4
Concomitant inoculation										
Fs + Bt	-	-	-	-	-	63.8	58.6	3.7	-	10.2
N + Bt	79.5	53.7	686.4	- 45.8	4.3	69.5	64.9	4.1	+ 28.1	13.6
N + Fs	91.8	65.8	752.3	- 40.6	4.7	65.9	60.8	3.3	+ 26.7	10.6
N + Bt + Fs	60.5	41.5	625.7	- 50.6	3.9	74.8	69.5	5.2	+ 40.5	14.7
Sequential inoculation (nematode 4 weeks prior to fungus)										
N → Bt	41.5	30.8	520.5	- 58.9	3.2	81.6	77.3	5.6	+ 75.0	18.7
N → Fs	48.8	34.5	572.5	- 54.8	3.6	77.5	75.8	4.4	+ 69.2	14.1
N → Bt + Fs	27.8	18.4	389.5	- 69.2	2.4	93.8	89.5	7.4	+ 100.0	20.6
Sequential inoculation (nematode 4 weeks later to fungus)										
Bt → N	78.3	43.8	586.4	- 53.7	3.7	72.5	69.7	4.2	+ 31.3	14.0
Fs → N	71.8	38.5	630.7	- 50.2	3.9	68.0	64.8	3.4	+ 30.8	10.9
Bt + Fs → N	54.8	30.9	528.9	- 58.2	3.3	80.3	76.8	5.4	+ 45.9	15.0
SE ±	0.65	0.53	0.54	0.04	-	0.58	0.61	0.06	2.50	-
CD at 5 %	1.82	1.50	1.52	0.12	-	1.62	1.72	0.17	7.00	-
CV %	3.73	4.60	0.43	0.43	-	3.39	3.83	5.64	27.11	-

Pi-initial population; Pf-final population; Rf-reproductive factor;
Initial population (Pi) of nematode: 160 larvae/250 cc soil;
Pi of *F. solani*: 3.1 10^6 CFU/g soil;Pi of *B. theobromae*: 3.0 10^6 CFU/g soil:
Pi of mixed population of mixed population of both pathogens: 3.6 10^6 CFU/g soil;
*Reduction (-) or increase (+) of individual/ combined inoculation over control

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 86-93

CORRELATION OF MORPHOLOGICAL AND ANATOMICAL FEATURES OF MULBERRY WITH RESISTANCE TO BACTERIAL LEAF SPOT

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ABSRACT

Bacterial leaf spot (BLS) caused by *Xanthomonas campestris* pv. *mori* is a major foliage production constraint covering all mulberry growing areas worldwide. The present study was carried out at the agro-climates of Berhampore, West Bengal with the objectives to establish correlation between morpho-anatomical traits and disease resistance, and grouping of diverse mulberry genotypes based on in planta traits for exploitation in mulberry improvement programme. Morphological and anatomical characteristics of 20 diverse mulberry genotypes, cultivar and improved strain with various levels of resistance to BLS were examined to determine which features were associated with resistance. The parameters assessed were: (i) stomatal frequency, (ii) thicknesses of upper and lower epidermal cell layers, and (iii) thicknesses of spongy and palisade parenchymatous tissues. Significant variability among the genotypes was observed for all the traits. The Pearson correlation coefficient indicated that the stomatal frequency possessed significant positive correlation with BLS severity index (DSI). While, the thicknesses of epidermal cell layers and parenchymatous tissues were negatively associated with DSI. Regression analysis showed a significant relationship between increased stomatal frequency and increasing DSI to BLS (R2=0.620) and reduced epidermal thickness and increasing DSI (R2=0.203). The dendrogram using complete linkage distance based on morpho-anatomical features showed that resistant genotypes were mostly grouped together. Five genotypes such as Morus rotundiloba, S-799, Morus multicaulis, Shrim-5 and MS-8 were in close proximity.

Key words: Bacterial leaf spot, Correlation, Clustering, Disease resistance, Morpho-anatomical traits

INTRODUCTION

Bacterial leaf spot (BLS) caused by *Xanthomonas campestris* pv. *mori* is a serious threat to mulberry (*Morus* spp.) foliage production reported worldwide (Akhtar and Sarwar,1988; Choi *et al.,* 1988; Coteanu,1971; Sato *et al.,*1981; Pandey and Singh,1989; Maji and Qadri, 1999). In India BLS occurs during rainy and autumn seasons. The disease appears as small water soaked spots in the lower surface of young leaf which gradually turns brown and causes premature defoliation during June to September month at temperature regime between 20 and 30ºC with high humidity of ~80% (Takasahi, 1980, Zing *et al.,* 1988; Gangwar and Thangavelu, 1995). Foliage loss due this disease often goes up to 15% (Kore *et al.,* 1985). Besides, no resistant cultivar is presently available. Farmers are generally relying on repeated application of combination antibiotics as disease control measure. However, chemical control is costly and needs a safe period of ~7 days before feeding the leaves to silkworm. Nevertheless, host plant resistance is the most sustainable and cost-effective approach to disease control but, knowledge of interactions between host and pathogen will help to achieve accurate and successful resistance breeding strategy (Gabler *et al.,* 2003; Gelalcha, 2003).

Moreover, the constitutive defense mechanisms which include morphological and anatomical features have strong correlation with disease resistance (Karadimtcheva 1981; Eibach 1994). Anatomical features of mulberry associated with foliar diseases as reported earlier are the leaf thickness (Philip *et al.,* 1991; Philip and Govindaiah, 1996), thickness

of parenchymatous leaf tissues (Vijaykumar, 1991) and of cuticle (Gupta *et al.,* 2005). Besides, Govindaiah and Sharma (1993) and Gupta *et al.,* (1995) reported that bacterial pathogen invades mulberry leaves through stomata. However, elucidation of the association between morpho-anatomical traits and resistance to Xanthomonas campestris pv. mori is still obscure. Similarly, attempts had been made to establish phyllogenetic relationship among mulberry genotypes based on important agronomic traits (Tikadar and Roy, 2002), but clustering of mulberry genotypes based on morpho-anatomical characters bearing strong correlation with disease resistance is hitherto unexplored. In the present study 20 mulberry genotypes were evaluated for BLS disease responsiveness and morpho-anatomical traits in order to establish a correlation of foliar defense mechanism with BLS resistance, and clustering of those genotypes based on in planta traits for utilization of resistant source(s) in mulberry improvement programme.

MATERIALS AND METHODS

Plant material

Twenty mulberry genotypes were evaluated at Central Sericultural Research and Training Institute, Berhampore, West Bengal (latitude: 24º 6'N; longitude : 88º 15'E; altitude : 19m above MSL and annual rain fall: ~1200mm). The plantation was established in augmented randomized block design (8.4 m. rows 0.6m. apart). For maintenance of plantation, decomposed FYM was applied @20mt /ha/year in 5 split doses. Nitrogen, phosphorus and potash were applied @336:180:112 at five split doses 20-25 days after ground pruning under recommended five crop schedule.

Visual disease scoring for BLS resistance was conducted 4 times at an interval of 7 days for 20 genotypes between 48-55 days after pruning using a 0-10 point scale of Horsefall and Cowllings (1978). Genotypes with a 1-2 disease score were designated as highly resistant and resistant, and score 3 as moderately resistant, score 4.5 as intermediate response and score ≥4.5 were categorised as susceptible. Three branches per plant for three plants of each genotype were rated for disease evaluation, and final disease scores were used for qualitative assessment. Disease incidence (DI) was calculated using the formula: DI= (%) (no. of infected leaves on the branch)/(total no. of leaves on the branch) x 100 (Gangawade and Patil, 2003). Disease Severity Index (DSI) was calculated according to Kim et al. (1999) using the following formula:

$$DSI = \frac{\sum (\text{Rating for each plant})}{(10 \times \text{number of plants rated})} \times 100$$

For anatomical studies 5th, 6th and 7th leaves from 60-days old shoots of all the genotypes were collected at 9 am in a beaker containing water. Subsequently measurements on thickness parenchymatous tissue; epidermal cell layers and stomatal frequency were recorded according to Banerjee *et al.,* (2006). Thickness of leaf and cuticle was expressed in µm. Stomatal frequency (no) was determined by using πr^2. In all cases ten readings were taken per observed microscopic field with three replications.

Statistical analysis

The estimates of descriptive statistic for foliar anatomical features were calculated to determine if significant correlation existed between disease severity and anatomical traits of mulberry. Pearson's correlation co-efficient were designed by bivariate analysis. For multiple regression analysis and the relationship among 20 lines based on the anatomical traits was portrayed graphically in the form of Dendogram using Statistica AXA 9.1 software.

RESULTS AND DISCUSSION

The mean DSI of the twenty genotypes evaluated for BLS disease reaction along with genetic background are shown in Table1. The DSI value ranges from 1.0 to 36.7 among the genotypes. Three genotypes were found highly resistant (1.0 to 3.0), four were resistant (>3-6.0) and three moderately resistant (>6-12.0), while five genotypes each exhibited intermediate responsive (>12-18.0) and susceptibility (>18.0) against the disease. Besides, significant variability was recorded among the tested genotypes for disease reaction. High broad sense heritability (>0.9) indicated the additive nature of BLS resistance. Our earlier study (Banerjee *et al.,* 2007) reported high broad sense heritability for the disease resistance. The observation regarding disease severity phenotypes is also similar with the findings of our earlier works (Banerjee *et al.,* 2009).

Significant variability among the genotypes were observed for the thickness of epidermal cell layer, parenchymatous tissue and stomatal frequency (Table3).The mean thickness of upper epidermal cell layers ranged from 9.3 to17.6 µm respectively. Miuraso (17.6) exhibited maximum upper epidermis thickness, followed by *M. rotundiloba* (16.4) and China white (15.4) in order. The mean lower epidermis thickness ranged from 4.2 to 14.4µm respectively. Besides, thickness of the palisade tissue was recorded maximum in *M. rotundiloba* (39.4 µm) and minimum in C-2016 (24.7 µm). Stomatal frequency was found maximum in S-1(48.3 mm2).

Moreover, thickness of cell layers in epidermis and parrenchymatous tissue was negatively correlated with the disease severity index to *Xanthomonas campestris* pv. *mori* infection (Table 4). While highly significant positive association was recorded between stomatal frequency and

Table1: Genetic background and mean resistance to bacterial leaf spot infection (DSI) of 20 mulberry genotypes

Genotype	Genetic background (*Morus*)	Accession No.	Origin	DSI	Disease reaction
Thailand lobed	*M. alba* L	IC - 493852	THI/Collection	1.0	HR
S - 799	*M.* spp	IC - 313891	WBL/Selection	2.8	HR
M. rotundiloba	*M. multicaulis*	EC - 493973	BUR/Collection	2.8	HR
Kokuso-13	*M. latifolia poir*	EC - 493778	JPN/OPH Collection	3.6	R
Ms-8	*M. alba* L	IC - 313966	UPR/Selection	4.2	R
M. multicaulis	*M. multicaulis*	EC - 493895	IDA/ Collection	5.5	R
China white	*M. indica* L	EC - 493799	CHI/Collection	5.8	R
Miuraso	*M. bombysis*	-	PAR/Collectio n	6.7	MR
Kolitha-9	*M. alba* L	IC - 314091	KAR/Collection	7.1	MR
	M. indica L	IC - 313823	WBL/Clonal		
Bush Malda			Collection	9.2	MR
Shrim-5	*M. alba* L	EC - 493798	BGD/ Collection	12.6	IR
Bishnupur -9	*M. indica* L	IC - 313831	WBL/Collection	12.6	IR
Sultanpur	*M. indica* L	IC - 313734	WBL/Collection	15.2	IR
C- 2016	*M. indica* L	-	Improved strain	17.2	IR
	M. alba L	EC - 493822	BUR/ Clonal		
S-1			Collection	17.7	IR
Nagaland local	*M. indica* L	IC - 313961	NAG/ Collection	19.2	S
M. australis	*M. australis poir*	EC - 493885	AUS/ Collection	21.2	S
Mysore local	*M. indica* L	IC - 313697	KAR/OPH Selection	22.4	S
	M. alba L	IC - 313872	PUN/ Clonal		
Sujanpur			Collection	24.1	S
KPG-1	*M. indica* L	IC - 313766	WBL/Collection	36.7	S

DSI=disease severity index

Table 2: Analysis of variance and broad sense heritability estimates (h2) of bacterial leaf spot disease severity index of 20 mulberry genotypes

Source	df	SS	MS	F value	P value
Replication	2	0.43	0.21		
Variety	19	4897.66	257.77	120.42	<0.0001
h^2=0.92					

Table 3: Thickness of epidermal cell layers, parenchymatous tissue and stomatal frequency of 20 mulberry genotypes

Genotype	Thickness of epidermis(µm)[a]		Parenchymatous tissue (µm)		Stomatal frequency[c]
	Upper	Lower	Palisade	Spongy	
Sultanpur	13.2±5.9	8.3±2.4	25.7±4.9	37.0±8.7	39.6±6.0
KPG - 1	9.6±4.1	4.9±1.2	28.9±6.6	32.8±7.1	38.0±2.8
Bush Malda-B	10.8±3.1	6.9±1.0	32.3±3.8	36.0±3.5	26.6±4.4
*M. australi*s	8.6±1.3	4.7±0.8	38.2±3.1	42.4±3.1	36.3±2.5
Miuraso	17.6±2.3	4.2±1.2	35.0±4.2	40.2±3.7	21.0±5.9
Thailand lobed	9.3±2.5	6.4±1.7	33.1±2.6	38.0±5.3	12.0±3.6
Kokuso-13	10.3±2.5	8.8±1.7	33.3±4.8	37.7±3.9	15.3±4.2
China white	15.4±2.8	11.8±1.9	28.9±2.8	35.3±5.1	10.7±3.4
Kolitha - 9	14.7±2.2	6.6±2.0	32.1±5.1	37.0±5.1	24.0±4.4
Nagaland local	9.6±4.1	7.6±4.1	29.6±4.1	36.8±3.5	41.0±6.1
Mysore local	14.2±2.3	12.7±1.5	35.8±3.1	39.7±3.0	33.3±5.0
C - 2016	11.3±3.3	8.8±1.7	24.7±5.7	41.9±3.2	24.3±5.2
Sujanpur	10.5±2.6	7.8±1.5	31.1±3.3	35.5±4.9	39.3±5.8
MS - 8	11.8±1.9	11.8±1.9	37.5±2.3	39.9±2.3	16.3±4.0
Bishnupur - 9	12.3±3	11.8±2.5	33.6±3.8	37.7±3.7	31.0±5.0
S - 779	15.2±2.5	14.0±1.2	36.0±4.0	39.7±4.3	19.6±7.4
S1	9.3±1.9	8.8±1.7	30.4±4.5	33.1±4.5	48.3±6.5
M. rotundiloba	16.4±2.6	14.4±1.6	39.2±2.0	42.1±1.9	12.0±4.2
Shrim - 5	11.8±3.6	11.8±3.6	34.5±7.3	37.5±7.2	16.7±5.7
M. multicaulis	12.5±3.4	12.7±3.2	34.8±5.1	37.2±5.1	18.3±3.6
LSD	4.4	3.1	6.3	6.8	7.1

[a] Thickness (µm± SD), n=10; [b] Thickness (µm± SD), n=10; [c] stomata per 100 mm^2 ± SD, n=10

Table 4: Correlation of thickness of epidermal cell layers, parrnchymatous tissue and stomatal frequency with DSI of bacterial leaf spot

		Thickness of epidermal cell layers		Parenchymatous tissue		Stomatal frequency
		Upper	Lower	Spongy	Pallisade	
DSI[d]	PC[b]	-0.45	-0.39	-0.38	-0.35	0.79
	Sig[c]	<0.005	NS[a]	NS	NS	<0.001
Upper epidermal	PC		0.43	0.24	0.32	-0.45
layer thickness	Sig		<0.005	NS	NS	<0.005
Lower epidermal	PC			0.35	0.25	-0.41
layer thickness	Sig			NS	NS	NS
Spongy	PC				0.50	-0.39
parenchyma	Sig				<0.005	NS
Pallisade	PC					-0.38
parenchyma	Sig					NS

[a] NS, not significant

[b] Pearson correlation

[c] Significance 2 -tailed

[d] Disease severity index

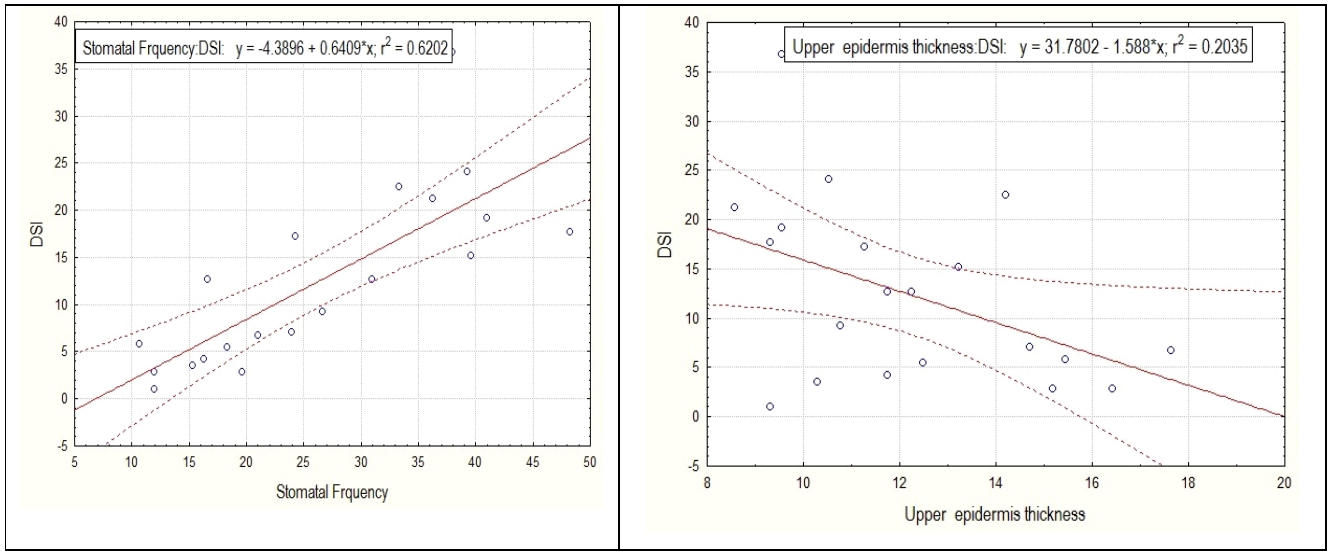


Fig1: Regression of different morpho-anatomical parameters and disease severity index to BLS. Dotted lines represent 95% confidence intervals on the prediction lines estimated from the data.

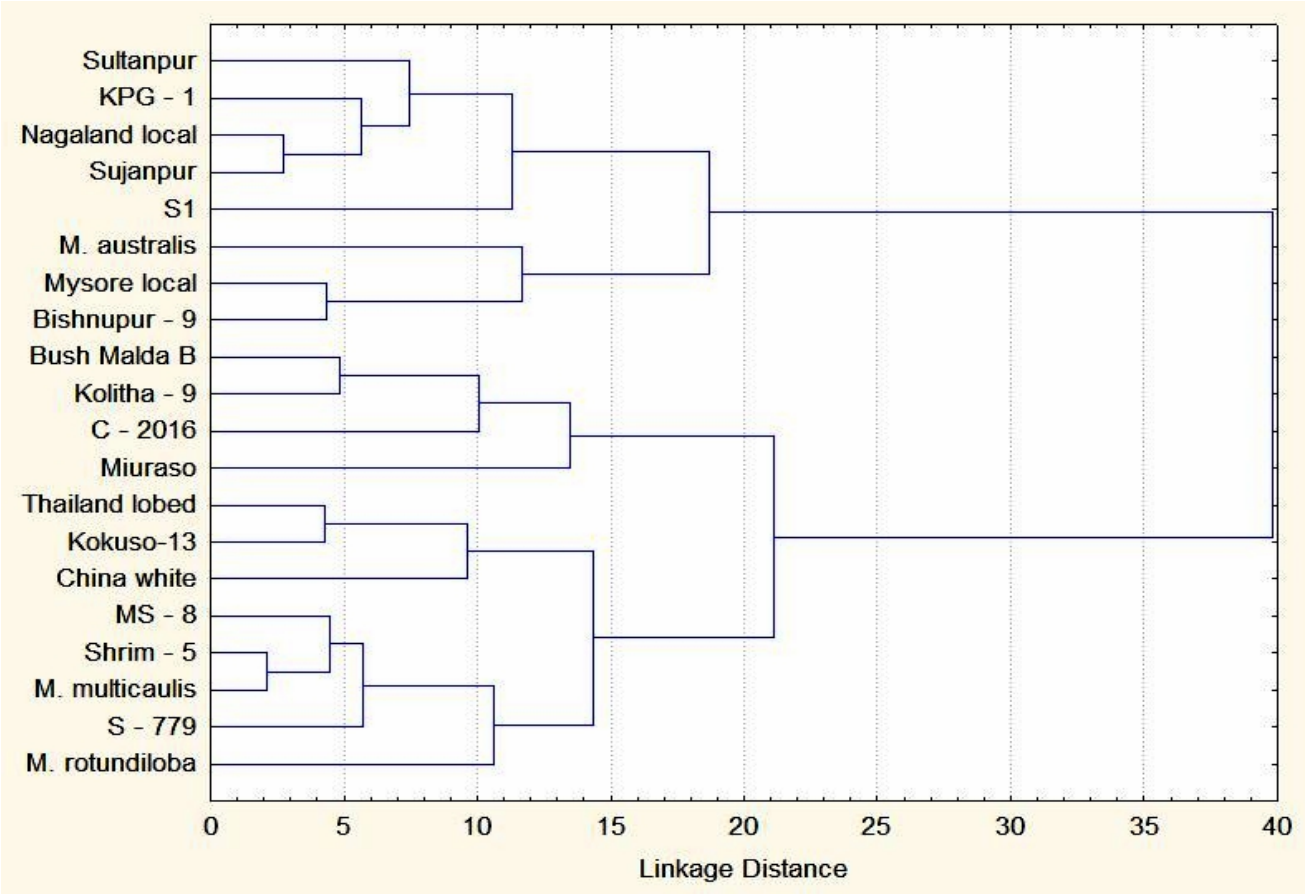


Fig. 2: A dendrogram generated by Statistica AXA 9.1 for 20 genotypes based on morpho-anatomical traits

DSI value, whereas other anatomical features were negatively correlated with stomatal frequency. The spongy and palisade parenchymatous tissue, and, thickness of upper and lower epidermal cell layers were significantly correlated among themselves.

Regression analysis showed a significant negative relationship of DSI with upper epidermal cell layers (R^2=0.203, P<0.05) and positive relationship with stomatal frequency (R^2=0.620, P<0.01) (Fig1). The relationship between stomatal frequency and DSI was the principal explanatory variable in estimating the resistance trait, and no significant resistance predictability was possible by adding a second explanatory variable. The multiple regression models incorporating the aforementioned significantly correlated features did not improve the coefficient of determination significantly (=R^2 value). The relationship between DSI and stomatal frequency, thickness of epidermal cell layers and parenchymatous tissue may be the plausible explanatory variables in resistance prediction.

Evidences for defense mechanisms against BLS infection has been previously described and assessed (Gupta *et al.,* 2005; Sharma *et al.,* 2005). The study revealed that susceptibility to BLS infection increased with decreasing epidermal thickness. This finding corroborates those of Philip and Govindaiah (1996) and Vijaykumar (1991). Moreover it was observed that spongy and palisade parenchyma cell layers were negatively correlated with BLS disease severity. The result is supported by the findings of Philip *et al.,* (1991).

A number of attributes of mulberry may be involved in protection from bacterial attack (Gupta *et al.,* 1995; Ravikumar *et al.,* 2004). We found that very susceptible genotypes mostly had more stomatal frequency, less thickness of epidermal cell layers and parenchymatous tissue. While the elite genotypes namely, S-1 and C-2016 exhibited intermediate response towards BLS disease severity and morpho-anatomical traits respectively. Similarly the identified resistant genotypes had higher stomatal frequency, thickness of epidermal cell layers and parenchymatous tissue. Besides, the dendrogram using complete linkage distance showed that the accession M. rotundiloba most diverse genotype among the tested lines. The eight strains namely, Thailand lobed. Kokuso-13, MS-8,

Shrim-5, S-799, *M. multicaulis,* China white and *M. rotundiloba* was genetically diverse for the component traits and could be useful genetic resources. The genetic affinity or similarity between the genotypes in the present study is due to the application of directional selection pressure for realizing high resistance to BLS. The genotypes *M.rotundiloba,* China white, M. multicaulis and S-799 with resistant response along with high significant superiority for most of the ancillary traits may be utilized for disease resistance breeding programme in mulberry.

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EFFICACY OF DIFFERENT INSECTICIDES AGAINST SUCKING PESTS OF MULBERRY AND THEIR SAFETY TO SILKWORM

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ABSTRACT

Quality food is required for healthy rearing of silkworm and quality production of silk. Many pesticides are used for control of pest and diseases of mulberry. Since these pesticides may cause hazard to silkworm, it is essential to know the safety period of these pesticides before feeding to the silkworm. In this view, seven insecticides used against major sucking pests of the area *viz.,* whitefly (*Bemisia tabaci*) and thrips (*Scirtothrips dorsalis*) were tested during 2003, 2004, 2005 and 2006 in a randomized block design with three replications. The mulberry leaves sprayed with insecticides were fed to silkworm at 3, 7 and 14 days after spraying. Imidachloprid 0.005% showed 88.68% reduction of thrips which was at par with Acetamaprid 0.0004% (82.30 %) and Fenobucarb 0.1% (79.45 %). In case of whitefly Imidachloprid 0.005% was significantly superior over rest with 88.72% reduction. However, successful cocoon formation was found in treatment DDVP 0.05% 14 days after spraying, which showed 90.88% cocoon formation. Thus, DDVP 0.05% is better for control of sucking pests as well as successful silkworm rearing which was found safe for silkworm rearing 14 days after spray.

Key words: Mulberry, Pesticides, Safe period, Silkworm, Sucking pests

INTRODUCTION

For quality and quantity production of silk, healthy rearing of silkworm with quality food is required. Many pesticides are used for control of diseases and pests of mulberry. These pesticides may be hazardous to silkworm. Therefore, it is essential to know safety period of these pesticides. In this view, few new insecticides which are used against major sucking pests of mulberry such as whitefly (Bemisia tabaci) and thrips, (Scirtothrips dorsalis) were tested.

MATERIALS AND METHODS

The experiment was conducted during 2003, 2004, 2005 and 2006 in a randomized block design with seven insecticides such as Profenophos (0.005%) Acetamaprid (0.0004%) Fenobucarb (0.1%), Imidachloprid (0.005%), Buprofenzin (0.025%), Ethofenprox (0.015%) and DDVP (0.05%) along with untreated control and replicated thrice. The mulberry leaves sprayed with insecticides were fed to silkworm at 3, 7 and 14 days after spraying for determining the safety period. In the laboratory, silkworm rearing was done following the standard procedures (Dandin et al., 2003). The data on percent reduction of sucking pests and percent successful cocoon formation under different treatments were recorded. The data collected were statistically analyzed (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

The data (Table 1) showed treatment Imidachloprid 0.005% which recorded 88.68% performed best for control of thrips population followed by Acetamaprid- 0.0004% (82.30 %) and fenobucarb 0.1 % (79.45 %) . There was no statistically significant difference between these treatments for reduction of thrips. In case of whitefly incidence, treatment with Imidachloprid 0.005% was found significantly superior over rest of the treatments recording 88.72 per cent reduction. However, treatment with Fenobucarb 0.1% (80.37 %), Ethofenprox 0.015% (78.34 %), Acetamaprid 0.0004% (77.69 %) and Profenophos 0.005% (76.13 %) were found statistically at par. There was no significant interaction between treatment and year indicating consistent performance of treatments over years.

As far as successful cocoon formation is concerned (Table 2), treatment with DDVP 0.05% recorded 90.88%

cocoon formation at 14 days after treatment and it was statistically at par with untreated control. The interaction between treatment and year was found to be non-significant, indicating consistent performance of treatments over years.

Misra *et al.* (2003) reported that some insecticides like Dimethoate, Quinalphos and methyl Parathion are effective against thrips. The insecticides sprayed mulberry leaves did not show any adverse effect on the rearing of silkworms. Feeding silkworms with mulberry leaves harvested from plots sprayed with Dimethoate after safe waiting period showed significant improvement in respect of larval weight, cocoon weight and shell weight as compared to the infested control (Kariappa and Narasimhanna, 1978). According to Muthuswami et al, (2010) thrips became regular pest of mulberry in Tamil Nadu and other southern states especially during March to June. They suggested that Acetamiprid may be used for the suppression of thrips along with other chemicals like Thiomethoxam and Dichlorvos. Feeding of silkworm with the mulberry leaves treated with chemicals

Table 1 : Mean per cent reduction of major sucking insect pests of mulberry in south Gujarat

Treatments		Thrips				Pooled	Whitefly				Pooled
		2003	2004	2005	2006		2003	2004	2005	2006	
T_1	Profenophos-0.005%	63.35 (79.49)	64.21 (65.73)	58.19 (72.18)	55.28 (67.57)	60.26 (75.39)	61.46 (76.52)	60.80 (58.06)	59.78 (74.67)	61.05 (76.58)	60.77 (76.13)
T_2	Acetamaprid-0.0004%	64.61 (78.52)	68.28 (74.49)	66.51 (84.11)	61.09 (76.62)	65.12 (82.30)	61.48 (76.80)	61.51 (59.67)	61.39 (75.59)	62.84 (79.16)	61.81 (77.69)
T_3	Fenobucarb-0.1%	63.75 (79.94)	63.23 (63.54)	64.00 (80.79)	61.18 (76.76)	63.04 (79.45)	63.53 (79.41)	61.15 (58.86)	60.39 (75.59)	69.73 (88.00)	63.70 (80.37)
T_4	Imidachloprid-0.005%	67.30 (84.28)	70.02 (78.61)	72.31 (90.77)	71.72 (90.17)	70.34 (88.68)	66.64 (83.56)	74.41 (86.08)	68.29 (86.31)	72.16 (90.61)	70.38 (88.72)
T_5	Buprofenzin-0.025%	51.15 (60.18)	60.68 (57.79)	56.66 (68.09)	60.01 (75.01)	57.12 (70.52)	60.89 (75.28)	55.99 (47.22)	56.00 (68.74)	55.08 (67.22)	56.99 (70.31)
T_6	Ethofenprox-0.015%	59.45 (73.49)	65.76 (65.49)	59.37 (74.05)	58.47 (72.65)	60.76 (76.13)	64.73 (81.58)	59.39 (54.87)	60.75 (76.14)	64.25 (81.12)	62.28 (78.34)
T_7	DDVP- 0.05%	54.21 (65.45)	57.52 (50.64)	56.46 (69.46)	59.39 (74.07)	56.90 (70.19)	59.32 (73.67)	52.79 (40.23)	55.44 (67.81)	65.29 (82.52)	58.21 (72.25)
T_8	Control	7.68 (4.83)	7.52 (0.03)	0.72 (0.00)	6.82 (1.41)	5.69 (0.98)	4.84 (1.85)	5.87 (0.01)	0.98 (0.00)	7.26 (1.60)	4.74 (0.68)
S.Em. ± (T)		3.77	4.07	2.05	1.89	2.96	2.56	3.74	2.062	1.64	2.56
C.D. at 5% (T)		11.42	12.36	6.230	5.69	8.92	7.76	11.33	6.25	4.96	7.68
C.V. %		10.41	9.88	5.18	6.03	7.97	7.90	10.62	7.60	4.98	7.88
S.Em. ± (T x (p) Y)		3.25	3.24	1.62	1.75	2.84	2.55	3.31	2.32	1.54	2.43
C.D. at 5% (T x (p) Y)		(9.27)	(9.25)	(4.63)	(5..28)	NS	(7.66)	(9.45)	(6.62)	(4.63)	NS

Figures outside the parenthesis are arcsin transformed values; NS = Not-significant,
T = Treatment, (p) = period

Table 2: Cocoon formation under different treatments

Treatments		Cocoon formation (%)/ Feeding leaves days after spray			
		3 days	5 days	7 days	14 days
T_1	Profenophos- 0.005%	0.91 (0.00)	0.91 (0.00)	7.42 (1.67)	44.50 (49.12)
T_2	Acetamaprid- 0.0004%	0.91 (0.00)	0.91 (0.00)	5.29 (0.85)	44.02 (48.29)
T_3	Fenobucarb- 0.1%	0.91 (0.00)	0.91 (0.00)	5.29 (0.85)	41.46 (43.82)
T_4	Imidachloprid- 0.005%	0.91 (0.00)	0.91 (0.00)	2.37 (0.17)	38.00 (37.90)
T_5	Buprofenzin- 0.025%	0.91 (0.00)	0.91 (0.00)	13.26 (5.25)	43.47 (47.33)
T_6	Ethofenprox- 0.015%	0.91 (0.00)	0.91 (0.00)	11.80 (4.18)	47.43 (54.22)
T_7	DDVP- 0.05%	0.91 (0.00)	47.41 (0.00)	64.01 (80.80)	72.42 (90.88)
T_8	Control	73.10 (91.55)	74.56 (92.91)	71.64 (90.08)	73.78 (92.20)
S.Em. ± (T)		1.21	1.10	2.08	1.70
C.D. at 5% (T)		3.57	3.11	5.87	4.80
C.V. %		21.54	20.11	31.69	11.06
S.Em. ± (T x Y)		1.24	1.85	4.14	3.23
C.D. at 5% (T x Y)		3.75	NS	NS	NS

Figures outside the parenthesis are arcsin transformed values NS = Non-significant,

about 30 days after spray showed marked improvement in larval weight and cocoon parameters compared with feeding the larvae with thrips infested leaves. The present findings are in confirmation with the previous reports.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 97-101

INCIDENCE OF PAPAYA MEALYBUG, *PARACOCCUS MARGINATUS* ON MULBERRY IN CHAMARAJANAGAR DISTRICT

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ABSTRACT

Papaya mealy bug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae) is native to Mexico is a significant pest of tropical and subtropical fruits, vegetables and ornamental plants. In India, it was first reported from Coimbatore, Tamil Nadu during July, 2008 infesting papaya. It has also made its appearance in Kerala during July 2009 infesting mulberry, Jatropha, Lantana, Eupetorium and Parthenium. In Karnataka, the occurrence was found during the first week of June 2010, while conducting a routine survey for insect pests in mulberry gardens in Chamarajanagar Taluk. Among 20 mulberry gardens surveyed, *P. marginatus* was observed in 8 mulberry gardens in six villages initially and then it spread to remaining 12 gardens within next few days. The incidence and intensity ranged from 5 to 100% and 50 to 100% respectively. Regular survey was continued on fortnightly basis in the mulberry gardens of these villages and recorded the incidence and intensity. The pest was also found infesting papaya, bhendi, brinjal, Hibiscus, Jatropha, Parthenium and Abutilon. Few native natural enemies were also recorded during the survey, which are probably playing major role in keeping the population in check. The pest could effectively controlled through biological control with inoculative release of *Acerophagus papayae*, a host specific exotic parasitoid.

Key words: *Acerophagus papayae*, Classical biological control, Mulberry, Papaya mealybug, *Paracoccus marginatus*

INTRODUCTION

Papaya mealy bug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae) is native to Mexico and is a significant pest of tropical and subtropical fruits, vegetables and ornamental plants (Miller and Miller, 2002). In India, it was first reported from Coimbatore, Tamil Nadu during July, 2008 infesting papaya in Tamil Nadu Agriculture University campus (Muniappan *et al*., 2008). It made its appearance in Kerala during July 2009 infesting mulberry, *Jatropha*, *Lantana*, *Eupetorium* and *Parthenium* (Krishnakumar and Rajan, 2009).

A survey conducted during July 2010 in the mulberry gardens of few villages in Chamarajanagar district revealed that papaya mealybug has succeeded in making its entry into Karnataka through neighboring Talawadi in Tamil Nadu (Shekhar *et al.,* 2011). Later, regular fortnightly survey was conducted and recorded incidence, intensity, alternate host plants, non-host plants and indigenous natural enemies.

MATERIALS AND METHODS

Survey of mulberry gardens for incidence of papaya mealybug and occurrence of its natural enemies

Mulberry gardens in five villages of Chamarajanagar district bordering Tamil Nadu such as Yediyur, Aanahalli, K.bMookahalli, Siddayyanapura and Dollipura were surveyed fortnightly and recorded incidence of papaya mealy bug and occurrence of its natural enemies. Alternate host plants as well as non-host plants present in the vicinity of mulberry gardens were also recorded. The incidence and intensity were calculated as follows

$$\text{Incidence (\%)} = \frac{\text{No. of plants affected}}{\text{Total no. of plants observed}} \times 100$$

Similarly, per cent intensity was also calculated based on the following formula:

$$\text{Intensity (\%)} = \frac{\text{No. of branches affected ininfested plant}}{\text{Total no. of branches present}} \times 100$$

Observation and collection of natural enemies

Few species of native natural enemies feeding on papaya mealybug were observed and recorded. The parasitized as well as mummified papaya mealybugs were collected in vials and observed for emergence of parasitoids.

Observation on alternate host plants

During the survey, several plant species (crops and weeds) serving as alternate host plants and few non-host plants were recorded.

Classical biological control

Since *P. marginatus* is an exotic pest, keeping in view of tremendous performance of host specific nymphal parasitoids such as *Acerophagus papayae, Anagyrus loecki* and *Pseudleptomastix mexicana* for control of the pest in countries like Palau, Guam, Sri lanka and Hawaii islands within a short span of 6 months (Muniappan *et al.,* 2006).Therefore, above three exotic parasitoids were imported by National Bureau of Agriculturally Important Insects (NBAII), Bangalore during July 2010 and developed a protocol for the multiplication of the same on potato sprouts (Shylesha *et al.,* 2010; Narendra Kumar *et al.,* 2011, Shylesha *et al.,* 20110).

Subsequently, along with NBAII, Bangalore and Tamil Nadu Agricultural University (TNAU), Coimbatore, the CSRTI, Mysore also established mass production units for implementing classical biological control of the pest (3 units in Tamil Nadu and 2 units in Karnataka) through maintenance, production and supply of A. papayae to the sericulturists for inoculative release at free of cost. In Karnataka, CSRTI, Mysore and RSRS, Chamarajanagar started the production of *A. papayae* in large scale for field release. Accordingly, more than 9,000 parasitoids were multiplied and released by sericulturists through extension units of Department of Sericulture in Chamarajanagar district.

RESULTS AND DISCUSSION

Infestation and Incidence of papaya mealybug in Chamarajanagar District

Heavy infestation was noticed on the dorsal surface along the veins and the midribs of older leaves and all areas of the tender leaves. Severely affected older leaves turned yellow and dried up. Tender leaves became crinkled, terminal shoots got bunched and distorted. Heavy mealybug populations produced a large volume of honey dew on which sooty mould growth was observed. Unlike pink mealybug, the exotic pest also attacked the sprouted buds in the pruned stumps.

Shekhar and Qadri (2009) reported that the affected leaves turn yellow and the plant growth retards. In addition to sucking of plant sap, they also inject toxic saliva into the plant system, which causes deformation of plant parts. Due to profuse honeydew secretion, certain species of ants develop symbiotic association with mealybugs only to feed on honeydew. The deposition of the honeydew on the plant also attracts development of black sooty mould. Thus, the nature of damage and symptoms of attack by papaya mealybug on mulberry are rather distinct from those caused by the pink mealybug, *Maconellicoccus hirsutus*, which infests only the apical portion of the mulberry and doesn't cause death of the plants.

The survey results revealed that the incidence started initially with a range of 5 to 70% (Average 65.71%) during June 2010 and gradually increased to 100%. Whereas in Tamil Nadu, due to severe attack of the papaya mealybug, brushing of silkworm layings has been found to have reduced drastically. As a result, the farmers could not brush the expected quantity of layings (Mahalingam *et al.,* 2010; Qadri *et al.,* 2010). However, in Chamarajanagar district, the incidence was declined to a minimum of 18.36% during December 2010 (Table 1), which may be due to release of exotic parasitoid, *Acerophagus papayae* during the month of November 2010.

Natural enemies

With respect to native natural enemies, one lepidopteran, one Chrysopid, two species of hymenopterans and three species of coccinellids were observed feeding on papaya mealybug (Table 2). Similarly, other survey works also have recorded the same indigenous native natural enemies under field condition. But they are not so effective in managing the huge populations of papaya mealybug as they have wider host range. Among the predators, *Spalgis epius* is seen devouring all the stages of the papaya mealybug, but their mass production is quite difficult under laboratory condition (Thangamalar *et al.,* 2010).

Alternate host plants and non-host plants

In India, *P. marginatus* has been reported to infest more than 60 genera of host plants, including field crops, fruit trees, ornamentals, weed and scrub vegetation. It favours plants with heavy latex in families such as Malvaceae, Solanaceae and Moraceae (Rabindra and Shylesha, 2011). However, in Chamarajanagare district also, the alternate host

plants included important crops like papaya (*Carica papaya*), guava (*Psidium guajava*), Jatropha, Hibiscus, cotton, brinjal, redgram, tomato, bhendi, cherry, pomegranate, cowpea, horse gram and beans. Many weed hosts such as congress grass (*Parthenium hysterophorus*), country mallow (*Abutilon indicum*), Hazardani (*Phyllanthus niruri*), chandvel (*Convolvulus arvensis*), garden sprug (*Euphorbia hirta*), wild mustard (*Cleome viscosa*), spider wort (*Commelina bengalensis*) and touch-me-not (*Mimosa pudica*), which were also observed to support the development and spread of papaya mealybug (Table 3). In addition, few non host plants of papaya mealybug were also recorded in the district (Table 4).

Biological control

Classical biological control is the introduction of co evolved natural enemies to a new locale where the insect pest has become invasive. It becomes imminent when an insect pest is accidentally introduced into a new geographical area without its associated natural enemies. A total of 9,000 adults of *Acerophagus papayae* were released (from Nov'10 to Jan"11) in papaya mealybug infested mulberry gardens of 21 farmers covering about 50 acres mulberry in Chamarajanagar district. Within 4 months of release of the parasitoids, 80-90% suppression in papaya mealybug infestation was recorded. During early part of 2003, in Republic of Palau, *A. papayae, P. mexicana* and *A. loecki* totalling 24,586 were imported and released. Among these, *A. loecki* and *A. papayae* were found to be promising whereas P. mexicana didn't do so as it failed to establish based on field recovery. Following the introduction of these exotic parasitoids, the populations of papaya mealybug could be brought down tremendously in a period of six months (Muniappan *et al.,* 2006). Again during the same year *ie.* 2003, same above parasitoids were introduced into Florida and their efficiency for establishment were measured after 3 years. Surprisingly, there was no recovery of *P. mexicana* whereas the other two parasitoids were found to be multiplying. However, *A. papayae* was found very well established in the field and more efficient in controlling *P. marginatus* than *A. loecki* (Amarasekare *et al.,* 2009; Shylesha *et al.,* 2011).

Timely monitoring of papaya mealybug incidence on mulbery gardens and other crops in Chamarajanagar district served as a base for inoculative release of exotic parasitoids in the area. Further, the exotic parasitoid, *A. papayae* was able to establish and colonize in the area successfully. Though the outcome of classical biological control has given rich dividends and the papaya mealybug infestation has reduced to minimal levels enabling the sericulturists to take up brushings to the extent of 80-90%, and also reversed the tendency of farmers to uproot the mulberry plantation and resulted into revival of the sericultural activities in severely affected areas, yet there is an urgent need to develop a total biological control package for the major pests of mulberry. The success of classical biological control using *A. papayae* has emerged as an excellent model reviving the sericulture to normalcy in Tamil Nadu and Karnataka states.

Table 1: Monthwise incidence of papaya mealybug in mulberry

Month	Incidence (%)	Intensity (%)	Temperature		Rainfall (mm)
			Min	Max	
June'10	65.71	82.86	21.00	31.00	81.2
July	57.50	56.67	20.00	30.00	64.9
Aug	40.86	40.31	20.10	30.44	96.5
Sep	60.64	51.24	19.47	30.32	122.4
Oct	42.62	47.44	18.93	30.07	130.8
Nov*	24.00	45.09	18.71	28.75	219.8
Dec	18.36	13.75	14.98	28.32	14.4

* Release of exotic parasitoid, *Acerophagus papayae* in the area

Table 2. Natural enemies associated with papaya mealybug

Order	Family	Name
Hymenoptera	Encyrtidae	*Leptomasytix sp.*
		Anagyrus sp.
Lepidoptera	Lycaenidae	*Spalgis epius*
Coleoptera	Coccinellidae	*Cryptolaemus montrouzieri*
		Scymnus coccivora
		Chilocous nigritus
		Naphus sp (?)
Neuroptera	Chrysopidae	*Mallada bonninensis*

Table 3. Important alternate host plants of papaya mealybug in Chamarajanagar district

Sl No	Common name	Important alternate Host plants
1	Papaya	*Carica papaya*
2	Guava	*Psidium guajava*
3	Bhendi	*Abelmoschus esculentus*
4	Brinjal	*Solanum melongena*
5	Tomato	*Solanum lycopersicum*
6	Cowpea	*Vigna ungiculata*
7	Red gram	*Cajanus cajan*
8	Horse gram	*Macrotyloma uniflorum*
9	Tapioca	*Manihot esculenta*
10	Hibiscus	*Hibiscus rosa-sinensis*
11	Kanagile	*Plumeria alba*
12	Red hot cat's tail	*Acalypha hispida*
13	Indian copper leaf	*Acalypha indica*
14	Jatropha	*Jatropha curcus*
15	Touch me not	*Mimosa pudica*
16	Jack	*Artocarpus heterophyllus*
17	Custard apple	*Annona squamosa*
18	Parthenium	*Parthenium hysterophorus*
19	Abutilon	*Abutilon indicum*
20	Lantana	*Lantana camera*
21	Beli Kalli (in Local language)	Beli kalli
22	Ekka	*Calotropis gigantia*
23	Eupetorium	*Eupatorium* sp.
24	Cassia	*Cassia sericea*
25	Sida	*Sida acuta*
26	Teak	*Tectona grandis*
27	Cherry	
28	Bauhinia	*Bauhinia purpurea*

Table 4. Important Non-host plants of papaya mealybug in Chamarajanagar district

Sl No	Common Names	Scientific Names
1	Maize	*Zea mays*
2	Jowar	*Sorghum bicolor*
3	Coriander	*Coriander sativum*
4	Coconut	*Cocos nucifera*
5	Neem	*Azaradirachta indica*
6	Indian lilac	*Melia azadirachta*
7	Adathoda	*Adathoda vasica*
8	Ailanthus	*Ailanthus excelsa*

ACKNOWLEDGEMENTS

The authors acknowledge the timely efforts made by the Director, NBAII, Bangalore in importing the exotic parasitoids. Thanks are also due to Director, CSRTI, Mysore, Scientist D and staff, RSRS, Chamarajanagar and counterparts of DOS for extending co-operation in conducting survey work as well as in implementing classical biolgical control programme.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 102-109

INTEGRATED MANAGEMENT OF DISEASES AND PESTS OF MULBERRY IN ODISHA STATE

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ABSTRACT

Mulberry (*Morus* sp.) leaf being the only food of silkworm *Bombyx mori* L. plays a vital role in sericulture as it alone is responsible for 38.20 % and one of the main factors for successful harvest of cocoon crop. Due to its evergreen & perennial nature and luxuriant foliage through out the year, mulberry is prone to different diseases caused by fungi, bacteria, virus, mycoplasma; and pests & non-insect pests of about 30 species. The quantity and quality of mulberry leaf is often hampered by the infestation of variety of pathogens, parasites, insects and non-insect pests. The annual leaf yield loss due to major diseases was estimated to be 20-30 % in India. Mulberry sericulture in Odisha State is mostly practiced in higher elevations up to 1000 meters above MSL The major mulberry diseases found in Odisha State are of Powdery Mildew caused by *Phyllactinia corylea* (Pers.) Karst, Leaf Spot caused by *Cercospora moricola* Cooke, Leaf Rust caused by *Peridiospora mori* Prasad, Leaf Blight (fungal) *Fusarium pallidoroseum* (Cooke) Sacc. and nursery diseases like collar rot, Die back, Stem canker and cutting rot. And, the major mulberry pests are Thrips (*Pseudodendrothrips mori*), Mealy bug (*Maconellicoccus hirsutus* Green), White fly (*Dialeuropora decempuncta* Quain. & Backer), Wingless Grass Hopper (*Neorthacris acuticeps* var. *nilgiriensis*), Termite (*Odontotermis obesus)* and Bihar hairy caterpillar (*Spilosoma obliqua)*. Distribution of pathogens, pests and non-insect pests; and disease severity & susceptibility varies from region to region. In the management single management may be successful for short term, loses its effectiveness in time because disease and pest can adjust to the tactic to overcome. So, integrated practice often result better environmental conservation due to reduction in frequency of fungicide or pesticide application. A study was conducted on the incidence of major foliar diseases and pests of mulberry during 2005 – 2010. Most of these diseases and pests are season specific. Biotic and abiotic factors play an important role in disease and pest infestation. It is rather difficult to establish a direct cause and effect relationship between any single climatic factors and disease & pest activity, because the effect of weather elements on disease & pest is confounded. However, temperature, relative humidity, rainfall, sunshine and wind speed are the important parameters that largely affect the activity of a particular disease and species of insect.

Key Words: Integrated management, Mulbery sericulture, Odisha state, Diseases and pests

INTRODUCTION

Mulberry (*Morus* sp.) leaf being the only food of silkworm *Bombyx mori* L. plays a vital role in sericulture as it alone responsible for 38.20 % and one of the main factors for successful harvest of cocoon crop. Due to its evergreen & perennial nature and luxuriant foliage through out the year, mulberry is prone to different diseases caused by fungi, bacteria, virus, mycoplasma; and pests & non-insect pests of about 30 species (Reddy, 1988). Thus, the quantity and quality of mulberry leaf is often hampered by the infestation of variety of pathogens, parasites, insects and non-insect pests. The annual leaf yield loss due to major diseases was estimated to be 20-30 % in India (Philip *et al*., 1994). Feeding of infected leaves to silkworm prolong larval period, reduces

larval weight & cocoon yield and silk quality ultimately resulting economic loss to the farmers (Quadri *et al*., 1999).

Odisha state situated in between 17^0 31' to 20^0 31' North Latitude and 81^0 31' to 87^0 30' East Longitude on the eastern coast of India with 482 km of coast line enjoys a tropical monsoonic climate with average annual rainfall of 1658.7 mm in 40.5 to 84.7 numbers of rainy days, normal rainfall of 1482.2 mm / annum and relative humidity of 75% in plains and of 60 % in inland region. The mean annual temperature of the state is influenced by its altitude, latitude and proximity to the sea and varies from 30^0 C to 40^0 C. Considering the congenial agro-climatic conditions, mulberry sericulture is mostly practiced in ten districts (*viz.,* Deogarh, Gajapati, Kalahandi, Kandhamal, Keonjhar, Koraput, Khurda, Mayurbhanj, Nayagarh, Rayagada) with higher elevations up to 1000 meters above MSL The major mulberry diseases found in Odisha State are of Powdery Mildew caused by *Phyllactinia corylea* (Pers.) Karst, Leaf Spot caused by *Cercospora moricola* Cooke, Leaf Rust caused by *Peridiospora mori* Prasad, Leaf Blight (fungal) *Fusarium pallidoroseum* (Cooke) Sacc. and nursery diseases like collar rot, Die back, Stem canker and cutting rot. And, the major mulberry pests are Thrips (*Pseudodendrothrips mori*), Mealy bug (*Maconellicoccus hirsutus* Green), White fly (*Dialeuropora decempuncta* Quain. & Backer), Wingless Grass Hopper (*Neorthacris acuticeps* var. *nilgiriensis*), Termite (*Odontotermis obesus)* and Bihar hairy caterpillar (*Spilosoma obliqua)*. Distribution of pathogens, pests and non-insect pests; and disease severity varies from region to region. Disease susceptibility also varies with varieties (Maji, 2006) viz. leaf rust in S1635, powdery mildew in S1, myrothecium leaf spot in S1635 etc. In the management single management may be successful for short term, loses its effectiveness in time because disease and pest can adjust to the tactic to overcome. So, integrated practice often result better environmental conservation due to reduction in frequency of fungicide or pesticide application.

MATERIALS AND METHODS

The study was undertaken at Regional Sericultural Research Station farm at Koraput since 2005.

A) Foliar disease Assessment

The disease incidence data was recorded at weekly intervals at RSRS farm Koraput and at monthly intervals at farmers' fields of nine farmers belonging to three villages (three farmers' fields of each village) of Koraput district. The plot size / farmer was 20 cents to one acre with somewhat similar mulberry varieties / age / spacing / pruning / cultural operations etc. Foliar disease incidence was recorded from fixed five plants (three standard branches of each plant), 4 in 4 corners except border plants and 1 from centre. Counted the total numbers of healthy and diseased leaves in each branch and put in grade 0-5 scales on the basis of percent of leaf area infected as follows:

0 = healthy leaf,
1 = 1-5 % leaf area infected
2 = 6-10 % leaf area infected
3 = 11-25 % leaf area infected
4 = 26-50 % leaf area infected
5 = 51-100 % leaf area infected

Calculated Percent Incidence (PI) or Infection percentage and Percent Disease Index (PDI) by following formula:

B) Pest infestation assessment

$$\text{Percent Incidence (PI)} = \frac{\text{No of plants infested}}{\text{No. of plants selected}} \times 100$$

$$\text{Percent Disease Index (PDI)} = \frac{\text{Sum of all individual rating}}{\text{TLA x MG (}i.e.5\text{)}} \times 100$$

TLA- Total no of leaves assessed
MG- Maximum grade

At RSRS farm Koraput pest infestation data was collected at weekly intervals from three mulberry plots (area 100 sq mt) covering 10 plants from each plot.

- For Tukra and Mealy bug incidence: Assessed percentage of shoots damaged in ten plants. Collected five affected shoots per holding and counted nymphs, adults and egg masses of mealy bug.
- For Thrips population: Selected three shoots of each plant, counted number of thrips per leaf (from top 4, 5, 6 & 7 th leaf).
- For White fly population: Recorded adult population from top 2 leaves, early nymph population from middle 2 leaves and late nymphal population from bottom 2 leaves. The total of 3 strata (6 leaves) provided population / plant. Like-wise data was collected from 3 plants, and counted percent of infestation by counting the percent of leaves affected @ 3 shoots / plant.
- For Bihar Hairy Caterpillar: Counted total no. of egg masses & caterpillars in 3 shoots / plant.

The percent of infestation was calculated by counting number of plants infested (one shoot / plant), out of the total selected plants as per the formula:

$$\text{Percent Infestation} = \frac{\text{No. of plants infested}}{\text{Total no of plants selected}} \times 100$$

Monthly average infestation of different diseases and pests were calculated and co-related with the abiotic factors like total rainfall, maximum and minimum temperature and relative humidity. The data recorded over four years (2006-

2010) were poled and analyzed and seasonal variations of disease incidence in terms of PDI is presented in table 1 and pest infestation in terms of population % is presented in table2.

C) Meteorological data recording

Meteorological data viz. maximum and minimum temperature (^{0}C), maximum and minimum relative humidity (%), rainfall (days and mm / day), sunshine hours and wind velocity were recorded daily for the whole month (table-3).

D) Forms and formulations

For spraying of fungicides or insecticides it required 150-180 liters of solution / one acre and fungicide / pesticide / insecticide solutions were prepared by considering their respective forms and infestation as follows:

- A Fungicide / Nematicide / Insecticide inhibit the causative agent to multiply further.
- A Fungicidal / Nematicidal / Insecticidal kill the causative agent.
- Powder form: WP- Wettable Powder, SP - Soluble Powder and G - Granular
- Liquid form: EC - Emulsifiable Concentrate and WS - Suspensions or Solurries
- High Volume Spray (HLV) - 400 lt / ha – when infestation is more than 50 %

  Low Volume Spray (LV) - 250 to 400 lt / ha – when infestation is below 50 %

  Ultra Low Volume (ULV) - 5 lt / ha – for prophylactic measure only
- Preparation of solution : A = % of Toxicant, B = Volume required, C = % of toxicant available,

  D = Volume of commercial formulation required

  $D = \frac{A \times B}{C}$ (Example 0.2 % x 15 lt / 50 lt = 0.06 kg = 60 gm)

  $\frac{White}{Red}$ = More poison (safe period 15 days)

  $\frac{White}{Blue}$ = Moderately poisonous (safe period 5-7 days)

  $\frac{White}{Green}$ = Les poisonous (safe period 3 days)

- Avoidable leaf yield loss= $\frac{YP - YU}{YP \times YP - YU} \times 100$

  YP- Yield of protected plots
  YU- Yield of unprotected plots

  Nursery Disease % = $\frac{\text{No. of cuttings infected}}{\text{No. of cuttings planted}} \times 100$

Management of Diseases, Pests and Non-pest Insects

A) Foliar Diseases

i) Powdery mildew

- Causative agent - fungus *Phyllactinia corylea* (Pers.) Karst.
- Occurs during the months from August – December. More prevalent in hilly region during rainy and winter season and in plains during winter.
- Appears ash coloured powdery growth in small patches on lower surface of leaves with a slight chlorotic spots on the upper surface. These patches gradually enlarge and spread to entire lower surface of leaf. As the disease advances, affected leaves turn yellowish and defoliate prematurely.
- Predisposing factors: Susceptible variety, irregular pruning, diurnal temperature 23-28 ^{0}C, relative humidity 65-80 % and excessive nitrogen application.
- Leaf yield loss accounts to about 15-20 % with significant reduction in protein and moisture content in infected leaves.
- Chemical control measures - Spray 0.2 % Carbendazim 50 % WP (Bavistin) i.e. 4 gm in one liter of water OR 0.2 % wettable Sulphur 80 WP (Sulfex) i.e. 2.5 gm in one liter of water twice at an interval of 15 days.
- Biological control measure - Foliar spray of *Bacillus* sp. - a phylloplane bacterial strain which reduce 48 % disease severity.
- Other management practices - Avoid dense plantation, cut / remove trees inside field that block sunlight and prune all adjacent plots simultaneously.
- Leaves can be fed to silkworms 15 days after spraying.
- Benefit Cost ratio is 15 : 1

ii) Leaf Spot (Brown)

- Causative agent - fungus *Cercospora moricola* Cooke
- Occurs during the months of rainy season and continues up to December.
- Appears minor circular light brown necrotic spots on leaves and adjacent spots later unite to form a larger spot. Necrotic tissues of such spots drop out and form the characteristic 'shot holes'. Highly infected leaves defoliate prematurely,
- Predisposing factors - Susceptible variety, frequent rainfall, diurnal temperature 20-25^0 C, and relative humidity 80-90 %.

- Leaf yield loss accounts to about 15-20 % with reduction in nutritive value of leaves.
- Chemical control measure - Foliar spray of 0.2 % Carbendazim 50 % WP (Bavistin) i.e. 4 gm in one liter of water twice at an interval of 15 days.
- Other management practices - Avoid dense planting and collect & burn diseased leaves.
- Leaves can be fed to silkworms 7 days after spraying.

iii) Leaf Rust

- Causative agent - fungus *Peridiospora mori* (Barclay) Prasad *et al*.
- Appears during August and continued up to March
- Appears hyaline tiny spots on lower surface of leaves, which later turns red to brown colour. Reddish brown spots appear concomitantly on upper surface of leaves. Severely infected leaves turn yellowish and margin of leaves become dry.
- Leaf yield loss accounts to 5 -10 %.
- Predisposing factors: Susceptible variety, irregular pruning, diurnal temperature of 23-28 ^{0}C and relative humidity of 60 – 80 %.
- Chemical control measures - Foliar spray of 0.2 % Copper oxy-chloride 50% WP (Blitox) i.e. 4 gm in one liter of water OR 0.2 % Tridiamefon 25 % WP (Bayleton) i.e. 8 gm in 10 liter of water OR 0.2 % Chlorothalonil 75 % WP (Kavach) i.e. 2 gm in one liter of water twice at an interval of 15 days.
- Leaves can be fed to silkworms 15 days after spraying.

iv) Leaf Blight

- Causative agent - fungus *Fusarium pallidoroseum* (Cooke) Sacc. and *Alternaria alternata* (Fries) Keissler
- Appears during the months of July to November
- Disease appears as burning of tips and margins of leaves.
- Chemical control measures - Foliar spray of 0.2 % Mancozeb 75 % WP (Dithane M-45) i.e. 2 gm in one litre of water.
- Leaves can be fed to silkworms 10 days after spraying.

B) Pests and non-pest insects

i) White fly

- Causative agent-*Dialueropora decempuncta* Quain. & Baker, *Aleuroclava pentatuberculata*
- Appears during the months July – November.
- White fly pierces and sucks the phloem sap of the leaves.
- Infestation accounts for 24 % leaf yield loss. Due to polyphagous nature the pest establishes very quickly.
- Mechanical control measures - Fix yellow sticky traps of size 2' x 1' @ 150 nos / ha, which reduces white fly about 25 %.
- Cultural control measures – Prune mulberry simultaneously in an area to avoid invasion of white fly in new flash.
- Chemical control measures - Spray 1 % DDVP 76 % EC (Dichlorovos) i.e. 2 ml in one liter of water, suppresses the adult population by 40 % and nymphal population by 92 % within 14 days OR 1 % Neem oil (with 0.15 % Azadirachtin) suppresses 50 % adult and 89 % nymphal population.
- Biological control measures - Release 500 pairs of Brumoides saturalis predator / ha, which suppresses 25 % whitefly population by 45 days.
- Leaves can be fed to silkworms 14 days after spraying.
- Benefit Cost ratio is 1.7 : 1

ii) Mealy bug

- Causative agent – *Maconellicoccus hirsutus* Green
- Appears through out the year but severe during pre monsoon and summer months.
- Pre disposing factors – When both temperature and humidity are high, low incidence during rainy and winter months.
- Infestation causes malformation of apical shoot due to thickening of affected portion of shoot, wrinkling and curling up of apical leaves, affected leaves become dark green colour and brittle.
- Mealy bugs suck the sap, resulting in stunted growth of plant and reduction in leaf yield.
- Infestation accounts for 24 % leaf yield loss.
- Mechanical control measures - Clip affected portions, collect in polythene bags and dip in 0.5 % soap solution i.e. 5 gm soap in one liter of water to destroy the pest and bury in a pit away from mulberry garden.
- Cultural management practices – Do not grow alternate host plants viz. Guava, Croton, Citrus, Hibiscus, Grapes, Lady's finger, Cotton, ornamental plants and weeds etc., in the vicinity of mulberry garden.

- Chemical control measures - Spray 0.2 % DDVP 76 % EC (Dichlorovos) i.e. 2 ml in one liter of water in 0.5 % soap i.e. 5 gm soap solution OR 0.1 % Dimethoate 30% EC (Rogor) OR Neem insectide i.e. 5 ml in 10 liter water, twice at an interval of 10 days.
- Biological control measures recommended – Release predatory coccinellid Lady Bird beetle *Cryptolaemus montrouzieri* Muls. @ 125 adults OR *Scyminus coccinova* @ 250 numbers / acre twice.
- Leaves can be fed to silkworms 10 days after spraying.

iii) Bihar Hairy Caterpillar

- Causative agent *Diacrisia obliqua* Walker
- Appears during the months August – January.
- Young caterpillars eat the green soft tissues of tender leaves leaving only the veins and later grownup caterpillars eat entire leaves, thus defoliating the plants.
- Mechanical management measures – Collect and destroy egg masses laid on lower surface of leaves and young caterpillars by crushing in initial stage and grownup caterpillars in later stage.
- Chemical control measures – Spray 0.2 % DDVP 76 % EC (Dichlorovos) i.e. 2 ml in one liter of water.
- Biological control measures – Release *Trichogramma chilonis* @ 5 Tricho cards (each with 20,000 parasitized eggs) / acre in two times at an interval of 3 days after pruning or harvesting.
- Leaves can be fed to silkworms 10 days after spraying.
- Benefit Cost ratio is 2.96 : 1

iv) Mites

- Causative agent *Odontotermis obesus, O. wallonensis, O. redemani and O. horni*
- Damages stem by sheathing, scrape the bark and damage the roots by tunneling.
- Chemical control recommended – Spray 0.2 % Chloropyriphos 2 % EC at bottom of plants or apply Phorate 10% CG at the infected site.

v) Thrips

- Causative agent – *Pseudodendrothrips mori* Niwa
- Prevails during the months of February to July.
- Pre disposing factors: Hot and dry summer.
- Affects the epidermal tissue of leaves making unsuitable for silkworm rearing.
- Appears light yellow coloured spots on leaves and leaf margin turns upside looking like a boat.
- Leaf yield loss accounts to about 24 %.
- Chemical control measures – Spray 0.1 % Dimethoate 30 % EC (Rogor) i.e. 3 ml in one liter of water.
- Leaves can be fed to silkworms 10 days after spraying.
- Benefit Cost ratio is 6 : 1

C) Nursery diseases

Nursery diseases viz. Die back, Cutting rot, Collar rot and Stem canker occur through out the year in all types of soils and crop loss estimated is about 30 – 35 %. Benefit Cost Ratio is 10:1.

i) Die Back

- Causative agent - fungus *Lasiodiplodia theobromae*
- Appears throughout the year in all types of soil.
- Disease appears as wilting and withering of leaves and dying of plant from top to bottom.
- Physical control measure – Solarization of soil before planting.
- Chemical control measures - Before planting broadcast Carbendazim 50 % WP (Bavistin) @ 8 kg / acre in nursery bed, dip cuttings in 0.2 % Carbendazim 50 % WP for 30 minutes and spray 0.2 % Carbendazim 50 % WP (Bavistin) i.e. 4 gm in one liter of water.

ii) Cutting Rot

- Causative agent - fungus *Fusarium solani*
- Appears throughout the year in all types of soil.
- Disease appears as rotting of cuttings and decaying of barks of cuttings.
- Loss of sapling estimated about 30-35 %.
- Physical control measure – Solarization of soil before planting.
- Chemical control measures - Before planting broadcast Carbendazim 50 % WP (Bavistin) @ 8 kg / acre in nursery bed, dip cuttings in 0.2% Carbendazim 50 % WP for 30 minutes and spray 0.2 % Carbendazim 50 % WP i.e. 4 gm in one liter of water.
- Biological control measure - Broadcast *Trichoderma harzianum* (Raksha) mixed with farmyard manure at 1: 60 ratios @ 2 kg / sq mt in nursery bed.

iii) Collar Rot

- Causative agent - fungus *Phoma sorghina* and *Phoma mororum*
- Appears throughout the year in all types of soil.
- Disease appears as rotting of cuttings near soil line.
- Physical control measure – Solarization of soil before planting.
- Chemical control measures - Before planting broadcast Carbendazim 50 % WP (Bavistin) @ 8 kg / acre in nursery bed, dip cuttings in 0.2 % Carbendazim 50 % WP for 30 minutes and spray 0.2 % Carbendazim 50 % WP i.e. 4 gm in one liter of water.
- Biological control measure - Broadcast *Trichoderma pseudokoeningi* (Nursery Guard) mixed with farmyard manure at 1: 60 ratios @ 2 kg / sq mt in nursery bed.

iv) Stem Canker

- Causative agent - fungus *Lasiodiplodia theobromae*
- Appears throughout the year in all types of soil.
- Disease appears as cutting does not sprout, even death of sprout and rotting & peeling off bark of cutting.
- Physical control measure – Solarization of soil before planting.
- Chemical control measures - Before planting broadcast Carbendazim 50 % WP (Bavistin) @ 8 kg / acre in nursery bed, dip cuttings in 0.2 % Carbendazim 50 % WP for 30 minutes and spray 0.2 % carbendazim 50 % WP i.e. 4 gm in one liter of water.

RESULTS AND DISCUSSION

Meteorological conditions of Koraput were humid and tropical with average rainfall of 1458 mm spread over 86 days. Maximum rainfall or precipitation occurs during June – September and is about 84 %. Humidity was found higher in the month of June, July, August, September and lower during the month of March, April and May.

Occurrence of brown leaf spot disease caused by *Cercospora moricola* Cooke was observed only during the months of August – November both at RSRS farm and farmers' mulberry garden. However, all the time the disease incidence was below economic threshold level (of PDI 5). Occurrence of leaf rust disease caused by *Cerotilium fici* (Cast.) Arth. was found round the year both at RSRS farm and farmers' mulberry garden but, higher incidence was found during October-November. On the whole the incidence of leaf rust was within the economic threshold level (of PDI 5). Powdery mildew was found to be very season specific and found when the mercury drops gradually from October onwards to January and high incidence was observed during November -December.

The seasonal incidence of mulberry pests showed that there is no infestation during winter season and minimum during summer and maximum during rainy season but always below economic threshold levels which is significant in the prevailing environmental conditions prevailed. Thrips infestation was maximum during April and May (15.0 %) and it corresponded with maximum temperature of the period and thus positively correlated. White fly infestation gradually increased from May to September. All biotic factors were equally important in influencing the intensity of this pest. Mealy bug infestation was prevalent mainly during summer and pre- monsoon seasons. Abiotic conditions of preceding month had high influence on mealy bug population. Its population appeared in April (13.83 %) and reached peak during May (17.27 %). One or two plants exhibited the symptoms partially and the pest injury is below the economic threshold level. There was no infestation of Bihar hairy caterpillar and this indicated the availability of other alternative plant species. Thus, the present information will be helpful to the sericultural farmers to estimate the expected mulberry crop loss due to different pests and take preventive measures.

CONCLUSION

Most of these diseases and pests are season specific. Biotic and abiotic factors play an important role in disease and pest infestation. It is rather difficult to establish a direct cause and effect relationship between any single climatic factors and disease & pest activity, because the effect of weather elements on disease & pest is confounded. However, temperature, relative humidity, rainfall, sunshine and wind speed are the important parameters that largely affect the activity of a particular disease and species of insect. The intensity of leaf rust, leaf spot and powdery mildew are high during August to December which is correlated to the favourable predisposing factors, predominantly optimum temperature, relative humidity and rainfall. Accordingly, necessary preventive / control measure i.e. spraying of 0.2 % Carbendazim 50 % WP (Bavistin) twice at 15 days interval is suggested soon after the appearance of the diseases.

The congenial environmental condition helps in normal growth of mulberry and the infestation diseases and pests is always below the economic threshold level.

ACKNOWLEDGEMENT

The authors express their sincere thanks to the Director, CSR&TI, Berhampore for providing necessary facilities and encouragements during the course of investigation.

Table 1: Pooled seasonal incidence data of major mulberry diseases in Odisha (2006-10)

Month	PDI of Disease			Percentage of Nursery diseases
	Leaf Spot	Leaf Rust	Powdery Mildew	
January	--	--	--	14
February	--	4.753	--	8
March	--	4.710	--	3
April	--	2.955	--	--
May	--	4.306	--	--
June	--	3.837	--	--
July	2.080	4.865	4.250	--
August	2.379	4.487	3.998	--
September	--	3.734	2.719	--
October	--	3.726	4.508	--
November	--	4.305	4.481	--
December	--	5.461	5.577	--

Table 2: Pooled seasonal incidence data of major mulberry pests in Odisha (2006-10)

Month	Pest Infestation (%)			Mealybug
	Thrips	White fly	Bihar hairy caterpillar	
January	--	--	--	--
February	--	--	--	--
March	--	--	--	--
April	9.0	--	--	13.83
May	15.0	--	--	17.27
June	9.0	--	--	8.83
July	5.5	7.5	--	5.0
August	4.0	10.0	--	--
September	3.7	18.5	--	--
October	2.0	--	--	--
November	1.0	--	--	--
December	0.8	--	--	--

Table –3: Pooled monthly average meteorological data of Koraput (2006 - 10)

Months	Temperature ^{0} C		Relative Humidity (%)	Rainfall (mm)	No of Rainy Days
	Max.	Min.			
April	38.95	21.16	83.37	39.00	4
May	33.59	22.39	81.91	59.65	6
June	29.78	22.94	69.57	273.60	13
July	25.43	17.81	91.86	332.52	18
August	27.07	20.52	91.84	433.05	19
September	28.84	20.53	91.66	180.77	14
October	28.78	19.04	90.39	68.72	8
November	28.37	13.16	84.15	28.60	1
December	27.42	13.82	80.43	19.97	1
January	29.17	11.61	85.69	11.10	1
February	32.50	13.30	79.38	10.87	1
March	33.14	18.13	68.32	--	--
Mean / Total	27.85	17.87	83.21	1457.85	86

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EFFICACY OF NEW PESTICIDES IN CONTROLLING WHITEFLY AND ITS IMPACT ON SILKWORM REARING

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ABSTRACT

Whitefly, *Dialeuropora decempuncta* Quaintance & Baker (Homoptera: Aleyrodidae) is a polyphagous pest, started causing severe damage to mulberry, *Morus alba* L. since 1994. They suck leaf sap causing chlorosis, dryness of leaves, leaf curl and sooty mould and results a culminating loss in yield of leaf to the tune of 10-24% especially during major silkworm cocoon crop seasons. Though several insecticides were recommended earlier for the control of whitefly in mulberry, but the continuous reliance on a single chemical insecticide may lead to pesticide resistance inflicting great economic losses to farming community. Hence, some newer insecticides which are less toxic, economical, biodegradable and easily available *i.e.*, thiamethoxam (Actara 25% WG), diafenthiuron (Pegasus 50%WP) and clothianidin (Dantap 50% WDG) were selected. After evaluating LC90 values of these three insecticides, it was considered desirable to evaluate the field effectiveness of these pesticides against whitefly and its bioassay for inclusion in Integrated Pest management program. The experiment was conducted in RBD. The effective concentrations of thiamethoxam (0.015%), diafenthiuron (0.0633%), clothianidin (0.0047%) were sprayed on mulberry leaves and each treatment was replicated thrice. Three plots were kept as unsprayed control. Among the three pesticides, the maximum suppression of the pest population was observed with thiamethoxam by 14th day, followed by diafenthiuron and clothianidin. Leaves from the treated plots were fed to silkworm after 7th day, 14th day and 21st day of spray from date of hatching in three replications. Another set of Stage wise mortality, larval weight and other economic parameters were studied and analyzed to evaluate the bio- safety of these pesticides. The observation revealed that in all the treatments the silkworm mortality is more when fed with leaves of 7 Days After Spray (DAS), but no mortality was recorded when fed with 14 DAS and 21 DAS. The findings revealed that out of three pesticides tested for the control of whitefly, thiamethoxam at 0.015% is most effective and there is no detrimental effect of the pesticide on silkworm after 14 days of spray.

Key words: *Dialeuropora decempuncta*, Pesticides, Pest population, Silkworm rearing

INTRODUCTION

The mulberry whitefly, *Dialeupora decempuncta* Quaintance & Baker (Homoptera: Aleyrodidae) has been found on mulberry from 1994 causing a severe damage to the foliage, which is the sole food plant for the silkworm, *Bombyx* mori L . They suck leaf sap causing chlorosis, dryness of leaves, leaf curl and sooty mould disease and results a culminating loss in leaf yield to the tune of 10-24% especially during major silkworm cocoon crop seasons. The advantage of pesticides are that it is easy to use, get a convincing control effect, applicable in an emergency, can be selected according to the circumstances, cost effective, both eliminating labour and being of low cost, also easily biodegradable, non toxic products are potentially suitable for use in Integrated Pest Management systems (Alkafahl *et al*,

1989). Thus development of specific management practices based on botanicals or new group of insecticides has become imperative. Though several insecticides were recommended earlier for the control of whitefly in mulberry, but the continuous reliance on chemical insecticides for control of whitefly in other agricultural crops has resulted several problems like development of pesticide resistance and environmental pollution leading to health hazards also. So efforts were made to avoid the environmental pollution by adopting some newer insecticides which are less toxic, economic, biodegradable and easily available i.e. thiamethoxam (Actara 25% WG), diafenthiuron (Pegasus 50%WP) and clothianidin (Dantap 50% WDG). The LC90 values of these three insecticides were worked out as 0.0131%, 0.0635% and 0.0046% respectively (Patnaik *et al*, 2009) . Hence it was felt necessary to study the field efficacy of these three insecticides which in turn will cause no adverse effect on environment and also to find out its optimum period in becoming free from toxicity after spraying these insecticides on mulberry for silkworm's consumption.

MATERIALS AND METHODS

The experiment was conducted at peak incidence of pest population in the mulberry field of Central Sericultural Research & Training Institute, Berhampore, West Bengal. The experiment was laid out in a Randomized Block Design. There were three treatments and an untreated control. Each treatment was replicated thrice. The effective concentrations of each insecticides i.e thiamethoxam (0.015%), diafenthiuron (0.0633%) and clothianidin (0.0047%) were sprayed on mulberry leaves. Data were recorded a day prior to the spray (pre-treatment population) and 7 days, 14 days, 21 days after treatment (post treatment population) from 10 randomly selected plants of each plot following the standard method of Nileson (1957). The comparative efficacy of all treatments were tested with Analysis of Variance (Snedecor and Cochran, 1967).

To determine the safe period for silkworm mulberry leaves from the treated plots were fed to silkworm after 7th day, 14th day and 21st day of spraying from date of hatching in three replications. Stage wise mortality, larval weight and other economic parameters like cocoon weight, shell weight, Shell%, Effective rate of rearing (ERR) and single filament length were studied and analyzed to evaluate the bio- safety of these insecticides. The data were statistically analyzed to determine the safe period for silkworm rearing.

RESULTS AND DISCUSSION

The data revealed that thiamethoxam at 0.015% reduced the population 99.81% followed by diafenthiuron at 0.0633% (99.62%) followed by clothinidin at 0.0047% (99.07%) with in 24 hrs after spray. In 3rd day after spray thiamethoxam controls the population 99.81% followed by diafenthiuron (99.19%) followed by clothianidin (99.02%). The 7th day data showed that diafenthiuron reduced the pest incidence 97.47% followed by clothianidin (96.93%) followed by thiamethoxam (96.82%). which was evident when compared with unsprayed control.(Table1) The observations were statistically analysed by using Analysis of Variance which has indicated significant variations among different concentrations of different treatments and also between different days after spray.

Similar results were observed by Rohilla *et al.*, (2004) in case of mustard aphid. They have recorded that 50 g a.i./ ha gave significantly higher mortality (98.4 %) . Thiamethoxam @ 50 a.i./ ha at an interval of 15 days effectively prevented the population build up of hopper on flowering of mango (Kumar *et al*.,1985). Seed dressing with thiamethoxam 70 WS @ 5.g.a.i./ kg seeds was best for the the management of shoot fly and afforded highest protection at 89.4% over control (Karibasavaraja *et al*., 2005).

Field efficacy of diafenthiuron 50% WP was evaluated against whitefly *Bemicia tabaci* on brinjal by Saradha & Nachiappan (2003). They showed that diafenthiuron @ 800 g.a.i./ha reduced the whitefly population maximum.Bhaskaran *et al* (2003) showed the efficacy of diafenthiuron (300 g.a.i./ ha) against spiraling whitefly (*Aleurodicus disperses* Russell) on guava plants though previously reported by Babu and David (1999) on spiraling whitefly.

The findings of the study have indicated that amongst these three insecticides tested, the consumption of leaves by silkworm sprayed with thiamethoxam (0.015%), diafenthiuron (0.0633%) and clothianidin (0.0047%) after 7 days resulted 100 % mortality but there was no mortality after 14 and 21 days of spray respectively. The feeding of sprayed leaves after 14th and 21st day showed no significant difference in all economic parameters when compared to control.(Table 2). The study revealed that thiamethoxam at 0.015% reduces maximum (99.82%) pest incidence and can safely be used for the control of whitefly, *Dialeuropora decempuncta* as it does not have deleterious effects on silkworm rearing after consumption of 14 days sprayed leaves.

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Table 1: Efficacy of different concentrations of thiamethoxam,diafenthiuron and clothianidin solution against whitefly population in the mulberry field.

Treatment	1 DAS	3 DAS	5 DAS	7 DAS
T0(Control)	60.93	62.89	67.40	65.52
T1(0.015%) Thiamethoxam	3.03	2.52	2.63	1.85
T2(0.020%) Thiamethoxam	0.76	0.29	1.60	1.73
T3(0.0633%) Diafenthiuron	0.00	0.00	1.20	1.08
T4(0.070%) Diafenthiuron	2.95	3.02	2.52	2.42
T5(0.0047%) Clothianidin	0.00	0.00	1.71	1.47
T6(0.005%) Clothianidin	3.01	1.64	0.00	1.30
T7 (Water)	3.15	4.18	4.96	2.30
T8(0.01%) Dichlorvos	1.99	3.38	4.42	2.46
CD at 5%	14.21	9.39	7.90	3.75

DAS : Days after spray

Table 2: Population reduction percentage of pest incidence by the different concentrations of insecticides

Treatment	1 DAS	3 DAS	5 DAS	7 DAS
T1	99.81	99.81	96.82	96.82
T2	97.05	98.43	95.31	95.23
T3	99.62	99.19	96.50	97.47
T4	98.77	97.35	96.70	95.07
T5	99.07	99.02	96.00	96.93
T6	92.31	95.04	98.59	96.33
T7	70.30	72.47	70.08	75.45
T8	96.43	93.51	91.28	95.13

DAS : Days after spray

Table 3 : Effect of feeding pesticides-sprayed leaves on economic traits of silkworm *Bombyx mori* L.

Treatment	Days	Mortality %	Larval Wt (g)	SCW (g)	SSWt. (g)	Shell %	ERR (No)	ERR (Wt)	FL (m)	Fecundity	Hatching %
Untreated	7	-	-	-	-	-	-	-	-	-	-
	14	11	2.51	1.15	0.18	16.01	8966	10.28	525	426	95.14
	21	12	2.61	1.19	0.12	17.65	8833	10.51	569	411	94.33
Thiamethoxam (0.015%)	7	100	-	-	-	-	-	-	-	-	-
	14	12	2.49	1.15	0.19	16.8	8833	10.15	581	388	98.11
	21	11	2.51	1.21	0.21	17.35	8900	10.76	546	430	96.13
Diafenthiuron (0.0633%)	7	100	-	-	-	-	-	-	-	-	-
	14	8	2.55	1.14	0.19	16.61	8310	10.55	529	394	96.28
	21	12	2.48	1.2	0.2	17	8800	10.53	514	412	96.33
Clothianidin (0.0047%)	7	100	-	-	-	-	-	-	-	-	-
	14	11	2.56	1.15	0.19	16.45	8966	10.34	600	387	96.64
	21	11	2.63	1.21	0.21	17.67	8933	10.77	603	433	97.46
CD (5%)	NS	NS	0.55	NS	NS	NS	NS	NS	433	NS	NS

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 114-117

OVICIDAL ACTIVITY OF VARIOUS PLANT EXTRACTS AGAINST THE PINK MEALYBUG *MACONELLICOCCUS HIRSUTUS* INFESTING MULBERRY.

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ABSTRACT

The pink mealybug, *Maconellicoccus hirsutus* infests mulberry crop and causes both qualitative and quantitative damage. Leaf yield loss was about 4500kg/ha/year, loss of dfls was 450/ha/year and decline in coccon production was by150kg/ha/year. A study was carried out to evaluate the efficacy of various botanical extracts for their ovicidal property against *M.hirsutus* infesting mulberry. The ovisacs containing eggs of *M.hirsutus* were transferred to the petridish having filter paper treated with different plant extracts. After 72 hours of treatment the number of eggs hatched and non-hatched were counted in each treatment and hatching percentage was worked out. Three replications were maintained. Neem oil (2%) recorded least hatching of eggs (5.18%) and it was followed by Neem seed kernel extract (9.21%) and Melia seed kernel extract (10.00%). The other effective treatments in descending order were *Vitex negundo*, pungam oil, mahua oil, Annona seed kernel extract, *Tagetes erecta* and *Nerium oleander* as against the control (56.57%). Treatments with *Synadenium grantii*, eucalyptus oil, geranium oil and *Artemisia vulgaris* had more than 24 per cent hatching.

Key words: Botanical extracts, Cocoon production, ***Maconellicoccus hirsutus,*** Mulberry, Ovicide

INTRODUCTION

Mulberry (*Morus* spp.) leaf is the only natural food consumed by the silkworm *Bombyx mori* L to produce a highly commercial commodity the silk cocoons which up on reeling produce the most elegant and valued fibre called silk. Like most of the other economic plantation and field crops, mulberry is also prone to the attack by varied pest complex belonging to a large number of insect orders. So far over 300 insect and non-insect species of pests are known to infest mulberry in varying intensities during different seasons and stages of the crop development (Naik, 1997). The major insect species known to have attained status of pests in mulberry belong to order, Lepidoptera, Hemiptera, Coleoptera, Thysanaptera, Orthoptera and Isoptera (Biradar, 1989).

Among the sap feeders infesting mulberry, incidence of thrips *Pseudodendrothrips mori* is reported (Sathyaprasad and Manjunath, 1993) to be the highest (42.55%) followed by mealybugs *Maconellicoccus hirsutus* (20.80%). According to Manjunath *et al*. (2000), the mulberry leaf webber *Diaphania pulverulentalis*, Bihar hairy caterpillar *Diacrisia obliqua* and *M. hirsutus* inflicted crop losses of 12-15%, 25-30% and 10-15% respectively. *M. hirsutus* in mulberry has assumed greater significance in recent years as it causes both qualitative and quantitative damage. It is reported to cause an estimated leaf yield loss of 4500 kg/ha/year, thus depriving the farmer of a brushing of 450 dfls/ha/year resulting in reduced cocoon production by 150 kg/ha/year. Moreover leaf quality is also affected.

MATERIALS AND METHODS

The test insect mealy bug was reared in the laboratory on pumpkin at 27±2ºC and 70±5% relative humidity (Babu and David, 1999). Based on the literature about anti-insect properties and also their local availability twenty nine plant species were initially selected and evaluated against the major insect pests of mulberry as detailed in Table 1. Plant extracts from leaves, rhizome, bulb and peel were prepared following the methods as mentioned below:

Table 1: List of plants tested against *M.hirsutus*

Botanical name	Common name	Family	Plant parts used
Acorus calamus L	Vasambu	Araceae	Rhizome
Adathoda vasica	Adathoda	Acanthaceae	Leaves
Allium sativum	Garlic	Amaryllidaceae	bulb
Annona squamosa	Custard apple	Annonaceae	ASKE
Argemone mexicana	Mexican weed	Papaveraceae	Leaves
Artemisia vulgaris	Artemisia	Asteraceae	Leaves
Azadirachta indica A Juss	Vembu	Meliaceae	Leaves, oil, NSKE
Calotropis gigantea	Milk weed	Euphorbiacae	leaves
Citrus limon	Orange peel	Rutaceae	Peel
Datura metal	Oomathai	Solanaceae	Leaves
Eucalyptus sp	Eucalyptus	Myrtaceae	Leaves
Gaultheria fragrantissima	Gaultheria	Ericaceae	Leaves
Geranium rotundifolium	Geranium	Geranaceae	Leaves
Jatropha curcas	Kattamanaku	Euphorbiaceae	Oil, JSKE
Lantana camera	Wild sage	Verbenaceae	Leaves
Mahua latifolia	Mahua	Sapotaceae	Oil, MSKE
Melia azedarach	Malaivembu	Meliaceae	Leaves
Nerium oleander	Arali	Apocynaceae	Leaves
Parthenium hysterophorus	Wild Congress weed	Asteraceae	Leaves
Pongamia glabra	Pungam	Fabaceae	Leaves, Oil, PSKE
Prosopis juliflora	Prosopis	Mimosoideae	Leaves
Rosemarinus officinalis	Rosemary	Lamiaceae	Leaves
Synadinium grantii	Synadinium	Euphorbiaceae	Leaves
Tagetes erecta	Marigold	Compositae	Leaves
Thuja occidentalis	Thuja	Cupressaceae	Leaves
Vitex negundo, Var. *Purpurensis L*	Notchi	Verbenaceae	Leaves

Table 2 : Ovicidal action of plant extracts against *M. hirsutus*

Botanical name	Plant parts used	Dose (%)	Hatching %*
A. indica	Leaves	10	21.10 (27.35) [ml]
A indica	Oil	2	05.18 (13.18) [a]
A. indica	SKE	5	09.21 (17.66) [b]
M. azedarach	Leaves	10	21.12 (27.35) [ml]
V. negundo	Leaves	10	13.21 (21.30) [d]
T. erecta	Leaves	10	16.81 (24.00) [d]
P. glabra	Leaves	10	23.20 (28.79) [p]
P. glabra	Oil	2	14.24 (22.14) [e]
P. glabra	SKE	5	17.21 (24.50) [h]
N. oleander	Leaves	10	15.20 (22.95) [g]
A. mexicana	Leaves	10	21.20 (27.42) [m]
D. metal	Leaves	10	20.91 (27.20) [l]
R. officinalis	Leaves	10	22.10 (28.04) [n]
P. juliflora	Leaves	10	22.9 (28.59) [o]
P. hysterophorus	Leaves	10	21.10 (27.35) [l]
L. camera	Leaves	10	23.20 (28.79) [p]
G. fragrantisima	Leaves	10	30.10 (33.27) [v]
A. vasica	Leaves	10	18.21 (25.25) [i]
A. vulgaris	Leaves	10	24.01 (29.33) [q]
A. calamus	Rhizome	5	19.00 (25.84) [j]
A. sativum	Bulb	5	28.21 (32.08) [t]
S. grantii	Leaves	10	30.10 (33.27) [u]
C. limon	Peel	10	20.12 (26.64) [k]
C. gigantea	Leaves	10	26.10 (30.72) [s]
M. latifolia	Oil	2	15.21 (22.95) [f]
M. latifolia	SKE	5	10.00 (18.43) [c]
J. curcas	Oil	2	20.20 (26.71) [k]
J. curcas	SKE	5	19.10 (25.91) [j]
C. martini	Oil	2	22.10 (28.04) [n]
T. occidentalis	Oil	2	22.10 (28.04) [n]
G. rotundifolium	Oil	2	25.10 (30.07) [r]
Eucalyptus sp.	Oil	2	30.91 (33.77) [v]
A. squamosa	SKE	5	15.00 (22.79) [f]
Control			56.57 (22.79) [f]
CD (P = 0.05)			0.03

* Mean of three replications.
In a column mean followed by same letter(s) are not significantly different at p=0.05 by DMRT.
Figures in parentheses are arc sin transformed values.

Aqueous extraction

The fresh plant part to be tested was washed with distilled water to remove dirt and chopped into small pieces. 100 grams of chopped material was grinded into a fine paste with the help of an ordinary crusher. The paste obtained was diluted in one litre of distilled water and filtered through muslin cloth. The concentration of the extract so prepared was 10 per cent.

Seed kernel extraction (SKE)

50 g. of smashed seeds was taken into muslin cloth and soaked for overnight in a litre of water. The same was squeezed and diluted with the water to get 5 percent concentration of the suspension. 1 g. of soap powder or teepol was added to the preparation and mixed thoroughly before spray.

The ovisacs containing eggs of *M. hirsutus* was transferred to petridish having filter paper treated with different plant extracts. After 72 hours of treatment, the number of eggs hatched and non-hatched were counted with the help of a hand lens in each treatment and hatching percentage worked out. Three replications were maintained.

RESULTS AND DISCUSSION

The data on the ovicidal action of plant extracts / SKE / oils against mealy bug is presented in Table 1. Egg hatching varied from 5.18 to 30.91 per cent. Neem oil (2%) recorded least hatching of eggs (5.18%) and it was followed by NSKE (9.21%) and MSKE (10.00%). The other effective treatments in descending order were *Vitex negundo*, pungam oil, mahua oil, ASKE, *Tagetes erecta* and *Nerium oleander* as against the control (56.57%).Treatments with *Synadenium grantii*, eucalyptus oil, geranium oil and *Artemisia vulgaris* had more than 24 per cent hatching.

The ovicidal action of neem oil (Beevi *et al*., 1992; Chandramohan *et al*., 1999) was already known in mulberry. Pongamia oil also showed ovicidal action. However, the relatively lower ovicidal action of neem products observed in the present investigation might be due to the presence of the protective filamentous waxy ovisac in which the eggs of *M. hirsutus* are enclosed. Additional supporting evidence is provided by the findings of Srinivas *et al*. (2007) who observed significant reduction in the hatchability of eggs in treatments with neem products *viz.*, NSKE, neem oil and Raksha.

The present investigations revealed that the botanicals *viz*., neem oil, NSKE, neem cake, pungam oil, PSKE, MSKE and leaf extracts of *V. negundo* and *T. erecta* have ovicidal effect against *M.hirsutus*. The mode of action of many plant materials believed to be any one or a combination of the effects such as contact, stomach or systemic poison, fumigant, antifeedant, repellent, ovicidal, sterilant and growth inhibitor. It is therefore concluded that natural products of neem can be employed as low priced alternatives to synthetic insecticides which can help to reduce pest incidence, protect mulberry ecosystem and are also affordable to small scale farmers in developing countries like India.

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Golden Jubilee Conference - Sericulture Innovations: Before and Beyond 2011, CSR&TI, Mysore, 118-121

BIO EFFICACY OF SOME BOTANICALS AGAINST SPIRALING WHITE FLY, *ALEURODICUS DISPERSUS* (RUSSELL) ON MULBERRY

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ABSTRACT

In India, mulberry is cultivated mostly in tropical region where it is cultivated as evergreen crop throughout the year. The luxuriant foliage of mulberry attracts various insect and non insect pests. Indiscriminate use of chemical insecticides to control insect pests causes pollution in environment which disturbs ecological balance. Development of resistance in insects to insecticides and resurgence of sucking pests is also an important demerit in chemical methods. Now a days, available plants in the eco system having insecticidal properties are being included in the plant protection strategies. Generally, the botanicals are more specific against insect pests. Hence in the present study, efforts were made to study the biological efficacy of *Azadirachta indica, Aloe vera, Cassia auriculata, Zingiber officinale, Curcuma longa, Allium sativum, Capsicum annum* and *Acorus calamus* fermented in cow urine against the target pest *A.dispersus.* The indigenously prepared botanical extract was sprayed at different concentrations for controlling the pest. After spraying, the data were collected at periodical intervals on pest reduction, population of natural enemies (Spiders and coccinellids) and bio-safety to silkworms. Results showed that the botanical extract reduced the target pest population to a greater extent and caused no deleterious effect on natural enemies (Spiders and coccinellids). It was found that a minimum of 10 days were required as safety period to young age silkworms after spraying of botanical extract.

Keywords: *Aleurodicus dispersus*, Bio-efficacy, Bio safety, Natural enemies, Plant extracts

INTRODUCTION

Mulberry is cultivated much in south India round the year. Mulberry leaves are major economic component in sericulture and its quality and quantity have direct impact on cocoon production. So far, over 200 insect and non insect pests are known to affect in different stages of mulberry at different seasons (Naik, 1997). Among the sap feeders on mulberry, *Aleurodicus dispersus* (Russell) infests up to 42.55% (Sathyaprasad and Manjunath ,1993). Indiscriminate use of chemical insecticides to control insect pests leads to environmental pollution and disturbs ecological balance. Development of resistance in insects to insecticides, residues in ecosystem and resurgence of sucking pests are also certain important weaknesses in chemical methods. Of late, certain plants in the ecosystem having insecticidal properties are being included in the Integrated Pest Management (IPM). Generally, the plant products have more specific action against target pests. Hence, a study was taken up with the objectives to study the bio efficacy of amalgamated extracts of *Azadirachta indica* (L)*, Aloe vera* (L)*, Cassia auriculata* (L)*, Zingiber officinale* (Roscoe), *Curcuma longa (L),Allium sativum (L),Capsicum annuum* (L) and *Acorus calamus* (L)fermented in cow urine to control *A. dispersus* and to study impact of botanicals on the population dynamics of spiders and coccinellids *besides* biological safety to the silkworm, *Bombyx mori* (L).

MATERIALS AND METHODS

The study was taken up at the mulberry garden of Regional Sericultural Research Station, Salem during

November 2009 to January 2010 under irrigated condition. The list of plants, its parts and quantity utilized for extraction is given below.

A. indica	Lea f	: 500 g
A. vera	Leaf	: 500 g
C. auriculata	Leaf	: 500 g
Z. officinale	Rhizome	: 50 g
C. longa	Rhizome	: 50 g
A. sativum	Bulb	: 50 g
C. annum	Un ripened fruit	: 50 g
A. calamus	Rhizome	: 50 g
Cow urine		: 4.5 l

The above mentioned leaf materials in specified quantity were well soaked in 6.5 litres of fresh cow urine in a sterile plastic container and mixed the paste of other materials. The mixture was allowed for fermentation up to 13 days. The mouth of the container was covered with a clean cloth to avoid contact with the house flies etc. During the process of fermentation, mixture was stirred every day thoroughly. After fermentation, the mixture was filtered and collected amalgamated plant extract in a separate container for experiment at different concentrations. The experiment was laid out in Randomized block design with seven treatments replicated thrice. The treatment details were T_1- 2%, T_2-3%, T_3- 4%, T_4 - 5%, T_5- 6%, T_6- DDVP@ 2.5 ml/l and T_7- Control. Data on population (%) of target pest, coccinellids and spiders over the pre count in tagged 25 plants reduction were collected periodically and subjected to ANOVA.

To study the biological safety, the treated leaves (T_3- 4%) were fed to hatched silkworm larvae at 2nd, 4th ,6th , 8th and 10th day of application of amalgamated plant extract and observed for mortality up to II moult.

RESULTS AND DISCUSSION

Results indicated that the T5 (6 %) of amalgamated botanical effectively reduced the pest population significantly at 1% level compared to other treatments and Control (Table 1). The population of spiders was significantly more (4.8 numbers / 25 plants) in T3 (4 %) and (4.1 numbers / 25 plants) in T5 (6%) than DDVP at 1% level (Table 2). Results revealed that the population of coccinellids was significantly more (9.9 numbers / 25 plants) in T2 (3%) at 1% level followed by all the treatments and also Control (Table 3).

The reduction in population of target pest, spiders and coccinellids might also be due to insecticidal and antifeedant effect of ingredients of amalgamated plant extract having various alkaloids and toxic substances. The Rutin present in the leaf of *A.indica* (Keeler and Tu, 1991) is having insecticidal effect apart from 83 other activites including as antifeedant, immunomodulator, larvistat and hemostat. The *A.vera* confers pesticidal activity due to the presence of 25 phytochemicals *viz*., acemannan, aloe-emodin, aloin, aluminum, ascorbic-acid, barbaloin, beta-sitosterol, chrysophanic-acid, chrysophanol, cinnamic-acid, coniferyl-alcohol, coumarin, cysteine, emodin, formic-acid, lignin, lupeol, p-coumaric-acid, palmitic-acid, polyphenols, rhein, selenium, thiamin, tin and zinc. The *C.auriculata* also has aloe-emodin and anthroquinones for pesticidal activity (Duke, 1992A). The rhizome of *Z. officinale* contains sesquiterpene zingiberene, zingerone, ß -camphene, ß - phallandrene, cineole, citral, borneol , zingiberol and gingerol (Ayensu,1981). Some unspecified parts contain unknown quantity of methyl eugenol (George Burdock, 2009). The turmeric, *C. longa* rhizome is known to have zingiberene 25%, minor amounts of eucalyptol, curcumin 0.3-5.4% and oleoresin contains curcumin (You-Ping Zhu, 1998). The essential oil of turmeric contains camphor and cineole up to 10% (El-Shereif, 2010). Garlic oil and its main component allyl disulphide are also proved to be effective against *Blattella germanica.* It is found that, using *Capsicum* xylene extract as constituent in boiled linseed oil formulation increased their toxicities against second instar larvae of cotton leaf worm compared with boiled linseed oil only. Capsaicin (8-methyl-N-vanillyl-6-nonemide) is an active ingredient responsible for heat in *Capsicum*. It's colorless, pigment crystalline alkaloid, thermo liable and more soluble in alcohols and oils (Govindarajan and Sathyanarayana 1991). Capsaicin has significant lethal and antifeeding effects on various invertebrates. The study conducted at the University of Agricultural Sciences, Dharwad showed that garlic chilli aqueous extract (2%) with garlic chilli kerosene extract (0.5%) controlled the *Helicoverpa armigera* (Hubner) up to 46.85 % in chick pea ecosystem (Rafiksab *et al*., 2011) . The rhizome of triploid and tetraploid, *A. calamus* is known to contain asarone up to 9-19% and 85-95 % where as dried rhizome has only 0.3% and 4.4-8.3 % respectively (Nico Vermeulen, 1998). It is found that *A. calamus* aqueous extract reduced the adult emergence of *Callosobruchus maculatus F.* up to 80.69% (Jayakumar, 2010).

Table 1: Effect of amalgamated botanicals on reduction of the pest *Aleurodicus dispersus* population (%)

Treatment	1st Day	2nd Day	3rd Day	4th Day	5th Day	7th Day	12th Day	17th Day	21st Day	26th Day	Mean
T1	15.58	24.47	19.41	13.17	9.12	3.92	-6.06	-9.72	-12.12	-14.12	4.37
T2	19.49	43.15	54.85	70.36	70.91	78.94	86.97	92.29	93.29	94.90	70.52
T3	43.78	67.41	60.33	72.01	80.07	86.51	91.84	95.82	97.35	98.47	79.36
T4	42.73	68.30	71.13	71.24	75.49	82.87	90.48	95.31	96.73	98.15	79.24
T5	72.25	84.30	87.23	87.37	91.61	94.38	96.50	96.50	97.88	97.88	90.59
DDVP	61.79	72.71	100.00	100.00	100.00	100.00	66.81	55.38	47.19	33.02	73.69
Control	11.11	17.98	13.22	9.66	5.48	-1.81	-8.11	-7.05	-10.27	-12.21	1.80
Level of significance	**	**	**	**	**	**	**	**	**	**	**
CD(.05)*	24.62	17.23	12.49	7.66	7.44	6.92	11.95	11.90	12.08	15.38	7.49
CD(.01)**	34.51	24.16	17.59	10.74	10.43	9.70	16.75	16.68	16.94	21.57	10.49

Table 2: Influence of amalgamated botanicals on spiders population

Treatment	Pre count	1st Day	2nd Day	3rd Day	4th Day	5th Day	7th Day	12th Day	17th Day	21st Day	26th Day	Mean	Percentage of reduction
T1	1.67	1.67	1.67	1.33	1.00	1.00	0.67	0.33	0.33	0.33	0.00	0.83	50.00
T2	3.33	3.33	2.67	2.67	2.67	2.33	2.33	1.67	1.33	1.00	0.33	2.03	39.00
T3	9.67	8.33	7.67	6.67	6.00	5.67	4.33	4.00	3.00	1.67	0.67	4.80	50.34
T4	8.00	6.00	5.00	4.33	3.33	2.00	1.33	1.00	0.67	0.33	0.67	2.47	69.17
T5	10.67	8.67	7.33	5.67	5.33	4.67	3.67	2.67	1.67	1.33	0.00	4.10	61.56
DDVP	3.33	2.00	2.00	0.00	0.00	0.00	0.00	1.67	2.00	1.67	2.33	1.17	65.00
Control	6.33	5.67	5.00	4.33	4.33	3.00	3.00	3.00	3.00	2.67	1.67	3.57	43.68
Level of significance		*	*	**	**	**	**	**	*	*	**	**	
CD(.05)*		5.38	4.67	3.93	3.47	2.79	2.52	2.38	2.15	2.10	1.33	2.81	
CD(.01)**		7.54	6.55	5.51	4.87	3.92	3.53	3.33	3.01	2.95	1.86	3.94	

Table 3: Influence of amalgamated botanicals on coccinellids population

Treatment	Pre count	1st Day	2nd Day	3rd Day	4th Day	5th Day	7th Day	12th Day	17th Day	21st Day	26th Day	Mean	Percentage of reduction
T1	13.33	12.67	11.67	11.00	8.67	7.33	6.00	5.00	4.33	2.33	2.00	7.10	46.75
T2	22.00	20.00	19.00	16.00	12.33	10.00	5.67	6.00	5.33	3.00	1.67	9.90	55.00
T3	12.00	10.33	9.33	6.33	6.00	6.00	3.67	3.00	2.00	1.67	1.67	5.00	58.33
T4	17.00	15.33	14.00	12.00	11.00	10.33	8.67	6.33	5.33	4.33	1.33	8.87	47.84
T5	8.00	7.00	6.33	5.67	5.00	4.67	3.67	3.33	3.33	2.67	2.00	4.37	45.42
DDVP	8.67	6.33	5.00	0.00	0.00	0.00	0.00	4.67	7.67	6.00	6.00	3.57	58.85
Control	18.33	16.67	13.67	12.00	9.00	7.33	6.00	4.67	3.00	2.33	0.00	7.47	59.27
Level of significance		**	**	**	**	**	**	NS	**	**	**	**	
CD(.05)*		7.53	7.18	6.06	4.55	4.40	4.20	3.67	3.16	3.16	3.08	4.52	
CD(.01)**		10.55	10.06	8.50	6.38	6.17	5.89	5.14	4.34	4.43	4.31	6.29	

The amalgamated botanical extract reduced the population of target pest to greater extent and conserves spiders and coccinellids in the ecosystem. It was found that a minimum of 10 days required as safety period to young age worms.

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INDUCED SYSTEMIC RESISTANCE THROUGH VARIOUS ORGANIC CAKES ON THE MANAGEMENT OF THRIPS *PSEUDODENDROTHRIPS MORI* (NAWA.) INFESTING MULBERRY

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ABSTRACT

Field evaluation of certain organic cakes *viz.,* neem cake, custard apple cake, Jatropha cake, Mahua cake, Pungam cake, castor and gingelly cake each @ 1000kg/ha with FYM @ 20MT/ha against *Pseudodendrothrips mori* infesting mulberry. All the treatments were incorporated in to the soil 15 days after pruning. Plot size was one cent and each treatment was replicated thrice. The population of thrips present in the three leaves representing top, middle, and lower portions were recorded at weekly intervals and expressed in number/3 leaves. The combination of FYM+ neem cake recorded the lowest population (1.45/3 leaves) as against 14.78 and 11.51/3 leaves in the treatment with recommended NPK and the untreated control. FYM+ neem cake recorded the maximum leaf yield (8100kg/ha/crop) followed by the treatment with the recommended NPK (7900kg/ha/crop). The inorganic fertilizers increased the plant growth by providing the nutrients to the plants in large quantity for shorter period of time. Thereby the plants were endowed with luxuriant growth which offered adequate and highly preferred food to the insects leading to heavy infestation of thrips. The remarkable difference in the population of thrips in organic cakes applied plots might have been attributed by low nitrogen and phenol contents in the leaves which exhibited induced resistance.

Key words: Induced systemic resistance, Mulberry, Population, *Pseudodendrothrips mori*

INTRODUCTION

Mulberry (*Morus* spp.) leaf is the only natural food consumed by the silkworm *Bombyx mori* L to produce a highly commercial commodity the silk cocoons which up on reeling produce the most elegant and valued fibre called silk. Like most of the other economic plantation and field crops, mulberry is also prone to the attack by varied pest complex belonging to a large number of insect orders. So far over 300 insect and non-insect species of pests are known to infest mulberry in varying intensities during different seasons and stages of the crop development (Naik, 1997). The major insect species known to have attained status of pests in mulberry belong to order, Lepidoptera, Hemiptera, Coleoptera, Thysanaptera, Orthoptera and Isoptera (Biradar, 1989).Among the sap feeders infesting mulberry, incidence of thrips, *Pseudodendrothrips mori* is reported (Sathyaprasad and Manjunath, 1993) to be the highest (42.55%) followed by mealybugs, *Maconellicoccus hirsutus* (20.80%). Frequent and large scale application of pesticides for the control of diseases and pests in crop plants has led to the ecological imbalance in agro ecosystem. Insecticides kill the natural enemies which led to outbreak of secondary pests. Development of resistance to insecticides and resurgence in the insects are the other serious problems posed by the frequent use of insecticides. Mulberry being the sole food plant of *Bombyx mori* use of chemical insecticides leave toxic residues in mulberry leaves as well as soil. Development of an appropriate insect pest management strategy that takes care of the mulberry ecosystem may provide a meaningful solution to avoid the above problems. Management of the insect pests through botanicals is emerging as a viable option. Keeping this in view, the present investigation was carried out to find out the efficacy of different oil cakes in reducing the incidence of *P.mori* infesting mulberry and their influence on mulberry leaf yield

MATERIALS AND METHODS

The field experiment was conducted in the farmers holding at Valkadu village, Salem district. Standard package of mulberry cultivation were adopted uniformly for all the treatments. The experimental details were as follows:-

Variety	MR_2
Design	RBD
Plot size	100 m^2
Spacing	90x90 cm
Replication	Three

Treatments:

T1: FYM@20MT/ha + Neem cake @ 1000 kg/ha

T2: FYM@20MT/ha + Custard apple seed cake @ 1000 kg/ha

T3: FYM @20MT/ha + Jatropha cake @ 1000 kg/ha

T4: FYM@20MT/ha + Mahua cake @ 1000 kg/ha

T5: FYM@20MT/ha + Pungam cake @ 1000 kg/ha

T6: FYM@20MT/ha + Castor cake @ 1000 kg/ha

T7: FYM@20MT/ha + Gingelly cake @ 1000 kg/ha

T8: FYM alone 20 MT/ha

T9: Recommended NPK 300: 120: 120 Kg/ha

T10: Untreated control

Additionally the treatments T1 to T8 were supplemented with 25% of recommended N. All the oil cakes were incorporated into the soil as per the treatment schedule at 15 days after pruning. Data on plant growth and yield parameters like number of shoots per plant, total length of shoots per plant, number of leaves/plant, total biomass production/plant were recorded. The population/damage of *P. mori* was conducted during Aug-Sep. The population of *P. mori,* present in the three leaves representing top, middle and lower portions were recorded after I, II, III and IV weeks of treatment from 20 randomly selected plants and expressed in number/leaf. For recording total leaf yield all the plants from net area of each plot were harvested and finally the yield/ha was calculated and expressed in kgs.

RESULTS AND DISCUSSION

During the entire periods of observation, thrips population differed significantly among various treatments. One week after application, FYM + neem cake recorded significantly lower population of thrips (0.61) followed by FYM + mahua cake (1.24) as against 7.9 nos in NPK treated plots and 6.24 nos/ 3 leaves in untreated control plots (Table 1). The highest per cent reduction of thrips was observed in the treatment FYM + neem cake (92.23%) followed by FYM+ Mahua cake (84.30%).

Two weeks after treatment, thrips population in various treatments ranged from 1.10 to 16.02 per three leaves. Among these, FYM + neem cake application recorded the lowest population of 1.10 / 3 leaves followed by FYM + mahua cake (2.40). The next effective treatments were FYM + Pungam cake and FYM + Jatropha cake which were on par with corresponding per cent reduction of 81.30 and 81.33 over NPK application alone. The untreated control recorded the highest population of thrips (12.38/ 3 leaves) with the corresponding per cent reduction of 22.72 per cent over NPK application.

Three weeks after application, *P. mori* population was very low in FYM + neem cake (2.01/3 leaves), FYM + custard apple seed cake (3.12) and FYM + pungam cake (3.20 nos/ 3 leaves) which were on par with each other. NPK as inorganic form recorded high population (18.53/ 3 leaves) as well as in control (14.11nos/ 3 leaves).

P. mori population recorded at fourth week after treatment ranged from 2.09 to 16.67/3 leaves in various treatments. The high per cent reduction over NPK was recorded in the treatment FYM + neem cake (87.46%) followed by FYM + pungam cake (82.54%), FYM + mahua cake (81.40%), FYM + custard apple seed cake (81.40%) and FYM + jatropha cake (80.68%) and which were on par with each other.

The overall mean population of thrips recorded during different period of observation revealed that FYM + neem cake recorded the lowest population(1.45/3 leaves) and inorganic NPK treated plots the maximum (14.78 /3 leaves) (Table 1). The treatments in descending order of effectiveness were FYM + mahua cake, FYM+castor cake and FYM + jatropha cake which were on par. The population recorded in the above treatments were 2.68 / 3 leaves. The treatment with recommended NPK recorded the highest population of *P. mori* 14.78 nos/ 3 leaves.

In the present investigation the mulberry plots treated with FYM + neem cake @ 1000 kg/ha showed significantly less population of thrips over NPK application as inorganic form. This is in agreement with the earlier findings on the efficacy of neem cake either alone or in combination with other manures and sprays in reducing the population of aphids, thrips and mites in chillies. (Krishnamoorthy *et al*. 2001; Rajendiran and Chandramani, 2002; Gundannavar *et al.*,2007; Giraddi and Varghese, 2007). The superiority of neem cake in the present study is in line with the findings of Varghese and Giraddi (2005) who reported that neem cake @ 500 kg/ha along with normal doses of NPK was superior in having least population of thrips and mites in chilli. The present study revealed the consistent effect of FYM + neem cake or mahua cake in reducing the incidence of *M. hirsutus,*

A. dispersus and *D. pulverulentalis* than other treatment combinations and NPK. It is in line with the findings of Samuthiravelu *et al.* (2004) and Ravikumar *et al.* (2005) in mulberry. The inorganic fertilizers increase the plant growth by providing nutrients to the plants in large quantity for shorter period of time. Thus the plants are endowed with the luxuriant growth which may offer adequate and highly preferred food to the insects leading to heavy insect population. On the other hand, the nutrient release from organic sources like oil cakes was rational and slow and thus making the plants less prone to insect attack**.** Effectiveness of organic amendments *viz*., neem cake and vermicompost besides neem derivatives against sucking pests has been documented by various workers Varghese and Giraddi (2005), Giraddi and Smitha (2004), and Mallikarjuna Rao *et al.* (1999a and 1999b).

Application of FYM + neem cake resulted in the production of more number of branches, leaves/ plant, long shoots, total biomass and leaf yield when compared to other oil cakes and NPK alone (Table-2). This is in corroboration with the finding of Samuthiravelu *et al.* (2004) that the neem cake @ 60 kg/ac + 75% N fertilizer showed better performance of mulberry. Neem cake contains fair amount of organic nitrogen (2.0 to 2.5%) and other nutrients besides various insect antifeedant constituents which might be the possible reason for preventing damage by pests and also resulting in to good leaf yield in mulberry, in the present investigation. Also the efficacy of neem cake persists for longer periods providing extended period of protection from the pests as it is applied to the soil and thus escaping from the fast degradation of the active ingredients like neem oil under high temperature and UV light.Further neem cake make the soil more fertile due to an ingredient that blocks soil bacteria from converting nitrogenous compounds into nitrogen gas and acts as a nitrification inhibitor and prolongs the availability of nitrogen in both short and long duration crops.

The present investigations revealed that the neem cake altered the biochemical contents in the mulberry and finally induced systemic resistance in mulberry plan against pests. Additionally it has increased the leaf yield as well as quality and thereby increasing the productivity of silkworm crops. It is therefore concluded that natural products of neem can be employed as low priced alternatives to synthetic insecticides which can help to reduce pest incidence, protect mulberry ecosystem and are also affordable to small scale farmers in developing countries like India.

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Table 1: Effect of different oil cakes on nymphal population of *P. mori* in mulberry

Season: Aug-Sep 2005

Treatments	Weeks after treatment *								Mean	
	I		II		III		IV			
	No./3 leaves	% reduction over NPK	No./3 leaves	% reduction over NPK	No./3 leaves	% reduction over NPK	No./3 leaves	% reduction over NPK	No./3 leaves	% reduction over NPK
FYM + neem cake	0.61 (1.05) a	92.23	1.10 (1.26) a	93.13	2.01 (1.58) a	89.15	2.09 (1.60) a	87.46	1.45 (1.40) a	90.19
FYM +custard apple seed cake	2.40 (2.00) e	69.62	3.21 (1.93) d	79.96	3.12 (1.90) b	83.16	3.10 (1.90) b	81.40	2.96 (1.86) d	79.97
FYM + Jatropha cake	1.91 (1.55) d	75.82	2.99 (1.84) c	81.33	3.42 (1.98) c	81.54	3.22 (1.93) b	80.68	2.68 (1.78) c	81.87
FYM + Mahua cake	1.24 (1.32) b	84.30	2.40 (1.70) b	85.02	3.56 (2.01) d	80.79	3.10 (1.90) b	81.40	2.58 (1.75) b	82.54
FYM + Pungam cake	1.75 (1.50) c	77.85	2.85 (1.83) c	81.30	3.20 (1.92) b	82.73	2.91 (1.85) b	82.54	2.68 (1.78) c	81.87
FYM + Castor cake	5.46 (2.44) h	30.89	6.98 (2.73) g	56.43	7.82 (2.88) f	57.80	6.11 (2.57) d	63.35	6.59 (2.66) f	55.41
FYM + Gingelly cake	4.90 (2.32) f	37.97	5.98 (2.54) e	63.09	6.82 (2.71) b	82.73	5.55 (2.46) c	66.71	5.81 (2.51) e	60.69
FYM alone	5.10 (2.37) g	35.44	6.22 (2.59) f	61.17	9.38 (3.14) g	49.38	6.81 (2.70) e	59.15	6.88 (2.72) g	53.45
Recommended NPK alone	7.90 (2.90) i	--	16.02 (4.06) i	--	18.53 (4.36)i	--	16.67 (4.13) g	--	14.78 (3.90) i	--
Untreated control	6.24 (2.60) h	21.01	12.38 (3.59) h	22.72	14.11 (3.82) h	23.85	13.33 (3.72) f	22.02	11.51 (3.47) h	22.12

* Mean of three replications.
In a column mean followed by same letter(s) are not significantly different at P=0.05 by DMRT.
Figures in parentheses are square root transformed values.

Table 2 Effects of different oil cakes on mulberry leaf production

Treatments	Season: Aug-Sep 2005				
	No. of shoots/ plant *	Total length of shoots*	No. of leave /plant*	Total biomass yield (kg/ha/crop)*	Leaf yield (kg/ha/crop)*
FYM + neem cake	10.0 [a]	1315 [a]	325 [a]	14305 [a]	8100 [a]
FYM +custard apple seed cake	8.5 [d]	1290 [d]	306d	13900 [d]	6780 [d]
FYM + Jatropha cake	8.7 [d]	1290 [d]	308 [d]	13910 [d]	6790 [d]
FYM + Mahua cake	9.9c	1300 [c]	310 [c]	13990 [c]	6970 [c]
FYM + Pungam cake	10.1d	1290d	310 [c]	13900 [d]	6770 [d]
FYM + Castor cake	9.9d	1288vd	309 [d]	14000d	6710 [d]
FYM + Gingelly cake	9.2d	1280d	306d	14010 [d]	6710 [d]
FYM alone	8.2 [e]	1081e	301e	13600 [e]	6600 [e]
Recommended NPK alone	10.2b	1300b	320 [b]	14240 [b]	7960 [b]
Untreated control	5.9f	930 [f]	214f	11210 [f]	5215 [f]

* Mean of three replications.
In a column mean followed by same letter(s) are not significantly different at P=0.05 by DMRT.

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EFFECT OF WHITEFLY POPULATION AND ABIOTIC FACTORS ON POPULATION DYNAMICS OF A NATIVE PREDATOR, *MICRASPIS DISCOLOR*

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ABSTRACT

In any ecosystem organisms interact with biotic and abiotic components of which some limiting factors maintain the population equilibrium. The factors that limit growth and regulate population dynamics can be used to make quantitative forecasting of an organism. In the present study, interaction of two species of whitefly, *Dialeuropora decempuncta* (Quaintance & Baker) and *Aleuroclava pentatuberculata* (Sundar Raj & David) (Homoptera: Aleyrodidae), major pests of mulberry and abiotic factors on a native predator, *Micraspis discolor* (F.) (Coleoptera: Coccinellidae) were studied for a period of three years during 2004-2007. It was revealed that the predator population was positively correlated with maximum relative humidity and the correlation coefficient (0.241) was found to be significant at 1% level. While the correlation between predator population and other factors like maximum and minimum temperature, minimum relative humidity and rainfall was found to be negative. In case of maximum and minimum temperature, the correlation coefficient was found to be negative but significant at 1% level having r values -0.277 and -0.308 respectively. But, the correlation with minimum relative humidity and rainfall was found not to be significant with r values -0.53 and -0.012 respectively. Availability of the host is also an important factor in determining the population build up of the predator. The correlation with the host population was found to be significant at 1% level. Further, the regression equation showed the effect of the weather factors and the host population. While studying the effect of the host populations on the predator, it was found that previous eight weeks' host population influenced the population of *M. discolor* and weather factors of previous 0-6 days found to influence the predator population. The combined effect of abiotic factors and the host population were integrated and a regression equation was developed for predicting the predator population.

Key words: Abiotic factors, Native predator, Population dynamics, Prediction model, Whitefly

INTRODUCTION

Population dynamics is the study of marginal and long term changes in the numbers, individual weight and age composition of individuals in one or several populations with reference to biological and environmental influences or changes. Population dynamics in insects are the result of interaction between physical conditions, population movements and both density dependent and independent factors. The relative importance of each of the factors might vary among populations or even within a population from time to time (Huffaker *et al*., 1984). The knowledge of insect population dynamics is essential for developing sustainable crop protection strategies and for safeguarding the health of the agricultural environments. The ecological factors affecting insect population are of major importance in insect

pest control. All available knowledge about the biotic and abiotic characteristics of the environment affecting the pest should be used in weaving a pattern of insect control for a specific pest in a specific place or area (Bodenheimer, 1938).

An understanding of the role of critical biotic and abiotic factors conducive for the occurrence of the predator will facilitate the forecasting of its abundance in advance. In mulberry crop, there is a limited scope of application of pesticides to protect the crop due to short spell from pruning to feeding of silkworms. So, advance information regarding the trends of predator population build up will be helpful to the farmers and policy makers to remain prepared for the mass augmentation and inundative release of the biological control agents and also reduce the indiscriminate use of pesticides.

Accordingly in the present study interactions between population of two species of whitefly, *Dialeuropora decempuncta* (Quaintance & Baker) and *Aleuroclava pentatuberculata* (Sundar raj & David) (Homoptera : Aleryrodidae) and their native predator *Micraspis discolor* (Fabricius) (Coleoptera : Coccinellidae) were worked out in order to facilitate the forecasting the native predator population for effective biological control of these serious pests.

METHODOLOGY

For studying the population dynamics of the whiteflies, *D.decempuncta* & *A.pentatuberculata* and their native predator, *M.discolor* weekly surveys (Hoddle and Van Driesche, 1999) were conducted in the Mulberry fields of Central Sericultural Research & Training Institute, Berhampore, West Bengal from 20 mulberry plants selected randomly (Schuster, 1998 and Assad et al., 2006). From each plant, adult whitefly population was collected from top two mulberry leaves, early nymphal counts were made from two leaves of middle region and the late nymphs from bottom two leaves (Ohnesorge and Rapp, 1986, Purohit and Deshpande, 1991, Lynch & Simmons, 1993, Naranjo and Flint, 1995, Karut and Sekeroglu, 2003, Das et al., 2007a). The life stages of *M.discolor* viz., egg masses, grubs, pupae and adult from the same plant were recorded during 2004-2007. The meteorological data viz., Maximum and minimum temperature, maximum and minimum relative humidity and rain fall were collected from the institute's meterological observatory. For establishing the correlation between the predator population and the biotic and abiotic factors, coefficient of correlation was worked out to determine, the positive or negative effect of weather factors and whether the correlation was significant or not. The significance level was specified.

Besides the coefficient correlation studies, multiple linear regression analysis was also done, considering all the factors so as to specify how many days preceding host population and weather factors are responsible to influence the population of the predator. The significance of f value of regression was determined. The time period for which the f value was found to be least was also worked out as it was found to be more significant.

RESULTS AND DISCUSSION

During the first year of study i.e. 2004-2005, the incidence of the predator started from the first week of November (0.05/plant) and reached maximum (0.15/plant) during last week of November and first week of December. Whereas in the following year, i.e. 2005-06, the incidence started from fourth week of October and during last week of the month, the predator population reached to maximum with 0.5/plant. During the third year, i.e 2006-07, maximum population was observed during the last week of October with a population of 0.3/plant (Fig. 1 a, b, c).

The role of different factors both biotic and abiotic can be assessed by the correlation studies. The coefficient of correlation was determined in phases relating the predator population with that of abiotic factors and host i.e. two species of whitefly population (Table: 1). In the present study, it was found that the population of *M.discolor* was positively correlated with maximum relative humidity and the correlation was also found to be significant at 1% level. The r value for the factor is 0.241. While the correlation of predator population with the other factors like maximum and minimum temperature, minimum relative humidity and rainfall was found to be negative. In case of maximum and minimum temperature, the correlation was found to be negative but significant at 1% level having r values -0.277 and -0.308 respectively. But the correlation with minimum relative humidity and rainfall was found not to be significant with r values -0.53 and -0.012 respectively.

The host *i.e.,* the availability of whitefly is also an important factor in determining the population build up of the predator. Accordingly, it was found that the host population of both the types of whiteflies played a significant role in the population growth of *M.discolor*. The correlation of the hosts was found to be positive and significant at 1% level. The r value for *D.decempuncta* was 0.47, while that of *A.pentatuberculata* was 0.228.

Further, Multiple linear regression analysis was performed to draw inference related to forecasting the predator population in mulberry eco-system. While studying the effect of the host populations on the predator i.e. *M. discolor*, it was noticed that such effect after 8 weeks was most significant, which means that previous 8 weeks host population tend to influence the population of *M.discolor*. The regression equation for it was found to be

$Y = 0.004 + 0.001x_1 + 0.0001\ x_2$

Where Y = population of *M.discolor*,

x_1 = Population of whitefly, *D.decempuncta*

x_2 = Population of whitefly, *A.pentatuberculata*.

With coefficient of determination,

$R^2 = 0.227664$ ($P=7.34 \times 10^{-9}$).

The regression equation showing the effect of the weather factors of previous 0-6 days is:

$Y = 0.273 + 0.010x_1 - 0.012\ x_2 + 0.001x_3 + 0.002x_4 - 0.001x_5$

Where Y= Population of *M.discolor*,

x_1 = Maximum temperature,

x_2 = Minimum temperature,

x_3 = Maximum Relative Humidity,

x_4 = Minimum Relative Humidity,

x_5 = Rainfall

With coefficient of determination,

$R^2 = 0.1453$ (P=0.000239).

The combined effect of the abiotic factors (previous 0 - 6 days) and the host population (previous 8 weeks) when put into regression equation (Fig.:2) it can be formulated as -

$Y = - 0.242 + 0.006x_1 - 0.007x_2 + 0.010x_3 + 0.001x_4 + 0.0004x_5 + 0.001x_6\ \ 5.378x_7$

Where Y= Population of *M. discolor,*

x_1 = Maximum temperature,

x_2 = Minimum temperature,

x_3 = Maximum Relative Humidity,

x_4 = Minimum Relative Humidity,

x_5 = Rainfall

x_6 = Population of whitefly, *D. decempuncta*

x_7 = Population of whitefly, *A. pentatuberculata*.

With coefficient of determination,

$R^2 = 0.261398$ ($P= 3.11 \times 10^{-7}$)

Table 1: Coefficient of correlation of *M.discolor*, abiotic and whitefly factors

Natural enemy	Max. Temp.	Min. Temp.	Max. R.H.	Min. R.H.	Rainfall	*D.decempuncta*	*A.pentatuberulata*
M. discolor	-0.279**	-0.308**	0.241**	-0.053	-0.012	0.476**	0.228**

* Significant at 5% ** Significant at 1%

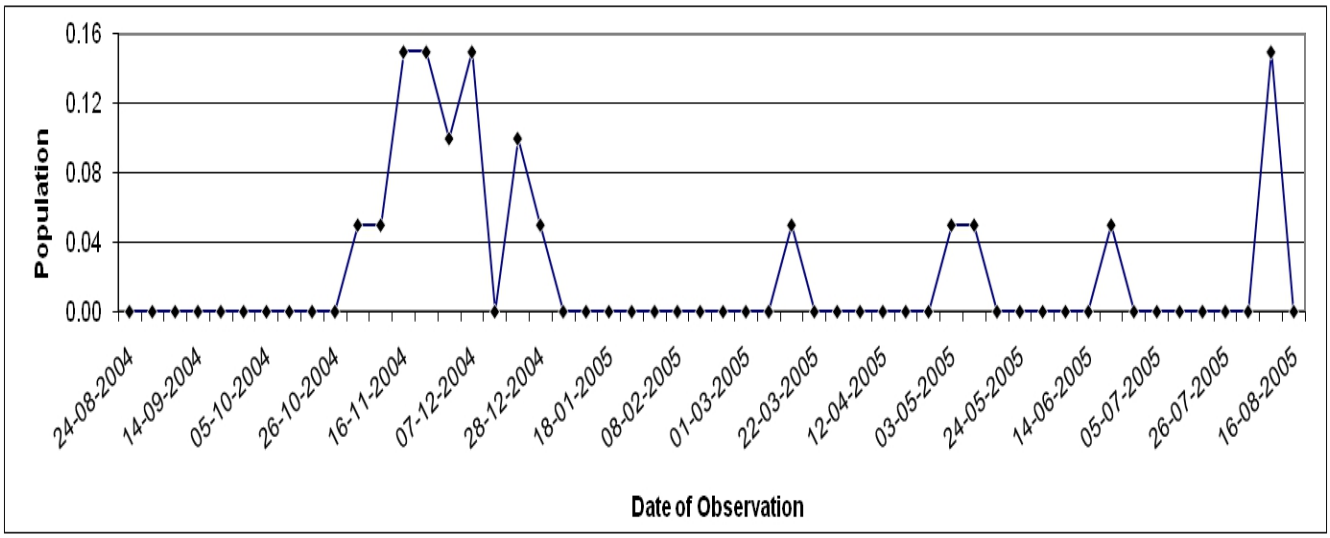


Fig. 1a: Incidence of *M. discolor* (No. / Plant) during 2004-05.

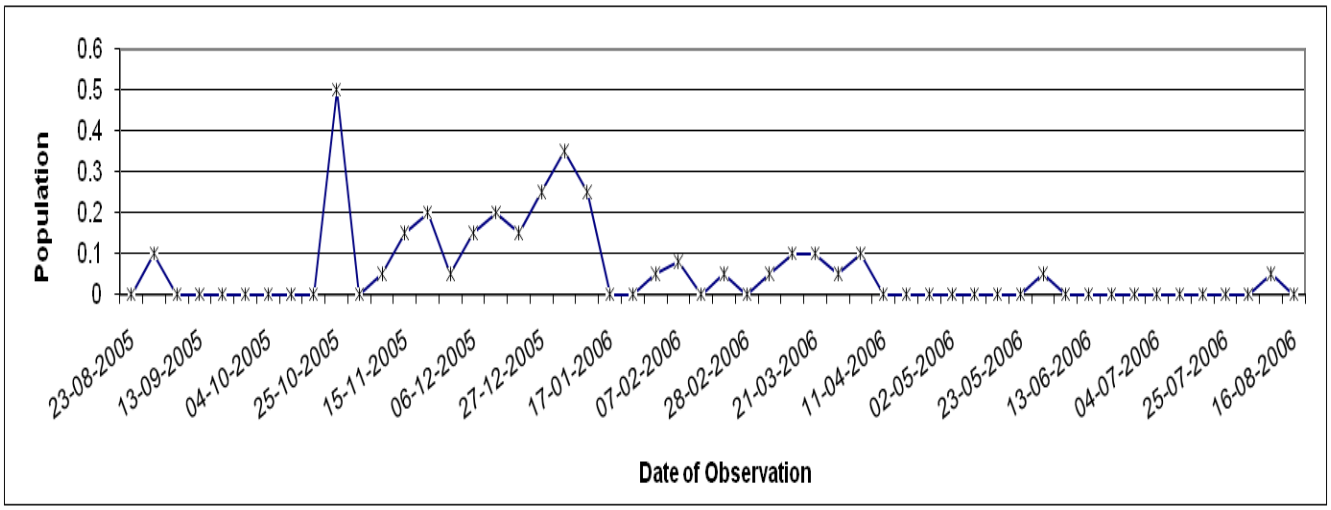


Fig. 1b: Incidence of *M. discolor* (No. / Plant) during 2005-06.

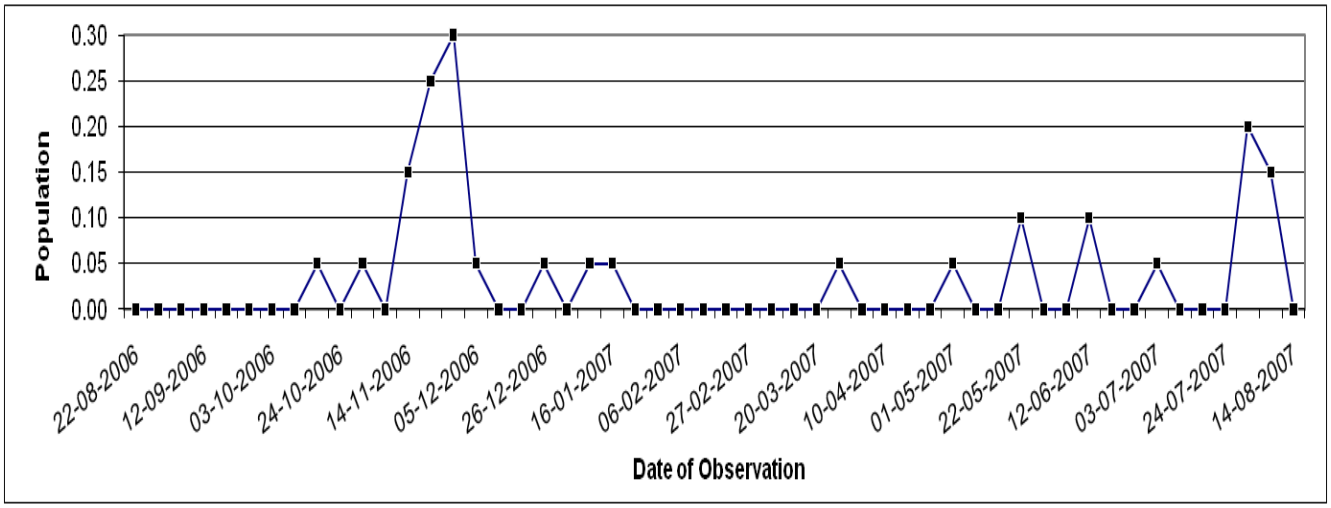


Fig. 1c: Incidence of *M. discolor* (No. / Plant) during 2006-07.

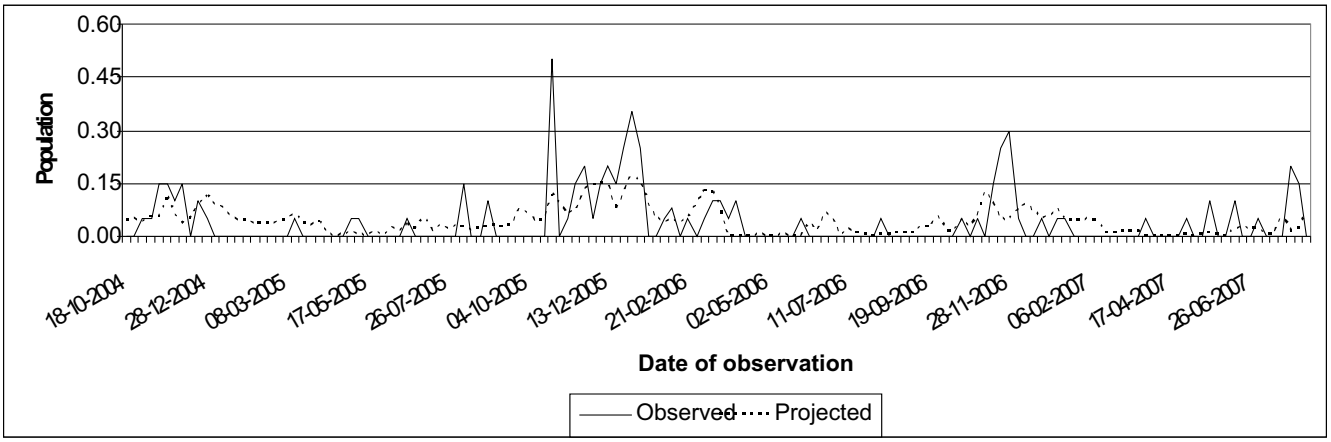


Figure 2: Correlation between seasonal incidence of *M. discolor*, host and abiotic factors.

It can be inferred that meteorological factors of previous 0-6 days and whitefly population of previous 8 weeks are able to influence the population buildup of *M.discolor*. These findings are helpful to the researchers for formulating computerized forecasting models which will be of direct applicability to the extension functionaries in predicting the probable *M.discolor* population during a particular period. Accordingly the extension functionaries will be providing inputs to the policy makers and farming community to take essential steps for mass multiplication of the predator and its inundative release as a prophylactic measure for containing the whitefly population thus preventing the probable outbreaks of this dangerous pest.

ACKNOWLEDGEMENT

Authors are thankful to The Director, Zoological Society of India, Kolkata for making arrangement for identifying the native predator.

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