Silkworm Host Plant Breeding: Trends, Challenges and Future Strategies

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MINISTRY OF
TEXTILES

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Foreword

Silk production in India is intricately linked with the diversity, productivity, and resilience of its host plants. As the backbone of sericulture, mulberry and vanya host plants not only provide the nutritional foundation for silkworm rearing but also determine the quality and scale of silk output. Over the decades, systematic breeding interventions have expanded their adaptability, productivity, and resistance potential, enabling the sericulture sector to meet evolving climatic, ecological, and market challenges. However, with the ambitious national goal of achieving 54,000 MT of silk production by 2030, the need for innovative host plant breeding strategies has become more pressing than ever.

It is against this backdrop that the *Host Plant (Mulberry and Vanya) Breeders' Meet* was convened on 8–9 July 2025 at the CSB-Central Sericulture Research and Training Institute, Mysuru, with the theme *"Innovative Host Plant Breeding Strategies: A Step Towards Doubling Silk Production."* The meet brought together breeders, researchers, administrators and policymakersfrom CSB and state sericulture research institutes, ICAR, and State Agricultural University. The deliberations not only reflected the achievements of host plant improvement but also highlighted the gaps, constraints, and emerging opportunities that must be addressed to sustain sericulture in the future.

This volume, *Silkworm Host Plant Breeding: Trends, Challenges and Future Strategies*, compiles twelve review papers presented during the technical sessions, along with the detailed proceedings of the meeting. It provides critical insights into breeding constraints, field-level challenges faced by farmers, and future breeding strategies. The emerging scope of speed breeding techniques and database-driven selection tools, which hold great promise for accelerating genetic improvement. The recommendations for vanya host plants, emphasizing the enlargement of germplasm resources, identification of productive and resilient germplasm, and integration of biotechnological and phenomic approaches in breeding to enhance genetic gains.

Collectively, the proceedings underscore the pressing need for climate-smart, nutrient-efficient, and pest-resistant cultivars capable of sustaining and strengthening sericulture under dynamic environmental conditions. It is hoped that this compilation will serve as a lasting reference for present and future generations of host plant breeders, guiding them in designing innovative breeding programmes that enhance leaf productivity and quality, while contributing to the sustainable expansion of silk production in the country.

Prof. (Dr.) M. B. Chatti
Vice Chancellor - Sanskriti University

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Message

It gives me immense pleasure to present the book *"Silkworm Host Plant Breeding: Trends, Challenges and Future Strategies"* by the CSB-Central Sericultural Research and Training Institute (CSB-CSRTI), Mysuru, based on Host Plant Breeders' Meet-2025 held on 8th & 9th July, 2025. The meet, with the theme *"Innovative Host Plant Breeding Strategies: A Step Towards Doubling Silk Production"* brought together a distinguished assembly of scientists, plant breeders and policy planners from across the nation to deliberate on the future of host plant improvement in Indian sericulture.

The discussions held during the two-day event reaffirmed that high-quality, climate-resilient, water & nutrient efficiency and pest & disease tolerant host plant varieties are the foundation for enhancing silk productivity and ensuring the sector's sustainability. The deliberations highlighted the critical need to integrate conventional breeding with advanced biotechnological tools, genomics and precision agriculture approaches. Such convergence of innovation and field-level applicability is essential for achieving the ambitious national target of producing 54,000 metric tonnes of raw silk by 2030.

I was particularly encouraged by the commitment shown by our scientific community to farmer-centric research, multidisciplinary collaborations and region-specific varietal development of both mulberry and vanya host plants. The strategies outlined ranging from accelerated breeding cycles to metabolomics-based evaluation will not only strengthen mulberry and vanya host plant improvement programs but also open avenues for value addition in allied sectors such as pharmaceuticals, cosmetics and seri-tourism.

This compilation stands as a valuable reference, capturing the rich exchange of ideas, innovative approaches and actionable recommendations that emerged from the meeting. I trust it will serve as both a guide and an inspiration for researchers, extension workers and policymakers dedicated to advancing Indian sericulture.

I congratulate the organizers, contributors and all participants for their dedicated efforts and I look forward to see those strategies translated into impactful outcomes that benefit our farmers and position India as a global leader in silk production.

Bengaluru,
25.08.2025

P. Sivakumar, IFS
Member Secretary, Central Silk Board

केंद्रीय रेशम बोर्ड
(वस्त्र मंत्रालय – भारत सरकार)
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Message

The Host Plant Breeders' Meet, organized at CSB-CSRTI, Mysuru on 8–9 July 2025, provided a vital platform for researchers, breeders, and stakeholders to assess the ongoing breeding strategies, exchange of research findings, and prepare future directions in seri-based host plant improvement. The event aimed to evaluate current breeding developments to address emerging challenges, and define specific strategic priorities for sustainable host plant development.

The meet brought together plant breeders, researchers, and policymakers from across the country to review progress and align breeding initiatives with the need of the sericulture sector. Mulberry, the food plant for the domesticated silkworm (*Bombyx mori*), remains primary for India's silk production. Breeders showcased mulberry varieties developed for higher yield and quality, stress tolerance and disease management. Emphasis was made on multi-location trials, molecular breeding, and accelerating germplasm evaluation to suit diverse agro-climatic zones. The adoption of advanced tools such as marker-assisted selection and genomic-assisted breeding was highlighted as a key driver for next-generation mulberry improvement.

Equal attention was also given to Vanya host plants - including *Terminalia* spp. (for tasar), *Shorearobusta* and *Quercus* spp. (for oak tasar), as well as castor and tapioca (for eri silkworms). Deliberations focused on conserving wild germplasm, overcoming domestication challenges, and developing varieties suited for plantation-based rearing systems. The urgent need for coordinated, field-based screening and selection was recognized to bridge the gap between research outcomes and field application.

The meet concluded with a shared commitment for strengthening collaborative breeding networks, improving farmer access to quality planting material, and aligning breeding objectives with climate resilience and silkworm nutrition.

The book entitled "*Silkworm Host Plant Breeding: Trends, Challenges and Future Strategies*", consolidate the progress in breeding, key challenges, and strategies for host plant improvement along with the proceedings of the Host Plant Breeder's Meet-2025, will serve as a valuable reference for the new generation of breeders embarking on fresh research projects in this field. I extend my congratulations to the authors and the editorial for successfully bringing out this comprehensive volume in a short span of time.

Bengaluru,
22.08.2025

Dr. S. ManthiraMoorthy
Director (Tech.), Central Silk Board, Bengaluru

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(वस्त्र मंत्रालय – भारत सरकार)
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Message

Sericulture, an agro-based cottage industry, has proven to be a strong driver of inclusive rural development. India is the only country producing all five commercial silk varieties, with a rich heritage of weaving exquisite fabrics. Through technological innovations from its research institutes and extensive extension programs, the Central Silk Board (CSB) has elevated sericulture from a livelihood activity to a major commercial sector, empowering farmers and strengthening the Indian silk industry.

High-yielding mulberry and vanya host plant varieties, authorized by CSB, with leaf yield of 60–65 MT/ha/year (mulberry) and 25–30 MT/ha/year (vanya), playing a pivotal role in improving silk quality and productivity.

The Host Plant Breeders Meet – 2025 (Mulberry & Vanya), with theme *“Innovative Host Plant Breeding Strategies: A Step Towards Doubling Silk Production”*, has been designed in line with CSB’s vision of becoming a global leader in sericulture. It will serve as a platform for experts, policymakers, stakeholders, and plant breeders to exchange ideas on enhancing productivity, sustainability, and climate resilience through advanced breeding approaches.

This book, “Silkworm Host Plant Breeding: Trends, Challenges and Future Strategies” provide a synoptic overview of breeding strategies, integrating biotechnology, genomics, data science, and phonemics’ for host plant improvement, and highlights the latest varieties developed for mulberry and vanya sericulture. The meet and its outcomes are expected to accelerate host plant improvement programs, contributing significantly to the national goal of doubling silk production**.**

Bengaluru,
25.08.2025

Dr. NareshBabu N. IFS
Joint Secretary (Technical)
Central Silk Board, Bengaluru

केंद्रीय रेशम उत्पादन अनुसंधान एवं प्रशिक्षण संस्थान
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Berhampore - 742101 (West Bengal)

Message

India is the largest consumer of silk and silk-related products, where silk is deeply woven into the country's culture, traditions, and heritage. The diverse cultural and artistic expressions across India are reflected in the variety of silk products and designs. India is uniquely blessed with four major types of silk - Mulberry, Eri, Tasar (tropical and temperate), and Muga - each possessing distinct characteristics and commanding its own niche market globally.

Mulberry silkworm (*Bombyx mori*) is monophagous, feeding exclusively on Morus spp., whereas Vanya silkworms, reared predominantly in forested regions on naturally grown or cultivated host plants, are polyphagous, though they exhibit distinct feeding preferences. Based on these preferences, Vanya silkworm food plants are classified as primary, secondary, and tertiary. Primary food plants of tropical tasar silkworm Antheraeamylitta include *Terminalia arjuna*, *T. tomentosa*, and *Shorearobusta*; for temperate tasar silkworms (*A. proylei*, *A. pernyi*, and *A. roylei*), primary hosts are *Quercusserrata*, *Q. griffithii*, *Q. incana*, *Q. semecarpifolia*, and *Q. himalayana*; for muga silkworm *A. assamensis*, *Perseabombycina* and *Litseamonopetala* serve as the main hosts; and for eri silkworm *Samiaricini*, *Ricinuscommunis* and *Heteropanaxfragrans* are preferred. The productivity and quality of silk are directly linked to the leaf productivity and quality of these host plants.

Sustained breeding efforts have been undertaken across CSB institutes to enhance the genetic potential of both mulberry and Vanya host plants. In mulberry sector, several high-yielding region-specific mulberry varieties have been developed by CSB-CSRTI, Mysuru; CSB-CSRTI, Berhampore; and CSB-CSRTI, Pampore, to suit tropical, subtropical, and temperate regions, respectively. Since inception of CSB-CSRTI, Mysuru, in the year 1961, due to continuous breeding interventions, the leaf yield potential has increased from 18–20 MT/ha/year in the Mysuru Local variety to 60–65 MT/ha/year in improved varieties such as V1, G4, and AGB8. The V1 variety, released in 1997, now occupies over 96% of the mulberry cultivation area in South India.

As far as Vanya host plants are concerned, CSB-CTRTI Ranchi, and CSB-CMERTI Lahdoigarh, have made significant progress in germplasm collection, characterization, and utilization to improve leaf yield and nutritional value.

Against this backdrop, the Host Plant (Mulberry and Vanya) Breeders' Meet, with the theme "Innovative Host Plant Breeding Strategies: A Step Towards Doubling Silk Production", was organized on 8–9 July 2025 at the CSB-Central Sericulture Research and Training Institute (CSB-CSRTI), Mysuru. The meet brought together scientists from the Central Silk Board and other research organizations, retired expert seri-host plant breeders, eminent experts from ICAR and State Agricultural University, Directors of CSB institutes, and administrators of CSB to review breeding progress, share experiences, discuss cultivation and breeding constraints, and chart future strategies for host plant improvement.

The technical sessions comprised ten presentations and two panel discussions, covering both mulberry and Vanya host plants. Deliberations focused on advances in mulberry breeding for different sericulture zones of India, germplasm management, and speed breeding approaches to shorten varietal development cycles; the need for climate-resilient, nutrient-efficient, and pest-resistant varieties; and the importance of broadening the gene pool of Vanya host plants through extensive germplasm collection and characterization. The integration of modern biotechnological and phenomic tools with conventional breeding was highlighted as a pathway to accelerate genetic gain in seri-host plants.

The present book, "*Silkworm Host Plant Breeding: Trends, Challenges and Future Strategies*", compiles twelve comprehensive review papers focusing on progress made in silkworm host plant breeding, biotechnological interventions, and rootstock breeding approaches in fruit species, with special emphasis on their applicability to host plants. These papers were presented during technical sessions, accompanied by the minutes and recommendations of the meeting. The content highlights key breeding achievements in mulberry and vanya host plants, germplasm conservation and characterization, explores the constraints encountered in varietal development and field cultivation, and outlines forward-looking strategies that integrate modern biotechnological tools with conventional breeding methods.

It is envisaged that this compendium will serve as a valuable reference for present and future generations of host plant breeders in designing innovative and effective breeding programmes aimed at enhancing leaf productivity and quality, thereby contributing to sustained growth in silk production. I extend my sincere appreciation to the authors, and contributors, editorial team for their dedicated efforts in bringing out this comprehensive volume within a short time frame.

Dr. S. Gandhi Doss
Director, CSB-CSRTI
Berhampore

Berhampore
24th August 2025

केंद्रीय रेशम उत्पादन अनुसंधान एवं प्रशिक्षण संस्थान
केंद्रीय रेशम बोर्ड, वस्त्र मंत्रालय, भारत सरकार
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Preface

India stands as the world's largest consumer of silk and silk-based products, where silk holds a significant place in the nation's cultural, traditional, and heritage fabric. The rich variety of silk products across the country reflects its diverse artistic expressions, supported by four major types of silk – Mulberry, Eri, Tasar (tropical and temperate), and Muga – each distinguished by unique properties and catering to specialized markets globally. The yield and quality of silk are fundamentally linked to the productivity, and nutritional value of both mulberry and Vanya host plants essential for silkworm rearing.

CSB-CSRTI Mysuru, together with CSB-CSRTI Berhampore, CSB-CSRTI Pampore, CSB-CTRTI Ranchi, and CSB-CMERTI Lahdoigarh, have been dedicated to advancing the genetic improvement of host plants through continuous breeding programs. CSB-CSRTI Mysuru has developed a number of high-performing, region-adapted mulberry varieties such as V1, G4, and AGB8, boosting leaf yield from 18–20 MT/ha/year to 60–65 MT/ha/year. The V1 variety, introduced in 1997, presently accounts for over 96% of mulberry cultivation in South India. At the same time other institutes also have made notable achievements in the mulberry variety development, collection, evaluation, and utilization of Vanya host plant germplasm, aimed at improving both leaf production and nutritional quality to support sustainable silkworm rearing.

In this context, the Host Plant (Mulberry and Vanya) Breeders' Meet, with the theme "Innovative Host Plant Breeding Strategies: A Step Towards Doubling Silk Production", was convened on 8–9 July 2025 at CSB-CSRTI, Mysuru. The event brought together scientists, experts, representatives from ICAR and Agricultural Universities, Directors of research institutes, and policymakers, to comprehensively deliberate on emerging challenges, and chart out future research and developmental strategies.

Technical sessions included ten presentations and two panel discussions covering advances in breeding, germplasm management, speed breeding, and the integration of modern biotechnological tools with conventional breeding to accelerate genetic gains.

This volume, "*Silkworm Host Plant Breeding: Trends, Challenges and Future Strategies*", compiles twelve review papers and meeting proceedings. It serves as a valuable reference for developing innovative breeding programs aimed at improving leaf productivity and sustaining growth in silk production. My appreciation goes to all contributors and the editorial team for their dedicated efforts in producing this publication.

Mysuru
6th September, 2025

Dr. P. Deepa
Director, CSB-CSRTI Mysuru

Editors' Preface

It gives us immense pleasure to present the book, "*Silkworm Host Plant Breeding: Trends, Challenges and Future Strategies*" a compilation based on the *Silkworm Host Plant (Mulberry & Vanya) Breeders' Meet-2025*, organized at CSB-CSRTI, Mysuru. This book brings together the collective wisdom, experiences, and outcomes of dedicated researchers and breeders who are working tirelessly to advance mulberry and vanya host plant improvement.

Sericulture continues to be a vital source of livelihood security and rural empowerment in India, with mulberry and non-mulberry host plants forming the backbone of the industry. The Host Plant Breeders' Meet-2025 was successfully organized by the CSB-Central Sericultural Research and Training Institute (CSRTI), Mysuru, on the 8th and 9th of July 2025. The deliberations at this meet revolved around breeding achievements, evaluation of germplasm resources, adoption of biotechnological tools, and future breeding strategies to address the growing challenges of climate change, soil constraints, pest and disease pressures, and the rising demand for sustainable silk production.

These proceedings capture in detail the latest developments across the tropical, sub-tropical, and temperate zones in mulberry breeding for irrigated, rainfed, and stress-prone environments, as well as new initiatives for breeding and enhancing the productivity of vanya host plants. This volume highlights the collaborative spirit of our research community and underscores the importance of integrating classical breeding with cutting-edge genomic, phenomic, and biotechnological tools.

We firmly believe that this volume will serve as a valuable reference for researchers, academicians, students, extension workers, and policy planners engaged in sericulture. It will also inspire future research directions aimed at developing resilient, high-yielding, and farmer-friendly varieties of host plants to ensure the sustainability and profitability of the silk industry.

We take this opportunity to acknowledge the contributions of all the authors, participants, and organizing team members who made this event and its documentation possible. Their commitment to scientific rigor and innovation is evident throughout the proceedings.

We are confident that this book will enrich the knowledge base of plant breeders of sericulture science and serve as a guiding resource for the next generation of breeders and stakeholders in the silk sector.

Editors

Mysuru
8th October, 2025

Contents

HOST PLANT BREEDING - FOUNDATION FOR COCOON PRODUCTION, FARMER'S INCOME AND FUTURE OF SERICULTURE

Dr. S. B. Dandin
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Respected dignitaries, esteemed colleagues, researchers, research scholars, extension workers, ladies and gentlemen;

It is my privilege to deliver this keynote address on a subject that forms the very foundation of sericulture - the role and improvement of host plants in ensuring the economics of cocoon production, farmer income, and the long-term sustainability of the silk industry. While sericulture is a multifaceted enterprise, involving science, technology, and skill, the success of the entire activity rests upon one crucial factor - the quality, sustainability, and continuous improvement of the host plant.

1. Introduction

Sericulture is among the oldest agro-based industries, providing livelihood security to millions of rural families across Asia, particularly in India. Unlike other agricultural activities, it is unique because silkworm rearing depends entirely on the host plant for its nutrition. For mulberry silkworm (*Bombyx mori*), mulberry leaves are the sole food. While non-mulberry silkworms like tasar, eri, and muga are polyphagous, they prefer to feed on a few specific plant species (primary food plants). Thus, the quantity, quality, and year-round availability of host plant leaves directly determine cocoon production and farmer profitability. It is rightly said: *"No leaves, no cocoons, no silk."*

2. Host Plant Role in Economics of Cocoon Production

Host plants are perennial resources that involve considerable initial establishment and maintenance costs, but they remain the most decisive factor in sericulture economics. Leaf quality and yield determine the number of disease-free layings (DFLs) brushed and cocoon output. The frequency of harvests dictates annual productivity and farmer income, while leaf nutrition and moisture directly influence silkworm health, cocoon weight, and filament quality. Recycling of farm waste and by-products also creates opportunities for value addition and diversified income.

3. Factors Affecting Cocoon Yield and Quality

Scientific assessments indicate that cocoon yield and quality depend mainly on leaf quality (38%) and the environmental factors (37%). Leaf quality itself is largely determined by mulberry variety (50%), with inputs such as water, manures, and fertilizers accounting for 35%, and crop protection from pests and diseases contributing 15%. This clearly demonstrates that genetic improvement of host plants has the single greatest impact in enhancing sericulture productivity.

4. Breeding Objectives to Evolve Superior Mulberry Varieties

The key objectives of mulberry breeding include improving leaf yield and quality in productive areas, developing varieties with drought and stress tolerance, evolving adaptable varieties suitable for non-conventional regions, and incorporating resistance against root rot, root knot, and major pests such as leaf folder, thrips, mites, and jassids.

5. Genetic Diversity in Mulberry

The genus *Morus* was established by Linnaeus in 1773 with six species; today, nearly 70 species are reported. Its distribution is multicentric, spanning four continents and ranging from sea level to ~4,000 meters in altitude, across diverse ecosystems from dry deciduous forests to tropical rainforests and temperate regions. Some species grow up to 200 feet with girths of 8–10 meters. Mulberry is renowned worldwide for several remarkable features. It was the first species through which sex in plants was demonstrated by Camerarius in 1694. The oldest known angiosperm tree, *Morus serrata* ($2n = 6x = 84$), around 4,000 years old, stands in Joshi Matt, Gopeshwar, Chemoli District of Uttarakhand, India. *M. nigra* possesses the highest chromosome number ($2n = 308$) among angiosperm trees. The genus also shows extraordinary variability in habit, habitat, morphology, and sex expression, making it a breeder's wealth for trait improvement. Moreover, it is one of the fastest-growing tree species among dicotyledonous angiosperms.

To conserve mulberry biodiversity, extensive germplasm collections have been established across the world. Major holdings include China (2,600 accessions), Japan (1,375), and India (1,317), which together represent the largest global repositories. Other countries also maintain valuable collections: South Korea (208), Bulgaria (140), France (70), Italy (50), and the USA (23). Smaller but significant collections exist in Colombo (4), Mexico (5), Peru (2), Argentina (2), Indonesia (5), and Taiwan (2). These germplasm banks serve as vital resources for breeding programs, conservation of genetic diversity, and future crop improvement.

6. Strengths and Biological Importance of Mulberry

Mulberry plays multiple roles beyond sericulture. It provides all four "F's" of human need – food, fodder, fuel, and fiber/timber. It is amenable to various growth forms and pruning systems and supports vegetative propagation, making multiplication easy. Most importantly, it forms the basis of the silk industry, directly influencing farmer income and national silk production.

7. Progress in Mulberry Breeding

Indian research institutions have made remarkable progress in mulberry host plant improvement. CSB-CSRTI, Mysuru developed superior mulberry varieties suited to different conditions, such as Kanva-2, S54, S36, V1, and G4 for irrigated regions; Kanva-2, S13, S34, and MSG2 for rainfed or moisture-stress conditions; S36 and G2 for chawki rearing; AR12 for alkaline soils; RC1 and RC2 for resource-constrained areas; and Sahana for intercropping with coconut plantations. These were developed through clonal selection, hybridization, open-pollinated hybrids, polyploidy, and mutation breeding. Over the decades, leaf productivity has improved substantially, from 20 to 65 MT/ha/year under irrigated conditions, along with enhanced leaf quality.

CSB-CSRTI, Berhampore has developed varieties for eastern and north-eastern India. For irrigated regions, S-1, S-799, and S-1635 were released; for saline soils, C776; for the hills of Jammu & Kashmir, S-146; and for the eastern hills, Tr-10 and BC-259. Yield gains in the Indo-Gangetic irrigated plains were significant, with varieties improving progressively from Kajli (9.8 MT/ha/yr) and Bombai (14.9) to S1 (28.6), S1635 (44.6), and C2038 (53.8). In rainfed, water-stress areas of eastern India, Kajli (8.0), S1 (9.0) and C1730 (14.3) were superior, while in hilly regions, Kosen (4.2), BC259 (8.7) and Tr23 (11.2) were found suitable.

CSB-CSRTI, Pampore developed region-specific varieties, namely Goshoerami for temperate conditions and Chakmajra for sub-temperate regions. Besides CSB institutes, the Karnataka State Sericulture Research and Development Institute (KSSRDI), Thalaghattapura, developed important varieties such as Viswa, Vishala (TR-4), Suvarna-1, Suvarna-2, and Suvarna-3 for different zones of Karnataka. Adaptability trials under the All India Coordinated Experiment on Mulberry (AICEM) confirmed the suitability of these varieties across the Indo-Gangetic plains, rainfed eastern India, and hilly regions. Continuous varietal replacement and adoption have resulted in a 20–30% increase in cocoon yield for farmers.

In other sericulture countries too, breeding programs have produced several promising mulberry varieties. In China, important varieties include He Tian Bai Sam, Daji Guan, Hei Lu Cai Sang, Xuan 972, Niu Gen Sang, Hei Ge Lu Tong Xiang Qing, Hong Chang

Sang, Hu Sang 197, Hu Sang 199, Huo Sang, Nong Sang 8, Yu 2, Zhong Sang 5801, Hong Pi Wa Sang, Hei You Sang, Da Hua Sang, Xiao Guan Sang Jia Ling-16, Guangdong Jing Sang, Lun 40, Lun 109, Sha 2, Da 10, Kang Qingio, Yun Sang 2, and Dao Zhen Sang. In Japan, promising varieties include Ichinose, Ichei, Kenmochi, KNG Minamisakai, Hayate Sakari, Mitsuminami Hinosakari, and Sin-Ichinose. In Thailand, improved varieties are BR-8, BR-4, BR-60, Noi Local, Kun Pai, Thaipecha, and Thai Beelad. In Vietnam, varieties such as Baulack and Thau Sang are cultivated, while in Brazil, varieties including Fernodias, Miura, Issaokina, Caupucha, Campinas, Luiz Paoleri, Rio da Pedras, Rosa da Fonesca, Sempra Verde, Tumarina, and Javanesa have been developed.

8. Pre-Requisites for Crop Improvement

Successful crop improvement programs must include exploration and collection of germplasm, introduction of exotic material, selection of promising types, hybridization and inter-mating for heterosis, mutation breeding, polyploidy induction, and application of biotechnological tools such as tissue culture and genetic transformation. These efforts are followed by multi-stage testing including Preliminary Yield Trials (PYT), Final Yield Trials (FYT), and Multi-Location Trials under AICEM. Finally, a seed multiplication chain comprising nucleus, breeder, foundation, and certified seed ensures large-scale dissemination of improved varieties.

9. Biotechnological Approaches and Future Strategies

Future breeding strategies must integrate modern biotechnology with conventional breeding. This includes evolving drought- and pest-resistant varieties, using marker-assisted selection (MAS) and QTL mapping, sequencing and annotating the mulberry genome, discovering SNPs for linkage mapping, undertaking genetic transformation of elite varieties, and biofortifying mulberry leaves to enhance nutritive value.

10. Challenges in Host Plant Breeding and Management

Despite significant progress, challenges remain. Climate change-related stresses such as drought and heat, newly emerging pests and diseases like mites, thrips, leaf roller, jassids, and root rot, soil degradation and nutrient deficiencies, fragmented landholdings restricting large-scale plantations, and weak propagation and dissemination systems continue to limit productivity.

11. Strategies for the Future

To overcome these challenges, it is essential to conserve and utilize the genetic resources of mulberry and vanya hosts, develop region-specific ideotypes with stress resistance, and establish network projects across all CSB institutions. Organizing breeders' meets every 3–5 years will facilitate collective progress. Systematic documentation, naming, and PPV&FRA registration of new varieties should be ensured. Building the capacity of next-generation scientists in genomics, molecular breeding, and conventional approaches, along with securing long-term funding, will be critical for sustained crop improvement.

12. Conclusion

In conclusion, host plants are not just supporting resources but form the very foundation of sericulture. The economics of silk production are inseparable from the economics of host plant breeding and management. While conventional breeding will remain the backbone of varietal development, molecular tools, genomics, and biotechnological interventions will accelerate precision breeding, broaden the genetic base, and build resilience against biotic and abiotic stresses. A multidisciplinary and coordinated approach will be the key to success. Strengthening our host plant base will ensure that sericulture continues to thrive, providing sustainable livelihoods, rural employment, and contributing significantly to the national economy. Indeed, *mulberry feeds millions – let us adopt it for prosperity.*

Thank you.

MULBERRY IMPROVEMENT FOR TROPICAL SERICULTURE: PRESENT STATUS, CHALLENGES AND FUTURE STRATEGIES

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Abstract

Mulberry (*Morus* spp.), the exclusive food source for the silkworm (*Bombyx mori* L.), plays a pivotal role in the socio-economic development of sericulture stakeholders. However, its productivity and leaf quality are often constrained by various biotic and abiotic stresses. These challenges have been addressed through sustained breeding efforts, resulting in the release of several mulberry varieties by the institute tailored to diverse agro-climatic conditions of the southern zone. Notable varieties include those suited for irrigated conditions (V1, G4, AGB8), rainfed and soil moisture stress environments (S13, S34, MSG2), limited input systems (RC1, AGB8), alkaline soils (AR12), coconut-based intercropping systems (Sahana), and chawki rearing (G2). Mulberry breeding is inherently slow due to its perennial nature and high heterozygosity, typically requiring 15–20 years for varietal development. To overcome these constraints, the integration of speed breeding strategies and precision phenotyping tools is essential to reduce breeding cycles and enhancing selection efficiency. This base paper reviews the historical breeding achievements, ongoing research initiatives, current limitations, and future directions aimed at improving mulberry productivity and quality to meet the growing demands of the silk industry.

Key words: breeding, germplasm evaluation, mulberry, polyploidy, V1 variety

Introduction

Mulberry sericulture is an important source of livelihood in India, significantly contributing to the socio-economic upliftment of its stakeholders. Unlike other cash crops, including horticultural crops, it offers quick returns within a short period. Mulberry (*Morus* spp.) is the sole food source for the silkworm (*Bombyx mori* L.) and belongs to the Moraceae family, which comprises 37 genera. The genus *Morus* includes over 60 species, of which five are sericulturally important: *M. indica*, *M. alba*, *M. bombycis*, *M. sinensis*, and *M. multicaulis*.

Mulberry is a perennial, cross-pollinated tree species characterized by a high level of heterozygosity. It exhibits wide adaptability and high phenotypic plasticity, enabling it to grow under diverse conditions – ranging from tropical to temperate climates, acidic to alkaline soils, low to high altitudes, rainfed to irrigated environments, and in forms varying from bush to tree. *Morus* spp. displays a wide range of ploidy, from haploid ($n = x = 14$) to decosaploid ($2n = 22x = 308$). Silkworm rearing depends directly on the constant supply of quality leaves, and the mulberry variety alone contributes about 50% towards cocoon production.

In India, mulberry is cultivated over 2.61 lakh hectares, producing 31,119 MT of raw silk (CSB, 2024–25). The majority of mulberry cultivation occurs in the tropical zone – mainly in Karnataka, Andhra Pradesh, Tamil Nadu, Telangana, and Maharashtra – which together account for about 90% of the total area under mulberry. In the sub-tropical and temperate zones, major cultivation areas include West Bengal, Himachal Pradesh, Jammu & Kashmir, and the north-eastern states.

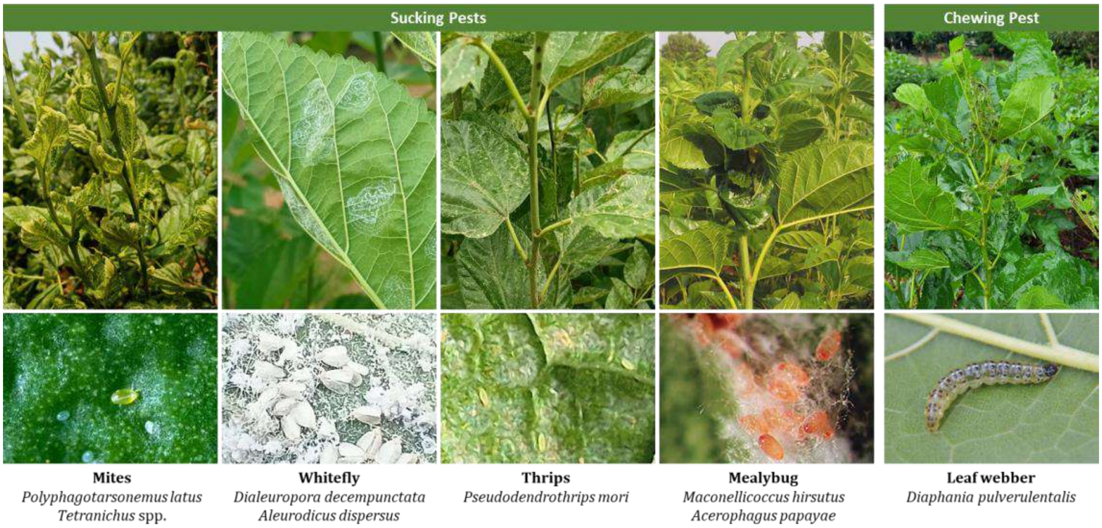
Mulberry trees are capable of producing high biomass within a short period (70 days) under cultivation, offering a distinct advantage for sericulture. The primary objective of mulberry breeding in tropical sericulture is to develop varieties with high leaf yield and superior quality. To achieve this, breeders focus on improving yield and quality traits, such as plant vigour, ideal plant type (ideotype), early sprouting, delayed senescence, high moisture retention capacity, high harvest index, rooting ability, and resistance or tolerance to biotic and abiotic stresses. In tropical regions, farmers cultivate mulberry year-round, typically taking five crops per year.

Mulberry breeding efforts in India gained momentum after the establishment of research institutes such as CSB-CSRTI Mysuru, CSB-CSRTI Berhampore, and CSB-CSRTI Pampore. Before this, sericulture relied on traditional (desi) varieties like 'Mysuru Local' (Naati Kaddi) in the South Zone, which had a low yield potential – 4–5 MT/ha/year under rainfed conditions and 18–20 MT/ha/year under irrigation – with poor leaf quality (thin, lobed leaves with low moisture content and retention capacity). Consequently, farmers had a limited rearing capacity and had to feed silkworms frequently (~4–5 times per day) due to poor leaf moisture retention.

Continuous breeding efforts by R&D institutes have led to the development of high-yielding mulberry varieties with improved leaf quality. Yield potential has increased nearly threefold (60–65 MT/ha/year for V1 and G4 under irrigated conditions) and fourfold under rainfed conditions (22–23 MT/ha/year for MSG2). Improved leaf quality has also reduced the feeding frequency to about twice a day. This progress has enabled farmers to enhance their rearing capacity and has made sericulture a more attractive occupation.

CSB-CSRTI Mysuru has developed various promising mulberry varieties using diverse breeding methods, including open-pollinated hybrid selection (Kanva-2, RFS-135, RFS-175, S-13, S-34), controlled-pollinated hybrids (V1, G4, G2, RC1), polyploidy breeding (AR12), mutation breeding (S36), and advanced generation breeding (AGB8). These varieties cater to different farming conditions: irrigated (V1, G4), rainfed (S12, S34), alkaline soil (AR12), soil moisture stress (MSG2), limited input conditions (RC1, AGB8), shade tolerance (Sahana), and specific rearing stages such as chawki (G2) and late age rearing (G4). Additional promising varieties have been developed by the Karnataka State Sericulture Research and Development Institute (KSSRDI), Thalagattapura (Vishala, Suvarna-2, Suvarna-3), and the Department of Sericulture, Tamil Nadu (MR2). Different varieties respond differently to inputs to achieve their maximum genetic yield potential.

Despite the availability of promising mulberry varieties, mulberry gardens in the southern zone face increasing challenges from biotic and abiotic stresses. In recent years, the crop has been severely affected by pests such as mites (*Polyphagotarsonemus latus*, *Tetranychus* spp.), thrips (*Pseudodendrothrips mori*), whitefly (*Dialeuropora decempuncta*, *Tetraleurodes mori*), pink mealybug (*Maconellicoccus hirsutus*), and leaf folder (*Diaphania pulverulentalis*) (Fig. 1), as well as snail damage in some areas. These sucking pests can cause up to 70% crop loss and render the leaves unsuitable for silkworm rearing, particularly during non-rainy seasons when pest infestations peak (Table 1).



Mites *Polyphagotarsonemus latus* *Tetranichus spp.*

Whitefly *Dialeuropora decempunctata* *Aleurodicus dispersus*

Thrips *Pseudodendrothrips mori*

Mealybug *Maconellicoccus hirsutus* *Acerophagus papayae*

Leaf webber *Diaphania pulverulentalis*

Fig. 1: Mulberry plants expressing symptoms caused by different pests

Mulberry is being affected with both foliar (leaf spot, rust and powdery mildew) and soil borne (root rot and root knot nematode) diseases (Figure 2), in which soil borne diseases are causing more loss. Root rot disease has also been reported with high severity across the southern zone, causing wilting and death of plants, which can eventually devastate entire plantations if left unmanaged. Similarly, root-knot nematode infestations lead to stunted plant growth due to root gall formation, significantly reducing yield. Because these soil-borne diseases are recurrent, their management adds to production costs. Developing resistant and high-yielding mulberry varieties is the most sustainable, eco-friendly, and economical solution to address these issues.

Table 1: Major pests of mulberry, damage and season of occurrence

Pest	Type of Damage	% Damage	Season
Leaf Webber	Leaf rolling, feeding	10-40	Monsoon (Jun-Dec)
Mealybug (Tukra)	Shoot malformation	10-30	Summer/Post-monsoon
Thrips	Leaf curling, streaks	15-30	Feb-May
Whitefly	Sooty mold, yellowing	10-30	Humid/Warm
Mites	Leaf curling, small leaf	40-70	Throughout year

Although several mulberry varieties have been developed to suit specific soil, climatic conditions, and farming needs, farmers often indiscriminately cultivate a single variety across all soil types and environments. This practice leads to low productivity in non-recommended soils and under unsuitable growing conditions.

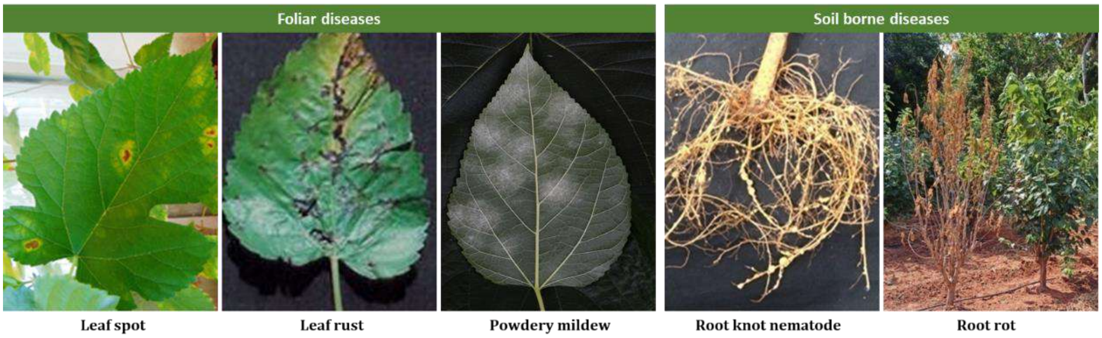


Fig. 2: Mulberry plants expressing symptoms of foliar and soil borne diseases
(Source: Arunakumar G. S.)

Based on physiography, bio-climate, soil characteristics, and the length of the growing period (LGP), India has been divided into 20 agro-ecological regions by the ICAR–National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS&LUP). Each region exhibits fairly uniform climatic conditions, landforms, and soil properties, which facilitate the transfer of agro-technologies and crop planning. Ecological features and constraints observed in each agro-ecological regions of South Zone are described in Table 2 and Fig. 3.

In this context, it is necessary to develop mulberry varieties specifically suited to these agro-ecological regions to enhance productivity.

Table 2: Agro-ecological regions of South zone and their characteristic features.

Region Code	Agro-ecological region	Places	Ecological features/constraints
3	Deccan Plateau, Hot Arid Eco-Region	Bellary, SW parts of Vijayapura and Raichur of Karnataka and Anantapur of Andhra Pradesh	▪ Hot and dry summer and mild winter. ▪ Erratic rainfall (400 to 500 mm), ▪ Severe drought ▪ LGP, < 90 days ▪ Alkaline and calcareous black soil
6	Deccan Plateau, Hot Semi-Arid Eco-Region	Deccan plateau, comprising most of the central and western parts of Maharashtra, northern parts of Karnataka and western parts of Andhra Pradesh.	▪ Hot and humid summer and mild and dry winter. ▪ Prolonged dry spells. ▪ Annual rainfall 600-1000 mm. ▪ LGP, 90-150 days. ▪ Soils are loamy and clayey
7	Deccan Plateau (Telangana) And Eastern Ghats, Hot Semiarid Ecoregion	Deccan plateau (Telangana) and major parts of Eastern Ghats of Andhra Pradesh	▪ Hot and moist summer and mild and dry winter ▪ Annual rainfall 600-1100 mm. ▪ LGP, 90-150 days. ▪ Red and Black (alkaline) soils ▪ Prolonged dry spells
8	Eastern Ghats And Tamil Nadu Uplands And Deccan (Karnataka) Plateau, Hot Semiarid Eco-Region	Eastern Ghats, southern parts of Deccan plateau, Tamil Nadu uplands, and western parts of Karnataka	▪ Hot and dry summer and mild winter ▪ Rainfall-600 to 1000 mm ▪ LGP - 90 - 150 days ▪ Soil is deficient in N, P and Zn
10	Central Highlands (Malwa and Bundelkhand), Hot Subhumid (Dry) Ecoregion	Malwa plateau and Bundelkhand uplands including Baghelkhand plateau, Narmada valley, Vindhyan scarplands and northern fringe of Maharashtra plateau	▪ Hot summer and mild winter ▪ Rainfall increasing trend towards east (1000-1500 mm). ▪ LGP, 150-180 days. ▪ Deficiency of N, P and Zn in soils
18	Eastern Coastal Plain, Hot Sub-humid to Semiarid Ecoregion	South-eastern coastal plain, extending from Kanyakumari to Gangetic Delta.	▪ Semiarid to sub-humid conditions ▪ Rainfall, 900-1100 mm (TN & AP); 1200-1600 mm (OS & WB) ▪ LGP, 90-210 days. ▪ Coconut is a dominant plantation crop of the region

			▪ Soil salinity (and sodicity at places) ▪ Prone to cyclone during monsoon
19	Western Ghats And Coastal Plain, Hot Humid-Perhumid Eco-Region	Sahyadris, western coastal plains of Maharashtra, Karnataka and Kerala States, including Nilgiri hills of Tamil Nadu.	▪ Hot and humid summer and warm winter ▪ Rainfall >2000 mm ▪ LGP, 90-210 days. ▪ Red and Lateritic Soils ▪ Steep slope, waterlogging

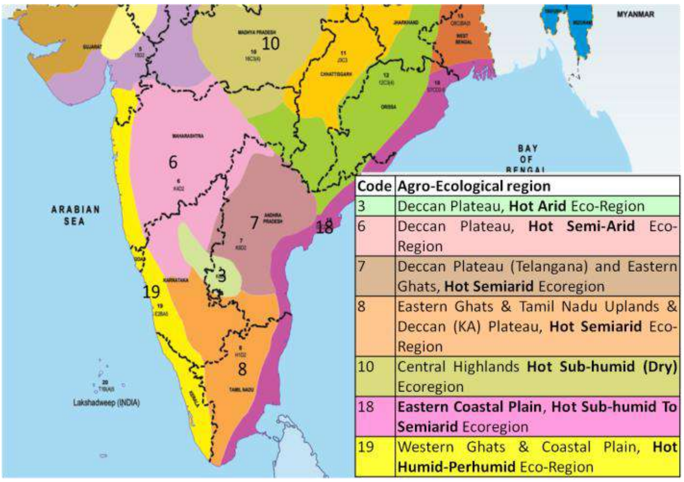


Fig. 3: Agro-ecological regions of south zone as per ICAR-NBSS-LUP

Present status of mulberry breeding

Exploration, Collection, and Characterization

Extensive exploration and collection efforts have led to the establishment of a rich mulberry germplasm ex situ field gene bank at CSGRC-Hosur, comprising 1,269 accessions, including 999 indigenous and 270 exotic types. These accessions form a diverse genetic base that supports all mulberry improvement research programmes in India. The germplasm is continually characterized for leaf yield, quality, and resistance or tolerance to biotic and abiotic stresses. About 400 selected accessions are maintained at the CSB-CSRTI Mysuru gene bank for research purposes.

Introduction

Introducing germplasm from other countries enriches breeding resources, enhances genetic diversity, and broadens the genetic base. However, it is crucial to prioritize introductions from regions with climatic conditions similar to those in India to ensure adaptability. Notably, most temperate varieties introduced into South India have failed due to poor adaptation.

Open Pollinated Hybridization (OPH)

Selection from open-pollinated hybrids is one of the fastest methods for crop improvement in mulberry. Given the dioecious and cross-pollinating nature of mulberry, populations are highly heterozygous, allowing breeders to exploit natural genetic variability (Dandin and Kumar, 1989). Seeds collected from desirable female parents yield progeny that are screened for superior traits. Varieties developed through this approach include Kanva-2, S-135, S-175, S-13, AR-11, and MR-2 (Mogili et al., 2023).

Controlled Pollinated Hybridization

Controlled hybridization remains the cornerstone of mulberry improvement, as it enables the combination of desirable traits from different genotypes. Repeated hybridization is often employed to integrate multiple superior traits into a single variety. Varieties developed using this method include S-34, V-1, G-4, G-2, RC-1, RC-2, Sahana, MSG-2, and AGB-8 (Mogili et al., 2023).

Mutation Breeding

In mulberry, which is vegetatively propagated, mutation breeding can help eliminate undesirable traits. Although this approach is a lower priority due to limited success globally, CSRTI-Mysuru has developed four varieties through chemical mutagenesis: S-30, S-36, S-41, and S-54 (Mogili et al., 2023).

Advanced Generation Breeding

Beyond first-generation hybrids, advanced generation breeding introduces new genetic variability, offering sustained genetic and economic gains over successive cycles. At CSRTI-Mysuru, this approach led to the development of AGB-8, a variety suited for sub-optimal irrigation, with a leaf yield potential of 47 MT/ha/year (Sarkar, 2000). This variety was also evaluated under AICEM-IV across 20 test centers in India under irrigated and rainfed conditions. In the southern zone, AGB-8 showed a 12% yield improvement over V1, with leaf quality on par with V1 (Mogili et al., 2023).

Polyploidy Breeding

The genus *Morus* is well-suited for polyploidy breeding due to its low chromosome number, reproductive versatility, and high foliage value. Among polyploids, triploids offer advantages such as greater genetic plasticity and tolerance to stress conditions. Indian efforts (Sarkar, 1993) have produced auto-tetraploids of K-2, S-30, S-36, S-41, S-54, RFS-135, RFS-175, S-13, S-34, and V-1 at CSRTI-Mysuru. Crosses between these tetraploids and diploids have yielded promising triploids, including AR-12, which is recommended for cultivation in the alkaline soils of southern India (Mogili et al., 2017).

Given the high adaptability of triploids, further breeding efforts were made to develop triploids by crossing diverse parents (tetraploid and diploid). Clonal evaluations were conducted under different soil moisture regimes in Primary Yield Trials (PYT) and across different planting systems in multi-location based Final Yield Trials (FYT). TRI-8 and TRI-9 were identified as promising genotypes. TRI-8 showed increased leaf yield over checks Vishala and G4 - by 12.4% and 13.3% in bush planting, and by 14.9% and 11.7% in tree planting systems, respectively. It also had the highest protein (15.32%), carbohydrate (29.91%), and silkworm feed conversion efficiency (Raghunath et al., 2023-24). The leaf yield parameters of TRI 8 along with checks are furnished in table 3. TRI-8 genotype has been recommended for the AICEM trial.

Table 3: Performance of TRI 8 genotypes for leaf yield and bioassay parameters

Leaf Yield Parameters	TRI-8	G-4	Vishala
No. of Shoots	20.6	18.7	20.8
Nodes/m	18.6	20.8	17.6
Shoot length (cm)	1761	1576	1883
Leaf moisture (%)	76.5	76.3	76.2
Leaf moisture retention (%)	82	80.1	78.6
Harvest Index	0.59	0.6	0.55
Yield (MT/ha/yr)	61.5	54.7	54.3
Bioassay Parameters			
Larval wt. (g)	4.63	4.17	4.31
Single cocoon wt. (g)	1.91	1.77	1.69
Single shell wt. (g)	0.42	0.39	0.35
Shell percent (%)	21.79	21.87	20.51
ERR by No.	8998	8874	7910
ERR by wt. (kg)	16.4	14.9	13.6
PECS	11.8	9.9	9.0

The Southern zone has varied climatic and edaphic conditions besides different cropping pattern; for instance, in Southern part and Eastern Ghat areas coconut plantations are more. For better suitability and productivity breeding efforts were made to develop varieties suitable for each growing conditions viz., irrigated, rainfed, alkaline soil, soil moisture stress, sub-optimal input conditions, exclusively for chawki and for inter-cropping in coconut plantations (Table 4).

Table 4: Improved mulberry varieties developed for cultivation in South India

Agro-climatic & Cultivation Conditions	Mulberry Varieties	Recommended Input Conditions	Yield Potential (MT/ha/yr)
Mulberry varieties for optimal input condition			
Irrigated conditions	Mysore local	FYM-20 MT/ha/year NPK @ 300:120:120 kg/ha/year Irrigation @ 1.5-acre inch Irrigation @ 7-10 days' interval * NPK @ 350:140:140 kg/ha/year	15-25
	Kanva-2		30-35
	S-36		35-40
	S-54		40-45
	MR-2		36-40
	V-1*		55-60
	Anantha		55-65
	DD		35-40
	Vishala		38-42
	G-4*		60-65
Mulberry varieties for specific growing conditions			
Rainfed/soil moisture stress conditions	Mysore Local	FYM-10 MT/ha/year NPK @ 100:50:50 kg/ha/year	3-4
	Kanva-2		4-6
	S-13		13-16
	S-34		13-16
	MSG-2		22-23
Intercrop in Coconut plantations (Shade tolerant)	Sahana	FYM-20MT NPK @ 300:120:120 kg/ha/yr 1.5 acre inch irrigation @ 7-10 days interval	32-35
Exclusive chawki plantation	G-2	FYM-40MT NPK @ 260:140:140 kg/ha/yr 1.5 acre inch irrigation @ 4-5 days interval	35-38

Each variety expresses salient features in terms of its plant growth parameters and biochemical content as described in Table 5.

In the southern zone, mulberry is cultivated in both bush and high bush forms under diverse planting geometries. Tailored packages of practices have been developed for each planting system to optimize growth, leaf yield, and resource-use-efficiency.

Development of Mulberry Genotype for Limited Irrigation and Fertilizer Input Conditions

The rising demand for quality silk necessitates the expansion of mulberry cultivation into marginal and drought-prone regions, as fertile lands are increasingly prioritized for food and other cash crops. These regions frequently experience erratic rainfall, water scarcity, or declining groundwater levels. Key drought-tolerance traits in mulberry include robust root architecture, high water-use efficiency (WUE), and strong

Table 5: Features of mulberry varieties cultivated in Southern India

Variety	Pedigree/ Parentage	Rooting ability (%)	Inter-Nodal distance (cm)	100 leaf wt. (g)	Total shoot length/ plant (cm)	Leaf moisture content (%)	Leaf moisture retaining capacity (%)	Protein (%)	Sugars (%)
Mysore Local	Locally adopted	>90	3.8	245	980	60-65	61-62	14-16	8-10
Kanva-2	OPH from M. local	>80	4.5	290	975	65-70	61-63	18-21	9-12
S-36	Ber. Local mutant (EMS)	>48	3.5	395-425	924	70-74	75-78	23-25	10-13
S-54	Ber. Local mutant (EMS)	>60	3.9	420-435	920	70-76	55-65	22-24	13-14
MR-2	OPH from exotic variety	>90	4.0	350-370	985	73-76	72-75	20-25	13-14
S-135	OPH from Kanva-2	>80	4.4	490-520	780	73-74	74-78	25-27	11-14
S-175	OPH from Kanva-2	>85	4.6	525-560	815	72-75	72-76	20-25	12-15
V-1	S-30 × Ber. C. 776	>90	5.2	530-560	1280	75-78	78-82	26-28	16-18
Anantha	Clone of S-175	>85	4.7	525-555	960	75-77	70-72	23-26	14-16
DD (Viswa)	Selection from Dehradun	>80	4.0	420-460	940	73-78	74-76	22-26	15-18
Vishala	Field Selection	>80	5.5	435-470	1260	73-74	76-78	23-26	16-18
G-4	*M. multicaulis* × S34	>90	3.9	416-425	1200	75-77	74-76	24-26	16-19
S-13	OPH from Kanva-2	>80	3.7	310-365	840	73-75	75-78	21-23	13-17

Variety	Pedigree/ Parentage	Rooting ability (%)	Inter-Nodal distance (cm)	100 leaf wt. (g)	Total shoot length/ plant (cm)	Leaf moisture content (%)	Leaf moisture retaining capacity (%)	Protein (%)	Sugars (%)
S-34	S-30 × Ber. C. 776	>75	3.8	325-390	860	73-76	74-77	20-24	12-16
AR-11	OPH from Kanva-2	>80	3.8	290-300	820	67-70	56-58	15-17	11-12
MSG-2	BR-4 × S-13	>89	3.9	410-420	1186	75-77	73-75	22-25	15-18
G-2	*M. multicaulis* x S34	>90	4.3	125-132	1170	79-81	81-83	25-26	12-13
AR-12	S41 (4x) × Ber. C776	>90	3.75	410-425	739	71-74	64-66	19-21	13-14
Sahana	Kanva-2× Kosen	>65	4.8	365-379	684	71-73	73-75	20-22	11-13
RC-1	Punjab local × Kosen	>90	4.6	400-410	678	72-73	74-77	21-23	14-16
RC-2	Punjab local × Kosen	>94	4.4	380-405	1025	72-73	70-73	20-23	12-16
AGB-8	(Sujanpur-5 × Philippines) × (K-2 x Black cherry)	>90	5.2	550-605	716	70-73	71-74	21-23	14-17

leaf-moisture retention capacity (Mamrutha et al., 2010). Notable varieties such as RC1, MSG2, and AGB8 have demonstrated significant yield potential (22–47 MT/ha/year) under rainfed or limited irrigation conditions.

Twenty-one F1 genotypes from seven crosses were evaluated over two years under both optimal (100%) and reduced (60%) irrigation and fertilizer input levels in a Primary Yield Trial (PYT). Pooled data from four crop seasons identified six genotypes that yielded 663–840 g/plant, performing comparably or better than Vishala (663 g/plant) under full input conditions. Under reduced input conditions, seven genotypes (418–596 g/plant) outperformed Vishala (415 g/plant) (Sarkar et al., 2024a).

The δ^{13}C values (–28.21 to –28.98), a surrogate trait for water-use efficiency, in five genotypes were comparable to that of AGB8 (–28.87), indicating high WUE. AMMI-based Simultaneous Selection Index (SSI) analysis revealed seven genotypes with moderate to high stability and high yield across seasons under both optimal and limited input conditions. SSR-based DNA fingerprinting was conducted to confirm the identity of genotypes and ensure the protection of these promising lines. These genotypes are currently undergoing Final Yield Trial (FYT) validation under both input conditions.

Table 6: Agronomic package of practices followed in South Zone

Particulars	Bush	High bush/Tree
Sapling age for planting	4-6 months	9 months
Establishment period	6 months	1.5 year
Spacing	(3’+5’) x 2’, 3’ x 3’	8’ x 8’, 10’ x 10’
FYM (2 splits)	25 MT/ha	8 kg/plant
Fertilizer (NPK), 5 splits	kg/ha/yr	g/plant/yr
First year	100: 50: 50	86: 35: 35
After establishment	350: 140: 100	258: 103: 103
Foliar nutrient (Poshan)	@7 ml/L, 25 DAP	@7 ml/L, 25 DAP
Irrigation	2L/day	2L/day
Green manure	Sunhemp, Dhaincha, 10kg/acre/ crop (onset of monsoon)	
Leaf yield (V1) MT/ha/yr	55	51

Mulberry Variety Coverage in the South Zone

Although several mulberry varieties have been developed, only a few occupy substantial cultivation areas in the South Zone. The variety V1 alone accounts for 96% of the total cultivated area, followed by MR2, which was developed by the Department of Sericulture, Tamil Nadu (Table 6). V1 is recommended for irrigated conditions with ideal soil pH; however, it is often cultivated indiscriminately across marginal soils, alkaline soils, coconut plantations, and areas with limited input, resulting in poor productivity under these non-recommended conditions.

Table 6: Mulberry variety-wise acreage (hectare) in south zone

State	Statistics as on	Kanva-2	V1	G4	G2	AR12	MSG2	S13	MR2	S36	S30	Vishala	Others	Total
AP	Mar. 22	-	51303.80	16.80	16.80	-	-	-	-	10.00	-	-	-	51347.00
KA	May 25	1037.45	116930.00	13.50	1.97	1.20	0.60	22.00	0.90	35.18	6.60	24.70	0.640	118071.00
TN	Jun. 25	-	13557.20	112.70	-	-	-	-	6096.80	1.40	-	-	-	19768.00
TL	Nov. 19	-	4684.00	8.20	3.40	-	-	-	-	6.00	-	-	-	4702.00
MP	Sep. 19	-	8.60	-	-	-	-	-	-	-	-	-	30.90	40.00
MH	Sep. 19	129.70	7920.00	2.00	-	-	-	-	-	-	-	-	-	8052.00
KL	Jul. 20	-	140.00	-	-	-	-	-	-	-	-	-	-	140.00
Total		1167.20	194543.60	153.20	22.20	1.20	0.60	22.00	6097.70	52.58	6.60	24.70	31.54	202120.00

RC1 & Sahana: Nil

Therefore, extension programs and on-farm trials are essential to promote suitable varieties that can enhance productivity under problematic conditions.

In order to facilitate the timely and easy availability of seed cuttings of promising mulberry varieties, a new seed multiplication channel has been established. A *Breeder Seed Plot* will be maintained at the main institute (CSB-CSRTI Mysuru), *Foundation Seed Plots* at the RSRS level, and *Certified Seed Plots* at the REC and farm-based Department of Sericulture (DoS) units. This seed multiplication system ensures the genetic purity of the varieties while enabling large-scale multiplication of seed material to reach farmers at the grassroots level. To promote these varieties, demonstration plots have been established at both RSRS and REC levels to showcase them to farmers.

Present Challenges

- **Lack of pest-resistant varieties:** In the southern zone, mulberry gardens are frequently infested with various pests such as mites (*Polyphagotarsonemus latus*, *Tetranychus* spp.), thrips (*Pseudodendrothrips mori*), whitefly (*Dialeuropora decempuncta*, *Tetraleurodes mori*), mealybug (*Maconellicoccus hirsutus*), and leaf folder (*Diaphania pulverulentalis*), among others. These pests can cause leaf yield losses of up to 100% and severely affect leaf quality, making it unfit for silkworm rearing.
- **Lack of resistant varieties against root rot and root knot diseases:** Soil-borne diseases such as root rot and root knot nematode infestations are significant threats, causing plant wilting, death, and reduced productivity.
- **Low productivity due to soil moisture stress and marginal lands.**
- **High fertilizer demand to achieve high biomass:** High-yielding mulberry varieties (such as V1 and G4) require large quantities of chemical fertilizers (350:140:100 kg NPK/ha/year), with particularly high nitrogen demands. Developing nutrient-efficient varieties is essential to reduce production costs and minimize environmental pollution.
- **Lack of mulberry varieties specific to silkworm seed production:** Developing mulberry varieties with leaf quality traits that enhance silkworm fecundity could significantly improve quality-seed production.

Biotechnological Approaches for Mulberry Improvement

Identification of QTLs for Biotic and Abiotic Stress

Efforts have been made to identify QTLs contributing to resistance against soil alkalinity and root rot disease in mulberry. The stress response of 38 contrasting accessions (20 tolerant and 18 susceptible) was evaluated in alkaline soil hotspots at

REC sub-unit Kinakanahalli and REC-Koppal, along with two checks - AR-12 (resistant check) and V1 (susceptible check). The study identified AR-12, MR2, Sahana, Bheriadangi-1, TR-7, T-36, Saranath-3, Kanthaloor-2, C-776, and Khodol as alkaline-tolerant genotypes at soil pH 9, showing better chlorophyll stability and glycine betaine production in the leaves. Two mapping populations - Sahana × V1 and MR2 × V1 - were developed for further study (Bhavya et al., 2021-22).

Genetic Diversity Study among Germplasm

To support parent selection in hybridization breeding, 172 mulberry germplasm lines representing different species were analyzed using 20 polymorphic SSR markers. These included *M. indica* (66), *M. alba* (39), *M. laevigata* (16), *M. latifolia* (22), *M. cathayana* (1), *M. atropurpurea* (1), *M. macroura* (1), *M. rotundiloba* (2), *M. sinensis* (1), *M. serrata* (1), and 22 unknown species. A total of 94 alleles were identified, with 2 to 7 alleles per locus (average 4.5). The PIC values ranged from 0.21 to 0.87, with a mean of 0.57, indicating moderate to high genetic diversity (Table 7). These informative SSR markers could be used for various studies in mulberry.

Table 7: Polymorphic SSR markers identified in mulberry germplasm
(Source: Gnanesh et al., 2023)

#	Marker name	No. of alleles	Effective no. of alleles	Expected hetero-zygosity	Shannon's index	Nei's Index	PIC
1	M2SSR81	3	1.48	0.31	0.58	0.17	0.24
2	Moso340-2	6	3.96	0.72	1.61	0.62	0.74
3	M2SSR87	3	2.93	0.68	1.18	0.52	0.59
4	Moso288	4	1.99	0.51	0.91	0.69	0.62
5	MULSSR253	4	2.93	0.72	1.36	0.68	0.61
6	M2SSR112A	2	1.56	0.34	0.58	0.32	0.29
7	MULSSR26	4	3.01	0.72	1.26	0.61	0.59
8	M2SSR68	3	1.81	0.44	0.78	0.42	0.47
9	MULSSR313	5	3.34	0.69	1.41	0.58	0.56
10	MULSSR258	7	4.26	0.76	1.59	0.88	0.86
11	MoSo-157-2	6	3.61	0.75	1.42	0.31	0.69
12	M2SSR36	5	2.74	0.68	1.21	0.18	0.58
13	M2SSR1	5	3.32	0.71	1.32	0.14	0.65
14	MULSSR85	7	6.52	0.89	1.98	0.48	0.87
15	MULSSR96B	5	3.39	0.74	1.66	0.68	0.69
16	M2SSR10	4	2.82	0.66	1.28	0.76	0.52
17	M2SSR89A	5	2.52	0.62	1.18	0.41	0.53
18	M2SSR107	3	1.31	0.28	0.58	0.52	0.21
19	M2SSR82	6	4.46	0.76	1.62	0.35	0.74

20	M2SSR20	7	2.58	0.68	1.36	0.71	0.59
	Mean	4.55	2.953	0.6175	1.2145	0.493	0.57

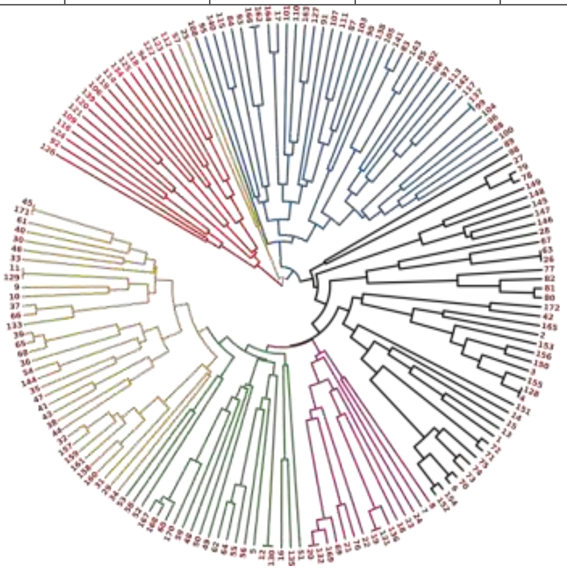


Fig. 4: UPGMA Dendrogram showing distribution of 172 mulberry germplasm based on SSR allele data (Arunakumar et al., 2021-22).

Phytogenic analysis divided the germplasm into two major clusters (figure 4 and table 8): **Cluster I** with two sub-clusters (IA and IB), and **Cluster II** with two sub-clusters (IIA and IIB). Sub-cluster IIB was further divided into IIB-1 and IIB-2. Within IIB-2, several super sub-clusters were identified, where admixtures of different *Morus* species and developed *Morus* varieties are distributed (Arunakumar et al., 2021–22).

Table 8: Clustering of mulberry genotypes using 20 polymorphic SSR markers (Source: CSB-CSRTI Mysuru Arunakumar et al., 2021-22)

Cluster/Sub cluster number		No. of germ-plasm	Name of the germplasm
Cluster I	Cluster IA	06	Thailand male, Kollegal, Baragarh-3, Thailand lobed, C-18 and Mandalaya
	Cluster IB	12	SRDC-3, Gamettee, Himachal local, Acc. 8, Calabresa, Vietnam-1, Lisbon, Karanjtoli-1, China-27, BR-8, Dehradun Local-4 and Papua New Guinea
Cluster II	Cluster IIA	02	*M.macroura* and *M. serrata*
	Cluster IIB	-	

Cluster II B	Sub-cluster IIB-1	39	Mysore local, KPG-11, Cuckpilla, UP-5, Reblaira, S-523, Tippu, Acc. 115, T-18, ERRC-103, ERRC-106, Monla-I, SRDC-2, ERRC-215, ERRC-180, Acc-118, UP-9, BR-2, Kota-4, S-1708, Acc.165, R-1, Acc.56, Semmedu, C-15, S-1635, Dhudia White, Australia, Bilidevalaya, English Black, Guzziola, ERRC-57, *M. tiliaefolia*, ERRC-73, C-6, S-763, Pillighat, Chekmajra and BU-33.
	Sub-cluster IIB-2	42	US-51(OPH), S-242, S-642, S-741, Rostelli, Japan, China Hybrid -2, Phillipines, Acc.134, Suvarna-1, Suvarna-2, Suvarna-3, Vishwa, *M. cathayana* (Hybrid), *Morus cathayana*, Sahana, Chandrapuri, Hosur-C3, Meergund-6, Zimbabwe-8, Hairythick, MVK-1, Hosur C8, Suwong Pong, Madhopur-1, Pannear Estate, S-13, MSG-2, China Black-A, Fukushima-OHA, Kokuso, Kokuso-20, Furcata, Moretti, Lun 40-2, Valparai-05, Thai pecah, Dharatwala, Nagpur-3, New Delhi, Lava Forest-1 and Serpentina
	Sub-cluster IIB-3	15	V-1, V-1 tetra, Bullato, Vishala, S-1, S-41, Pouri-1, KNG, AGB-8, Ankara, Seekupari, Jabalpur, Saranath-1, Belona and Ujjain-2
	Sub-cluster IIB-4	21	RFS-135, RFS-135 tetra, Kanva-2, K-2 tetra, AR-12, Palsana-3, Keeraithodu, Haridwar-4, G-4, RC-2, S-30, *M. rotundiloba*, *M.lhouseringe*, Nao Khurkul, AR-11, UP-22, Majhkhali, RC-1, Roso, MR-2 and Goshoerami
	Sub-cluster IIB-5	35	Sabbawala-2, Nellathana Estate, Malkai Local, MS-3, Laholi-1, Kajali, Sangsey, Vadapuram, Bagaban Masijd, Bonniampadi, S-36, School, Salem, Thattahalli Villa-1, Sujanpur-5, Punjab local, Nowshera-1, Palampur Local, *M. multicaulis* (ME-0168), *M. multicaulis* (ME-0006), Naudan-1, Kosen, Birds Foot, L-6, Nalhdwara-1, Ranchi-5, Churai Mohal, C-776, Farabori, S-34, S-34 tetra, G-2, Pouri-2, Assama Bola, Thandikudi and Jalalgarah-3

The genome size (GS) of four different ploidy levels (2n = 2x, 3x, 4x, and 6x) was assessed through flow cytometry analysis and ranged from 0.72±0.005 pg (S-30) to 2.89 ±0.015 pg (*M. serrata*), representing approximately a 4.01-fold difference. The predicted ploidy levels were further confirmed through metaphase chromosome counts.

Model-based population structure analysis grouped 82 germplasm accessions into three populations (K = 3), showing a moderate level of correlation between the populations and the different *Morus* species. This suggests that genetic variation, rather than ploidy, contributes to trait plasticity, likely as a result of the high heterozygosity imposed by natural cross-pollination (Gnanesh et al., 2023).

Genetic Engineering in Mulberry for Soil Moisture Stress Tolerance

High moisture retention capacity (MRC) in mulberry leaves is vital for improving silkworm growth, development, and cocoon quality. To enhance tolerance to soil moisture deficit and improve leaf nutritional traits, transgenic approaches were used by co-expressing transcription factors that regulate multiple stress-responsive pathways. Three transgenic lines co-expressing *AtDREB2A* and *AtSHN1* were developed via *Agrobacterium*-mediated transformation of cotyledon and hypocotyl explants of mulberry var. *G4*. These lines exhibited improved cuticular resistance, reduced post-harvest water loss, and enhanced physiological traits - including photosynthetic rate, WUE, relative water content, and proline accumulation - under 60% field capacity (Sarkar et al., 2024b).

Engineering Photosynthesis in Mulberry for Climate Resilience

Enhancing photosynthetic efficiency in C3 plants by introducing C4 enzymes is a promising strategy for improving biomass and yield (Yadav & Mishra, 2019). The C4 pathway improves CO_2 assimilation and optimizes water, nitrogen, and radiation use efficiencies while enhancing tolerance to heat and drought stress (Kandoi et al., 2016; Yadav et al., 2020). Three transgenic mulberry lines were developed by incorporating a heterologous phosphoenol pyruvate carboxylase (PEPC) gene using *Agrobacterium*-mediated transformation. These lines showed significantly improved photosynthetic rate, WUE, stomatal conductance, transpiration, relative water content, and proline accumulation under 60% field capacity compared to wild-type plants (Sarkar et al., 2025). These engineered lines hold strong potential for confined, multi-location field trials to evaluate leaf yield, quality, and adaptability under both irrigated and moisture-stressed conditions, in compliance with biosafety regulations.

Phenotypic Characterization of Mulberry Germplasm Accessions

Growth and Leaf Yield Parameters

A total of 203 germplasm accessions, including checks (V-1 and Kosen), were evaluated using an augmented randomized block design. Genetic variability parameters, correlations, and diversity among the germplasm for yield-related traits were assessed.

Development of Mapping Populations for Root Rot Resistance by Pseudo-Test Cross Strategy

A pseudo-test cross mapping population (200 F_1 progenies) from a cross between *M. multicaulis* (ME-0168) and Thailand Male was screened against root rot pathogens (*Fusarium solani* and *Lasiodiplodia theobromae*) for two seasons under glasshouse conditions. Forty-five progenies were identified as resistant to both pathogens based on wilting and rotting percentages (ArunaKumar et al., 2021-22).

Phenotypic Characterization of Germplasm for Drought Adaptive Traits

Phenotyping for drought adaptive traits and water-use efficiency (WUE) parameters was conducted on 208 germplasm accessions over two seasons. Traits evaluated included chlorophyll content, epicuticular wax, specific leaf weight, leaf area, stomatal number, growth parameters (e.g., shoot length, shoot weight, leaf weight), and root traits (e.g., number of roots, root weight, length and weight of the longest root). Significant differences were observed in total above-ground biomass and leaf yield under irrigated and rainfed conditions. Under rainfed conditions, 26 genotypes were identified, among which *MI-0006*, *MI-0504*, *MI-0753*, *MI-0285*, *MI-0577*, *MI-0028*, and *MI-0108* showed higher total above-ground biomass per plant (Sheshshayee et al., 2021-22).

Evaluation of Mulberry Genetic Resources for Uptake and Utilization Efficiency of Nitrogen, Phosphorus, Zinc, and Sulphur

In this experiment, 230 accessions were evaluated in pots at two fertilizer levels - recommended dose of fertilizer (RDF) and 30% RDF. Based on growth and yield parameters, efficient genotypes were identified for potential use in breeding nutrient-efficient varieties (Sobhana et al., 2021-22).

Comparative Quantitative and Qualitative Analysis of Secondary Metabolites for Biomarker Identification

Primary metabolites (proteins, carbohydrates, amino acids, ascorbic acid, and tocopherol) were estimated in fresh leaves of 10 genotypes (*V1*, *G2*, *G4*, *S13*, *K2*, *Mysore Local*, *S36*, *MR2*, *MS2*, *Morus multicaulis*) over six crops. Higher levels of primary metabolites were found in *V1*, *Morus multicaulis*, *G4*, and *G2*, while *MR2* and *Mysore Local* had the lowest. Silkworms fed on *V1* leaves exhibited improved reeling parameters: 85.34% reelability, 842 m average filament length, the lowest renditta (7.4 kg), and 67.46% raw silk recovery, followed by *G4*, *K2*, and *Morus multicaulis*. Secondary metabolites identified by LC-MS and HRMS in the 10 genotypes included ribitol, arabinitol, 1-deoxynojirimycin, morusimic acid A/C, morusimic acid B/D, fagomine, caffeoylquinic acid isomers I/II, cyanidin hexoside, dihydrokaempferol-hexoside, quercetin-hexoside, and kaempferol malonyl hexoside (Thulasiram et al., 2021-22).

Development of highly productive and widely adapted mulberry using exotic and wild germplasm

A total of 2179 hybrid seedlings derived from six crosses *M. multicaulis* × Thailand Male, Punjab Local × Cathayana hybrid, G2 × Thailand Male, BR 8 × ERRC 103, Hosur C3 × V1 and *M. multicaulis* × V1 and three OPH's from English Black, G2 and G4 were evaluated. Based on growth and yield parameters 60 genotypes were shortlisted for PYT (Annual Report 2023-24).

Current Ongoing Breeding Programs at CSB-CSRTI Mysuru

1. **Evaluation of promising genotypes for higher leaf yield and resistance to root rot and root knot diseases (PIE 01022 SI)**

Objectives

a. Identify superior genotypes with higher yield, quality, and resistance to root rot and root knot nematode diseases.

b. Confirm resistance levels under artificial inoculation.

Progress

Thirty-six genotypes from 10 cross combinations were evaluated for six crop seasons under a 6^2 lattice design with two replications. Screening against *Fusarium solani*, *Lasiodiplodia theobromae*, and *Meloidogyne incognita* is ongoing under glasshouse and hotspot field conditions at three locations covering two states (Karnataka and Tamil Nadu).

2. **Final yield evaluation under limited irrigation and fertilizer conditions (PIE 01036 SI)**

Objectives

a. Evaluate genotypes for leaf yield under 100% and 60% irrigation and fertilizer levels.

b. Assess leaf quality under these conditions.

Progress

Seven genotypes short-listed from primary trials are being evaluated under rain-out shelters with precision irrigation (equipped with water meter and tensiometer).

Future Breeding Strategies to Enhance Silk Production

Development of Productive Varieties for Problematic Soils

Salinity, alkalinity, moisture stress, and marginal lands present major challenges for mulberry cultivation. Popular varieties such as G4 and V1 provide high yields under optimal inputs and fertile soils with proper agronomic practices. However, their productivity drops significantly in problematic soils. Since a large area falls under these soil types, developing varieties that can surpass the productivity of existing varieties would substantially boost silk production and enhance farmers' income.

Development of Productive Varieties for High-Temperature Regions

Mulberry cultivation is expanding into non-traditional areas such as Maharashtra (MH), Madhya Pradesh (MP), Uttar Pradesh (UP), Gujarat (GJ), and Rajasthan (RJ). These regions experience high summer temperatures (up to 45°C), which create soil moisture stress. There is an urgent need to develop productive varieties that can withstand these high-temperature conditions.

Grafting as a Strategy to Mitigate Soil-Borne Biotic and Abiotic Stresses

The high success rate of grafting offers an opportunity to use stress-tolerant rootstocks for desired scion varieties. This approach is commercially viable under low-density planting systems. Currently, grafting is used to propagate mulberry germplasm accessions that are difficult to root through stem cuttings. Deploying stress-tolerant genotypes as rootstocks can help promising varieties overcome soil-borne biotic stresses (e.g., root rot, root knot diseases) and abiotic stresses (e.g., soil moisture stress, salinity, and alkalinity). Grafting provides a quick solution to field problems. The development or identification of superior rootstock genotypes is a critical priority.

Speed Breeding Approaches

Currently, mulberry variety development takes about 20 years, including hybridization, individual plant evaluation (4–5 years), primary yield trials (5–6 years), final yield trials (5–6 years), and multi-locational trials in AICEM (5–6 years) (Vijayan et al., 2012). To address field challenges more quickly, it is essential to adopt speed breeding approaches. This can be achieved through modern phenomic tools, reducing clonal evaluation periods via early or precise prediction of genotypic performance (by identifying traits that correlate between young and mature plant performance), and redefining the number of crops evaluated during clonal evaluation phases (PRT, PYT, FYT, and AICEM).

Mulberry Varieties for Silkworm Seed Production

Studies aimed at identifying leaf nutrient qualities that enhance silkworm fecundity are essential. Suitable mulberry varieties for adapted seed rearers could significantly contribute to improving seed production.

Screening and Identification of Mulberry Germplasm for Major Insect Pests and Diseases

Systematic screening of mulberry germplasm is vital to identify resistant donor lines for developing pest- and disease-resistant varieties.

Use of Phenomic Tools in Breeding

The adoption of advanced phenomic tools in breeding programs enables rapid and precise screening of large populations, greatly increasing the scope for selecting desirable genotypes.

Development of Nutrient-Efficient Varieties

Developing nutrient-efficient, high-yielding varieties is essential to reduce input costs and minimize environmental impact.

Conclusion

Mulberry improvement for tropical sericulture has made significant strides through diverse breeding strategies, resulting in high-yielding, stress-tolerant varieties that have enhanced silk production and farmer livelihoods. However, emerging challenges such as biotic and abiotic stresses, climate variability, and the need for nutrient efficiency call for innovative approaches. Future efforts must focus on developing varieties suited for problematic soils, high-temperature regions, and silkworm seed production. Integration of modern tools like genomics, phenomics, and speed breeding will accelerate varietal development. Collaborative R&D and targeted extension activities will be essential to ensure sustainable, eco-friendly, and profitable sericulture in the tropics.

References

Arunakumar G. S., Gnanesh B. N., Supriya M. and Harshitha M. M., Sustaining Mulberry Yield: Identification of QTLs Conferring Resistance to Root Rot Disease by Linkage Mapping and Trait Introgression. Annual Report 2021-22, CSB-Central Sericultural Research and Training Institute, Mysuru, pp 41-49.

Bhavya M. R., Gayathri T., Sanath Kumar Y. N., Mahalingappa K. C. and Bharatesh S. Mapping QTLs for alkalinity tolerance in Mulberry (Morus spp.). Annual Report 2021-22, CSB-Central Sericultural Research and Training Institute, Mysuru, pp 31-34.

Das D, Bhattacharyya S, Bhattacharyya M, Shashankar P, Ghosh A and Mandal P (2022) Transcriptome analysis of mulberry (Morus alba L.) leaves to identify differentially expressed genes associated with post-harvest shelf-life elongation. Scientific Reports, 12: 18195. https://doi.org/10.1038/s41598-022-21828-7

Gnanesh BN, Mondal R, Arunakumar GS, Manojkumar HB, Singh P, Bhavya MR, Soubhagya P, Shreyas M Burji, Mogili T, Sivaprasad V (2023) Genome size, genetic diversity, and phenotypic variability imply the effect of genetic variation instead of ploidy on trait plasticity in the cross-pollinated tree species of mulberry. PLoS ONE 18(8): e0289766. https://doi.org/10.1371/journal.pone.0289766

Kandoi D, Mohanty S, Govindjee, Tripathy BC (2016) Towards efficient photosynthesis: overexpression of Zea mays phosphoenolpyruvate carboxylase in Arabidopsis thaliana. Photosynthesis Res., 130(1–3): 47–72. https://doi.org/10.1007/s11120-016-0224-3

Khurana P, Checker VG (2011) The advent of genomics in mulberry and perspectives for productivity enhancement. Plant Cell Reports, 30: 825–838. https://doi.org/10.1007/s00299-011-1059-1

Mamrutha HM, Mogili T, Lakshmi KJ, Rama N, Kosma D, Udaya Kumar M, Jenks MA, Nataraja KN (2010) Leaf cuticular wax amount and crystal morphology regulate post-harvest water loss in mulberry (Morus species). Plant Physiology and Biochemistry, 48(8): 690–696. http://doi.10.1016/j.plaphy.2010.04.007

Mogili, T., Sarkar, T., Gnanesh, B.N. (2023). Mulberry Breeding for Higher Leaf Productivity. In: Gnanesh, B.N., Vijayan, K. (eds) The Mulberry Genome. Compendium of Plant Genomes. Springer, Cham. https://doi.org/10.1007/978-3-031-28478-6_3

Narendra Kumar JB, Vinod Kumar and Sivaprasad V (2016) Biological control of insect pests in mulberry sericulture. CSB-Central Sericultural Research & Training Institute (CSB-CSRTI), Central Silk Board (CSB), Ministry of Textiles: Govt. of India, Mysuru, Karnataka, India. https://www.csrtimys.res.in/sites/default/files/ebooks/2016-1.pdf

NBSS&LUP Staff (2015) ICAR-NBSS&LUP Serving Science & Society p 26.

Saeed B, Baranwal VK, Khurana P (2016) Comparative transcriptomics and comprehensive marker resource development in mulberry. BMC Genomics, 17: 98. https://doi.org/10.1186/s12864-016-2417-8

Raghunath M.K., Manjappa, Sarkar T. Arunakumar G.S., Hanumantharayappa S.K., Kulkarni S.B., Kiran Kumar K.P., Babulal, Mary Josepha Sherry A.V. and Gandhi Doss S. Evaluation of superior triploid mulberry genotypes for leaf yield under bush and tree planting system in different agro-climatic conditions. Annual Report 2023-24, CSB-Central Sericultural Research and Training Institute, Mysuru, 21-26.

Sarkar T, Gowda RMB, Doss SG, Raghunath MK, Manjappa MT, Naik VG, Bhuvaneswari E, Arunakumar GS (2024a). Selection of F1 mulberry (Morus indica) genotypes for optimal and sub-optimal input conditions based on leaf yield, quality, and yield attributes. Trees, 38: 49–64. https://doi.org/10.1007/s00468-023-02465-7

Sarkar T, Nataraja KN, Sajeevan RS, Dhanyalakshmi KH, Doss SG, Raghunath MK, Sivaprasad V (2025) Co-expression of AtDREB2A and AtSHN1 in transgenic mulberry (Morus spp.) confers tolerance to drought and salinity and reduces post-harvest water loss. Plant Growth Regulation, 105: 773–786. https://doi.org/10.1007/s10725-025-01306-6

Sarkar T, Ravindra KN, Sidhu GK, Doss SG, Raghunath MK, Gayathri T, Ramesha A, Raghavendra AS, Sivaprasad V, Mogili T, Arunakumar GS (2024b). Overexpression of phosphoenolpyruvate carboxylase gene of Flaveria trinervia in transgenic mulberry (Morus spp.) leads to improved photosynthesis rate and tolerance to drought and salinity stresses. Plant Cell, Tissue and Organ Culture, 156: 26. https://doi.org/10.1007/s11240-023-02646-9

Sheshshayee M. S. and T. Gayathri, Discovery of QTL to drought adaptive traits by association mapping in Mulberry. Annual report 2021-22, CSB-Central Sericultural Research and Training Institute, Mysuru, pp 64-66.

Sobhana V., Ravindra and Dhaneshwar Padhan, Genetic enhancement of Mulberry through Genomic Approaches Sub Component: Identification of QTLs for Nutrient Use Efficiency.

Annual Report, 2021-22, CSB-Central Sericultural Research and Training Institute, Mysuru, pp 50-55.

Thulasiram V., Gayathri T. and Bhuvaneswari E., Comparative quantitative and qualitative analysis of secondary metabolites for identification of biomarkers responsible for feed quality in mulberry. Annual report 2021-22, CSB-Central Sericultural Research and Training Institute, Mysuru, pp 66-71.

Yadav S, Rathore MS, Mishra A (2020) The pyruvate-phosphate dikinase (C4-SmPPDK) gene from Suaeda monoica enhances photosynthesis, carbon assimilation, and abiotic stress tolerance in a C3 plant under elevated CO_2 conditions. Frontiers in Plant Science, 11: 345. https://doi.org/10.3389/fpls.2020.00345

Zou J, Zhang Q, Amoako FK, Ackah M, Li H, Shi Y, Li J, Jiang Z, Zhao W (2024) Genome-wide transcriptome profiling of mulberry (Morus alba) response to boron deficiency and toxicity reveals candidate genes associated with boron tolerance in leaves. Plant Physiology and Biochemistry, 207: 108316. http://doi.10.3389/fpls.2020.00345

MULBERRY IMPROVEMENT IN EASTERN AND NORTH-EASTERN INDIA: CURRENT STATUS, CHALLENGES, AND STRATEGIC INTERVENTIONS

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Abstract

Mulberry leaf is the primary economic component in sericulture, directly influencing cocoon yield and quality. Leaf yield and nutritional quality are critical determinants of profitability and the overall success of silk cocoon production. However, mulberry improvement in Eastern and North-Eastern (E&NE) India faces several biological and breeding constraints, including a slow breeding cycle, long gestation periods, limited availability of suitable germplasm, inadequate understanding of the genetic basis of economically important traits, and challenges in applying advanced molecular breeding techniques. Environmental stresses - such as water scarcity, low temperatures, hailstorms, flooding, and outbreaks of insect pests and diseases - further limit mulberry productivity and degrade leaf quality across the region. Currently, improved mulberry varieties such as S-1, S-1635, and K-2 collectively account for over 90% of the cultivated area in E&NE states. Current breeding programs are increasingly focused on enhancing leaf yield and developing climate-resilient varieties with improved tolerance to abiotic and biotic stresses. Despite the availability of improved varieties, mulberry breeding in the region remains largely dependent on conventional methods such as hybridization and selection. The transition to advanced tools like marker-assisted selection (MAS) and genomic selection is yet to gain momentum. Additionally, limited adoption of improved varieties by marginal sericulture farmers - often due to poor awareness, limited accessibility, and socio-economic barriers - remains a significant bottleneck. Addressing these challenges calls for a multi-pronged strategy that includes: Accelerated breeding through modern biotechnological tools; widening the genetic base via germplasm exploration; developing varieties with greater stress tolerance; strengthening farmer extension services and varietal dissemination efforts. Such integrated efforts are essential to realize the full potential of mulberry improvement in the Eastern and North-Eastern regions and ensure sustainable growth of the sericulture sector.

Key words: biotechnological tools, climate-resilient, mulberry improvement, stress tolerance

Introduction

Silk is a natural protein fibre produced from the insect species belonging to the bombycid (*Bombycidae*) and Saturniid (*Saturniidae*) family. Silk is one of the luxurious fabrics and plays a significant role in textile industry along with exports. Sericulture is the practice of rearing silkworms for the production of raw silk is a tradition agro-based industry and provides year-round employment to the rural masses. India following strategic research advancements and successful implementation of developmental programmes attained the second position in silk production. India is the second largest silk producer (41,115 MT in 2025) after China and has the unique distinction of producing all five commercial varieties of silk. Mulberry silk production alone contributes to 76.82% (29,892 MT) and rest 23.18% is wild silks viz., Eri (7,183 MT), Tasar (1,586 MT) and Muga (252 MT) in India (2024-25). Mulberry sericulture activities not only create opportunities of silk production, but can also play a significant role in achieving several Sustainable Development Goals (SDGs) related to poverty reduction, economic growth, environmental sustainability and women Empowerment. The present global scenario clearly indicates the enormous opportunities for the Indian Silk Industry. The global silk market is valued at $18.7 billion in 2025 is projected to reach $34.1 billion by 2031 with CAGR of 8.2%. Hence, sericulture research priorities should focus on enhancing silk production efficiency, quality, and sustainabilityto meet the demands international markets and increase the profitability of farmers.

Mulberry is a woody perennial widely adaptable multipurpose tree species belonging to the class Dicotyledonae; order Urticales; family Moraceae and genus *Morus* (Hooker 1885). It has a wide range of chromosome numbers, ranging from 2n=28 to 2n=308 ploidy levels from 1x to 22x. The somatic chromosome number 2n=2x=28 for *M. alba*, *M. bombycis*, M. *laevigata*, *M. microphylla* and *M. Rubra* and polyploidy series of 2n=56, 84 and 112 for M*. Cathayana*, M*. teliaefolia*, *M. nigra* (Janaki Ammal, 1948). Only five *Morus* spp. (*M. indica*, *M. alba*, *M. bombycis*, M*. sinensis* & *M. multicaulis*) are sericulturally important among fourteen species across the world. The *morus* species such as *M. indica*, *M. alba*, *M. Serreta* and *M. laevigata* are widely distributed in different parts of India (Kanjilal et al. 1940). Mulberry is native to Indo-China region and is widely distributed in Asia, Europe, America, Africa and Australia. The mulberry germplasm collection of India is vital for sustainable silk industry and scientific advancements. The sole conservation center (Central Sericultural Germplasm Resource Centre) houses more than 1300 diverse array of mulberry landraces and wild relatives, offering a rich source of genes for resistance to biotic and abiotic stresses, crucial for developing climate resilient modern varieties.

Mulberry is extensively cultivated in India for silkworm rearing as is the only source of food for the domesticated silkworm, *Bombyx mori* L. Mulberry is a hardy plant capable of thriving well under a variety of soil and climatic conditions. The Eastern and North-Eastern region significantly contributes to the overall sericulture development of the country. Mulberry sericulture is practiced across all thirteen states of the Eastern and North-Eastern region, with West Bengal, Assam, Tripura, Mizoram, and Meghalaya emerging as the major silk-producing states. It comprises seven agro-ecological zones showing wide variation from place to place due to difference in topography, physiographic and rainfall (Table 1). It is observed that this region contributed 16.44% of total raw silk production in India during 1951-52 has declined to 8.10 % in 2023-24 due to relatively faster growth of production in other parts of the country. This region characterized by widely scattered seri-farmers with small land holdings (<0.25 acre), little production capacity (50-100 dfls/crop), which are mostly practiced by women and weaker sections of the society (Das et al., 2000). Mulberry cultivation is facing numerous challenges such as abiotic stress (high temperature, cold stress, acidity, salinity, water logging, low fertility), biotic stress (sucking pests, foliar diseases, root rot, stem borers, etc.,), soil degradation, climate change impacts, and inefficient resource management. These factors are significantly impacting productivity of quality leaves and the overall sustainability.

In the subtropical regions of India, the Central Sericultural Research and Training Institute (CSRTI), Berhampore serves as the only national-level research institute dedicated to mulberry improvement through the utilization of indigenous genetic resources. To address the location-specific research and development (R&D) needs of diverse agro-climatic zones, CSB-CSRTI Berhampore operates three regional research stations: Koraput – catering to the tropical sericulture zones; Jorhat – focusing on the subtropical regions; Kalimpong – addressing the requirements of the sub-temperate areas; These centers play a pivotal role in developing region-specific mulberry varieties, enhancing productivity, and supporting sustainable sericulture across Eastern and North-Eastern India.

Mulberry sericulture is practiced across all thirteen states of Eastern and North-Eastern India, encompassing a total area of approximately 30,000 hectares. The region contributes about 2,500 metric tonnes (MT) of raw silk to the country's annual production, underscoring its importance in India's sericulture landscape. It is a significant source of livelihood in rural communities especially for women and economically weaker sections. Mainly improved host plant varieties play a major role in determining the sustainability and profitability of sericulture. Successful silkworm rearing is directly associated with the continuous supply of quality mulberry leaves and

Table 1: Constraints in Mulberry Cultivation in Eastern and North-Eastern India: A Regional Analysis

Climate	Agro-Climatic Zone	Agro-Ecological Zones (AER)	AER No.	States	Rainfall (mm)	LGP (days)	Constraints for mulberry cultivation
Tropical	Eastern Plateau and Hills	Hot sub-humid red & yellow soils,	11	Chhattisgarh	1200–1600	150-180	Drought stress, N, P deficiency, Low productivity
		Hot subhumid red & lateritic soils	12	Odisha, Jharkhand, West Bengal	1000–1600	150-180	Drought stress, N, P, Zn & B deficiency
	East Coast Plains and Hills	Hot sub-humid to semi-arid, alluvium soils	18	West Bengal, Odisha	900–1600	90-210	Soil salinity, Water logging, Pest and Diseases
Sub tropical	Middle Gangetic Plain	Hot sub-humid (moist) with alluvium soils	13	Bihar	1400–1600	180-210	N, P, Zn deficiency, Pest and Diseases
	Lower Gangetic Plain	Hot subhumid (moist) to humid, with alluvium soils	15	West Bengal plains and Assam	1400–2000	>210	Water logging, Low temperature, Pests and Disease
	Eastern Himalayas	Warm perhumid, with red & lateritic soils	17	Nagaland, Manipur, Mizoram, Tripura, Meghalaya & hills Assam	1600–2600	>210	Acidic soil, Soil erosion, N, P deficiency, Low productivity
Sub temperate	Eastern Himalayas	Warm per humid with brown and red hill soils	16	Sikkim, Arunachal and hills of West Bengal	2000–4000	>210	Low temperature, Acidic soil, Steeply slope land, Low productivity

mulberry leaf production alone contributes to more than 60% to silk cocoon production. Mulberry leaf productivity has enhanced considerably over past three decades employing conventional breeding methods, suitable cultivation practices and improved crop protection measures. The deployment of conventional breeding techniques (Selection, hybridization, polyploidy, mutation and backcross) lead to develop several improved mulberry varieties, which are being exploited by the farmers regularly.

The introduction of improved mulberry varieties has significantly enhanced leaf productivity across various agro-climatic zones, contributing to 3- to 6-fold increases in yield and enabling sustainable cocoon production. The observed improvements are as follows: Irrigated zones: Leaf yield increased from 12–15 MT/ha/year to 50–55 MT/ha/year; Rainfed zones: Improved from 8–10 MT/ha/year to 18–24 MT/ha/year; Hilly zones: Enhanced from 6–8 MT/ha/year to over 20 MT/ha/year. These advancements have played a crucial role in stabilizing cocoon output and improving the economic returns for sericulture farmers across Eastern and North-Eastern India. Development of improved mulberry variety with higher productivity and adaptability to different agro-ecological zones is of paramount importance for effective sericulture farming to enhance silk productivity. In order to develop improved mulberry varieties, the breeders should look for sources of creating novel variation by mutation, polyploidy, pre-breeding and exotic genetic resources. Application of biotechnological techniques such as marker-assisted selection, transgenesis and genome editing should enable development of suitable mulberry varieties with desirable traits and meet specific challenges.

Table 2: Status of mulberry area and raw silk production in E&NE States (2023–24)

States	Districts (No.)	Villages (No.)	Farmers (No.)	Area (Ha.)	Raw silk (MT)
1.Assam	34	1424	30031	2369	15
2.Arunachal	6	5	20	100	2
3.Manipur	10	270	6041	2469	38
4.Meghalaya	5	210	3455	3401	65
5.Mizoram	10	211	2301	1090	68
6. Nagaland	3	335	1585	370	4
7.Sikkim	4	62	1150	179	0.5
8.Tripura	8	229	15550	1864	116
NE region	80	2746	60133	11842	308
9. Bihar	5	728	5021	425	0.8
10.Chhattisgarh	21	136	892	6	6
11.Jharkhand	4	33	880	550	1
12.Odisha	4	111	270	127	0.3
13.West Bengal	3	1009	102038	14892	2105
Eastern region	37	2017	109101	16440	2113
E & NE States	117	4763	169234	28282	2422
All over India				263352	29892

Mulberry varietal development for East and North-Eastern India– current Status

Mulberry germplasm resources are being maintained centrally at CSGRC-Hosur (1330 accessions) and limited accessions (180 accessions) are also maintained at the institute for utilization in new varietal development. Germplasm evaluation is crucial for understanding the genetic diversity and to make informed decisions about traits to incorporate into new mulberry varieties, ultimately enhancing leaf productivity and resilience. Germplasm conservation at different agro-ecological zones is essential for adapting to specific climates and providing resources for breeding new mulberry varieties at main institute or regional stations. Mulberry breeding involves manipulating genetics to enhance characteristics like yield, disease resistance, and nutritional quality. This field utilizes techniques ranging from simple selection of desirable plants to more complex molecular methods. In mulberry, several breeding methods such as introduction, selection, heterosis, mutation, polyploidy, backcross breeding, inter-specific hybridization and transgenic breeding were applied for improvement in yield, leaf productivity and quality. Mulberry breeders at the institutes have developed several high yielding mulberry varieties employing conventional breeding techniques.

Mulberry varieties were introduced from temperate sericulture countries directly and were utilized for improvement of existing ones by incorporating desirable traits from introduced mulberry varieties. Most of the introduced varieties are not proven to be successful except Goshoerami, Kosen for temperate regions. The open-pollinated hybrids (OPH) are developed through natural pollination, where ineither one of the parent or both the parents are unknown. Several open pollinated hybrids in mulberry S-1, S-799, S-1635, S-146, *etc*., which were exploited for natural heterozygous is contributed significantly to silk production. These varieties are presently cultivated in larger areas of Eastern and North-Eastern region. The clonal selectionis another traditional breeding methodthat has led to the development of high yielding variety Vishala (45-50 MT) recommended for irrigated conditions of Eastern region.

Hybridization between two desirable parents or heterosis breeding is common method of mulberry improvement of leaf yield and quality. It is also known as controlled pollinated hybridization (CPH), wherein the desirable traits in different parents were brought together into a single genotypeand the F1 seeds obtained will be raised in seedling nursery. The F1 seedlings were raised in the experimental plot, field for selection within and between families (PRT: progeny testing). Since mulberry accessions are highly heterozygous, the success of hybridization method mostly relies on the production of superior F1 hybrids (Das, 1984). The desirable F1 with improved traits will be evaluated in small plot area (PYT: preliminary yield evaluation) for important yield attributes, nutritive quality, palatability, propagation traits along with tolerance to

Table 3: Mulberry varieties for Sub-tropical sericulture developed by CSRTI Berhampore

Sericulture Zones	Variety	Leaf Yield [t/ha/yr]		Leaf Moisture (%)	Soluble protein (mg/g)	Soluble sugar (mg/g)	Year of release	Characteristics
		Irrigated	Rainfed					
Irrigated Zone	S-1	29-30	9-10	72-73	21-24	30-34	1970	Leaf yield
	S-799	35-40	10-12	77-78	30-31	34-35	1990	Leaf yield
	S1635	40-45	13-16	78-79	31-32	33-34	1995	Leaf yield
	C2038	53-54	17-21	79-80	32-33	38-40	2017	Leaf yield
	CBP2	58-60	21-24	76-77	34-35	44-45	2024	Yield& disease
Himalayan Hill zone	Kosen	-	6-8	78-79	32-33	44-45	1960	Leaf yield
	BC_259	-	8-9	78-79	21-22	28-29	1980	Leaf quality
	S-146	-	10-11	76-78	22-24	26-28	2000	Leaf yield
North-East Hill zone	Tr-10	-	16-18	72-73	23-24	25-26	1995	Leaf yield
	Tr-23	-	24-25	73-75	25-26	31-32	2017	Leaf yield
Rainfed Zone	S-1	-	8-10	72-74	21-24	30-34	1970	Leaf yield
	C1730	-	13-15	74-76	28-30	35-36	2012	Drought
	C2058	-	16-18	74-76	33-34	40-42	2023	red- laterite soil
Specific Condition	C-776	34-38	-	76-77	29-30	29-30	2018	Saline soil
	C2028	35-37	-	78-79	28-29	41-42	2018	Flooding areas

different biotic or abiotic stresses. The superior genotypes identified will be further evaluated in large scale (final yield evaluation: FYT) at one or more locations for leaf productivity, pest and disease severity, cocoon parameters and its adaptability. The promising mulberry varieties developed are finally tested in All India Coordinated Experimental trials on Mulberry (AICEM) at major sericulture zones of India. The superior varieties with atleast more than 10% fresh leaf yield advantage over latest check variety will be authorized by mulberry variety authorization committee (MVAC) and released for commercial exploitation in specific state, region or throughout India. The mulberry varieties C-2028, CBP-1(C-2038), CBP-2 (C-1360) etc., were developed by CPH method. Some of these varieties are most popular with the farmers for their productivity and adaptability. Further, few early sprouting genotypes (C-2060 & C-2065) with tolerant to low temperature stress and higher leaf yield potential (60-65 MT/ha/Yr) were recently developed by CPH method. These high yielding and stress tolerant genotypes are suitable for high density plantation for silk yield enhancement in subtropical regions of East and NE India.

The polyploidy breeding method has also been utilized successfully for mulberry improvement through development of triploid varieties. Triploid mulberry varieties are valued for their superior leaf yield and quality. These varieties are developed through natural or controlled hybridization between diploid and tetraploid parents (Das et al., 1970). Mulberry being a vegetative propagated foliage tree with comparatively a less number of chromosomes, it is highly suitable for the induction of polyploidy for its improvement. In triploid breeding, target genes accumulated to get high hybrid vigour and these were reported to be very superior over diploids in terms of leaf nutrition, genetic adaptability and resistance to environmental stress (Funabiki 1964). In Japan, sericulture industry began to prosper with utilization of a large number of natural triploids (Oswa, 1916). In India, large numbers of auto-tetraploids were developed with colchicines treatments and triploid varieties thus developed mulberry varieties are released for hilly zones (Tr-8, Tr-10, Tr-23) and rainfed zone (C-1730-drought tolerant). Further, few triploids superior for leaf productivity under irrigated condition were identified for silk yield enhancement in subtropical region. The physiological breeding approach involves selecting plants based on their physiological growth traits, rather than yield attributes was attempted. Few high yielding genotypes (PP-8 and PP-10) with higher physiological efficiency and wider adaptability were developed. These physiologically efficient genotypes may be commercially exploited after testing under AICEM programme.

Mutation breeding in mulberry is considered as low priority research area as it has not resulted in any viable variety in India. Few mulberry varieties such as S-30, S-36, S-

41 and S-54 were developed by chemical mutagenesis at CSB-CSRTI, Mysuru. However, in a vegetative-propagated crop like mulberry, mutation breeding could still be a useful tool for selecting mutants resistant or tolerant to pests or eliminating certain undesirable characteristics. And the efforts are essential to initiate mutation breeding programme in coordination with BARC-Bombay. Breeding for biotic and abiotic stress resistance is a process of developing mulberry varieties that are more tolerant to environmental challenges, such as pests, diseases, and adverse conditions like drought, low temperature, low fertility. The tolerant mulberry varieties for specific stress conditions are developed by selecting parents with desirable traits and using traditional breeding methods, as well as modern genetic techniques. The core mulberry germplasm was screened for resistance to diseases and molecular markers associated with resistant genes were identified in segregating population. New resistant genotypes for powdery mildew(CBP-2/C-1360) and bacterial leaf spot (C-2070) diseases with superior performance over regional variety C-2038 were developed. Low nutrient stress tolerant variety C-2058(C-9) suitable for sustainable leaf production in low fertility environments or red and laterite soils is being popularized.

Molecular breeding is a method that combines traditional plant breeding with molecular biology techniques to improve mulberry varieties. Several genomic resources have been generated employing genomic tools such as transcriptome, metabolomics, functional genomics, tissue culture (regeneration protocols), molecular markers and genetic engineering (transgenesis). These molecular techniques could be further exploited efficiently for mulberry genetic improvement programmes. The putative markers associated with genes conferring resistance to powdery mildew, leaf spot etc were identified in pseudo F2 segregating population. Identified few QTLs associated with yield traits could be introgressed into a productive mulberry variety through marker assisted breeding (MAB) programmes. The indian mulberry genome sequencing and resequencing programmewill open new windows to exploit genetic/genomic variations in future breeding programmes.

Tissue culture based in vitro selection methods would be useful for identifying mulberry genotypes for tolerance to salinity, alkalinity and water stress. Salt tolerant variety C-776 was identified through *in-vitro* screening for salinity stress. C-776 is recommended for coastal zones having leaf yield potential of 34-36 MT/ha/y and having moderately salinity tolerant (up to an EC of 7.8 mhos/cm) trait. The somaclonal variation in mulberry refers to the genetic or epigenetic changes that occur during *in-vitro* (tissue culture) propagation of mulberry plants. One somaclonal mutant SV-1 with superior leaf yield, leaf size and thickness of the leaf overthe mulberry variety S-1 was identified. Regeneration in mulberry is genotype dependent and regeneration protocols may also be developed in subtropical varieties. Development of gynogenic haploid and triploid mulberry were attempted using ovary and endosperm culture. However, developments of homozygous double haploid lines in mulberry are not reported so far. Ectopic expression of genes and transcription factor (TF) coding genes (Hva1, Osmotin, bch1 and SHN1) that showed tolerance to abiotic stress may also be exploited in subtropical mulberry.

The genetic potential of mulberry varieties can be fully realized only under optimal agronomic and input conditions. In subtropical regions, the currently recommended nutrient dose for irrigated mulberry cultivation - 336:180:112 kg NPK/ha/year along with 20 MT of farmyard manure (FYM) - has remained unchanged for over five decades. While effective for earlier genotypes, this outdated recommendation is increasingly inadequate to meet the nutrient demands of modern, high-yielding varieties. To exploit the full genetic potential of these improved cultivars, there is a pressing need to develop and implement variety and system-specific agronomic packages tailored to the prevailing cultivation conditions (irrigated, rainfed, and hilly terrains). A significant yield gap - ranging from 20% to 40% - has been observed between research station outputs and on-farm performance, particularly in rainfed and hill ecosystems. To bridge this gap, farmers are increasingly adopting integrated crop management strategies, including the use of soil and foliar supplements such as: Hydrogels (for moisture retention); Poshan (balanced micronutrient formulation); Morizyme-B (bio-stimulant for enhanced growth and resilience). Furthermore, there is a growing emphasis on the development and promotion of climate-resilient mulberry varieties that are suitable for high-density planting systems and multipurpose applications (leaf & fodder). Such advancements are critical for ensuring sustainable enhancement of silk production in subtropical regions, particularly in the context of climate variability, land fragmentation, and resource limitations.

Tree type cultivation could become the norm for mulberry cultivation across India due to water scarcity, easy maintenance, less pests and disease incidence, better leaf quality and also for the effective utilization of waste lands. Tree type cultivation of popular mulberry varieties along the bunds of agriculture lands may be promoted for increasing cocoon production. The Distinctiveness, Uniformity and Stability (DUS) test guidelines has been developed for mulberry (*Morus* spp.) with 35 descriptors and 34 example varieties, facilitate protection of new mulberry varieties. However, DUS characterization and registration of developed mulberry varieties for sub-tropical sericulture may be initiated with establishment of collaborativecenter at Berhampore. Although several improved mulberry varieties are developed, only few varieties such as S-1, S-1635, BC259 etc. are predominantly cultivated by the farmers in E& NE India.

Moreover, efforts should be made to strengthen the extension services and developmental supports for engaging farmers to increase cultivation of new mulberry varieties under technologies transfer programmes. Hence, developing improved mulberry varieties is crucial for boosting silk productivity to meet the increasing global demand for silk goods, especially with limited resources and changing environmental conditions.

Table 4: Mulberry cultivation practices and crop schedules for subtropical sericulture

Condition/System	Irrigated	Rainfed	Hills
Bush system	Low bush	Low and High	Mid and High
Plants density (Spacing)	High (60 x 60 cm)	Medium (90 x 90 cm)	Low (>90 x90 cm)
FYM/ Vermicompost	20 MT/ha/y	10 MT/ha/y	10 MT/ha/y
Nutrients [Kg/ha/y]	NPK::336:180:112	NPK::100:50:50	NPK::100:50:50
Harvest Method	Shoot	Leaf and shoot	Leaf
Crop seasons (No./y)	5	3-4	2-3
▪ Monsoon	Jun.–Jul., Aug.–Sep.	Jul.–Sep.	-
▪ Autumn	Oct.–Nov.	Sep.–Oct.	Aug.–Sep.
▪ Spring	Jan.–Feb.	Feb.–Mar.	Mar.–Apr.
▪ Summer	Mar.–Apr.	Apr.–May	May–Jul.

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Challenges and future strategies in mulberry improvement for subtropical Sericulture

- The availability ofsub tropically adopted diverse and well-characterized mulberry germplasm with economical traits is a limiting factor.
- Mulberry exhibits complex genetics and limitations in understanding the genetic basis of economical traits making it challenging to identify and combine desirable traits through breeding.
- Mulberry's dioecious in nature and variable sex expression complicates breeding efforts, as it requires cross-pollination between selected individuals.
- Mulberry being a nutritive foliage crop is susceptible to various pests and diseases outbreak, which complicates the selection of suitable parents
- Lack of advanced breeding techniques like marker-assisted selection and genetic engineering in mulberry breeding due to limited knowledge and resources.
- Long breeding cycle and gestation period due to the perennial nature of mulberry delays the development and release of improved varieties.
- Genotype-Environment Interactions makes it challenging to identify superior varieties that perform consistently well across different regions.
- Mulberry being a highly cross-pollinated and heterozygous plant, the genetic analysis is very difficult.
- Mulberry flowering is seasonal with extremely asynchronous and also exhibit considerable sterility due to polyploidy
- Lack of proper understanding of interrelationship among important leaf characters and inheritance pattern in juvenile stage with that of the adult stage makes the selection/prediction difficult.

Climate change is one of the biggest environmental threats and the study showed that the Indian sub-continent is likely to experience a warming of over 3-5°C and significant changes (increases and decreases) in flood, cold stress, high temperature, drought frequency, pests and disease severity.Developing climate resilient mulberry varieties that perform equally well throughout the year is much needed to improve the silk productivity as the leaf yield in subtropical region falls to the lowest level during winter months due to low temperatures (~10°C) and in summer due to low soil moisture content (13-23%). Due to low temperature as well as short day length during winter, mulberry takes long time for bud development and sprouting during colder seasons. The growth of mulberry becomes very slow and stunted causing a severe scarcity of quality leaf, which is aroundless than 50% of the normal season leaf yield. Due to these constraints, the farmers are compelled to reduce the quantum of rearing particularly bivoltine during February crop. Hence, the sericulture farmers cannot avail the benefit of silkworm rearing particularly bivoltine crop during the congenial rearing seasons due to non-availabilityof late senescence and cold tolerant mulberry varieties.

Mulberry cultivation in Eastern rainfed zones faces frequent and severe droughts, so development of drought-tolerant mulberry varieties increasingly important for sustainable sericulture. Though mulberry grows luxuriantly under rainfed condition, however they failed miserably against prolonged stress of water at different growth stages during post monsoon season. None of the existing mulberry varieties showedtolerance against severe water stress and emphasis was given on the identification of better variety for rainfed condition with 15-16 tons of annual leaf yield (Rahaman et al, 1999). Sericulture is confined to the poorer section of the farming community with size of their mulberry gardens being less than half an acre. The marginal farmers are more dependent on sericulture and application of chemical fertilizers is found to be the major constraints due to its high cost. Hence, development of suitable nutrient use efficient mulberry genotypes or tolerant to low nutrient stress is essential for the benefit of the sericulture farmers. Further, the closed mulberry plantation with wider leaf varietiesalong with poor management resulting less quantity of quality leaves. Hence, development of mulberry varieties with narrow branches suitable for high density plantation is necessary for quick adoption of improved varieties.

Cocoons are the economical product of sericulture and there is strong association between leaf protein content and production efficiency of cocoon shell (Machii and Katagiri, 1991). Therefore, an increase in protein level of mulberry leaves may lead to improvement in silk productivity. Soil acidity is also the major problem in the hills and more lands are becoming unproductive every year due to accumulation of acidic salts in the regions where the silkworm rearing is an age-old practice. The strategy for maintaining the sericulture production at the optimum level in these areas could be the use of mulberry variety with comparatively high acid tolerance (Ghosh et al., 2012). The outbreak of the pests and disease at field level is increasing day by day. Since the mulberry leaf is available throughout the year, it makes the plant prone to various sucking pests which alone estimated to cause a leaf loss of about 40-50 % (Mahadeva, 2011). Therefore, use of host resistant is one of the cheapest and best ways to evade the infestation in mulberry.

Generally, mulberry is grown as a monoculture crop and it can be successfully grown as an intercrop in between the rows of plantation crops like Mango, coconut or with short duration beans, vegetables and food crop as means of additional source of income to a sericulturist. However, a shade tolerant and nutrient efficient compact canopy type mulberry varieties suitable for inter cropping will help in further expansion of sericulture in these traditional areas. Genetic improvement of mulberry yield potential through conventional breeding have been distressingly slow mainly because of the complexity of the traits that need to be introgressed coupled with the perennial nature of this crop. The applications of modern molecular and genomic tools are expected to strongly complement the breeding efforts in enhancing yield potential of mulberry (Khurana and Checker, 2011). Understanding trait genetics and identification of genetic factors with stable performance across environments based on precise phenotyping is essential to harness the benefits of modern genomics technology and the process is referred as genomics-assisted breeding (GAB) (Varshney *et al*., 2005).

Popularization of improved varieties will be a continuous process should be taken as top priority to replace the local and obsolete varieties in a phase wise manner. The popularization of new high yielding mulberry varieties is carried out inlimited effort under routineextension programmes likeawareness, TOT and CPP. In addition to these, large scale varietal expansion has to be taken up from state farms having the seed stock garden multiplied from the nucleus stock of CSRTI, Berhampore. The overall strategies of mulberry improvement for subtropical sericulture are as follows.

- Introduction, conservation and evaluation of diverse mulberry germplasm under subtropical climate for identifying suitable parents
- Breeding of narrow leaf compact type mulberry varieties for high density plantation in the productive areas of subtropical irrigated zones.
- Development of variety with drought tolerance, heat resistance along with nutrient use efficient will ensure comprehensive resilience in rainfed zones
- Development of variety with deep rooting, cold tolerance and suitable for leaf harvest will ensure sustainable leaf production in hilly zones.
- Breeding mulberry varieties with strong and thin shoots suitable for mechanical shoot harvest.
- Development of multi-purpose mulberry variety suitable for integration in agroforestry.
- Improving the efficiency of physiological process like photosynthesis and improved nutritional qualities through physiological breeding approach.
- Developing molecular resources and tools for understanding the genetic basis of complex traits to identify the specific genes.
- Application of advanced techniques such as genomics, high-throughput phenotyping, less time-consumingbreeding methods through molecular approach, and gene editing technologies like CRISPR-Cas9 will help to achieve faster mulberry improvement.

Conclusion

Traditional mulberry breeding techniques have played a crucial role in significantly enhancing leaf yield and tolerance to various environmental stresses. Varieties developed through classical methods of hybridization and selection have contributed to a three- to six-fold increase in leaf productivity across different agro-climatic regions. These approaches primarily relied on exploiting dominant genetic variance to improve economically important traits such as leaf yield, biomass, and adaptability. However, mulberry breeding remains a resource-intensive and time-consuming process, constrained by a prolonged juvenile phase and limited understanding of the genetic basis of key economic traits. In addition, the potential of wild relatives and exotic mulberry species remains largely underutilized, despite their rich reservoir of traits such as disease resistance, leaf quality, and abiotic stress tolerance. The advent of genomics and molecular breeding offers transformative potential to overcome these limitations. Techniques such as marker-assisted selection (MAS) allow for the early and precise identification of desired traits at the seedling stage, thereby enhancing selection efficiency and reducing the breeding cycle duration. While traditional breeding methods continue to be relevant, they are now being strengthened by modern tools including - whole genome sequencing, molecular markers, genome editing (eg. CRISPR), high-throughput phenotyping platforms, *etc*. The integration of conventional and molecular approaches is paving the way for precision breeding in mulberry, aimed at developing climate-resilient, high-yielding varieties tailored to diverse production systems. This convergence holds immense promise for addressing the challenges of climate change, enhancing farm-level productivity, and achieving targeted national silk production goals.

References

Checker VG, Chibbar AK, Khurana P (2011) Stress- inducible expression of barley hva1 gene in transgenic mulberry displays enhanced tolerance against drought, salinity and cold stress. *Transgenic Res.*, 21: 939–957. https://doi.org/10.1007/s11248-011-9577-8

Das BC (1984) Mulberry varieties, exploitations and pathology. *Sericologia*, 24: 369–372.

Das BC and Krishnaswami S (1965) Some observations in interspecific hybridization in mulberry. *Indian J. Seric.*, 4: 1–8.

Das C, Sahu PK, Sengupta T, Misra AK, Saratchandra B, Sen SK (2002) Selection of drought tolerant genotypes for crop improvement in mulberry (*Morus* sp.). *Journal of Tree Sciences,* 19(1&2): 47-53.

Ghosh MK, Shivnath, Ghosh PK, Misra AK, Ghosh A and Bajpai AK (2012) Genetic divergence in relation to physiological parameters in exotic mulberry (*Morus* sp.) germplasm accessions. *Adv. Plant Sciences,* 25(1): 219-225.

Khurana P and Checker VG (2011) The advent of genomics in mulberry and perspectives for productivity enhancement. *Plant Cell Reports*, 30: 825-838. https://doi.org/10.1007/s00299-011-1059-1

Machii H and Katagiri K (1991) Varietal differences in nutritive values of mulberry leaves for rearing silkworms. *JARQ*, 25: 202-208.

Mahadeva A (2011) Influence of thrips (*Pseudodendrothrips mori*) infestation on the biochemical constituents and photosynthetic pigments of mulberry (*Morus* sp.) leaves. *International journal of plant, animal and environmental sciences*, 1(3): 57-63.

Rahaman MS, Doss SG, Vijayan K, Setua M and Roy BN (1999) Performance of improved varieties of mulberry under rain fed condition in West Bengal. *Indian Journal of Agricultural Science*, 69: 752-754. https://epubs.icar.org.in/index.php/IJAgS/article/view/27042

Varshney RK, Graner A, Sorrells ME (2005) Genomics assisted breeding for crop improvement. *Trends Plant Sci*., 10: 621-630. http://doi.10.1016/j.tplants.2005.10.004

Vijayan K, Chakraborti SP, Roy BN, Sen SK (1998) Winter hardy mulberry varieties: a need. Indian Silk, 37(2): 6–8.

CURRENT STATUS AND FUTURE PERSPECTIVES OF MULBERRY BREEDING FOR NORTH WEST INDIA WITH SPECIAL EMPHASIS ON TEMPERATE REGIONS

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Abstract

India's sericulture industry, the world's second-largest silk producer, plays a vital role in rural economies, particularly through mulberry sericulture in North West India. This region, encompassing Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Uttarakhand, Uttar Pradesh, and Rajasthan, presents diverse agro-climatic zones favorable for mulberry cultivation, especially for high-quality bivoltine silk production. Mulberry (*Morus* spp.) cultivation varies regionally, with temperate zones supporting tree-type mulberry varieties and sub-tropical areas favoring bush and tree forms. Historically, traditional mulberry varieties in North West India showed low yields, prompting breeding programs to develop high-yielding, adaptable, and stress-tolerant varieties. Since the 1960s, the Central Sericultural Research & Training Institutes (CSRTI) have developed multiple improved varieties using classical and advanced breeding methods, including clonal selection, mutation breeding, and somatic hybridization. Recent efforts focus on temperate region-specific challenges, such as cold tolerance, through biotechnological interventions and molecular studies identifying key stress-responsive genes. Collaborative research with international partners aims to broaden the genetic base and adaptability of mulberry varieties. Future programs emphasize germplasm conservation, DUS testing, cold tolerance breeding, and advanced genomic tools to accelerate mulberry improvement. These integrated breeding and biotechnological strategies aim to enhance mulberry productivity and sustainability, thereby strengthening sericulture's socio-economic impact in North West India's diverse agro-climatic zones.

Key words: cold tolerance breeding, conventional breeding, mulberry breeding, somatic hybrids

Introduction

India's sericulture industry is a cornerstone of its rural economy, blending tradition with innovation to become the world's second-largest producer of silk. It involves cultivating mulberry trees (*Morus* spp.) to feed silkworms (*Bombyx mori*), which then spin silk cocoons. Mulberry sericulture plays a crucial role in rural development, employment generation, and economic growth. The North West India encompasses diverse agro-climatic regions that present varying levels of potential for mulberry sericulture**,** which is the most prominent form due to its superior silk quality. This region includes the states of Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Uttarakhand, Uttar Pradesh and Rajasthan (Table 1). The North West Indian sericulture is broadly identified into temperate and sub-tropical sericultural zones. Temperate area is bestowed with salubrious climate, ideally suited for bivoltine sericulture. Land availability, climate and socio-economic conditions of the region favour bivoltine sericulture development in whole of North West India (Shabnam et al., 2018). Among these, the temperate regions of the Western Himalayas particularly Jammu & Kashmir and parts of Himachal Pradesh and Uttarakhand offer a unique agro-ecological niche for mulberry cultivation. These areas, characterized by moderate summers and cold winters, support the growth of temperate mulberry varieties with distinct leaf morphology and high nutritive value for silkworm rearing. The seasonal dormancy in these regions aligns well with bivoltine sericulture practices, which are known for producing high-quality silk.

Mulberry (genus *Morus*, family Moraceae) is an eco-friendly, economically vital deciduous tree, valued especially for its leaves the primary food source for domesticated silkworms. Native to the Himalayan foothills, it thrives in diverse agroclimatic zones and supports biodiversity, rural livelihoods, and sustainable development (Rohela et al., 2020; Saini et al., 2023, 2025; Shabnam et al., 2018). Mulberry is cultivated under various systems, including different planting densities, pruning methods, harvesting schedules, and agronomic practices. In the southern and eastern parts of India, mulberry is typically grown as low to high bush types, whereas in the north-western regions particularly in Jammu & Kashmir, Punjab, Himachal Pradesh, and Uttarakhand it is grown as low, medium, and high tree forms (Chauhan et al., 2018). In temperate regions, mulberry cultivation is tailored to seasonal changes, with pruning and harvesting timed to spring growth and autumn dormancy. This requires region-specific research to optimize practices for high leaf yield and quality. Breeding goals vary by location, making careful evaluation and selection of suitable genotypes essential for diverse environments and management systems.

Indian Sericulture and Early Mulberry Varieties

While sericulture in India dates to the Vedic era, the systematic development of mulberry-based sericulture began around three centuries ago. This progress was largely driven by the support and patronage of regional rulers across different parts of the country. In Eastern India, states like West Bengal, Bihar, Odisha, and Assam played a pivotal role in its growth. Similarly, the Madras Presidency- covering areas of present-day Karnataka and Tamil Nadu - contributed significantly in Southern India. Meanwhile, in Northern India, Jammu & Kashmir emerged as a major centre for sericulture, enjoying a well-established and thriving silk industry during the pre-independence period. At that time, mulberry varieties were primarily cultivated as bushes in Bengal (with notable types such as Bush Malda, Takda, Bombaiya, Kajli, Vishnupur, and Berhampore Local) and in the Madras/Mysore regions (including Mysore Local, Yenne Ranginakaddi, Boodhukaddi, and Sultan Kaddi). In contrast, Kashmir and Punjab favored tree-type varieties like Shahtul, Botatul, and Chahtatul. However, these traditional mulberry varieties had relatively low yield potential, producing only about 6 to 10 metric tons per hectare annually (Tiakder et al., 2014).

Objectives of Mulberry Breeding

Development of the high yielding varieties (HYVs) with desired traits is the prime objective of every breeding programmes. The primary objectives in mulberry breeding is to breed varieties for higher foliage, leaf quality, greater adaptability, rapid and efficient clonal propagation of the material (variety) (Fig. 1). Suitable clones may be obtained by crossing two known parents or seedlings from outstanding mother trees through open population, followed by vegetative selection and field trials under different agro-management. Largely, the mulberry improvement programs are mainly targeted towards the following aspects:

1. **Breeding mulberry varieties for improvement in foliage yield and nutritional quality in productive areas.**
   a. Growth habit (quick recovery after pruning), Vigour, Sprouting, Leaf senescence, Rooting ability
   b. Total soluble protein (TSP), Total Soluble Carbohydrate (TSC), Total Chlorophyll Content (TCC), Moisture Content (MC %), Moisture Retention Capacity (MRC %)
2. **Breeding mulberry varieties with wider and specific adaptability**
   a. Varieties with uniform/favored environments/conditions.
   b. Varieties with relatively better performance in poor environments/conditions.

Table 1: Agro-climatic zones of North & North-Western region of India

#	State	Area under mulberry plantation (ha)	No. of agro climatic zones	Mean annual rainfall (mm)	Altitude (m)	Soil Type	Mulberry varieties
1.	Jammu & Kashmir	7000	04 (Outer plains, Outer hills, Middle mountain and Inner mountain)	600-2000	360-5200	Slitty loam to Clay loam and brown pH 6.5-7.5	Goshoerami, PPR-1, K2, Punjab Local, Sujanpur local, S-1, S-146, S-1635, C-2038
2.	Punjab	1249	05 (Hot humid, Rainfed, Sub-humid, Semi-arid, Shivalik hills)	300-1400	180-600	Alluvium of Indus system pH 6.0-8.5	S-146, K2, Sujanpur local, Punjab local, S-1
3.	Himachal Pradesh	3568	06 (Sub-tropical, Sub-humid, High hills, Cold and dry, Alpine high land and fridged arid zone)	800-2000	365-4500	Clay loam pH 5.5-5.7	K2, S-146, S-1635, S-34, S-13, S-1, Tr-10, Himachal local
4.	Haryana	356	04 (Shivalik hills, Tert-iary rocks, Indo-gangtic alluvial plains, Arawali Delhi wedge – Arid, Semi-arid and humid)	300-1500	300-800	Clay loam Reddish and brown pH 7.4-7.9	S-146, S-1635, K2, S-1
5.	Uttar Pradesh	4007	03 (North hill, South hill / Plateu, gangetic plains	750-1200	70-300	Alluvial sandy and clay loam	S-146, S-1635
6.	Uttarakhand	1937	05 (North-west hill area, mid height, high height, Bugyal area and snow clat)	1100-2000	600-4500	Sandy loam and forest brown pH 6.0-6.5	S-146, S-1635, Tr-10, S-13, S-34, S-36, S-54, S-1635, $BC_2 59$
7.	Rajasthan	-	09 (Hyper aird, arid, semi-arid, humid, sub-humid, plain, arawali landscape, eastern upland and luni river basin)	180-1500	300-1000	Black cotton sandy pH 6.5-9.5	S-1, K2, S-13, S-34, S-146, V-1, S-1635

3. Breeding for stress (biotic and abiotic) tolerant mulberry varieties

a. Diseases and insect pests: Leaf spot, powdery mildew, leaf rust, tukra, leaf webber

b. Abiotic Stresses: Drought, salinity, alkalinity, heat, cold tolerance

Fig. 1: Breeding objectives for mulberry cultivation under the temperate climatic conditions of the Kashmir Valley

The breeding objectives sometimes differ according to the specific needs of state/ region and the traditional practices. The specific objectives could be determined by studying the problems of the area or region. The socio-economic condition of the area and the acceptability of farmers need to be considered by the breeders. For example, the mulberry rearers prefer the un-lobed mulberry leaf over the lobed leaf while the farmers in Japan prefer four to five shallow lobed leaf.

Evolution of suitable varieties with improved plant type/ higher yield for limited irrigated and rain-fed areas for varied agro-edaphic & cultural practices under "Bush, Dwarf & Tree-type of plantation with superiority over existing ones (early sprouting, late-leaf-shedding,) for specific regions needs to develop. Likewise, varieties amenable to vegetative propagation by "stem-cuttings" with early sprouting habit is the need for evolution of cold, snowy or little-snowing areas of temperate pockets (HP, Uttarakhand and Jammu & Kashmir).

Current Status of Mulberry Breeding in Temperate Region

1. Harnessing Exotic and Indigenous Mulberry Diversity

Following the establishment of the Central Silkworm Seed Station (CSSS), Pampore in 1958, several temperate mulberry cultivars from Japan were introduced to replace the low-yielding indigenous mulberry varieties traditionally cultivated in the Kashmir Valley. These exotic cultivars, although high-yielding, exhibited poor rooting ability and were not well-suited for propagation through stem cuttings. Historically, the Kashmir region relied on the cultivation of local tree-type mulberry varieties, with an estimated population of approximately 3.3 million mulberry trees during the early 1960s, prior to the introduction of Japanese varieties. To ensure the propagation of these newly introduced high-yielding cultivars, the State Sericulture Department established government mulberry graft nurseries, which produced between 100,000 to 150,000 grafted saplings annually, tailored to temperate conditions of the valley. In contrast, Himachal Pradesh witnessed a steady increase in the population of locally adapted mulberry trees, growing from 50,000 in 1952 to 119,868 by 1957 in hilly regions. Similarly, in Punjab, approximately 160,000 mulberry trees - predominantly ‘Punjab Local’ and ‘Sujanpur Local’ varieties - were available to support silkworm rearing activities. In Uttar Pradesh, although sericulture activities began modestly in 1948, the Doon Valley recorded rapid progress by utilizing leaves from around 50,000 local mulberry trees, as documented in the CSB All India Directory on Silk Industry (1958). The yield performance of the temperate cultivars introduced from Japan and other regions, and their subsequent cultivation in the Kashmir Valley, is summarized in Table 2 (Kour, 2009).

Table 2: Leaf yield ability of Japanese mulberry cultivars introduced in Kashmir valley

Varieties	Leaf Yield (kg/tree)			Leaf yield (kg/ha)	100 Leaf weight (g)	Leaf moisture (%)	LMRC after 6 h (%)
	Spring	Autumn	Total				
Goshoerami	7.10	7.90	15.00	22425	451.30	75.70	91.80
KNG	6.20	6.30	12.50	18688	256.50	74.10	88.10
Ichinose	3.30	5.20	08.50	12708	244.20	73.20	88.70
Kokuso-20	4.70	5.20	09.90	14800	266.30	73.50	87.60
Chinese White	3.40	4.20	07.60	11362	193.40	72.30	86.10
TR-10	4.60	5.10	09.70	14502	241.30	74.10	87.10
Rokokayaso	4.20	5.10	09.30	13904	172.80	72.40	87.30
Average	4.80	5.60	10.40	15548	260.80	73.60	88.10

LMRC: Leaf moisture retention capacity

2. High-Yielding Mulberry Varieties Developed by CSRTI (Berhampore and Mysore) and their suitability in Sub-Tropical Agro-Climatic Zones of North-Western States

Since the 1960s, mulberry breeders at CSRTI, Berhampore, Mysuru and Karnataka State Sericulture Research and Development Institute, Thalaghattapura, Bengaluru have developed a wide array of high-yielding mulberry varieties by harnessing both exotic germplasm and indigenous genetic resources. A range of classical and advanced breeding techniques were employed, including:

- **Selection and Clonal Selection**: S-1, Kanva-2, DD (Viswa), Vishala
- **Mutation Breeding**: S-30, S-36, S-41, S-54
- **Polyploidy Breeding**: Tr-4, Tr-8, Tr-9, Tr-10, Tr-23, C-1730
- **Backcross Breeding**: $BC_2$59
- **Open and Free Pollination Techniques**: RFS-135, RFS-175, S-13, S-34, S-799, S-146, S-1635, MR-2, S-1608
- **Controlled Hybridization of Selected Parental Lines**: S-146, C-763, C-776, C-1730, C-216, C-2017, C-2028, C-2038, G-2, G-4, V-1, K2 × Kosen (Sahana), RC1, RC2

These mulberry varieties exhibit a leaf yield potential ranging from 14,000 to 20,000 kg/ha/year under rainfed conditions, and 20,000 to 60,000 kg/ha/year under irrigated conditions, depending on the agro-climatic zone, soil characteristics, and agronomic management practices (Tikader et al., 2014).

Most of these varieties have been evaluated through local and regional trials conducted in Jammu & Kashmir, Himachal Pradesh, Uttarakhand, and Uttar Pradesh, including multi-location testing under AICEM-I, II, and III programmes. Based on their performance, they have been found suitable for cultivation across various states of North-Western India, as in Table 2.

Under AICEM Phase-IV, three test entries viz., C-1360, AGB-8, and PPR-1 developed by the three CSR&TI (Berhampore/Mysore/Pampore) of Central Silk Board were evaluated across four test sites in North-Western India. Based on preliminary observations, C-1360 demonstrated superior performance across all test locations, indicating its broader adaptability. Additionally, under the temperate climatic conditions of the Kashmir Valley, PPR-1 emerged as a promising entry, exhibiting favourable traits such as high leaf yield, strong rooting ability, early sprouting, and positive results in silkworm bioassay studies.

3. Breeding Programmes carried by CSB-CSRTI, Pampore Focused on High-Yielding, Clonally Propagable Mulberry Varieties

Over the past decades, significant efforts have been directed toward the development of superior mulberry varieties tailored to the temperate and sub-tropical regions of the North-Western Indian states. These efforts have employed both conventional breeding approaches and biotechnological interventions to enhance genetic potential and adaptability under diverse agro-climatic conditions.

3.1. Conventional Breeding Approach

3.1.1. Temperate Region

After attaining the status of a research institute in 1990-91, CSR&TI, Pampore initiated preliminary breeding experiments for mulberry improvement during 1995-96. These efforts involved the use of several exotic cultivars, with crosses made between Goshoerami × Chinese White, and a mixed pollen cross of S1301 × S799. Additionally, open-pollinated hybrid seeds collected from Goshoerami as the female parent were used to raise F_1 seedlings. Through successive cycles of selection and yield trials, eleven promising strains were identified and subjected to final yield evaluation, resulting in the selection of three superior strains: S-106, S-140, and S-145 (Bakash, 2011). A joint scoring technique was employed to evaluate and shortlist 11 F_1 selections. Based on the scoring outcomes, three selections *viz.,* S-140, S-145, and S-106 were identified as superior and subsequently selected for further consideration (Shabnam et al., 2012). Subsequently, multi-location trials of these strains were conducted at three different sites within the Kashmir Valley. Among these, S-140 emerged as the highest yielder, exhibiting improved agronomic characteristics, enhanced leaf feeding value for silkworm rearing, strong rooting ability suitable for propagation *via* stem cuttings, and early sprouting behaviour during spring traits highly desirable under the agro-climatic conditions of the Kashmir division (Shabnam and Sharma, 2016; Shabnam et al., 2017). This newly developed selection, S-140, was officially named PPR-1 has been tested across 20 test centres in India (Source: PIE13001MI AICEM Phase–IV).

A total of 26 crosses were successfully performed, involving temperate accessions as female parents and tropical accessions as male parents. Due to a limited availability of suitable male parents and asynchronous flowering, none of the indigenous accessions could be incorporated into the breeding program. The resulting F_1 progeny were raised during 2006-07 to evaluate seed germination and frost tolerance. It was observed that seed set and germination percentages were generally below 30% in most crosses. Additionally, frost damage in one-year-old seedlings was notably high, reaching up to 80%. This phenomenon is typical under temperate climatic conditions where, during crossing and seed development, the average monthly temperature ranges between 14–

16°C and average sunshine hours range from 5 to 6 hours. These environmental factors adversely affect the pollen-pistil interaction and consequently reduce seed set efficiency (Fotadar et al., 2006).

A mulberry breeding research project entitled *"Development of Superior Mulberry Varieties through Controlled Hybridization for North-West Indian States" (PIB-3586)* was undertaken to develop high-performing mulberry genotypes suitable for temperate and sub-temperate regions. Controlled hybridizations were carried out using the crosses ME-0253 × ME-113, ME-0253 × MI-0240, and ME-0253 × MI-0308, resulting in the development of 273 F_1 progenies. These progenies were evaluated through Progeny Row Trials (PRT), and 40 progenies were selected based on preliminary performance indicators. The selection criteria included a comprehensive set of morphological and physiological traits such as plant height, resistance to frost damage, early sprouting ability, moisture content and retention capacity, growth habit, branching pattern, shoot coloration (young and mature), phyllotaxy, internodal distance, lenticel density and shape, number and thickness of branches, bud morphology, leaf apex shape, leaf shape and margin, leaf base, surface texture, nature, color, glossiness, leaf area, and petiole length. Additionally, observations on disease and pest incidence, rooting ability, and leaf yield-related traits were systematically recorded. Currently, four of these promising progenies are undergoing Primary Yield Trials (PYT) under the research project PIE030016SIC at the CSB-CSRTI, Pampore, for further evaluation and potential release.

Currently, CSB-CSR&TI, Pampore is engaged in an international collaborative research project, *AIB03006CI: Indo-Uzbekistan Collaborative Research Project for Improvement of Mulberry and Silkworm Breeding in Temperate Regions of India and Uzbekistan*, in partnership with the Scientific Research Institute for Sericulture (SRIS), Tashkent, Uzbekistan. As part of this project, four mulberry varieties *viz.,* Balkhi-tut, Marvarid-tut, Nar-tut, and Katlama-tut are planned to be imported and systematically evaluated for key economic traits. The objective is to identify and develop superior mulberry varieties well-adapted to the temperate agro-climatic conditions of the Kashmir Valley.

The Central Sericultural Research and Training Institute (CSR&TI), Pampore, currently conserves a rich collection of 80 diverse mulberry (*Morus* spp.) genotypes encompassing exotic and indigenous accessions from temperate, sub-tropical, and tropical regions of India and abroad. Complementing this, the P4 Basic Seed Farm (BSF), Manasbal, harbors an even broader assemblage of 144 mulberry genetic resources, which includes the 80 genotypes maintained at CSB-CSR&TI, Pampore, along with an additional set of 50 temperate-specific genotypes acquired from the CSB-Central Sericultural Germplasm Resources Centre (CSGRC), Hosur. Owing to its unique agro-climatic conditions, P4 BSF, Manasbal has been designated as the *"Temperate Safety Backup Centre"* for mulberry germplasm conservation. The strategic conservation of this genetic wealth plays a pivotal role in mulberry improvement programs by serving as a valuable reservoir of traits for stress tolerance, disease resistance, and productivity enhancement. These germplasm resources are essential for the development of climate-resilient and region-specific mulberry cultivars through systematic breeding and selection, ultimately contributing to the sustainability and productivity of temperate sericulture.

3.1.2. Sub-Tropical Region

As part of the mulberry improvement program, the research project PIB-3629 titled "Development of Mulberry Genotypes for Rainfed Hill Farming in North West India" was undertaken with a focus on strategic trait-based hybridization. A total of 12 cross-combinations were executed between selected indigenous and exotic mulberry genotypes, resulting in the generation of 933 F_1 progenies. Based on preliminary evaluation for key agronomic and adaptive traits, 23 promising progenies were shortlisted for further evaluation and advancement in the breeding pipeline. A follow-up project, entitled *PIE03015SIC: Evaluation of Drought-Tolerant Mulberry Genotypes through Preliminary Yield Trials for Rainfed Sericulture in the Jammu Region*, is currently ongoing. This project aims to assess the performance and yield potential of selected drought-tolerant genotypes under rainfed conditions to support sustainable sericulture practices in the region.

In addition to ongoing conventional mulberry breeding programs, two targeted mulberry evaluation initiatives are currently underway in the sub-tropical regions of North Western India to address region-specific productivity and quality challenges. The research project, *PIB03013SI: Development of High-Yielding Quality Mulberry (Morus spp.) Genotypes under Sub-Tropical Conditions of Northern India*, focuses on enhancing genetic variability and selection of promising genotypes. Under this initiative, polyclonal seeds were collected from diverse mulberry genotypes orchard maintained at CSB-CSR&TI, Berhampore, and hybrid progenies were raised. Following preliminary screening based on key agro-morphological traits, selected progenies are now under evaluation under field conditions for their yield potential and adaptability. Another research project, *PIE03009SI: Evaluation of Mulberry Genotypes for Improvement in Productivity and Quality under Sub-Tropical Conditions of Jammu*, aims to assess the field performance of various mulberry genotypes sourced from CSRTI Pampore and Berhampore. These genotypes are currently undergoing systematic field trials to evaluate traits related to biomass yield, leaf quality, pest and disease resistance, and regional adaptability.

These breeding programs are of significant importance for strengthening the mulberry cultivation base in temperate and sub-tropical zones of the North West region. They are expected to result in the identification and eventual recommendation of superior mulberry genotypes tailored to local agro-climatic conditions, thereby improving the sustainability and profitability of sericulture.

3.2 Biotechnological Interventions (Temperate Region)

Using plant tissue culture-based somatic hybridization techniques, three somatic hybrids SH1 (PPR-1/Ichinose), SH2 (PPR-1/Chinese White), and SH3 (PPR-1/PPR-1) were developed under the research project *PIB-3571: Evolution of Superior Mulberry Variety Suitable for Temperate Regions through Somatic Hybridization*. These hybrids were subsequently evaluated under the follow-up project *PIE03012SI: Evaluation of Mulberry Somatic Hybrids* at the institute level. The evaluation focused on ploidy determination, leaf yield performance, key biochemical parameters, and silkworm bioassay. Among the three, two somatic hybrids SH2 and SH3 were identified as promising candidates for further development and deployment in temperate sericulture regions.

Under the research project *PIC03014SI: Evolving Superior Mulberry Varieties for Temperate Regions through in-vitro Mutagenesis*, using *in vitro* plant tissue culture techniques, elite temperate mulberry varieties viz., Ichinose, KNG, Goshoerami, Chinese White, and PPR-1 were subjected to mutagenesis using various chemical mutagens, including 1-ethyl-1-nitrosourea (ENU), methyl methanesulfonate (MMS), ethyl methanesulfonate (EMS), diethyl sulfate (DES), sodium azide (SA), and hydroxylamine (HA). Based on survival rates and regeneration potential, calli derived from Chinese White, Goshoerami, and PPR-1 treated with ENU, MMS, and EMS successfully regenerated into plantlets. These regenerated plantlets have been transferred to pots and are currently undergoing hardening for acclimatization under controlled conditions.

To enhance cold tolerance in mulberry, a bioinformatics-based *in silico* analysis was conducted under the research project *PIB-3579: Identification of Cold Tolerant Genes for the Improvement of Mulberry Genotypes*. The study identified several key cold-responsive genes, including *WRKY46, Spermidine Synthetase, Dehydrin (DHN), ERD10, 14-3-3, Universal Stress Protein (USP), Annexin 2, TIFY10, Annexin-like Protein, Cysteine Proteinase Inhibitor (CI), and Cold-Regulated 413 Plasma Membrane 2 (COR413),* which exhibited significant upregulation under cold stress conditions. Among the genotypes examined, the Gurez mulberry genotype showed the highest expression levels of most of these genes, indicating a stronger molecular response to cold stress compared to Goshoerami and Leh2.

These biotechnological interventions demonstrate significant potential for mulberry improvement in temperate regions. Somatic hybridization facilitated the development of genetically superior hybrids with enhanced traits, while in vitro mutagenesis may introduced novel variations for selection of stress-tolerant lines. *In silico* identification of cold-responsive genes provides molecular targets for breeding cold-resilient genotypes, collectively contributing to the development of high-yielding, climate-adapted mulberry varieties suitable for temperate sericulture.

Planned Activities for Future Mulberry Improvement Programmes

For the continued advancement of mulberry improvement programs in the temperate and sub-tropical regions of North West India, several strategic activities are planned to enhance genetic gain, trait association, and varietal development.

Germplasm Rejuvenation

- Rejuvenate conserved mulberry germplasm collections maintained in gene bank.
- Enhance the viability of long-term conservation efforts.

DUS Testing

- Conduct Distinctness, Uniformity, and Stability (DUS) testing of new mulberry varieties recommended for temperate region.
- Facilitate as a collaborative DUS center for varietal registration.

Sexual Variant Studies

- Assess the sexual variations in the germplasm for utilization in hybridization.
- Investigate the effect of sexual variants on yield-related traits.

Cold Tolerance Breeding

- Utilize the Gurez genotype, which exhibits upregulated cold-tolerant gene expression, as a donor parent in breeding programs.
- Develop gene-specific molecular markers for the selection of cold-tolerant mulberry lines.

Fast-Tracking Trait Discovery

- Genome-Wide Association Studies (GWAS) and Genomic Prediction (GP)
- Identify marker-trait associations across mulberry diversity panel.
- Determination of estimated breeding values
- Doubled Haploid Development
- Employ androgenesis for the generation of doubled haploids.
- Accelerate trait fixation and breeding cycle timelines.

Field Level Evaluation Studies through the Follow-up Research Projects

- PIE03016SIC (Final Yield Trial Evaluation of mulberry progenies; PIE03012SI (Assessment of Mulberry Somatic Hybrids) and AIB03006CI (Evaluation of Uzbekistan mulberry genetic resources for identification of suitable genotype to be used as parent in breeding programme).

Collaboration with ICAR Institutions

- In collaboration with ICAR-IGFRI, RRS Srinagar, and ICAR-CITH Srinagar, the available mulberry genetic resources will be systematically characterized for fodder and fruit-related traits under the proposed Sericulture Centric Integrated Farming System research project.
- Characterization will facilitate the development of comprehensive passport data, supporting effective documentation, utilization, and conservation of mulberry germplasm.

Deliverables

- Strengthening of the mulberry breeding pipeline.
- Development of high-performing, climate-resilient mulberry cultivars.
- Support for sustainable sericulture practices.

References

Baksh S (2011) Breeding of early sprouting and high yielding mulberry varieties amenabkle to propagation by stem cuttings with high survival ability for rainfed cultivation in Kashmir and other temperate regions of North India. In: *Golden Jubilee Conference – Sericulture Innovations: Before and Beyond*, CSR&TI, Mysore, pp. 1-15.

Chauhan SS, Saini P, Rohela GK, Shukla P, Shabnam AA, Ghosh MK (2018) Present position and future strategies of mulberry breeding for north-west India: an overview. In: Seri-Breeders' meet-2018 held at Central Silk Board, Bengaluru on 20th –21st Feb 2018, pp 22–33.

Fotadar RK, Chauhan SS, Dhar A and Khan MA (2006) Screening of F_1 progeny for evolving mulberry genotypes with high rootability under temperate conditions. In: Abstract: *Regional Seminar on Prospects and Problems of Sericulture as an Economic Enterprise in North West India*, November, 11th-12th 2006, RSRS, Sahaspur, Dehradun, pp. 25-29.

Kour R, Darji GM and Khan MA (2009) कश्मीर में वर्षाश्रित परिस्थिति में शहतूत की उपजातियों का जैव अमापन–एवं निष्पादन. *Indian Silk*, 48(4): 40-42.

Rohela GK, Shukla P, Kumar R, Chowdhury SR (2020) Mulberry (*Morus* spp.): an ideal plant for sustainable development. *Trees, Forests and People*, 2:100011 https://doi.org/10.1016/j.tfp.2020.100011

Saini P, Aziz D, Gonal B, Rohela GK and Gnanesh BN (2025) Mulberry: Approaches for genetic Improvement. CSR&TI, Pampore, pp. 1-137. ISBN: 978-81-978345-3-0.

Saini P, Rohela GK, Kumar JS, Shabnam AA and Kumar A (2023) Cultivation, utilization, and economic benefits of Mulberry. In: The Mulberry Genome, B. N. Gnanesh and K. Vijayan (Eds.), Springer Nature Switzerland AG, pp. 13-56. https://doi.org/10.1007/978-3-031-28478-6_2

Shabnam AA and Sharma SP (2016) Improved mulberry variety (PPR-1) for temperate region. CSR&TI, Pampore, Bulletin no. 20.

Shabnam AA, Chauhan SS, Khan G, Shukla P, Saini P and Ghosh MK (2018) Mulberry breeding strategies for north and North West India. *Int. J. Adv. Res. Sci. Eng.*, *7*(4): 2124-2133.

Shabnam AA, Fotadar RK, Baksh S and Koul MA (2012) Evaluation Technique for Preliminary Selection of F1's under Temperate Conditions of Kashmir. *Research Journal of Agricultural Sciences*, 3(6): 1303-1304.

Shabnam AA, Baksh S, Dhar A, Fotadar RK, Lochan R, Chauhan SS and Rathore MS (2017) Evolution of mulvberry (*Morus* spp.) variety (PPR-1) for propagation under temperate climatic conditions of jammu & Kashmir. In: Proc. XIII Agricultural Science Congress – 2017 Climate Smart Agriculture held at UAS, Bengaluru 21-24 February 2017, p.294.

Tikader A, Saratchandra B, Vijayan K and Singh R (2014) Mulberry germplasm management and utilization. A. P. H. Publishing Corporation, New Delhi.

SERI-BIODIVERSITY FOR POSTERITY: CURRENT STATUS, CHALLENGES, AND FUTURE ROADMAP

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Abstract

Seri-biodiversity is a crucial component of the natural resources that support economic, social, and cultural development. Like any other biodiversity, seri-biodiversity is constantly threatened by human activities such as deforestation, pollution, and climate change, etc. Owing to this Central Sericultural Germplasm Resources Centre (CSGRC), Hosur, conserves valuable genetic diversity of mulberry (*Morus* spp.) and silkworm (*Bombyx mori* L.), which is of National importance and a foundation for the prosperity of sericulture and the centre is recognized as a National Active Germplasm Site (NAGS), aiming to conserve, manage, and utilize seribiodiversity exclusively for sustainable sericulture. Currently, the ex situ field gene bank (FGB) maintains 1317 mulberry accessions from 28 countries and 14 species. Mulberry accessions were characterized using 100 phenotypic descriptors, and potential trait-specific accessions were identified, which are available in the Mulberry Germplasm Information System (MGIS) database. However, conserving and maintaining enormous germplasm with limited manpower, resources, and climatic conditions is challenging. As a result, there is an urgent need for systematic advancement for future utilization and conservation of seri-germplasm resources.

Key words: genetic resources, germplasm, mulberry, sericulture, trait-specific

Introduction

In India, a rich and valuable genetic diversity of mulberry (*Morus* spp.) and silkworm (*Bombyx mori* L.) is available, which serves as a national treasure and forms the foundation for the sustainable development and prosperity of sericulture in the country. This invaluable germplasm is systematically conserved and maintained at the Central Sericultural Germplasm Resources Centre (CSGRC), located in Hosur, Tamil Nadu. The gathering of Biological Diversity (CBD) has bestowed the nation's rights on the existing genetic resources. With the recent development concerning the breeders and farmers rights towards variety protection linked with Intellectual Property Rights (IPR) was made effectively by signing of General Agreement on Trade and Tariff (GATT). In this context, the protection of the genetic material has become more important.

The Central Silk Board (CSB) established the Silkworm and Mulberry Germplasm Station (SMGS) at Hosur, Tamil Nadu in February 1991. Later, in April 2000, it was renamed as the Central Sericultural Germplasm Resources Centre (CSGRC), and designated to function as a nodal centre at the national level for all germplasm-related activities pertaining to both mulberry and silkworm. The CSB-Central Sericultural Germplasm Resources Centre (CSB-CSGRC, Hosur) is recognized as National Active Germplasm Site (NAGS) for mulberry by the National Bureau of Plant Genetic Resources (NBPGR), New Delhi and for silkworm by the National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru. This centre was recognized as an advanced research centre by Mysore University and Karnataka University, Dharwad. Presently, the centre is recognized as a research centre for higher education by Periyar University, Salem, Tamil Nadu.

Mandate

- Exploration, Collection, Characterization, Evaluation, Conservation and Documentation of Sericultural Germplasm Resources.
- Commercialization and Promoting Sustainable Utilization of Sericultural Germplasm Resources.
- Creating awareness and training stakeholders on conservation, management and utilization of sericultural germplasm resources.

Vision

To act as the nodal agency for registration, evaluation and conservation of Seri-genetic resources.

Mission

To register the Seri-genetic resources in India, research activity facilitating utilization of Seri-genetic resources for crop improvement programme, conservation of Seri-genetic resources, national posterity and prevention of extinction.

Activities

- To explore, collect and introduce mulberry and silkworm germplasm.
- To undertake characterization, classification, preliminary evaluation and cataloguing of germplasm collection for promoting and utilization of seri-genetic resources.
- To serve as the long-term National Repository of Sericultural Genetic Resources and National Accessioning.
- To play a leading role in inter-institutional collaboration for the screening, testing, and evaluation of sericultural germplasm.

- To co-ordinate import and export of seri-genetic resources along with quarantine facility pertaining to incoming germplasm and issuing phytosanitary certificate for export of germplasm.
- To serve as the National Data Base and Herbarium/ Display of seri-genetic resources.
- To supply the germplasm to all needy organizations.
- To impart training in seri-germplasm resource management.
- To protect seri-germplasm resources from extinction and preserve such national heritage for posterity.

1. Mulberry germplasm for a sustainable utilization

Mulberry is a hardy, woody perennial plant belonging to the genus *Morus* of the family Moraceae. It possesses several important agronomic traits such as high foliage yield, shorter gestation period, and strong adaptability to diverse environmental conditions, making it highly suitable for sericulture-based cultivation systems. Mulberry leaves are exclusively used as feed for silkworm for the production of raw silk. Mulberry silk contributes around 90% of the total global raw silk production and helps to the livelihoods of many people across the globe. Many nutritional benefits and medicinal values are recognized in the mulberry plant. Mulberry leaves and fruits rich in protein and vitamins, it is exploited as animal feed/food products in many countries. Recently, India is also exploiting it for various purposes. The concept of biodiversity conservation and gene bank maintenance has gained great momentum in recent times as impending global climatic changes threaten the sustainability of biodiversity (Annual Report, 2023-2024). CSGRC, Hosur currently conserves 1317 diverse mulberry accessions representing 29 countries belonging to 14 species in the ex situ field gene bank (FGB). Characterization of 1269 mulberry accessions has been completed and the promising trait-specific accessions have been identified and documented which can be accessed at Mulberry Germplasm Information System (MGIS) databse. An updated catalogue was published in 2022 incorporating details on mulberry germplasm's morphological, reproductive, and economical parameters (Catalogue on Mulberry, 2021). The Centre is imparting training to students, and other stakeholders in various aspects of mulberry germplasm conservation, characterization, and evaluation and using frontier areas of biology in research. The Central Sericultural Germplasm Resources Centre (CSGRC) undertakes the following major activities to meet the diverse requirements of stakeholders and to promote sustainable sericulture development.

1.1. Mulberry germplasm diversity, exploration, survey, collection and introduction

Biodiversity is increasingly threatened by global climatic changes and is vulnerable to extinction; therefore, the systematic exploration, conservation, and utilization of mulberry germplasm is imperative for its protection (Vijayan et al., 2011). The Centre has, so far, conducted 84 exploratory expeditions across diverse ecological regions - ranging from the Himalayan belts to the Andaman and Nicobar Islands - encompassing forests, biosphere reserves, deserts, national parks, the Western Ghats, agricultural lands, and other ecosystems. Through these efforts, a total of 1,032 diverse mulberry accessions have been collected and conserved (Fig. 1-2). As a result, it represents a huge diversity of mulberry genetic resources (Fig. 3). This also includes a few germplasms provided by other institutes of CSB. The future collection is to be focused for collecting samples with adaptive traits. All mulberry germplasm, both indigenous and exotic have been systematically conserved and maintained at CSGRC as per DUS descriptors.

1.2. Mulberry germplasm conservation

According to the Convention on Biological Diversity (CBD, 1992) the conservation of mulberry genetic resources was carried out *in situ* (inside its habitat), and *ex-situ* (outside the natural habitat) conservations.

1.2.1. In situ conservation

In situ conservation refers to the preservation and maintenance of a species within its natural habitat, allowing it to evolve and adapt to environmental changes while maintaining its natural interactions within the ecosystem. The Indian government has established 18 Biosphere Reserves and among them, Uttarakhand, Nandadevi, Manas,

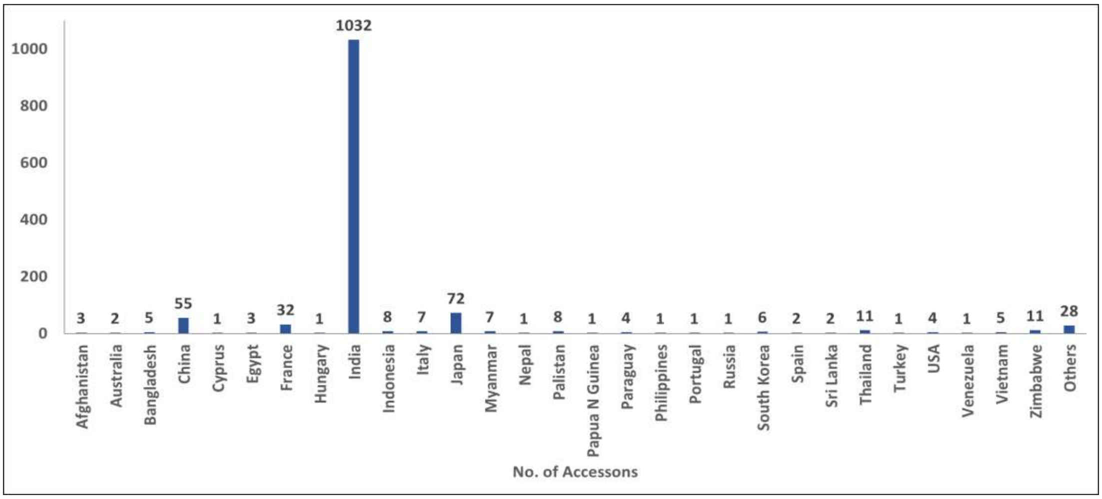
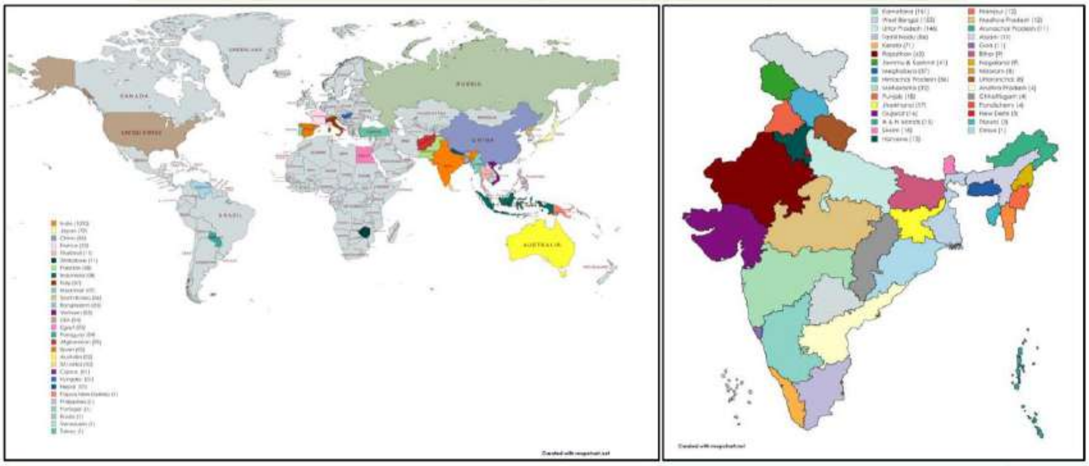


Fig. 1: Country wise mulberry germplasm collection



Total accessions conserved	1317
Number of countries explored	28

Indigenous	1032
Exotic	285

Fig. 2: Country & State wise Mulberry (*Morus* spp.) Germplasm collection

Fig. 3: Morpholgical variation of mulberry leaf

Nokrek, North Andaman, and Great Nicobar are potential reservoir for *in situ* conservation of mulberry. *M. serrata* is worshiped at several places in Garhwal and Kumaon regions of Himalayas and *M. laevigata* conserved in Punjab, Eastern Himalayas of south and west Sikkim, West Bengal, Assam, Meghalaya and Manipur (Naik et al., 2015). Further, *M. alba*, *M. indica* and *M. laevigata* are available in western ghats covering Kerala, Tamil Nadu and Karnataka, Madhya Pradesh, Maharastra, Rajasthan, and Odissa. On-farm conservation refers to maintaining high-yielding varieties of mulberry in farmers' fields, home gardens, and landscapes particularly in irrigated systems in traditional sericulture areas.

1.2.2. Ex situ conservation

Ex situ conservation involves the preservation of genetic resources that are collected from natural habitats, wild populations, or cultivated lands and maintained at a designated location, such as gene banks, field gene banks, botanical gardens, or research institutions. Ex situ conservation has been practiced by several nations and a number of mulberry genetic resources have been conserved in field gene banks of China (2,600), Japan (1,375), India (1,317), Korea (615), and Bulgaria (140). The representative images of *ex situ* FGB of CSGRC is given in Fig. 4-6. Each mulberry accession has a unique identification number, National Accession Numbers (Indigenous collections, IC and Exotic collections, EC) provided by NBPGR for the protection of mulberry genetic resources globally. Additionally, passport data of all accessions are documented.

Fig. 4: *Ex-situ* field gene bank (indigenous and exotic FGB, Mulberry species garden, fruit garden) maintained at CSGRC-Hosur

1.2.3. Cryopreservation

Cryopreservation technology serves as an alternative ex situ conservation strategy for mulberry genetic resources, involving the use of liquid nitrogen at ultra-low temperatures of ⁻15°C or below to ensure long-term preservation of viable germplasm. The benefit of cryo-conservation is the ability to save germplasm (from biotic and abiotic stresses) for a long period to maintain the genetic diversity of a species or genotype.

Fig. 5: Variation of mulberry germplasm (morphotype and species level)

Fig. 6: Morphological variation of mulberry fruits

CSGRC has cryopreserved 338 mulberry accessions at ICAR-NBPGR, New Delhi (Table 1). Further, the Center has recently proposed a collaborative project with ICAR-IIHR, Bengaluru entitled "Standardization of protocol for cryopreservation of mulberry genetic resources using pollen and vegetative tissues" (Atmakuri et al., 2009).

Table 1: Number of mulberry germplasms cryopreserved at ICAR-NBPGR, ND

#	*Morus* spp.	No. of Accessions
1	*M. indica*	151
2	*M. alba*	52
3	*M. laevigata*	27
4	*M. latifolia*	18
5	*M. bombycis*	7
6	*M. serrata*	3
7	*M. multicaulis*	3
8	*M. sinensis*	2
9	*M. macroura*	2
10	*M. australis*	2
11	*M. rubra*	1
12	*M. nigra*	1
13	*M. cathayana*	1
14	*M. tiliaefolia*	1
15	*M. rotundiloba*	1
16	*Morus* spp.	66
	Total	338

1.3. Characterization and evaluation of mulberry germplasm

Characterization of mulberry genetic resources determines the structural and functional attributes of the accessions and is highly essential for their genetic identity and use (Thriveni et al., 2024). Out of 1317 mulberry genetic resources, the complete characterization of 1269 mulberry accessions have been carried out so far (up to X phase of the continuous mulberry germplasm maintenance program), covering morphological, anatomical, reproductive, biochemical, *etc*. and to a lesser extent at the molecular level (Fig. 8). Under recently concluded project "Molecular Characterization of Mulberry Genetic Resources for the Identification of Duplicates and their Effective Utilization", suspected duplicates were screened using 12 SSR markers and scored the polymorphic alleles using binary format. The data matrix was subjected to multivariate cluster analysis and 14 mulberry accessions were confirmed as true duplicates (Thriveni et al., 2024).

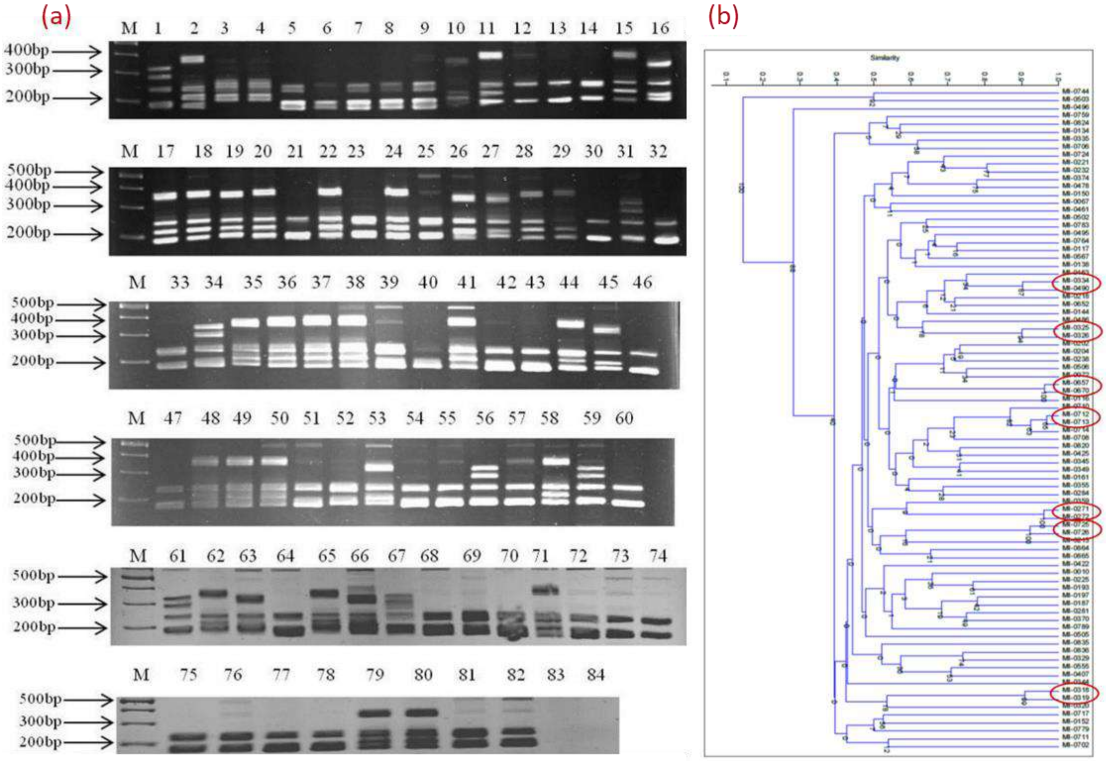


Fig. 8: (a) PCR profile of suspected duplicates of mulberry (b) Cluster analysis showing identified duplicates (Source: Thriveni *et al.*, 2024)

Under recently concluded project "Studies on cytological status of mulberry genetic resources" developed a protocol for mitotic metaphase chromosome count using shoot meristematic tissue of mulberry. A step-by-step, economically feasible protocol for the pretreatment, fixation, enzymatic treatment, staining, and squashing of meristematic shoot tips (Fig. 9a). Using the protocol, a total of 200 mulberry accessions studied, 154 accessions are diploid (2n=2x=28), 03 accessions are aneuploid (2n=2x=30), 23 accessions are triploid (2n=3x=42), 14 accessions are tetraploid (2n=4x=56), 05 accessions are hexaploid (2n=6x=84) and 1 accession decasoploidy (2n=22x=308) were identified (Mondal et al., 2023). To confirm the ploidy level cytotypes, genome size was estimated by FCM of selected ploidy (2x, 3x, 4x, 6x, and 22x) accessions, which were identified through chromosome number count (Fig. 9b). The information is useful for future ploidy breeding/conservation/ identification of ploidy associated traits.

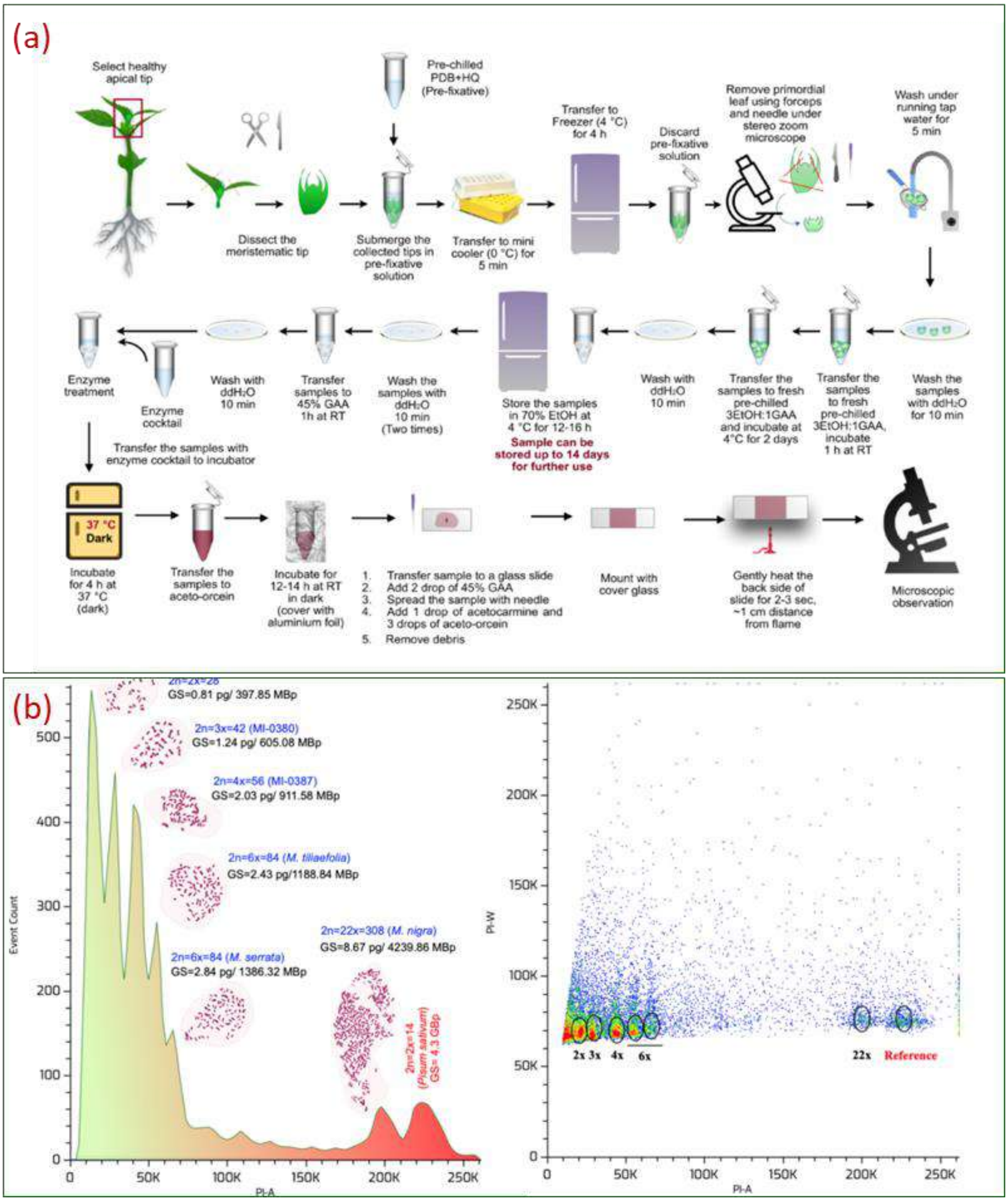
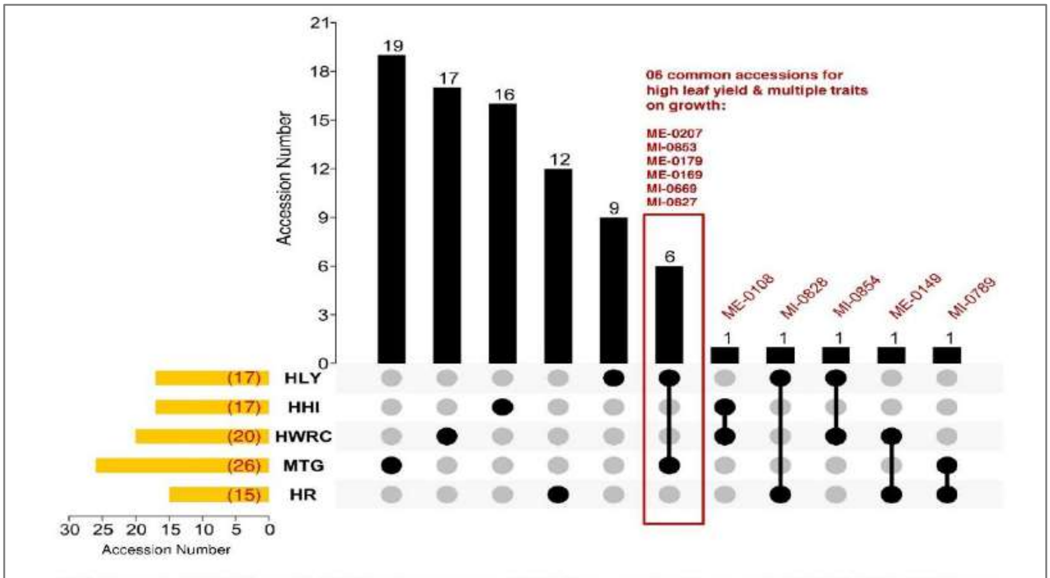


Fig. 9: (a) Workflow of developed protocol for mitotic metaphase chromosome count using shoot meristematic tissue of mulberry. (b) Different autotypes (metaphase plates) and ploidy level (flow cytometry analysis) of *Morus* L. (Source: doi: 10.21769/BioProtoc.4643).

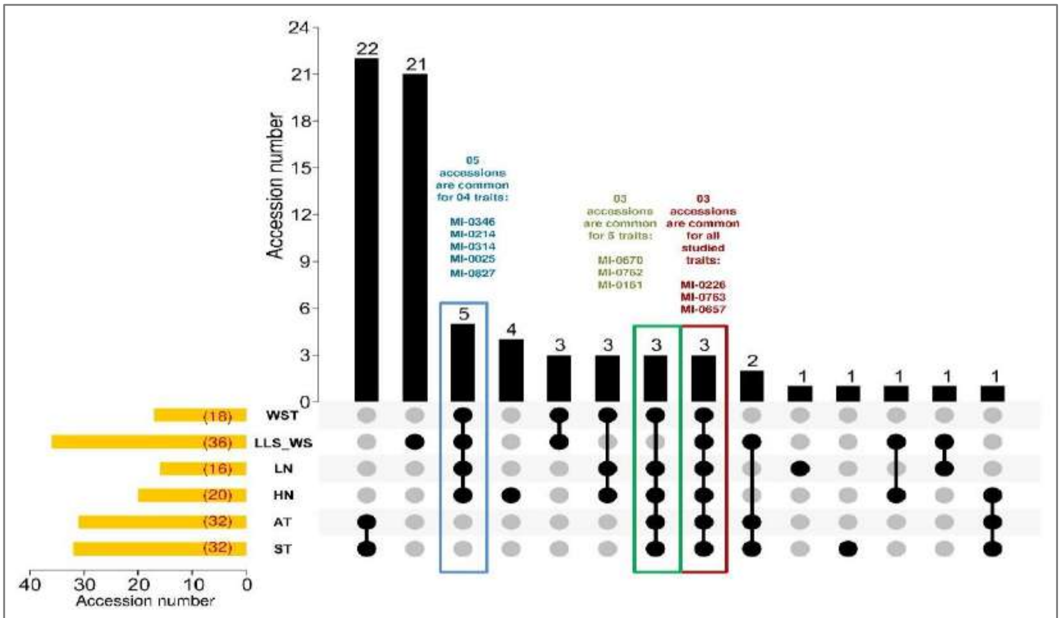
1.4. Trait-specific mulberry genetic resources identified for utilization

The promising accessions for various traits are presented in Fig. 10 and Fig. 11.



HLY, High leaf yield (4-7 Kg/plant); HHI, High harvest index; HWRC, High water retention capacity (79-89%); MTG, Multiple traits on growth; HR, High rooting (80-100%)

Fig. 10: Promising mulberry accessions based on characterization and evaluation



Abbreviation: WST, Water stress traits; LLS, Low leaf senescence under water stress; LN, low N2; HN, high N2; AT, Alkaline tolerance (pH 8.5-9); ST, Saline tolerance (EC 6-8 dS/m)

Fig. 11: Promising mulberry accessions for water and nitrogen use efficiency

a. All India mulberry germplasm evaluation programme (AIMGEP)

Mulberry germplasm multilocation evaluation programme at the national level was conducted by CSGRC involving eight regional centers located in different agroclimatic zones with a view to identifying potential mulberry germplasm for developing region-specific varieties. Identified mulberry accessions suitable for various regions like Hosur, Tamil Nadu (MI-0437, MI-0376), Berhampore, West Bengal (MI-0310, MI-0324, MI-0376), Pampore, Jammu & Kashmir (ME-0167, ME-0130, ME-0173, ME-0168), Mysore, Karnataka (MI-0310, MI-0326), Coonoor, Tamil Nadu (ME-007, ME-0033, ME-0130, ME-0169), Miransahib, Jammu & Kashmir (MI-0324, MI-0252), Sahaspur, Uttranchal (MI-0439, MI-0416, MI-0431), Jorhat, Assam (MI-0154, MI-0369, MI-0416, MI-0349, MI-0388).

b. Utilization of mulberry genetic resources

The mulberry germplasm is viewed as a source of genetic diversity to support crop improvement. CSGRC has been supplying mulberry genetic resources for breeding, research, and training purposes to various stakeholders (29 indenters). The details of mulberry genetic resources supply are given in Fig. 12.

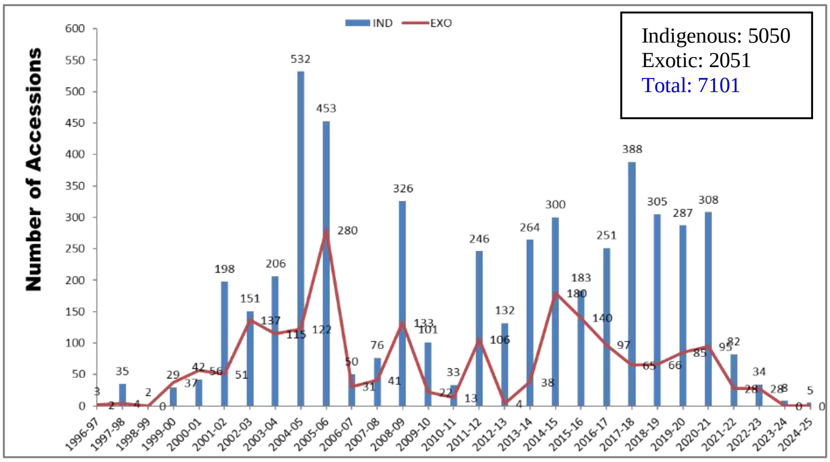


Fig. 12: Mulberry germplasm supply from CSGRC (1996-2025)

c. Mulberry Germplasm Registration

The Centre has formulated guidelines for registering potential germplasm (Fig. 13) in favour of the breeders /institutes to protect Intellectual Proprietary Rights (IPR).

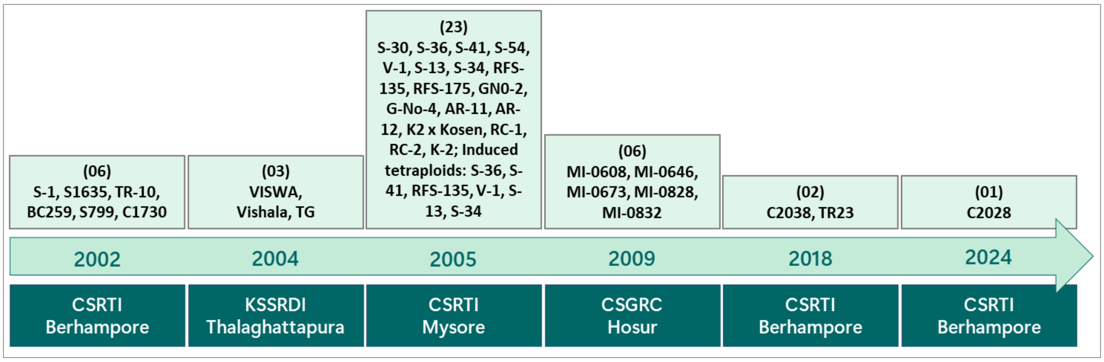
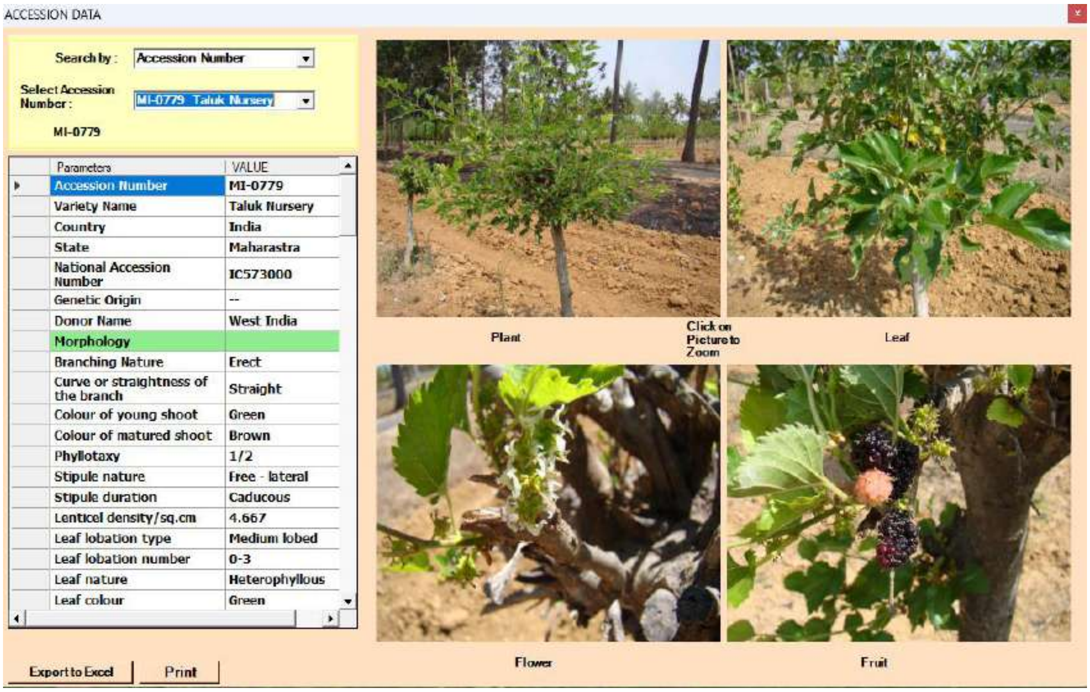


Fig. 13: Details of mulberry genetic resources registered at CSGRC

d. Mulberry Germplasm Information System (MGIS)

A well-developed and the user-friendly database contains passport, morphological, anatomical, reproductive, growth, and biochemical data, and trait-specific accessions on mulberry germplasm available on the CSGRC website (Fig. 14).



Search by : Accession Number

Select Accession Number: MI-0779 Taluk Nursery

MI-0779

Parameters	VALUE
Accession Number	MI-0779
Variety Name	Taluk Nursery
Country	India
State	Maharastra
National Accession Number	IC573000
Genetic Origin	--
Donor Name	West India
Morphology	
Branching Nature	Erect
Curve or straightness of the branch	Straight
Colour of young shoot	Green
Colour of matured shoot	Brown
Phyllotaxy	1/2
Stipule nature	Free - lateral
Stipule duration	Caducous
Lenticel density/sq.cm	4.667
Leaf lobation type	Medium lobed
Leaf lobation number	0-3
Leaf nature	Heterophyllous
Leaf colour	Green

Fig. 14: Webpage of MGIS database

e. Mulberry genetic resources for climate-smart sericulture

- Develop new climate-resilient mulberry varieties
- Broaden the genetic base
- Increased productivity & stress tolerance

- Improve Nutrient use efficiency
- Identify novel genes
- Utilize genetic resources for non-sericulture purpose

f. Biotechnological interventions in mulberry germplasm activities

Analyses of genetic variations found in various genotypes including the wild ones in contrasting environments will reveal the genes in adaptation to climatic changes. This can be achieved through comparative whole genome sequencing techniques and omics-based approaches (genomics, transcriptomics, epigenomics, proteomics, metabolomics, and phenomics).

High-quality genomic and transcriptomic data generated through Next Generation Sequencing (NGS) are available for M. notabilis, M. alba, and M. indica providing information on novel genes that determine various traits. These gene markers enhance the scope of marked-assisted selection for the improvement of trait-specific mulberry in terms of productivity, quality, and climate resilience apart from unraveling the genetic diversity and relatedness among genotypes of the same species and relationships among geographically divergent species.

Other molecular markers like SSRs and SNPs can be used to establish the genetic identity of the available seri-genetic resources and to sort out the suspected duplicate accessions that can minimize the management and operational costs. Such projects are ongoing at CSGRC. Gene/DNA banking is an efficient, simple, and long-term method to conserve genetic information as DNA extracted from mulberry can be stored at low temperatures for many years and can be introduced through genetic techniques whenever required.

Technological advances, particularly transgene-based, genome editing, and molecular breeding technologies will facilitate the development of elite genotypes with durable adaptation to climate change and other abiotic and biotic stresses. The future programme includes the inclusion of trait-specific data with molecular markers, resequencing of genomes to detect allelic variability, mapping quantitative traits among germplasm accessions and also wild ones, and targeting the utilization of genetic resources.

Challenges

- Conservation and maintenance of extensive germplasm resources with limited manpower and infrastructural resources
- Need of screening germplasm for trait specific characters to develop cultivars able to overcome emerging pests & diseases, adapt to changing climates

(drought, flood, etc), enhance nutritional value (leaf and fruits), and expand production into new environments.

- Limitation of quarantine facilities to carry out examination for pests and pathogens of seri-genetic resources.
- Pedigree evaluation and barcoding.
- International germplasm exchanges to deal with new environmental and climatic. Conditions (linkages with National and International GeneBanks).
- New germplasm materials with value addition (viz., transgenic varieties) with the integration of new tools of biotechnology for the users in new era.

Future Plan of action for improvement of silk production vis-à-vis for conservation of seri-genetic resources

- Screening germplasm to develop cultivars tolerant to climate change scenario (drought, flood, etc), enhanced nutritional value (leaves and fruits), and expand production into new environments.
- Protocol development for the conservation of new germplasm materials with value addition.
- Pre-breeding strategies to be developed by utilizing the locally adapted breeds to introgress desired traits from other exotic or evolved breeds.
- Identifying potential parents through hot spot evaluations / network projects and screening using advanced physio-biochemical and / or molecular tools for development of climate resilient germplasm.
- Development of package of practices for mulberry fruit yielding accessions for commercialization.

Conclusion

Conservation efforts must be complemented by the effective and sustainable utilization of germplasm resources to maximize the value of large collections and justify the long-term investments made in conserving the gene pool. Enhanced utilization not only increases the practical value of genetic resources but also serves as a strong incentive for their continued and effective conservation. There is, therefore, an urgent need to intensify the use of seri-germplasm resources, both for direct commercial exploitation and for indirect use in breeding programs, aimed at developing high-yielding and resilient varieties or breeds. This can be achieved by selecting well-characterized and thoroughly evaluated parental materials, which are readily available in the gene bank at CSGRC, Hosur. Strategic utilization will ensure the conservation system remains dynamic, demand-driven, and closely aligned with the evolving needs of the sericulture sector.

Reference

CSGRC at a Glance, 2023

CSGRC Annual Report, 2023-2024

Catalogue on Mulberry (*Morus* spp.) Germplasm Volume-6 (2021)

Atmakuri AR, Chaudhury R, Malik SK, Kumar S, Ramachandran R, Qadri SM (2009) Mulberry biodiversity conservation through cryopreservation. *In Vitro Cell. Dev. Biol. Plant,* 45: 639–649. http://doi.10.1007/s11627-008-9185-3

Mondal R, Antony S, Gnanesh BN, Thanavendan G, Ravikumar G, Sreenivasa BT, Doss GS, Vijayan K (2023) A protocol for mitotic metaphase chromosome count using shoot meristematic tissues of mulberry tree species. Bio Protocol, 13(17): e4643. http://doi.10.21769/BioProtoc.4643

Girish Naik V, Dandin SB, Tikader A, Pinto MV (2015) Molecular diversity of wild mulberry (*Morus* spp.) of Indian subcontinent. *Indian Journal of Biotechnology*, 14: 334-343.

Thriveni MC, Gowda GR, Thanavendan G, Sakthivel N, Nishitha Naik V (2024) Studies on the variability of indigenous mulberry germplasm for growth and yield traits. *International J. Plant & Soil Science*, 36(6): 108-16. https://doi.org/10.9734/ijpss/2024/ v36i64611

Thriveni MC, Deepa S, Sakthivel N, Nishitha Naik V (2024) Identification of duplicates in mulberry germplasm using morphological descriptors and SSR markers. *Asian Journal of Research in Crop Science*, 9 (4): 269-88. https://doi.org/10.9734/ajrcs/2024/v9i4317

Vijayan K, Saratchandra B, da Silva JA (2011) Germplasm conservation in mulberry (*Morus* spp.). *Scientia Horticulturae*, 128: 371-379. http://doi:10.1016/j.scienta.2010.11.012

GENOMICS INTERVENTIONS IN MULBERRY CROP IMPROVEMENT AND CONSERVATION EFFORTS

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Abstract

Molecular breeding presents a promising avenue to accelerate mulberry improvement by addressing the constraints of traditional methods. Cutting-edge techniques such as GWAS, QTL mapping, transcriptomics, and genomic selection allow for accurate trait identification and early selection. Integrating multi-omics approaches and developing SNP chips will further boost breeding efficiency and genetic resources management. This integrated strategy paves a way for developing resilient, high-yielding mulberry varieties to sustainably strengthen the sericulture industry.

Key words:

Introduction

Mulberry (*Morus* spp.) is a perennial plant of immense economic importance as the primary food source for the monophagous silkworm (*Bombyx mori* L.), the backbone of the sericulture industry. Enhancing mulberry productivity, resilience, and quality traits is vital for sustaining silk production. Traditional breeding methods in mulberry have significantly contributed to yield improvement and adaptation; however, these approaches are time-consuming due to the long juvenile period, heterozygosity, and the influence of environmental factors. Significant biotechnological advances have emerged to complement conventional breeding efforts for developing climate-resilient mulberry varieties with enhanced productivity and quality (Vijayan et al., 2021).

Revolutionary developments in genomics have transformed mulberry improvement prospects. Recent completion of high-quality telomere-to-telomere genome assemblies, such as the 341.88 Mb genome of *Morus mongolica* with 21,657 protein-coding genes, represents a significant leap forward. Comparative genomic analysis revealed that chromosomal breakage and fusion events in *Morus* species are localized to centromeric regions of *M. notabilis*. This finding, derived from genomic comparisons between *M. mongolica* and both *M. alba* and *M. notabilis*, provides crucial molecular evidence for understanding the evolutionary mechanisms driving chromosome restructuring in the *Morus* genus. The centromere-specific localization of these breakage-fusion events offers significant insights into the chromosomal evolution patterns that have shaped *Morus* species divergence and genomic architecture over evolutionary time (Yang et al., 2025).

Comprehensive chloroplast genome studies of 25 mulberry plants have provided new insights into genome characteristics and phylogenetic relationships, while chromosome-level reference genomes for domesticated mulberry species have been established (Li et al., 2016). These genomic resources have accelerated the identification of candidate QTLs and genes associated with disease resistance, cold tolerance, and drought tolerance (Chikkaswamy et al., 2012; Garcia-Gómez et al., 2019; Naik et al., 2014; Zhu et al., 2025). This led the development of transgenic mulberry varieties with enhanced stress tolerance (Checker et al., 2012a). Several genes have been successfully introduced into mulberry via Agrobacterium-mediated transformation to enhance stress tolerance and leaf quality. Genes like *hva1*, and osmotin improved drought and salinity resistance. Overexpression of β-carotene hydroxylase1(*BCH1)* enhanced heat, light, and UV tolerance. *AtSHN1* increased leaf wax content, reducing water loss. *FtPEPC* boosted photosynthesis and water-use efficiency. These modifications support climate-resilient mulberry production (Checker et al., 2012b; Das et al., 2011; Saeed et al., 2015; Sajeevan et al., 2017). Additionally, CRISPR/Cas9 and epigenomic tools offer precise gene editing and regulation, presenting promising approaches for future genetic improvement in mulberry and boosting sericulture sustainability.

With advancements in molecular biology, molecular breeding approaches offer promising tools to overcome these limitations by enabling precise and accelerated selection. Techniques such as QTL mapping, GWAS, DNA barcoding, transcriptomics, and genomic selection provide a deeper understanding of complex traits at the molecular level. These approaches can enhance selection efficiency, enable early diagnosis of desirable traits, and contribute to the protection and management of genetic resources in mulberry.

Ongoing efforts at CSB-ISBR towards Host Plant Improvement

Mapping and Evaluation of Mulberry Rootstock for Root Rot (*Lasiodiplodia theobromae*) Resistance

The objective of the project is to identify genomic regions or genes associated with root rot resistance in a mulberry mapping population and to evaluate potential rootstock-scion combinations for root rot resistance and desirable scion traits through grafting. A mapping population was developed at CSR&TI, Mysore by crossing a resistant parent, with a susceptible parent. The resulting F_1 progenies has been utilized for genotyping using ddRAD sequencing to facilitate the identification of genomic regions linked to root rot resistance. High-quality SNP marker data has been generated and processed, forming the basis for QTL analysis, which is currently being initiated using multiple tools such as ICIMapping (GACD), WinQTL Cartographer to ensure the robust detection of trait-linked loci. In parallel, evaluation of rootstock-scion combinations through grafting experiments is underway, aimed at identifying combinations that not only confer resistance to root rot but also retain desirable scion traits for agronomic performance.

DNA Barcoding of Mulberry (*Morus* spp.) Germplasm and Authorized Varieties as part of conservation efforts

The Central Sericultural Germplasm Resources Centre (CSGRC) currently conserves 1,317 diverse mulberry germplasm accessions, including 1,032 indigenous and 285 exotic germplasm collected from 29 countries. Classical taxonomy classifies species based on subtle morphological differences leading to significant limitations such as, influence of vegetative traits by environmental factors, thereby misidentification issues. Additionally, the existences of cryptic species which are genetically distinct groups but appear morphologically identical to knows taxa raising significant difficulty in accurate species identification.

Morus is a messy genus due to its heterozygosity and ploidy. The taxonomy of *Morus* has been a subject of ongoing debate due to factors such as its broad geographical distribution, morphological variation, hybridization between species, extensive domestication history, and the introduction of non-native varieties. These challenges underline the need for molecular techniques like DNA barcoding, which offer more precise and reliable species classification by incorporating genetic data. DNA barcoding relies on standardized genetic sequences, often derived from mitochondrial or chloroplast genomes, which are stable, unaffected by environmental influences, and present in all plant tissues. By focusing on conserved regions of the genome that evolve slowly, DNA barcoding enables accurate species identification.

Conservation is a continuous effort. Commercial mulberry varieties are critical for the sericulture industry, and proper management, ownership, and enhancement of their germplasm are vital for the sericulture sector’s growth. Traditional morphological identification methods are time-consuming, costly, and often unreliable due to phenotypic plasticity as mentioned above. One effective solution to these challenges is the development of DNA-based signatures for mulberry varieties. DNA profiling and barcoding can complement traditional DUS (distinctness, uniformity, and stability) testing, improving accuracy and supporting varietal protection.

A project is currently underway at CSB-ISBR to address this issue of germplasm redundancy. The objective is to identify a core set of mulberry germplasm at the species level using DNA barcoding and to establish genome-wide allele profiles for authorized mulberry varieties to enable precise identification and varietal protection. Authorized mulberry varieties from CSR&TI, Mysore, CSR&TI, Berhampore and CSR&TI, Pampore will be subjected to DNA barcoding in order to reduce redundancy in germplasm bank. These collected accessions will be screened using Simple Sequence Repeat (SSR) primers followed by scoring based on banding patterns and allele sizes to facilitate the generation of allele fingerprints. The unique SSR profiles will successfully distinguish all the collected varieties, contributing to the development of a core germplasm set. Simultaneously, DNA barcoding will be employed to identify accessions with desirable economic traits at the species level. A molecular barcode system is currently being developed, which will serve as a valuable tool for the protection of authorized mulberry varieties and support legal varietal authentication. The DNA barcode information in mulberry genotypes will also be useful in the selection of genetically contrasting parental lines for hybridization studies.

Harnessing Genomic Innovation for Future Host Plant Improvement

In the coming years, molecular breeding in mulberry can be significantly advanced through several strategic research directions. Genome-wide association studies (GWAS) using diverse germplasm collections can be undertaken to identify novel genomic regions and candidate genes associated with the important economic traits. These markers can be validated and utilized in marker-assisted selection (MAS) to accelerate the breeding process. Transcriptomic approaches offer another promising avenue, where gene expression profiling under different abiotic and biotic stress conditions can help identify key regulatory genes and stress-responsive pathways. Development of high-density molecular linkage maps using SSR and SNP markers will further enable precise mapping of quantitative trait loci (QTLs) for complex agronomic traits, supporting efficient trait introgression. There is also scope for designing mulberry-specific SNP chips and genotyping arrays to facilitate large-scale, rapid, and cost-effective genotyping, which will aid in variety identification, diversity analysis, and breeding decisions. Genomic selection (GS) can be explored by integrating phenotypic and genotypic data to build prediction models based on genomic estimated breeding values (GEBVs), allowing early and accurate selection of superior genotypes and reducing breeding cycles. Additionally, studies on microRNAs (miRNAs) and epigenomic modifications such as DNA methylation and histone modifications can provide insights into the regulation of key developmental and stress-responsive genes. Future research can also focus on constructing a mulberry pangenome to capture the full extent of genetic diversity and structural variations. Integrating multi-omics approaches, including genomics, transcriptomics, proteomics, and metabolomics, will provide a holistic understanding of trait architecture and further accelerate mulberry crop improvement.

Conclusion

Molecular breeding offers a transformative approach for accelerating mulberry crop improvement. The integration of genomics, bioinformatics, and biotechnology can help unravel complex traits, protect valuable germplasm, and develop resilient, high-yielding cultivars. Moving forward, studies like GWAS, transcriptomics, SNP chip development, and genomic selection will provide a comprehensive toolkit to achieve precision breeding in mulberry. This synergy between traditional and molecular approaches holds the key to meeting the growing demands of sericulture sustainably.

Reference

Checker VG, Chhibbar AK, Khurana P (2012a) Stress-inducible expression of barley Hva1 gene in transgenic mulberry displays enhanced tolerance against drought, salinity and cold stress. *Transgenic Res*., 21(5): 939-957. http://doi:10.1007/s11248-011-9577-8

Chikkaswamy BK, Paramanik RC, Debnath A, Sadana M (2012) Evaluation of genetic diversity in mulberry varieties using molecular markers. *Nature Sci*., 10(6): 45-60. (ISSN: 1545-0740). http://www.sciencepub.net/nature

Das M, Chauhan H, Chhibbar A, Rizwanul Haq QM, Khurana P (2011) High-efficiency transformation and selective tolerance against biotic and abiotic stress in mulberry, *Morus indica* cv. K2, by constitutive and inducible expression of tobacco osmotin. *Transgenic Res*., 20: 231-46. http://doi.10.1007/s11248-010-9405-6

Garcia-Gómez B, González-Alvarez H, Martínez-Mora C, Cenis LJ, Pérez-Hernández CDM, Martínez-Zubiaur Y, Martínez-Gómez P (2019) The molecular characterization of an extended mulberry germplasm by SSR markers. *Genetika*, 51(2): 389-403. https://doi.org/10.2298/GENSR1902389G

Li QL, Guo JZ, Yan N, Li CC (2016) Complete chloroplast genome sequence of cultivated *Morus* L. species. *Genet. Mol. Res*., 15(4) http://doi.10.4238/gmr15048906

Naik VG, Thumilan B, Sarkar A, Dandin S, Pinto M, Sivaprasad V (2014) Development of genetic linkage map of mulberry using molecular markers and identification of QTLs linked to yield and yield contributing traits. *Sericologia*, 54: 221-229.

Saeed B, Das M, Khurana P (2015) Overexpression of β-carotene hydroxylase1 (BCH1) in Indian mulberry, *Morus indica* cv. K2, confers tolerance against UV, high temperature and high irradiance stress induced oxidative damage. *Plant Cell, Tissue and Organ Culture* (PCTOC) 120: 1003-1014. https://doi.org/10.1007/s11240-014-0654-6

Sajeevan RS, Nataraja KN, Shivashankara KS, Pallavi N, Gurumurthy DS, Shivanna MB (2017) Expression of Arabidopsis SHN1 in Indian mulberry (*Morus indica* L.) increases leaf surface wax content and reduces post-harvest water loss. *Frontiers in Plant Science*, 8: 418. http://doi.10.3389/fpls.2017.00418

Vijayan K, Sangannavar P, Chattopadhyay S, Dezmirean D, Ercisli S (2021) Cultivation of mulberry: an important genetic and economic source, Mulberry, CRC Press. pp. 32-44.

Yang J, Peng Y, Yang F, Meng G, Kong W (2025) The telomere-to-telomere genome assembly of the wild mulberry, *Morus mongolica*. Scientific Data, 12: 694. https://doi.org/10.1038/s41597-025-05040-6

Zhu C, Qin Y, Liu C, Hou Z, He J, Wang P, Hu D, Wang X (2025) Unraveling phenotypic diversity and genetic structure of mulberry germplasm via GWAS: Key candidate genes and their molecular breeding potential. *Scientia Horticulturae*, 349: 114226. http://doi.10.1016/j.scienta.2025.114226

LEVERAGING MODERN BREEDING AND GENOMICS TOOLS TO OVERCOME KEY CONSTRAINTS IN MULBERRY (*MORUS* SPP.) CULTIVATION

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Abstract

Mulberry (*Morus* spp.), the exclusive host plant for the silkworm (*Bombyx mori*), forms the backbone of the sericulture industry. However, its cultivation and improvement are constrained by multiple biological and agronomic challenges. Chief among them are the long breeding cycle (15–20 years), high heterozygosity, vulnerability to pests such as thrips, mites, and mealybugs, and low productivity in marginal land conditions. The most widely cultivated variety, V1, lacks a viable alternative, making the system vulnerable to both biotic and abiotic stresses. Moreover, genomic resources in mulberry are still limited, which slows down trait discovery and molecular breeding efforts. In this context, modern breeding and genomic tools offer promising solutions to accelerate variety development, enhance resistance, and improve productivity. This article discusses the critical issues in brief in mulberry cultivation and elaborates on how tools such as genome sequencing, marker-assisted selection, genomic selection, transcriptomics, and genome editing can address these bottlenecks.

Key words: genomics tools, germplasm characterization, modern breeding, mulberry

1. Introduction

Mulberry improvement has traditionally been based on classical selection and hybridization methods, which are inherently slow due to the plant's perennial nature and heterozygosity. New varieties often take over 15 years to develop and release, limiting the responsiveness of breeding programs to emerging challenges. Compounding this issue is the narrow genetic base of elite varieties, particularly V1, which dominates the mulberry landscape. Although V1 is high-yielding, it is also highly susceptible to pests and soil-borne diseases, especially root rot. Its performance under low-input or marginal conditions is also poor, leaving farmers with limited alternatives. Further, breeding efforts are constrained by the lack of high-quality reference genomes, limited functional markers, and a general dearth of genomic tools compared to major crops. Modern breeding technologies including genomics, transcriptomics, genome editing, and high-throughput phenotyping offer unprecedented opportunities to overcome these hurdles. Their integration into mulberry improvement programs can help shorten breeding cycles, enhance trait precision, and develop varieties that are better suited to both intensive and marginal sericulture zones.

2. Challenges in Mulberry Cultivation

Several critical constraints continue to limit the productivity and resilience of mulberry crops. One of the most devastating issues is root rot, caused by pathogens like Phytophthora, Fusarium, and Macrophomina. It leads to sudden wilting and plant death, particularly in poorly drained or pathogen-infested soils. Traditional varieties, including V1, show limited resistance to these pathogens. Moreover, mulberry is highly vulnerable to a range of pests such as thrips, red spider mites, whiteflies, leaf rollers, and mealybugs. These pests degrade leaf quality and quantity, which directly affects cocoon yield in silkworms. Another major problem is the long breeding cycle up to 20 years caused by the perennial and heterozygous nature of the plant. Unlike annuals, mulberry does not offer rapid generation turnover, making genetic gain per unit time very low. Furthermore, V1’s poor adaptability to degraded or low-input lands limits mulberry expansion in marginal regions. The lack of an alternative variety to V1 increases vulnerability to climate change and disease outbreaks. Finally, the limited availability of high-resolution genomic data and molecular markers hampers trait discovery and precision breeding.

3. Modern Breeding and Genomics Solutions

Modern tools in molecular biology and genomics can transform the way mulberry is bred and cultivated. These tools address the core challenges by enabling trait discovery, reducing breeding time, and improving selection accuracy.

3.1. Genome Sequencing and Pan-Genomics

The first step towards genomics-enabled breeding is the development of high-quality reference genomes. While draft genome sequences exist for certain *Morus* species (Jiao *et al.*, 2020, Jain *et. al*., 2022), there is an urgent need to generate chromosome-level assemblies using long-read sequencing and Hi-C technologies (He *et al*., 2013). A pan-genome built using multiple diverse genotypes can capture both core and dispensable genes, providing a complete picture of allelic diversity in mulberry. Such resources enable the identification of genes responsible for root rot resistance, drought tolerance, and leaf productivity. Once key genes are known, they can be targeted in breeding programs or through genome editing.

3.2. Genotyping-by-Sequencing (GBS) and SNP Marker Development

GBS is a cost-effective and rapid method for discovering genome-wide single nucleotide polymorphisms (SNPs). These markers are critical for conducting association studies and constructing high-density genetic linkage maps. Using GBS, researchers can perform quantitative trait loci (QTL) mapping for complex traits such as leaf yield, disease resistance, and pest tolerance. SNP arrays can also be developed from these datasets, providing a high-throughput and reproducible platform for genotyping breeding populations. Once markers associated with key traits are validated, they can be used for selection in early generations, bypassing the need for long-term phenotypic evaluations.

3.3. Marker-Assisted Selection (MAS) and Genomic Selection (GS)

MAS is especially effective when major-effect QTLs or genes are known for traits such as root rot resistance or flowering behavior. It enables early-stage selection based on DNA profiles rather than field data, reducing the time and cost of breeding. For polygenic traits like biomass yield, leaf quality, or drought tolerance, genomic selection (GS) is more suitable. GS uses genome-wide marker data to predict the genetic value of individuals, even before they are phenotyped. This is particularly useful in a heterozygous crop like mulberry, where multiple alleles interact to determine trait expression. By applying GS, breeders can make more informed crosses and selections, significantly improving the efficiency and accuracy of breeding programs.

3.4. Speed Breeding and Controlled Environment Phenotyping

Speed breeding protocols, although challenging in perennials, can still be partially implemented in mulberry using growth regulators and controlled environments. Techniques such as pruning, gibberellic acid treatment, and nutrient optimization can induce earlier flowering or shoot regeneration. When combined with automated phenotyping platforms using drones, imaging, and environmental sensors, these tools can help breeders screen large populations faster and more accurately. Such platforms are invaluable for tracking disease progression, leaf area index, and other agronomic traits.

3.5. Genome Editing using CRISPR/Cas9

CRISPR/Cas9-based genome editing offers a precise method to enhance or silence specific genes of interest. In mulberry, potential targets include susceptibility genes involved in fungal infections, negative regulators of growth, and genes affecting flowering or branching (Moulidharshan *et al*., 2025). Editing these genes can result in disease-resistant, early-maturing, or higher-yielding plants without introducing foreign

DNA, which also aids regulatory approval. However, one major challenge is the development of efficient transformation and regeneration protocols in mulberry. Research must prioritize establishing reliable *in vitro* systems to fully exploit CRISPR's potential in this crop.

3.6. Transcriptomics and Proteomics

Functional genomics, particularly transcriptomic profiling through RNA-Seq, provides insights into the genes that are differentially expressed during stress conditions, disease infection, or different developmental stages (Mahesh et al., 2021). For instance, by comparing gene expression between a root rot-resistant and susceptible genotype, researchers can pinpoint candidate resistance genes. Similarly, proteomics reveals stress-responsive proteins and post-translational modifications that regulate plant defense. These studies not only inform marker development but also guide genome editing and transgenic interventions.

3.7. Germplasm Characterization and Core Set Development

Mulberry has a rich pool of genetic diversity spread across various wild species, landraces, and cultivated varieties. However, this diversity remains underutilized. Molecular characterization using SSRs, SNPs, or whole-genome resequencing helps identify novel alleles and unique accessions. Developing a genetically diverse core collection allows for efficient phenotypic and genotypic evaluation, reducing redundancy in breeding programs. Pre-breeding efforts using wild species can also be initiated to introgress novel traits.

3.8. Tissue Culture and Clonal Propagation

Tissue culture provides a powerful means to rapidly multiply elite genotypes or genome-edited lines. It ensures genetic fidelity and uniformity, especially important in a heterozygous crop like mulberry. Micropropagation can also be used for rejuvenating old mother plants or conserving valuable germplasm. Additionally, somatic embryogenesis offers a pathway for developing transformation systems needed for genome editing. Establishing reliable protocols in multiple genotypes will significantly accelerate varietal dissemination and biotech-based trait improvement.

4. Conclusion

The integration of modern breeding and genomics tools presents a transformative opportunity for mulberry improvement. By leveraging genome sequencing, molecular markers, genome editing, and high-throughput phenotyping, breeders can overcome the intrinsic limitations of traditional methods. These tools not only accelerate breeding but also enable precision in selecting and stacking multiple desirable traits. To fully realize this potential, there is a need for strategic investments in genomic infrastructure, skilled human resources, and interdisciplinary collaborations. With these advancements, mulberry cultivation can become more resilient, productive, and sustainable, ultimately strengthening the sericulture value chain.

5. References

He N, Zhang C, Qi X, Zhao S, Tao Y, Yang G, Lee T-H, Wang X, Cai Q, Li D, Lu M, Liao S, Luo G, He R, Tan X, Xu Y, Li T, Zhao A, Jia L, Fu Q, Zeng Q, Gao C, Ma B , Liang J, Wang X, Shang J, Song P, Wu H, Fan L , Wang Q, Shuai Q, Zhu J, Wei C, Zhu-Salzman K, Jin D, Wang J, Liu T, Yu M, Tang C, Wang Z, Dai F, Chen J, Liu Y, Zhao S, Lin T, Zhang S, Wang J, Wang J, Yang H, Yang G, Wang J, Paterson AH, Xia Q, Ji D and Xiang Z (2013) Draft genome sequence of the mulberry tree *Morus notabilis*. *Nature communications,* 4: 2445. http://doi.10.1038/ncomms3445

Jain M, Bansal J, Rajkumar MS, Sharma N, Khurana JP, Khurana P (2022) Draft genome sequence of Indian mulberry (*Morus indica*) provides a resource for functional and translational genomics. *Genomics,* 114(3): 110346. http://doi.10.1016/j.ygeno.2022.110346

Jiao F, Luo R, Dai X, Liu H, Yu G, Han S, Lu X, Su C, Chen Q, Song Q (2020) Chromosome-level reference genome and population genomic analysis provide insights into the evolution and improvement of domesticated mulberry (*Morus alba*). *Molecular plant,* 13(7): 1001-1012.

Meng C, Li F, Sun H, Zhang R, Hui T, Qian Y, Aichun Zhao A, Jiang Y (2020) Chromosome-Level Reference Genome and Population Genomic Analysis Provide Insights into the Evolution and Improvement of Domesticated Mulberry (*Morus alba*). *Molecular Plant,* 13(7): 1001-1012. https://doi.org/10.1016/j.molp.2020.05.005

Mahesh H, Shirke MD, Wang G-L, Gowda M (2021) In planta transcriptome analysis reveals tissue-specific expression of pathogenicity genes and microRNAs during rice-Magnaporthe interactions. *Genomics,* 113(1): 265-275. https://doi.org/10.1016/j.ygeno.2020.12.018

Moulidharshan R, Savitha G, Pavithra M (2025) CRISPR and Beyond: A Review of Genome Editing Technologies Transforming Silkworm (*Bombyx mori*) and Mulberry (*Morus* spp.) Research. *Journal of Advances in Biology & Biotechnology,* 28(7): 1068-1079. https://doi.org/10.9734/jabb/2025/v28i72623

GENETIC ENHANCEMENT APPROACHES FOR ROOTSTOCK DEVELOPMENT IN FRUIT TREE SPECIES

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Fruit crops play a vital role in improving human health, supporting ecosystems, and promoting sustainable agriculture and economic growth. They enhance dietary variety by offering essential nutrients while adding flavour, colour, and appeal to meals. Fruits are an abundant source of important vitamins such as C, A, and K, which boost immune function, vision, and blood clotting. Fruits such as apples, pears, and berries are rich sources of dietary fibre, which plays a crucial role in promoting gastrointestinal health, attenuating postprandial glycemic responses, and reducing serum cholesterol concentrations. Fruits contain phytochemicals like flavonoids and polyphenols that have strong antioxidant properties, effectively fighting oxidative stress and helping prevent chronic diseases such as cardiovascular disease, cancer, and neurodegenerative disorders. For example, antioxidant-rich fruits like blueberries and oranges are linked to better cognitive function and a decreased risk of age-related cognitive decline. Furthermore, the natural sugars and phytonutrients in fruits are known to positively affect mood, energy, and metabolic health.

Regular fruit consumption has been linked to reduced risks of obesity, type 2 diabetes, and heart disease. Specific fruits also offer targeted health benefits - bananas, for example, provide potassium that supports blood pressure regulation, while citrus fruits aid in collagen synthesis and wound healing. Beyond their nutritional benefits, fruit crops contribute to ecological sustainability by enhancing biodiversity, improving soil health, and sequestering carbon, thereby playing a role in mitigating climate change. Economically, fruit cultivation supports rural and urban livelihoods through income generation, value-added processing, and export trade. As integral components of the agricultural value chain, fruit crops are vital not only for public health but also for food security, environmental sustainability, and economic resilience.

Mulberry (*Morus spp.*) is a fast-growing, woody perennial plant characterized by high heterozygosity and wide adaptability across diverse agroclimatic zones. It is primarily cultivated for its foliage, which serves as the sole food source for the domesticated, monophagous silkworm *Bombyx mori* L., forming the foundation of sericulture. Beyond its importance in silk production, mulberry also produces fleshy, sweet, and nutritious berries that are gaining attention for their health benefits and commercial potential.

Mulberry fruits are low in calories yet rich in essential phytonutrients, including polyphenols, vitamins, and minerals, which contribute to their reported antioxidant, antitumor, neuroprotective, and hypolipidemic effects. They also contain a broad range of essential amino acids - such as isoleucine, leucine, lysine, and methionine - and minerals like potassium, calcium, magnesium, iron, and zinc. Additionally, organic acids such as malic, citric, succinic, and tartaric acids contribute to their nutritional profile (Jiang and Nie, 2015). Among fruit colour variants, purple mulberry fruits have been found to contain higher levels of total sugars and anthocyanins compared to red and purple-red varieties, as sugars act as precursors for anthocyanin synthesis (Aramwit et al., 2010). In contrast, red mulberry fruits tend to have higher concentrations of ascorbic acid and β-carotene. The primary anthocyanins present are cyanidin-3-glucoside and cyanidin-3-rutinoside, compounds known for their potential as natural dietary modulators and food colorants (Wrolstad, 2001).

Notably, mulberry fruits exhibit higher phenolic content than other berries like blackberry, blueberry, and raspberry, reinforcing their value as a potent source of antioxidants (Kim et al., 1996, 1998). *Morus alba* fruits, in particular, are traditionally recognized for their cooling and laxative properties and have been used in managing throat infections, dyspepsia, and melancholia (Jain and DeFilipps, 1991). They are also applied in cases of appetite loss, flatulence, and parasitic infections such as tapeworm. Given their diverse health-promoting properties and increasing consumer demand, mulberry fruits offer significant untapped potential for the food, nutraceutical, and healthcare industries.

Conservation of Mulberry Germplasm

At the Central Sericulture Germplasm Research Centre (CSGRC), Hosur, India, several elite accessions, including *MI-0118, MI-0171, MI-0249, MI-0300, MI-0497, MI-0512, MI-0059, MI-0506, MI-0380, MI-0572, ME-0004,* and *ME-0042*, have been identified with notable variation in fruit yield per plant. In addition, specific accessions of *Morus laevigata,* such as *MI-0365, MI-0428, MI-0531,* and *MI-0340* are recognized for producing long, sweet fruits. Similarly, accessions of *Morus alba* like *MI-0442, MI-0511,* and *MI-0469* bear highly-sweet, white fruits. Despite their comparatively low leaf yield, which constrains their applicability in sericulture, these genotypes possess considerable promise for fruit-oriented utilization and value addition, particularly in nutraceuticals and functional foods.

Seed Propagation in Fruit Crops

Seed propagation is one of the oldest and most straightforward methods of plant multiplication. While not always ideal for commercial fruit production due to genetic variability, it remains crucial in breeding programs, rootstock development, and propagation of certain species. In crops such as citrus, mango, guava, and apple, seed-derived rootstocks are commonly employed for grafting purposes.

Seed propagation is especially valuable in genetic improvement programs aimed at developing new cultivars with enhanced traits. Fruits like papaya, phalsa, jamun, loquat, and passion fruit are frequently propagated by seed. In crops like mango and citrus, polyembryonic varieties are preferred for seed propagation, as they allow for the production of true-to-type plants due to nucellar embryony.

However, seed propagation has notable limitations. In many cross-pollinated and highly heterozygous species, seedlings show significant genetic variation and often do not breed true-to-type. Moreover, seed-propagated plants typically undergo a prolonged juvenile phase, leading to delayed fruiting. This method also results in inconsistent yield and fruit quality, making it less suitable for uniform commercial production compared to vegetative propagation techniques.

Vegetative Propagation in Fruit Crops

Vegetative propagation is a widely adopted technique in fruit crop cultivation, aimed at producing true-to-type plants, reducing the juvenile phase, and ensuring uniformity in yield and fruit quality. By cloning elite genotypes, this method effectively preserves desirable traits such as fruit taste, texture, and overall market value. Moreover, vegetatively propagated plants often reach reproductive maturity sooner than seed-propagated counterparts, leading to earlier and more consistent fruiting.

An additional advantage of vegetative propagation lies in the selection and use of specialized rootstocks that impart resistance to abiotic stresses such as drought and salinity, or biotic challenges like soil-borne diseases. The use of dwarfing rootstocks also allows for better control over tree size, enabling higher orchard densities, improved canopy management, and easier harvesting operations.

Common vegetative propagation methods in fruit crops include:

- *Stem cuttings:* Commercially used in grapes, figs, pomegranates, and guavas.
- *Layering:* Practiced in crops such as pomegranate, litchi, guava, lemon, and sapota.
- *Budding:* Suitable for peach, plum, ber, and citrus.
- *Grafting:* Practiced in Mango, Apple, Jack fruit, Jamun

- *Micropropagation (Tissue Culture):* Widely used in banana, strawberry, and pineapple for rapid multiplication and disease-free plant production.

Advanced Grafting Strategies

To enhance grafting outcomes and combine multiple beneficial traits, several advanced grafting techniques have been developed:

- *Inter-stock Grafting:* Involves inserting an additional stem segment (interstock) between the rootstock and scion. This technique is used to combine desirable traits such as dwarfing, disease resistance, or improved compatibility.
- *Multi-varietal Grafting:* Allows multiple scion varieties to be grafted onto a single rootstock, facilitating space-saving, enhancing aesthetic diversity, and enabling cross-pollination in self-incompatible species.
- *Grafting using stress-adapted Rootstock:* Focuses on selecting rootstocks with specific tolerance to drought, salinity, alkalinity, or nutrient-poor soils, thereby improving resilience under challenging agro-climatic conditions.

Mulberry is primarily propagated vegetatively to ensure true-to-type clones, rapid multiplication, and uniformity in leaf yield, especially critical for sericulture. Mulberry plants can be propagated through several methods *viz*., stem cuttings, grafting, and layering. Each method has its advantages and is suited to different varieties and conditions.

Table 1: Common Vegetative Propagation Techniques in mulberry

Method	Description	Suitable Varieties / Regions
Stem Cuttings	Hardwood cuttings (15–20 cm) with 3–4 buds are planted.	Tropical regions (e.g., South India)
Grafting	Root, bud, or shoot grafting is used for poor-rooting varieties	Temperate regions (e.g., Kashmir)
Layering	Simple, mound, or air layering for difficult-to-root types	Used in both tropical and temperate
Micropropagation	In vitro culture using nodal segments or shoot tips for clonal fidelity	Somatic hybrid development and transgenics

Table 2: Grafting Techniques

Technique	Description	Advantages	Disadvantages
Cleft Grafting	Scion inserted into a split rootstock	Simple, widely used	Labor-intensive, lower success in hardwood
Whip & Tongue	Interlocking cuts on scion and stock	Strong union, high success	Requires skill, precise cuts
Bark Grafting	Scion inserted under bark flap	Useful for thick rootstocks	Risk of poor cambium contact
Bud Grafting	Bud inserted into rootstock bark	Economical, uses less material	Lower success in woody species
Side Grafting	Scion inserted into side of rootstock	Good for field conditions	Slow healing, needs protection

Compatibility is highest when the scion and rootstock are closely related. Same species are almost always compatible. The same genus is often compatible, but with exceptions. Same family is sometimes compatible, but less reliable. Different families are rarely compatible due to genetic divergence. The vascular cambium layers of both parts must align closely to allow proper healing and vascular connection (xylem and phloem formation).

Stenting (Cutting-Grafting) Technique

Stenting, also known as cutting-grafting, is a highly effective vegetative propagation method that allows for the simultaneous execution of grafting and rooting, making it particularly suitable for the rapid multiplication of horticultural crops. This technique has been successfully applied in a variety of species, including apple, plum, pear (Hartmann et al., 2002), and pomegranate (Karimi, 2011).

The success of adventitious root initiation and formation via stenting is influenced by several factors, such as environmental conditions (e.g., temperature, humidity) and the physiological status of the rootstock (Park and Jeong, 2012). Among the various growth regulators, exogenous application of auxins, particularly indole-3-butyric acid (IBA), has been extensively documented to enhance rooting efficiency in plant cuttings (Hartmann et al., 2002).

In mulberry, the splice stenting technique shows promise for propagating black mulberry (*Morus nigra*) onto white mulberry (*Morus alba*) rootstocks. Notably, the application of IBA at 1000 mg L^{-1} has been shown to significantly improve rooting success in such grafted cuttings (Solgi et al., 2022), further highlighting the potential of this method for efficient clonal propagation in mulberry improvement programs.

Cost of Production Considerations

The choice of grafting method significantly impacts the overall cost of production. Manual grafting, while widely practiced, incurs high labor costs and offers limited scalability, making it less efficient for large-scale operations. Bud grafting is relatively economical in terms of material input; however, its success rate can be inconsistent, depending on environmental conditions and operator skill.

Whip and tongue grafting, although more labor-intensive, is associated with a higher success rate, which can justify the additional labor costs through improved plant establishment and uniformity. On the other hand, mechanized grafting requires a substantial initial investment in equipment and infrastructure. Nevertheless, it significantly reduces the per-unit cost of propagation when applied to large-scale commercial production, making it a cost-effective solution in the long term.

Mechanization in Grafting

Presently, few private nurseries are using imported grafting machines, which are very expensive and the availability of service and maintenance is hard.

Indigenous semi-automatic grafting machine

An indigenous semi-automatic grafting machine was designed and developed by ICAR-Indian Institute of Horticultural Research, Bengaluru.

The grafting machine consists of

- The trays for loading portray with seedlings
- Gripper for holding scion and root stocks of seedlings,
- Cutting arms with blades
- Pneumatically operated linear actuators
- PLC programme and
- Compressor

In the automated grafting system, scion and rootstock seedlings are placed into their respective clamps. Once loaded, the process is initiated - the gripper and clamping cylinders are activated, securely holding the seedlings in position. The knife cylinder is then engaged to perform precise cuts on both seedlings, effectively dividing each into two parts.

Following the cutting operation, rear pneumatic cylinders remove the unwanted portions of the seedlings. The main pneumatic cylinder (x-axis) then moves the sliding mechanism to bring the cut surfaces of the scion and rootstock into alignment at the joining position. At this stage, the two parts are manually secured together using a plastic grafting clip.

Once grafting is complete, the clamping and gripper mechanisms are deactivated, and the grafted seedling is manually removed. The entire sequence is managed via an HMI-operated (Human-Machine Interface) control panel, with programmable logic controller (PLC) automation ensuring accurate sequencing and operation.

The machine is capable of performing up to 150 grafts per hour, slightly higher than the manual grafting rate of 130 grafts per hour, while maintaining a comparable success rate in graft establishment. The estimated cost of the machine is approximately ₹6.0 lakhs, making it a viable option for scaling up vegetative propagation with improved efficiency and consistency.

Strategic Applications of grafting in fruit crops

- **Mango**: Soft wood and epicotyl grafting are common; rootstocks are selected for vigour and disease resistance.
- **Guava**: Patch budding and cleft grafting are used to combat wilt and root rot.
- **Citrus:** Bud grafting onto trifoliate orange or sour orange rootstocks for nematode resistance.
- **Apple & Pear**: Whip and tongue grafting onto dwarfing rootstocks (M9, MM106) for orchard management.
- **Grapes**: Grafted onto phylloxera-resistant rootstocks like 1103 Paulsen or Dog Ridge.

Grafting for Leaf Yield

- Leaf biomass and canopy: Grape vines grafted onto vigorous rootstocks show denser canopies and higher leaf biomass (Somkuwar et al., 2025)
- Guava and citrus grafted onto disease-resistant rootstocks maintain healthier foliage under root rot stress (Ashokkumar et al.,2019)

Grafting for Temperature Stress

- Cold tolerance: Use of hybrid cold-tolerant rootstocks ‘CPHVODÁRNA’, ‘CPH 43’, ‘CPH 17’, ‘CPH 22’, ‘CPH 49’ (Blážková et al., 2002) and ‘Mazzard’ (*P. avium*) in Cherry (Turhan et al., 2012).
- Apricot ‘Haggith’ (*P. armeniaca*) seedling rootstocks for cold hardiness (Layne et al., 1975).

Drought Tolerance

- ‘SV2-7’ (*P. fruticosa*) and ‘OV14’ (*P. cerasus*) drought-tolerant rootstocks (Ljubojević et al., 2017).
- Cherry: Wild cherry (*P. microcarpa* and P*. incana*) seedling rootstocks for drought resistance (Jalili et al., 2023).
- Almond: Wild almond (*P. ramonensis* and *P. webbii*) seedling rootstocks for tolerance to drought (Gerbi et al., 2021).
- *Prunus webbii* is one of the most drought-tolerant genotypes among four *Prunus* species (Jurado-Mañogil et al., 2024).

Tolerance to waterlogging

- Sour cherry ‘Daqingye’ (*Prunus pseudocerasus*) and ‘Gisela 6’ (*P. cerasus* × *P. canescens*) have higher levels of ROS scavenging ability (Jia et al., 2019).

Flood-tolerance

- Plum rootstock ‘MP-29’ (*P. umbellata* × *P. persica*) (McGee et al., 2022).

Salinity tolerance

- Prunus rootstock, ‘Mariana 2624’ is most salt-tolerant among the plum rootstocks (Toro et al., 2021).
- Among peach and almond rootstocks, ‘Empyrean 1’ (*P. persica* × *P. davidiana*), ‘Cornerstone’ (*P. persica* × *P. dulcis*), and ‘Bright’s hybrid 5’ (*P. dulcis* × *P. persica*) have strong salt tolerance (Sandhu et al., 2020).

Nutritional Stress

- **Nutrient use efficiency**: The peach rootstock ‘Shannong-1’ exhibits higher nitrogen use efficiency (Chen *et al*., 2022).
- The peach rootstock ‘Garnem’ exhibits higher calcium use efficiency (Aras *et al*., 2021).

- Peach root stock, GF677 (*Prunus dulcis* Miller × *P. persica* (L.) Batsch) has stronger tolerance to iron chlorosis (Sun et al., 2022).
- Prunus rootstocks, 'Adesoto' (*P. insititia*), 'Felinem' (*P. dulcis × P. persica*), 'GF677', 'Krymsk 86' (*P. cerasifera* × *P. persica*), and 'PAC 9921-07' (*P. besseyi* × *P. salicina*) × *P. armeniaca*) strong tolerance to iron chlorosis (Jiménez *et al*., 2008).
- Flordaguard' (*P. persica*) with high zinc tolerance (Somavilla et al., 2018).

Rootstock Breeding in Fruit Crops

Breeding rootstocks for perennial fruit crops is a long-term, multi-phase process that requires careful planning, large populations, and specialized screening techniques. Rootstock breeding is a slow but strategic process, often taking 15–25 years from initial cross to commercial release.

Rootstock breeding focuses on traits like:

- Abiotic stress tolerance (drought, salinity, alkalinity)
- Biotic resistance (nematodes, soil-borne pathogens)
- Vigor control (dwarfing, precocity)
- Compatibility with scions
- Root architecture (deep, fibrous, non-suckering)

Breeding methods for rootstock improvement

Clonal Selection: This method is used in crops like apple, citrus, and grape. It involves the selection of superior individuals from existing populations. The time frame is 5–10 years, and the population size is 500–1000 clones. The screening involves field trials, graft compatibility, and stress tolerance

Hybridization: This method involves crosses between elite parents or wild relatives and combines traits like disease resistance and dwarfing. The timeframe is 15–20 years (due to the long juvenile phase), and the population size is 10,000–100,000 seedlings. The screening techniques include early-stage screening using molecular markers and greenhouse stress tests. This is followed by mid-stage screening by grafting trials with commercial scions and late-stage screening by conducting multi-location field trials.

Mutation Breeding: is induced by physical mutagens like gamma rays, and chemical mutagens *viz*., EMS, or X-rays. The specific traits targeted are, dwarfing or disease resistance. The timeframe is 10–15 years and population size is 1000–5000 mutants. The screening method involves morphological changes, stress assays, and graft performance

Polyploidy Breeding: is induced using colchicine or oryzalin. It enhances vigor, stress tolerance, and seedlessness. The timeframe is 8–12 years and the population size is 500–2000 polyploids. The screening method include Flow cytometry, root morphology, and graft compatibility.

Table 3: Phases of Evaluation & Screening Techniques

Phase	Duration (Years)	Activities & Screening Techniques
Phase I: Seedling Screening	1–3	Germination, root vigor, stress assays (salinity, drought)
Phase II: Nursery Evaluation	2–4	Root architecture, propagation ability, and graft compatibility
Phase III: Field Trials	5–10	Multi-location trials, scion performance, yield, disease resistance
Phase IV: Advanced Testing	3–5	Long-term productivity, fruit quality, and adaptability

Examples of Rootstock Breeding Programs

- Apple (*Malus spp.):* Geneva® series developed for fire blight resistance and dwarfing
- Citrus: Super Sour hybrids bred for HLB tolerance and salinity resistance
- Mango: Polyembryonic cultivars like Olour and Bappakai screened for salinity tolerance
- Grapes: Dogridge salinity tolerance
- Papaya: Resistance to PRSV using *Vasconcellea cauliflora* and *V. cundinamarcencis*
- Guava: *Psidium cattleianum* var. *cattleianum, P. cattleianum* var. *lucidum* and *P. friedrichsthalianum* identified as sources of resistance to guava wilt (*Fusarium oxysporum* f. sp. *psidii*) and root-knot nematode (*Meloidogyne incognita*)
- Pomegranate: Wild pomegranate, Daru and Nana as sources of Bacterial blight and wilt.

Genetic improvement in mulberry

Genetic improvement of mulberry is mainly aimed for improving productivity and quality of leaf for silk production. Conventional plant breeding techniques including tissue culture and molecular biology methods are employed in mulberry genetic improvement programmes to develop varieties for improved leaf productivity and biotic/abiotic stress tolerance (Sarkar et al., 2018).

Rootstock Breeding in Mulberry

Rootstock breeding in *Morus* spp. (mulberry) is gaining momentum as a strategic approach to enhance resilience against abiotic stresses like drought, salinity, and temperature extremes and biotic stress like root rot and root knot nematode diseases while also improving leaf productivity and root vigor.

Conventional Breeding Approaches

Selection of Tolerant Genotypes*: Qinglong mulberry* is known for its salt tolerance and is used as a rootstock for high-yielding cultivars like *Tieba mulberry*. Field screening under stress conditions helps identify rootstocks with superior water and nutrient uptake. (Zhang *et al*., 2018)

Hybridization*:* Crosses between stress-tolerant wild species and elite cultivars are used to combine vigour with resilience.

Grafting Trials*:* Grafting high-yielding scions onto stress-tolerant rootstocks improves leaf yield and reduces oxidative damage under salinity.

Table 4: Advanced Biotechnological Tools

Tool/Technique	Application in Rootstock Breeding
Marker-Assisted Selection (MAS)	Identification of stress-resistance genes for early screening
Transgenesis	Introduction of genes like *HVA1* (from barley) for drought/salinity tolerance
RNA Interference (RNAi)	Silencing of undesirable genes to improve stress response
Somatic Hybridization	Fusion of protoplasts from different species to create novel rootstocks
Genomic Tools	Use of SSR, SNP markers to assess genetic diversity and compatibility

Key Traits Targeted

Abiotic Stress Tolerance: Enhanced Na^+ exclusion and K^+ uptake under salt stress, improved PSII photochemical efficiency and reduced ROS accumulation

High Leaf Yield: Selection for larger leaf area, higher biomass, and better nutrient transport

Root Biomass: Vigorous root systems improve anchorage, water absorption, and nutrient uptake

Rootstock Breeding Objectives for Mulberry Improvement

- Develop mulberry rootstocks that:
- Thrive under drought and salinity stress
- Support high leaf yield (critical for sericulture)
- Exhibit vigorous root systems for better nutrient uptake

Phase 1: Germplasm Collection & Evaluation

- Select diverse genotypes from wild and cultivated *Morus* species
- Characterize for:
    - Stress tolerance traits (leaf turgor, chlorophyll retention under drought/salinity)
    - Root traits (root length, density, biomass)

Phase 2: Conventional Breeding Techniques

- **Hybridization:** Cross elite varieties with stress-tolerant types. Example: *Morus alba* × *Morus laevigata* for drought tolerance
- **Selection:**
    - Screen progenies under stress conditions in the greenhouse and field
    - Use scoring indices for salt/drought tolerance and leaf productivity
- **Grafting Trials:**
    - Graft high-yielding scions onto stress-tolerant rootstocks
    - Evaluate graft compatibility, leaf yield, and survival rates

Table 5: Phase 3: Biotechnological Integration

Tool	Purpose	Sample Application
Micropropagation	Rapid multiplication of elite rootstocks	Tissue culture from nodal segments
MAS (Marker-Assisted Selection)	Early selection for stress-related genes	SSR markers linked to Na^+/K^+ transport
Transcriptomics	Identify stress-inducible genes	Compare gene expression under salinity
CRISPR/Cas9 Editing	Targeted gene modification	Knock-in of *DREB* genes for drought tolerance
Somaclonal Variation	Generate novel variants	Culture explants & screen for vigor traits

Phase 4: Performance Trials

- Multi-location trials to test rootstocks under varied stress conditions

Traits Targeted for Leaf Yield

- High leaf biomass per shoot
- ROS levels under stress and Leaf nutrient content (NPK)
- Moisture retention and chlorophyll content
- Resistance to leaf spot and powdery mildew
- Early sprouting and fast regrowth
- Root dry weight

Traits Targeted for Fruit Yield

- Fruit size, sweetness (Brix), and color
- Non-suckering root system
- Resistance to fruit drop and pests
- Extended shelf life of fruits

To enhance mulberry genetic improvement for superior leaf yield and fruit quality, contemporary breeding approaches should be strategically combined with conventional hybridization and selection methodologies. These methods offer precision, speed, and the ability to target complex traits.

At present, the research on mulberry rootstocks focuses mainly on tolerance of drought, waterlogging, and salt. Zhang *et al*. (2018) reported that grafting using Qinglong mulberry with salt tolerance as rootstock and Tieba mulberry with high yield and good quality as scion could improve salt tolerance. In addition, Mo *et al*. (2021) showed that the *Morus multicaulis* Perr. seedling has stronger drought tolerance, while *Morus atropurpurea* Roxb. seedling has stronger waterlogging tolerance. It is essential to the mulberry industry, and it will become a useful approach in commercial cultivation of mulberry fruit by using good rootstocks.

Rootstocks play a critical part in contemporary fruit crop cultivation, affecting a variety of traits that determine vigour, yield, quality and stress tolerance. Research has advanced in rootstock-scions interactions, resistance to diseases, abiotic stress tolerance, and nutrient use efficiency in some crops. With increasingly complex global challenges, rootstock research will be an essential part of the effort to guarantee future success and sustainability of fruit production. New technologies in genomics, breeding methods, and environmentally friendly farming practices have immense potential for the creation of the next generation of rootstocks that will boost the productivity and resilience of fruit crops across the globe.

References

Aramwit P, Bang N, Srichana T (2010) The properties and stability of anthocyanins in mulberry fruits. *Food Res. Int.* 43: 1093-1097. http://doi.10.1016/j.foodres.2010.01.022

Aras S, Keles H, Bozkurt E (2021) Physiological and histological responses of peach plants grafted onto different rootstocks under calcium deficiency conditions. *Scientia Horticulturae*, 281 (2021) 109967. https://doi.org/10.1016/j.scienta.2021.109967

Ashokkumar N, Poornima K, Kalaiarasan P and Kavino M (2019) Screening and histological characterization of guava (*Psidium guajava* L.) cultivars against root knot nematode, *Meloidogyne enterolobii*. *Pest Management in Horticultural Ecosystems*, *25*(1): 84-92. http://doi.10.13140/RG.2.2.21024.92169

Chen QJ, Lian M, Guo J, Zhang BB, Yang SK, Huang KX, Peng FT, Xiao YS (2022) Comparative Transcriptome Analysis of Two Peach Rootstocks Uncovers the Effect of Gene Differential Expression on Nitrogen Use Efficiency. *Int. J. Mol. Sci*., 23, 11144. http://doi.10.3390/ijms231911144

Gerbi H, Paudel I, Zisovich A, Sapir G, Ben-Dor S, Klein T (2021) Physiological drought resistance mechanisms in wild species vs. rootstocks of almond and plum. *Trees*, 36: 669–683. https://doi.org/10.1007/s00468-021-02238-0

Hartmann HT, Kester DE, Davies FT and Geneve RL (2002) Plant Propagation: Principles and Practices. 7th Edition, Prentice-Hall, Englewood Cliffs.

Jain SK, De Filipps A (1991) Medicinal Plants in India. Reference Publications Inc., Algonac Michigan II, 438.

Jalili S, Arzani K, Prudencio AS, Salazar JA, Martínez-García PJ, Bouzari N and Martínez-Gómez P (2023) Integrated Morphological, Physiological and Molecular Analysis of the Drought Response in Cultivated and Wild *Prunus* L. Subgenera *Cerasus* Species. *Plant Mol. Biol. Report.* 41: 440-453. https://doi.org/10.1007/s11105-023-01379-5

Jia LT, Qin X, Lyu DG, Qin SJ and Zhang P (2019) ROS production and scavenging in three cherry rootstocks under short-term waterlogging conditions. *Sci. Hortic.,* 257: 108647. https://doi.org/10.1016/j.scienta.2019.108647

Jiang Y and Nie WJ (2015) Chemical properties in fruits of mulberry species from the Xinjiang province of China. *Food Chem*., 174: 460–466. http://doi.10.1016/j.foodchem.2014.11.083

Jiménez S, Pinochet J, Abadía A, Moreno MÁ, Gogorcena Y (2008) Tolerance Response to Iron Chlorosis of *Prunus* Selections as Rootstocks. *HortScience,* 43: 304–309. http://doi.10.21273/HORTSCI.43.2.304

Jurado-Mañogil C, Martínez-Melgarejo PA, Martínez-García P, Rubio M, Hernández JA, Barba-Espín G, Diaz-Vivancos P and Martínez-García PJ (2024) Comprehensive study of the hormonal, enzymatic and osmoregulatory response to drought in *Prunus* species. *Sci. Hortic.,* 326: 112786. https://doi.org/10.1016/j.scienta.2023.112786

Karimi HR (2011) *Stenting (Cutting and Grafting)* - A Technique for Propagating Pomegranate *(Punica granatum L.).* Journal of Fruit and Ornamental Plant Research, 19(2): 73-79.

Kim SY, Park KJ, Lee WC (1998) Anti-inflammatory and antioxidative effects of *Morus* spp. fruit extract. *Korean J. Med. Crop Sci*. 6: 204- 209.

Kim TW, Kwon YB, Lee JH, Yang IS (1996) A study on the antidiabetic effect of mulberry fruits. *Korean J. Seri. Sci*., 38: 100-107.

Layne REC and Harrison TB (1975) 'Haggith' Apricot: Rootstock Seed Source. *Hort. Science*, 10: 428.

Ljubojević M, Zorić L, Maksimović I, Dulić J, Miodragović M, Barać G and Ognjanov V (2017) Anatomically assisted cherry rootstock selection. *Sci. Hortic.,* 217: 197–208. http://doi.10.1016/j.scienta.2017.01.049

McGee T, Schaffer B, Shahid MA, Chaparro JX Sarkhosh A (2022) Carbon and nitrogen metabolism in peach trees on different *Prunus* rootstocks in response to flooding. *Plant Soil*, 475: 427–441. http://doi.10.1007/s11104-022-05377-6

Mo R-L, Zhang N, Zhou Y, Dong Z-X, Zhu Z-X, Li Y, Zhang C, Jin Q, and Yu C (2021) Influence of eight rootstocks on fruit quality of *Morus multicaulis* cv. 'Zijing' and the comprehensive evaluation of fruit quality traits*. Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 49(1): 12598. https://doi.org/10.15835/nbha50112598

Park YG and Jeong BR (2012) Effect of Light Intensity during Stenting Propagation on Rooting and Subsequent Growth of Two Rose Cultivars. *Flower Research Journal*, 20(4): 228–232. http://doi.10.11623/frj.2012.20.4.228

Sandhu D, Kaundal A, Acharya BR, Forest T, Pudussery MV, Liu X, Ferreira JFS, Suarez DL (2020) Linking diverse salinity responses of 14 almond rootstocks with physiological, biochemical, and genetic determinants. *Sci. Rep., 10*, 21087. http://doi.10.1038/s41598-020-78036-4

Sarkar T, Mogili T, Gandhi Doss S and Sivaprasad V (2018) Tissue Culture in Mulberry (*Morus spp.)* Intending Genetic Improvement, Micropropagation and Secondary Metabolite Production: *A Review on Current Status and Future Prospects.* In: Biotechnological

Approaches for Medicinal and Aromatic Plants, pp. 467–487. http://doi.10.1007/978-981-13-0535-1_21

Solgi M, Taghizadeh M and Bagheri H (2022) Response of black mulberry onto white mulberry rootstock to stenting (cutting-grafting) techniques and IBA concentrations. *Ornamental Horticulture*, 28: 78-84. http://doi.10.1590/2447-536x.v28i1.2413

Somavilla LM, Simão DG, Tiecher TL, Hammerschimitt RK, de Oliveira JMS, Mayer NA, Pavanello EP, Trentin E, Belles SW and Brunetto G (2018) Structural changes in roots of peach rootstock cultivars grown in soil with high zinc content. *Sci. Hortic.* 237: 1-10. https://doi.org/10.1016/j.scienta.2018.03.059

Somkuwar RG, Gobade N, Deshmukh NA, Upadhyay AK and Ramteke SD (2025) Rootstocks influences, growth, bunch yield, quality, and raisin recovery in Manjari Kishmish grapes. *Plant Archives*, *25*(1): 2196-2202. https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.1.318

Sun SX, Li J, Song HY, Chen D, Tu MY, Chen QY, Jiang GL and Zhou ZQ (2022) Comparative transcriptome and physiological analyses reveal key factors in the tolerance of peach rootstocks to iron deficiency chlorosis. *3 Biotech*, *12*, 38. https://doi.org/10.1007/s13205-021-03046-6

Toro G, Pimentel P and Salvatierra A (2021) Effective categorization of tolerance to salt stress through clustering Prunus rootstocks according to their physiological performances. *Horticulturae*, *7*(12): 542. https://doi.org/10.3390/horticulturae7120542

Turhan E and Ergin S (2012) Soluble Sugars and Sucrose-Metabolizing Enzymes Related to Cold Acclimation of Sweet Cherry Cultivars Grafted on Different Rootstocks. *Sci. World J.* 979682. http://doi.10.1100/2012/979682

Wrolstad RE (2001) Anthocyanins - Bioactivity and coloring properties. In R. E. Wrolstad (Ed.), Current Protocols in Food Analytical Chemistry (pp. F1.2.1–F1.2.13). John Wiley & Sons.

Zhang Huihui, Xin Li, Shubo Zhang, Zepeng Yin, Wenxu Zhu, Jinbo Li, Liang Meng, Haixui Zhong, Nan Xu, Yining Wu4 and Guang yu Sun (2018) Rootstock Alleviates Salt Stress in Grafted Mulberry Seedlings: Physiological and PSII Function Responses. Frontiers in plant science, 9 https://doi.org/10.3389/fpls.2018.01806

CONSERVATION, CHARACTERIZATION, AND GENETIC IMPROVEMENT OF TASAR HOST PLANTS: PRESENT STATUS AND FUTURE STRATEGIES

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Abstract

The Tasar silk industry in India is undergoing significant changes, driven by evolving market demands, the impacts of climate change, and the growing emphasis on sustainable sericulture practices. *Terminalia arjuna* and *Terminalia tomentosa*, the key host plants for the tropical Tasar silkworm (*Antheraea mylitta*), are vital for maintaining cocoon quality and overall productivity. This paper presents a comprehensive overview of the germplasm-based research efforts undertaken at CSB-CTRTI, Ranchi, aimed at the genetic enhancement and conservation of these essential host plants. The research encompasses activities such as germplasm exploration, clonal propagation, in-vitro regeneration, evaluation for tolerance to biotic and abiotic stresses, biochemical assessments, and breeding for improved yield and quality. The findings of these studies have important implications for advancing plant breeding programs, promoting conservation efforts, and enhancing commercial utilization. This paper also highlights breeding strategies for improving these species, with an emphasis on traits like drought resilience, disease resistance, enhanced leaf yield, and superior nutritional value. Both traditional and modern biotechnological approaches are examined, along with recommendations to guide future improvement programs.

Key words: breeding strategies, genetic improvement, germplasm exploration, tasar host plants

Introduction

India holds a unique position in global sericulture as the only country producing all five known commercial silks, including tropical varieties, and ranks as the second-largest silk producer. Among these, Tasar silk stands out for its natural sheen, durability, and thermal properties, with a deep-rooted association with tribal communities who engage in silkworm rearing and cocoon collection from forests. Traditionally forest-based, Tasar culture has evolved towards systematic, commercial rearing through block plantations of primary host plants, *Terminalia arjuna* (Arjun) and *T. tomentosa* (Asan), on forest, marginal, and non-agricultural lands, contributing to both silk production and afforestation. A major challenge in expanding Tasar plantations has been the limited availability of improved host plant varieties, making germplasm conservation critical. Recognizing this, systematic collection and conservation of Tasar host plant genetic resources were initiated in 2000 under the National Agricultural Technology Project. The CSB-Central Tasar Research and Training Institute (CSB-CTRTI), Ranchi, established a field gene bank at Nagri, Jharkhand, conserving 341 accessions across nine species, including *T. arjuna* (190) and *T. tomentosa* (94). This gene bank is recognized as the National Active Germplasm Site (NAGS) by NBPGR, New Delhi. The conserved germplasm serves as the foundation for host plant breeding programs aimed at enhancing productivity, addressing climate change challenges, and meeting the evolving needs of the Tasar silk industry.

India ranks as the world’s second-largest silk producer, with tasar silk playing a vital role in the country's non-mulberry sericulture sector. The productivity and quality of tasar silk are closely linked to the availability and performance of its primary host plants, *Terminalia arjuna* (Arjun) and *Terminalia tomentosa* (Asan). However, the industry faces significant challenges due to unpredictable climatic conditions, soil degradation, and the growing demand for superior-quality silk. Addressing these challenges requires the development of improved cultivars of these *Terminalia* species. To promote sustainable growth and enhance the resilience of the tasar sector, it is essential to conserve, develop, and effectively utilize a diverse gene bank of tropical tasar host plants. This gene bank comprises a rich collection of germplasm, including *Terminalia arjuna*, *T. tomentosa*, *T. bellerica*, *T. chebula*, *T. myriocarpa*, *Anogeissus latifolia*, *Lagerstroemia indica*, *L. parviflora*, and *L. speciosa*, gathered from various agro-climatic regions across India. These genetic resources have been subjected to comprehensive, multi-trait evaluations to assess their potential for future breeding and conservation initiatives. This paper highlights key achievements in tropical Tasar host plant improvement and outlines future breeding strategies.

Breeding Strategies for the Improvement of *Terminalia arjuna* and *T. tomentosa*

1. Germplasm Exploration and Conservation

Germplasm exploration and conservation are vital for the sustainability and growth of the tasar silk industry, which depends largely on the continuous availability of quality host plants. Collecting germplasm from varied agro-climatic zones enables the identification of plant genotypes with desirable characteristics such as higher leaf yield, improved nutritional content, drought resistance, and tolerance to diseases. A diverse genetic pool forms the foundation for developing superior cultivars that can meet the increasing demands of the tasar sector.

In the face of growing challenges such as climate change, erratic weather patterns, and soil degradation, the conservation of diverse germplasm becomes even more critical. It ensures access to resilient and adaptable plant varieties capable of thriving under environmental stress, thus strengthening the sustainability of tasar plantations, especially in tribal and marginal areas.

Through systematic exploration, rare, endangered, and locally adapted plant genotypes can be identified and preserved, preventing their loss due to deforestation and other human activities. These genetic resources hold immense potential for future breeding programs, ecological restoration, and enhancing the overall genetic strength of tasar host plants.

The establishment of a well-maintained gene bank provides a reliable source of quality planting materials, which directly impacts leaf availability and cocoon production. This, in turn, supports the livelihood of tribal communities who are primarily dependent on tasar sericulture for income.

In 2003, Kumar and colleagues (under the project PIE 4633) initiated the development of a Tasar host plant gene bank with a focus on the exploration, collection, evaluation, and maintenance of *Terminalia* species (Kumar et al., 2003) As part of this initiative, 341 accessions of different host plant species were established in the field gene bank. These accessions were systematically evaluated for key traits influencing tasar silkworm rearing. Notably, three accessions of *Terminalia arjuna* (102, 123, and 135) demonstrated superior leaf yield, with accessions 123 and 135 also showing good drought tolerance. To support ongoing and future breeding efforts, systematic characterization of *T. arjuna* and *T. tomentosa* germplasm was carried out (Suryanarayana *et al.*, 2005 and Kumar *et al.*, 2009a&b; 2010). Fifty accessions of each species were evaluated for morphological, anatomical, physiological, growth, and biochemical traits to assess their variability and potential for genetic improvement (Table 1, 2, 3 & 4)

Table 1: Characterization of 50 *T. arjuna* accessions:

#	Parameters	Range	Mean	SE±	CV (%)
1	Lamina length (cm)	10.12 - 20.52	13.68	0.32	17.03
2	Lamina width (cm)	3.66-14.06	5.23	0.21	29.25
3	Petiole length (cm)	0.11-1.16	0.54	0.02	36.49
4	Lamina length/petiole length (ratio)	11.92-94.34	28.60	1.87	46.25
5	Leaf weight (g)	2.21-7.39	4.11	0.15	26.27
6	Petiole weight (g)	0.01-0.15	0.065	0.003	33.33
7	Lamina weight (g)	2.1-7.28	4.04	0.15	26.48
8	Leaf weight/Petiole weight (ratio)	32.21-302.20	76.17	6.89	64.04
9	Laminar index	96.81-99.66	98.35	0.09	0.65
10	Internodal distance (cm)	1.5-2.90	2.06	0.04	15.53

11	Moisture (%)	62.58-78.57	67.35	0.44	4.69
12	Moisture retention capacity (%)	61.44-76.64	65.36	0.43	4.66
13	Stomata/mm^2	186.76-625.07	381.98	15.16	28.06
14	Length of stomata (μm)	21.81-31.3	26.46	0.27	4.15
15	Width of stomata (μm)	10.46-19.48	15.48	0.21	9.68
16	Pore length of stomata (μm)	13.39-22.30	16.90	0.26	11.06
17	Pore width of stomata (μm)	3.68-6.99	0.11	5.58	14.15
18	Stomata Pore area (μm)	60.51-149.51	95.34	2.66	19.72
19	Number of chloroplast in guard cell	6.33-12.66	8.68	0.19	16.12
20	Cuticle thickness (μm)	2.57-26.49	12.27	0.72	41.8
21	Upper epidermis thickness (μm)	12.61-31.98	20.72	0.72	24.56
22	Palisade thickness (μm)	96.57-185.223	141.28	3.16	15.85
23	Spongy parenchyma thickness (μm)	88.5-281.60	171.62	5.59	23.05
24	Lower epidermis thickness (μm)	6.45-32.30	18.11	0.91	35.89
25	Total thickness (μm)	256.08-496.29	364.02	8.14	15.82
26	Ratio of palisade /spongy tissue	0.49-1.42	0.85	0.02	22.35
27	Chlorophyll a (mg/g)	0.66-1.72	1.14	0.04	25.43
28	Chlorophyll b mg/g	0.42-1.76	0.89	0.04	32.58
29	Chlorophyll a / Chlorophyll b	0.64-2.33	1.32	0.04	21.21
30	Total chlorophyll (mg/g)	1.24-3.49	2.02	0.07	26.34
31	Phenol (μg/mg)	0.23-5.63	1.84	0.17	67.93
32	Reducing sugar (μg/mg)	2.64-20.8	7.86	0.46	41.85
33	Non-reducing sugar (μg/mg)	3.6-14.75	8.17	0.34	29.98
34	Proline (μmol/g)	7.83-84.25	41.30	2.87	49.22
35	Protein mg/g	12.26-36.11	21.90	0.91	29.49
36	Stomatal conductance (m mol/m^2/s)	224-575	355.55	12.47	24.81

Table 2: The rearing details of characterized 50 accessions of *T. arjuna*

#	Species	Larval duration (days)	Mature single larvae weight (g)	Single cocoon weight (g)	Single shell weight(g)	Shell Ratio (%)
1	*T.arjuna*	28.00	35.33	11.49	1.55	13.51
2	*T.arjuna*	28.00	36.67	11.47	1.52	13.29
3	*T.arjuna*	28.00	37.33	15.37	1.89	12.39
4	*T.arjuna*	29.00	37.25	12.85	1.45	11.28
5	*T.arjuna*	30.00	36.76	14.23	1.78	12.50
6	*T.arjuna*	28.00	37.13	12.54	1.37	10.92
7	*T.arjuna*	29.00	39.17	12.73	1.46	11.46
8	*T.arjuna*	29.00	35.49	12.67	1.34	10.57
9	*T.arjuna*	30.00	39.29	13.35	1.66	12.43
10	*T.arjuna*	28.00	36.74	12.54	1.38	11.00
11	*T.arjuna*	29.00	36.39	12.97	1.58	12.18
12	*T.arjuna*	29.00	38.63	13.11	1.44	10.98
13	*T.arjuna*	28.00	39.52	13.58	1.50	11.04
14	*T.arjuna*	30.00	38.99	12.61	1.43	11.34
15	*T.arjuna*	31.00	30.29	13.20	1.44	10.90
16	*T.arjuna*	29.00	41.09	12.27	1.33	10.83
17	*T.arjuna*	29.00	37.25	12.16	1.38	11.34

18	*T.arjuna*	30.00	37.50	11.57	1.25	10.96
19	*T.arjuna*	31.00	39.20	14.21	1.71	12.44
20	*T.arjuna*	30.00	35.00	12.50	1.45	11.75
21	*T.arjuna*	27.00	38.17	11.75	1.46	12.51
22	*T.arjuna*	28.00	37.13	10.48	1.40	13.40
23	*T.arjuna*	30.00	37.49	13.38	1.47	10.98
24	*T.arjuna*	29.00	40.19	13.86	1.58	11.39
25	*T.arjuna*	29.00	37.37	12.92	1.47	11.37
26	*T.arjuna*	28.00	37.23	14.48	1.54	10.65
27	*T.arjuna*	29.00	39.35	13.55	1.55	11.43
28	*T.arjuna*	29.00	35.09	13.30	1.58	11.87
29	*T.arjuna*	30.00	37.76	12.44	1.29	10.36
30	*T.arjuna*	27.00	38.17	14.58	1.74	11.91
31	*T.arjuna*	27.00	36.00	10.21	1.35	13.22
32	*T.arjuna*	27.00	54.50	13.84	1.70	12.45
33	*T.arjuna*	27.00	36.17	10.65	1.44	13.48
34	*T.arjuna*	27.00	39.67	11.56	1.65	14.30
35	*T.arjuna*	28.00	38.83	10.32	1.38	13.56
36	*T.arjuna*	31.00	49.00	12.06	1.28	10.76
37	*T.arjuna*	31.00	39.00	10.06	1.23	12.21
38	*T.arjuna*	30.00	34.50	12.68	1.48	11.94
39	*T.arjuna*	31.00	34.50	11.94	1.15	9.67
40	*T.arjuna*	30.00	34.00	12.41	1.25	10.12
41	*T.arjuna*	29.00	34.97	13.68	1.64	12.03
42	*T.arjuna*	29.00	39.42	12.76	1.78	13.98
43	*T.arjuna*	30.00	35.00	11.57	1.37	12.15
44	*T.arjuna*	29.00	45.00	13.22	1.55	12.15
45	*T.arjuna*	29.00	37.30	10.55	1.44	13.51
46	*T.arjuna*	29.00	37.17	12.32	1.59	12.89
47	*T.arjuna*	33.00	35.00	10.79	1.50	13.78
48	*T.arjuna*	30.00	34.00	14.31	1.71	12.04
49	*T.arjuna*	29.00	38.00	13.79	1.69	12.16
50	*T.arjuna*	32.00	50.50	9.74	1.17	12.02
	Mean	29.14	38.85	12.61	1.49	11.96
	Range	27-33	30.29-54.50	9.74-15.37	1.15-2.07	9.67-14.29
	SE ±	0.19	0.64	0.18	0.02	0.14

Table 3: Characterization of 50 accessions of *T. tomentosa*

#	Parameters	Range	Mean	SE±	CV (%)
1	Lamina length(cm)	8.10-23.13	16.38	0.54	23.68
2	Lamina width(cm)	4.35-13.7	8.09	0.28	24.72
3	Petiole length(cm)	0.25-1.11	0.61	0.02	32.78
4	Lamina length/petiole length(ratio)	10.57-59.74	29.74	1.45	34.63
5	Leaf weight(g)	2.07-11.72	5.94	0.30	36.19
6	Petiole weight(g)	0.04-0.25	0.11	0.007	36.36
7	Lamina weight(g)	2.03-11.51	5.83	0.29	36.19
8	Leaf weight/Petiole weight (ratio)	33.50-118.57	56.09	2.29	28.86

9	Laminar index	96.96-99.15	98.07	0.06	0.45
10	Inter nodal distance(cm)	1.52-3.53	2.28	0.06	20.17
11	Moisture (%)	62.65-84.06	69.25	0.50	5016
12	Moisture retention capacity (%)	58.90-83.10	67.48	0.51	5.36
13	Stomata/mm^2	169.9-617.70	342.58	15.51	32.09
14	Length of stomata (µm)	15.50-30.85	26.08	0.38	10.29
15	Width of stomata (µm)	11.98-26.56	16.03	0.31	13.91
16	Pore length of stomata (µm)	13.00-21.94	17.22	0.23	9.63
17	Pore width of stomata (µm)	3.81-6.94	5.51	0.12	15.60
18	Stomata Pore area (µm)	54.00-134.74	95.25	2.64	19.64
19	Number of chloroplast in guard cell	5.33-13.00	8.22	0.24	20.92
20	Cuticle thickness (µm)	5.73-28.06	14.04	0.63	31.83
21	Upper epidermis thickness (µm)	10.54-28.04	17.68	0.64	25.56
22	Palisade thickness (µm)	85.98-195.35	13.088	3.67	19.86
23	Spongy parenchyma thickness (µm)	103.02-296.78	167.29	5.35	22.64
24	Lower epidermis thickness (µm)	10.56-32.20	17.93	0.68	26.88
25	Total thickness (µm)	256.11-502.80	347.83	7.49	15.23
26	Ratio of palisade /spongy tissue	0.41-1.36	0.80	0.02	23.75
27	Chlorophyll a(mg/g)	0.25-1.94	0.89	0.04	34.83
28	Chlorophyll b (mg/g)	0.18-1.30	0.70	0.03	35.71
29	Chlorophyll a/Chlorophyll b	0.75-3.64	1.335	0.06	34.58
30	Total chlorophyll (mg/g)	0.49-2.66	1.64	0.07	32.92
31	Phenol (µg/mg)	0.51-4.94	1.71	0.13	53.21
32	Reducing sugar (µg/mg)	3.06-17.35	9.17	0.44	34.46
33	Non-reducing sugar (µg/mg)	3.64-17.45	8.68	0.40	32.83
34	Proline (µmol/g)	8.61-84.38	42.61	3.14	52.10
35	Protein (mg/g)	8.95-41.90	20.02-1.24		43.75
36	Stomatal conductance (m mol/m^2/s)	111.00-423.33	249.76	11.42	32.34

Table: 4. The rearing details of characterized 29 accessions of *T. tomentosa*

#	Species	Larval duration (days)	Mature single larvae weight (g)	Single cocoon weight (g)	Single shell weight (g)	Shell Ratio (%)
1	*T.tomentosa*	33.00	49.50	14.47	1.48	10.31
2	*T.tomentosa*	28.00	48.00	12.76	1.63	12.94
3	*T.tomentosa*	29.00	50.20	13.06	1.55	11.96
4	*T.tomentosa*	29.00	45.00	10.99	1.37	12.43
5	*T.tomentosa*	27.00	39.00	15.79	2.07	13.13
6	*T.tomentosa*	28.00	34.62	11.82	1.31	11.08
7	*T.tomentosa*	29.00	37.18	12.30	1.43	11.62
8	*T.tomentosa*	30.00	37.21	12.54	1.46	11.64
9	*T.tomentosa*	30.00	40.00	12.75	1.56	12.23
10	*T.tomentosa*	30.00	36.00	8.68	1.20	11.27

11	*T.tomentosa*	31.00	36.00	10.11	1.19	12.00
12	*T.tomentosa*	30.00	37.00	11.68	1.33	11.50
13	*T.tomentosa*	28.00	39.50	13.36	1.56	11.74
14	*T.tomentosa*	28.00	40.15	13.45	2.01	14.97
15	*T.tomentosa*	30.00	39.00	11.21	1.26	11.55
16	*T.tomentosa*	30.00	41.00	13.08	1.75	10.50
17	*T.tomentosa*	30.00	34.50	10.67	1.38	12.97
18	*T.tomentosa*	30.00	40.00	13.70	1.52	11.04
19	*T.tomentosa*	31.00	38.00	10.39	1.25	12.11
20	*T.tomentosa*	28.00	38.83	11.29	1.64	14.53
21	*T.tomentosa*	28.00	35.82	11.42	1.54	13.71
22	*T.tomentosa*	31.00	33.00	11.75	1.45	12.40
23	*T.tomentosa*	29.00	38.83	10.26	1.44	14.00
24	*T.tomentosa*	29.00	39.33	12.09	1.47	12.22
25	*T.tomentosa*	32.00	40.00	13.08	1.34	10.26
26	*T.tomentosa*	29.00	40.83	10.47	1.40	13.40
27	*T.tomentosa*	30.00	41.00	14.43	1.74	12.16
28	*T.tomentosa*	30.00	50.00	14.42	1.55	11.00
29	*T.tomentosa*	29.00	40.90	13.52	1.43	10.60
	Mean	29.58	38.69	12.02	1.467	12.10
	Range	28-32	33-50	8.68-14.43	1.19-2.01	10.26-14.97
	SE±	0.22	0.67	0.301	0.03	0.25

Further, the best performing germplasm resources (accessions) identified were used as parent material for the breeding project, "PIB 4697: Development of superior hybrids of *Terminalia arjuna* and *Terminalia tomentosa* for higher leaf yield and quality", carried out at CSB-CTRTI, Ranchi. The progeny was scored under a pot experiment and the progeny with highest scores are being evaluated under the project PIB 04009 SI.

The germplasm collection of CSB-CTRTI Ranchi includes 180 accessions of *Terminalia arjuna* and 80 accessions of *Terminalia tomentosa*. The accessions were studied for various morpho-physiological characters, drought tolerance and disease tolerance under various projects. A total of three accessions of *T. arjuna* Acc. 102, Acc. 123 and Acc. 135 were shortlisted with higher leaf yield and leaf quality over local controls. These accessions have been evaluated for their efficacy and applications have been submitted to CSB-CSGRC Hosur for registration of tasar host plant accessions. A total of four accessions of *Terminalia arjuna* and four hybrids of *Terminalia* spp., are being evaluated under the project PIB04009SI at three different centres for field level performance in terms of survival, leaf yield and leaf quality. The three improved accessions were found to be superior to other hybrids and accession and local controls in terms of survival and success in plantation establishment with 95% survival under irrigated conditions and 85% under rainfed conditions, although the leaf quality data is still waited for the hybrids.

The germplasm conserved in this gene bank is a valuable resource for the genetic improvement of tasar food plants. It provides a foundation for advanced research, including molecular breeding, *in-vitro* propagation, and the development of climate-resilient, high-yielding varieties through biotechnological tools. Furthermore, conserving these host plant species contributes to biodiversity protection and helps maintain ecological balance within forest ecosystems.

A new project has been initiated in March 2025, titled “Development of Standard Operating Procedure (SOP) for Tasar Host Plant Gene Bank and Maintenance of the Gene Bank using Recommended Cultural Practices (PIG04033MIC)”. The objectives are to formulate SOPs for the conservation and management of Tasar host plant genotypes and to ensure effective maintenance of the gene bank by adopting recommended cultural practices.

Germplasm exploration and conservation efforts are essential for securing the future of the tasar silk industry. These activities not only ensure a stable raw material supply but also contribute to environmental conservation and the socio-economic development of communities engaged in tasar sericulture

2. Clonal and *In-vitro* Propagation Techniques

2.1 Clonal Propagation

Seed propagation of *T. arjuna* and *T. tomentosa* is often limited by poor seed viability, low germination rates, and genetic heterogeneity. Clonal propagation overcomes these limitations by providing a reliable and efficient method for producing quality planting material. Plants produced through clonal propagation are genetically identical, resulting in uniform growth, leaf yield, and quality across plantations. This uniformity is essential for efficient tasar silkworm rearing, as it ensures consistent availability of quality leaves.

Research has identified that leaf node cuttings, particularly during April–September, yield better rooting results in *T. arjuna* and *T. tomentosa*. Use of alcohol wash and double-phase planting significantly enhanced rooting in semi-hardwood cuttings (Sinha *et al.*, 2002).

2.2 *In-vitro* Propagation

In vitro propagation enables the large-scale production of elite, high-performing genotypes with desirable traits such as high leaf yield, superior nutritional content, drought tolerance, and disease resistance. Plants developed through in vitro techniques are genetically identical to the parent, ensuring uniformity in growth, leaf yield, and quality. It allows for the production of planting material irrespective of seasonal constraints, ensuring a continuous supply of seedlings for plantation programs.

Protocols using MS media with BAP, NAA, and additives such as coconut water and activated charcoal showed success for shoot initiation. However, survivability post-hardening varied between genotypes (Tirkey *et al.*, 2003).

3. Genetic Improvement for Abiotic Stress Tolerance

Tasar plantations are often established in drought-prone, degraded, and marginal lands where environmental stresses such as water scarcity, high temperatures, poor soil fertility, and salinity are common. Developing stress-tolerant genotypes of *T. arjuna* and *T. tomentosa* ensures better survival, growth, and productivity under such challenging conditions. Abiotic stresses, particularly drought and soil nutrient deficiency, adversely affect leaf production, which is directly linked to tasar silkworm growth and cocoon yield. Stress-tolerant varieties maintain higher leaf yield and quality even under unfavorable environmental conditions, thereby supporting consistent silk production. Genetic improvement for abiotic stress tolerance enhances the overall resilience of host plant populations, reducing the risk of plantation failures due to extreme weather events. This ensures the long-term sustainability of tasar plantations in vulnerable areas. Systematic evaluation and selection of naturally stress-tolerant accessions from diverse agro-climatic regions provide the genetic base for breeding programs. Fast-growing, drought-tolerant accessions of *T. arjuna* were identified using physiological and biochemical parameters. Accessions 525, 523, 135, and 123 showed higher proline accumulation, RWC, and STI scores under drought conditions (Pandiaraj *et al.*, 2022). Advanced breeding approaches, including marker-assisted selection, in vitro screening, and biotechnological interventions, can accelerate the development of stress-tolerant varieties.

4. Screening for Biotic Stress Resistance

Biotic stresses, including pest infestations and diseases, pose significant threats to the productivity and health of tasar food plants, primarily *Terminalia arjuna* (Arjun) and *T. tomentosa* (Asan). The quality and availability of leaves, which directly affect tasar silkworm (*Antheraea mylitta*) growth and cocoon production, depend largely on the resilience of these host plants to biotic stresses. Therefore, systematic screening for biotic stress resistance is a critical component of host plant improvement programs. A total of 107 accessions were screened for tolerance to leaf spot, black nodal girdling, and powdery mildew. Many accessions exhibited moderate to high tolerance across disease types. These findings guide future resistant breeding programs (Gargi *et al.*, 2011).

5. Biochemical and Anatomical Characterization

Biochemical and anatomical characterization of tasar food plants, particularly *Terminalia arjuna* (Arjun) and *T. tomentosa* (Asan), is an essential component of systematic breeding programs aimed at improving leaf yield, quality, and stress tolerance. Understanding these characteristics helps in the precise selection of superior genotypes, thereby contributing to the development of high-performing varieties suitable for sustainable tasar sericulture. Characterization of 94 accessions involved analysis of 22 leaf anatomical parameters and 8 biochemical traits. Traits like sugar content, protein, and proline significantly contributed to genetic divergence. SEM analysis showed genotypic differences in stomatal distribution (Kumar *et al.*, 2010).

6. Mutation and Polyploidy Breeding

Mutation breeding involves the induction of genetic changes using physical or chemical mutagens to develop new and desirable traits in plants. This technique is useful for creating variability, especially in long-gestation species like *Terminalia* where natural variation is limited. Polyploidy breeding involves the induction of chromosome doubling, resulting in plants with multiple sets of chromosomes. Polyploid plants often exhibit enhanced growth, vigor, and stress tolerance, which are desirable traits for tasar food plants. Polyploidy was induced using colchicine (0.4%) leading to observable changes in morphology and anatomy. EMS and hydroxylamine mutagenesis yielded phenotypically altered lines with higher branching and novel leaf form (Beck *et al.*, 2009).

7. Hybridization and Molecular Characterization

Hybridization is a conventional yet powerful breeding technique aimed at combining desirable traits from different parent plants to develop superior genotypes. In the context of tasar food plants, hybridization focuses on improving leaf yield and nutritional quality to enhance silkworm growth and cocoon production, developing stress-tolerant varieties capable of withstanding drought, pests, and diseases prevalent in tasar-growing regions and enhancing adaptability to diverse agro-climatic conditions to expand the cultivation range.15 F_1 hybrids were developed from selected parental lines. Molecular characterization using RAPD and ISSR confirmed hybridity. Some hybrids showed male-specific markers, aiding future marker-assisted selection strategies (Kumar *et al.*, 2013).

8. Seed and Provenance Studies

Seed and Provenance Studies play a crucial role in identifying genetically superior, location-adapted, and high-performing genotypes. Significant variability was observed in seedling vigour and biomass among different provenances. Selected plus trees from

Jharkhand and Madhya Pradesh exhibited superior growth parameters for propagation (Hembrom *et al.*, 2009).

9. Bioassay and Host Plant Evaluation

The improvement of tasar food plants through breeding programs necessitates rigorous bioassay and host plant evaluation to assess the suitability and performance of different genotypes for tasar silkworm (*Antheraea mylitta*) rearing. These evaluations ensure that only the most productive, nutritious, and stress-tolerant plant materials are selected for large-scale plantation and silkworm feeding. Correlation between silk yield parameters and leaf traits such as protein and phenol content was established using bioassays. Promising accessions were identified for enhancing tasar cocoon yield and quality.

10. Agronomical Trials for Enhanced Growth

Genetic improvement through breeding programs is essential, optimizing agronomical practices through systematic trials is equally critical to realize the full genetic potential of improved genotypes. Field trials with FYM + N + growth regulators (cytokinin, GA_3, H_2O_2) showed up to 71% improvement in plant growth parameters, effectively reducing the gestation period for Arjuna plantations (Sinha *et al.*, 2011).

Future Strategies for improvement of Tasar Host Plants

Conventional breeding in *Terminalia* species is constrained by their long juvenile phase, high heterozygosity, and small flower size, making repeated hybridization and inbred development impractical. Due to these challenges, alternative breeding approaches, including selection, clonal propagation, and development of non-conventional emasculation techniques, are essential for Tasar host plant improvement. The productivity and sustainability of tasar sericulture largely depend on the genetic improvement of primary host plants like *Terminalia arjuna*, *T. tomentosa*, and associated species. To meet the growing demand for quality planting material and to address the challenges posed by climate change and declining forest resources, the following future strategies are recommended for the improvement of tasar host plant:

1. Germplasm Exploration and Conservation

- Conducting systematic surveys across different agro-climatic regions to identify high-performing, rare, and stress-tolerant genotypes of tasar host plants.
- Expanding and strengthening field gene banks and ex-situ conservation efforts to safeguard genetic resources for future use.

- Comprehensive documentation, along with molecular profiling of available germplasm, to support targeted breeding and improvement programs.

2. Conventional Breeding Initiatives

- Selecting and propagating genotypes with superior traits such as high leaf yield, resistance to pests and diseases, and tolerance to drought through mass selection and clonal multiplication.
- Developing improved varieties by utilizing promising accessions identified through systematic evaluation.
- Establishing seed orchards to ensure the large-scale availability of quality planting material for plantation programs.
- Selection of germplasm having superior rooting ability in vegetative propagation is important. Varieties responsive to low input and varieties with low gestation period needs to be developed

3. Utilization of Biotechnological Interventions

- In Vitro Propagation: Employing tissue culture techniques for rapid and large-scale multiplication of elite planting material.
- Marker-Assisted Breeding (MAB): Identifying molecular markers linked to desirable traits and incorporating them into breeding programs to accelerate varietal development.
- Genetic Engineering: Exploring the potential of transgenic approaches to introduce traits like stress tolerance and improved leaf quality, while adhering to regulatory norms.
- Genomic Research: Undertaking genome sequencing and molecular mapping to gain deeper insights into genetic variability and trait inheritance patterns.

4. Development of Climate-Resilient Varieties

- Screening germplasm and breeding for traits such as drought, salinity, and temperature tolerance to enhance plant performance under adverse environmental conditions.
- Incorporating proven drought-tolerant genotypes like *T. arjuna* accessions 123 and 135 into breeding programs to improve plantation resilience.
- Integration of Conventional and Modern Approaches

- Combining traditional selection and breeding methods with modern biotechnological tools to increase efficiency and precision in host plant improvement.
- Enhancing the skills and technical capacity of researchers and field workers through training in advanced breeding and biotechnology practices.

5. Strengthening Research Collaborations

- Establishing strong partnerships with national and international research institutions, universities, and biotechnology organizations to facilitate resource and knowledge sharing.
- Ensuring adequate funding and infrastructure support to enable sustained progress in host plant breeding and improvement programs.

6. Farmer-Centric Approaches

- Developing and distributing improved planting material tailored to specific agro-climatic conditions to maximize plantation success.
- Encouraging farmers' participation in varietal evaluation, field demonstrations, and feedback collection to promote wider adoption of improved host plant varieties.

Conclusion

The comprehensive gene bank-based research has enabled significant advancements in host plant development for tasar sericulture. Integration of biotechnological tools, abiotic/biotic stress resilience screening, and hybridization has opened pathways for sustainable tasar cultivation. Further genomic and omics studies could enhance precision breeding. A strategic blend of conventional breeding, advanced biotechnological tools, and germplasm conservation will be key to the future improvement of tasar host plants. These efforts will contribute to higher productivity, climate resilience, and the sustainable growth of tasar sericulture, ultimately benefiting tribal communities and strengthening India's silk industry.

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References

Beck S, Sinha PS, Kumar R, Sinhadeo SN, Vijayapraksh NB (2009) Improvement of host plants of tasar silkworm through induction of polyploidy and mutagenesis. Compendium of

Research Projects of Host Plant Improvement Division (2000-2020), CSB-CTRTI, Ranchi 15.

Gargi Kumar R, Sinha SK, Sinha PS (2011) Screening of the Germplasm of *Terminalia arjuna* Bedd. and *T. tomentosa* W&A for tolerance against three major foliar diseases. Compendium of Research Projects of Host Plant Improvement Division (2000-2020), CSB-CTRTI, Ranchi 14.

Hembrom I, Kumar R and Gargi (2009) Studies on various provenances of *Terminalia arjuna* Bedd. and *T. tomentosa* W&A. Compendium of Research Projects of Host Plant Improvement Division (2000-2020), CSB-CTRTI, Ranchi 17.

Kumar R, Anupam A, Supriya R, Singh MK, Vijayprakash NB (2010) Genetic divergence and gene source studies in *Terminalia arjuna* Bedd. *Indian J. Plant Genet. Resour*., 23(3): 306-309.

Kumar R, Beck S, Joshi MC and Gargi (2003). Exploration, collection, evaluation and maintenance of *Terminalia, Lagerstroemia* and *Anogeissus* spp. Annual Report (2003-04), CSB-CTRTI, Ranchi 38-40.

Kumar R, Gargi, Alpana Anupam, Richa Supriya, Singh MK and Vijayaprakash NB (2009a) Genetic divergence and gene source studies in *Terminalia arjuna* Bedd. *Indian J. Plant Genet. Resour*., 23(3): 306-309.

Kumar R, Gargi, Alpana Anupam, Richa Supriya, Vijayprakash NB (2009b) Morphological characterization of *Terminalia tomentosa*-Primary food plant of Tasar silkworm *Antheraea mylitta* D. Indian forester, 135(12): 1677-1685.

Kumar R, Hembrom I and Gargi (2010) Morpho-Physio-Anatomical characterization of *Terminalia* spp. Annual Report (2010-11), CSB-CTRTI, Ranchi 1-2.

Kumar R, Hembrom I and Gargi (2013) Development of superior hybrids of *T. arjuna* and *T. tomentosa* for High leaf yield and quality. Compendium of Research Projects of Host Plant Improvement Division (2000-2020), CSB-CTRTI, Ranchi 18.

Pandiaraj T, Harendra Yadav, Manjappa and Singh DK (2022) Screening of Arjun (*Terminalia arjuna*) Accessions based on Drought Tolerance Indices under various Environmental conditions. Biological Forum – An International Journal, 14(1): 1521-1525.

Sinha PS, Beck S, Joshi MC, Gangopadhyay A, Sinha AK, Sinha BRRP (2002) Clonal propagation of Tasar food plants Arjun and Asan. Annual Report (2001-02), CSB-CTRTI, Ranchi 30-33.

Sinha PS, Kumar R, Rai S, Prasad BC (2011) Preliminary trials for enhancing the growth rate of *T. arjuna* plants for reducing the gestation period. Compendium of Research Projects of Host Plant Improvement Division (2000-2020), CSB-CTRTI, Ranchi 22.

Suryanarayana N, Kumar R and Gargi (2005) Monograph on Indian Tropical tasar silkworm food plants (*Terminalia* spp.), CTRTI, Ranchi.

Tirkey J, Thangavelu K and Sinha AK (2003) *In-vitro* propagation and selection of variability in the Tasar food plant. Compendium of Research Projects of Host Plant Improvement Division (2000-2020), CSB-CTRTI, Ranchi 11.

OAK TASAR HOST PLANTS: CURRENT STATUS, CHALLENGES, AND FUTURE PROSPECTS

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Abstract

Oaks (family *Fagaceae*) are ecologically and economically significant forest trees, serving as primary host plants for oak tasar silkworms (*Antheraea* spp.) in temperate and sub-tropical regions. India harbors over 35 oak species, with *Quercus serrata*, *Q. griffithii*, *Q. incana*, and others supporting tasar silkworm rearing in the northeastern and northwestern Himalayan regions. However, the sector remains heavily reliant on wild tree populations due to the absence of improved varieties and structured breeding programs. Key challenges include limited germplasm diversity, habitat loss, poor propagation techniques, and a lack of climate-resilient lines. To ensure the sustainability of oak-based sericulture, urgent efforts are needed for systematic germplasm collection, characterization, conservation, and genetic improvement. Establishing a dedicated National Germplasm Resource Centre at RSRS, Imphal, and employing biotechnological interventions will play a crucial role in preserving biodiversity and enhancing silk productivity in fragile mountain ecosystems.

Keywords: genetic diversity, germplasm conservation, host plant improvement, oak tasar host plants, *Quercus sp.,*

Introduction

Oaks, belonging to the family *Fagaceae*, represent a vital group of forest tree species distributed across tropical, temperate, and sub-arctic regions globally. The family comprises four genera - *Quercus*, *Lithocarpus*, *Castanea*, and *Castanopsis* - of which *Quercus* is the largest, encompassing over 400 species (Trelease, 1924; Camus, 1926). In India, more than 35 oak species have been recorded, with approximately 15 species of *Quercus* predominantly distributed along the sub-Himalayan belt from Kashmir to Arunachal Pradesh, extending into the states of Assam, Meghalaya, Mizoram, Nagaland, and Manipur, between 2,000 to 9,000 feet above mean sea level.

Among these, *Quercus serrata* and *Q. griffithii* serve as the primary host plants for the oak tasar silkworms *Antheraea proylei*, *A. pernyi*, and *A. roylei* in Northeast India, while *Lithocarpus dealbata* supports *A. frithi* and *A. roylei*. In North-Western India, *Q. incana*, *Q. semecarpifolia*, and *Q. himalayana* are the main host species for temperate tasar silkworm rearing. Globally, several *Quercus* species such as *Q. liaotungensis*, *Q. dentata*, *Q. acutissima*, *Q. variabilis*, and *Q. mongolica* are exploited for *A. pernyi* in China, *A. yamamai* in Korea and Japan, and for Saturniidae moths in countries like Mexico, Colombia, and the United States (Piegler, 1999).

Despite this rich diversity, oak tasar sericulture in India continues to rely heavily on wild host plant resources due to the lack of improved cultivars and structured breeding programs. Systematic efforts for conservation, characterization, and genetic enhancement of oak host plants remain largely absent. Habitat degradation, deforestation, and unsustainable land use further threaten the ecological niches of these species, jeopardizing both biodiversity and the sustainability of oak tasar culture.

Given the ecological and economic significance of oak-based sericulture, there is an urgent need for region-specific strategies focused on germplasm collection, evaluation, conservation, and genetic improvement. The establishment of dedicated gene banks and the adoption of modern biotechnological tools will be critical for ensuring the long-term sustainability of oak host plants and the livelihoods they support in the fragile mountain ecosystems of India.

Current Status of germplasm resources

India's oak tasar host plant resource is concentrated mainly in the North East (e.g., Arunachal Pradesh, Nagaland, Manipur) and North West (e.g., Uttarakhand, Himachal Pradesh, Jammu & Kashmir). *Q. serrata* and *Q. griffithii* dominate the host base in the North East, while *Q. incana*, *Q. semecarpifolia*, and *Q. himalayana* are prevalent in the North West.

Currently, farmers rely heavily on wild trees for rearing tasar silkworms due to the absence of characterized and improved planting materials. Genetic erosion through deforestation and habitat destruction has further threatened host plant populations, necessitating immediate conservation and utilization strategies. While several global gene banks maintain broad collections of plant genetic resources, the germplasm base for oak tasar host plants remains narrow in India, limiting the scope of crop improvement programs.

Challenges

- Limited Germplasm Diversity: Narrow genetic base restricts breeding potential.

- Lack of systematic collection and characterization of germplasm
- Dependency on Wild Trees: Farmers largely depend on natural stands, which are inconsistent in quality and vulnerable to climate variations.
- Habitat Loss: Deforestation and land-use changes are major threats to oak populations.
- Absence of Improved Varieties/Morphotype: No officially recommended or commercially released varieties or morphotype exist for large-scale cultivation.
- Slow Growth and Propagation Issues: Most oak species are slow-growing and difficult to propagate, making mass multiplication a challenge.
- Long gestation period and reproductive barriers: Long juvenile phase and lesser understanding of reproductive biology hinder the breeding activities

Future Breeding Objectives

To address the above challenges, future breeding and improvement programs for oak tasar host plants should aim to:

1. Widen the Germplasm Base

- Explore and collect diverse accessions from North East and North West India.
- Incorporate traits from wild relatives and underutilized species.

2. Characterization and Evaluation

- Assess collected accessions for morphological, physiological, biochemical, and ecological traits suitable for oak tasar rearing.
- Identify lines with superior leaf yield, nutritional value, and pest/disease resistance.

3. Conservation of Genetic Resources

- Establish both in situ and ex situ conservation measures.
- Develop a National Germplasm Resource Centre at RSRS, Imphal, for oak tasar host plants.

4. Identification and Development of Improved Varieties/Morphotype

- Select and breed superior lines for commercial rearing.
- Promote participatory selection involving local communities and farmers.

5. Standardization of Propagation Techniques

- Develop vegetative propagation protocols to mass-multiply elite genotypes.

- Explore micro propagation and tissue culture for difficult-to-propagate species.

6. Climate-Resilient Breeding

- Target traits like drought tolerance, frost resistance, and adaptability to altitude variations.
- Use molecular tools to accelerate selection efficiency.

Conclusion

India possesses rich and underutilized oak genetic resources critical for the sustenance and expansion of oak tasar silk production. However, the lack of systematic collection, evaluation, and breeding has constrained the development of improved host plant varieties. Strengthening the germplasm base, characterizing existing diversity, and initiating focused breeding and conservation programs are essential to ensure the ecological and economic sustainability of oak tasar culture. Establishing RSRS, Imphal, as a National Germplasm Resource Centre will be a pivotal step in preserving and utilizing these valuable genetic resources for future varietal improvement and commercial cultivation.

References

Trelease W (1924) The American Oaks. Mem. Natl. Acad. Sci., 20, 1-225

Camus A (1936-54) Les Chennes Monographic dugenere *Quercus* and Monographic du genere *Lithocarpus* Encycl. Econ. Syivic. VI-VIII, Lechevalier, Paris.

Peigler RS (1999) Taxonomy, distribution and sericultural potential of the American species of *Antheraea* (Saturniidae). Bull Ind. Acad. Seric. 3(1):1-9.

MUGA HOST PLANTS BREEDING: CURRENT STATUS, CHALLENGES AND FUTURE PROSPECTS

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Abstract

Muga silk, produced by the endemic silkworm *Antheraea assamensis*, holds a unique place in India's sericulture sector due to its natural golden sheen and regional specificity to Northeast India. The success of Muga culture largely depends on the quality and availability of primary host plants *Persea bombycina* (Som) and *Litsea monopetala* (Soalu). This review provides a comprehensive overview of the current status of these host plant resources, highlighting their distribution, genetic diversity, propagation methods, and challenges in large-scale cultivation. Despite their ecological and economic importance, systematic improvement programs are limited, with inadequate efforts in molecular characterization, standardized agro-practices, and stress resilience. Recent progress in hybrid selection, polyploidy induction, and integrated agroforestry approaches offers scope for enhancing host plant productivity. Strengthening germplasm conservation, adopting biotechnological interventions, and promoting sustainable cultivation models are essential for advancing the Muga silk industry.

Keywords: *Antheraea Assamensis*, Muga Host Plants, Breeding strategies, Challenges, Current Status, Advanced breeding tools

1. Introduction

India holds the unique distinction of being the only country in the world that produces all five commercially recognized varieties of silk - Mulberry, Eri, Muga, Temperate Tasar, and Tropical Tasar. Among these, Muga silk stands out due to its distinctive golden sheen and is indigenous to Assam and the adjoining northeastern states. The growth and productivity of Muga silkworms are significantly influenced by the availability and nutritional quality of their host plants, which underscores the need for scientific approaches in host plant management and genetic improvement. Unlike the monophagous mulberry silkworm, which feeds exclusively on *Morus* species, the Muga silkworm (*Antheraea assamensis*) is multivoltine and polyphagous, meaning it can thrive on more than one type of host plant. The host plants used for Muga silkworm rearing are broadly categorized into three types - primary, secondary, and tertiary - based on their accessibility, usage frequency, and economic importance in sericulture (Bhattacharya et al., 1993). The primary host plants, *Som* (*Persea bombycina Kost.*) and *Soalu* (*Litsea monopetala Roxb.*), are most widely cultivated and serve as the main food sources for Muga silkworms. These species are used extensively for both seed and commercial crops, forming the backbone of Muga silkworm cultivation. Secondary host plants such as *Dighloti* (*Litsea salicifolia Roxb.*) and *Mejankori* (*Litsea cubeba Pers.*) are used less frequently and typically come into play during periods when primary host plants are unavailable. These secondary plants help maintain silkworm rearing continuity in times of host plant scarcity. Tertiary host plants are employed only under critical conditions when neither primary nor secondary host plants are accessible. They are typically used for short durations and limited to specific larval stages, primarily to ensure the survival of the larvae. However, silkworms reared on secondary and tertiary hosts generally exhibit reduced cocoon yield, productivity, and quality when compared to those reared on primary host plants. The list of host plants of muga silkworm are indicated in Table 1.

Table 1: Host plants of muga silkworm *A. assamensis* (Helfer) their family and distribution in India

Food plants	Family	Distribution in India
Persea bombycina Kost.	Lauraceae	Northeastern India
Litsea monopetala (Roxb.) Pers.	Lauraceae	Assam, Odisha, Eastern Himalayas, Maharashtra
Litsea salicifolia (Roxb. ex Nees.) Hook. f.	Lauraceae	Northeastern India
Litsea cubeba (Lour.) Pers.	Lauraceae	Assam, Manipur, Nagaland
Michelia champaca L.	Magnoliaceae	Assam, Andaman & Nicobar Island, Andhra Pradesh, Odisha, Southern India
Cinnamomum camphora (L.) J. Presl.	Lauraceae	Assam, Meghalaya, Maharashtra
Cinnamomum tamala (Buch.-Ham.) T. Nees & C. H. Eberm.	Lauraceae	Assam, Meghalaya, Maharashtra
Actinodaphne angustifolia (Bl.) Nees.	Lauraceae	Assam, Meghalaya, Arunachal Pradesh, Central India, Peninsular India
Actinodaphne obovata (Nees.) Bl.	Lauraceae	Sikkim, Assam, Manipur, Meghalaya, Arunachal Pradesh
Actinodaphne sikimensis Meissn.	Lauraceae	Sikkim, Assam, Manipur, Meghalaya, Arunachal Pradesh

Celastrus hindsii Benth.	Celastruceae	Sikkim, Arunachal Pradesh, Assam, Nagaland, Meghalaya
Cinnamomum bejolghota (Buch. Ham) Sweet	Lauraceae	Assam, Meghalaya
Cinnamomum glanduliferum (Wall.) Meisn.	Lauraceae	Assam, Meghalaya
Cinnamomum glaucescens (Nees.) Hand.-Mazz.	Lauraceae	Northeastern India
Gmelina arborea Roxb.	Verbenaceae	Throughout India
Lindera latifolia Hook.	Lauraceae	Assam, Meghalaya
Litsea glutinosa Lour.	Lauraceae	Northeastern India
Litsea nitida (Roxb.) Hook.	Lauraceae	Northeastern India
Magnolia pterocarpa Roxb.	Magnoliaceae	Assam, Meghalaya
Michelia oblonga Wall. ex.f. & Thomas	Magnoliaceae	Assam, Manipur, Madhya Pradesh, Rajasthan, Uttar Pradesh, Bihar
Machilus odoratissima Nees.	Lauracae	Northeastern India
Persea duthei King.	Lauraceae	Northeastern India
Persea glaucescens (Nees.) D.G. Long	Lauraceae	Assam, Meghalaya, Kerala
Phoebe lanceolata (Nees.) Nees.	Lauraceae	Assam, Meghalaya
Plumeria acutifolia Poiret	Apocynaceae	Northeastern India
Polyalthia simiarum Benth. & Hook.	Apocynaceae	Andaman & Nicobar Islands, Assam, Meghalaya, Odisha, Sikkim, West Bengal
Sarcostemma brevistigma Wight & Arn.	Apocynaceae	Northeastern India, Kerala
Symplocos grandiflora Wall. ex A.DC.	Symplocaceae	Northeastern India
Symplocos paniculate Miq.	Symplocaceae	Northeastern India
Symplocos ramosissima Wall. ex G. Don	Symplocaceae	Northeastern India
Zanthoxylum armatum DC.	Rutaceae	Northeastern India, Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Orissa, Andhra Pradesh
Zanthoxylum rhetsa (Roxb.) DC.	Rutaceae	Assam, Karnataka, Kerala, Meghalaya, Manipur, Odisha
Ziziphus mauritiana Lam.	Rhamnaceae	Throughout India except Jammu & Kashmir, Himachal Pradesh

Source: Devi *et al.,* 2021

Muga silkworm host plants prefer sloppy, well-drained, and humus-rich acidic soils, (pH 4.0 to 6.8) and rainfall between 1000-4200 mm annually with humid wet, and warm climatic conditions. Som plants grow up to an altitude of about 600 meters while

Soalu is up to 1000 meters above sea level. Additionally, the production and quality of host plant leaves are not uniform in different muga rearing areas of Northeast India like Assam, Meghalaya, Arunachal Pradesh, and Nagaland. This suggests the sub-region level variation in geological, topographic, climatic conditions, and physico-chemical and biological properties of soil.

2. Breeding objectives for improvement in muga host plants

The breeding objectives for muga host plants are aimed at enhancing both the quantitative and qualitative traits of the foliage to support optimal silkworm growth and cocoon production. A key goal is to increase leaf yield per plant to meet the high feeding requirements of multi-voltine muga silkworms. Simultaneously, improving the nutritive value of the leaves - such as protein, moisture, and sugar content - is essential for better larval development and silk yield. Accelerating plant growth rate and optimizing canopy architecture are also targeted to ensure quick and sustained leaf availability across seasons. Moreover, breeding efforts focus on enhancing adaptability to diverse agro-climatic zones and developing resistance to major biotic (pests and diseases) and abiotic (drought, salinity, temperature extremes) stresses. These improvements collectively aim to support sustainable and resilient Muga sericulture systems in Northeast India.

3. Present Status of Muga Host Plant Genetic Resources

A major constraint in the improvement of muga host plants is the limited understanding of their genetic makeup, which hampers the development of effective breeding strategies for enhancing leaf yield (Thangavelu et al., 2005; Tikader et al., 2013). The systematic collection of genetic resources of muga host plants began in 1988 at the Regional Sericultural Research Station (RSRS), Boko, Kamrup, Assam, and was further expanded in 1999 by the CSB-Central Muga Eri Research and Training Institute (CSB-CMER&TI), Lahdoigarh, Jorhat, Assam, where a dedicated germplasm conservation center was established at GCC, Chenijan, Jorhat. Currently, CSB-CMER&TI maintains 51 accessions of Som, while 22 accessions of Soalu have been morphologically characterized; however, further breeding efforts are required for their genetic improvement. Though Digloti and Mejankari are being promoted under the Transfer of Technology (ToT) initiatives, they still lack well-established and standardized cultivation protocols (CSB-CMERTI, 2022). In the case of tertiary host plants, only a limited number have been conserved, and their germplasm has been enriched gradually through collection efforts from nearby forests and surrounding regions.

4. Host Plant Germplasm Characterization

Genetic variability present in the germplasm forms the fundamental basis for the genetic improvement of plant species through various breeding programs. Setting breeding objectives requires a clear understanding of both the nutritional needs of the silkworm and the available genetic diversity within host plant populations. The genetic base of existing germplasm collections can be strengthened by introducing new gene pools through systematic exploration, collection, and characterization efforts. Initially, germplasm exploration in Assam and Meghalaya yielded 14 cultivars of Som and 10 cultivars of Soalu. Following preliminary evaluations, 8 Som and 10 Soalu genotypes were selected for detailed analysis. These were evaluated for morphological characteristics, floral biology, propagation traits, chemical composition, and bioassay performance (Siddiqui et al., 2000; Singh et al., 2000; Thangavelu et al., 2005; Tikader and Kamble, 2010). Considerable morphological diversity was noted among these genotypes, particularly in traits such as rachis number per inflorescence, rachis length, flower count per rachis, flower size, perianth structure, and peduncle length (Tikader et al., 2013; Thangavelu et al., 2005). The time required for bud sprouting after pruning ranged from 30 to 82 days. Biochemical profiling of 14 Som morphotypes revealed that crude protein content varied between 8.52% and 11.32%, lipid content between 5.42% and 7.10%, crude fiber ranged from 19.62% to 28.07%, total ash from 3.72% to 5.09%, lignin from 7.84% to 16.0%, cellulose from 20.27% to 35.9%, and moisture content from 46.0% to 65.0% (Tikader et al., 2013). Successful muga silkworm rearing is largely influenced by the availability of high-quality leaves, along with proper management and favourable climatic conditions. Being cross-pollinated and primarily propagated through seeds, muga host plants exhibit significant genotypic variability. These include wide differences in morphometric and reproductive attributes such as the number of bud coverings, leaf shape and size, leaf weight, flower count, and stomatal density. Both inter-populational and intra-populational variability are highly pronounced, reflecting a high degree of heterogeneity, which in turn restricts gene flow and fosters the emergence of new, adaptive genotypes (Ram et al., 1993). Extensive phenotypic diversity has also been observed in traits related to rooting - such as rooting percentage, number of primary and secondary roots, root length, and survival rate. Among these, the number of secondary roots displayed the highest genetic coefficient of variation, followed by primary root count. All traits showed high heritability estimates, and genetic advance was most significant for secondary root number, survival rate, and primary root count. Rooting success showed strong phenotypic and genotypic correlations with primary and secondary root numbers, longest root length, and survival percentage (Ram et al., 2009). Variations in macro- and micro-morphological traits, such as leaf growth, size, shape, color, taste, and odour, also differ significantly across genotypes. A study by Gogoi et al. (2009) analyzed four autotetraploid Som genotypes alongside their diploid parents using 24 qualitative and 24 quantitative descriptors to assess their Distinctness, Uniformity, and Stability (DUS). Of the 24 qualitative characters, 14 were found to be monomorphic, 7 dimorphic, and 3 polymorphic, underscoring their utility for genotype characterization and classification (Table 2).

Table 2: DUS characteristics of Som

Qualitativecharacters	
Growth nature	Bushy, upright, intermediate, spreading, drooping
Branching nature	Straight, slightlycurved, curved
Young shoot colour	Light green, green, purple, greenish purple
Mature shoot colour	Brown, gray, grayish green, greenish brown
Phyllotaxy	Distichous (1/2), tristichous (1/3), pentastichous (2/5)
Lenticel density/cm^2	Sparse (<5), medium(5-9), dense (>10)
Lenticel shape	Round, elliptical, oval
Bud shape	Round, acutetriangle, long triangle, spindle
Bud attachment	Slanting outward, adhering to branch, tilting to one side
Leaf type	Simple, compound
Leaf nature	Lobed, unlobed
Leaf shape	Elliptical-narrow elliptic (L:W=3:1), elliptic (2:1), wide elliptic (1.5:1); Obovate oblaceolate (3:1), obovate (2:1)
Leaf apex	Acute, acuminate, attenuate
Leaf margin	Entire, repand
Leaf base	Acute, obtuse, cuneate
Leaf angle	Acute (<35°), semierect (35°-75°), horizontal (>75°-90°)
Shape of the leaf scar	Circular, elliptical, triangle
Young leaf colour	Light green, green, greenish purple, purple
Mature leaf colour	Light green, green, dark green
Mature leaf surface	Smooth, smooth with glossiness
Petiole colour	Light green, green, light purple, purple
Vein colour	Light green, green, light purple, purple
Venation	Craspe dodromous (simple, semicraspendodromous, mixed), Camptodromous (brochidodromous eucamptodromous)
Veinlets	Simple, branched

Quantitative traits:	
Lamina length (L) (cm)	Pedicel length (mm)
Lamina width (W) (cm)	Number of petals/flower
L: W ratio	Number of stamen/flower
Petiole length (cm)	Number of rudimentary stamen/flower
Lamina length (L) (cm)	Pedicel length (mm)
Lamina width (W) (cm)	Number of petals/flower
Petiole width (cm)	Stamen length (mm)
Protecting cover number of flowering bud	Anther length (mm)
Leaf thickness(µm)	Anther width (mm)

Number of stomata/field	Style length (mm)
Stomata size Lx W (μm)	Number of fruits/inflorescence
Inflorescence length (cm)	Fruit length (mm)
Inflorescence width (cm)	Fruit width (mm)
Number of flowers/inflorescence	Fruit weight (g)

5. Hybridisation

Following the characterization and evaluation of germplasm accessions, pre-breeding activities are undertaken to introduce desirable traits into select accessions, which can then serve as potential candidates for cultivar development. In this context, a crossability study was conducted to assess the feasibility of hybridizing *Soalu* (*Litsea monopetala*) with *Dighloti* (*Litsea salicifolia*), as both species belong to the same genus and share an identical chromosome number (2n = 2x = 24). Additionally, they exhibit synchronized flowering periods, making them suitable for hybridization. The resulting hybrids were found to be fertile, and bioassay trials with muga silkworms yielded highly promising outcomes (Tikader, 2013). Apart from this successful attempt, limited efforts have been made to hybridize *Som* (*Persea bombycina*) with *Soalu* or with other related species.

6. Polyploidy breeding

Given that vegetative propagation is feasible in muga host plants, polyploidy breeding has emerged as a promising area of research in recent years. *Persea bombycina* is naturally diploid, possessing a chromosome number of 2n = 2x = 24. While this species occurs both in the wild and under cultivation, there have been no documented cases of naturally occurring polyploids in Som (Gogoi et al., 2009). However, tetraploid Som plants have been successfully developed by treating diploid individuals with colchicine. These induced tetraploids exhibited improved resilience and increased leaf yield (Gogoi et al., 2009). Nonetheless, some trade-offs were observed, including reductions in plant height, daily growth rate, and internodal length. Therefore, to combine the advantages of vigorous growth and superior leaf quality, the development of triploid Som genotypes through crosses between tetraploids and selected diploidsis considered essential.

7. Biotic Stress Management

Biotic stresses, including diseases and insect pests, pose significant challenges to the cultivation of muga host plants. One of the major diseases affecting Soalu is leaf blight, caused by *Colletotrichum gloeosporioides*. As of now, no resistant genotype has been identified for this disease. However, effective control is achieved through the application of 'Phytoblighton', an eco-friendly bio-formulation. In the case of stem borer infestation, an integrated pest management strategy has proven highly effective. This includes the use of botanical extracts such as neem and castor, mechanical methods like plastic trunk wrapping, and the introduction of biological control agents such as *Trichogramma* spp., collectively achieving control success rates of up to 95% (CSB-CMER&TI, 2007).

8. Constraints and Knowledge Gaps

Muga sericulture in Northeast India faces several critical limitations that hinder its sustainable development. Firstly, the genetic makeup of the host plants remains insufficiently explored, limiting targeted breeding efforts. Secondly, molecular characterization has not yet been undertaken, which is essential for identifying genetically diverse parents for breeding programs. Thirdly, there is a lack of standardized agronomic practices aimed at producing high-quality leaves suitable for silkworm rearing. Additionally, no universally accepted method exists for the vegetative propagation of these host plants, further constraining large-scale cultivation.

Efforts to expand and utilize the genetic base of host plants have been minimal. There is an urgent need for long-term, integrated strategies that not only conserve these valuable genetic resources but also enhance their diversity through interdisciplinary approaches within biological sciences. Another major challenge stems from the inherently cross-pollinated and heterozygous nature of these species, which makes it difficult to achieve uniformity in seed propagation. Although morphological characterization has been conducted to some extent, the absence of biochemical and molecular-level analysis increases the risk of redundancy in germplasm repositories. Moreover, climate variability, the ongoing erosion of biodiversity, and the limited availability of region-specific genotypes further complicate breeding, conservation, and cultivation efforts.

9. Strategic Interventions for Host Plant Improvement

To strengthen the role of host plants in vanya sericulture, the establishment of a National Germplasm Resource Centre dedicated to Muga and Eri host plants is crucial. Such a center would support systematic exploration and the conservation of promising accessions through both in-situ and ex-situ approaches, especially from lesser-known or unexplored regions (Neog et al., 2005). Breeding efforts should prioritize the development of high-yielding Som triploid varieties. The adoption of modern biotechnological approaches - such as tissue culture, micropropagation, and marker-assisted selection - can significantly speed up the process of varietal improvement. Additionally, promoting extension activities through Kissan Nurseries and Chawki gardens will help in the widespread distribution of elite planting materials and improved cultivation practices.

10. Integration with Climate Resilience and Agroforestry

Sustainable development of Muga and Eri host plants necessitates their integration into agroforestry and social forestry programs. Such models can enhance biodiversity, sequester carbon, and reduce vulnerability to climatic extremes. Eco-friendly production systems must be promoted to align with global sustainability mandates (Tikader & Rajan, 2012).

11. Conclusion

The sustainable growth of Muga sericulture in India is intrinsically linked to the conservation, improvement, and scientific management of its host plant resources. Despite being the cornerstone of golden Muga silk production, host plants like *Persea bombycina* (Som) and *Litsea monopetala* (Soalu) remain underexplored in terms of genetic, biochemical, and molecular characterization. The existing wide phenotypic and genotypic variability offers great potential for breeding programs aimed at enhancing leaf yield, quality, stress tolerance, and environmental adaptability. However, efforts are still at a nascent stage, with limited progress in hybridization, polyploidy breeding, and vegetative propagation.

Addressing the challenges such as lack of genomic information, standard agronomic practices, and propagation protocols requires multi-disciplinary and multi-institutional collaboration. Establishment of a National Germplasm Resource Centre and use of advanced biotechnological interventions like tissue culture, marker-assisted selection, and development of triploids can significantly accelerate varietal improvement and ensure availability of quality planting materials. Further, integrating host plant cultivation with climate-resilient agroforestry systems will ensure ecological sustainability while providing livelihood security to rural communities engaged in vanya sericulture. Future strategies must also focus on region-specific genotype identification, conservation of wild genetic resources, and building institutional capacities for long-term host plant research and extension services.

Thus, a concerted and strategic approach combining conventional and modern tools is imperative for unlocking the untapped potential of muga host plants, thereby reinforcing India’s global leadership in non-mulberry silk production and contributing meaningfully to the nation's bioeconomy and sustainable development goals.

12. References

Bhattacharya A, Saikia SK, and Goswami D (1993) Scientific inference to the traditional muga rearing. *Indian Silk*, 32: 35-41.

Devi B, Chutia M and Bhattacharyya N (2021) Food plant diversity, distribution, and nutritional aspects of the endemic golden silk producing silkworm, *Antheraea assamensis* –a review. *Entomol. Exp. Appl.*, 169: 237-248. https://doi.org/10.1111/eea.13021

Gogoi SN, Barua M and Chakravorty R (2009) Studies on morphological characters of induced autotetraploid Som, *Persea bombycine* (King ex. Hook f.) Kost. genotypes. *Indian Journal of Genetics and Plant Breeding*, 69: 145–151.

Neog K, Gogoi SN and Chakravorty R (2005) Present status and constraints of Muga silkworm host plant germplasm conservation. In: Barah A, Neog K, Hazrika U, editors. Proceedings of the workshop on strategies for maintenance of non-mulberry silkworm and host plant germplasm. Jorhat, Assam, India: CMERTI, Central Silk Board; 2005. p. 1-10.

Ram R, Goswami BC and Kumar S (1993) Vegetative propagation of Litsea salicifolia. *Indian Silk*, 32: 38–50.

Ram R, Samson MV, and Bhatt MM (2009) Variability and genetic diversity in rooting parameters of *Persea bombycina* Kost. *Indian J. For*., 32: 433-435.

Siddiqui AA, Lal B, Bhattacharya A and Das K (2000) Nutritional status in morpho-variants of Som. *Indian Silk*, 2: 28-33.

Singh K, Srivastava A, Prakash D, Das PK, Siddiqui AA, and Raghuvanshi SS (2000) Ranking of foliar constituents in morphotypes of muga food plant - *Machilus bombycina* King. *Sericologia,* 32: 169-174.

Thangavelu K, Tikader A and Sen AK (2005) Strategies for conservation of muga host plant genetic resources. Present status and constraints of muga silkworm host plant germplasm conservation. In: Proceedings - Strategies for maintenance of non-mulberry silkworm and host plant germplasm held at Central Muga Eri Research & Training Institute, Lahdoigarh, Jorhat, Assam, India on March 10 - 11, pp 37- 47.

Tikader A and Kamble CK (2010). Seri-biodiversity status with reference to the host plants in India. *Asian Aust J. Plant Sci. Biotech*., 4: 1-11.

Tikader A, Vijayan K and Saratchandra B (2013) Improvement of host plants of Muga silkworm (*Antheraea assamensis*) for higher productivity and better adaptation: A review. *Plant Knowledge Journal*, 2(2): 83–88.

ERI HOST PLANTS BREEDING: CURRENT STATUS, CHALLENGES AND FUTURE PROSPECTS

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Abstract

Ericulture, an important segment of Indian sericulture, is highly dependent on the quality and availability of host plants for sustainable cocoon production. This paper reviews the current status and improvement strategies for eri silkworm (*Samia ricini*) host plants, focusing on key species like castor (*Ricinus communis*), kesseru (*Heteropanax fragrans*), borpat (*Ailanthus grandis*), and tapioca (*Manihot esculenta*). Despite ongoing efforts in germplasm collection and conventional breeding, major gaps remain in stress tolerance, propagation methods, and region-specific cultivation practices. Recent progress in hybridization, tissue culture, and bioassays has identified superior lines, but the adoption of modern tools such as marker-assisted breeding, polyploidy, mutation breeding, and genomic approaches is still limited. Integrating conventional and modern strategies, along with improved crop management module and mass propagation protocols, is essential for developing high-yielding, climate-resilient host plants. Strengthening these aspects will enhance leaf productivity, silkworm performance, and the long-term viability of ericulture.

Keywords: breeding strategies, ericulture, host plant improvement, molecular breeding, *Samia ricini*, tissue culture

Introduction

Sericulture, a traditional agro-based enterprise/industry, plays a crucial role in strengthening rural and tribal livelihoods by generating employment and income across various regions of India. Among its diverse sectors, ericulture has witnessed significant growth in recent years and is gaining global recognition due to the superior quality of eri silk and the resilience of the eri silkworm (*Samia ricini*) to varied climatic conditions. Ericulture holds special significance in north-eastern India, where it is well integrated into agroforestry-based farming systems (Mahesh & Arun Kumar, 2020). As per the Sericultural Statistics of India (2023–24), the country recorded a total raw silk production of 38,913 metric tons, with eri silk contributing 7,183 metric tons, ranking second after mulberry silk. Beyond silk production, ericulture also contributes to food and nutritional security, particularly in the North-Eastern region, where pupae are consumed as a traditional protein source, adding significant economic value (Kichu *et al.,* 2015).

The eri silkworm (*Samia ricini*) is a multivoltine and polyphagous species known to feed on more than 30 different host plants (Kumara *et al.,* 2023). These host plants are broadly classified into primary, secondary, and tertiary categories based on their influence on larval feeding preference, growth, development, and cocoon production. Among them, *Castor* (*Ricinus communis*) and *Kesseru* (*Heteropanax fragrans*) are considered primary hosts due to their superior suitability for eri silkworm rearing. Secondary hosts include species such as *Borpat* (*Ailanthus grandis*), *Tapioca* (*Manihot esculenta*), *Payam* (*Evodia flaxinifolia*), and *Borkesseru* (*Ailanthus excelsa*), which also support good larval performance and cocoon yield. Tertiary host plants, though capable of supporting the complete life cycle of the silkworm, are generally less preferred. These include a diverse group of species such as *Ailanthus glandulosa*, *Ailanthus tryphysa*, *Artocarpus heterophyllus*, *Carica papaya*, *Celastrus monospermus*, *Cinnamomum cecicodaphne*, *Cinnamomum glanduliferum*, *Daucuscarota*, *Ficus benghalensis*, *Gmelina arborea*, *Hodgsonia heteroclita*, *Jatrophacurcas*, *Jatropha multifida*, *Micromelum pubescens*, *Michelia champaca*, *Oroxylum indicum*, *Plumeria acutifolia*, *Plumeria rubra*, *Sapium eugenifolium*, *Sapium sebiferum*, *Spathodea campanulata*, *Terminalia catappa*, *Zanthoxylum alatum*, *Zanthoxylum rhetsa*, and *Zizyphus mauritiana* (Das *et al.,* 2020; Kumara *et al.,* 2023). In contrast, several non-host plant species are unsuitable for eri silkworm rearing, as they do not support completion of the insect's life cycle. These include *Acalypha indica*, *Morus alba*, *Morinda citrifolia*, *Leucaena leucocephala* (Radhika *et al.,* 2017); *Calotropis gigantea*, *Nerium odorum*, *Parthenium hysterophorus*, *Annona squamosa*, *Pongamia pinnata*, *Sesbania grandiflora*, *Cocos nucifera* (coconut), and *Musa spp.* (banana) (Subramanian *et al.,* 2013); as well as *Acacia ferruginea*, *Bauhinia purpurea*, *Bambusa arundinacea*, *Bambusa vulgaris*, *Sapinduse marginatus*, *Peltophorum ferrugineum*, *Samanea saman*, *Swietenia macrophylla*, *Tabebuia argentea*, *Cassia auriculata*, *Ficus religiosa*, *Hardwickia binata*, *Manilkara hexandra*, *Simarou baglauca*, *Acalypha gracilens*, *Lantana camara*, and *Cassia fistula* (Naik and Murthy, 2013).

Eri-culture ensures multiple income sources from cocoon shells, edible pupae, and castor seeds or tapioca tubers, depending on the host plant. In North-East India, pupae consumption adds economic value, often becoming a primary income driver. Host plants like kesseru and borpat also provide timber or firewood, further enhancing returns. Expanding ericulture in castor and tapioca-growing areas can significantly boost farmer income (Sarmah and Gogoi, 2011). Among all host plants, castor is considered the most superior, due to its contribution to high cocoon yield, quality, and shorter larval durations. Unlike castor, most other host plants are perennial, although some perennial variants of castor are also available in nature. Castor and tapioca are cultivated extensively in northwestern, northeastern, and southern states, while Borpat, Kesseru, Borkesseru, and Payam are prevalent in northern and northeastern India (Arora and Gupta, 1979; Reddy *et al.,* 2002; Patil, 2004; Manjunatha *et al.,* 2010; Manjunatha and Murthy, 2013; Ahmad *et al.,* 2012; Das *et al.,* 2020).

For developing any improved host plant varieties, key breeding parameters include high leaf productivity and biomass yield, early sprouting and vigorous growth, enhanced rooting ability, superior nutritional quality with reduced levels of anti-nutritional factors, and resistance or tolerance to both biotic and abiotic stresses. Like any other crop, eri host plants are significantly influenced by climatic and edaphic variables, such as erratic rainfall, waterlogging (common in NE states), extreme temperatures, drought (prevalent in southern India), salinity, heavy metal toxicity, and declining soil health (e.g., low organic carbon, nutrient deficiencies). These challenges vary across agro-climatic zones including Southern India (Karnataka, Andhra Pradesh, Telangana, Kerala, and Tamilnadu), Northwestern states (Gujarat, Rajasthan), Northern states (Madhya Pradesh, Uttar Pradesh, Bihar, and Odisha) and Northeastern states (Assam, Meghalaya, Nagaland, Manipur, Arunachal Pradesh, Sikkim, and Tripura).

To address these region-specific challenges and develop location-specific, climate-resilient host plant varieties, breeding programs must focus on diversity exploration, including the collection of indigenous and exotic germplasms, hybridization and selection, mutation breeding, polyploidization, and introduction programs. Integration of modern biotechnological tools, such as tissue culture, molecular breeding and marker-assisted selection (MAS), can further accelerate the development of superior eri host plant genotypes with desirable traits suited to diverse ecological conditions.

Present Status of Germplasm Resources

At CSB-CMERTI, Lahdoigarh, Jorhat, the current repository of eri host plant germplasm comprises 61 lines of castor (*Ricinus communis*), 17 genotypes of cassava (*Manihot esculenta*), 10 accessions of kesseru (*Heteropanax fragrans*), 4 accessions of borpat (*Ailanthus grandis*), and 5 accessions of borkesseru (*Ailanthus excelsa*) (Phukan et al., 2006; Sarmah *et al.,* 2013). Despite this collection, the overall germplasm base remains limited, warranting expansion and systematic conservation to support future breeding programs. These germplasm resources are conserved at the Germplasm Conservation Centre (GCC) at Chenijan and Farm No. 1 of the Institute. Other species such as Payam (*Evodia flaxinifolia*), *Gmelina arborea*, and Papaya (*Carica papaya)* have been identified as regionally important host plants for eri silkworms. However, these species remain largely unexplored and require further systematic germplasm exploration and evaluation (Tikader *et al.,* 2013). Strengthening the germplasm base through targeted collection and conservation will be vital for future breeding and genetic enhancement of eri host plants.

Breeding Objectives and Management Strategies for Eri Host Plants

The primary objectives of breeding programs for eri silkworm host plants are centered on the development of high-yielding genotypes with superior leaf biomass, enhanced nutritional composition, and increased tolerance to both biotic and abiotic stresses. Key goals include improving varietal performance in traditional cultivation zones, developing stress-resilient lines suitable for drought- and pest-prone areas, and creating broadly adaptable cultivars to support the expansion of ericulture into non-traditional and marginal regions, thereby ensuring long-term sustainability.

In terms of host plant management, efforts are also directed toward the development of standardized Packages of Practices (PoP) tailored to each host species. This includes optimizing propagation techniques for mass multiplication and establishing comprehensive crop management protocols encompassing Integrated Pest Management (IPM), Integrated Disease Management (IDM), and Integrated Nutrient Management (INM) approaches to ensure healthy, sustainable host plant production systems.

Present status of breeding approaches

Conventional breeding approaches, namely exploration, germplasm collection, characterization, evaluation, hybridization, and selection have so far formed the core of improvement programs for eri host plants. These methods have facilitated the identification of promising genotypes, especially in castor and kesseru. One project is undergoing on the development of mass propagation technique of borpat through tissue culture. However, the application of advanced breeding tools such as marker-assisted selection, genomics-based approaches, and biotechnological interventions remains largely unexplored, highlighting a significant opportunity to accelerate genetic enhancement in eri host plants.

Germplasm collection, characterization and evaluation

A project entitled *"Collection, characterization, evaluation and conservation of perennial host plants for eri silkworm rearing"* aimed at exploring genetic resources of eri host plants was implemented at CSB-CMERTI. As part of this initiative, 10 accessions of Kesseru (*Heteropanax fragrans*), 4 of Borpat (*Ailanthus grandis*), and 5 of Borkesseru (*Ailanthus excelsa*) were collected and are being maintained at the Germplasm Conservation Centre (GCC), Chenijan.

Ten Kesseru genotypes, coded HF 001 to HF 010, were evaluated based on agronomic performance, nutritional quality, and leaf palatability to eri silkworms. Biochemical assays revealed that some accessions recorded peak values for key traits, including carbohydrate content (28.35%), soluble protein (1058 mg/100g), crude fibre (7.55%), phenols (70.86 mg/100 g), and tannins (2.85%). Bioassays demonstrated highest cocoon and shell weights of 3.20 g and 0.40 g, respectively. Among the *Kesseru* accessions, HF 008 and HF 005 emerged as superior lines, yielding 27.57 MT/ha/year and 26.72 MT/ha/year of leaves, respectively representing yield advent-ages of 10.28% and 6.68% over the benchmark plantation average (25 MT/ha/year) achieved with traditional varieties under improved management.

Borpat (*Ailanthus grandis*) and Borkesseru (*Ailanthus excelsa*) have been identified as promising secondary host plants for eri silkworm rearing in the absence of primary hosts, owing to their favourable biomass production, larval acceptability, and favourable leaf nutritional properties. To facilitate field-level adoption, multi-location demonstrations were conducted across Borpathar (Golaghat), Nagajangka and Morangial (Jorhat), and Barekuri (Tinsukia), engaging 250 farmers. The trials yielded encouraging results, with an average shell production of 11.83 kg per 100 dfls, and average single cocoon and shell weights of 3.47 g and 0.51 g, respectively. As part of the project, chemo-profiling of *A. grandis* and *A. excelsa* was completed, assessing key biochemical parameters including crude fibre, phenol, tannin, total carbohydrate, and β-sitosterol content. Notably, β-sitosterol, reported to act as a feeding stimulant was found in the highest concentration in semi-mature leaves of *A. grandis* (69.63mg), followed by mature (45.95 mg) and tender leaves (31.34 mg), indicating its potential role in enhancing larval feeding behaviour. Total carbohydrate content, a primary energy source for silkworms, was observed to be highest in *Castor*, with levels comparable to *A. grandis* across all leaf maturity stages, ranging from 32.3% to 40.07%. Crude fibre content was highest in *Kesseru*, followed closely by *A. grandis* (12.83–25.51%), whereas *Castor* exhibited the lowest fibre content among the host plants evaluated.

In earlier studies on *Castor* (*Ricinus communis*), high-yielding, non-bloomy accessions, NBR-1, NBR-2, and NBR-3, were evaluated and recommended for commercialization (Sarmah et al., 2002; 2011). These accessions produce 12–13 MT of leaves per hectare and are well-suited to eri silkworm rearing due to their nutritional quality and palatability. Furthermore, a newly identified line, Accession 22, demonstrated enhanced leaf yield, biomass accumulation, and resistance to biotic stress in comparison to the popular NBR-1 cultivar under recently concluded project. A total of 50 *Castor* accessions were obtained under a Material Transfer Agreement from ICAR-IIOR, Hyderabad. The total castor germplasm repository includes elite genotypes such as perennial advanced lines, Nagaland Local, AP-1, FTP-1, and FTP-2, along with the NBR series.

Regarding cassava germplasm collection, a total of 17 accessions comprising both germplasm and improved genotypes. These include elite cultivars such as Sree Reksha, Sree Pavithra, Sree Jaya, and Aromal. Of these, nine accessions were sourced from ICAR-CTCRI, Kerala, one improved variety (YTP-1) was obtained from Tamil Nadu, and the remaining accessions were collected from various Northeastern states, including Nagaland Red, Nagaland White, Mokokchung Local, Kokrajhar Local, Majuli Local, Meghalaya Local, and Manipur Local. However, systematic characterization and evaluation of these accessions for their suitability in ericulture have not yet been undertaken.

Hybridization and selection in castor

Among the all the host plants, hybridization has been attempted in castor. It has been effectively utilized in castor to combine desirable traits such as perennial nature, high leaf biomass, and stress tolerance. A recently concluded project on “Genetic enhancement of castor germplasm for development of productive perennial varieties” led to the identification of Accession-22, a promising genotype exhibiting superior leaf yield, pest tolerance, and high biomass potential. As part of this program, six advanced perennial castor lines have been developed through successive hybridization and selection cycles, and are currently under evaluation in the F_4 and F_5 generations for their potential use in eri-based sericulture systems.

Tissue culture for mass propagation in borpat

The availability of quality planting material is a significant challenge in the large-scale propagation of *Ailanthus grandis* (*Borpat*), largely due to delayed flowering and seed formation limitations. The species typically initiates flowering only after 25–30 years of growth, and its seeds, being lightweight, are easily dispersed by wind or drop prematurely, making seed collection difficult and unreliable. To overcome this constraint, a collaborative project with the ICFRE–Rain Forest Research Institute (RFRI), Jorhat, is currently in progress to standardize tissue culture protocols for *A. grandis*. The project aims to establish an efficient *in vitro* propagation method using leaf explants to produce true-to-type clones, thereby enabling mass multiplication of elite genotypes for sustainable eri silkworm host plant development.

Host Plant improvement: Research gaps and future breeding strategies

Host plants are the cornerstone of sustainable ericulture, directly influencing silkworm productivity, cocoon yield, and silk quality. Past breeding efforts in ericulture have largely focused on the exploration, collection, and morphological characterization of germplasm across the agro-climatic zones of North-east India. In castor, recent advancements such as interspecific hybridization and selection of perennial lines have opened avenues for enhanced foliage yield and sustained leaf availability. However, in the face of emerging challenges, including climate variability, increasing incidence of pests and diseases, and the need for continuous leaf supply, there is an urgent need to diversify and strengthen breeding strategies.

To accelerate the genetic improvement of eri host plants, it is imperative to integrate both conventional and modern breeding tools, similar to those successfully adopted in mainstream agricultural crops. The current research scenario highlights several critical gaps that must be addressed to achieve these objectives.

Present research gaps

- Narrow/limited gene pool/germplasm resources for eri host plants
- Limited efforts made on development of systematic package of practices for tapioca, kesseru and borpat suitable to NE region specifically for specifically ericulture
- Limited efforts were made on development of host plant varieties suitable for north eastern climatic conditions
- Lack of host plant varieties resistance/tolerance to biotic stress
- Minimal/limited efforts on development of nutrient management (INM) practices specific to enhance sustainable leaf production
- Limited/minimal efforts made on development of host plant-based Integrated pest and disease (IPM and IDM) management packages
- Lack of castor variety tolerance to water logging, specifically in NE regions
- Host plant varieties resistance/tolerance to abiotic stressis lacking
- Non availability of quality seed material
- Lack of vegetative propagation techniques in kesseru and borpat
- Limited/lack of standard operating procedure for tissue culture in kesseru and borpat
- Lack of dual purpose variety in castor and cassava
- Lack of molecular studies carried out on host plant
- Poor understanding of genotype × environment (G×E) interactions, affecting varietal stability across different agro-ecological zones
- Scientific assessment of changing environmental impact on eri host plants is lacking.

Future breeding approaches/strategies

Significant gaps persist in both the management and genetic improvement of eri host plants, which must be addressed to enhance leaf yield, quality, and adaptability under diverse agro-climatic conditions. A comprehensive breeding framework integrating conventional and modern approaches is crucial for developing superior host plant varieties tailored to the evolving needs of ericulture.

Germplasm exploration and collection

North-Eastern India is a primary center of diversity for several eri host plants such as kesseru *(Heteropanax fragrans*), borpat (*Ailanthus grandis*), and tapioca (*Manihot esculenta*), while regions in North-West and Southern India also possess significant genetic diversity for castor (*Ricinus communis*) and tapioca. There is immense potential to explore and collect diverse and underutilized germplasm across different agro-climatic zones of India, particularly from the NE region. This will enhance the genetic base of breeding programs and facilitate *ex-situ* conservation for future breeding use.

Germplasm characterization and evaluation

Comprehensive morphological, anatomical, physiological, and biochemical characterization of collected germplasm is crucial for identifying superior lines with desirable traits such as high leaf biomass, regrowth potential, nutritional quality, and stress tolerance. Evaluation under different environmental conditions and silkworm performance-based screening (Bioassay evaluation) will help identify elite donor lines for breeding.

Development of standard package of practices for eri host plants

Formulation of crop-specific package of practices is essential for major eri host plants such as kesseru, borpat, and tapioca, particularly under the agro-climatic conditions of Northeast India. These POPs should address optimal agronomic practices including spacing, pruning, irrigation, and harvesting schedules to maximize leaf yield and quality across seasons.

Development of standard vegetative propagation technique

The large-scale propagation of perennial eri host plants such as *Borpat* (*Ailanthus grandis*) and *Kesseru* (*Heteropanax fragrans*) is constrained by the limited availability of quality seed material. In *Borpat*, the major limitation arises from delayed reproductive maturity, as the species typically flowers only after 25–30 years. Additionally, the seeds are lightweight and prone to wind dispersal or premature dropping, making their collection both difficult and unreliable. Although *Kesseru* produces seeds annually, seed collection is equally challenging. Fruit bunches must be covered with nets before seed maturity to prevent bird predation and seed loss. Moreover, the seeds have a short viability period, necessitating timely and careful harvesting, which complicates seed-based propagation. Given these constraints, there is an urgent need to develop and standardize efficient vegetative propagation techniques for these species. Methods such as stem cuttings, air layering, and tissue culture should be optimized to enable mass multiplication of elite genotypes. These approaches will not only ensure high survival rates and uniform growth but also facilitate the production of true-to-type planting material suitable for commercial eri host plant cultivation.

Development of INM, IPM and IDM for host plants

To ensure sustainable cultivation and productivity of eri host plants, there is an urgent need to develop comprehensive Integrated Crop Management (ICM) practices encompassing Integrated Nutrient Management (INM), Integrated Pest Management (IPM), and Integrated Disease Management (IDM). Among eri host plants, Castor is particularly vulnerable to pest infestations, which can result in up to 70% leaf loss, severely impacting eri silkworm rearing (Kumara *et al.,* 2023). Key pests affecting castor include leaf hoppers, semiloopers, castor hairy caterpillars, jassids, and capsule borers. Similarly, Cassava is frequently attacked by sucking pests, particularly leaf hoppers, while Tapioca is severely affected by cassava mosaic virus, a disease vectored by whiteflies. Castor crops are susceptible to several diseases, including wilt, seedling blight, rust, leaf blight, brown leaf spot, powdery mildew, stem rot, and bacterial leaf spot. In Kesseru, leaf blight poses a significant threat during the nursery stage. Future ICM modules should be tailored to region-specific pest and disease profiles along with few pests (Sarmah et al., 2013) and emphasize the use of organic amendments, bio-control agents, and environmentally friendly practices. Such approaches will not only improve plant health and productivity but also minimize ecological impacts, ensuring the long-term sustainability of eri host plant cultivation.

Hybridization and recurrent selection

Hybridization is an effective breeding approach for improving eri host plants by introducing genetic variability and combining complementary traits from diverse parental lines. It facilitates the development of superior genotypes with improved leaf biomass, enhanced nutritional value, better regrowth potential, and tolerance to environmental stresses. Recurrent selection complements hybridization by enabling the selection of individuals with desirable traits over successive generations. Through repeated cycles of selection and inter-mating, this method helps in the accumulation of beneficial alleles and the gradual enhancement of complex traits such as leaf yield, plant architecture, and resilience. Together, hybridization and recurrent selection provide a robust framework for the systematic improvement of eri host plants, ensuring the development of high-performing and stable varieties suited for sustainable eri culture across diverse agro-ecological zones.

Mutation breeding

Among the host plant, cassava, being a vegetatively propagated crop, is well-suited for mutation breeding, which serves as an effective tool to induce genetic variability and eliminate undesirable traits. It helps overcome limitations like excessive branching, high anti-nutritional content, poor regrowth, and disease susceptibility. Induced mutants (Chemical mutagens) with enhanced leaf biomass reduced cyanogenic content, vigorous sprouting, and better stress tolerance can be developed. This approach enables the selection of dual-purpose cassava clones with high leaf yield for ericulture and stable tuber yield for food and industrial use.

Polyploidy breeding in cassava

Polyploidy breeding holds strong potential for cassava (2n=2x=36, diploid) improvement by enhancing both leaf biomass for ericulture and tuber yield for food and industrial use. Being vegetatively propagated, cassava is ideal for polyploid induction, which helps overcome limitations of poor flowering and seed set. Induced polyploid such as autotetraploids (2n = 4x = 72) and triploids (2n = 3x = 54) offer potential for developing dual-purpose host plants with larger, nutrient-rich leaves ideal for eri silkworm rearing, along with high starch-yielding tubers for food and industrial use. Future breeding efforts can harness polyploidy to enhance both foliar and tuber traits. ICAR–CTCRI success in developing high-yielding polyploid varieties (Sree Harsha) underscores the promise of this approach in ericulture. Future efforts should focus on colchicine or oryzalin-induced polyploidy in elite lines, supported by phenotypic, cytological, and biochemical screening. Evaluating leaf traits, regrowth ability, and silkworm performance under field conditions will help identify ideal clones. Integrating polyploidy breeding with high-throughput tools can lead to the development of cassava varieties suited for both ericulture and tuber-based livelihoods.

Genomics studies and molecular breeding

Genomic studies and molecular breeding represent advanced approaches for accelerating genetic improvement in eri host plants. Despite their critical role in ericulture, limited genomic information is currently available for key host species castor, kesseru, borpat and tapioca. Genomic approaches including genome sequencing, transcriptomics, and genotyping-by-sequencing (GBS), can facilitate the identification of genes and quantitative trait loci (QTLs) associated with economically important traits such as high leaf biomass, improved nutritional content, regrowth potential, and tolerance to biotic and abiotic stresses. Molecular breeding techniques, such as marker-assisted selection (MAS) and genomic selection (GS), enable precise and efficient introgression of target traits into elite genetic backgrounds. These approaches reduce breeding cycles and enhance the accuracy of selection, particularly for complex traits governed by multiple genes.

Tissue Culture and Genetic Engineering in Eri Host Plant Improvement

Tissue culture is a vital tool for the rapid propagation and conservation of elite eri host plant genotypes, particularly those with poor seed viability or limited vegetative propagation options, such as *kesseru* (*Heteropanax fragrans*) and *borpat* (*Ailanthus grandis*). Techniques such as micropropagation, somatic embryogenesis, and callus culture enable the production of disease-free, uniform planting materials and support ex situ conservation of valuable germplasm. Genetic engineering offers opportunities to introduce specific traits, such as resistance to pests and diseases, enhanced stress tolerance, or improved leaf nutritional quality into eri host plants that are otherwise difficult to achieve through conventional breeding. Advanced biotechnological tools such as *Agrobacterium*-mediated transformation and emerging genome editing technologies like CRISPR-Cas can be utilized to precisely modify genes associated with desirable traits without altering the overall genetic background of the plant. These techniques hold significant potential in overcoming specific physiological and reproductive limitations in perennial host plants like *Borpat* (*Ailanthus grandis*). In particular, such approaches may be employed to break apical dominance and overcome reproductive barriers, thereby facilitating improved vegetative growth and reproductive efficiency for enhanced propagation and utilization in ericulture.The integration of tissue culture and genetic engineering holds significant promise for overcoming propagation barriers and enhancing the genetic potential of eri host plants, thereby ensuring sustainable leaf supply and supporting the long-term growth of ericulture.

Conclusion

Efforts toward host plant management and improvement in ericulture have been limited and fragmented. Major gaps persist in germplasm diversity, stress tolerance, propagation methods, and region-specific cultivation practices. To address these challenges, a comprehensive approach integrating conventional and modern breeding tools is essential for developing high-yielding, climate-resilient, and nutritionally rich host plant varieties. Parallel development of vegetative propagation techniques, package of practices, and integrated crop management modules (INM, IPM and IDM) will ensure year-round leaf availability and sustainable cultivation. Strengthening these aspects is crucial for enhancing the productivity and long-term viability of ericulture.

References

Ahmed SA, Sarmah MC and Rajan RK (2012) New report of Syonaka (*Oroxylum indicum* (L.) Benth. Ex Kurz.) as a food plant of Eri Silkworm, *Samia ricini* Donovan (Lepidoptera: Saturniidae) in Assam, India. *Munis Entomology & Zoology*, 7(1): 650-652.

Arora GS and Gupta IJ (1979) Taxonomic studies on some of the Indian non-mulberry silk moths (Lepidoptera: Saturniidae). *Memoir's-Zoological Survey of India, Calcutta*, 16: 1-63.

Das SK, Sahu BK and Singh D (2020) Host plant diversity of non-mulberry silkworms: A review. *Journal of Pharmacognosy and Phytochemistry,* Sp 9(3): 109-113.

Kichu N, Imtinaro L and Neog P (2015) Influence of host plants on rearing performance and cocoon characters of eri silkworm, *Samia cynthia ricini* Boisduval. Indian J. of Entomol., 77(1): 88-91.

Kumara RR (2023) Breeding in Host Plants of Eri Silkworm for Rearing Suitability. *Mysore J. Agric. Sci*., 57(3): 24-43.

Mahesh DS and Arun Kumar KP (2020) Status of ericulture in Northeast India. Insect Environment, 22: 68-69.

Manjunatha NC and Murthy C (2013) Evaluation of new host plant species for ericulture. *International Journal of Plant Protection,* 6(2): 444-448.

Manjunatha NC, Patil GM, Murthy C, Awaknawar JS, Shekharappa, Alagundagi SC (2010) Development and economic cocoon parameters of eri silkworm *Samia cynthia ricini* Boisduval (Lepidoptera: Saturniidae) as influenced by new hosts. *Journal of Agricultural Science*, 23(5): 716-721.

Naik MC and Murthy C (2013) Evaluation of new host plant species for Ericulture. *Internat. J. Plant Protec.,* 6: 444-448.

Patil GM (2004) Organically raised *Mechelia champaca* L., a potential new host plant of eri silkworm, *Samia cynthia ricini* Boisduval. *Abstract in*: National Seminar on Prospects of Organic Sericulture and Sericultural Byproduct Utilization: 39-52.

Phukan JCD, Sarmah MC, Kakati PK and Chakravorty R (2006) Kesseru, *Heteropanax fragrans* (Roxb.) Seem – An Important Perennial Food Plant of Eri Silkworm. In: Lead papers and abstracts, National Workshop on Eri food plants held on 11-12th October, 2006 by CMERTI, Lahdoigarh, pp. 50-61.

Radhika SA, Sakthivel N and Sahayaraj K (2017) Acceptance of tertiary and non-food plants by eri silkworm, *Samia cynthia ricini* Boisduval (Lepidoptera: Saturniidae). *Munis Entomology and Zoology*, *12*(1): 127-132.

Reddy DNR, Gowda M and Narayanaswamy KC (2002) Ericulture: An Insight. *Zen Publication, Banglore, India*, 82.

Sarmah M and Gogoi D (2011) A focus on the eri silkworm host plant bio-resources and its development through technological intervention and prospects in Biotechnology – hitherto in Emerging areas of seri-biotechnology. *(Course Material /Invited Talks) Edited by M. Chutia and K. Das, CMERTI, Lahdoigarh*, pp. 20–31.

Sarmah MC, Ahmed SA and Sarkar BN (2013) New pests of Kesseru, *Heteropanax fragrans* (Roxb) Seem a perennial host plant of eri silkworm, *Samia ricini* (Donovan). *Mun. Ent. Zool.*, 8(2): 900-901.

Sarmah MC, Chutia M, Neog K, Das R, Rajkhowa G and Gogoi SN (2011) Evaluation of promising castor genotype in terms of agronomical and yield attributing traits, biochemical properties and rearing performance of eri silkworm, *Samia ricini* (Donovan). *Industrial Crops and Products*, 34(3): 1439-1446.

Sarmah MC, Datta RN, Das PK and Benchamin KV (2002) Evaluation of certain castor genotypes for improving ericulture. *Indian J. Seri*. 41(1): 62-63.

Sericultural Statistics in India - A Glance, 2023-24. Accessed on 30.06.2025

Subramanianan K, Sakthivel N and Qadri SMH (2013) Rearing technology of eri silkworm (*Samia cynthia ricini*) under varied seasonal and host plant conditions in Tamil Nadu. *International Journal of Life Sciences Biotechnology and Pharma Research*, *2*(2): 130-141.

Tikader A and Kamble CK (2010) Seri-biodiversity status with reference to the host plants in India. *Asian Aust J Plant Sci Biotech*, 4: 1-11.

MINUTES AND RECOMMENDATIONS OF SILKWORM HOST PLANT (MULBERRY AND VANYA) BREEDERS' MEET-2025

Innovative Host Plant Breeding Strategies: A Step Towards Doubling Silk Production

The Host Plant Breeders Meet-2025 was successfully organized by CSB-Central Sericultural Research and Training Institute (CSRTI), Mysuru, on 8th and 9th of July 2025. The event convened a distinguished gathering of the scientists, plant breeders, Directors and policy makers, from across the country, all actively engaged in mulberry and vanya sericulture research and development. The participants list is included as Annexure-1.

The central theme of the meet, ***Innovative Host Plant Breeding Strategies: A Step Towards Doubling Silk Production***, was thoughtfully designed to align with India's strategic vision of becoming a global leader in silk production. The discussions and deliberations focused on enhancing silk productivity and quality, sustainability, and climate resilience through the adoption of advanced host plant breeding techniques.

The meet served as a vital platform for sharing recent scientific advancements, breeding innovations, field-level experiences, and policy insights. Emphasis was placed on the need for climate-smart cultivars, nutrient-efficient and pest-resistant mulberry and vanya host plant varieties, and integrated breeding approaches that combine conventional methods with modern biotechnological and phenomic tools. The event concluded with a roadmap of collaborative strategies aimed at accelerating host plant improvement programs, ultimately contributing to the goal of doubling silk production in the country.

Day 1: Inaugural Session of Host Plant Breeders' Meet-2025

The event commenced with the registration of participants, followed by the inaugural session, which began with the National Anthem and a welcome address by Dr. S. Gandhi Doss, Director, CSB-CSRTI Mysuru. In his address, Dr. Doss emphasized the crucial role of host plant improvement in enhancing silk productivity, sustainability, and resilience to climate change. The two day's event, was inaugurated by the Chief Guest of the Meet, Shri P. Sivakumar, IFS, Member Secretary of the Central Silk Board. The formal inauguration was marked by the traditional lighting of the lamp symbolizing the illumination of knowledge and collaboration in sericultural science.

Delivering the inaugural address, the Chief Guest, Shri P. Sivakumar, IFS, Member Secretary, Central Silk Board, emphasized the strategic importance of research in host plant breeding, particularly in line with India's vision for achieving self-reliance in quality silk production. He highlighted the critical need for developing climate-resilient and high-yielding mulberry and vanya plant varieties to ensure sustainable growth in sericulture and to double the country's silk production.

He urged scientists to formulate a clear roadmap to meet the ambitious target of producing 54,000 metric tonnes of raw silk by 2030, positioning India as a global leader in silk production. Furthermore, he encouraged researchers to develop innovative plant hybrids to meet production goals through both vertical and horizontal expansion of silk. He noted the growing application of mulberry and vanya plants in diverse sectors such as pharmaceuticals, cosmetics, and Seri tourism.

The inaugural session continued with the Keynote Address by the Chairman of the Meet, Dr. S. B. Dandin, Former Vice Chancellor of UHS, Bagalkot, and former Director of the Central Silk Board. Dr. Dandin reflected on the significant progress achieved in host plant breeding over the years and urged the scientific community to proactively address emerging challenges such as pest resistance, drought tolerance, and the nutritional enhancement of host plants. He emphasized the need to leverage advanced technologies including Biotechnology, Artificial Intelligence, and Nanotechnology to bridge the gap between laboratory research and field-level application, thereby enabling large-scale commercialization and impact.

A Special Address was delivered by Dr. S. Manthira Moorthy, Director (Technical), emphasizing the need to develop new host plant hybrids with superior leaf quality and higher leaf yield in enhancing the overall yield of raw silk. He urged scientists to formulate a strategic roadmap for the next 5 to 10 years, focusing on innovation and sustainability. Further, he has highlighted emerging trends in the commercial exploitation of secondary metabolites from host plants, particularly in the pharmaceutical industry.

The inaugural session saw the contribution of all Directors from the CSB Research Units, as well as the representatives of the Department of Sericulture and State Sericulture Research Institutes from the Southern States. In attendance were distinguished former scientists, senior scientists and Experts in the field of seri host plant breeding, alongside senior scientists from IIHR and UAS, GKVK, Bengaluru. The inaugural session concluded with a vote of thanks by Dr. S. Mahiba Helen.

Technical Session: Innovative Host Plant Breeding Strategies-Mulberry

The technical session under the Chairmanship of Dr. S. B. Dandin, was initiated in presence of Chief Guest, Shri P. Sivakumar, IFS, Member Secretary, Central Silk Board; Guest of Honours Dr. S. Manthira Moorthy, Director (Technical) and Dr. Naresh Babu, IFS, Joint Secretary (Technical). The presentation on current status, challenges and future prospects of mulberry improvement across different sericultural zones of India were presented by the Directors of CSB Research Institutes. During the presentations, Dr. Naresh Babu, IFS, Joint Secretary (Technical), emphasized the critical need for fostering collaborative partnerships with leading universities, national research institutions, and international organizations to advance sericultural research. He underscored that addressing emerging challenges in the sector such as climate resilience, host plant improvement, disease management, and genetic enhancement requires a multidisciplinary and integrated research approach. He further advocated for leveraging the strengths of academic and research institutions in fields such as biotechnology, genomics, data science, and agronomy, to accelerate innovation and ensure that cutting-edge scientific developments are effectively translated into field-level applications for the benefit of farmers and stakeholders in the silk value chain.

Presentations included:

1. **Mulberry Breeding Strategies for Tropical Sericulture:** Dr. S. Gandhi Doss, Director, CSB-CSRTI, Mysore presented the current status, challenges and future prospects of mulberry breeding for tropical sericulture. He provided an overview of the current status of authorized mulberry varieties and their cultivation practices in Southern India. He highlighted recent advancements in research, including AGB8 variety under pipeline for the release, triploid breeding, nutrient use efficiency, drought tolerance, resistance to root rot and root knot diseases and production of secondary metabolites. He also discussed molecular diversity analysis and the development of transgenic mulberry for enhanced soil moisture stress tolerance and photosynthetic efficiency. Further, emphasized on innovative breeding strategies such as speed breeding, genome editing, and the application of genomic and phenomic tools aimed at developing climate-resilient mulberry varieties tailored for tropical sericulture.
2. **Mulberry Breeding Strategies for Eastern and North-Eastern region:** Dr. Maheswari, Director, CSB-CSRTI, Berhampore presented the current status, key challenges, and future prospects of mulberry breeding for sub-tropical sericulture. She provided a comprehensive overview of the existing authorized mulberry varieties and their performance potential across Eastern and North-Eastern India. The presentation highlighted recent research advancements, including triploid breeding, tolerance to low nutrient stress and drought, as well as resistance to powdery mildew and bacterial leaf spot diseases. In addition, the importance of physiological breeding approaches and trait-based marker associations was discussed. She also emphasized the need for adopting innovative breeding strategies such as marker-assisted

selection, advanced generation breeding, mutational breeding, and genomic selection. These approaches are crucial for developing region-specific and climate-resilient mulberry varieties tailored to the unique needs of sub-tropical sericulture.

3. **Mulberry Breeding Strategies for North and North-Western India:** Dr. Aftab Ahmad Shabnam, Scientist-D, CSB-CSRTI, Pampore, presented the base paper on the "Current Status and Future Perspectives of Mulberry Breeding for North and North-Western India." He provided an in-depth overview of the authorized mulberry varieties currently in use and their performance, along with key outcomes from ongoing and completed breeding programs. The presentation showcased recent advancements in research, including somatic hybridization and the development of varieties exhibiting traits such as frost and drought tolerance, early sprouting, and enhanced rooting ability. The significance of *in vitro* culture techniques in the conservation and genetic improvement of mulberry was also highlighted. Furthermore, he emphasized the need for collaborative breeding initiatives with temperate countries and the conservation of germplasm adapted to temperate climates. He outlined advanced breeding strategies, including Genome-Wide Association Studies (GWAS), double haploid production, identification of candidate genes for cold tolerance, and marker-assisted selection. These approaches aim to develop region-specific, climate-resilient mulberry varieties suited to the specific agro-climatic needs of sub-tropical and temperate sericulture.
4. **Seri-biodiversity Management Strategies**: Dr. V. Nishitha Naik, Director, CSB-CSGRC, Hosur, presented the base paper titled “Seri-Biodiversity Conservation, Management, and Utilization for Posterity: Status, Challenges, and Future Strategies.” She provided a detailed overview of the center's activities, including the protocols for registration of improved genetic material. She underscored the importance of quarantine facilities for screening incoming germplasm and the issuance of phytosanitary certificates for the export of seri-germplasm. The presentation also covered significant progress in molecular characterization, cytological studies, and evaluation of mulberry accessions for stress tolerance and key economic traits. She further highlighted the need for future strategies focusing on the evaluation and conservation of germplasm resilient to climate change, improved nutritive quality, and resistance to pests and diseases. The importance of pre-breeding approaches and the development of standardized conservation protocols were also emphasized as critical steps for sustainable utilization of seri-biodiversity.
5. **Genomics Strategies for Mulberry Improvement**: Dr. Harshita B.S., Scientist-B at CSB-ISBR, Bangalore, presented the base paper titled “Genomic Interventions in Mulberry Crop Improvement and Conservation Efforts.” She highlighted the ongoing

initiatives at Institute for Seri-Biotech Research (ISBR) including the mapping of root rot resistance genes and DNA barcoding of mulberry germplasm. She also outlined future strategies for accelerating mulberry improvement, such as Genome-Wide Association Studies (GWAS), Genomic Selection, integrated omics approaches, and genome editing technologies.

6. **Breeding Strategies in Fruit Tree:** Dr. Anuradha Sane, Principal Scientist, IIHR, Bangalore, delivered a presentation on “Breeding Strategies for the Genetic Improvement of Fruit Tree Species.” She provided an overview of the key challenges and current breeding approaches in the genetic enhancement of fruit trees. Emphasizing future directions, she highlighted strategies such as the collection of wild germplasm, fundamental research on trait inheritance, development of climate-resilient varieties, rootstock breeding for biotic stress tolerance, marker-assisted selection, and participatory plant breeding for fruit crop improvement.
7. **Modern Breeding Tools for Mulberry:** Dr. Mahesh H.B., Assistant Professor, UAS, GKVK, Bengaluru has presented the paper on “Leveraging Modern Breeding and Genomics Tools to Overcome Key Constraints in Mulberry”. He has presented the Molecular breeding strategies such as Genomic Assisted Selection (GAS), Genome Wide Association Studies (GWAS), Genome Editing, Speed Breeding and Advanced Mutational Screening. Further, highlighted the need for re-sequencing of *Morus* accessions for developing the disease, pest and stress tolerant varieties.

Panel Discussions on Mulberry

A panel discussion, chaired by Dr. K. Vijayan and co-chaired by Dr. K. Jhansi Laxmi, provided a platform for host plant breeders, and expert scientists to share key challenges and strategies for addressing them. The discussion culminated in synthesizing the presentations and prioritizing future strategies for mulberry improvement.

General Recommendations

- **Farmer-Centric Breeding**: Incorporate ground-level feedback from farmers to define breeding objectives. Field visits by breeders were emphasized to bridge research–reality gaps.
- **Multidisciplinary Collaboration**: Geneticists, physiologists, soil scientists, molecular biologists, and computational experts must work in tandem for next-generation varieties.
- **Trait-Linked Breeding**: Focus on secondary traits and identification of markers for biotic/abiotic stress resistance. Development of SOPs for phenotyping with AI/image analysis was stressed.

- **Efficiency Traits**: Prioritize input-use efficiency (nutrients, water) in new varieties to meet sustainability goals.
- **Enhanced Germplasm Utilization**: The national germplasm database should integrate multilocational data, genomics, and phenotype characterization generated by CSGRC and other institutes.
- **Breeding Cycle Acceleration**: Intigrate modern molecular and computational techniques with conventional breeding to reduce the breeding cycle.
- **Polyploidy for wider adaptability**: Triploids have better tolerance to abiotic stresses and hence promote triploid development using high yielding induced tetraploids.
- **Inbred lines for hybrid development:** Develop inbreds using conventional/tissue culture/molecular techniques for exploiting heterosis and discect genetics of economic traits.
- **Decentralized Evaluation**: Multilocational evaluation of genotypes at FYT to reduce varietal release duration.
- **Post-Release Promotion**: Establish seed and demonstration plots at RSRS/REC/DOS. Farmer field demonstrations are essential to build trust.
- **Climate Smart Varieties**: Integrate modern gene-editing techniques to produce stress-resilient, high-yielding cultivars.
- **Metabolomics in Evaluation**: Incorporate metabolic profiling for selection of nutritionally superior mulberry genotypes for silkworm health and commercial value.

Institute-Specific Recommendations

CSB-CSRTI, Mysuru

- As the Mysuru institute covers a vast jurisdiction, region-specific varieties should be developed and released for local cultivation, with necessary policy changes undertaken where required.
- Training should be provided to scientists of all nested units involved in variety testing.
- Greater emphasis should be placed on developing water- and nutrient-efficient mulberry varieties.
- Breeding for root rot resistance should be prioritized.

CSB-CSRTI, Berhampore

- Cold-tolerant mulberry varieties should be developed to ensure adequate leaf supply for spring crops. Plant genetic resources from J&K may be utilized, as these genotypes exhibit good cold tolerance and can sprout under low temperatures.
- Powdery mildew- and sooty mould-resistant varieties need to be developed to promote bivoltine sericulture in regions where these diseases are prevalent during favourable silkworm crop seasons.
- Waterlogging-resistant varieties are required in several parts of West Bengal; hence, efforts should be directed toward their development.
- State-specific varieties for different NE states should be identified by evaluating and testing high-yielding mulberry varieties through coordinated efforts of different institutes.

CSB-CSRTI, Pampore

- In the temperate sericulture zones of Jammu and Kashmir, varieties capable of sprouting immediately after winter are desirable; hence, efforts should focus on developing early-sprouting types.
- For the subtropical zone of NW India, late-senescence varieties should be developed.
- Rooting ability in temperate varieties is generally poor compared to tropical ones. Therefore, high-rooting, high-yielding varieties should be developed, using Gosheorami as one parent due to its superior yield over other temperate types.
- Frost-induced leaf damage is common in colder regions of J&K and Ladakh, causing significant loss of leaf lamina. Frost-tolerant varieties should be developed using locally adapted genotypes as one parent. Previous work on identifying cold-tolerant genes from collections in cold arid zones should be advanced through marker-assisted selection breeding.
- Drought-tolerant varieties should be developed for the subtropical climates of NW India, building upon the work already initiated in this direction.
- The recently developed somatic hybrid technology at this Institute should be extensively utilized in variety development programs, with somatic hybrids evaluated at multiple temperate locations.
- Sodic soils pose major challenges in subtropical NW India, particularly in Uttar Pradesh. Focused research is needed to develop varieties suited to these conditions,

and previously developed types such as AR-12 should be re-evaluated for adaptability and performance under sodic soils.

- New variety evaluations should be conducted exclusively in high bush (tree) mode, as this is the prevalent field planting system.

CSB-CSGRC, Hosur

- Extend cytological evaluation to all accessions to determine ploidy status for parent selection in breeding.
- Generate phenotypic, genotypic, and genomic data (in collaboration with UAS Bangalore) for effective utilization.
- Identify fruit-yielding accessions and supply them to breeding institutes for value addition.
- Undertake metabolomic studies to find nutritionally superior accessions for sericulture, pharmaceuticals, and nutraceuticals.
- Support other institutes in hybridization and OP seed collection from selected parents.

CSB-ISBR, Kodathi

- Provide molecular biology support to the other institute for taking-up breeding related projects/ programmes.

Day 2: Innovative Host Plant Breeding Strategies -Vanya Sector

The second day (09-07-2025) focused on the breeding and conservation strategies of vanya host plants- Tasar, Muga, Oak Tasar and Eri. The base paper presentations were delivered by Director, CSB-CTRTI, Ranchi and Scientists from CSB-CMERTI, Lahdohigarh.

Technical Presentations

1. **Breeding Strategies for Tasar Host Plants**: Dr. N. B. Chowdary, Director, CSB-CTRTI, Ranchi, presented the base paper titled *“Conservation, Characterization, and Genetic Improvement of Tasar Host Plants – Present Status and Future Strategies.”* In his address, he provided a comprehensive overview of the recent advancements in the conservation, evaluation, and genetic enhancement of Tasar host plants, with particular emphasis on interspecific hybridization and the identification of alternative host species. He highlighted the significant progress made in identifying region-specific superior *Terminalia* hybrids and optimizing suitable cultivation practices for the establishment of block plantations. He also emphasized the urgent need for future strategies to focus on host plants that are easily propagated, possess

a short gestation period, exhibit resistance to pests and diseases, require low input, and offer high productivity. In the context of Oak Tasar host plants, he stressed the importance of prioritizing the multiplication and widespread distribution of elite *Quercus* species, especially in light of their potential suitability for indoor rearing systems. He further advocated for the expansion of the germplasm base, the integration of conventional and molecular breeding approaches, and the strengthening of both national and international research collaborations to accelerate the development of climate-resilient Tasar host plant varieties

2. **Breeding Strategies for Eri Host Plants:** Dr. Harisha R, Scientist-B, CSB-CMERTI, Lahdoigarh, presented the base paper titled *"Eri Host Plants: Current Status, Challenges, and Future Prospects."* He highlighted the significance of Eri silk as the second-largest silk producer after mulberry, underlining its vital role in ensuring food and nutritional security, particularly in the North Eastern Region. He provided a comprehensive overview of the recommended accessions, existing cultivation practices, major constraints, and ongoing breeding efforts aimed at the genetic improvement of Eri host plants. Emphasizing the importance of developing dual-purpose and perennial castor varieties, he noted their potential to enhance the sustainability and expansion of Eri sericulture. Furthermore, he outlined future strategies, including the need to broaden the genetic base, promote *in vitro* propagation techniques, undertake molecular characterization, and implement systematic breeding programs for developing high-yielding and resilient host plant varieties, thereby facilitating the commercial scaling of Eri cultivation.

3. **Breeding Strategies for Muga and Oak Tasar Host Plants:** Dr. Om Prakash Patidar, Scientist-C, CSB-CMERTI, Lahdoigarh, presented the base paper titled *"Muga and Oak Tasar Host Plants: Current Status, Challenges, and Future Prospects."* He outlined the recent advancements, existing constraints, and ongoing challenges in the improvement of Muga host plants. He elaborated on current cultivation practices, propagation methods, and the potential for intercropping Muga host plants with commercially viable crops to enhance land use efficiency. Dr. Patidar emphasized the need to adopt systematic breeding approaches to support the genetic improvement and expansion of Muga cultivation. Additionally, he addressed the specific challenges associated with the enhancement of Oak Tasar host plants, highlighting the need for targeted interventions to overcome limitations and ensure sustainable development in this sector.

Panel Discussions on Vanya Host Plants

The panel discussion with Vanya host plant breeders and experts, chaired by Dr. Rajendra Kumar and co-chaired by Dr. C. M. Babu, emphasized conserving genetic diversity and modernizing vanya host plant breeding through genomics and phenomics.

General Recommendations of Panel Discussions–Vanya Host Plants

- Conservation of genetic resources of *Vanya* host plants - Eri, Muga, tropical tasar, and temperate tasar - should be properly maintained, systematically characterized, and scientifically catalogued.
- Breeders must take into account the needs and priorities of farmers before formulating breeding programmes.
- Breeding should be undertaken through multidisciplinary approaches, following well-defined phenotypic standard operating procedures (SOPs).
- A pan-India germplasm collection should be explored with geo-coordinated documentation to facilitate future genotype tracking.
- A comprehensive catalogue of all host plants should be prepared and updated at least once every three years.
- Superior genotypes should be identified through molecular characterization techniques.
- Seed nurseries of promising varieties should be maintained at the RSRS/REC level to ensure availability for further multiplication and distribution.
- At least one plant species of *Vanya* host plants should be subjected to genome sequencing at the chromosome level to generate genomic resources for future improvement.
- The pathway linking plant proteins to silk protein synthesis in silkworms needs to be studied to provide insights for future molecular breeding.
- Working germplasm collections should be maintained at respective institutes.
- SOP of promising lines to be developed to facilitate evaluation under AICEM pattern

Specific Recommendations – Vanya Host Plants

Tasar

- About **10% of trait-specific germplasm** may be developed into a core collection for use in future breeding programmes.

- **Grafting approaches** can be adopted as a short-term strategy to overcome the long gestation period for flowering and to address soil-related constraints.
- **Inter- and intra-specific hybridization** among host plants should be explored to enhance genetic variability.
- **Advanced molecular breeding approaches** should be employed to reduce the time required in conventional breeding and to effectively assess genetic diversity.
- **Seedlings developed from superior genotypes** should be propagated and distributed instead of relying on saplings.
- *Lagerstroemia speciosa* could be explored as a potential host for chawki rearing purposes.

Muga

- Germplasm of Muga host plants from unexplored areas should be collected and systematically maintained at the Institute.
- **Hybridization and polyploidy breeding** may be explored in the identified germplasm to broaden variability and improve traits.
- Superior germplasm of **Som and Soalu**, already identified, should be multiplied and supplied to farmers for establishing economic plantations along forest peripheries.
- Superior **Soalu accessions** need to be identified for seed crop rearing during the summer season.

Eri

- Conservation of breeding germplasm should be carried out in protected environments such as polyhouses to maintain genetic purity.
- Hybridization among already identified superior accessions can be undertaken, and superior progenies should be raised for further multiplication.
- **Waterlogging tolerance studies in castor** should be conducted to identify suitable lines for flood-prone areas of the North Eastern Region, ensuring stable leaf production under stress conditions.
- Studies to **break apical dominance and enable vegetative propagation in Borpat** should be initiated to support large-scale planting material production through clonal methods.
- To enhance the suitability of **Borpat-fed pupae for human consumption**, detailed studies are required to address factors influencing their palatability.

- Superior accessions identified through germplasm evaluation should be advanced to **multilocation and adaptive trials** to assess their performance under diverse agro-climatic conditions of the NE region.
- **Seed viability and preservation studies in Kesseru (***Heteropanax fragrans***)** should be undertaken to overcome challenges of short seed shelf life, ensuring effective conservation and timely sowing.
- **Vegetative propagation and tissue culture protocols for Kesseru** should be standardized to ensure year-round supply of elite planting material.
- **Long-term seed storage techniques for castor** need to be developed with emphasis on maintaining vigour and germination potential across multiple cropping seasons.
- **Advanced generation perennial castor lines** developed under earlier projects should be purified, stabilized, and re-evaluated for field-level performance and scalability across different Eri-growing regions.

Oak Tasar

- Oak tasar host plant germplasm can be explored and collected from NE regions.
- Selection of superior accessions to be made from already popular *Quercus* sp. for commercial cultivation
- Focus on the multiplication and supply of superior *Quercus* sp.
- *Quercus serrata* for NE zone &*Quercus incana* for NW zone may be focused

Valedictory Session

The final session featured:

- Presentation of outcomes by panel chairs Dr. K. Vijayan (Mulberry) and Dr. Rajendra Kumar (Vanya)
- Feedback from institute directors and senior experts
- Concluding remarks by the Chairman
- Vote of thanks delivered by Dr. Manjappa, Sci-D
- The meet concluded with the National Song

Conclusion

The Host Plant Breeders' Meet-2025 laid out a visionary roadmap aimed at fostering the development of sustainable, climate-resilient, and economically viable host plant varieties to support the future of Indian sericulture. The deliberations during the meet emphasized the strategic integration of advanced molecular breeding tools, genomic selection, phenotyping platforms, and data-driven decision-making frameworks to enhance breeding efficiency and precision. A strong focus was placed on adopting stakeholder-oriented strategies that align scientific innovations with the practical needs of farmers, industry partners, and policymakers. This multi-pronged approach is poised to catalyze transformative changes across the sericulture sector and significantly contribute to the realization of India’s ambitious goal of doubling silk production, in line with national priorities for rural development, employment generation, and agricultural sustainability.

Dr. S. B. Dandin
Chairman

Annexure-1

List of participants

1. Shri P Sivakumar, IFS, Member Secretary, Central Silk Board, Bengaluru
2. Dr. SB Dandin, Former VC, UHS Bagalkot, Chairman of the Breeders' meet
3. Dr. S Manthira Moorthy, Director (Tech.), Central Silk Board, Bengaluru
4. Dr. Naresh Babu N, IFS, Joint Secretary (Tech.), Central Silk Board, Bengaluru
5. Dr. Gandhi Doss S, Director, CSB-CSRTI Mysuru
6. Dr. M Maheswari, Director, CSB-CSRTI Berhampore
7. Dr. Sardar Singh, Director, CSB-CSRTI Pampore
8. Dr. V Nishitha Naik, Director, CSB-CSGRC Hosur
9. Dr. NB Choudary, Director, CSB-CTRTI Ranchi
10. Dr. K Vijayan, Scientist-D (Retd.), Central Silk Board, Expert Member
11. Dr. T Mogili, Scientist-D (Retd.), Central Silk Board, Expert Member
12. Dr. Rajendra Kumar, Scientist-D (Retd.), Central Silk Board, Expert Member
13. Dr. SN Gogoi, Scientist-D (Retd.), Central Silk Board, Expert Member
14. Dr. Anuradha Sane, Principal Scientist, ICAR-IIHR Bengaluru, Expert Member
15. Dr. Mahesh HB, Assistant Professor, UAS, GKVK, Bengaluru, Expert Member
16. Dr. N Siddalingaswamy, Scientist-F, KSSRDI Thalagattapura
17. Dr. Mahadeva A, Scientist-D, KSSRDI Thalagattapura
18. Dr. K Jhansilakshmi, Scientist-D, RCS Head, Central Silk Board, Bengaluru
19. Dr. CM Babu, Scientist-D, RCS, Central Silk Board, Bengaluru
20. Dr. Prashant Sangannavar, Scientist-D, RCS, Central Silk Board, Bengaluru
21. Dr. Dr. S Balasaraswathi, Sci-D, CSB-CSRTI Mysuru
22. Dr. R Bhagya, Scientist D, CSB-CSRTI Mysuru
23. Dr. Dayananda, Scientist-D, CSB-CSRTI Mysuru
24. Dr. R Meenal, Scientist D, CSB-CSRTI Mysuru
25. Dr. Mahiba Helen S, Scientist D, CSB-CSRTI Mysuru
26. Ms. GS Geetha, SRA, CSB-CSRTI Mysuru
27. Dr. Arun Kumar KP, Scientist D, CSB-ISBR Bengaluru
28. Dr Aftab Ahmad Shabnam, Scientist-D, CSB-CSRTI Pampore
29. Dr. Santosh Kumar Magadam, Scientist-D, CSB-RSRS Jammu
30. Dr. Pawan Saini, Scientist-D, Central, CSB-CSRTI Pampore
31. Dr. Suresh K, Scientist D, CSB-CSRTI Mysuru

32. Dr. Gulab Khan Rohela, Scientist-D, CSB-CSRTI Mysuru
33. Dr. Ravindra, Scientist D, CSB-CSRTI Mysuru
34. Dr. Kusuma L, Scientist D, CSB-CSRTI Mysuru
35. Dr. Chandrakanth N, Scientist D, CSB-CSRTI Mysuru
36. Dr. Yeruva Thirupathaiah, Scientist-D, CSB-CSRTI Mysuru
37. Dr. Gayathri T Scientist-D, CSB-CSRTI Mysore
38. Dr. Sobhana V, Scientist-D, CSB-CSRTI Mysuru
39. Dr. Mallikarjun G, Scientist-D, CSB-CSRTI Mysuru
40. Dr. Manjappa, Scientist-D, CSB-CSRTI Mysuru
41. Dr. Ranjini MS, Scientist D, CSB CSRTI Mysuru
42. Dr. Dhaneshwar Padhan, Scientist-C, CSB-CSRTI Mysuru
43. Dr. Yallappa Harijan, Scientist-C, CSB-CSRTI Berhampore
44. Shri Raju Mondal, Scientist C, CSB-CSGRC Hosur
45. Dr. MC Thriveni, Scientist-C, CSB-CSGRC Hosur
46. Dr. Om Prakash Patidar, Scientist C, CSB-CMERTI Lahdoigarh
47. Dr. Revappa M Rebasiddanavar, Scientist B, CSB-CSRTI Mysuru
48. Ms. Boggala Vajramma, Scientist-B, CSB-CSRTI Mysuru
49. Dr. Sowmiya K, Scientist-B, CSB-CSRTI Mysuru
50. Ms. Tamilselvi C, Scientist B, CSB- CSRTI Mysuru
51. Dr. Latha Preethi A, Scientist -B, CSB-CSRTI Mysuru
52. Dr. Harshitha BS, Scientist-B, CSB-ISBR Kodathi
53. Shri Haragopal Dutta, Scientist B, CSB-CTRTI Ranchi
54. Dr. Harisha R, Scientist B, CSB- CMERTI Lahdoigarh
55. Dr. Nandan M, Scientist-B, CSB-CSGRC Hosur
56. Smt. Pushpavati N, STA, CSB-CSRTI Mysuru
57. Shri Justin Kumar J, STA, CSB-CSRTI Mysuru

Event in Pictures


Lighting the Lamp


Inaugural Address


Participants listened attentively


All in a frame


Chairman Begins the Session


Delegates in attention

The CSB-Central Sericultural Research & Training Institute (CSB-CSRTI), Mysuru, is a pioneer research institution in tropical sericulture, established in 1961 at Channapatna, Karnataka, under the Central Silk Board, Ministry of Textiles, Government of India. In 1963, the Institute was relocated to Mysuru and renamed as the Central Sericultural Research and Training Institute (CSRTI) following the merger with the Sericulture Training School of the Central Silk Board.

Over the decades, CSB-CSRTI Mysuru has excelled in research and development, training, and extension, significantly contributing to the Indian silk industry by enhancing both productivity and quality of silk. The Institute has developed several high-yielding mulberry varieties adapted to diverse tropical agro-climatic zones, forming the backbone of improved silk production in India. It continues to play a pivotal role in introducing advanced mulberry varieties, promising silkworm hybrids, improved rearing technologies, and effective pest and disease management practices. These innovations are driving sustainable growth and overall development of the sericulture sector.

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