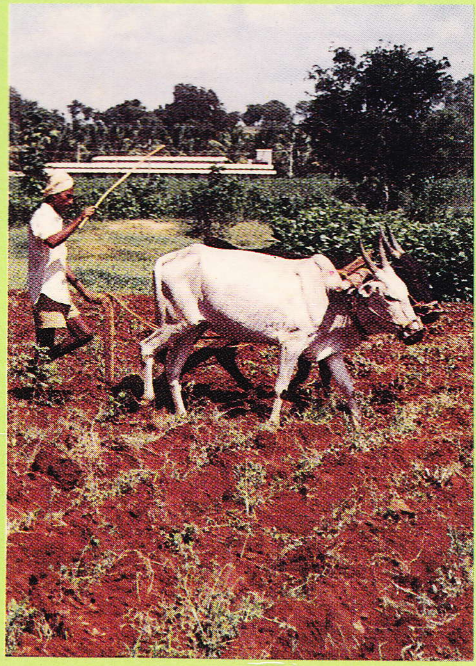
Problematic Soils of Tropical Mulberry Garden and Their Management



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Problematic Soils of Tropical Mulberry Garden and Their Management

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Introduction

Soil

Alongwith atmosphere, *Soil* constitutes the natural medium which supports the growth of plants on earth's surface. Soil is perhaps the more important of the two as plants derive their most essential nourishment from it. It not only serves as a reservoir of food and water needed by the plants, but also provides a mechanical anchorage for them. Furthermore, the air circulating in its pore space aerates the plant roots. In simple, the soil may be defined as a thin layer of earth's crust made up of disintegrated and decomposed rocks, containing complex mineral compounds, organic matter, water, air and living organisms like bacteria, fungi, protozoa, insects, worms etc.

Formation of soil

Soil formation is a very slow but ceaseless biochemical process. Soils are formed by the mechanical disintegration and chemical decomposition of parent rocks. There are three principal kinds of parent rocks: (i) Igneous rock (ii) Sedementary rock and (iii) Metamorphic rock. The weathering of rocks may thus be physical or chemical. The principal agents of physical weathering are heat, water, wind, plants and animals, while the chemical decomposition of rocks is brought about by solution, hydrolysis, carbonation, oxidation and reduction etc.

Types of soil

On the basis of the scientific information available so far, the soils of India have been classified into following major groups:

1. Alluvial soil
2. Black soil
3. Red soil
4. Laterite and lateritic soil
5. Mountain and hill soil
6. Arid and desert soil
7. Saline and alkali soil
8. Peaty and other organic soils

Soils suitable for tropical mulberry garden

Selection of soil is of prime importance in mulberry cultivation. At the time of selection, it is to be remembered that the quality of soil of mulberry field has a profound influence not only on the mulberry leaf yield, but also on its quality. The fertility of soil ultimately affects the growth of the silkworms and thereby quantity and quality of the cocoons produced. In this respect, mulberry is quite distinct from other crops like paddy, wheat etc., as comparatively their quality is not of so much importance.

The soil of mulberry plantation must be capable of maintaining the mulberry plants for prolonged maximum productivity of quality leaves. The ideal mulberry soils are the ones which contain adequate amount of all essential elements in the forms readily accessible to plants, are in good physical condition to support and contain just the right amount of water and air for desirable root growth. Since mulberry is a deep rooted, perennial, hardy and monoculture crop, the soil should be capable of supplying sufficient air, water and nutrients even in the deeper layers where the rhizosphere exists. The soil should not only contain the essential elements, proper amount of air and water but also it must be available to mulberry plants, regularly.

Though mulberry is tolerant to a wide range of soil conditions, it grows well on loamy soil of high fertility. In general, the soil for mulberry should be deep, well-drained, clayey loam to loam in texture, friable, porous, fertile and with good water retention capacity. Slightly acidic soils with a pH value around 6.8 which are free from injurious salts are ideal for good growth of mulberry plants. Saline and alkaline soils and also highly acid soils should be avoided and if not possible, should be suitably reclaimed.

Soil reaction (pH)

One of the outstanding physiological characteristics of the soil solution is its reaction (pH). Since micro-organisms and higher plants respond so markedly to their chemical environment, the importance of soil pH and the factors associated with it, has long been recognized.

The term pH is from the French word *Pouvoir hydrogene or hydrogen power.* The soil pH is the negative logarithm of the hydrogen ion (H^+) concentration in solution. The soil reaction is an indication of the acidity or basicity of the soil and is measured in pH units. The scale goes from 0 to 14 with pH 7 as the neutral point. At pH 7, hydrogen ion (H^+) concentration equals the hydroxyl ion (OH^-) concentration. From pH 7 to 0, the soil is increasingly more acidic; from 7 to 14, the soil is increasingly more basic (alkaline).

Slightly acidic soils with a pH value around 6.8, free from injurious salts are ideal for good growth of mulberry plants. The acidic as well as alkaline soils are not suitable for the growth of mulberry. But both types of problematic soils — acidic and alkaline, are encountered in tropical mulberry gardens. This booklet deals with identification and management of these problematic soils of mulberry garden.

Acid soil

The soil acidity is common in all the regions where precipitation is high enough to leach appreciable amounts of exchangeable bases from the surface layers of soils. Its occurrence and influence on the plants are so widespread that it has become one of the most discussed properties of soil.

Although soils of mulberry garden having pH below 7 are considered to be acidic, but from the practical point of view, soils with pH less than 6.5 and which respond to liming may be considered as *Acid Soils*. The percentage base saturation and the pH are used as criteria to distinguish acid soils from the non-acid ones.

Strongly acid soils are not productive for mulberry plants. On strongly acid soils, the mulberry produces yields less than its potential for one or more of the following reasons:

(i) aluminium toxicity,
(ii) manganese toxicity,
(iii) iron toxicity in a few soils,
(iv) calcium deficiency,
(v) magnesium deficiency,
(vi) molybdenum deficiency and
(vii) nitrogen, phosphorus and sulphur deficiency.

On the basis of pH measurements, the degree of soil acidity is indicated in Table 1.

Table 1 Correlation between pH and degree of acidity

pH	Reaction
6.6 to 7.5	Nearly neutral
6.1 to 6.5	Mildly acidic
5.6 to 6.0	Moderately acidic
5.1 to 5.5	Strongly acidic
4.6 to 5.0	Very strongly acidic
4.5 and below	Extremely acidic

Formation of acid soil

The soils of mulberry garden become acidic when considerable portions of the exchangeable *cations* (positive ions) are hydrogen (H^+) and various forms of hydrated aluminium. The acidity in soils develops to a certain extent from the acidic parent materials, but largely develops because of leaching. As water containing hydrogen cations from various weak acids (such as carbonic and organic acids), ammonium-containing fertilizers, sulphur-containing fertilizers and fungicides etc., moves through the soil, some of the hydrogen cations replace absorbed exchangeable cations, such as Ca^{++}, Mg^{++}, K^+ and Na^+; then water carries the removed cations deep into the soil profile or into the ground water. This process is known as *leaching*.

Reclamation of acid soil

It is generally agreed that the soil acidity and the physiological conditions of soil are the result of the lackness of exchangeable metallic cations. The quantity of these adsorbed cations control the percentage base saturation and thereby indirectly determines the H-ion concentration of the soil solution. Consequently, a rectification of the adverse physiological set up of an acid soil is logically attained by adding suitable quantities of certain compounds carrying one or more of these necessary metals. This simplifies the problem to that of choosing the compounds that will most suitably do the job.

The compounds of metallic cations chosen for supply must possess certain characteristics for their practical and effective use. For example, these materials must be cheap and abundant and while reacting with the soil they should definitely reduce the H-ion concentration. Moreover, they must not be too rapid. Also the metallic cations supplied should stimulate the aggregation of the soil colloids and should not leach from the soil too easily.

Considering all these aspects, *lime* is found to be the most suitable compound for the reclamation of acidic soil.

Lime, the reclamatory measure of acid soil

Lime is a material added to soil to raise the pH (to lessen the acidity). Columella, a Roman philosopher, recorded the use of lime for this purpose in A.D. 45, but Edmund Ruffin, a Virginia farmer — scientist (1825 — 1845), might have been the first person to apply lime on the soil specifically to correct a condition that he said was soil acidity. Today, lime is one of the most common mulberry soil amendments.

In most mulberry gardens, lime is applied as impure calcium carbonate (ground limestone). Mulberry plant response to added lime does not occur immediately, perhaps not for several weeks or months and large amounts are usually needed to be effective. On acid soils, continuous use of ammonium nitrogen fertilizer without the application of lime may decrease the productivity of the soil by making it more acidic.

Types of lime

Liming materials are usually the carbonates, oxides, hydroxides and silicates of calcium and magnesium. More than 90% of the lime applied in the mulberry field is calcium carbonate, next is carbonates of calcium plus magnesium (dolomite lime); a much smaller quantity is composed of calcium oxide or calcium hydroxide.

Effect of lime on acid soil

The addition of lime raises the soil pH, thereby eliminating most of the major problems of acid soils. Mulberry plants respond to liming because it improves microbial activity; corrects calcium, magnesium and molybdenum deficiencies; lessens aluminium, manganese and iron toxicities; improves the phosphorus availability and makes potassium more efficient in plant nutrition.

Lime requirement of acid soil

Soil acidity and lime have a fairly good correlation, so the pH of the soil can be used as an index of the differing lime needs of mulberry soils. The texture of the soil also plays an important role in the determination of lime requirement of acid soils. The lime (finely ground) requirements of different mulberry soils upto a depth of 3 feet as determined by Hutchson and Mclennal's method, are presented in Table 2.

Table 2 Limestone requirement of different mulberry soils (Mt/Ha)

Soil Regions and Textural Classes	Quantity of Limestone required to raise pH to a standard value of 6.5, from		
	pH 3.5	pH 4.5	pH 5.5
WARM TROPICAL REGIONS			
a. Sands and loamy sands	12.50	8.75	5.00
b. Sandy loams	—	15.00	8.75
c. Loams and silt loams	—	27.50	15.00
d. Clay loams	—	43.75	25.00

Efficiency of liming material

The effectiveness of the lime material depends upon the chemical as well as the physical guarantees. The chemical guarantee is expressed as calcium carbonate, calcium oxide or elemental calcium equivalent to the impure whole material. The physical guarantee defines the physical size of the particles, because fine particles are 100 percent effective, medium ones about 40 per cent and coarse ones ineffectual for several years. The neutralising index — the product of both chemical and physical guarantees — is a more accurate representation of the liming material efficiency than either factor alone.

Method of applying lime

Required amounts of lime should be applied to the mulberry garden in two or more applications, part before and part after ploughing; small amounts can be disked-in after ploughing. Lime application to no-till fields is less efficient, but still worthwhile. Liming benefits must be maintained by adding average amounts of approximately one metric tonne per hectare of lime every 4 to 5 years to replace lime neutralized by leaching, acid-forming fertilizers, acidic waters and losses from mulberry plant removal and soil erosion.

Red Soil

Peaty Soil

Desert Soil

Mountain and Hill Soil

Lateritic Soil

Alluvial Soil

Saline Soil

Black Cotton Soil

Alkaline soil

Alkalinity occurs when there is a comparatively high degree of base saturation. The presence of salts, especially calcium, magnesium and sodium carbonates, also gives a preponderance of OH-ions over H-ions in the soil solution. Under such conditions, the soil is alkaline and sometimes, especially if sodium carbonate is present, very strongly so, a pH 9 or 10 being not uncommon. Alkaline soils are, of course, characteristic of most arid and semiarid regions.

Classification of alkaline soils

The alkaline soils have been classified under three heads: Alkali, Saline-Alkali and Saline. The characteristics of different types of alkaline soils are presented in Table 3.

Table 3 Characteristics of different types of alkaline soils

Types of soils	pH	Electrical conductivity (mmhos/cm)	Exchangeable sodium (%)
Saline soil	Less than 8.5	More than 4	Less than 15
Saline-alkali soil	Variable	More than 4	More than 15
Alkali soil	More than 8.5	Less than 4	More than 15

Alkali soil

Alkali soils are those which are salt-affected and contain sufficient exchangeable sodium to affect the plant growth. The exchangeable sodium percentage is greater than 15 and the electrical conductivity is less than four mmhos/cm at 25°C for these soils. The pH reading is more than 8.5. At high pH and in the presence of carbonate ions, calcium and magnesium are precipitated. Hence, these soils contain small amounts of these cations, sodium being the predominant one. Alkali soils cause great damage to the roots of mulberry which makes sprouting difficult and if sprouted, the growth of mulberry is retarded.

These soils usually occur in semiarid and arid regions in small irregular areas, which are often called *slick spots.* In India, an area of 2.8 million hectares consists of such alkali lands and is affected by the highly alkali conditions. These soils contain high amounts of sodium carbonate and sodium bicarbonate salts which lead to high pH. This adversely affects both the physical and nutritional properties of the soils and thus make the soils very unhospitable for mulberry growth.

The exchangeable sodium present in alkali soil may have a profound influence on the physicochemical properties. The alkali soil tends to become more dispersed as the proportion of exchangeable sodium increases and this leads to an unfavourable conditions for mulberry growth. High pH and exchangeable sodium percentages are the chief factors which are responsible for nutrient imbalance and reduction in the availability of plant nutrients in alkali soils. It is necessary to know the fertility status of these soils for making an efficient use of fertilizers. These soils are deficient in total and available nitrogen content but have better status of phosphorus and potassium.

Nitrogen is the most limiting nutrient in alkali soils as the organic matter content is extremely low due to scanty vegetation and the available nitrogen content decreases with the increase in pH. To obtain good mulberry, it is essential to make judicious use of fertilizers so as to make up the deficiency of available nutrients.

Table 4 Different intensities of alkali soil

Instensities	pH	Electrical conductivity (mmhos/cm)	Exchangeable sodium (%)
Low	8.6 to 9.0	Less than 4	Around 15
Low to medium	9.0 to 9.4	Less than 4	15 to 30
Medium to high	9.4 to 9.6	Less than 4	30 to 50
High to very high	9.6 to 9.8	Less than 4	50 to 70
Extremely high	More than 9.8	Less than 4	More than 70

Reclamation of alkali soil

The following different measures (Table 5) which vary in quantity depending upon the pH, electrical conductivity and exchangeable sodium percentage of the soil, are the package of scientific practices which help in reclamation of alkali soils for proper cultivation of mulberry plants on these soils. These reclamatory measures include two types of materials, viz., organic and inorganic.

After the application of any of the inorganic measures the soils should be well drained to leach the soluble salts and to get the required pH value, i.e., slightly acidic to neutral, for suitable mulberry growth.

Table 5. Different reclamatory materials and their requirement

Materials	Quantity (Mt/Ha.)
Organic	
Press mud (available in sugar factory)	20 to 40
Farmyard manure	20 to 40
Inorganic	
Sulphur	0.5 to 1
Gypsum	2 to 4

The use of gypsum on alkali land is often recommended for the purpose of changing part of the caustic alkali carbonates into sulphates. The soil must be kept moist in order to hasten the reaction and the gypsum should be cultivated into the surface, not ploughed under. The treatment should be supplimented later by a thorough leaching of the soil with irrigation water in order to free from it some of its sodium sulphate.

The use of sulphur is advantageous, especially where sodium carbonate is in abundance. The sulphur upon oxidation yields sulphuric acid which not only changes the sodium carbonate to the less harmful sulphate but also tends to reduce the intensity of alkalinity.

Moreover, press mud and farmyard manure can also be used for the reclamation of alkali soil with success.

Importance of leaching

Alkali soils are characterised by high exchangeable sodium percentage values and also contain soluble salts mainly in the form of sodium carbonate and bicarbonate. Frequently, these soluble salts are accumulated in the surface layers in high quantities. Under such conditions, it is very essential to leach down excessive salts from the soil so that surface layer does not contain excessive soluble salts.

If the soluble salts are not leached, the applied gypsum will react with soluble carbonates and bicarbonates resulting in formation of calcium carbonate and render the applied gypsum less effective for replacing the excessive sodium from the soil. Therefore, leaching is essential after the application of inorganic measures for the reclamation of alkali soils.

Saline soil

Saline problems are generally most pronounced in mulberry gardens of tropical and sub-tropical regions because of insufficient annual rainfall to flush accumulated salts from the mulberry root zone. It also develops from the combination of high evaporative demand and shallow depth of ground water, so that considerable salt is moved to the soil surface and accumulated during evaporation.

The main sources of salts in tropical and sub-tropical mulberry gardens are rainfall, mineral weathering, fossil salts and various surface waters and ground waters which redistribute accumulated salts, often as a result of man's activities.

Diagnosis of saline soils of mulberry garden

Diagnosis of potential or existing salinity problem of mulberry gardens is normally carried out by analysing irrigation water, drainage water and soil. When interpreting irrigation water and drainage water analysis, it should be remembered that the salt concentration of the soil increases during water extraction by mulberry plants, with concurrent increases in the sodium absorption ratio. The main predictive parameters for salinity problems are the soil reaction (pH), electrical conductivity and the exchangeable sodium percentage. The term *saline* is used in connection with soils for which the electrical conductivity is more than 4 millimhos/cm at 25°C and the exchangeable sodium percentage is less than 15. In no case does the pH reading exceed 8.5. For specialised plants like mulberry, sodium and chloride analysis should also be considered. In recent years, the terminology committee of the Soil Science Society of America has recommended that the limit of electrical conductivity of saline soils be decreased to 2 millimhos/cm because of the large number of plants can be injured by salinity even in the electrical conductivity range of 2 to 4 millimhos/cm.

Saline soils are often recognised by the presence of white crusts of salts on the surface. Soil salinity may occur in soils having distinctly developed profile characteristics or in undifferentiated soil material such as alluvium.

The chemical characteristics of soils classified as saline are mainly determined by the kinds and amounts of salts present. The amount of soluble salts present controls the osmotic pressure of the soil solution. Sodium comprises more than half of the soluble cations and hence it is not absorbed to any significant extent. The relative amounts of calcium and magnesium present in the soil may vary considerably. Soluble and exchangeable pottassium are ordinarily minor constituents, but occasionally they may be major constituents. The chief anions are chloride, sulphate and sometimes nitrate. Small amounts of bicarbonate may occur, but soluble carbonate is almost invariably absent.

Reclamation of saline soils of mulberry garden

Reclaiming saline soils is a recurring and challenging problem. Long term planning is important to the success of saline soil management of mulberry garden. Much of the early work was of a trial and error nature, because reclamation principles were poorly understood. Much progress has been made during the past 30 years, with the advent of computer modelling contributing significantly to predictions of the effectiveness of various reclamation procedures.

Reclamation of saline soils is essentially a process whereby soil solution of high salt concentration is displaced by less concentrated solution. The reclamation process is aimed at removing or lowering the salinity growth factor, so that mulberry will suffer minimal yield reduction. The reclamation of saline soils of tropical mulberry garden can be managed by the following processes.

LEACHING

Reclaiming saline soils of tropical mulberry garden requires sufficient leaching with a good quality water to remove excess soluble salts from the mulberry rooting zone. The inhibiting factors generally include one or more of the following:

(a) Inadequate drainage because of a high water table, low soil hydraulic conductivity because of restrictive layers or both,

(b) Inadequate supply of good quality leaching water and

(c) The cost of water.

Knowing initial soil conditions and the final desired (tolerable) soil salinity for the mulberry plant, the quantity and quality of water to be used for leaching can be determined. In addition, leaching efficiency can be improved by regulating conditions at the soil surface.

Early reclamation practices involved leaching by water ponded on the soil surface. A general rule was to apply a given depth of water to remove 80% of the soluble salt from the same depth of soil. The salt removal efficiency can be significantly improved by the combination of ponded leaching with periodic application of small quantities of water by sprinkling.

IRRIGATION

Proper irrigation practices in mulberry garden are important to the management of saline soils. Furrow irrigation, for example, usually applies considerable water in excess of mulberry needs. This extra water tends to leach excess salt from the mulberry root zone; although water movement initially takes salts to the mid-row position where mulberry traditionally are grown.

Most tropical soils contain large amounts of residual salt. Irrigations, if frequent enough, keep the salt moving downward in the soil profile. Situations where too little water is applied or where infiltration problems are encountered, salt damage to the crop is almost evident.

Timing of irrigations to maintain a high level of available water in the mulberry root zone during critically sensitive growth stages can also prove to be a highly useful approach.

MULCHING

Water and soluble salt movement through soil is a dynamic process. When sufficient water has been applied for leaching, there is a net downward movement of water and salt. As the soil surface dries and as mulberry uses water, the direction of movement may then reverse towards the point of water use. As the water is transpired or evaporated, most of the soluble salt is left in the soil where it accumulates until subsequently moved again by water. Any practice that will reduce the upward movement of water and salt by reducing evaporation or by increasing infiltration will enhance salt leaching and soil reclamation.

Surface mulches could reduce upward water and salt movement sufficiently. Straw mulches effectively reduce evaporation from dry land mulberry soils. Such mulches enhance leaching by rainfall sufficiently to keep mulberry producing lands in production for an area affected by salt.

MULBERRY SALT TOLERANCE

Mulberry salt tolerance can be defined as the ability of mulberry plants to survive and produce economic yields under the adverse conditions caused by soil salinity. Salt tolerance of mulberry is typically expressed in terms of the decreased leaf yield associated with increased soil salinity or as relative leaf yield on saline versus non-saline soils.

The adverse effects of salts on mulberry plants are generally divided into three categories. Often of over-riding importance is the osmotic or total salt effect, which affects the ability of the plant to absorb water for its growth processes from the soil solution. The second category involves specific-ion effects or the toxicity of specific ions to various plant physiological processes. The third category is the secondary specific-ion effect of sodium. Excess exchangeable sodium can lead to soil swelling and/or dispersion, causing water infiltration, aeration and root panetration problems.

Therefore, the best and most economic and effective way to manage the salinity problem of tropical mulberry garden is the evolution of salt tolerance varieties of mulberry, which is to be achieved yet.

Thus there is a need to undertake a preliminary screening to find out the promising mulberry varieties suitable for saline soils which ultimately leads to the field trials of the promising salt tolerant varieties.

Conclusion

It is a fact that mulberry leaf is the most important component contributing towards the raw silk yield and any effort to increase the raw silk yield/ha, will have a direct bearing on the increase in the leaf yield invariably. This factor assumes greater importance today, when the efforts are on to step up the country's raw silk yield/ha. The success now rests on a good farm management and in turn good farm management needs regular soil testing. The soil test in the hands of a soil scientist may perhaps be compared with the thermometer in the hands of a physician.

Although, the concept of soil testing gained attention as early as in the last century itself, but its introduction into the mulberry in particular, is comparatively a new concept and needs to catch the interest of the farmers. The time has come to evaluate the soil of the mulberry garden before taking up a new plantation as well as for periodical analysis of the soils of the existing mulberry gardens and to ensure rectification of the problems by way of package of practices discussed in this booklet to maintain an ideal condition of the soil for the best yield of quality mulberry leaf.