Chapter 8

Nutrition

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1. Introduction

The coconut is a perennial plantation crop that stands for few decades in the same field and absorbs the nutrients in the same proportion from a limited soil volume. Coconut is a heavy feeder of nutrients and a crop having simultaneous vegetative and reproductive growth all through the year. This nature demands a constant supply of all the required nutrients year around in order to achieve the potential productivity. Hence, needs a careful nutrient management strategy developed based on the nutrient exhaust and soil nutrient availability and uptake. Thereby, the knowledge on the nutrient requirement, functions of nutrients, deficiency and toxicity, soil characteristics and the nutrient management techniques becomes paramount important for a successful coconut farming. Soil characteristics are dynamic both spatially and temporally. Therefore, their nutrient supplying power, constraints and management requirement are unique to each soil type. Hence, soil and nutrient management should be tailor made for each soil unit. Coconut is grown worldwide in different soil types. Thus, the basic understanding on the soils of coconut and their characteristics and constraints will strengthen the knowledge on coconut nutrition and its management.

2. Coconut growing Soils

In worldwide coconut is grown mainly in red, laterite, sand, alluvium, coralline volcanic and peaty soil types. Among these, red and laterite soils are found to be the largest soil type under coconut cultivation especially in India and Sri Lanka. These soils are loose, porous, well drained soils with low cation exchange capacity and poor water retention power. They are highly leached acidic soils with low bases and excess aluminum, iron and manganese content.

Sandy soils are the second major soil type found under coconut. This soil type is found in coconut plantations of coastal belts of India and Sri Lanka. Sandy soils are found in the coconut plantations in West Africa, Madagascar, Mozambique and Malaysia. These are loose single grained soils with low clay and silt content. Therefore, this soil type is poor in water and nutrient retention capacity. They are low in soil fertility status and the leaching losses of applied nutrients are more compared to other soil types. Hence, this soil type needs special soil and nutrient management practices.

Alluvium soils are considered the best suited for coconut among all the soil types. The deep alluvial loamy soils are highly fertile and well drained hence, poses minimum production constraints for coconut. The deep loamy soils of the deltaic regions of Godavari, Cauvery, Krishna, Mahanadi, Brahmaputra and Ganga in India are extensively cultivated with coconut. In Sri Lanka, the loamy soils of alluvia of the Ma-Oya, Deduru-Oya and Batholu-Oya rivers and their tributaries in the North-West province and the estuarine deposits of the silted up Negombo, Madampe, Mundel and Puttalam lagoons on the West Coast are highly productive (Child, 1974). Similarly, alluvial limestone deposits in Philippines, which are exceptionally fertile (Cooke, 1936) and marine alluvial soils in Indonesia are having the best coconut plantations.

Coral soils are a mixture of coral, sand and rock and moreover entirely calcareous (Newton, 1967). Hence, deficiency of iron, manganese, nitrogen and potassium are observed. Fertility of this soil type depends on the organic matter content and degree of weathering. This soil type is found in the coconut groves of Lakshadweep (Arabian sea) and some parts of Andaman and Nicobar islands in India and Maldive Islands. Though the soils are poor in organic matter and few plant nutrients, the under ground partially saline water supply all the nutrients in the island habitats wherever the coconut production is good.

In Indonesia and in the Philippines, coconut is cultivated in the volcanic soils, which are generally fertile soils and the coconut productivity is good. Clay soils are generally a least suitable soil for coconut cultivation especially the soils with a stiff clay sub soil are posing severe constraint for coconut cultivation. Estuarine clays In Sri Lanka formed by the silting up of estuaries and lagoons are considered to be unsuitable for coconut because these soils become waterlogged during monsoon and baked and cracked during dry weather. Deep ploughing, husk burying, draining and leguminous cover cropping are some of the practices suggested for improving such areas (Child, 1974). Peaty soils in Malaysia, having organic carbon more than 80 per cent are not generally suitable for coconut (Cooke, 1936). But, large coconut areas in Malaya exist under heavy clays and peaty soils. In India, Kari or Peaty soils found in Kerala are strongly acidic and deficient in phosphorus and calcium. Regular reclamation and nutrient management is required in this soil for coconut cultivation.

3. Nutrient Requirement of Coconut

The annual exhaust computed from one hectare of 173 palms in sandy loam soil is 65.6, 29.7, 84.5, 47.4 and 20.3 kg of N, P_2O_5, CaO and MgO respectively taking into account the nuts, fallen leaves, spathes and the stem growth (Pillai and Davis, 1963). In Phillipines, the annual mineral nutrient demands of coconut estimated at per hectare basis are 95 kg K, 65 kg Cl, 50 kg N, 11 kg Na, 7 kg P, 8 kg Mg, 5 kg Ca and 4 kg S (Magat, 1998). The amounts of macronutrients lost through the removal of plant components from the field of *typica* x *typica* coconut palms yielding an average of 17, 38 nuts ha^{-1} $year^{-1}$ in Sri Lanka, were 116.79 kg N, 14.02 kg P, 245.43 kg K, 40.47 kg Ca, and 33.66 kg Mg per hectare per year. The amounts of micronutrients lost were 1.14 kg Fe, 0.63 kg Mn, 0.13 kg Cu, 0.44 kg Zn and 0.26 kg B per hectare per year (Somasiri *et al.*, 2003).

The nutrient exhaust studies showed that the proportionate requirement of NPK of the palm in terms of N, P_2O_5, K_2O is 2:1:3. The quantitative order of requirement of major nutrients for adult bearing palm is K>N>Ca>Mg>P. Potassium dominates the nutrient requirement of the palm while P requirement is found to be the least (Pillai and Davis, 1963; Ramadasan and Lal, 1966). Potash was found to be the most removed, followed by nitrogen, calcium, magnesium and phosphorus. The quantity of nutrients removed varies with the soil type and yield. Palms growing on coastal alluvium removed 70 kg K_2O ha^{-1} but the average removal from red sandy loam and laterite was around 53 kg K_2O ha^{-1} (Ramanandan and George, 1982). The total nutrient exhausted in the coconut based cropping system ranged from 130.45, 18.29 and 172.64 kg of N, P and K respectively per hectare in the full dose of recommended fertilizer to 97.11, 13.06 and 125.45 kg ha^{-1} of N, P and K, respectively in the no fertilizer treatment (Subramanian *et al.*, 2005).

The quantity of K exhausted through the harvest of bunches is 78 per cent and that used for the growth of stem and leaves is only 22 per cent. Potassium is the nutrient removed in the highest quantity and the highest proportion found in the nuts which suggests the importance of potassium nutrition in coconut productivity. Among the macro nutrients, the proportion of Ca used for the development of bunches is the least but for the growth and development of stem and leaves is the highest suggesting the importance of Ca for the growth of leaves/stem. The quantity of Ca exhausted through the shedding of leaves alone is 73.8 percent. In the case of Mg, the quantity removed for the growth of stem and leaves is about 60 per cent while that exhausted through the harvest of bunches is about 40 percent. The nitrogen and phosphorus removal are almost fifty per cent for vegetative (stem and leaves) parts and for the yield of nuts (Pillai and Davis, 1963).

4. Mineral Nutrients

4.1. Nitrogen

Nitrogen is an essential constituent of amino acids, proteins, nucleic acids and chlorophyll. Visible symptoms of nitrogen deficiency are yellowing of foliage and stunted growth. In the initial stages of deficiency the leaf losses green color and the whole leaf shows uniform/continuous yellowing (Figure 8.1). In the advanced stages older leaves develop uniform golden yellow color and the younger leaves starts yellowing. Inflorescence abortion and reduction in the number of female flower per inflorescence occurs. Size of the leaves and number of functional leaves reduce. In the advanced stage the stem just below the crown starts tapering and

Figure 8.1: Nitrogen Deficiency Symptoms.

appears like a pencil point with few leaves on the crown. The inflorescence fails to emerge or produces very few female flowers and the palms become unproductive.

Nitrogen deficiency occurs in dry climatic condition where the nitrification is less. In calcareous soils, due to alkalinity, which reduces the mineralization of organic matter, results with nitrogen deficiency. Sandy soils which are deficient in organic matter, prolonged waterlogging condition and soils with poor or inadequate nutrient management also shows nitrogen deficiency. Application of organic manure and nitrogenous fertilizers improves the growth parameters of palms. The full effect of nitrogen fertilizer results when the sulphur and potassium levels are sufficient in the soil. Excess N application adversely affects the copra yield. Leaf analysis is the best diagnostic method and 1.8-2.0 per cent N in the 14^{th} leaf is the critical limit. Based on experiments conducted nationally and internationally, it has been well accepted that soils with 1 per cent organic C status was ideal for coconut cultivation. Further, long-term observations concluded that 70 to 80 ppm of mineralizable nitrogen in soil is optimum. Blakemore *et al.* (1972) reported that 0.30 g kg^{-1} of total nitrogen is critical for tropical soils. Studies on the effect of slow release N and P fertilizers (different combinations of urea, urea formaldehyde, neem coated urea, lac coated urea mixed along with coir dust, tar, single super phosphate, mussorie rock phosphate and muriate of potash) revealed that among the slow release N fertilizers urea form, neem cake coated urea and coir dust mixed with urea have been found to remain for a long period in the sandy soil, thus facilitating availability of N in the more permeable soil. Mussorie phosphate is equally efficient as super phosphate in sandy soil (Bopaiah *et al.*, 1998).

4.2. Phosphorus

Phosphorus is an essential constituent of many vital cellular compounds like ATP, ADP, AMP, RNA, DNA and other phosphorylated sugars and fats. Phosphorus requirement in terms of quantity is comparatively less and the deficiency is not widespread. Phosphorus deficiency does not result with characteristic visual symptom apart from slowing down of growth and shortening of fronds (Manciot *et al.*, 1979a). The leaves are dark green in colour accompanied with stunted growth and rosette appearance in the young palm.

Only few reports from Madagascar, India, Sri Lanka and Ivory Coast showed favorable effect of P-manuring on coconut yield after several years of continuous P-applications (Manciot *et al.*, 1979a). Mussorie phosphate is equally efficient as super phosphate in sandy soil (Bopaiah *et al.*, 1998). Phosphorus is the least mobile element in the soil, therefore the loss of P by leaching is minimum which leads to the built up of P in soil when P-fertilizers are continuously used and the residual effect was observed a number of years later. In Sri Lanka, very poor latosols with traces of available P showed good response from applications of 0.12 kg P per palm. The soil phosphorus potential was then built up to a level, at which discontinuance of P application did not lead to any reduction in yield for at least five years (Child, 1974). Similar results were reported by Khan *et al.* (1990) in India. Available soil phosphorus (0-30 cm) had been increased from 84 ppm to 121 ppm when annual fertilization of P was done at the rate of 320 g P_2O_5 palm^{-1} for 14 years. They further observed in plots where P was not applied, it has been decreased from 84 ppm to 21 ppm during the same period. They reported that skipping P application for 14 years (1975-1989) did not show any adverse effect either on yield or foliar P levels which suggest that the recycling of P reserves can sustain coconut productivity for longer periods. A phenomenal build up of phosphorus was observed in the high density multispecies cropping system involving 18 crops over a period of three years. Similar trend was observed in mixed farming and coconut-cocoa mixed cropping systems at CPCRI, Kasaragod (Bavappa *et al.*, 1986).

A foliar content of 0.11-0.12 per cent P (frond 14) can be regarded as critical for coconut under Indian conditions. Further work at ICAR-CPCRI revealed that if soil available P is less than 10 ppm, full recommended dose of 320 g P_2O_5 palm^{-1} year^{-1} may be applied and for a soil test value of 10 to 20 ppm, 50 per cent of the same may be applied. For soil test values of more than 20 ppm, P application can be skipped.

4.3. Potassium

Potassium is the most abundant cation in the cytoplasm and makes a major contribution in the osmotic potential of plant cells. Therefore, plays a major role in regulating water economy in plants and imparts drought tolerance. It also imparts disease resistance to plants. Potassium activates a variety of enzymes in plant cells. It is very much concerned in the biosynthesis of proteins, fats, fibre and sugars. Potassium maintains plant cells turgid and helps the translocation of photosynthates from the leaves to the sink areas, mostly the nuts in the palm. Being mobile within cells, tissues and in long distance transport through the xylem and phloem, during deficiency it is translocated from mature leaves to young leaves. Therefore, the deficiency symptoms starts from the older leaves.

Potassium deficiency adversely affects all the production factors, particularly the nut set. The first visible symptom is the development of rusty spots in two longitudinal bands on either side of the midrib with slight yellowing of the lamina (Figure 8.2). The yellowing is more marked towards the tip of the leaflets. When the yellowing intensifies, the older leaves assume an orange-red

Figure 8.2: Potassium Deficiency.

tinge while the younger leaves remain green. The yellowing is never uniform like nitrogen. Leaflets are greener at the base than the distal ends where necrosis starts by the rusty spots coalescing into numerous irregular brown blotches. In the advanced stage, characteristic to potassium deficiency the yellowed surface becomes necrotic resulting into more of a necrotic appearance than of yellowing. This is different from Mg-deficiency where the palms show more of chlorotic appearance than of necrotic. In the early stages, K-deficiency starts with yellowing of leaves in the middle of the crown and necrosis of older leaves in the advanced stages. The dried up older leaves hang beside the trunk. The growth in general is reduced, the trunk becomes slender leaflets become short, and the number of inflorescences, nut set and nuts bunch^{-1} get reduced. The deficiency symptoms are usually visible only when the leaf K level (frond 14) falls below 0.4 per cent. Potassium deficiency leads to chlorosis and leaf scorch, and the development of poor crown with short fronds (Salgado, 1953).

Being a heavy consumer of potassium, if it is in short supply the severity of K-deficiency has been found to be one of the most limiting factors for coconut production. The very good yield response is observed on its correction through potassium fertilization. Scorching of leaf tips was corrected by K manuring (Menon and Pandalai, 1958). Potassium deficiency in the early pre-bearing stage may not be fully corrected by subsequent K additions in the bearing stage and remains less productive than the palms never suffered potassium deficiency (Fremond and Cuvrier, 1971). Hence, the adequate potassium supply should be ensured right from the planting for higher productivity. Moreover, potassium manuring results with early bearing. The optimum soil values reported for potassium is 0.2 cmol kg^{-1} in Malaysia (Chan, 1978). Application of K results in the improvement of all yield parameters such as the number of bunches palm^{-1}, number of female flowers bunch^{-1}, fruit setting, number of nuts bunch^{-1}, copra nut^{-1} and the total copra out turn palm^{-1} (Fremond, 1964; Mancot *et al.*, 1979b). More than ten fold increase in yield was obtained with 450 g K_2O palm^{-1} year^{-1} and the increase was about thirteen fold with 900 g K_2O palm^{-1} year^{-1} at the Coconut Research Station, Balaramapuram Kerala (India) on red loam soil (Wahid *et al.*, 1988).

Potassium adsorption is antagonized by the high concentration of Ca, Mg and Na. The critical level of 0.8-1.0 per cent K in frond 14 is practiced for regulating the K-nutrition of the traditional varieties. High potassium fertilization induces Mg deficiency and high Mg application induces potassium deficiency in soils with poor K levels. The studies on interaction between plant available potassium and magnesium in highly leached red yellow podzolic soils with laterite in Southern coastal area of Sri Lanka and its effect on coconut palm showed that the application of potassium decreased the quantity of both exchangeable and water extractable magnesium and application of magnesium fertilizer decreased the quantity of exchangeable potassium in soils which is attributed to low cation exchange capacity and base saturation of the soils (Somasiri, 1997).

4.4. Calcium

Calcium is a less mobile element and plays a major part in the formation of cell walls. Calcium relates with proper growth and functioning of stem and leaves. Calcium is involved in membrane stability and cell integrity and it also helps maintenance of acid-base equilibrium in the sap. Calcium activates only a limited number of enzymes in plants than K or Mg. Calcium deficiency in coconut is not very common. The visual symptoms are yellowing of leaflet tips with yellow to orange ring-shaped spots spread on the leaflets which later become necrotic and brown, and eventually the leaf dries up. Symptoms appear first in the middle leaves before appearing in the oldest. Visual symptoms of Ca deficiency appear with leaf Ca levels below 0.1 per cent (Mancot *et al.*, 1979 b).

Regulated additions of Ca through Ca-bearing fertilizers or light addition of liming materials may be followed for supplying the Ca requirement of the palm (Cecil, 1981). This is important considering the heavy loss of Ca by crop removal and also by excessive leaching under high rainfall conditions in the tropics. The critical level of Ca is 0.3 per cent Ca in frond 14 for regulating the Ca requirement of the palm under West Coast conditions of India (Cecil, 1984) and in the Philippines (Magat, 1979).

4.5. Magnesium

Magnesium is the central atom of the chlorophyll molecule. Mg is involved in the regulation of cellular pH and the cation-anion balance in the cell. Magnesium activates a variety of physiologically important enzymes and also involved in Mg-dependent ATPase activity in the plant membrane. It also has an essential function as a bridging element for the aggregation of ribosome subunites which is necessary for protein synthesis. When the level of Mg is deficient or in the presence of excessive levels of K, the subunite dissociate and protein synthesis is impaired.

Chlorosis of matured leaves is the most obvious visible symptom of Mg-deficiency (Figure 8.3). Magnesium deficiency starts as yellowing at the tip of leaflets

Figure 8.3: Magnesium Deficiency Symptoms.

at the distal part of mature leaves which gradually spreads towards the basal parts of the leaflet as well as the leaf. As the deficiency advances, characteristically yellowing becomes intense in the periphery of the leaf blade leaving a narrow longitudinal green band parallel to the midrib on either side of the leaflet. When the deficiency gets worse, yellowing further intensifies, the number of green leaves becomes less and necrosis sets in at the tips of the leaflets. The other characteristic symptom is that the deficient leaf part which is exposed to sunlight shows intense yellowing while the part of the same leaflet in the shade remains green. In the advanced state, intense yellowing accompanied by severe necrosis and browning develops, and the mature leaves wither away prematurely leading to a lesser number of functioning leaves on the crown. The frond production rate is reduced, onset of bearing is delayed in young palms and the productivity is adversely affected.

Nethsinghe (1963) observed in Sri Lanka that the magnesium deficiency symptoms could appear when the Mg content (frond 6) was less than 0.2 per cent. A critical level of 0.2 per cent Mg (frond 14) was suggested as a diagnostic aid for regulating Mg nutrition of the palm under West Coast condition of India (Cecil, 1981 and 1988). The suggested critical levels were 0.3 per cent in Malaya Kanapathy (1971). 0.2 per cent in the Philippine (Magat, 1976). Magensium deficiency is common in acid sandy soils. Magnesium deficiency is caused by inadequate soil supply or due to imbalance of nutrients like K/Mg or Ca/Mg ratio. Due to heavy input of K^+ and NH^{4+} fertilizers, displacement of Mg from its exchange site occurs and resulting in leaching loss of Mg (Ochs and Ollangnier, 1977). A threshold level of 0.2-0.5 m.e/100 g of exchangeable Mg out of 1.0 m.e/100 g of total exchangeable cations is suggested (Mancot *et al.*, 1979 a). At higher Mg/K ratios, the action is not significant (Cecil, 1981, 1988).

Application of Mg-fertilizers corrects the deficiency and resulting with re-greening of chlorotic foliage accompanied improvement in growth and yield of nuts. As much of 40 per cent effect on yield was observed by Mg application when K was in the sufficiency level, but magnesium influenced only on the number of nuts/tree and had no effect on the copra/nut (Mancot *et al.*, 1979b; Cecil, 1981). Significant high response on growth, flowering and initial yields of young palms was observed with the application of 500 g MgO $palm^{-1}$ $year^{-1}$. A depressive effect of K on leaf Mg content was observed when the soil and the leaf Mg contents were low and had a synergistic effect when the Mg levels were improved due to regular Mg additions. The action of K-fertilizers on leaf Mg content largely depends on the balance between K and Mg in the soil. The depressive action is severe when the exchangeable Mg/K ratio in the soil is less than 2.0-2.5.

4.6. Sulphur

Sulphur is an essential component of the sulpholipids in cell membranes, amino acids cysteine and methionine. It is also a constituent of several coenzymes and prosthetic groups such as ferredoxin, biotin and thiamine pyrophosphate. Moreover, sulphur plays a key role in the redox systems in plants. It is involved in oil synthesis, copra quality as well as chlorophyll synthesis. Sulphur deficiency inhibits protein synthesis and causes a reduction in the chlorophyll content. Sulfur deficiency shows similarity with the nitrogen deficiency. Sulphur deficient leaves are yellowish orange to orange in colour but the nitrogen deficiency shows uniform yellowing. Sulphur deficiency affect the young leaves but the nitrogen deficiency affects the older leaves first. Both nitrogen and sulphur deficiency reduces the nut size but in case of nitrogen deficiency the copra is normal whereas the sulphur deficiency produces rubbery copra.

Sulphur deficiency occurs with foliar sulphur content below 0.13 per cent in frond 14. The critical level of 0.15-0.20 per cent S is widely practiced for regulating the sulphur requirement of the palm. Regular use of sulphur containing fertilizers could take care of the sulphur requirement of the palm. Organic manuring may increase the organic sulphur status of soil and reducing leaching losses. Intensive leaching of nutrients in the humid tropics, makes the soil deficient in sulphur. Use of sulphur-free fertilizers like urea and rock phosphate in place of superphosphate and ammonium sulphate tends to cause shortage in supply of sulphur to the palm. S-deficiency did not seem to be an immediate problem for coconut in the West Coast of India, but continued application of sulphate-free fertilizers could eventually lead to S-deficiency conditions. The inclusion of any one of the S-bearing fertilizers like ammonium sulphate, single superphosphate, Ammo-phos, magnesium sulphate or sulphate of potash may be included in the fertilizer schedule for coconut wherever possible to manage sulphur deficiency (Cecil and Pillai, 1976).

4.7. Iron and Manganese

Iron is an essential constituent of certain enzymes, especially the cytochromes, which participate in the electron transfer system. Iron concentration is low in young leaves and gradually increases with maturity of the leaves. The internal recycling of this nutrient is very much restricted. Iron deficiency occurs in coconut as gradual yellowing in all the leaves. Yellowing of the entire leaflets occurs in all the leaves. Yellowing develops as longitudinal strips parallel to the veins and the leaf becomes completely yellow in the advanced stage but no necrosis. The rachis and leaflets become shorter. Iron deficiency can be differentiated from nitrogen deficiency with the appearance of characterisitic strip yellowing/discolouration in the initial stages.

Manganese is a co-factor in some of the oxidative enzymes and participates in the oxidation–reduction reactions in the plant. Similar to that of iron, Mn concentration is low in young leaves and increases with maturity. The critical level of Mn is considered as 60 ppm in frond 14. Mn deficiency is not observed in acid tropical soils but found on coral soils. The acid laterite and red soils has high Fe and Mn content, their contents may often reach to toxic levels, particularly under anaerobic conditions. It is found to be in a moderate level in alluvial, volcanic, peat and clay soils, low in coastal sandy soils and very low in coral soils. The high calcium carbonate content of the coral soils, affect the uptake of Fe and Mn by the palm. Severe deficiencies of Fe and Mn were reported in the coral tolls of Oceania which were not corrected by soil application of iron and manganese salts (Pomier, 1964, 1969). He also suggested the placement of 400 g ferrous sulphate and 100 g manganese sulphate in a hole dug deep near the bole region, and this treatment was reported to be effective for a period of three years.

4.8. Boron

Boron is a relatively immobile element. It is concerned in the water relations in cells and in the translocation of sugars in plants, it enhances tissue respiration, it is concerned in the nitrogen metabolism and the oxidation –reduction equilibrium in cells. Boron is an essential micronutrient for coconut, which helps in the multiplication of meristematic tissues, hence, deficiency leads to the death of the apical growing point preceded by abnormal/deformed growth of young leaves. It helps the metabolism of protein, synthesis of pectin, maintenance of water relation, translocation of sugars, fruiting process, growth of pollen tube and in the development of flowers and fruits.

The symptoms of the diseases are the fusion of young fronds, emergence of shorter fronds that crowd around the apex, development of deformed and crinkled pinnae, development of 'hook' at the frond tip and also at other parts of the frond, development of fronds with very short unfolded pinnae either on one or both the sides of the rachis with zig-zag foldings, necrosis on rachis and frond tips and the development of black necrotic stumpy frond without any pinnae in the advanced stage and finally the growth of the bud is arrested and the palm dies (Figure 8.4).

The unaffected outer whorls of leaves remain normal throughout and even for quite some time after the death of the growing point. Laminal expansion is very much restricted and the affected pinnae become thicker than normal and brittle. The crowding of young abnormal fronds around the bud gives a choked appearance to the palm and hence named as 'frond choke'. In some cases the young affected fronds show 'Witches' broom' appearance. In other cases the petiole of the new frond becomes very thick and forms a tubular structure enclosing the entire space of the apex (Figure 8.4).

The symptoms, *viz.*, crinkling, whipping, hooking, cracking, bulging in the base of the nut; cracking in the husk, shell and inside the mesocarp; discolouration of mesocarp, decaying of the kernel resulting in poor quality copra; production of nuts without shell formation; formation of branched inflorescence, inflorescence with blackish colour, etc. are due to boron deficiency.

The deficiency in young coconut is characterized by the presence of deformed leaf fronds or "little leaf", followed by non-splitting or delayed opening of leaflets that usually appear in zigzag-like pattern in advanced or severe deficiency stage. The apical shoot blackens, exhibiting growth failure and death of tissues and plant per se (Magat, 2008).

Boron toxicity symptoms in coconut are the development of reddish yellow colouration at the tips and margins of leaflets of the older leaves which is followed by severe necrosis of the leaflets, particularly at the distal parts, which makes the affected leaflets curved downwards.

The critical level of boron is 9-11 ppm in frond 14. The critical limit for hot water soluble boron was 0.1 ppm (Pillai *et al.*, 1983) Small quantities of boron are added to the soil through rock phosphate as a contaminant. Since the concentration range

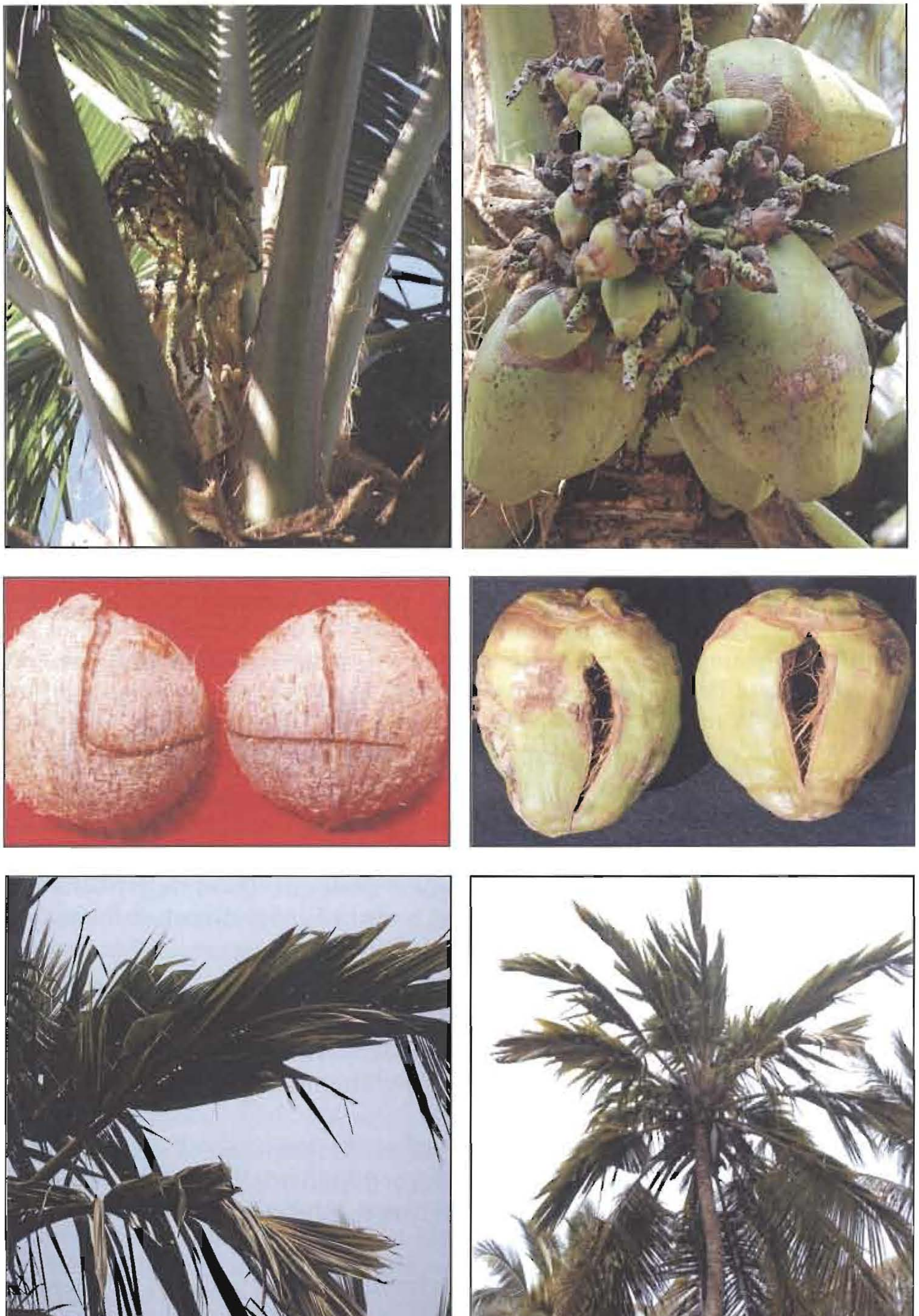

Figure 8.4a: Boron Deficiency Symptoms.

Figure 8.4b: Boron Deficiency Symptoms.

between deficiency and toxicity of boron is very narrow, the application of borax requires special care. Baranwal *et al.* (1989). recommended soil application of borax decahydrate at 50 g per palm just after the appearance of crown choke symptoms. In slightly advanced stages, two applications of borax, 50 g each, at an interval of 3-4 months was found necessary for the redemption of the disorder. Application of borax 120-180 g/plant with husk burial is recommended which helps in remission of B deficiency symptoms about 65 per cent of deficient palms. Yield increase of boron application is due to its important role in cell wall formation and in pollen tube but the interval between the boron foliar levels at maximum fruit yield and the intoxication levels is rather short. Therefore, applications of boron fertilizer to coconut palm trees should be very carefully planned to avoid plant intoxication (Prado, 2008).

4.9. Zinc and Copper

Zinc deficiency is characterized by formation of small leaves wherein the leaf size is reduced to 50per cent. Leaflets become chlorotic, narrow and reduced in length. In acute deficiency, flowering is delayed. Zinc deficiency will also causes button shedding. The characteristic symptoms include severe bending of rachis of the young leaves accompanied by yellowing and drying of leaf tip which appears rimmed with brown and yellow while the middle portion remains normal green. The deficiency symptoms are termed as peripheral leaf desiccation. This involves severe bending of the rachis of the youngest leaves accompanied by yellowing and desiccation of the leaf tip with the central part remaining green. When the deficiency is severe, new leaves are deformed and are abnormally short giving the palm a runty sagging appearance. Petioles form arc-shape, eventually losing turgidity. Premature dry up and necrosis of the tips of leaflets occurs. Leaf color changes from dark green to yellow from the tips towards the leaf petiole while the lamina along the midrib remains green.

Acidic, laterite and lateritic soils are deficient in zinc. Copper deficiency is common in the peat soils, minerally poor acid sands and gravels as well as the highly calcareous sands. Liming reduces the availability of Cu (Southern and Dick, 1967). Addition of organic manures and zinc and copper sulphates reduces the corresponding deficiency. Care should be taken to avoid buidup of these nutrients especially copper in to toxicity level. Micronutrient deficiency (Cu and Zn) was observed in Coconut Rapid Decline (CRD) disorder affected palms. Two years after micronutrient or common salt treatment, number of total fronds and functional green fronds in the canopy were increased. The stomatal diffusive resistance of these palms was also reduced after two years showing an improvement in palm water status (Wijebandara and Ranasinghe, 2004).

4.10. Molybdenum

The requirement of molybdenum for coconut is very small and deficiency of molybdenum is not widespread in coconut farming.

5. Soil Management for Coconut Nutrition

Soil properties are important factors which influences the adequate nutrient and water supply to coconut in order to achieve higher productivity of coconut. Among the soil properties soil physical properties are more important since they are challenging to modify than managing the soil fertility. Coconut requires at least 1 metre of fertile soil for healthy coconut growth (Ganarajah, 1953) because 96 per cent of the roots present in 0-120 cm depth in middle aged palm (Maheshwarappa *et al.*, 2000). Moreover, more number of main roots was found in layer of 31-60 cm depth and decreases in the deeper layers (61-90 and 91-120 cm) (Dhanapal *et al.*, 2000). Presence of hard soil pan, bed rock or permanent water table within one metre depth will not be preferable. Even if the initial growth and yield is good coconut growth and productivity may start declining after few years and hence is considered as unsuitable for coconut.

High moisture extraction by coconut roots was confined to a depth ranging from 20 to 120 cm and of 20 to 250 cm in soils of *Andigama* (gravelly soil) and *Madampe series* (sandy loam soil), respectively in Sri Lanka, due to differences in soil compaction levels. Soil compaction higher than 250 N/cm^2 restricted the activity of coconut roots in the gravelly soil. Soil compaction limits the water absorption ability of coconut roots vertically from the base of the tree, rather than coconut root growth and penetration. Intercropping with *Gliricidia sepium* under coconut showed the possibility of improving degraded soil conditions (Vidhana Arachchi *et al.*, 1999). Growing *Gliricidia sepium* as intercrop plays a major role in improving physical characters of infertile gravelly soils (Vidhana Arachchi and De S. Liyanage, 1996).

Sandy soils having very low clay content leads to high infiltration and percolation rate coupled with low CEC and low organic carbon content, this soil type is subject to high leaching loses of applied nutrients during monsoon and severe moisture stress due during summer. Since, they pose a great challenge to cultivate in this soil type. Even regular application of chemical fertilizers failed in building up soil nutrient status in littoral sandy soil mainly due to low nutrient retention capacity of the soil (Srinivasa Reddy *et al.,* 1999). Improvement of the soil organic matter content is a prerequisite for the successful management of coconuts on such soils. Husk burial in the coconut basin and burial of dried coconut husk in trenches and/or applying 5 cm thickness of coir pith in the planting zone significantly increases yield of coconut intercrops like fodder due to higher soil moisture, nutrient availability especially potassium and enhanced biological activities in the rhizosphere when soil moisture conservation measures were implemented. Moreover, this soil moisture conservation techniques enables more biomass production from sandy soil which can on recycling improves the organic matter content and thereby improves the water and nutrient retention capacity of low CEC soils (Subramanian *et al.,* 2007).

Rate of *in situ* N-mineralisation in the Coconut Based Cropping System with clove, banana and pineapple as component crops where the wastes produced were vermicomposted and applied to all crops was higher in coconut basin area (2.2 ppm N per day) upto $1/3^{rd}$ of recommended fertiliser dose (Palaniswami *et al.,* 2010). Biomass recycling under mixed farming practices results with higher water holding capacity, reduction in the bulk density and higher hydraulic conductivity under mixed farming treatments compared to monocropping of coconut. Increase in maximum water holding capacity of soil (from 24.0 to 33.6 per cent), improvement in porosity of soil (38.2 and 39 per cent 44.5 and 46.0 per cent) and reduction in bulk density of soil (1.54 g cc^{-1} to 1.40 g cc^{-1}) both in coconut manuring circles (basins) and grass cultured plot was also observed (Palaniswami *et al.,* 2008).

Coconut palm adapts to a wide range of soil acidity. Soil acidity generally gives an indication about the nutrient availability. The pH of representative Indian soils is reported to be in the range of 5.2 to 8.0 (Menon and Nair, 1952). Coconut can be cultivated in the soil pH range of 5 to 8 (Mancot *et al.,* 1979). The ideal soil pH for coconut growing soils ranges between 5 to near neutral (Fremond, 1964). Red and lateritic soils of humid tropical conditions, have $A1^{3+}$ as the dominant cation, hence, their pH is very low (4.2-5.8) on the other hand, the pH of alluvial soils tends towards neutral. The principal management practices that should be imposed is to correct the soil acidity by liming and soil alkalinity by gypsum application as per the lime requirement or gypsum requirement of the soil. In case of acid sulphate soils, the correction of acidity and suppression of aluminum could be achieved only by using magnesium silicate. The coral soil, which contains calcium as the dominant cation followed by Mg, is in the pH range of 7.8-8.5.

Coconut being a semi-halophytic plant can tolerate soil salinity up to 0.6 per cent which is beyond tolerable limits to many other crops. Hence, the total soluble salt in the soil is not a serious problem for coconut cultivation (Sankaranarayanan *et al.,* 1958). In case of low lying areas with frequent sea water inundation, submergence with brackish water may suffer with excess salinity needs drainage and check bunds to prevent inundation. The coconut plantations grown in the saline/alkaline soils may also have limitation by the salts. Developing underground drainage by mixing the heavy soil with sand will remove salt through free drainage. Application of acid farming chemicals like sulphur or gypsum application may reduce salt problem.

Soil fertility status and constraints are specific to the different coconut soils. Generally, the sandy soils contain very low amount of soil nitrogen. But it is found to be high in the case of swampy, Kari (Peaty) and alluvial soils. Blending organic matter with NPK fertilizers significantly increased the available nitrogen in littoral sand in the West Coast of India (Nambiar *et al.*, 1983). In general, the management of soil phosphorus does not pose a serious problem to coconut cultivation. In the case of sandy soil, both total and available soil phosphorus is very low but it is high in alluvial balck and swampy soils. The phosphorus status of laterite, lateritic, and red soils is medium but the supplying power would be fairly high. This is primarily because the reverted phosphorus is made available to the crop in course of time. Phosphorus build up would take place due to continuous application of fertilizers containing phosphates (Muliyar and Wahid, 1973). The soil potassium content depends on the nature and composition of the parent material from which the soil is formed (Grapham and Fox, 1971). It is low to medium in coconut growing soils of humid tropics, but it is high in alluvial soils and those formed under semi-arid conditions such as black soils. The swampy soils also contain moderately high amount of soil potassium. In a long term experiment conducted in littoral sandy soil with the annual application of fertilizers for a period of 32 years to coconut showed a marked increase in the available phosphorus and potassium status in soil, but a marginal change in soil available nitrogen status. The yield of coconut increased with the higher levels of nutrient application, and the highest yield was recorded in the treatment of 1000:437:1667g of N, P, K palm^{-1} yr^{-1} (Srinivasa Reddy *et al.*, 2001). Field experiment on studying the effect of application of composted coir pith (CCP) alone and in combination with NPK (50 per cent) resulted in the increase in organic carbon of the soil and higher K content of coconut leaf. The nut yield produced with the application of CCP + NPK was significantly higher compared to other treatments (Upadhyay *et al.*, 2009).

The application of fertilizers through drip fertigation resulted in a marked increase in available nitrogen, phosphorus and potassium status in soil. The research results show that through fertigation technique 50 per cent saving of chemical fertilizers is possible which ensures the higher efficiency of nutrients in crop production (Subramanian *et al.*, 2012). A study on the effect of fertigation on the productivity of coconut conducted at Horticulture Research Station, Arsikere, Karnataka indicated the possibility of saving 25 per cent of the recommended fertilizers by adopting fertigation, which also ensures higher productivity in coconut (Basavaraju *et al.*, 2014).

A critical evaluation of nutritional factors involved in coconut productivity carried out by Mathewkutty *et al.* (1997) in West Coast Tall palms aged 25 to 35 years showed that continuous use of conventional fertilizers had lead to a stage of negative response for them owing to the deficiency of non recommended/applied elements like Mg and S and excess of Ca, Fe and Mn limits coconut yield. The plant nutrient limitation may occur through the low nutrient content in soil or the antagonistic effect of the high content of other nutrients. Therefore, to ensure the sufficient supply of all the nutrients depends on the balanced nutrient status in the soil. Among the non traditional fertilizer nutrients magnesium sulphur and boron are very important as far as coconut productivity and production problems are concerned. Due to leaching losses these nutrients are generally in short supply in many of the coconut growing humid tropical soils. Soils very low in organic matter and continuously cropped without sulphur containing fertilization are likely to suffer S-deficiency. Hence application of sulphur containing fertilizers and organic manure will improve the sulphur nutrition.

Except very acid soils Ca nutrition to coconut is not a major issue. Liming material in the acid soils will improve the calcium supply. Magnesium availability depends on the balance among the other cations in the soil. Micronutrients especially iron, manganese, copper and zinc are easily soluble and readily available under acid conditions. The availability of iron and manganese are generally high in acid laterite and red soils, moderate in alluvial, volcanic, peat and clay soils, low in coastal sandy soils and very low in coral soils. The requirement of molybdenum for coconut is very small and its problem has not been felt in coconut farming. Among micronutrients, boron is deficient in most of the acid laterite, red, alluvial and coastal sandy soils. A study was conducted to determine the Cu and Zn contents in soil and coconut leaves in the coconut triangle. In the coconut triangle of Sri Lanka, 72.27 per cent and 37.96 per cent soil samples were below the critical Cu level of 0.4 mg/kg and Zn level of 0.5 mg/kg, respectively. Moreover, 68 per cent and 84 per cent leaf samples were below the critical Cu level of 5 mg/kg and Zn level of 30 mg/kg respectively. Therefore, Cu and Zn levels in some of the areas in the coconut triangle, are deficient and the availability of these nutrients depend on pH and organic carbon of the soil (Jayasinghe *et al.*, 2014). Similarly, soil available Zn, Cu and B were deficient in 89, 62 and 5 per cent area respectively in the two major coconut growing districts Coimbatore and Tiruppur districs of Tamilandu India (Selvamani, 2014). Since the difference between the toxicity and deficiency levels are very narrow in case of micronutrients their supply through fertilizers should be site specific and made based on soil nutrient status to avoid toxicity issue.

6. Conclusion

Perennial nature of the coconut plantations continuously exploits the nutrients of limited volume of soil for decades. The high requirement of the nutrients by coconut coupled with the imbalanced nutrient supply leads to the nutrient deficiency or toxicity. Therefore, irrespective of the natural fertility of the soil emergence of deficiency of initially sufficient nutrients, is observed in a long term, that warrants the continuous monitoring of the nutrient status of the coconut soils in order to identify the emerging nutrient deficiency. Moreover, the fertilizer schedule should be tailor made for the soil condition in a balanced way to meet the requirement of the crop thereby sustained higher productivity could be achieved in the coconut plantations.

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