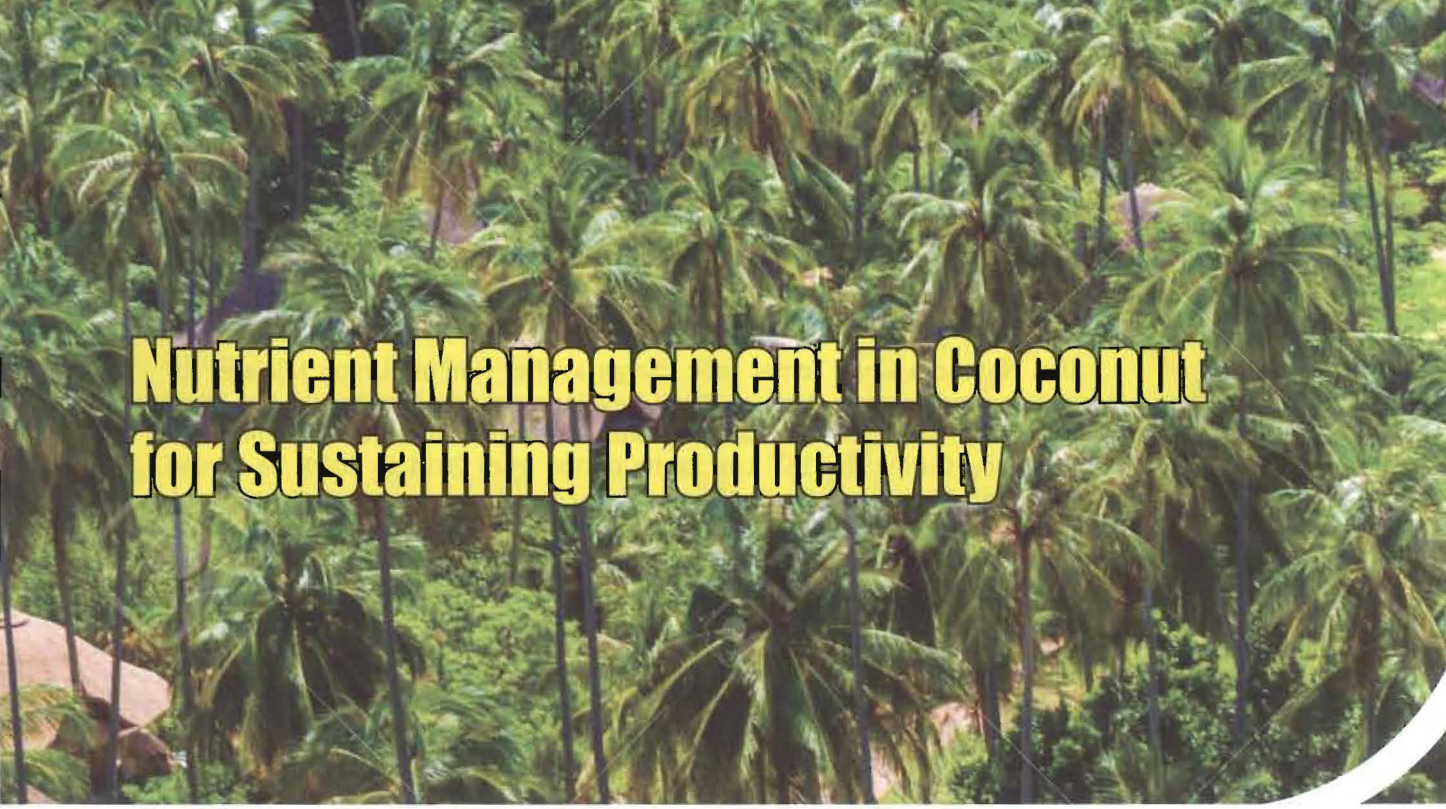

Nutrient Management in Coconut for Sustaining Productivity

Jeena Mathew., V.Krishnakumar. S. Indhuja and A. Abdul Haris
ICAR-Central Plantation Crops Research Institute, Regional Station, Kayamkulam

Coconut, the tree of life ('Kalpa Vriksha') is indeed a boon to mankind by being bestowed with the innate potential to supply food, feed, fiber, health drink, building material and thus forming an inevitable component of our daily life. In terms of its life cycle, coconut palms may sometimes outlive humans and will be having a production period of 6 to 8 decades. During this period, the potential productivity of the palm can be extracted to the fullest extent only if the nutrient removal through the nut harvest as well as due to the removal of crop residues are adequately replenished.

> **Food is vital for every living thing and coconut palms being a perennial plantation crop require balanced nutrition to compensate for the nutrients which are lost from the system through the harvest of nuts as well as through palm residues.**

Nutrient requirement of coconut

Among the seventeen essential nutrients required universally for the growth of all the plants, the nutrients which are of great importance for coconut are nitrogen(N), potassium(K), calcium(Ca), magnesium(Mg), sulphur(S), phosphorus(P),Chlorine (Cl) and boron(B). Based on a study conducted at ICAR-CPCRI Regional Station, Kayamkulam, it has been found that the magnitude of nutrient uptake in an apparently healthy adult palm is of the order

889 gram nitrogen 389.7 gram calcium, 1075 g potassium, 71.6 g magnesium, 229.69 g sulphur, 321.63 mg boron, 2304 mg zinc, 569 mg copper and 1784 mg manganese. Among all the nutrients, potassium leads in the fore front in the total nutrient uptake by an apparently healthy palm. Seventy four per cent of the total potassium is stored as reserve biomass (stem) whereas the amount stored in the recyclable biomass (palm components which can be recycled back to the soil) constitutes 24 per cent of the total potassium uptake. Hence it can be seen that considerable quantity of nutrients are being stored in the biomass of coconut.

In a healthy soil, the optimum rate of available nitrogen, phosphorus and potassium is 280-560 kg/ha, 10-25 kg/ha and 110-280 kg/ha respectively. The content greater than 300 ppm, 120 ppm and 5 ppm is the optimum requirement of calcium, magnesium and sulphur in a healthy soil. In the case of micronutrients such as zinc, copper and manganese, the soil content less than 1 ppm is considered to be deficient. The boron content less than 0.5 ppm in the soil is deficient where as the content less than 5 ppm is considered to be deficient with regard to iron.

Role of nutrients on coconut productivity

Food is vital for every living thing and coconut palms being a perennial plantation crop require balanced nutrition to compensate for the nutrients which are lost from the system through the harvest of nuts as well as through palm residues. It is also mandatory to apply the right quantity of the nutrients at the right time and in the right proportion. Both the condition of excess nutrition as well as under nutrition is hazardous in terms of antagonistic nutrient interaction as well as hindered crop nutrient uptake. Hence it is appropriate to understand the role of individual nutrients on the growth and productivity of coconut.

Primary Nutrients (Nitrogen, Phosphorus and Potassium)

Nitrogen is a constituent of amino acids, proteins and nucleic acids. The pyrole rings constituting the porphyrin structure of chlorophyll and other bio molecules contains nitrogen in them. Being the main component in soil organic matter, soils which are organically poor as well as that of reclaimed soils encounter the deficiency of nitrogen. However prevalence of water logged condition will result in the loss of available nitrogen and thereby causes the exhibition of nitrogen deficiency symptoms in coconut palms. Stunted growth and chlorotic leaves of seedlings are common in nitrogen deficient soils. Nitrogen promotes the uptake of phosphorus and potassium and hence the deficiency of nitrogen will hinder the uptake and assimilation of other nutrients as well. In addition to these factors, application of organic manures having a wide C:N ratio as that of poultry manure may result in the temporary locking up of nitrogen and result in nitrogen deficiency particularly in young palms.

The general symptom of nitrogen deficiency (figure 1.) is the reduction in chlorophyll content with golden yellow coloration of older leaves near the petioles and light brown colour near the end, which later dries out. Yellowing starts from the tip of the leaf and leaflets progresses along the midrib. The peculiarity of nitrogen deficiency is that mid rib also turns yellow.

Fig1 Nitrogen deficiency symptom in coconut

The deficiency can be managed through the application of nitrogenous fertilizers depending on the soil test data. Prevalence of water logged condition should be avoided to prevent the gaseous loss of applied nitrogen. Recommended dose of organic manure should also be applied to maintain the organic matter status in soil.

Another major nutrient involved in coconut nutrition is phosphorus. Being a component of nucleic acid, and its involvement in the energy transfer and cell respiration, it is a vital nutrient for the growth of all plants. In coconut, phosphorus nutrition is essentially important for the growth of young palms particularly for the root proliferation and development. Initial flowering is greatly influenced

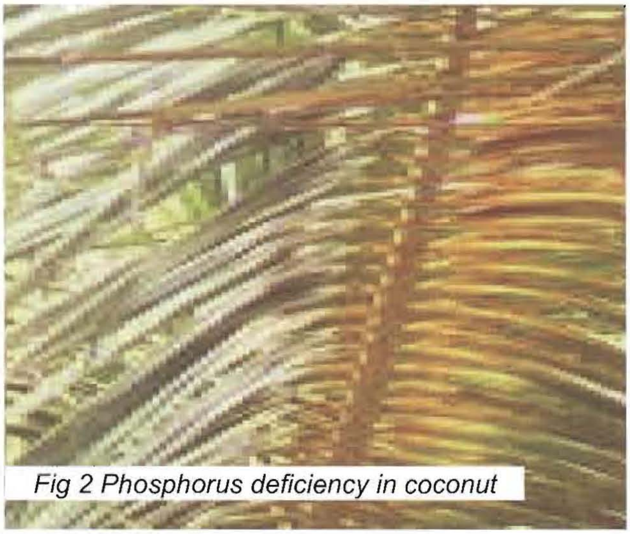

Fig 2 Phosphorus deficiency in coconut

by the availability of phosphorus. Moreover, for the efficient functioning of nitrogen, phosphorus supply in the requisite amounts need to be ensured. Ensuring the availability of soil phosphorus is required for the proper establishment of juvenile palms. The deficiency of phosphorus is commonly encountered in laterite soils as well as in extremely acidic (pH less than 4.5) and calcareous soils. Under conditions of phosphorus deficiency, there will be restricted root growth. In the leaves, deficiency symptoms are manifested as purplish discoloration (Fig.2.). Phosphorus deficiency can be managed by the application of recommended dose of phosphatic fertilisers.

However, continuous application of phosphatic fertilisers may result in the buildup of available phosphorus in the soil. This situation will result in the reduced availability of micronutrients particularly zinc and boron. If the level of available phosphorus in soil determined through systematic soil analysis in soil testing laboratories is greater than 20 ppm, application of phosphatic fertilisers can be skipped for the next two years and later it can be resumed depending on the availability in soil.

Potassium is the key nutrient in coconut production systems and is removed in the greatest proportion from coconut. Apart from imparting resistance to the attack of pests and diseases, potassium also confers abiotic stress tolerance particularly drought. It regulates the opening and closure of stomata and thereby regulates the water balance in the plant system. It is necessary for the formation of sugar, fat and fibrous material. It also has a role in the production of female flowers and nut setting. Being 'Kalpa Vriksha', all the palm parts

If the level of available phosphorus in soil determined through systematic soil analysis in soil testing laboratories is greater than 20 ppm, application of phosphatic fertilizers can be skipped for the next two years and later it can be resumed depending on the availability in soil.

Fig3 Potassium deficiency in coconut

are effectively utilized for various purposes. Hence if the nutrients which are removed from the system through these palm components are not replenished, nutrient deficiency symptoms will occur in the palm.

Soil conditions such as over liming, excess application of magnesium sulphate and soil acidity trigger the occurrence of potassium deficiency in coconut palms. Light sandy soils with low cation exchange capacity and less organic matter are more prone to the occurrence of potassium deficiency symptoms in coconut. In this regard, it should be considered that while intercropping of potassium exhaustive crops such as tuber crops, fodder grass, banana and pineapple in coconut gardens, they should be grown by giving adequate fertilizers based on the requirement of the individual crops.

During potassium deficiency, there will be orangish discoloration in the outer leaves and the occurrence of orange colored spots (Figure 3). The discoloration starts from the tip of the outer leaves and progresses along the margin towards the base. But the mid rib portion remains green. Leaf tip becomes withered and necrotic. Later the necrotic spots join together giving a scorched appearance. The appearance of a green triangle with the base in the lowest leaflets and apex towards the tip is a characteristic feature of potassium deficiency in coconut. Addition of soil test based potassium fertilizers along with the recycling of palm residues in the basin help to overcome its deficiency.

Secondary nutrients (Calcium, Magnesium and Sulphur)

In coconut nutrition, straight fertilizers are often applied at the recommended doses, but over exhaustion from the soil due to crop removal coupled with the ever aggravating problem of soil acidity can result in the deficiency of secondary nutrients such as calcium, magnesium and sulphur.

Calcium is the base nutrient ion associated with the imparting of turgidity and vigor to the leaves. It is essential for the developing tissues and cell wall development. Acidic soils contain low calcium and continuous crop removal can result in the deficiency of calcium. Calcium is an immobile element in plant and the deficiency symptoms first appear on the youngest leaves. Calcium deficiency in coconut palms are manifested as loss of vigor and turgidity in the youngest tissues, necrosis and death of the bud. Under conditions of calcium deficiency, spraying 0.5% calcium nitrate solution is recommended. Lime application@ 1 kg per palm two weeks prior to fertiliser application will supply calcium to the soil.

Being the central ion in chlorophyll, magnesium has a definite role in the pigment system and affects the photo synthetic capacity of the plant. It also enhances the production of female flowers and activates several enzyme systems in the plant. In the case of deficiency, yellowing of the older leaves start from the tip and extend towards the base and later the younger leaves also turns yellow (Fig. 5). Magnesium deficient leaves have distinctly green leaf centres and bright lemon yellow to orange margins. Yellowing occurs principally in those parts of the leaf which are exposed to sunlight. In most of the cases, the shaded part remains green.

Magnesium deficiency can be managed by the application of magnesium sulphate@ 500g per palm during the application of second dose of fertilizers.

Another important secondary nutrient for coconut is sulphur. Sulphur is required for the formation of oil and improves the quality of oil and copra. It also improves the nut characters. During sulphur deficiency, yellowing initiates on the youngest leaves with older leaves remaining green. Leaves droop

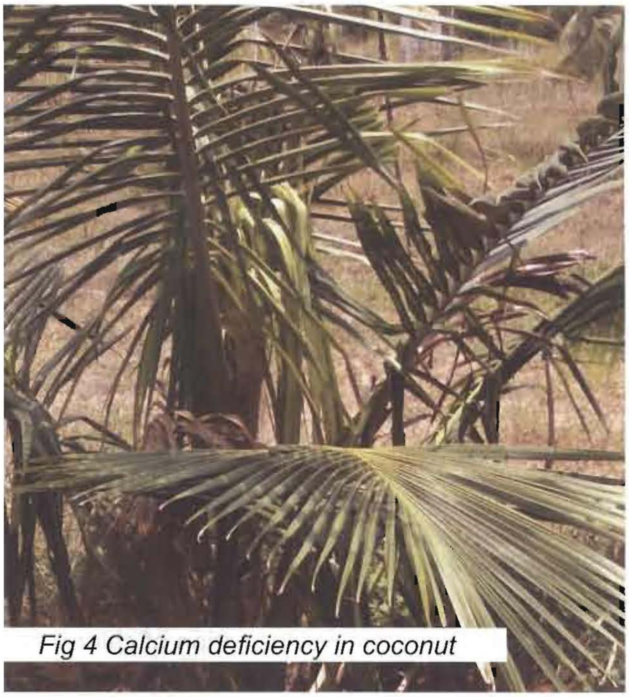

Fig 4 Calcium deficiency in coconut

as the stem becomes weak. In older palms, leaf number and size are reduced. Group of dead fronds develops around the stem due to weakness of the rachis. Nuts may fall prematurely. Rubbery copra is a characteristic symptom of sulphur deficiency in coconut.

Micronutrients

Boron is an essential micronutrient for coconut, which helps in the multiplication of meristematic tissues. It helps in the metabolism of protein, synthesis of pectin, maintenance of water relation, translocation of sugars, tissue respiration, fruiting process, growth of pollen tube and in the development of flowers and fruits. Wide spread deficiency of boron is noticed in the coconut growing areas which is attributed mainly to the continuous removal through cropping, and also due to the non replenishment of the same along with regular fertilizer application.

The deficiency symptoms of boron appear on the leaves, roots, inflorescence and nuts. Since boron is an immobile element in plant, the first symptoms appear on the youngest leaf. Meristematic tissues are seriously affected by boron deficiency. Fasciation ie., the failure of the leaves to split open is the major foliar symptom of boron deficiency and is referred as 'crown choke disorder'. There will be crinkling and reduction in elongation of young leaves (Figure 6). Pollen production, pollen grain germination and pollen tube development will be adversely affected. There will be poor nut setting and button shedding will be rampant. In certain conditions, occurrence of 'Hen and chicken disorder' wherein both old and young nuts occur within the same bunch is also noticed.

Mathew *et al.* (2018) found the critical boron level in coconut leaf as 13.27 mg/kg and that in soil as 0.48 ppm. The critical level indicates the level of boron in soil and leaf below which deficiency symptoms appear and above which toxicity symptoms will occur. Boron deficiency in coconut can be managed by the application of 40 g each borax during June, September, December and March along with organic manures. Irrigation is to be ensured for greater use efficiency of added boron. It is also mandatory to correct the acidic soil reaction by the addition of dolomite@ 1 kg per palm before the application of borax.

Iron is a catalyst for the formation of chlorophyll and is also a constituent of enzymes associated with respiration and oxidation systems. Iron gets precipitated in the non available forms under alkaline and calcareous soils and under conditions of excess phosphorus there will be fixation of iron as insoluble phosphates. Under acidic soil conditions, deficiency of iron is usually not encountered.

Uniform chlorosis is the symptom associated with iron deficiency. All the leaves from the top of the crown to the base will have a pale green or dark yellow discoloration. There will be gradual yellowing of the leaflets in longitudinal strips parallel to the veins. In the advanced stages the leaf becomes completely yellow. There will be shortening of the rachis and the leaflets. Absence of necrosis in any part of the leaf is a characteristic symptom of iron deficiency.

As in the case of iron, deficiency of manganese also occurs in alkaline and calcareous soils with pH greater than 7.0. Manganese deficiency is caused primarily by high soil pH. Mild manganese deficiency symptoms include, new leaves emerging chlorotic with longitudinal necrotic streaking. The base of this leaf shows the curling or frizzling which is characteristic of more severe manganese deficiency.

The deficiency of copper is seen in highly acid sandy soils and in heavy organic soils, as well as in highly calcareous and alkaline sols. Liming reduces the availability of copper in deficient soils. Severe bending of the rachis of the youngest leaves, accompanied by yellowing and desiccation of the

Fig5 Magneisum deficiency symptoms in coconut

leaf tip which is rimmed with brown and yellow and the central part remain green. As the symptoms develop, dried out part spreads and gives the palm a saggy appearance.

Zinc catalyses oxidation in plant which is and is essential for the transformation of carbohydrates, helps in the formation of auxins, and promotes the water absorption. Button shedding along with the shortening of the crown is the reported symptom of zinc. Zinc deficiency is characterized by formation of small leaves wherein the leaf size is reduced to 50%. Leaflets become chlorotic, narrow and reduced in length. In acute deficiency, flowering is delayed.

Chlorine is associated with the stomatal conductance and the maintenance of water balance. The deficiency of chlorine is seen in the palms located in the inland areas. There will be reduced growth rate of the palms with reduction in size and number of nuts. Leaves will be droopy and indicates signs of moisture stress which may result in the breakage of fronds. There will be stem cracking and frequent occurrence of stem bleeding. Marked incidence of grey leaf blight is also reported.

The visual symptoms are observed when the palm has already been affected by the deficiency of the particular nutrient. Hence it is better to periodically monitor the soil and palm health through systematic soil as well as through leaf analysis.

Strategies for balanced nutrition in coconut

As nutrition plays a vital role on sustaining palm health and productivity, suitable management strategies are to be adopted from the initial years onwards. The care and management attributed in the juvenile stages are indeed reflected in the productivity of the palm at later stages. Hence systematic nutrient management strategies are to be adopted for exploiting the palm production potential to the fullest extent.

Correcting Soil Reaction

For the efficient use of applied nutrient inputs, soil pH should be in the range of 6.0 to 6.5. In acidic soil pH can be corrected by the application of lime or dolomite@ 1 kg per palm two weeks prior to the application of fertilizers. Dolomite is the carbonate of calcium and magnesium. The liming materials should also be thoroughly mixed in the soil. Presence of adequate soil moisture is essential for ensuring the chemical reaction in soil for correcting the soil acidity by liming.

Integrated nutrient management in coconut

Nutrient removal by the palm depends on the stage of growth of the palm as well as soil fertility status. Under Kerala conditions, the nutrient recommendation for the adult palm is 500: 320: 1200 gram N: P_2O5: K_2O, which can be supplied through 1 kg urea, 1.5 kg mussoriephos and 2 kg muriate of potash. The entire fertilisers can be applied in two splits depending on the availability of rains. $1/3^{rd}$ of the recommended dose of fertilisers can be applied in the beginning of the South West Monsoon and the remaining $2/3^{rd}$ fertilisers can be applied by the time of the North East monsoon during September-October. The fertilisers can be broadcasted around the palm by taking basins at a radius of 1.8 meter and 25 cm depth and mixed thoroughly during May – June. During the second split of fertiliser application, basins can be closed with the incorporation of 25kg organic manure.

The first dose of fertiliser is to be applied 3 months after planting @ $1/10^{th}$ of the dose recommended for the adult palms. One year after planting 1/3rd of the adult palm dose is required and two years after planting $2/3^{rd}$ of the adult palm dose is to be applied. From the third year of planting onwards, full dose as recommended can be applied.

In Tamilnadu, manuring is done in two equal splits during June-July and December-January. Phosphatic fertilisers are applied as superphosphate in the basins or as Di Ammonium Phosphate through drip irrigation when the quality of irrigation water is good. Under irrigated conditions, the fertilisers can be applied in 3-4 split doses. The fertiliser recommendation for coconut in Kerala, Tamil Nadu and Karnataka are presented in Table 1.

Table 1. Nutrient recommendation for coconut

Stage of the palm	Organic manure	Urea	Mussoriephos	Muriate of potash
	kg/palm		g/palm /year	
Kerala				
3 months after planting	5	100	160	200
1 year after planting	5	360	535	668
2 year after planting	10	720	1065	1300
3 year after planting onwards	25	1000	1600	2000
Tamil Nadu				
6 month after planting	10	-	-	-
1 year after planting	20	304	400	500
2 year after planting	30	608	800	1000
3 year after planting	40	911	1200	1500
4 year after planting	50	1215	1600	2000
Karnataka				
3 months after planting	20	109	200	225
1 year after planting	20	347	600	676
2 year after planting	20	716	1200	1350
3 year after planting onwards	50	1085	1600	2000

*(Source: **1**. Coconut Cultivation Practices. 2007.ICAR- Central Plantation Crops Research Institute, Kasargod, Kerala. Eds. (Dhanapal, R., Thampan, C).Extension Publication No. 179.p.26. **2**.http://www.agritech.tnau.ac.in/expert_system/coconut/coconut_mainfield.html) **3**. Package of Practices Recommendations, University of Agricultural Sciences, Bengaluru*

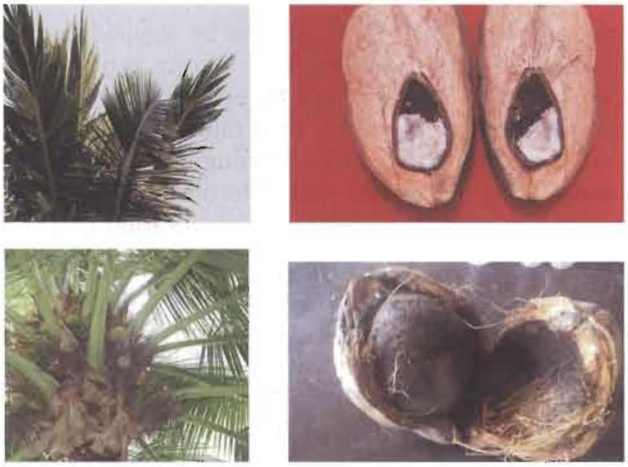

Fig6 Boron deficiency symptoms in coconut

Plant growth promoting rhizobacteria (PGPR) are known to improve plant growth. Most of the coconut rhizobacteria cultured from different coconut growing tracts of India belonged to Pseudomonas, Bacillus, Enterobacter and Actino bacter etc exhibiting multiple plant beneficial traits.

Microbes aid coconut biomass recycling

Agro residues from coconut gardens constitute a huge biomass (12-14 t/ha/annum) of lingo cellulosic nature partly recalcitrant to microbial degradation. Coconut leaves, husk and coir pith form mulching materials in basins. Mulching is to done at the end of monsoon and thus helps to conserve moisture, to maintain ambient soil temperature and to encourage microbial activity in the root zone thereby enabling the crop to withstand harsh summer. Before the onset of next monsoon, brittled mulch along with farmyard manure can be incorporated into the soil. Once sufficient moisture is received, microbial decomposition is initiated and continued involving succession of diverse microbial groups and function. Soil microbes create humus (by degrading organic matter) that are described as the 'life force of soil'. Humus helps soil to retain moisture and encourages crumb structure formation thus making the soil more porous. Mechanical shredding of leaves and techniques like coconut leaf vermicomposting and coir pith composting accelerates biodegradation of agro residues of coconut gardens. Apart from rapid decomposition, composting methods results in an increase in the population of beneficial microbial communities such as free-living nitrogen fixers, phosphate solubilizers, fluorescent pseudomonas and silicate solubilizers resulting in enhanced plant growth.

Microbes enhance nutrient availability in coconut

Plants are not capable of fixing atmospheric di nitrogen into ammonia and expend it directly for its growth. Thus the atmospheric nitrogen is converted into plant utilizable forms by biological nitrogen fixation (BNF). Beijerinckia, Azospirillum,Herbaspirillum, Burkholderia, Azoarcus, Bacillus are a few common nitrogen fixing bacteria associated with coconut roots. Most of these are effective bio inoculants for better establishment of coconut nursery seedlings.

Some heterotrophic bacteria and fungi are known to have the ability to solubilize mineral nutrients like phosphate, potassium, zinc and silicate from insoluble sources and making them available to plants. Eg. Pseudomonas sp., Enterobacter sp., Acinetobacter sp., Bacillus sp., Micrococcus sp., Coryne bacterium sp. and Alcaligens sp. are the common nutrient solubilizers encountered in coconut plantation soils. Aspergillus sp. and Penicillum sp. are two predominant phosphate solubilizing fungi occurring in the coconut rhizosphere. These microbes produce organic acids such as gluconic acid and others that help in dissolution of insoluble nutrients. Soil application of biofertilizer formulation of nitrogen fixing bacteria, Azospirillum brasilense and phosphate solubilising bacteria, Bacillus subtilis @ 100 g per palm per year along with organic manures is recommended.

Plant growth promoting rhizobacteria (PGPR) are known to improve plant growth. Most of the coconut rhizobacteria cultured from different coconut growing tracts of India belonged to Pseudomonas, Bacillus, Enterobacter and Actino bacter etc exhibiting multiple plant beneficial traits. 'Kera Probio' is a talc based bioinoculant containing PGPR- Bacillus megatherium suitable for biopriming coconut and vegetables seedlings.

The symbiotic association between mycorrhizal fungi and the roots by Arbuscular Mycorrhizal (AM) fungi increase the surface area of a plant root system helping plants to absorb more water and improving nutrient uptake like phosphorus (P), nitrogen (N), and micronutrients.

Eg. A soil based AMF bioinoculant, 'KerAM' containing Claroideo glomusetunicatum, one of the dominant sp. from coconut rhizosphere has been released, the application of which improves nutrient and water absorption in coconut seedlings.

Legumes as a component for basin fertility enrichment

Symbiotic association of N fixing bacteria (Rhizobium) with legume crops such as cowpea, mimosa and sun hemp is also being explored for enhancing nitrogen availability in coconut gardens. For utilizing the positive effect of leguminous crops, sowing of 100 gram cowpea seeds after the addition of first dose of fertilizers is required. With the initiation of flowering by one or two plants, they can be incorporated to the basin. Basin management of coconut by growing legume crops helps in producing 15-20 kg green manure/basin and their incorporation provides around 100-150 g N/palm along with other major nutrients. By growing legumes in interspaces of 1 ha coconut garden, 15 to 20 tons of fresh biomass can be incorporated in soil.

Irrigation

One of the critical resources in coconut production is the availability of water. Water is the medium for absorption of plant nutrients. For all physiological process within the plant including photosynthesis water is essential. There is constant upward movement of water from soil solution through the roots of palms under transpiration pull. Sufficient water should be available in the root zone to maintain plant functions and productivity. Though the coconut growing regions in the coastal belt are endowed with high rainfall, the rainy period is confined to a few months during the monsoon season. The palm experiences moisture stress and drought conditions for varying periods extending up to 6-7 months in a year which affects productivity. In the coconut growing region other than the coastal belt coconut has to be grown throughout the year by supplemental irrigation. When irrigation water is delivered through hose pipes, about 500 litres water is required to be applied per week per palm. But when drip irrigation is followed, irrigation is scheduled to compensate the loss of water through evapo transpiration which amounts to 40-50 litres per day for adult palms, under Kerala conditions.

Nutrient mixtures for the growth and productivity of coconut palms

Considering the soil and plant nutrient dynamics in the different coconut growing tracts of Kerala, ICAR-CPCRI, Regional Station, Kayamkulam has formulated different mixtures and conducted incubation as well as field studies on the release pattern and absorption by coconut plants. Based on the detailed experiments, two nutrient mixtures viz., 'Kalpa Poshak' and 'Kalpa Vardhini' have been developed for juvenile and adult coconut palms, respectively. Kalpa Poshak' comprises the nutrients such as potassium, boron, sulphur, zinc, copper whereas 'Kalpa Vardhini' contains potassium, magnesium, sulphur, boron and zinc in different concentrations. The dose recommended for 'Kalpa Poshak' is 40 g/ palm during first year after planting and 100 g/ palm for the second and third years of planting. The dose for 'Kalpa Vardhini' is 500g/ palm/year, which has to be applied in two splits. These mixtures are to be applied ten days after the application of normal recommended dose of fertilisers.

Conclusion

Being a perennial plantation crop, systematic adoption of appropriate nutrient management strategies can ensure the realization of the potential yield of the palm. Moreover replenishing the nutrients based on the palm requirement can restore the soil and palm health and thereby can sustain the palm productivity. Nutrient management also enriches the microbial activity and favors the soil biodiversity. Through the addition of palm residues, considerable amount of nutrients can be recycled back to the system, which is very essential to maintain the vitality of the system in a sustainable manner. These strategies may help in realizing higher yield which can help in achieving the ultimate objective of enhancing the farmers' income.

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