Research Article

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Coconut-growing soils of Kerala: 2. Assessment of fertility and soil related constraints to coconut production

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Abstract

Growth, productivity and health of coconut plantations in humid tropics are influenced by soil qualities. Fertility of coconut-growing soils of Kerala was assessed by analysing samples drawn from the distinct agro-ecological regions of the state: Central and Eastern Palakkad, Northern Kerala, Central Kerala and Southern Kerala, Onattukara sandy plain and coastal sandy plain. The strongly acid soils of Northern and Central Kerala and Onattukara sandy plain are unfavorable for plant nutrient availability and microbial processes. Surface and sub-soils of Central Kerala and sandy plains have low levels of organic carbon. Available phosphorus was high in soils of Southern Kerala and Onattukara sandy plain. Plant available potassium was not adequate in these coconut-growing soils. The nutrient levels in soils of Central Kerala and sandy plain were extremely low. The same pattern was true for secondary nutrients calcium and magnesium. Soils of all regions have adequate levels of available sulphur, iron and manganese. Copper and zinc deficiency was recorded for laterite soils of central region and sandy soils of Onattukara and coastal plain. Plant available boron was deficient in all regions except for the soils of Southern Kerala. Molybdenum levels were marginal in coconut growing soils, except for the soils of Palakkad. Overhead climate and soil moisture availability does not constrain the palm in the state except for Eastern Palakkad where irrigation during dry period is an absolute necessity. The extensive areas of midland laterites and Onattukara sandy plain with strong acid reaction and aluminium in soil solution severely constrain coconut. The acid soils also suffer from deficiencies of potassium, calcium, magnesium, copper, zinc and boron. These soil related constraints affect coconut production significantly and alleviation of the same through liming and adequate application of deficient nutrients can ensure satisfactory yields from the palm.

Keywords: Coconut-growing soils of Kerala, plant available nutrients, soil acidity, tropical soils

Introduction

Coconut palm grows well in warm humid tropics with abundant sunshine and moisture. The palm can grow in wide range of soils provided they are deep, well drained, free of hard pan near surface and not excessively gravelly or stony (Child, 1964). By this reckoning, the coconut-growing soils of Kerala are suitable for the crop. However, the palm health and yield are affected by the chemical environment and fertility of the soil. The assessment of soil fertility is generally carried through estimation of soil reaction (pH), electrical conductivity of soil solution and plant available macro, secondary and micronutrients.

The first of the two companion papers (Nair *et al.,* 2018) presented the basic characteristics of the coconut-growing soils drawn from the six distinct agro-ecological regions of coconut production in Kerala. The focus of this paper is on evaluation of fertility of coconut-growing soils and the identification of soil related constraints to palm health and productivity.

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Materials and methods

Horizon wise soil samples collected from the six sites (Nair *et al*., 2018) were used for the fertility assessment and to know its status in coconut-growing tracts of Kerala. The air dried, ground and sieved samples were utilized for determination of pH in 1:2.5 soil water suspension (Jackson, 1973) and organic carbon content of soil was analyzed by wet digestion method (Walkely and Black, 1934). Available phosphorus was extracted with Brays solution and measured spectrophotometrically (Bray and Kurtz, 1945) followed by atomic absorption spectrophotometry (AAS) adopted for estimating available potassium, calcium and magnesium after extraction with 1 *M* Ammonium acetate (Jackson, 1973). Available sulphur was estimated turbidometrically after extraction with 0.15 per cent $CaCl_2$ (William and Steinberg, 1959; Vogel, 1969). Iron, manganese, copper and zinc were extracted with 0.1 *M* HCl (Sims and Johnson, 1991) and estimated through atomic absorption spectrophotometry. Available boron was extracted with hot 0.02 *M* $CaCl_2$ and estimated colorimetrically using azomethine-H reagent (Gupta, 1967). Available molybdenum was estimated by extraction with ammonium oxalate (Tammas Reagent) followed by GTA in AAS (Grigg, 1953).

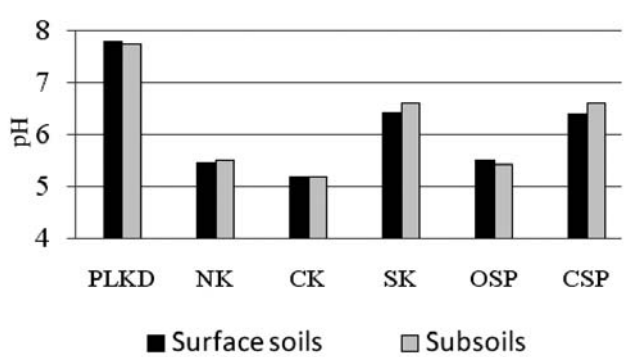
Results and discussion

The fertility of coconut-growing soils assessed through measurement of soil pH, organic carbon content and available nutrients *viz.,* P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, B and Mo is presented and discussed in the following sections**.** The electrical conductivity of the soil is not presented as the soils from all sites including those from very near sea coast tested for extremely low levels of soluble salts (<0.2 dS m^{-1}). The extreme leaching condition brought in by high rainfall and the rapid permeability of soils to water is responsible for the very low salt content in soils.

Soil reaction

Near neutral soil reaction is the best chemical environment for coconut palm, ensuring adequate amount of plant available forms of mineral nutrients, providing enough basic cations and promoting biological activity. Coconut-growing soils of Central and Eastern Palakkad, Southern laterites and coastal sandy soils only had desirable soil reaction. The soils of coconut-growing areas of Northern Kerala, Central Kerala and Onattukara regions suffer from very strong acid reaction (Fig.1) with pH below 5.5. Soil pH below 5.5 is marginal for the growth of the palm (Child, 1964). The strong acidification of the soils in coconut-growing areas of Northern and Central Kerala and Onattukara sandy plains can be attributed to the depletion of bases under high rainfall, continuous crop production with substantial inputs of acid forming fertilizers, low return of crop residues to the soil and little attention paid to liming of acid soils. Extensive studies on soil qualities in the erstwhile Travancore-Cochin by Pandalai *et al.* (1958b) indicated strong acidification of soils in Central Kerala. Comparing the pH values reported some seventy year back with current levels, we found substantial lowering of the soil pH to the present day.

Strongly acid soils are stressed environment for plant growth, impairs plant availability of nutrients, and microbial processes responsible for organic matter decomposition and nitrogen fixation (Rousk *et al.,* 2009; Bru *et al.,* 2011; Abraham, 2015). Closely associated with soil acidification is the aluminium in soil solution. Al^{3+} in soil solution is toxic to the plants. The element gets into soil solution where the pH of the soil is below 5.5 and when it reaches 4.5 or below, the soil solution contains enough aluminium to harm most crop plants. Root damage is the most common effect. Samples of surface and sub-soils drawn from Northern and Central Kerala



PLKD-Palakkad; NK-Northern Kerala; CK-Central Kerala; SK-Southern Kerala, OSP-Onattukara Sandy plain; CSP-coastal sandy plain

Fig. 1. Soil reaction of coconut-growing soils of Kerala

and Onattukara sandy plains tested for high levels of extractable aluminium (Fig. 2).

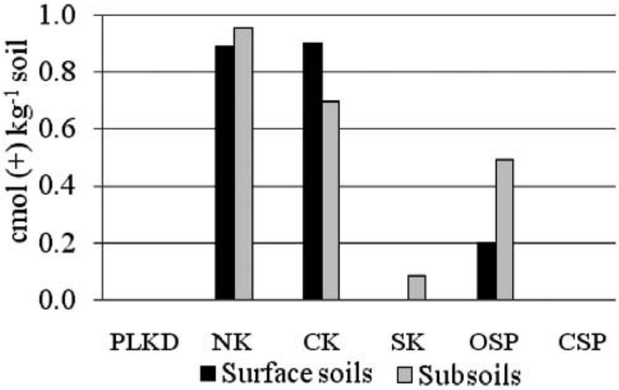


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Fig. 2. KCl extractable aluminium of coconut-growing soils of Kerala

Organic carbon

Organic carbon content of soils is considered as a good measure for natural availability of plant nutrient nitrogen. High level of organic carbon not only provide part of nitrogen requirement of plants but also enhance nutrient and water retention capacity and creates favorable chemical and biological environment in soil. Maintaining high levels of organic matter in soil is essential for low activity clay soils of tropics as it ensures net negative charge and consequent benefits in the soil system (Baert and Van Rast, 1998). Surface and subsoils of Central Kerala, Onattukara and coastal sandy plains have low level of organic carbon (Fig. 3). Return of palm residues to the base of coconut

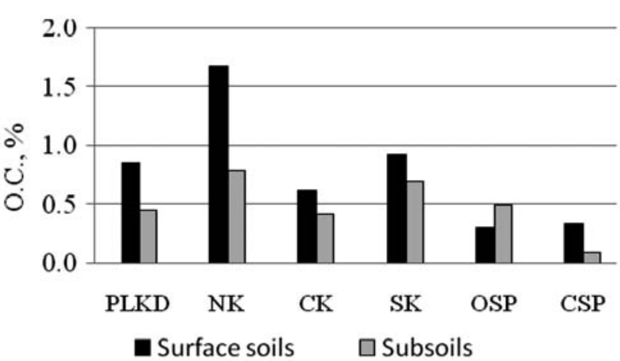

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Fig. 3. Soil organic carbon content of coconut-growing soils of Kerala

and practice of zero tillage in the plantations can ensure build up of adequate levels of soil organic carbon (Somasiri *et al.,* 2003).

Available phosphorus

Phosphorus is the second limiting nutrient for crop production in lateritic soils containing large quantities of oxide minerals which fix the applied phosphorus to forms unavailable to plants. The coconut-growing soils of Northern and Central Kerala, and coastal sandy plains were deficient in the nutrient while soils from Southern Kerala and Onattukara sandy plains tested for high levels (Fig. 4).

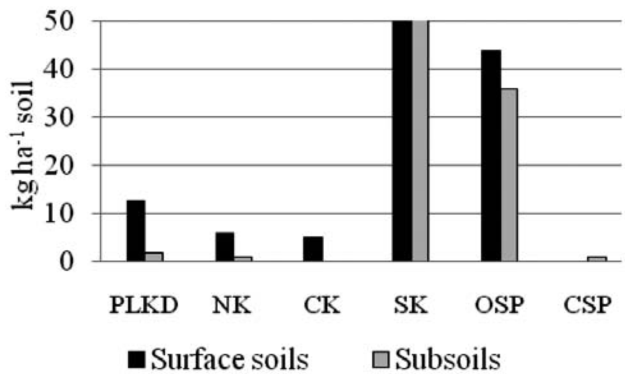

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Fig. 4. Available phosphorus of coconut-growing soils of Kerala

Available potassium

Monocots like coconut has large requirement of potassium. The highly weathered and leached laterite soils of Kerala and coastal sandy soils, developed under humid tropics, do not have any significant resources of potassium bearing minerals. Besides, the very low cation exchange capacity of these soils does not permit retention of potassium in any significant quantities. Surface and subsurface layers of soils from Eastern Palakkad and Northern and Southern Kerala had medium levels of available potassium while the samples from other regions were deficient (Fig. 5). Potassium should be applied as chloride salt (not as sulphate) as the palm has specific requirement for chloride in significant quantities (Von Uexkull, 1990; Wahid *et al*., 1993; Braconnier and Auzac, 1990; Braconnier and Bonneau, 1998).

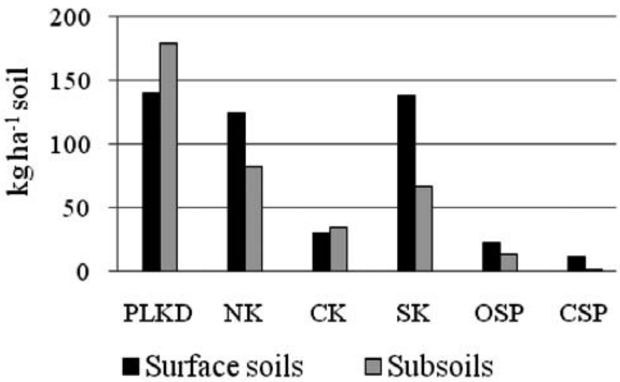

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Fig. 5. Available potassium of coconut-growing soils of Kerala

Available calcium

Surface and subsoils in laterite soils of Central Kerala, sandy soils of Onattukara and coastal plains are deficient in the nutrient element (Fig. 6). Highly weathered tropical soils are generally deficient in available calcium and the minerals bearing the element. Calcium is a structural component of cells in plants. Adequate calcium content in soils is important for it influences many physical, chemical and biological processes. Nitrogen fixing micro-organisms are almost absent from calcium depleted acid soils. Earthworms also do not inhabit calcium deficient soils (Lavelle *et al.,* 1998).

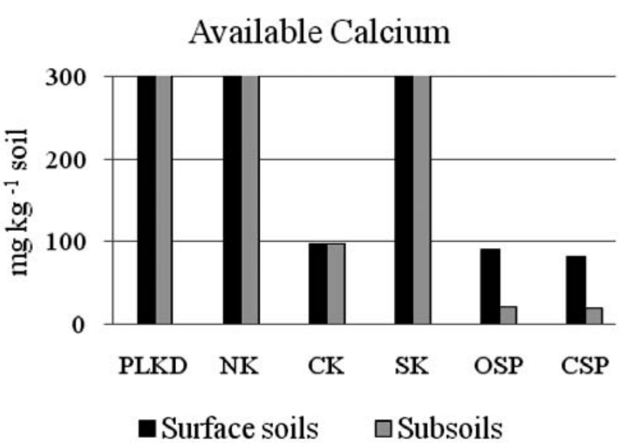

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Fig. 6. Available calcium content of coconut-growing soils of Kerala

Available magnesium

Magnesium is an important constituent of chlorophyll and hence indispensible for photosynthesis. Extreme deficiency of the element in Central Kerala and Coastal sands was reported as early as nineteen fifties and its relation to yellowing of coconut was established (Pandalai *et al*., 1958a, b; Cecil, 1975; Valiathan *et al*., 1992). Available magnesium was tested adequate for only soils drawn from Palakkad and Southern Kerala (Fig. 7).

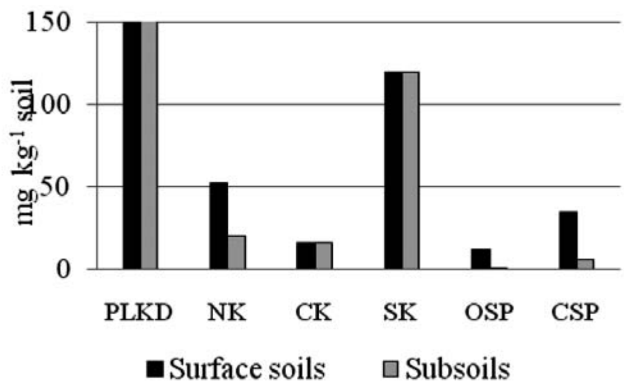

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Fig. 7. Available magnesium content of coconut-growing soils of Kerala

Plant available sulphur, iron and manganese

Soils of coconut-growing areas from all sites were found to have adequate levels of sulphur, iron and manganese (Table. 1).

Available copper

Soils drawn from coconut gardens of Palakkad and Northern Kerala had adequate levels of copper in surface and subsoils (Fig. 8) whereas, the samples drawn from other regions were deficient in the element. Replacement of copper fungicide with other chemicals as prophylactic measure to control fungal diseases in effect excluded the external inputs of element and leads to soil deficiency.

Available zinc

Available zinc was deficient in soils of coconut-growing regions except Palakkad and Southern Kerala (Fig. 9).

Table 1. Plant available nutrients in coconut-growing soils

Depth (cm)	pH	Extr. Al^{3+} cmol (+) kg^{-1} soil	O.C., %	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B	Mo
				kg ha^{-1}		mg kg^{-1} soil								
Central and Eastern Palakkad														
0-15	7.74	0.00	1.20	19.31	165	2156	489	4	22.5	31.6	1.5	7.1	0.24	0.85
16-30	7.84	0.00	0.52	6.28	115	2219	516	2	18.4	14.1	1.4	0.7	0.44	0.60
31-49	7.88	0.00	0.53	3.02	151	2760	737	4	13.7	13.5	1.6	0.5	0.31	0.40
50-77	7.84	0.00	0.56	3.95	172	2722	683	6	12.1	6.7	1.9	0.5	0.26	0.31
76-103	7.72	0.00	0.44	2.56	174	4486	904	3	8.7	5.4	1.9	0.4	0.24	0.31
104-133	7.67	0.00	0.32	0.00	206	3853	999	6	6.8	3.4	1.7	0.4	0.43	0.37
134-160	7.54	0.00	0.39	0.00	190	2897	733	7	5.9	2.0	1.2	0.3	0.36	1.00
Northern Kerala														
0-20	5.48	0.63	2.09	8.84	16	561	79	4	28.6	12.5	2.7	1.4	0.01	0.27
21-46	5.41	0.15	1.26	3.02	89	285	27	6	18.2	6.0	1.4	0.3	0.21	0.21
47-71	5.38	1.45	0.99	2.79	80	316	17	4	16.8	7.1	1.2	0.3	0.26	0.25
72-103	5.41	1.23	0.78	0.00	74	254	18	4	14.2	7.2	0.9	0.3	0.38	0.28
104-150	5.66	0.18	0.59	0.00	93	370	26	2	13.0	5.5	0.9	0.3	0.13	0.30
Central Kerala														
0-22	5.18	1.00	0.70	7.21	13	58	13	8	8.9	1.1	0.4	0.2	0.03	0.23
23-40	5.19	0.80	0.55	3.02	46	135	20	8	9.1	3.3	0.4	0.2	0.26	0.24
41-66	5.02	0.93	0.54	0.00	62	120	18	10	6.1	5.6	0.3	0.2	0.24	0.23
67-102	5.28	0.65	0.37	0.00	34	106	16	10	7.3	4.0	0.4	0.1	0.43	0.32
103-120	5.24	0.50	0.35	0.00	8	62	15	13	4.3	2.6	0.3	0.1	0.33	0.41
Onattukara sandy plain														
0-17	5.55	0.10	0.32	44.22	26	93	12	11	14.3	0.8	0.6	1.1	0.18	0.18
18-36	5.46	0.30	0.29	43.52	18	88	12	21	9.5	0.7	0.5	0.1	0.13	0.16
37-62	5.43	0.45	0.32	46.55	18	25	1	10	6.8	0.3	0.5	0.1	0.11	0.10
63-95	5.42	0.53	0.67	25.13	8	14	0	12	5.5	0.3	0.4	0.2	0.13	0.23
Coastal sandy plain														
0-13	6.33	0.00	0.52	0.00	19	113	48	7	11.5	1.9	0.4	0.9	0.11	0.13
14-48	6.45	0.00	0.15	0.00	3	50	21	10	8.9	0.6	0.3	0.2	0.13	0.09
49-69	6.58	0.00	0.15	0.00	1	28	15	13	7.9	0.4	0.3	0.2	0.08	0.18
70-99	6.46	0.00	0.06	0.00	1	9	0	15	6.7	0.4	0.3	0.2	0.04	0.14
100-130	6.76	0.00	0.08	2.56	1	16	3	13	7.1	0.4	0.3	0.2	0.03	0.12
Southern Kerala														
0-14	6.4	0.00	0.93	454.2	138	600	120	25.4	17.9	74	0.4	4.93	1.71	
14-31	6.6	0.00	0.70	76.5	67	560	120	26.3	5.9	30	0.2	0.8	0.58	

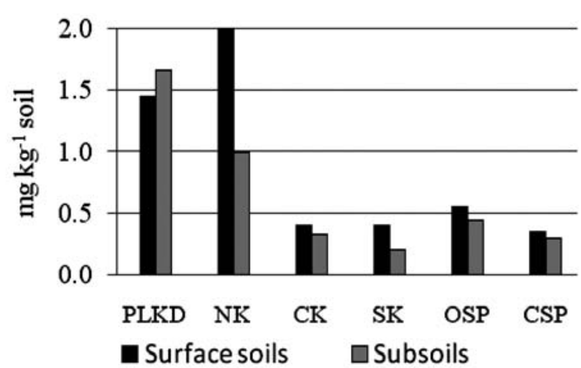

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Fig. 8. Available copper content of coconut-growing soils of Kerala

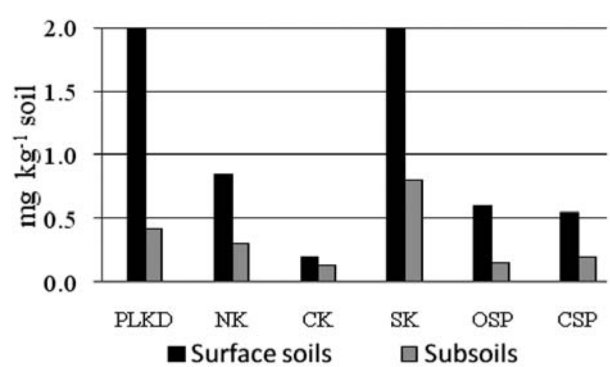

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Fig. 9. Available zinc content of coconut-growing soils of Kerala

Available boron

Boron bearing minerals in rocks and soils have high solubility in water and deficiency of the element can be expected in highly weathered soils of humid tropics, when depleted of organic matter. Crown root disease of coconut, emergence of shorter leaves with deformed, crinkled and rudimentary leaflets and severe tip necrosis are attributed to boron deficiency (Chakrabarty, *et al*., 1970; Broschat, 2009; Kamalakshiamma *et al*., 2002). All the coconut-growing soils except those of Southern Kerala were deficient in available boron (Fig. 10).

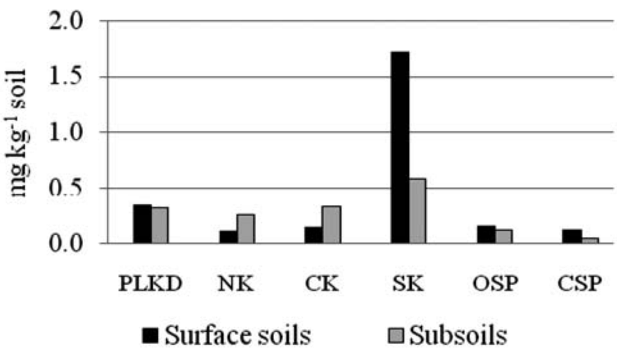

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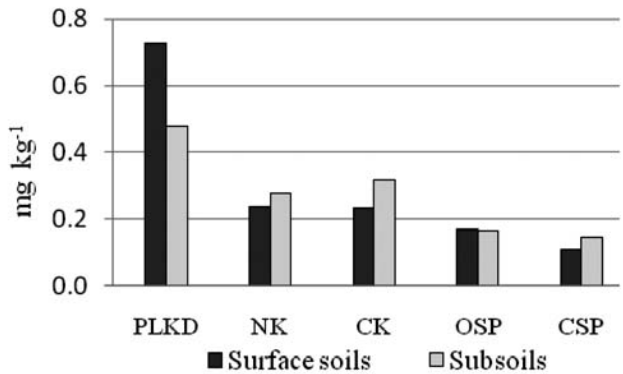
Fig. 10. Available boron content of coconut-growing soils of Kerala

Available molybdenum

Molybdenum deficiency is more likely in acid soils. Soils can be considered deficient in the nutrient when the content is less than 0.1 ppm, marginal when the content is between 0.1 to 0.3 ppm and above sufficient. By that reckoning, coconut-growing soils of Palakkad only tested for sufficient level, and soils from other regions were marginal (Fig. 11).

Plants often express adverse soil condition and deficiencies of nutrient through visual diagnostic symptoms. For identifying nutrient deficiencies, visual plant symptoms are useful, but it should be noted that plant growth and yield are often limited by lack of nutrients much before any symptoms are evident, even to an experienced agronomist. This subclinical deficiency is often inferred to as ‘‘hidden hunger’’. The delayed expression of visual symptoms is more pronounced in perennial crops like coconut. Again, it is not necessary that all the palms in a



PLKD-Palakkad; NK-Northern Kerala; CK-Central Kerala; SK-Southern Kerala, OSP-Onattukara sandy plain; CSP-coastal sandy plain

Fig. 11. Available molybdenum content of coconut-growing soils of Kerala

field are affected as is the case often observed in annual crops. Many nutrient deficiency symptoms are often mistaken for symptoms of diseases/pest attack. Regular soil quality monitoring combined with leaf tissue analysis can forewarn plant nutrient deficiencies, real or hidden and should form the basis for nutrient management of coconut plantations.

Soil related constraints to coconut in Kerala

Overhead climate and soil moisture availability in no way affects coconut palm in Southern and Central Kerala. Palms in Northern Kerala and Coastal sandy soils can gain from irrigation during summer months. For the palms of Central and Eastern Palakkad irrigation is an absolute necessity. Physical properties of soil like depth, texture, bulk density, infiltration and permeability to water present no limitation for coconut.

Soil reaction in extensive areas of the coconut crop production is quite unfavorable with strong acidity and aluminium in the soil solution. They are severely constraining to the palm chemically and biologically. The only exception is soils of Palakkad and Southern Kerala. The soils of Northern Kerala, Central Kerala, Onattukara Sandy plain and Coastal sandy plain suffer from extensive deficiencies of mineral nutrients like potassium, calcium, magnesium, copper, zinc and boron. Soils of Central and Eastern Palakkad and Southern Kerala constituting just around 10 per cent of the coconut-growing areas are relatively free from soil related constraints to the palm. This is reflected through better palm health and productivity in the regions. Soil related constraints galore in of ninety per cent of the coconut growing areas of the state, coastal sandy soils and midland laterites, and poor health of the palms and low productivity is a manifestation of the poor soil health.

Soil management recommendations for coconut

The following recommendations on soil management can be drawn from the findings of this study.

1. Regular liming of acid soils, preferably through application of dolomite. Application of gypsum to alleviate sub-soil acidity.
2. Practice of zero tillage and return of all palm residues to its base to maintain high levels of organic matter in soil.
3. Application of 2 kg muriate of potash (MOP) per palm per year in as many splits as possible. Additionally, 2 kg of common salt (NaCl) per year to meet the demands of chlorine by coconut.
4. External inputs of zinc sulphate, copper sulphate and borax at the rate of 100 g per plant in two splits annually for three years and there after reduced to half shall alleviate the deficiencies of micronutrients. In order to ensure adequate soil levels of molybdenum annual application of ammonium or sodium molybdate at the rate of 20 g per plant is recommended.

The external inputs of soil amendments and chemical fertilizers can be surface applied (or even on surface mulch) as the copious rainfall in coconut-growing tracts shall ensure their movement into the soils. The satisfactory coconut yield realized in Central and Eastern Palakkad and Southern Kerala (with little soil related constraints to the palm) lends credence to contention that alleviation of soil chemical constraints can ensure satisfactory production of nuts from coconut-growing areas of Northern Kerala, Central Kerala, Onattukara Sandy plain and Coastal sandy plain and keep the debilitating diseases at bay**.**

Acknowledgement

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