NUTRITIONAL REQUIREMENT OF COCONUT AND COCONUT BASED FARMING SYSTEMS IN INDIA

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ABSTRACT

The growth of young palms is influenced maximum by N, followed by K. While the effect of P has been marginal, it shows favourable interactions with N and K on growth and nut yield. Nutrient removal studies indicate that K is the dominant requirement for increasing the productivity of the palm. Increased rates of N had an adverse effect on copra content while K showed beneficial effect on all production factors. The hybrids (COD × WCT and its reciprocal cross) did not show response to levels beyond 500 g N + 500 g P_2O_5 + 1000 g K_2O/palm/year under rainfed conditions while high yielding West Coast Tall showed response to 1000 g N + 1000 g P_2O_5 + 2000 g K_2O/palm/year.

Magnesium has been a limiting nutrient in coastal sandy and laterite soils and the correction of Mg deficiency leads to 30–35 per cent increase in yield. Recycling long-term resources of soil P has been suggested and 10 to 12 ppm soil available P was found to sustain adequate P supply to palms. Boron is found to be a limiting element, particularly in the north-eastern region, leading to "Crown Choke" disorder in the palm which is corrected by judicious application of boron. The growth of young palms and yields of bearing palms were not affected when 50 per cent of K requirement was replaced by sodium chloride (common salt).

Limited organic farming with leguminous green manure crop in the coconut manuring circle is an encouraging practice for improving the fertility and nitrogen use efficiency. Coconut based high density cropping systems are found to require proportionately lower quantities of mineral fertilisers.

INTRODUCTION

The coconut palm, a tree crop of the humid tropics, is versatile in its adaptability to a wide range of soil and climatic conditions. Currently it is grown in an area of about 1.51 million ha in the country confined mainly to the states encompassed by the west and east coasts of which the west coast accounts for nearly 85 per cent (Table 39.1). The major area under the crop (91.45 per cent) is concentrated in the four southern states namely, Kerala (50.07 per cent), Karnataka (15.38 per cent), Tamil Nadu (14.95 per cent) and Andhra Pradesh (4.04 per cent).

Table 39.1: Area and production statistics in India 1989–90

Sl. No.	*State/U.T.*	*Area ('000 ha)*	*Production (M. nuts)*	*Yield of nuts/ha*
1.	Kerala	864.1	4527	5239
2.	Karnataka	232.9	1202	5159
3.	Tamil Nadu	226.4	2358	10415
4.	Andhra Pradesh	61.2	731	11938
	Total	1384.6 (91.45%)	8818	—
5.	Others (Orissa; Goa; Andaman and Nicobar Islands; West Bengal; Assam; Maharashtra; Tripura; Lakshadweep and Pondicherry)	129.3 (8.55%)	882	—
	Total	1513.9	9700	—

Figures in parentheses indicate percentage of total area
Source: Coconut Development Board, Kochi, Kerala.

Soils, Fertility and Production Constraints and their Management

A broad account of different soils under coconut in the country has been reported by Sankaranarayanan and Velayutham (1976 a; 1976 b). The morphological and the physico-chemical characteristics of typical soils from different agro-climatic regions of the country were studied by Khan *et al.* (1978). The soils were broadly classified under the four orders, namely, Alfisols, Entisols, Ultisols and Vertisols, and their classification up to sub-group level was also attempted. The major coconut growing soils of different states of the country are given below:

KERALA

Kerala is the premier coconut growing state in the country. It has three physiographic regions running parallel to each other from north to south namely the highlands in the east, the lowland in the west and the midland in between. Coconut cultivation is mainly confined to the lowland regions bordering the west coast with level topography and the midland with an undulating terrain and elevation up to 100 m. The major area is under rainfed culture.

Laterite Soil

This soil type occupies the major portion of the coconut area of the state and is found in all the 14 districts. Its fertility is medium in N, low in available P and K, poor in exchangeable cations with low CEC, high in free oxides of iron and aluminium, and acidic in reaction. Proper soil conservation measures to check erosion and run off on slopes are needed. A typical laterite soil of the Nenmanda series in Kozhikode district is classified as Oxic haplustult (Khan *et al.*, 1978).

Coastal Sandy Soil

This is the second major soil group found along the narrow coastal strip on the west. This soil is very poor in organic matter and nutrients and slightly acidic to neutral in reaction. Inadequate nutrient status and drought in summer months are the major production constraints. Judicious application of organic manures combined with inorganic fertilisers and summer irrigation are needed to improve the soil physical properties and fertility status of these soils. A typical coastal sandy soil of the Onattukara series in Kollam district is classified as Ustoxic quartzipsamment (Khan *et al.*, 1978).

Red Sandy Loam

This soil occurs largely in the three northern districts namely, Kozhikode, Kannur and Kasaragod, and in parts of Thiruvananthapuram district in the south and it occupies an area next to coastal sandy soil. These soils are reported to be of transported nature and had undergone a process of imperfect laterisation (Koshy and Varghese, 1972). It is medium in fertility status and acidic in reaction. As this soil has the desirable physical properties it supports good plantations wherever adequate management practices are followed. A typical red sandy loam soil of the Vellayani series in Thiruvananthapuram district is classified as Vermic ustorthent (Khan *et al.*, 1978).

Alluvial Soil

This soil is largely in parts of Kannur, Kozhikode, Thrissur, Ernakulam and Alappuzha districts of the state. The physical and chemical characteristics vary widely from place to place.

Reclaimed Marshy Soil

These soils are formed through the reclamation of the low-lying swampy and marshy lands adjoining backwaters and are locally termed as *Kari, Kaipad* and *Pokali* soils. They are subject to seasonal flooding and to the ebb and flow of tidal actions. They are found in isolated pockets of Kannur, Thrissur, Ernakulam, Alappuzha and Kottayam districts. The reclamation process consists of forming mounds by heaping up layers of soil, sand and organic wastes to a height of 1 m above the ground level/water table and then coconut seedlings are planted. In course of time the gaps between the mounds are filled using sand and organic wastes and are provided with drainage channels in between the rows of palms. Lack of adequate soil mineral mass and high acidity/salinity are the major production constraints of these soils. The reclamation and subsequent management of such gardens are generally expensive. However, under regular reclamation/management practices, the palms perform well on these soils. These reclaimed soils are invariably black in colour, rich in organic matter and nitrogen, and low to medium in P and K. They are extremely acidic with a fair amount of soluble salts. Correction of acidity and elimination of Al toxicity can be achieved to a certain extent by the use of magnesium silicate.

KARNATAKA

The major coconut growing soils of Karnataka state are the coastal alluviums, laterite soils and red soils of *maidan* area. The laterite and red soils are subject to severe moisture stress in summer and respond well to irrigation and manuring.

TAMIL NADU

The major coconut growing soils of Tamil Nadu are the coastal alluviums, river alluviums and red and black soils. In general, coconut is cultivated under irrigated conditions in these soils.

ANDHRA PRADESH

Coconut cultivation is confined to the deltaic alluvium (Udic chromustert, Khan *et al.*, 1978) and coastal alluvial soils.

ASSAM

Alluvial soils of the deltaic regions of Brahmaputra and its tributaries.

ANDAMAN AND NICOBAR ISLANDS

(i) Coastal alluvium, and (ii) forest loams.

GOA

(i) Laterite, (ii) coastal alluvium, and (iii) river alluvium.

GUJARAT

(i) Coastal alluvium, (ii) river alluvium, and (iii) medium black soils.

LAKSHADWEEP ISLANDS

Coral soils, which are sandy in texture, excessively drained, low in organic matter, N and K, and high in available P. The soils are highly calcareous (93 per cent $CaCO_3$) with pH ranging from 7.5 to 8.9. Large applications of organic matter to soil are much needed and the palms respond well to nitrogen and potash application.

MAHARASHTRA

(i) Laterite soil, and (ii) coastal alluvium.

ORISSA

Coastal and deltaic alluviums.

PONDICHERRY

(i) Coastal alluvium, (ii) deltaic alluvium, and (iii) laterite.

WEST BENGAL

Coastal and deltaic alluviums. They need improvement in drainage and amelioration through gypsum application.

Nutritional Requirements and Nutrient Dynamics/Response in Relation to Productivity

The coconut palm is a heavy consumer of nutrients, particularly K, Cl and N for its growth and productivity.

Nutrient Export

Nutrient exhaust values usually provide useful guidelines for approximating the quantity of nutrients and their proportion in which they are to be applied. The nutrient exhaust studies conducted in India by Pillai and Davis (1963) and Ramadasan and Lal (1966) show that the proportionate requirement of NPK of the palm in terms of $N:P_2O_5:K_2O$ is 2:1:3 and the quantitative order of requirement of major nutrients for adult bearing palm is $K > N > Ca > Mg > P$ which suggests that K is the dominant requirement of the palm while P requirement is the least. The quantity of major nutrients removed annually by a single palm (West Coast Tall) yielding an average of 40 nuts and producing 13 fronds per year as well as the quantity immobilised by the growing stem is estimated to be 321 g N, 69 g P, 406 g K, 196 g Ca and 72 g Mg (Pillai and Davis, 1963).

Table 39.2: Percentage removal of nutrients for the yield of nuts and for the growth of stem and leaves by West Coast Tall palm (Pillai and Davis, 1963)

Plant parts	*N*	*P*	*K*	*Ca*	*Mg*
Stem + leaves	49	50	22	77	59
Yield of nuts	51	50	78	23	41

It is seen that N and P are utilised more or less equally for the growth of stem and leaves and for the production of nuts. The proportion of K exhausted through the harvest of bunches is 78 per cent and that for the growth of stem and leaves is only 22 per cent. The data also suggest that increased productivity would eventually be accompanied by a proportional increase in the uptake of nutrients, particularly K.

Fertiliser Requirement of Nursery Seedlings

Nelliat (1972) was of the view that young seedlings are in short supply of nutrients for a major part of their one year growth in the nursery. He recommended the application of NPK fertilisers in the months of December, February and April to supply 40 kg N, 20 kg P_2O_5 and 40 kg K_2O per application per ha in nurseries where seednuts are planted in the month of May-June. This may ensure production of seedlings with favourable nutrient status so as to facilitate better establishment, faster growth and early bearing in the main field.

Fertiliser Requirement of Young Palms

Systematic fertilisation of young palms helps faster and vigorous growth and reduce the pre-bearing age. At Veppankulam (Tamil Nadu), application of NPK at the adult palm dosage of 340 g N, 230 g P_2O_5 and 450 g K_2O/palm/year helped the palms to flower one year ahead of the control (no fertiliser) palms. When double the above dosage was applied, the pre-bearing age was further reduced by four months (Varisai Mohammad *et al.*, 1969). Further trials on littoral sand (Anon., 1971) and sandy loam soil (Anon., 1972) showed that regular NPK fertilisation was essential for the satisfactory growth of young palms. Application of NPK fertiliser to young palms of COD × WCT and WCT × COD hybrids and high yielding talls resulted in highly significant increase in all growth characters and helped early flowering (Nelliat and Muliyar, 1971) and significantly influenced the leaf nutrient levels (Kamaladevi *et al.*, 1972) (Table 39.3).

Table 39.3: Foliar nutrient levels averaged over genotypes under different fertiliser levels at the fifth year of planting (Kamaladevi *et al.*, 1972)

Fertiliser levels	*Nutrient status (%) (Frond, 9)*				
	N	*P*	*K*	*Ca*	*Mg*
Mo	1.40	0.12	0.46	0.30	0.18
M1	1.50	0.13	0.82	0.29	0.19
M2	1.55	0.12	0.92	0.30	0.16
CD (5%)	0.095	NS	0.075	NS	0.03

Mo: (Control); M1: 500 g N + 500 g P_2O_5 + 1000 g K_2O/palm/year.
M2: 1000 g N + 1000 g P_2O_5 + 2000 g K_2O/palm/year.

In general the effect of N on vegetative growth of young palms was maximum followed by K while P showed favourable interaction with N and K. Nelliat (1972) recommended the application of one-tenth of the adult palm dose of fertilisers about three months after planting in the main field, one-third in the second year, two-thirds in the third year and the full dose in the fourth year onwards.

Fertiliser Requirement of Adult Palms

Large-scale fertiliser demonstration trials conducted all over the west coast of India showed that application of 340 g N, 340 g P_2O_5 and 680 g K_2O/palm/year had resulted in an increase of 35 per cent in yield of nuts and 44 per cent in copra outturn over the cultivators' practice. In certain locations where the above fertiliser dose was not responsive, significant increase in yield was obtained when the K_2O level was raised to 900 g/palm/year (John and Jacob, 1959).

In a 3^3 NPK factorial experiment on sandy loam soil at CPCRI, Kasaragod, higher level of N had an adverse effect on copra content while K levels showed positive response (Muliyar and Nelliat, 1971). They also reported that for palms yielding less than 60 nuts annually, the optimum dose of N ranged between 400 and 650 g and that of potash (K_2O) between 890 and 1210 g/palm/year.

Wahid *et al.* (1988) have concluded from a 3^3 NPK factorial experiment the need to supply N and K in augmenting coconut yield particularly K at increased rates (Table 39.4). They observed that the main effect of P was marginal. Further the importance of balanced application of N, P and K was evident from the significant NP, NK and PK interactions.

Table 39.4: Effect of nutrient interaction on the cumulative nut yield per palm (1976 to 1985) (Wahid *et al.*, 1988)

N × P	*Yield*	*N × K*	*Yield*	*P × K*	*Yield*
N_0P_0	139.33	N_0K_0	36.87	P_0K_0	46.91
N_0P_1	133.96	N_0K_1	179.33	P_0K_1	267.00
N_0P_2	138.42	N_0K_2	194.21	P_0K_2	264.67
N_1P_0	160.50	N_1K_0	22.00	P_1K_0	23.63
N_1P_1	357.21	N_1K_1	323.96	P_1K_1	383.75
N_1P_2	226.92	N_1K_2	398.67	P_1K_2	362.92
N_2P_0	278.54	N_2K_0	24.75	P_2K_0	12.58
N_2P_1	281.13	N_2K_1	451.40	P_2K_1	303.94
N_2P_2	414.76	N_2K_2	498.27	P_2K_2	463.56
C.D. (0.05)	125.95		125.95		125.95

Exptl. site: CRS, Balarampuram, Red sandy loam soil.

The foliar N levels were increased as a consequence of N fertilisation. However, the values even at the N_2 level of treatment (680 g N/palm/year) were below the suggested critical level of 1.8 per cent for nitrogen. Whether further addition of N would increase yield as well as leaf N content and reasons for low N content of palms is an aspect worthy of investigation. The absorption of K was increased and Mg decreased with increased rate of KCl application while P fertiliser levels did not show any improvement in the foliar P status (Table 39.5).

It was further observed that (Wahid *et al.*, 1988) muriate of potash proved superior to sulphate of potash for coconut manuring and phosphatic fertilisation did not show significant response in nut yield in many of the field trials. The fertiliser requirement of coconut in laterite soils was found to be 500 g N, 250 g P_2O_5 and 1250 g K_2O/palm/year and that of the reclaimed marshy soils of the backwater regions of Kerala (Thomas, 1968) was found to be 250 g N, 340 g P_2O_5 and 680 g K_2O/palm/year.

The general recommendation from C.P.C.R.I. for fertilising the adult bearing palms is to apply 500 g N, 320 g P_2O_5 and 1200 g K_2O/palm/year in two split doses namely, one-third of the above dosage during May–June (pre-monsoon) and two-third during September–October (after the cessation of rains) (Nelliat, 1972). Under average management of coconut gardens, a minimum of 340 g N, 170 g P_2O_5 and 680 g K_2O/palm/year may be applied in two splits as above (Anon., 1989).

Table 39.5: Effect of inorganic fertilisation on major nutrient composition of palms at Balaramapuram (Wahid *et al.*, 1988)

Treatment	*Nutrient level (%) (Frond, 14)*						
	N	*P*	*K*	*Ca*	*Mg*	*S*	*Cl*
N_0	0.91	0.11	1.48	0.28	0.33	0.10	0.61
N_1	1.07	0.12	1.39	0.26	0.35	0.11	0.70
N_2	1.03	0.12	1.19	0.34	0.34	0.10	0.73
P_0	1.04	0.11	1.31	0.26	0.33	0.11	0.66
P_1	1.01	0.12	1.33	0.28	0.34	0.10	0.72
P_2	0.96	0.12	1.42	0.33	0.35	0.11	0.67
K_0	0.99	0.11	0.54	0.31	0.40	0.10	0.66
K_1	0.99	0.12	1.37	0.30	0.32	0.10	0.69
K_2	1.03	0.11	2.15	0.27	0.30	0.11	0.70
C.D. (0.05)	0.09	NS	0.31	0.07	0.06	NS	NS

Effect of Long-term NPK Fertilisation on the Mineral Nutrition and Yield of Three High-Yielding Genotypes

The effect of long-term NPK fertilisation on soil, leaf nutrient concentrations and yield of three high-yielding genotypes was studied after 18 years of planting (Khan *et al.*, 1986). The improvement in N nutrition of the palm due to fertilisation was reflected on the foliar N levels (Table 39.6). However, no marked improvement was seen in the soil mineralisable nitrogen contents. Higher dose of fertilisers (M_2) had apparently no effect on the N content of the leaves over the lower level (M_1). Even after the continuous fertilisation for 18 years, leaf P levels were not raised to the suggested critical level of 0.12 per cent for phosphorus. The available soil P (Bray I) of the M_0 plots ranged between 9 and 20 ppm and around 10 ppm was found to be sufficient for maintaining adequate plant P levels (Table 39.7). As in the case of N, the K content of all the three genotypes was raised to the sufficiency level by M_1 level of fertilisation while M_2 level had no additional effect in improving the leaf K status.

Table 39.6. Soil nutrient status (ppm) under different levels of NPK fertilisation (Samples from 0 to 100 cm depth averaged over genotypes). (Khan *et al.*, 1986)

*Fertiliser level**	*pH*	*Available nutrients*			*Available micronutrients (DTPA extract)*			
		N	*P*	*K*	*Zn*	*Cu*	*Fe*	*Mn*
M_0	5.1	75	15	18	0.21	0.20	10	30
M_1	4.7	80	63	55	0.28	0.55	14	41
M_2	4.7	86	93	70	0.36	0.50	17	44

*Same as under Table 39.3.

Table 39.7: Effect of different levels of fertilisers on plant nutrient levels (Frond 14) of three coconut genotypes

*Genotypes/ Fertiliser level**	*(%)*						*(ppm)*			
	N	*P*	*K*	*Ca*	*Mg*	*Na*	*Cu*	*Zn*	*Fe*	*Mn*
WCT										
M_0	1.4	0.11	0.7	0.23	0.17	0.25	6	20	93	593
M_1	1.7	0.11	1.0	0.33	0.17	0.14	6	18	96	711
M_2	1.7	0.11	1.1	0.27	0.15	0.13	7	17	90	648
COD×WCT										
M_0	1.4	0.11	0.6	0.26	0.23	0.24	6	19	99	599
M_1	1.6	0.11	1.0	0.26	0.18	0.11	8	18	108	585
M_2	1.7	0.11	1.1	0.27	0.11	0.10	9	15	108	620
WCT×COD										
M_0	1.4	0.10	0.6	0.25	0.26	0.27	10	24	96	521
M_1	1.6	0.11	1.1	0.26	0.16	0.14	8	18	86	615
M_2	1.6	0.11	1.1	0.30	0.15	0.11	8	16	73	678
CD (0.05) Fertiliser	0.09	NS	0.12	0.03	0.03	0.03	—	—	—	—

*Same as under Table 39.3.

While the high-yielding WCT palms continue to respond to fertilisers beyond the M_1 level, the COD × WCT hybrid showed maximum response to M_1 level and the WCT × COD hybrid showed only marginal increase in yield beyond M_1 (Table 39.8). The COD × WCT hybrid outyielded the other two genotypes. The data suggest that on red sandy loam soil the palms respond more to N and K fertilisers for satisfactory growth and yield.

Table 39.8: Nut yield of three coconut genotypes under different fertiliser levels

*Genotypes/ Fertiliser levels**	*Yield of nuts/palm/year (July 1982–June 1983)*			*Cumulative yield (1972–1983)*		
	M_0	*M_1*	*M_2*	*M_0*	*M_1*	*M_2*
WCT	33.7	66.9	84.4	131	435	578
COD×WCT	45.9	92.2	94.7	293	936	737
WCT×COD	26.4	79.2	80.4	87	473	503

*Same as under Table 39.3.

Monitoring the residual effect of long-term phosphorus application (22 years) Khan *et al.* (1990) observed that withholding application of phosphatic fertilisers for 14 years did not affect the yield and nutrition of adult coconut palms (Tables 39.9 and 39.10).

Interestingly VA mycorrhizal infection was more (79 per cent) in the root zone of palms where P application was withheld compared to palms receiving 50 per cent of recommended dose (52.1 per cent) and full dose (47.9 per cent). Population of P solubilising bacteria was also higher in the plots where P application was withheld. This suggested the beneficial association of micro-organisms in supplying phosphorus from accumulated soil reserves.

Table 39.9: Effect of phosphorus skipping on available P status in coconut basin. (Khan *et al.*, 1990)

Treatment	*Soil available P (ppm)*							
	1975				*1990*			
	0–30	*30–60*	*60–90*	*Mean*	*0–30*	*30–60*	*60–90*	*Mean*
P_0	84.00	24.00	23.66	43.85	20.64	9.81	7.83	12.72
P_1	88.42	24.20	12.00	41.54	67.95	12.06	11.29	30.43
P_2	84.25	34.15	12.75	43.72	120.75	26.95	12.66	53.29
SE/plot	—	—	—	—	20.60	9.85	3.14	—
C.D.	—	—	—	—	16.01	7.66	2.44	—

P_0 — control; P_1 — 160 g P_2O_5/palm/year; P_2 — 320 g P_2O_5/palm/year;
N and K applied at recommended dose.

Table 39.10: Effect of phosphorus skipping on leaf P (Frond 14) content and yield of palm

Treatment	*1975*		*1989*	
	Leaf %P	*Yield*	*Leaf %P*	*Yield*
P_0	0.093	103.2	0.119	109.07
P_1	0.092	101.1	0.120	102.36
P_2	0.096	99.6	0.114	108.71

Khan *et al.* (1985) while evaluating the comparative efficiency of four phosphate carriers, namely, superphosphate, ammonium phosphate, nitrophosphate and rock phosphate, recommended rock phosphate as the ideal carrier of P for coconut as the soil content receiving rock phosphate gave the best reflect on plant P and enriched all P fractions in the soil and influenced the overall yield.

Root CEC and Coconut Nutrition

The relationship among cation exchange capacity (CEC) of roots, yield and cationic concentrations in soil and plant of different yield groups of West Coast Tall palms (Wahid *et al.*, 1974) showed that K contents of both soil and plant were positively correlated with yield while root CEC was negatively correlated with yield as well as leaf K content emphasising the importance of K in increasing nut yields. The study also suggested a critical level of 0.8 to 1 per cent for potassium (Frond 14) for coconut. The CEC of coconut roots ranged from 12.1 to 23.0 m.e./100 g.

Ca, Mg and S Nutrition

Crop removal studies (Pillai and Davis, 1963) suggest that the requirement of Ca and Mg are higher than that of P for coconut. Specific instances of Ca deficiency conditions or the direct effect of Ca on yield of the palm was not reported in India. However, liming of acid soils was found to favour the uptake of N, P and Mg by the palm. For acid soils, one kg of slaked lime or dolomite per palm per year is recommended. A critical level of 0.3 per cent Ca (Frond 14) has been suggested (Cecil, 1991).

Magnesium has been observed to be one of the most limiting nutrients for young palms. Magnesium deficiency has been more common on acid sandy and laterite soils with low Mg content and is also induced by imbalance of nutrients like high K/Mg or Ca/Mg ratios in soils and leaf tissues (Pandalai *et al.*, 1957; Pandalai, 1959; Cecil, 1975). Higher dose of K fertilisers was found to depress foliar Mg content and induce Mg deficiency in the palm (Khan *et al.*, 1986). Regular application of magnesium sulphate (hydrated) at the rate of 500 g MgO/palm/year from the time of field planting on a Mg-deficient sandy soil in the west coast of Kerala (India) had increased the growth parameters at a highly significant level, reduced the pre-bearing age by 9.1 months, increased the initial yield up to the fourteenth year by 34 per cent (Table 39.11), and maintained Mg content of soil and leaf to desired levels (Cecil, 1981).

Table 39.11: Main effect of Mg on growth, flowering and initial yield of WCT palms planted in 1970

Treatment	*Girth at collar (cm)*	*Height (cm) (36 months)*	*Fronds produced up to Dec. '80 (No.)*	*Proportion of palms (%) in flower at 74 months*	*Pre-bearing age (months)*	*Yield of nuts/ palm up to Dec. '84*
Mg_0	63.5	325.4	96.9	31.4	78.4	313.4
Mg_1	72.8	356.1	105.0	59.7	69.3	419.4
C.D. (0.05)	4.5	14.7	—	10.2	2.4	—
Per cent increase	14.6	9.4	8.4	90.1	−11.6	33.8

Mg_0 — Control; Mg_1 — 500 g MgO/palm/year.

Kamalakshi Amma *et al.* (1982) observed that application of 500 g MgO/palm/year gave a significant increase in growth and yield and 1000 g MgO/palm/year did not show any superiority. The addition of Mg may be regulated up to a maximum dose of 3 kg magnesium sulphate ($MgSO_4 \cdot 7H_2O$) per palm per year based on the extent of limitation of Mg and the exchangeable Mg/K ratio values of soil. An exchangeable Mg/K ratio of 2.0 in the soil (0 to 50 cm depth) and the foliar content of 0.2 per cent Mg in frond 14 are considered as critical for regulating the Mg requirement of the palm (Cecil, 1988).

Critical studies on sulphur nutrition of the palm were not attempted. A survey of coconut growing tracts of Kerala (Pillai, 1975) indicated that sulphur content (Frond 14) ranged from 0.10 to 0.16 per cent. Cecil (1981) observed improvement in plant S levels due to regular application of sulphur bearing fertilisers like ammonium phosphate (15 % S) and magnesium sulphate (13 % S) and the foliar levels were maintained at 0.20 to 0.23 per cent S in frond 14, suggesting that inclusion of any one of the S-bearing fertilisers like ammonium sulphate, superphosphate, ammonium phosphate, magnesium sulphate or sulphate of potash will avoid sulphur deficiency conditions (Cecil and Pillai, 1976).

Sodium Chloride Nutrition

Field fertility studies involving application of 50 per cent of K requirement as sodium chloride and the rest as muriate of potash did not show any difference in the growth of young palms or on the productivity of bearing palms (Table 39.12). The early flowering index of NaCl-treated palms was higher than that of KCl-treated palms (Wahid *et al.*, 1988). Further studies are in progress at CPCRI, Kasaragod.

Table 39.12: Effect of NaCl on growth and flowering of D × T hybrids (planted in 1976) and on yield of bearing West Coast Tall palms (Wahid *et al.*, 1988)

Treatment (g/palm/year)	*D × T hybrids*		*West Coast Tall*
K_2O + Na_2O	*No. of fronds produced (1976 to 1985)*	*Early flowering index*	*Mean post-treatment yield (nut/palm/year) (adjusted)*
0 + 0	73.9	1.0	69.7
1000 + 0	73.3	1.9	86.8
750 + 250	78.3	2.6	73.8
500 + 500	79.2	2.4	84.8
250 + 750	72.7	2.6	83.0
0 + 1000	77.5	2.4	75.0
CD ($P = 0.05$)	NS	NS	15.6

The chlorine levels of West Coast Tall palms in the above experiment ranged between 0.75 and 0.82 and was not significantly different among the treatments.

Micronutrients

The tropical acid soils are in a fortunate position with respect to the cationic elements Fe, Mn, Cu and Zn. These cations are easily soluble and readily available under acid conditions and are not generally found limiting in the nutrition of the palm.

Availability of boron poses problem of deficiency in acid laterite, alluvial and coastal sandy soils. The boron deficiency disorder known as "Crown Choke" disease has been a serious problem in Assam and West Bengal (Baranwal *et al.*, 1989). From a recent survey in Assam (Anon., 1990), 10.8 per cent of the palms were found affected by the disease and the total annual loss in yield due to the malady was estimated at 6.38 million nuts. Cecil and Pillai (1978) reported 5.7 ppm B in affected palms and 9.2 ppm B in comparable tissues of healthy palms. Baranwal *et al.* (1989) also reported that Ca/B ratio (on equivalent basis) was significantly lower for healthy palms when compared with diseased palms. It is interesting that the Ca/B ratio of palm in a healthy area was much lower than that of palms in the affected area (Table 39.13).

Table 39.13: Leaf B content and Ca/B ratio of palms in healthy and diseased areas (Baranwal *et al.*, 1989)

Condition of palm	*Leaf rank*	*Leaf B (ppm)*	*Ca/B ratio*
Diseased area			
Healthy palms	n/2 or (n+1)/2	7.4	95
Diseased palms	n/2 or (n+1)/2	5.4	145
Healthy area			
Healthy palms	n/2 or (n+1)/2	9.4	71
Healthy palms	frond, 14	10.2	—

Soil application of borax (decahydrate) at the rate of 50 g/palm just after the appearance of the symptoms was recommended. In slightly advanced stages, two applications of borax, 50 g each, at an interval of three to four months was found necessary for the recovery (Baranwal *et al.*, 1989).

Distribution of Microflora in the Root Zone and their Activity

Microbial population was high in multispecies high density cropping system (Bavappa *et al.*, 1987), multistoreyed cropping and mixed farming (Bopaiah, 1990) systems compared to that in monocropping of coconut. Nair (1974) described the microbial component as an important factor in enhancing the yield of coconut under the influence of cocoa as mixed crop. Bopaiah (1988) found enhanced activities of dehydrogenase, phosphatase and urease in root region soils of coconut compared to those in the interspaces.

Biological Nitrogen Fixation

Coconut based cropping systems favoured higher population of asymbiotic nitrogen fixers compared to monocropping of coconut (Potty and Jayasankar, 1983). The occurrence of the associative N_2-fixer Azospirillum was reported from coconut and a number of component crops under the different coconut based cropping systems. Studies on the distribution of Azospirillum under different management practices revealed greater number of the bacteria in plots which were not receiving fertilisers for a long time (Ghai and Thomas, 1988).

The green manure/cover legume-*Rhizobium* interaction is found to be an efficient N_2-fixing system in coconut gardens. It was found that *Pueraria phaseoloides* and *Calopogonium mucunoides* were promiscuous in their rhizobial requirement in coconut soils with acidic reaction. Studies on organic farming with leguminous green manure crops within the coconut basin (1.8 m radius area around the bole) during the rainy season (four to five months) showed that *P. phaseoloides, Mimosa invisa* and *C. mucunoides* produced 15 to 19 kg and 25 to 28 kg of green matter per basin in sandy and laterite soils, respectively, and increased the microbial activity (Thomas and Shantharam, 1984).

Nutritional Studies on Coconut-based Cropping System

In coconut farming, fertilisers constitute the major component of energy-based input. In intensive cropping with tree crops, the application of fertilisers according to the estimated requirement for each crop is certainly not the most efficient and economic way of utilising native and applied nutrients (Oelsligle *et al.*, 1976). However component crops were fertilised based on their individual requirement for want of information on fertilising/managing the system as a whole.

A poly-culture involving coconut, namely, coconut-cacao combination, and a high density multi-species cropping system involving several component crops offer a vast scope of recycling of organic matter to a large extent. Varghese *et al.* (1978) reported biomass addition to the soil through shed leaves of a five-year-old stand of cacao under single and double hedge systems of planting to the extent of 818 kg and 1785 kg/ha/year, respectively. Organic carbon content of soil was considerably enriched through this addition (Table 39.14) and it was estimated that under double hedge system about 50 kg N, 11 kg P_2O_5 and 85 kg K_2O/ha/year were returned to soil through leaf fall.

Table 39.14: Organic carbon content of the soil in a coconut-cacao intercropping system. Verghese *et al.* (1978)

Treatment	*Organic carbon %*		
	Pre-experimental period	*Experimental period*	
	0–30 cm	*0–15 cm*	*15–30 cm*
1. Unirrigated coconut	0.25	0.36	0.27
2. Irrigated coconut	0.25	0.56	0.56
3. Coconut + cacao in single hedge + pineapple + pepper	0.25	0.61	0.56
4. Coconut + cacao in double hedge + pineapple + pepper	0.25	0.76	0.58

Such recycling of nutrients through organic litter fall offer scope to reduce fertiliser input. Nair (1979) visualised an annual storage of 41.7 kg P_2O_5/ha in pure coconut system compared to 44 kg P_2O_5 ha in 30-year-old coconut with five-year-old cacao mixed crop system. He recommended skipping of P application in alternate quarters to coconut and thereby reducing the P input by 56 kg P_2O_5/ha/year.

In a high density multispecies cropping system with coconut and 17 component crops, the nutrient budget and balance studies indicated considerable build up of P and K in the system as a whole, while N and Mg got depleted. The depletion of Mg was uniform irrespective of the levels of fertilisers (one-third, two-third and full dose of recommended fertilisers for component crops and coconut) applied while the addition of full dose of fertilisers reduced the N depletion rate. The heavy build up of P and K in the system suggest the adequacy of one-third dose of P and K for maximum system productivity. Though there was an indication to the effect that N continued to deplete, the total yield of the main and component crops was unaffected during the period of study (1983 to 1985) even at one-third dose of fertiliser application. This aspect needs further investigation.

Diagnostic Techniques: Soil Testing Tissue Analysis

Cultivated crops are influenced by many factors, and nutrient supply from the soil is one of them. Soil testing and plant analysis have merits and demerits in diagnosing a situation specific problem related to crop nutrition. Pioneering work of IRHO scientists to judge the palm health based on critical levels in diagnostic leaf has been acclaimed as the best for coconut.

Soil Analysis

Long-term observations lead to conclude that 70 to 80 ppm of mineralisable nitrogen in soil (Subbaiah and Asija, 1956) and 10 to 12 ppm Bray-I extractable phosphorus can sustain sufficient levels in coconut (Khan *et al.*, 1986). Critical level of soil available K (1 N NH_4OAc) was found to be 50 to 65 ppm. This information, though needs revision, served as the best guide for recommending fertilisers in the absence of plant analysis. Khan *et al.* (1989) proposed that if soil available P is less than 10 ppm, full recommended dose of 320 g P_2O_5/palm/year 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.

Further, phosphorus and potassium desorption models were constructed taking into account the response or reaction of the soils to added fertilisers (unpublished work). The models aim at maintaining the soil phosphorus (Table 39.15) and potassium (Table 39.16) fertility level at 20 ppm and 80 ppm respectively.

A similar model for potassium for red sandy loam soil was found to give an indication of higher K to be added for a given STV due to basic differences in soil characteristics.

Leaf Analysis

No systematic studies have been conducted in India to fix critical levels of major and secondary nutrients for coconut. However, the various data on leaf analysis and nutrient responses available in the country suggest the following critical levels (Frond, 14) for the tall variety of coconut.

N — 1.7–1.8 per cent
P — 0.11–0.12 per cent

K — 0.8–1.0 per cent
Ca — 0.3 per cent
Mg — 0.2 per cent

Table 39.15: P prescription for coconut on red sandy loam soil based on STV (g P_2O_5/palm/year)

STV (ppm)	*Desired level of P in soil (ppm)*									
	2	*4*	*6*	*8*	*10*	*12*	*14*	*16*	*18*	*20*
2	0	80	160	235	315	395	475	550	630	710
4		0	80	160	235	315	395	475	550	630
6			0	80	160	235	315	395	475	550
8				0	80	160	235	315	395	475
10					0	80	160	235	315	395
12						0	80	160	235	315
14							0	80	160	235
16								0	80	160
18									0	80
20										0

Table 39.16: K prescription for coconut on laterite soil based on soil test values (STV) (g K_2O/palm/year)

STV (ppm)	*Desired level of K in soil (ppm)*							
	80	*70*	*60*	*50*	*40*	*30*	*20*	*10*
0	1514	1238	1062	885	708	531	354	177
10	1238	1062	885	708	531	354	177	0
20	1062	885	708	531	354	177	0	
30	885	708	531	354	177	0		
40	708	531	354	177	0			
50	531	354	177	0				
60	354	177	0					
70	177	0						
80	0							

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DISCUSSION

K.S. Jayasekara: How severe is the Mg deficiency in coconut in Kerala?

S.R. Cecil: Magnesium deficiency is common in acid laterite and coastal sandy soils in Kerala. It is severe in acid sandy soils where foliar Mg levels of palms are in the range of 0.10 to 0.15 per cent.

W. Krishnamurthy Rao: If P is skipped for a considerable time as recommended, what would be its impact on Zn status and its effect on yield?

H. H. Khan: Zn status of the leaf tissue (Frond 14) did not change due to withholding phosphorus application and no deleterious effect on yield was recorded.

P.K. Vijayachandran: Will the present use of urea, rock phosphate and muriate of potash likely to lead to deficiency of sulphur in due course?

S.R. Cecil: Studies have shown that contribution from precipitation in the coconut growing regions (ranged between 12.2 and 28.5 kg) and the degradation of mulch in the manuring circle seems to take care of the palm's requirements of sulphur. It is however advisable to monitor the leaf tissue levels for sulphur.