POTASSIUM AND SULPHUR NUTRITION OF COCONUT

C. Palaniswami and A K Upadhyay[1]
Central Plantation Crops Research Institute
Kasaragod 671 124

The role of potassium in the soil and thereby in the crop nutrition is very important and complex. It can be very well understood from the statement of Albrecht (1943), who rightly epitomized that, "Because of the prevalence of its minerals in the lithosphere, of its readily soluble nature, of its readiness to become insoluble and inexchangeable from the colloid, of its movement from the vegetation to the soil through leaching from the tops or exchange from the roots, and of its reserve in the silt and sand minerals to buffer the clay; K is so nomadic that its performances in any particular situation are difficult to interpret". In plant potassium plays a number of indispensable roles like maintaining the ionic balance of the cell, water relations etc. The type of clay and parent material mainly governs the availability of potassium in the soils. In general, the soils having montmorillonite and illite as clay minerals are supposed to be rich in K reserves. The chemistry of K in soil and plant is very complex. In the nature, the potassium cycle consists of depletion from soil reserve on account of leaching losses beyond root zone, uptake and removal by the crops and addition through release of K from minerals, fertilizers and organic matter and debris.

In the Indian agriculture, potassium is second or comparable to nitrogen in its importance. It is one of the three major nutrients removed in appreciable amounts from the soil and has to be replenished quickly to the soil nutrient pool to offset any yield decline. Tandon and Narayan (1990) identified 47 districts in India are deficient in K, whereas 192 is medium and 122 districts high in potassium status. This is based on soil fertility map prepared in 1976. And it is long way since we have come *i.e.* another two decades. Knowing the fertilizer usage with regard to potassium, it can safely be said that now atleast more than 50 % of the soils will definitely require K application in order to give optimum crop yields.

---

1 National Research Centre for Grapes, Pune -412307, Maharashtra

1. POTASSIUM

1.1 Coconut Growing Soils and their Potassium Status

In general, coconut like any other plantation crops is grown on variety of soils namely lateritic and laterite, littoral coastal sand, red sandy loams, alluviums, coral, peaty and black soils. The ideal coconut growing soils are well drained and aerated with a minimum depth of 80 to 100 cm, pH range between 5 to near neutral, adequate nutrient availability and water holding capacity (Fremond, 1964). The major coconut growing soils are laterite, lateritic, coastal sand and alluvial. Except for alluvials, all the other soils have low native fertility and poor physical properties.

The major area of the coconut being in South India suffers from prolonged spell of high temperature and high rainfall leading mainly to leaching losses of silica and bases from parent material with concurrent accumulation of oxides of Fe and Al. This leads to the formation of laterites, a dominant soil group under plantation crops. As shown in table 1 and various studies have long established that the soils are acidic in reaction with poor native fertility, low CEC, a characteristic of Kaolinite as dominant clay minerals and have high presence of sesquioxides. Based on the ratings of Muhr *et al*. (1963), Pillai (1975) has reported that all the soil groups of Kerala under coconut are generally deficient in available K and no soil group following under high ratings. The mean values for coastal sandy soil in the 0-50 cm and 50-100 cm layers were 12.2 and 10.9 ppm and corresponding values for sandy loam soils were 28.4 and 28 ppm, respectively. Robert Cecil (1981) reported similar values for the sandy loam soil of Kayamkulam. Surveying the soils of Badagara taluk, a premier coconut-growing tract, Ramanandan (1977) reported that the soils were poor in K. Krishnakumar and Koshy (1976) held similar opinion for ‘Poonthalpadam’ area in Kerala where the exch. K varied from 0.07 to 0.24 m.e 100 g^{-1}. Bastin and Venugopal (1986) indicated that the alfisols, which are intensively cultivated for coconut, are generally low to medium in potash status (Table 1).

1.2 Potassium Dynamics in Soil

Critical studies on soil potassium in relation to coconut nutrition are lacking except for some manurial experiments with potassium as one of the factorial component (Biddappa *et al.* 1993). Hameed Khan *et al*. (1982) found that K adsorption was comparatively more and uniform in laterite soils than in red sandy loam, river alluvium and coastal sands cultivated to coconut. The magnitude of the constants K and 1/n and the difference in the values of Freundlich adsorption isotherm was attributed to the contents and nature of clay minerals in these soils. The influence of clay minerals in K supply to the nutrient pool was also indicated by Ramanathan and Krishnamoorthy (1976).

Table 1. Available K status in different red soil (alfisols) series of Kerala

Soil series/Location	Available potassium status (ppm)		
	Mean	Range	Rating
Vellayani (Trivandrum)	23.7	12.1-36.6	Low
Cheriyoor (Quilon)	34.2	12.3-68.1	Low, Medium
Bhavanikkavu (Quilon)	44.4	20.2-75.1	Low, Medium
Beypore (Calicut)	36.8	6.0-112.7	Low, Medium
Chirakkal (Cannore)	40.8	12.1-113.6	Low, Medium
Kunhimangalam (Kasaragod)	19.6	4.5-34.3	Low

Hameed Khan *et al*. (1982) further observed that desorption of applied K showed a constant release after third and fourth extraction, irrespective of soil groups. Even after the 8th extraction, a constant release of 1.5 to 2.5 ppm K was removed in two extractions. The soils under the present study were dominated by kaolinite clay minerals, which have no interlattice binding sites for K, and hence cannot hold any non-exchangeable K (Patil *et al*. 1976). As K is likely to get depleted more easily from the feeding zone and the K pool also cannot restore much K needed by the coconut palm, which has a heavy demand for potassium, there is a need for evolving a more suitable way of K management. Report of John and Jacob (1959) on extensive fertilizer demonstration studies involving 24,000 coconut trees in the west coast of India lends support to the above contention. They indicated that application of additional dose of potash and higher doses of NPK resulted in increased yield where standard dose failed to elicit adequate response in farmer's field.

The selective distribution of potassium in representative soils (Hameed Khan *et al*. 1982) revealed that the major part of applied K was extracted with boiling HNO_3 followed by 1 N NH_4OAc and more or less uniform extraction of K in 0.01 M $CaCl_2$. Variation in water soluble K among soil groups was attributed to initial available K in soils, prior to saturation with K for the study. There was evidence to show that applied K was converted into difficult exchangeable forms and the equilibrium between exchangeable and labile-K is maintained relatively faster in these soils. Further, in the incubation experiments with different coconut growing soils, highest water soluble K fraction was obtained in sandy soil followed by laterite, red sandy loam and alluvial soils. The exchangeable K fraction was highest in red sandy loam followed by laterite, alluvial and sandy soil. The non exchangeable K fraction was highest in alluvial followed by laterite, red sandy loam and sandy soil (Upadhyay, A. K. 1997. Annual Report. 1997. Central Plantation Crops Research Institute, Kasaragod). This variation in the fractional distribution of K is on account of the variation in the mineralogical constituent of the soil and the initial soil K status.

Soil profiles from three soil series of Kannur district were analysed for different K fractions. In Dharmadham series, the water soluble K ranged from 4 to 39 ppm, Exch. K from 1 to 69 ppm and non Exch. K from 11 to 98 ppm whereas the water soluble K ranged from 4 to 18 ppm, Exch. K from 2 to 53 ppm and non Exch. K from 37 to 71 ppm in Kunhimangalam series. In Pilathara series, the water soluble K ranged from 4 to 8 ppm, Exch. K from 10 to 36 ppm and non Exch. K from 44 to 125 ppm. In general, the soils are poor in K status, and will need investment in the form of K currency for high yields (Upadhyay, A. K. 1997. Annual Report. 1997. Central Plantation Crops Research Institute, Kasaragod).

1.3 Response to K Application

Coconut has unique feature among the plantation crops in that it flowers and fruits through out the year. Hence, adequate water and nutrients should be maintained during the entire period. Proper nutrition during early stages has a profound influence on yields during the productive lifetime of the species. Foale (1968) reported that nutrient contribution by endosperm to the growing seedling decreased from 4th month after germination, suggesting that the young seedlings are actually in short supply of nutrients for major part of their one year growth in the nursery when seedbed is not adequately supplied with nutrient. Though, food reserves where adequate as far as carbon compounds and nitrogen were concerned (Harris, 1970), potassium uptake was more and the experiments indicated the advisability of applying potassium. Application of balanced fertilizers consisting of N, P, K, Ca and Mg to the nursery seedlings improved the vigour and quality of seedlings (Nelliat *et al.* 1976). The seedlings obtained from seednuts collected from palms manured with K displayed better vigour and growth than those obtained from unmanured plots (Nelliat, 1973).

1.3.1 Influence of potassium on young palms

On an average one leaf is produced every month and this leaf remains on the palm for at least 3 years. In young immature trees, lack of K results in shortening of the lifespan of leaves, decreased leaf size and reduced rate of leaf production. This extends the immature phase and the trees grown under such conditions will not commence before 10 –12 years of age, whereas palms receiving adequate nutrition will start bearing from 3-4 years from field planting itself. Thus, the importance of K is not only for the faster development and vigorous growth, but also for reducing the prebearing period (Smith, 1968). The palms, which received adequate nutrition from the beginning, produced more yield than those supplied after maturity. In coconut experiments in the Ivory Coast (Fremond and Ouvrier, 1971), the effect of applying K and the time of field planting was compared to withholding K applications until the age of bearing (Table 2). The later practice was decidedly inferior for all palms. Similarly, palms fertilized with KCl and N or NP from transplanting time in an inland-upland area of Philippines recorded initial flowering in less than four years and significantly higher nut and copra production than those palms, which did not receive KCl. In a sandy loam soil at Kasaragod, palms which received 1.0 kg N and 1.5 kg K_2O flowered first (Nelliat, 1978).

1.3.2 Influence of potassium on adult palms

Coconut continuously mines the soil of the nutrients from the soil nutrient bank to produce higher yields. The potassium levels influence the yield and yield attributing characters in coconut. Menon and Pandalai (1958) on reviewing the work of various workers has summarised that coconut responded positively to potassium application and K had beneficial effect on copra production compared to nitrogen which had an adverse effect. This further reflects the importance attached to potassium in coconut nutrition.

Application of 340 g N, 340 g P_2O_5 and 680 g K_2O/palm/ year improved the nut yield by 35 % and copra out turn by 44 % in the cultivators gardens where the palms were hitherto unmanured. Further, where response to fertilizer application was not observed, significant increase was obtained when K level was raised to 900 g K_2O/palm/year (John and Jacob, 1959). Muliyar and Nelliat (1971) reported that potassium improved all the nut characters studied *viz.* weight of whole nut, weight of husked nut, volume of husked nut and copra weight per nut, whereas nitrogen had an adverse effect. In a long term fertilizer experiment in red loam soil, Wahid *et al.* (1988) recorded significantly higher nut yield with potassium application. Besides early bearing was also achieved with increased levels of K application. The yield was 7, 68 and 77 nuts palm^{-1} year^{-1} in the 21st year after planting under no fertilizer, 450 g K_2O and 900 g K_2O palm^{-1} year^{-1} respectively.

Table 2: Timing effects of first potash fertilizer application on the performance of young coconut palms

Year	Characteristics observed	Time of K application	
		From field planting	From bearing age only
1956	No. of fronds	8.89	7.69
1958	Length of frond (cm)	256	233
1959	Girth (cm)	124.1	105.4
1960	No. of fronds (one yr)	11.7	10.7
1962	Kg copra ha^{-1}	2,560	272
1966	Kg copra ha^{-1}	2,480	2,272
1970	Kg copra ha^{-1}	-	2,096
1961-1970	Cumulative yield (kg ha^{-1})	17,344	12,704

A desorption equilibrium model was prepared for laterite and red sandy loam soils for computation of the amount of K_2O palms^{-1} needed to raise the available potassium content of soil to a desired level. Though Hameed Khan *et al.* (1986) have indicated 50-60 ppm of available K as a desired level (based on its reflect on plant K and yield), however, in the present study, 80 ppm available K (1 N NH_4OAc) was assumed as the base value in the coconut basin to maintain a plant content of 0.8-1.0% (Annual report, 1985). To regulate satisfactory release of K for coconut, a ready reckoner table was prepared to guide the level of K_2O to be applied per palm (Table 3). It was observed that the potential buffering capacity (PBC^{-k}) of laterite and red sandy loam soil with reference to potassium was different and hence the amount of K to be applied is less for laterite soil compared to red sandy loam to sustain available K content at 80 ppm.

1.6 Nutrient Interaction in the System

The interaction of potassium with level of other nutrient is more important than that of with the qualitative factors like form of fertilizer, method and date of application, crop variety, etc. Several studies have revealed strong interactions of potassium with other nutrient elements like Ca, Mg, Na and N. Smith (1968) opinioned that the critical level of K is operated when nitrogen was at sufficient level and suggested N: K ratio of 2.25 when N level was less than 1.8 per cent. Experiments conducted at Ratnagiri in Maharastra (AICCAIP, 1983) have indicated that the response to higher level of N (750 g N palm^{-1} year^{-1}) application was manifested only in the presence of potassium. In the absence of K fertilizer, response was noticed only upto the lower level of N (375 g).

Table 3. Dosage of K required for laterite and red sandy loam soil to raise the soil test value of K to any predetermined level (g K_2O palm/year)

Soil test value	80	70	60	50	40	30	20	10
Laterite Soil								
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							
Red sandy loam soil								
0	2087	1826	1565	1305	1043	782	522	260
10	1826	1565	1305	1043	782	522	260	0
20	1565	1305	1043	782	522	260	0	
30	1305	1043	782	522	260	0		
40	1043	782	522	260	0			
50	782	522	260	0				
60	522	260	0					
70	260	0						
80	0							

Manciot *et al.* (1979) reported that there exist strong antagonisms between K-Ca, K-Mg and K-Na. Often, Mg level in the tissue decreased consequent upon high fertilization. Application of potassium lead to a significant drop in the content of Ca, Mg and Na in the leaf (Table 4). The antagonistic effect of combined level of Na, Ca and Mg on K in the palms when judged through foliar analysis.

Coomans (1977) observed that application of K had induced the Mg deficiency in coconut hybrids, but Mg application had no effect on leaf K level. However, Brunin(1970) reported that in Tall cultivars when the leaf K levels were between 0.7 and 1.2%, application of high rates of Mg significantly reduced K contents. The results of a fertilizer experiment conducted on MAWA hybrid by IRHO (Table 5 ; Manciot *et al.* 1979) concluded that magnesium fertilization is beneficial only when the K is adequate in supply or the K deficiency is corrected. The results showed that Mg application had a beneficial effect on the copra yield only if K fertilizers were also applied. Similarly higher levels of K manuring increased the yield only in the presence of Mg. In fact, higher levels of K application had a depressive effect on copra yield in the absence of Mg fertilization.

Table 4: Effect of KCl application on the nutrient concentrations in the leaf

KCl appln. (kg palm^{-1} year^{-1})	Nutrient content (%)					
	N	P	K	Ca	Mg	Na
Control	1.8	0.091	0.20	0.495	0.567	0.166
5	1.75	0.097	0.98	0.507	0.188	0.294
10	1.74	0.094	1.38	0.401	0.159	0.234
15	1.74	0.097	1.55	0.392	0.125	0.181

Table 5: Influence of K and Mg application on the copra yield (kg palm^{-1} year^{-1}) of hybrid coconut

K appln. (KCl kg palm^{-1} year^{-1})	Mg application (Kieserite kg palm^{-1} year^{-1})			Mean
	0	0.6	1.2	
0	33.0	32.6	32.9	32.8
1.2	66.6	77.4	75.0	73.0
2.4	41	88.1	88.7	72.6
Mean	46.9	66.0	65.5	

The results of the experiments conducted at CPCRI, Kasaragod in red sandy loam and lateritic soils have shown that application of NPK fertilizer without Mg showed significant reduction in leaf Mg content (Khan *et al.* 1986). Loganathan and Atputharajah

(1986) observed in their study in Sri Lanka that application of muriate of potash increased the leaf K and Cl contents, but decreased the Mg and Ca contents.

2. SULPHUR

Sulphur is an important nutrient for crop production. More emphasis on high analysis fertilisers (S-free) and increased crop yields have led to a perceptible decline in sulphur content of soils in India. In India, sulphur deficiencies is scattered in 90 - 100 districts (Tandon and Narayan, 1990). Around 80-90% of the sulphur in soil is present in organic fraction. Its availability in soil will depend on its rate of mineralisation. In contrast to nitrogen, the mineralisation and immobilisation of sulphur has not been studied in any greater detail until the last decade (Classon and Ramaswami, 1990). This recent increase in interest reflects an increased understanding of sulphur nutrition requirements of plants and consequently an awareness of the need for greater understanding of the amounts and transformations of soil sulphur. Classon and Ramaswami (1990) reported that rate of mineralisation of native sulphur in soils was higher during the first or second week, when favourable environmental factors such as moisture and temperature are prevailing.

Elemental sulphur is an important source of sulphur fertilizers. It has not been widely accepted because it is not available until oxidised to SO_4^{2-} ions, thus there is lag period before it is available for crop (Germida and Janzen, 1993). The information on the rate at which soils oxidise elemental sulphur under favourable conditions (oxidative capacity) is necessary to determine the level of variability in oxidative capacity among soils and to make compensatory adjustment in application rate (Janzen and Bettany, 1987). Earlier investigations have indicated considerable variability in the activity among soils (Attoe & Olson (1966), Vitolins and Swaby (1969) and Rehm & Caldwell (1969)).

The sulphate-S production as influenced by the time indicated that the rate of mineralisation of sulphur, in case of kari, sandy and laterite soils increased from 20 days after incubation to 40 days after incubation. Further, a plateau was reached after 60 days of incubation *ie.* decline in net mineralisation of sulphur followed by increase upto 80 days after incubation. This increase in rate of mineralisation upto 40 days after incubation might be due to the presence of organic matter which can be easily decomposed into plant available fraction (SO_4^{2-}-S). Further being mainly coconut growing soils, the crop residue addition is mainly of coconut. Lignin is an important constituent of coconut ranging to as high as 31.9 % in leaves (Thomas *et al.* 1997). Thus decline upto 60 days after incubation may be due to highly resistant organic complex e.g. lignoprotein complexes present which required more time period for decomposition (Waksman and Tenney, 1927). Only when these materials have broken down into simpler compounds then again the rate of mineralisation of sulphur increased as evident at 80 days after incubation. However, the trend in case of red sandy loam was different. The rate of sulphur mineralisation decreased from 20 days after incubation to 60 days after incubation, after which it registered an increase upto 80 days after incubation.

The rate of mineralisation of sulphur was more in case of Kari soil (0.9134 μg SO_4^{2-}-S/day) followed by sandy (0.8118 μg SO_4^{2-}-S/day), laterite (0.6465 μg SO_4^{2-}-S/day) and lastly red sandy loam (0.414 μg SO_4^{2-}-S/day). The rate of mineralisation is more in Kari soils as the organic carbon content is more. This can be corroborated by the findings of Rajendra Prasad *et al*. (1984). However, in case of sandy soils eventhough the organic carbon was least of all the four soil types under study, the rate of mineralisation was more than red sandy loam and laterite soils. This may be due to the presence of easily decomposable organic matter. Secondly, no significant correlation was observed between org.C and rate of mineralisation. This has also been reported by Williams (1967). Mineralisation potential of sulphur in sandy & laterite soils have been found to be negative. This may be due to the presence of small amounts of readily available SO_4^{2-} - S as stated in table 1, leading to immobilisation of the mineralised native sulphur by the microbes. This can be further substantiated by fig. 1 which clearly depicts the SO_4^{2-} - S production trend after 20 days of incubation.

Table 6: Parameters and correlation coefficients of linear relationship between cumulative sulphur mineralised in soils and incubation time.

Soil type	Intercept	x coefficient (μg SO_4^{2-} S day^{-1})	R^2 Value
Sandy Soil	-12.38	0.812	0.95**
Red Sandy Loam	30.10	0.414	0.87**
Laterite	-8.20	0.647	0.87**
Kari	5.10	0.914	0.85**

** - Significant at 1 % level

Oxidised sulphur after six days of incubation was found to be highest in Kari soil followed by sandy, laterite and red sandy loam soil (table 3). The oxidative capacity of the soils for sulphur followed the same trend(table 3). Infact this also follows the trend as mentioned for rate of mineralisation. Highest oxidizable sulphur present in the kari soil can be attributed to heavier soil texture, which oxidises more rapidly than the lighter ones (Burns, 1984; Classon & Ramaswami, 1990). Secondly, the organic matter content was very high in kari soils thereby leading to more sulphur oxidation. This implies that heterotrophic organisms are the predominant oxidizers in this soil because heterotrophic oxidizers are stimulated whereas the chemoautotrophs are inhibited by the presence of high carbon substrate (Pepper & Miller, 1978). However in case of other soil types, the organic matter content being low, it could be the chemoautotrophic oxidizers which gets stimulated. But, in case of coarse soils like sandy soil, higher porosity might have influenced the oxidation rates. The wide differences in oxidative capacity cannot be related to any single factor rather it is governed by the integrated effects of a number of parameters and no single parameter is predominant in effect (Janzen & Bettany, 1987).

Table 7: Oxidation potential of sulphur in soils

Soil type	Oxidised S after 6 days (ppm)	Oxidative capacity (µg SO_4^{2-} S cm^{-2} day^{-1})
Sandy Soil	22.48	15.50
Red Sandy Loam	17.17	11.82
Laterite	20.51	14.13
Kari	24.18	16.68

In a filed experiment at CPCRI Kasargod in young Laccadive Ordinary palms with two sources of sulphur viz. Magnesium sulphate and ammonium sulphate at three different levels i.e 200, 400 and 600 g S per palm per year indicated that the variation in leaf S content was found to be non significant (Table 8). However, trend indicated that application of sulphur led to increased leaf S content over control.

Table 8: Effect of sources and levels of S on leaf S content

Treatment	S %
1. Control	0.21
Amm. sulphate	
2. @200g	0.26
3. @400g	0.32
4. @600g	0.34
Mag. Sulphate	
5. @200g	0.22
6. @400g	0.29
7. @600g	0.41
CD (5%)	NS

REFERENCES

AICCAIP (1983). Progress Report 1982-83. All India Coordinated Coconut and Arecanut Improvement Project, CPCRI, Kasaragod. p. 40-43 (mimeo).

Albrecht, W. A. (1943). Potassium in soil colloid complex and plant nutrition. Soil Sci. 55: 13-21

Anonymous (1985) Central Plantation Crops Research Institute, Annual report of 1985, Kasaragod, India. 214 pp.

Attoe, O.J. & Olsen, R.A. (1966) *Soil Sci*. **101**, 317.

Bastin, B. and Venugopal, V.K. (1986) Available nutrient status of some red soils (alfisols) from different regions of Kerala. *Agric. Res. J. Kerala*. **24**(1): 22-29.

Biddappa, C.C., Khan, H.H., and Cecil, S.R. (1993). Potassium in coconut growing soils. In Proc. Sym. On Potassium for plantation crops held at Bangalore on Nov. 6-8, 1990. Dr.Mahatim Singh *et al.* (eds) Potash Research Institute of India, Gurgaon, 111-120

Brunin, C. (1970). Magnesium nutrition in the coconut grooves of Ivory Coast. *Oleagineux* **25**: 269-274.

Burns, G.R. (1984) *Oxidation of sulphur in soils. Tech. Bull. No. 13*. The Sulphur Institute, Washington D.C. 20006

Classon, D. & Ramaswami, P.P. (1990) *Madras Agic. J.* **77** , 70.

Coomans, P. (1977). Premiers resultas experimentaux sur la fertilization des cocotiers hybrids en Cote-d-Ivoire. *Oleagineux* **32** (4): 155-166.

Foale, M.A. (1968). Seedling growth pattern. Aust. J. Agri. Res., 19: 781-89.

Fremond, Y. (1964). The contribution of IRHO to the study of mineral nutrition of the coconut palm. Proc. Second Sessn. FAO Tech. Wkg. Pty. Cocon. Prod. Prot. & Process. Colombo, Sri Lanka.

Fremond, Y. and Ouvrier, M. (1971) Importance to the young coconut palm of suitable mineral nutrition from the time of field planting on a beach sand. Oleagineux 26: 609-618.

Germida, J.J. & Janzen, H.H. (1993) *Fert. Res*. **35**, 101.

Hameed Khan, H., Gopalasundaram, P., Joshi, O.P. and Nelliat, E.V. (1986) Effect of NPK fertilization on the mineral nutrition of coconut genotypes. *Fert. Res*. **10**: 185-190.

Hameed Khan, H., Joshi, O.P and Biddappa, C.C. (1982) Adsorption-desorption and selective distribution of phosphorus and potassium in relation to soil fertility potential in major coconut growing soils of India. In: Proc. PLACROSYM-V, 1982. (Ed. In chief) K.V. Ahamed Bavappa, Central Plantation Crops Res. Instt., Kasaragod, India. pp. 411-424

Harries, H.C. (1970) The Malayan dwarf supercedes the Jamaican Tall coconut. 1. Reputation and performance. Oleagineux, 25:527-31

Janzen, H.H. & Bettany, J.R. (1987) *Soil Sci.* **143**, 444.

John, C.M. and Jacob,K. (1959) Fertilizer demonstrations in coconut in West Coast – A review. Proc. First Conf. Cocon. Res. Workers, Trivandrum, India.

Krishnakumar, A.K. and Koshy, M.M. (1976) Influence of amount of clay and nature of clay minerals on potassium availability. *Bull. Indian Soc. Soil Sci.* **10**: 78-85.

Lognathan, P. and Atputharajah, P. P. (1986). Effect of fertilizers on yield and leaf nutrient concentration in coconut. *Tropical Agriculture* **63**: 143-148.

Manciot, R., Ollagnier M and Ochs, R. (1979) Mineral nutrition and fertilization of coconut around the world. II. Study of different elements. *Oleagineux*. **34**: 576-580

Menon, K. P. V. and Pandalai, K. M. (1958) The coconut palm – A Monograph. Indian Central Coconut Committee, Ernakulam. pp. 384.

Muhr, G.R., Datta, N.P., Sankarasubramoney, H., Leley V.K. and Donahue, R.L. (1963) Soil testing in India. IInd Edn. United States Agency for International Development Mission to India, New Delhi, pp. 118.

Muliyar, M. K. and Nelliat, E. V. (1971). Response of coconut palm to N, P and K application on the West Coast of India. *Oleagineux* **26** (11): 687 – 689.

Nelliat, E.V. (1973) NPK nutrition of coconut palm- A review. J. Plant. Crops, 1(suppl):70-80

Nelliat, E.V. (1978) K nutrition of plantation crops- a review of work done in India. In Potassium in soils and crops, Potash Research Institute of India, New Delhi. P. 367-378.

Nelliat, E.V., Nair, P.K.R. and Kushwaha, B.L. (1976) Effect of month of harvest of seednuts and fertilizer application to nursery on vigour and quality of coconut seedlings. J. Plant. Crops 4: 16-20

Patil, A. J., Kale, S.P. and Shingte A.K. (1976) Effect of alternate wetting and drying on fixation of potassium. *Bull. Indian Soc. Soil Sci*. **10**: 132-137.

Pepper, I.L. & Miller, R.H. (1978) *Soil Sci*. **126**, 9.

Pillai, N.G. (1975) Studies on mineral nutrition of coconut palm with special reference to the root (wilt) disease. Ph.D. Thesis. University of Keral, Trivandrum.

Rajendra Prasad, D., Subbba Rao, A. & Subba Rao, I.V. (1984)) *J. Indian Soc. Soil Sci*. **32**, 744.

Ramanandam. P.L. (1977) Nutritional studies in coconut soils and coconut palm. Ph.D. Thesis, University of Kerala.

Ramanathan, K.M. and Krishnamoorthy, K.K. (1976) A study on the relationship between certain soil characters and K fixation. *Bull. Indian Soc. Soil Sci*. **10**: 42-45.

Rehm, G.W. & Caldwell, A.C. (1969) *Agron. J*. **61**, 333.

Robert Cecil, S. (1981). Mineral nutrition of the coconut palm (*Cocon nucifera* L.) in health and disease with special emphasis on calcium and magnesium. Ph.D. Thesis. University of Kerala, Trivandrum.

Smith, R.W. (1968) Effect of fertilizer on the early growth and yield of Malayan coconuts in Jamaica. 3rd Session, FAO Tech. Wkg. Pty. Cocon. Prod. Prot. & Proce, Jogjakarta, Indonesia.

Tandon, H. L.S. and Narayan, P. (1990). Fertilizers in Indian agriculture – past, present and future(1950-2000). Fertilizer Development and Consultation Organisation, New Delhi. pp. 160 + viii.

Thomas, George V., Prabhu, S.R., Reeny, M.Z. & Bopaiah, B.M. (1997) Evaluation of lignocellulosic biomass from coconut palms as substrate for cultivation of *Pleurotus sajor caju* (Fr.) Singer. Paper presented at Indian Mushroom Conference on 10-12 Sept.'97, NRC on Mushrooms, Solan, H.P.

Vitolins, M.I. & Swaby, R.J. (1969) *Aust. J. Soil Res*. **7**, 171.

Wahid, P. A., Nambiar, P. K. N., Jose, A. I. And Rajaram, K. P. (1988) Soils and nutrition. In: Six Decades of Coconut Research; Kerala Agricultural University, Vellanikkara, Trichur, pp. 46-80.

Waksman, S.A. & Tenney, F.G. (1927) *Soil Sci*. **24**, 275.

Williams, C. H. (1967) *Pl. Soil* **26**, 205.