Journal of Plantation Crops 13 (1): 11–21 June, 1985

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Review Article

A REVIEW OF INDIAN WORK ON PHOSPHORUS NUTRITION OF COCONUT*

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INTRODUCTION

Fertilizer application to coconut though known to give good economic returns was not being practiced by farmers due to many reasons. From the growers point of view, economic management of an input reserve is of prime importance. Though increase in yields and growth has resulted due to general fertilizer application, phosphate requirement of coconut palm has always been a debating question when specific fertilizer recommendations were made based on soil and foliar analyses. Various workers (Eden, Gowar and Salgado, 1963; Child, 1974; Pillai and Davis, 1963) opined that P needs of the palm are less. A critical review on phosphate fertilization of coconut by Wahid, Kamala Devi and Haridasan (1977) did not project the details of experience gained in India adequately. The presentation here examines the various aspects of P nutrition of coconut in the country.

THE PLANT

The coconut palm (*Cocos nucifera* L.), grows in the humid tropics of India over an area of 1.1 million hectare accounting for an annual production of 5619 million nuts. It lacks a tap root and possesses a continuously growing terminal bud commonly known as cabbage. The cultivar West Coast Tall is widely grown in the coastal belt of Kerala, Karnataka, Goa, Maharashtra, Gujarat and interior of Tamil Nadu. Though other cultivars like East Coast Tall (Tamil Nadu, Andhra Pradesh and West Bengal), Tiptur Tall (Karnataka), Benaulim (Goa and Maharashtra), Gangabondam (Andhra Pradesh) are also grown in different geographical regions of the country, information on specific nutrient needs under varying agro-ecological conditions is lacking. The fertilizer dose of 500 g N, 320 g P_2O_5 and 1200 g K_2O $palm^{-1}$ $year^{-1}$ evolved for Kerala conditions is uniformly followed in the fertilizer programmes in the country.

Coconut palm is grown under highly heterogeneous conditions of soil ranging from littoral sand to clay in situations from poorly drained low lying marshes to well drained uplands

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** Present address: Central Institute of Horticulture for Northern Plains, Lucknow-6, Uttar Pradesh, India and hill tops and in acid to highly calcareous soils (Menon and Pandalai, 1960, Khan, Sankaranarayanan and Narayana, 1978).

PHOSPHORUS PROFILE IN THE PLANT

Concentration of a nutrient in a tissue depends on the physiological function for which it is needed at that site. Phosphorus contents of the leaves were always found to be higher in the younger leaves compared to older leaves though contents varied as a function of time and season maintaining the same gradient in the crown. The P contents were lower in the crown during summer irrespective of the fact that the palms were fertilized or not, indicating a minimal internal flux during the summer period (Table I).

Kamala Devi and Velayutham (1978) observed an increase in P content of nut water upto sixth month and a gradual decrease thereafter in the three genotypes studied. However, the P content of kernel gradually increased with the increase in the highest values at full maturity (Table II).

PHOSPHORUS AND CROP RESPONSE

Phosphorus uptake is small (15 to 18 kg ha^{-1}), nearly one tenth of the total uptake of potassium as well as chlorine. It is an important nutrient as it enters into the regeneration of adenosine triphosphate and phosphoproteins (Manciot, Ollagnier and Ochs, 1979). Phosphoric acid has been found to increase the girth at collar, number of leaves and rate of leaf production in seedlings (Mathew and Ramadasan, 1964). Deficiency of phosphate in soil retards growth, delays flowering and also ripening of nuts.

Table I. *Phosphorus distribution in the crown*

Leaf rank	Fertilized palms			Unfertilized palms		
	Jan.	May	Sept.	Jan.	May	Sept.
1	0.138	0.122	0.149	0.149	0.121	0.149
6	0.136	0.120	0.129	0.140	0.118	0.141
11	0.135	0.116	0.127	0.140	0.112	0.136
16	0.127	0.108	0.125	0.133	0.106	0.127
21	0.121	0.095	0.116	0.118	0.096	0.118

Table II. *Changes in P content of nut water and kernel with maturity of nut in different genotypes*

Month	P in nut water mg/l			Kernel P (%)		
	WCT	D×T	T×D	WCT	D×T	T×D
4	48	40	44	–	–	–
6	118	120	131	–	–	
8	186	194	192	0.070	0.075	0.072
10	140	152	148	0.090	0.099	0.114
12	108	97	103	0.207	0.232	0.214

Kunhi Muliyar and Nelliat (1971) observed that application of P did not improve any of the nut characters, *viz.*, weight and volume of unhusked nut and husked nut whereas it increased copra out-turn nut^{-1} both at lower level (340 g P_2O_5 $palm^{-1}$) and at higher level (680 g P_2O_5 $palm^{-1}$) of annual application. However, the last three years of the experiment and combined 10 years' data showed significant effect with respect to yield. They opined that the significant difference in yield may probably be due to accumulation and slow release of fixed phosphorus from the soil. The response function was linear in shape and the optimum dose of P was found to be beyond the highest dose tried. Based on the response surface function, the optimum doses ($palm^{-1}$ $year^{-1}$) of N, P and K were found to be 0.47 kg N, 1.00 kg P_2O_5 and 0.89 kg K_2O.

Ramanandan (1964) observed that phosphoric acid application does not appear to influence yield. Increase in yield due to its application was little (Table III).

In an NPK experiment on young palms (started in 1965) on red sandy loam soil at Kasaragod, the response to applied P was obtained for two consecutive years (1978 and 1979). Higher levels of P at 1000 and 1500 g P_2O_5 $palm^{-1}$ $year^{-1}$ gave significantly more nuts and influenced female flower production (Table IV). However, the response was not consistant and significant in succeeding years (Anonymous, 1982).

Table III. *Effect of graded doses of phosphorus application on yield of palms*

Nitrogen		Potassium		Phosphorus	
Dose (kg $tree^{-1}$)	Mean yield (nuts $palm^{-1}$)	Dose (kg $tree^{-1}$)	Mean yield (nuts $palm^{-1}$)	Dose (kg $tree^{-1}$)	Mean yield (nuts $palm^{-1}$)
0.00	47.8	0.00	50.3	0.00	49.3
0.34	55.1	0.34	52.8	0.34	53.0
0.68	53.7	0.68	53.5	0.68	54.3
C. D. at 5%	3.34		N.S.		3.28

(N, P and K were supplied through ammonium sulphate, superphosphate and muriate of potash respectively)

Table IV. *Nut yield and female flower production at different levels of N, P_2O_5 and K_2O in sandy loam soil (1977–'78)*

Nutrient level (g $palm^{-1}$ $year^{-1}$)	Yield of nuts ($nuts^{-1}$ $palm^{-1}$)			Female flower production (No. $palm^{-1}$)		
	N	P	K	N	P	K
500	44	37	43	136	122	143
1000	51	52	50	164	168	158
1500	45	51	46	146	155	144
S. E. (±)	3	3	3	13	13	13
C. D. at 5%	N.S.	11	N.S.	N.S.	32	N.S.

The results of an NPK experiment (Balaramapuram, Kerala) initiated in 1964 revealed significantly high yield of 5386 nuts ha^{-1} in the treatment P_1 (225 g $palm^{-1}$) followed by P_2 (450 g $palm^{-1}$) and P_0 (no P) with 4227 and 2709 nuts ha^{-1}, respectively. As highest dose of P (450 g P_2O_5 $palm^{-1}$) continued to induce a depressive effect on yield of nuts, it was inferred that application of P_2O_5 beyond 225 g $palm^{-1}$ $year^{-1}$ may not be advisable under typical red sandy loam soil conditions. The PK interaction was significant at 5 per cent only. Highest yield of 8491 nuts ha^{-1} was obtained in P_1K_2 combination followed by P_1K_1 and P_2K_2 with 7561 and 7377 nuts ha^{-1} respectively and were on par with each other. Application of potassium at K_1 (450 g K_2O $palm^{-1}$) and K_2 (900 g K_2O $palm^{-1}$) showed a depression in yield when dose of P was increased to P_2 level. Similar was the response for PN interaction but was not significant (Anonymous, 1980).

NUTRIENT EXHAUST STUDIES

Pillai and Davis (1963) estimated that from a sandy soil of average fertility, 22.5 kg N, 12 kg P_2O_5 and 34.2 kg K_2O were annually removed by 70 palms growing in an acre and yielding 40 nuts $palm^{-1}$ $year^{-1}$. It was indicated that the maximum quantity of phosphorus is lost from the palms through the leaves and nuts (Table V).

Among the different parts of the palm analysed, kernel contains 0.56 per cent P_2O_5 followed by petiole and leaf sheath (0.51%), spadix (0.31%), stem (0.26%), leaflet (0.24%), spathe (0.164%), husk (0.15%) and shell (0.15%). Considering all the above, they opined that the recommended dose of 340 g P_2O_5 $palm^{-1}$ $year^{-1}$ appeared to be a luxury dose and the same can be reduced to 170 g without any adverse effect for atleast sandy soils of West Coast tract.

Various workers in their different studies projected the nutrient exhaust data by coconut palm (Table VI).

SYSTEM ANALYSIS AND P FERTILIZATION NEEDS

Considering the annual fluxes of nutrients, Nair (1979) visualised an annual storage of 41.7 kg P_2O_5 ha^{-1} in pure coconut system compared to 44 kg P_2O_5 ha^{-1} in 30 year old coconut with 5 year old cocoa mixed crop system. Based on build up of P in root zone of coconut, activity of P solubilizing microorganisms (Nair and Rao, 1977) and sluggish response of palms to P

Table V. *Percentage distribution of exhaust of nutrients by different parts*

Parts of the palm	Percentage of total exhaust				
	N	P_2O_5	K_2O	CaO	MgO
Nuts	43.0	40.0	63.0	15.3	25.1
Peduncles	4.2	7.0	12.1	3.3	11.4
Spathes	3.5	2.9	2.7	4.5	4.9
Leaves with stipules	41.2	45.1	12.4	73.8	56.5
Stem	8.1	5.0	9.8	3.1	2.2

Table VI. *Nutrient exhaust by coconut palm*

Reference	Basis	Nutrient removal (Kg)			Ratio		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
Pillai (1919)	2000 nuts $acre^{-1} Yr^{-1}$	8.2	2.3	17.2	1 :	0.3 :	2.1
Patel (1938)	Recommendations for annual addition $acre^{-1}$	10.9	5.4	27.2	1 :	0.5 :	2.5
Ramanandan (1977)	a. 175 palms ha^{-1} (nuts alone)	22.0	8.0	71.0		–	
	b. – do –	21.0	6.0	55.0		–	
	c. – do –	17.0	6.0	52.0		–	
Pillai and Davis (1963)	70 palms $acre^{-1}$ yielding 40 nuts $palm^{-1}$	22.5	12.0	34.2	1 :	0.5 :	2.0

a – coastal sandy alluvium; b – red sandy loam; c – laterite

(Kunhi Muliyar and Nelliat, 1971), a modification in the fertilizer schedule for coconut-cocoa mixed cropping system was suggested in which he recommended skipping of P application in alternate quarters to coconut thereby reducing the P input by 56 kg P_2O_5 ha^{-1} $annum^{-1}$ (Table VII).

INTERACTIONS WITH OTHER NUTRIENTS

Phosphorus and K contents of the leaf were found to be highly correlated ($r = +0.53^{**}$ to 0.74^{**}) according to Wahid, Kamala Devi and Haridasan (1977). Our studies indicated that constant levels of N and K and varying P levels could positively influence the absorption of N ($r = +0.47^{**}$) as judged by foliar level. The trend was not always significant. The increasing soil available P levels were also not found to influence either way the contents of Fe, Mn, Cu and Zn in the palm. Though a depression in the absorption of Fe, Mn and Zn was seen at higher P levels, the differences shown by the palms are not statistically significant.

NUTRIENT TRANSFORMATION FOLLOWING FERTILIZER APPLICATION

Kamala Devi and Velayutham (1977) found that maximum P concentration in the 14th leaf (0.170%), unopened leaf (0.146%) and outer leaf (0.139%) were obtained on the fifth day after fertilizer application. The increase in P concentration was 14-25 per cent in unopened leaf, 29-47 per cent in the 14th and outer leaves. They could not visualise appreciable differences among the genotypes (WCT, D×T and T×D) in the concentration of nutrients. For N, P and K, the best time of sampling the reference leaf to ascertain the magnitude of fertilizer effect on the nutrient content was indicated as five days and two days respectively after fertilizer application. Eventhough, younger leaves contain more phosphorus, the study indicated that the initial absorption appears to be controlled by physiological maturity of the leaves.

FERTILIZER PLACEMENT STUDIES

Fertilizer utilization efficiency of a crop is governed by the extent of root

Table VII. *Modifications in the fertilizer schedule for coconut + cocoa mixed cropping (kg ha⁻¹)*

Period	N		P_2O_5		K_2O	
	Present	Suggested	Present	Suggested	Present	Suggested
February	43.8	43 8	28.0	28.0	105.0	105.0
May	43.8*	21.0	28.0	Skip.	105.0	52.5
	17.5**	17.5	7.0	7.0	24.5	24.5
August	43.8	21.0	28.0	Skip.	105.0	52.5
October	43.8*	43.8	28.0	28.0	105.0	105.0
	17.5**	17.5	7.0	7.0	24.5	24.5
Total	210.2	164.6	126.0	70.0	469.0	364.0
Difference		(-45.6)		(-56.0)		(-105.0)

* Coconut; ** Cocoa

surface available for absorbing nutrients and the concentration of nutrients in the soil solution. Kushwah et al. (1973) exploring the rooting pattern of coconut reported the presence of only few roots in the 30 cm layer of the soil and a majority of the roots (82%) in 30-120 cm depth in regularly manured and cultivated plots. As P mobility is restricted (Barber, 1962), its placement in the most absorbing zone will be ideal for efficient utilization of nutrient. Studies employing ^{32}P on the uptake pattern of coconut (Dwivedi, Ray and Ninan, 1981) revealed that trench method of application of P is better than basin method, strip method and hole method. Eventhough ^{32}P was detected in the foliage (first fully opened leaf) after 7, 8 and 11 days in hole, trench and strip and basin method respectively, average highest accumulation of activity (cpm g^{-1} dry matter) resulted due to trench method of application. The studies also revealed the superiority of plant injection techniques, particularly through the cut end of roots over soil placement methods; the rate of absorption of activity found by former was 10 to 60 times faster over latter. Plant injection techniques also resulted in the detection of activity after 4, 8, 12 and 18 hours after application through cut end of roots, stem, leaf axils and growing root tips, respectively. The results of the investigation advocated that the fertilizer application through trenches around the bole of a palm for normal areas and feeding of nutrients through plant injection methods for problematic areas (water saturation and diurnal soil water fluctuations etc.) may prove ideal.

P CARRIERS FOR COCONUT

Khan et al. (1985) while evaluating the comparative efficiency of four phosphate carriers, *viz.*, superphosphate, ammonium phosphate, nitro phosphate and rock phosphate, recommended rock phosphate as the ideal carrier of P for coconut as the soil contents receiving rock phosphate gave a best reflect on plant P and enriched all P fractions in the soil and influenced overall yield. Rock phosphate is also cheaper and more suitable for acid soils.

Ramanandan (1977) compared the usefulness of tri-sodium phosphate (an alkaline carrier with 17.4% P_2O_5 and a byproduct obtained from extraction of rare earths from monozite sand) with single superphosphate on coconut. During 4th, 5th and 7th year, single superphosphate was found to be significantly superior to former and both were superior to control. Not much could be discerned on pH of soil due to the use of TSP. However, Khan et al. (1985) recorded significantly lower pH by the use of ammonium phosphate as P carrier.

FERTILIZER MANAGEMENT

Utilisation of build up reserves in soil is the most ideal and economic way of management of coconut groves. Khan et al. (1983) indicated that phosphate fertilizer application can profitably be skipped (witheld) for atleast six years in situations where soil available P is around 20 to 25 ppm in 30 to 60 cm depth in coconut basin. They arrived at this conclusion after monitoring soil levels, plant levels and yield of palms. Interestingly they observed that plant P levels were not influenced even when soil available P levels drained to 59 ppm at 0 to 30 cm depth and 10 ppm at 30 to 60 cm depth (Fig. 1) and also when the soil available P values increased considerably. The yield variations were never statistically significant. The usefulness of foliar P levels as a guide to fertilizer application and yield judgement were questioned. Wahid et al. (1975) observed that when the fertilizer application was discontinued for one year, the foliar levels of N and K were lowered and not that of P. Kamala Devi, Velayutham and Haridasan (1976) did not observe any increase in leaf P content due to graded doses of fertilizer application.

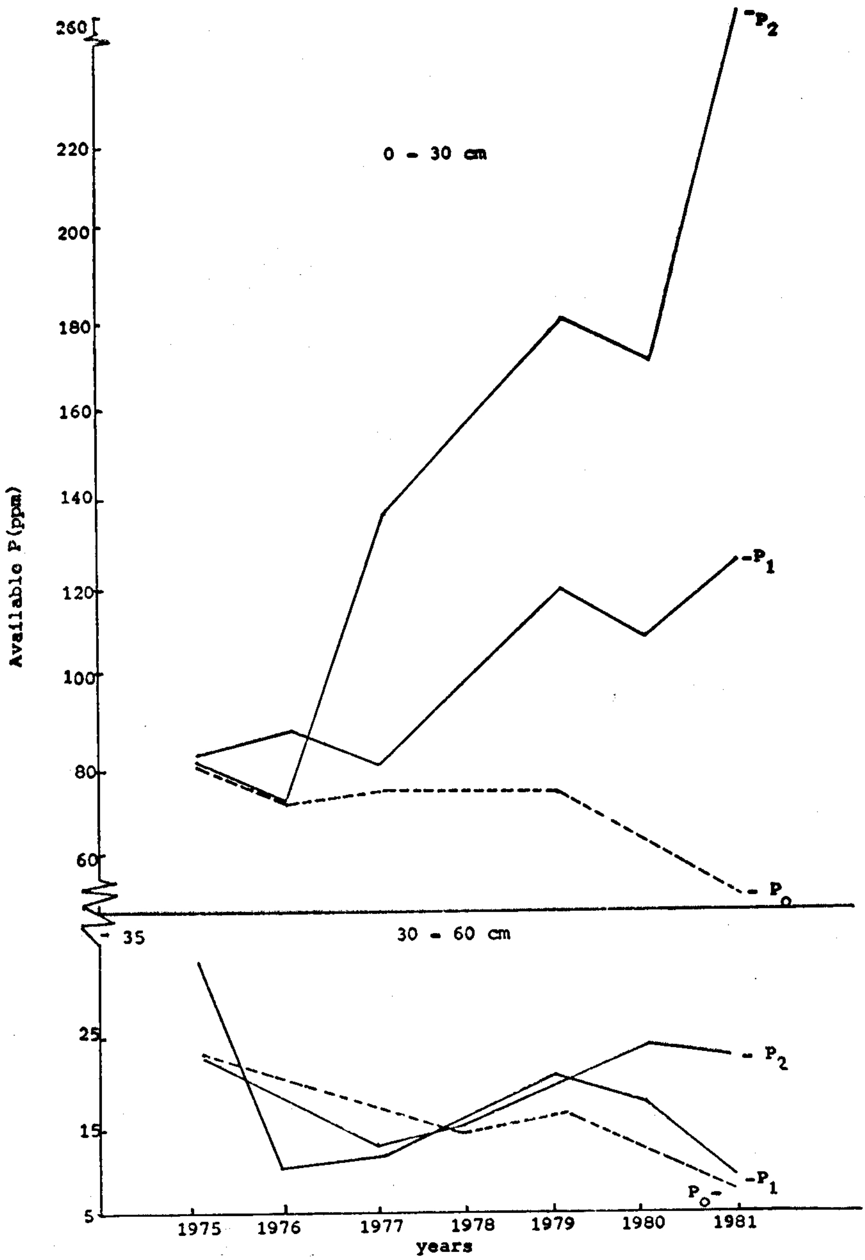
MYCORRHIZAL ASSOCIATION IN COCONUT NUTRITION

Most plant species growing under natural environment harbour mycorrhizae for mutual benefit. Lily (1975) first reported mycorrhizal infection in coconut *(Endogone fasciculates)* but did not relate it to phosphate nutrition. Ramesh, Joshi and Khan (1984) identified four species of mycorrhizae, namely, *Glomus mosseae* (GM), *Gigaspora gigantia* (GG), *Glomus macrocarpus* (GMA) and *Sclerocystis rubiformis* (SR) associated with coconut roots. They observed reduction in mycorrhizal infection with the increase of added as well as available P (Table VIII). Spore density of *Glomus mosseae* decreased with the addition of highest level of P. Aluminium bound P expressed as per cent of total fractions was found to be negatively related to mycorrhizal infection percentage. In view of the positive relationships between available P and spore density of GG, GMA and SR, the possibility of inoculating the coconut roots with suitable fungus to effectively recycle the accumulated P levels of soils was visualised.

PHOSPHORUS APPLICATION AND COCONUT DISEASES

Potty and Radhakrishnan (1978) inferred from a nutritional experiment a distinct and pronounced influence of P fertilization on stem bleeding incidence,

Fig. 1. Influence of phosphorus skipping (P_0) and fertilization (P_1, P_2) on available P–PPM



P_1 = 160 g P_2O_5/palm/year; P_2 = 320 g P_2O_5/palm/year

Table VIII. *Relation between different forms of P and VA mycorrhizae in coconut rhizosphere*

Treatment	VA mycorrhizal infection percentage	population density (no. g^{-1})				Leaf P (%)	Available P (ppm)		Al-P as % of total
		GM	GG	GMA	SR		Bray I	Olsen	
M_0	82.3	47.5	16.6	1.3	3.6	0.106	7.6	6.2	1.13
M_1	57.3	68.7	218.4	41.2	47.2	0.110	257.9	83.7	67.12
M_2	42.5	11.1	97.5	31.6	33.1	0.122	384.5	120.0	71.5

M_0 – No fertilizers; M_1 – 500 g N, 500 g P_2O_5, 1000 g K_2O palm^{-1} year^{-1}; M_2 – 1000 g N, 1000 g P_2O_5, 2000 g K_2O palm^{-1} year^{-1}

which increased with increase in the levels of P. They observed that stem bleeding was more when nitrogen supply was deficient and soil P availability was in excess. Bhaskaran, Jaganathan and Chandrasekar (1978), however, observed that higher doses of nitrogen and potash favoured faster rate of increase in disease in Thanjavur wilt of coconut, whereas P even at higher levels lowers the rate. On the contrary, Cecil et al (1978) indicated that in root (wilt) diseased coconut palms the main effect of P was not found favourable on any of the characters studied, *viz.*, girth at collar, production of leaves, functioning leaves, flowering and yield of nuts.

CONCLUSION

Though phosphorus is a very important nutrient for coconut, the information presented suggests that phosphorus is normally not a limiting nutrient for coconut production. More so, adult palms have not been found to be much benefitted by annual P applications. Fertilizer experiments have shown that the P needs are low, responses slow and inconsistant.

Fertilizing young coconut palms upto bearing stage and experiments to study the effect of discontinuing P application periodically thereafter will be worth investigating.

Soil P levels are to be relied more than foliar levels in judging the P needs of coconut groves. Evaluation of critical soil P levels under constant N and K fertilization over years will be rewarding in view of the lack of relationship of plant P levels on yield.

Experiments directed towards isolation and incorporation of specific species of mycorrhizae at graded levels of P application will lead to draw valuable information on the effective utilization of accumulated P reserves of the soil consequent to fertilizer application.

A survey of laterite, red sandy loam and sandy soils to study the soil and plant P levels with contemplated studies on obtaining information on requirement of P fertilization, soil critical levels and soil test methods will be other areas worth investigating.

Evaluation of coconut germplasm material to identify cultivars which show more nutrient absorption and utilization, particularly of phosphorus under a given situation, to use them in evolving ideal genotypes for better utilization of P should also be the concern of breeders as such habits are linked with higher productivity (Beaufils, 1956).

ACKNOWLEDGEMENTS

The authors are thankful to Dr. K. V. Ahamed Bavappa, Director, Central Plantation Crops Research Institute, Kasaragod for the encouragement and to Dr. P. Rethinam, Project Coordinator, AICCAIP, Kasaragod for reading through the manuscript.

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