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RESIDUAL EFFECT OF LONG-TERM PHOSPHORUS APPLICATION ON SOIL AND PLANT NUTRIENT CONTENTS, MYCORRHIZAL ASSOCIATION AND YIELD OF COCONUT

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ABSTRACT

Skipping of phosphorus application to adult coconut palms has resulted in reduction of soil available P in manuring circle (0-90 cm) from 43.88 ppm to 12.72 ppm over a period of 14 years and also had no deleterious effect on P nutrition and yield of palms indicating residual effectiveness of phosphorus. Application of P at two levels showed no advantage in further enhancement of P nutrition and yield. The mean soil available P was 12.72, 38.43 and 53.29 ppm in P-0, P-1 (160 g P_2O_5 palm^{-1} year^{-1}) and P-2 (320 g P_2O_5 palm^{-1} year^{-1}) respectively. N, P, K, Na, Ca, Mg, Fe, Mn, Zn, and Cu contents of the palm (Frond 14) were also not significantly different among the treatments and were in sufficiency range. Interestingly, VA mycorrhizal infection was more in the P-0 treatment (79.3%) compared to P-1 (52.1%) and P-2 (47.9%). Population of P solubilizing bacteria was also higher in P-0 treatment indicating the involvement of microbial population in P nutrition of coconut. The mean yield of the palms (1989) viz., 109.07, 102.36 and 108.71 nuts palm^{-1} per year^{-1} in P-0, P-1 and P-2 treatments respectively and the cumulative yield for four years did not show significant differences among the treatments. It was indicated that residual phosphates of 40 ppm in 0-90 cm in depth in the basin could sustain adquate P nutrition and normal yields for 14 years. Also soil available phosphorus status of 10-12 ppm maintained sufficiency level of P in the coconut palm. Soil available P of less than 10 ppm warrants full recommended dose to be applied (P2) and soils testing 10-20 ppm need only 50% of recommended dose (P1). For soils testing more than 20 ppm, application of phosphorus can be withheld for certain years.

INTRODUCTION

Phosphorus added initially to the soil is not irreversibly lost and is often a potent reservoir for plant growth in subsequent years. Rationalizing fertilizer application warrants application of fertilizers based on crop requirements. P, an immobile nutrient, is known to persist in the soil and offers scope for utilization economically based on soil test and associated plant analysis. Kamprath (1967), Dubin (1970) and Novias and Kamprath (1978) examined this possibility with other crops. An experiment was started to withhold phosphorus application to adult coconut palms where soil available phosphorus was already built up consequent to long-term fertilizer use. Effect of residual P for 14 years on adult coconut palms is discussed.

MATERIALS AND METHODS

An RBD experiment with six treatments and seven single palm replications, was started in May, 1975 on 22-year-old west coast tall palms. The palms were regularly fertilized at recommended levels for 22 years. The experimental treatments were 0, 160 and 320 g P_2O_5 palm^{-1} year^{-1} as superphosphate and two levels of slaked lime at 0 and $1/2$ lime requirement over basal application of 500 g N as urea and 1200 g K_2O as muriate of potash. The slaked lime application was withdrawn after two years leaving only three treatments with 14 replications each.

The pH of the soil in the coconut basin was between 4.1 and 5.2 and organic carbon varied from 0.65 to 0.14% with depth. The available phosphorus (Bray-I)was 84-88 ppm at 0-30 cm depth and 24-34 ppm at 30-60 cm depth, when the experiment with differential P levels was started.

Soil samples were collected during May, 1989 from palm basins at three depths 0-30, 30-60 and 60-90 cm at a distance of 1.0 to 1.2 m away from the bole. The processed 2 mm fraction was used for analysis of available phosphorus (Bray-1 (Jackson, 1967) and available micronutrients (Lindsay and

Norvell, 1978) were analysed by atomic absorption spectrophotometer (AAS). Rhizosphere soil samples along with coconut roots were collected up to 50 cm depth for scoring mycorrhizal colonization, intensity of infection, spore count and P solubilizers (Gerdermann and Nicolson, 1963).

Leaf samples were collected from the 14th leaf (Prevot and Bacby, 1962), washed with 1% detergent solution, rinsed with distilled water, oven-dried at 65°C for 72 hours, powdered in a Wiley Mill with steel blades. This 0.5 mm fraction was analysed for P (Vanadomolybdate), K, Na (flame photometry) (Jackson, 1967), and Ca, Mg, Fe, Mn, Zn, and Cu by AAS in 1:2 $HClO_4$: HNO_3 acid extract (Allen, 1971). N was estimated by micro-Kjeldahl method (Jackson, 1967).

RESULTS AND DISCUSSION

a) **Soil available P :** Skipping of phosphorus (P_0) to adult coconut palms for 14 years has resulted in decrease in soil available P (Table I) from 84 ppm to 20.64 ppm in 0-30 cm layer of the manuring basin. At 30-60 cm depth it was reduced from 24.00 to 9.80 ppm and at 60-90 cm depth from 23.66 to 7.73 ppm. When the 0-90 cm layer was considered as a whole, the reduction in the soil available P was from 43.88 to 12.72 ppm over 14 years. When P has been applied at 50% of the recommended dose (160 g P_2O_5 palm^{-1} year^{-1}) it registered an increase in available P for some years (Hameed Khan *et al.* 1983). However, 1989 sampling indicated a slight reduction compared to the pre-treatment level. Application of P at the recommended dose (320 g P_2O_5 palm^{-1} year^{-1}) increased soil available P considerably. Though a linear trend in the soil available P was observed with increasing levels of P application, the values showed undulating trends within the levels of application over years. Computation of soil available phosphorus on volume basis confirmed these observations (Table II).

b) **Soil pH and Ec :** The soil pH varied between 4.5 and 5.0 among the treatments and was not significantly different at 0-30 cm depth in the basin but the differences were significant for 30-60 and 60-90 cm depths (Table III). A reduction in pH with increasing levels of P application was observed at 30-60 and 60-90 cm depths. There was no trend in the Ec of soil under different treatments (Table IV).

Table I. Effect of phosphorus skipping on available P status in coconut basins

Treatment	Soil available P (ppm) at different depths: 1975				1989			
	0-30	30-60	60-90	Mean	0-30	30-60	60-90	Mean
P_0	84.00	24.00	23.66	43.88	20.64	9.81	7.73	12.72
P_1	88.42	24.20	12.00	41.54	67.95	12.06	11.29	30.43
P_2	84.28	34.15	12.75	43.72	120.75	26.95	12.66	53.29
SE/plot	—	—	—	—	20.60	9.85	3.14	—
CD	—	—	—	—	16.01	7.66	2.44	—

Table II. Amount of available P at different depths held by soil in 3.05 m³ of coconut basin

Treatment	Available phosphorus in kg: 1975				1981			
	0-30	30-60	60-90	Total	0-30	30-60	60-90	Total
P_0	0.357	0.103	0.100	0.559	0.088	0.042	0.033	0.163
P_1	0.375	0.103	0.051	0.529	0.289	0.051	0.048	0.388
P_2	0.385	0.145	0.054	0.557	0.511	0.114	0.054	0.679

Table III. Effect of P on soil pH

Treatments	pH depth wise			
	0-30	30-60 cm	60-90	Mean
P_0	4.81	4.92	5.04	4.92
P_1	4.92	4.76	4.71	4.79
P_2	4.84	4.53	4.52	4.62
Mean	4.85	4.74	4.76	—
SE/plot	0.35	0.28	0.14	—
CD	—	0.22	0.11	—

Table IV. Soil Ec (µ mhos cm^{-1}) under different P treatments

Treatments	0-30	30-60 cm	60-90
P_0	109.39	70.95	43.51
P_1	69.93	60.23	58.85
P_2	87.04	82.54	68.09
SE/plot	36.72	33.38	35.33
CD	28.53	—	11.91

c) **Soil available micronutrients :** Soil available Zn was significantly different and less than the critical level in P_0 and P- applied treatments (Table V). Moreover, no definite influence of graded levels of P on Zn availability was noticed. It is likely that even at the highest dose tried P was inadequate to immobilise Zn. Soil available Fe increased with increase in levels of P application and was well above the critical level of 4.5 ppm irrespective of P treatments. No marked differences in soil available Mn was perceptible due to the P treatments. There was a decrease in the soil available Cu with increasing levels of P applied and the differences however were found to be significant only for 0-30 cm depth where it was above the critical level. Earlier long-term studies on application of phosphates had shown that phosphates might not effect the availability of Cu to be of any practical consideration (Kanwar, 1976).

d) **Leaf analysis :** Withholding of phosphorus for 14 years did not lower P levels, eventhough soil available P was reduced from a pre treatment level of 43.88 ppm (1975 mean available P - 0-90 cm depth) to 12.72 ppm over a period of 14 years. The residual phosphate was adequate to meet the P requirement of coconut. Werner (1970) and Novias and Kamprath (1978) reported similar observations in other crops. Similarly, increase in soil available P due to continuous application at two rates (Table I) also did not influence positively the foliar P levels (Table VI). This observation is, in conformity with the findings of Jenson and Jacobson (1980). The foliar P content in all the treatments was not significantly different and was near critical level of 0.12%. Hameed Khan *et al* (1986) observed that a soil available phosphorus of 15 ppm (Bray-1) could sustain the palms in sufficiency level. Normal dose of N and K under varying levels of P did not influence N, K, Na, Ca and Mg nutrition of the palm significantly (Table VI).

Observations on micronutrient contents of the palms indicated no significant differences in Fe, Zn and Cu due to withholding phosphorus for 14 years. The micronutrient contents of the palms were well above sufficiency level. Mn content was found to be depressed with increasing levels of P and the differences were apparent between P_0 and P_2 and P_1 and P_2. Eventhough Fe content showed a similar

Table V. Soil available micronutrients (ppm) under different P treatments at three depths

Treat-ment	Zn				Cu				Fe				Mn			
	0-30	30-60	60-90	Mean	0-30	30-60	60-90	Mean	0-30	30-60	60-90	Mean	0-30	30-60	60-90	Mean
P_0	0.25	0.15	0.16	0.18	0.60	0.37	0.28	0.41	15.95	12.69	12.57	13.74	11.03	9.56	8.05	9.54
P_1	0.17	0.06	0.04	0.09	0.42	0.36	0.24	0.33	20.38	14.10	11.50	15.32	11.85	10.80	10.23	10.96
P_2	0.27	0.11	0.11	0.16	0.55	0.42	0.26	0.41	21.76	16.43	12.90	17.04	12.03	10.91	10.49	11.14
SE/plot	0.07	0.03	0.05	—	0.14	0.13	0.09	—	3.60	2.34	2.68	—	1.95	1.35	1.78	—
CD	0.05	0.02	0.04	—	0.11	—	—	—	2.80	1.81	—	—	—	1.05	1.38	—

Table VI. Foliar nutrient contents (%) (Frond,14) as influenced by levels of P

Treatment	P	K	N	Ca	Mg	Na
P_0	0.119	1.125	1.792	0.223	0.247	0.216
P_1	0.120	1.179	1.766	0.240	0.251	0.225
P_2	0.114	1.161	1.815	0.240	0.228	0.224
SE/plot	0.01	0.20	0.15	0.03	0.05	0.04
CD	—	—	—	—	—	—

trend, the differences were not significant.

e) **Inter relationship of nutrients** : No correlation between soil available P and foliar P was observed eventhough significant differences in soil available P persisted with increased levels of P application. Similarly, no definite correlations of phosphorus level on micronutrient relationship was also observed. This might be due to lower levels of P applied as the P requirement of coconut is low.

f) **Mycorrhizal association and population of P solubilizers** : In the P skipped treatment where available P was comparatively low, mycorrhizal association was 79.29% (Table VII) and however this reduced with increasing rates of P application. Sanders and Tinker (1971) and Jalali and Tareja (1980) also observed higher VA mycorrhizal infection percentage associated with low available P. Intensity of infection and spore count followed similar pattern. The higher colonization and infection in P skipped treatments may favour increased availability of residual phosphorus to the host plant which might probably be one of the reasons for sustaining sufficiency levels of P in the tissues as also opined by Jensen and Jacobsen, (1980).

Table VII. VA mycorrhizal association in different P treatments

Treat-ment	% Colonization	Intensity of infection (%)	Spore count gram^{-10} soil
P_0	79.29	38.14	128.86
P_1	52.14	20.14	94.00
P_2	47.86	17.43	81.86
SE/plot	16.03	8.82	39.70
CD	18.67	10.28	—

There were no differences in the count of P solubilizing fungi which were on an average 2330 to 2820 gram^{-1} of soil in different P treatments. However, P solubilizing bacteria were higher in P skipped treatment (Table VIII) which might favour increased P availability to the host plant.

g) **Yield** : Differences in yield of nuts were not significant in the treatments during 1988-89. Though variation in yield in the treatments was observed as a function of time, the differences were not significant for 1985-86, 1986-87, and 1988-89. Similar observations for earlier years up to 1980-81 were reported by Hameed Khan *et al.* (1983). Cumulative yields for four years could not establish any differences due to treatments (Table IX).

h) **Conclusion** : From the long term observations recorded over 14 years it could be concluded that recycling of P reserves can sustain coconut yields for longer periods and soil tests and plant analysis are better guides in P management of coconut groves. An available P status of 10-12 ppm can sustain sufficiency levels in palms. Mycorrhizal infection might also play a significant role in P nutrition of coconut.

Table VIII. P solubilizers in different P treatments

Treat-ment	Fungi x 10^3 g^{-1} soil	Bacteria x 10^4 g^{-1} soil	Total x 10^4 g^{-1} soil
P_0	2.35	6.09	6.33
P_1	2.33	4.36	4.60
P_2	2.82	5.79	6.08
SE/plot	1.34	2.30	2.28
CD	—	—	—

Table IX. Yield (nuts $palm^{-1}$ $year^{-1}$) under P treatments

Treatment	1985-86	1986-87	1987-88	1988-89	1985-86 to 1988-89
P_0	126.6	96.78	89.21	109.07	421.71
P_1	130.0	84.50	98.21	102.36	451.07
P_2	138.0	92.50	96.28	108.71	435.50
Gen. mean	131.55	91.26	94.57	106.71	424.10
SE/plot	42.24	21.33	34.40	34.20	111.42
CV %	32.11	23.37	36.38	32.05	26.27

It is suggested that when soil available P is less than 10 ppm, recommended dose of P (320 g $palm^{-1}$ $year^{-1}$) may be applied and soils testing 10-20 ppm need 50% of the recommended dose (160g P_2O_5 $palm^{-1}$ $year^{-1}$). If soil test value is more than 20 ppm, P application can be withheld for some years.

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