

Accumulation and Migration of Phosphate Applied as Rock Phosphate in an Oil Palm Plantation

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ABSTRAK

Satu eksperimen telah dijalankan bagi mengkaji penghimpunan dan perpindahan P yang diberikan dalam bentuk Fosfat Batuan Pulau Christmas kepada kelapa sawit di tanah siri Kuala Brang (Typic Paleudult). Pokok-pokok kelapa sawit ini telah dibaja selama 17 tahun berturut-turut dengan kadar 0, 44 dan 88 kg P/ha/tahun. Kebanyakan daripada P didapati terhimpun di dalam 10 cm lapisan atas tanah, dan berada dalam bentuk Ca-P > Fe-P > Al-P. Pertambahan kadar pemberian P telah didapati menambah P yang diekstraks secara Olsen, jumlah P, P bukan organik, KPK, dan nilai pH tanah.

ABSTRACT

An experiment was conducted to study the accumulation and migration of P applied as Christmas Island Rock Phosphate (15% P) to an oil palm crop grown on Kuala Brang soil series (Typic Paleudult). These oil palm trees were fertilized for 17 consecutive years at the rate of 0, 44 and 88 kg P/ha/year. Most of the P was found to accumulate mainly in the top 10 cm of the soil and were present in the order of Ca-P > Fe-P > Al-P. Olsen extractable P, total P, inorganic P fractions, soil CEC and pH were found to increase with increasing rates of P applied.

INTRODUCTION

In Malaysia, ground rock phosphate, especially Christmas Island Rock Phosphate has been extensively used for plantation crops like rubber and oil palm. This is due to the acid soil conditions and the relatively cheaper price of the natural phosphate fertilizer compared to manufactured P fertilizers (Sharifuddin and Zaharah, 1980).

This study was initiated to investigate the fate of P fertilizer that has been broadcasted around the weeded circle of the oil palm trees for 17 consecutive years. The source of the P fertilizer used was Christmas Island Rock Phosphate

(15% P). The soils for this study were sampled from an area where a 3 × 3 × 3 × 3 factorial experiment was conducted to study the effects of N, P, K and Mg fertilizers and their interactions on oil palm performance and yield. This experiment was conducted by Harrison Malaysian Plantation Berhad in Sg. Mahang Estate, Kubang Division on oil palms grown on Kuala Brang series soil (Typic Paleudult). The fertilizer trial was started in 1964 until 1981. These soils were sampled for the present study in May 1983.

MATERIALS AND METHODS

Soil samples were collected from plots that received 0, 44 and 88 kg P/ha/year. The

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samples were collected using a core auger up to a depth of 50 cm. Each soil core was divided into different soil depths of 0–10 cm, 10–20 cm, 20–30 cm and 30–50 cm. A total of 4 core samples were made for each fertilizer level. These soils were air-dried, ground and sieved through a 0.5 mm sieve for analyses. Soil analyses carried out were: soil pH (1:2.5), total P (Jackson, 1947), P fractionation (Chang and Jackson, 1957), sodium bicarbonate extractable P (Olsen *et al.*, 1954), Bray and Kurtz no. 2 extractable P (Bray and Kurtz, 1945) and cation exchange capacity using ammonium acetate at pH 7.0.

RESULTS AND DISCUSSION

Soil pH

The average soil pH for the zero P treatment was 4.45. A highly significant increase was

noted when the P fertilizer added was increased to 44 and 88 kg P/ha/year (Table 1). This is due to the effect of the Ca present in the rock phosphate, which increased the base saturation of the soil, thus increasing the pH value. The highest pH value was found in the 0–10 cm soil depth and decreased significantly with increasing soil depths.

Cation Exchange Capacity

At the highest rate of P application, the CEC values of the top 10 cm of the soil increased significantly ($P = 0.05$) from 0 to 44 kg P/ha/year. A highly significant difference ($P = 0.01$) was found between CEC value in the top soil layer between 0 and 88 kg P/ha/year treatments (Table 2). This may be due to the increase in the negative charge resulting from the accumulation of P in the soil (Tessens and Zaharah, 1982). The increase of CEC values with depths for each P level was found to be not significant.

TABLE 1
Soil pH values at different soil depths and P rates

P rates kg/ha/year	Soil Depths (cm)			
	0–10	10–20	20–30	30–50
0	4.67 ^a	4.40 ^a	4.24 ^a	4.25 ^a
44	4.91 ^b	4.80 ^b	4.63 ^b	4.50 ^b
88	5.39 ^c	4.93 ^c	4.84 ^c	4.76 ^c

Values in the same column followed by the same letter are not significant at $P = 0.01$.

TABLE 2
Effect of P fertilizer on soil cation exchange capacity
(Cmol [–]/kg soil)

P rates kg/ha/year	Soil Depths (cm)			
	0–10	10–20	20–30	30–50
0	8.23 ^a	10.08 ^a	10.6 ^a	10.07 ^a
44	11.13 ^a	10.43 ^a	12.03 ^a	10.67 ^b
88	16.30 ^b	12.85 ^b	12.85 ^b	13.95 ^b

Values in the same column followed by the same letter are not significant at $P = 0.05$.

Total P

It was found that the soil in the zero P treatment has an average of 0.53 mg P/g soil in the top 10 cm of the profile and the value decreased significantly with soil depths. The higher P content in the top soil horizon may be due to the accumulation of P present in the organic matter derived from the plant (Table 3). The addition of 44 kg P/ha/year increased the P content significantly to 1.66 mg P/g soil in the top 10 cm of the soil profile. A significant increase was also found in the 10 – 20 cm soil depths.

A highly significant increase was found in the top 10 cm of the soil when 88 kg P/ha/year was added. It was seen that the increase in total P was two fold when the P rates was increased from 44 to 88 kg P/ha/year. A significant increase in the total P content of the 10 – 20 cm soil layer was also observed. No significant increase in total P content was observed for all P levels at soil depths below 20 cm. It can thus be

concluded that P movement in the soil below 10 cm depths is negligible.

P Fractions

The Ca-P, Fe-P and Al-P fractions of the inorganic P present in the soil is shown in Table 4. Most of the added P was found to be in the Ca-P fraction followed by Fe-P and Al-P. The same trend was found by Pushparajah *et al.* (1977) when rock phosphate was applied to Hevea plants for 14 years. This is due to the rock phosphates, which contain high values of mono-calcium phosphate which contributes to the higher fraction of the Ca-P which can persist in acid soils (Sauchelli, 1965).

The highest amount of Ca-P fraction was found in the 0-10 cm soil depths at the highest rate of P applied. It is significantly higher than the Ca-P content at the 0 and 44 kg P/ha/year treatments. A drastic reduction in the Ca-P content with soil depths was also observed.

TABLE 3

Effects of different of different P rates on total P content of the soil (mg P/g soil) at different soil depths

P rates kg/ha/year	Soil Depths (cm)			
	0 – 10	10 – 20	20 – 30	30 – 50
0	0.53 ^a	0.07 ^a	0.06 ^a	0.05 ^a
44	1.66 ^a	0.15 ^a	0.07 ^b	0.06 ^a
88	3.26 ^b	0.22 ^b	0.08 ^b	0.07 ^b

Values in the same column followed by the same letter are not significant at P = 0.05.

TABLE 4

Effects of different rates of P fertilizer applied on P fractions present in the soil at different soil depths

P rates kg P/ha/year	Ca-P (ug/g)				Fe-P (ug/g)				Al-P (ug/g)			
	Soil Depths (m)											
	1	2	3	4	1	2	3	4	1	2	3	4
0	456	21	9	5	80	42	37	31	11	6	5	5
44	1051	31	10	6	424	51	48	42	69	10	6	6
88	2398	38	15	9	581	77	48	45	43	17	17	12

Soil depths: 1 = 0 – 10 cm, 2 = 10 – 20 cm, 3 = 20 – 30 cm, 4 = 30 – 50 cm.

TABLE 5
Effects of different P rates on extractable P at different soil depths

P rates kg P/ha/year	Extractable P (ug P/g soil)							
	Olsen - P				Bray 2 - P			
	Soil Depths (cm)							
	0 - 10	10 - 20	20 - 30	30 - 50	0 - 10	10 - 20	20 - 30	30 - 50
0	9.1 ^a	4.1 ^a	2.6 ^a	3.0 ^a	139.0 ^a	3.3 ^a	2.3 ^a	5.3 ^a
44	17.6 ^a	6.3 ^a	3.4 ^a	3.2 ^a	618.1 ^b	11.6 ^a	5.1 ^a	2.6 ^a
88	114.4 ^b	28.8 ^b	7.4 ^b	4.1 ^a	1596.6 ^c	47.2 ^b	5.4 ^a	2.6 ^a

Values in the same column followed by the same letter are not significant at $P = 0.05$.

The amount of Fe-P fraction present in the soil was also found to be highest in the top 10 cm of the soil, and at the highest P rate applied. Fe-P content of the soil in the 10 - 20 cm soil depths and lower were not significantly different for all the treatments.

Al-P fraction was found to be the lowest fraction present compared to Ca-P and Fe-P fractions for all treatments. The same trend was observed by Yost *et al.* (1981) and Pushparajah *et al.* (1977).

Extractable P

The amount of P extracted by 0.1 M HCl + 0.03 M NH_4F (Bray 2-P) and 0.5 M NaHCO_3 , pH 8.5 (Olsen-P) extracts were found to increase with increasing rates of P applied (Table 5). The higher P values were also found in the top 10 cm of the soil. It was observed that Bray 2-P was much higher than Olsen-P at all levels of P application and at all soil depths. This indicates that the Bray and Kurtz extracting solution is a much stronger extractant compared to the Olsen extract. This is confirmed by the fact that the Bray 2-P values obtained were not significantly different with soil depths, and different rates of P applied (except the top 10 cm of the soil).

CONCLUSION

Continuous application of rock phosphate fertilizer in an oil palm plantation has resulted in

the P being accumulated mainly in the top 10 cm of the soil profile. Most of the P added were present in the order of Ca-P > Fe-P > Al-P. There was a significant increase in the total P, inorganic P fractions, extractable P, soil CEC and pH with increasing rates of P applied. Olsen extracts were found to be a more sensitive extractant than Bray and Kurtz no. 2 to estimate available P in soils.

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