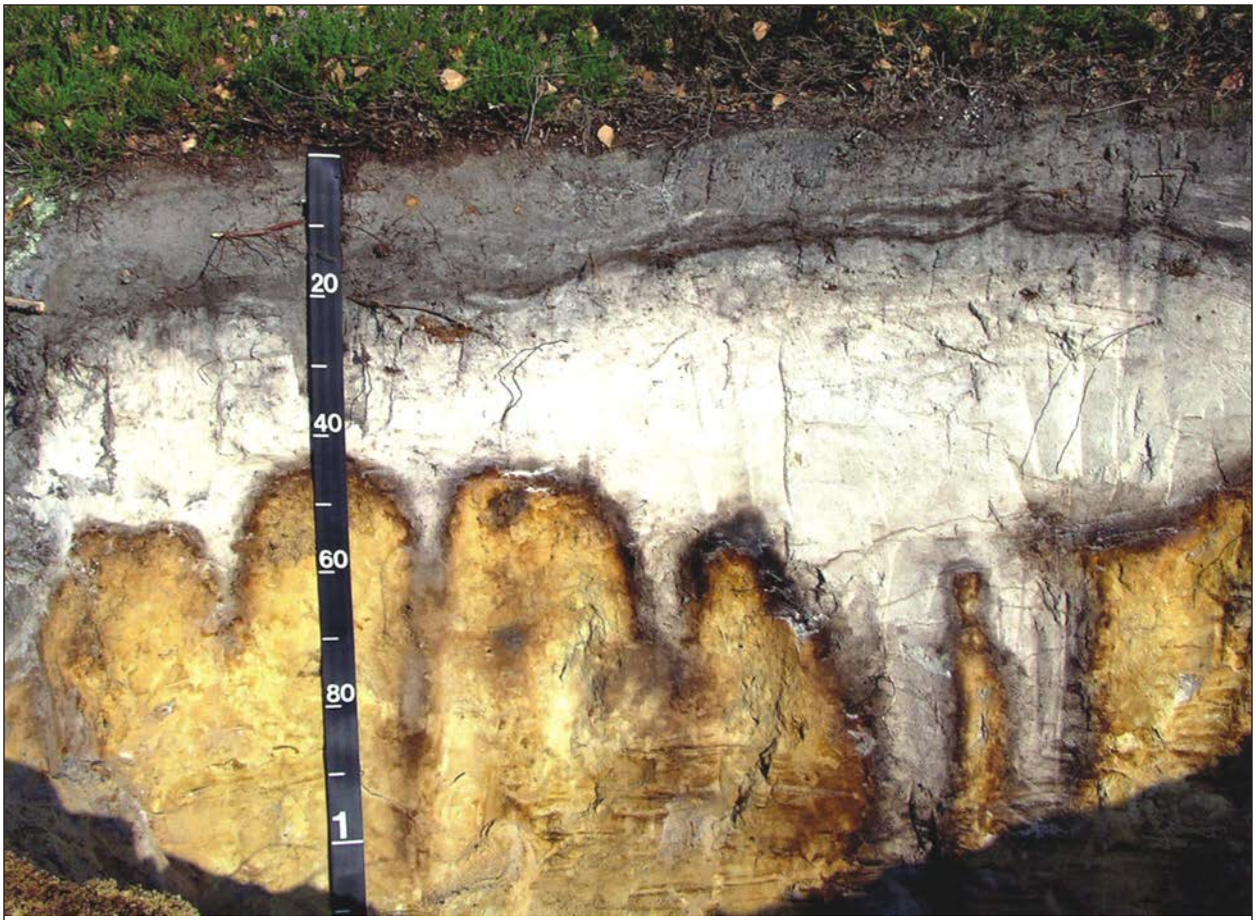

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Elucidating How the Capacity of Cultivated Tropical Peat Soils to Supply Phosphorus Relates to Available Phosphorus Forms in Pineapple Production

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Abstract: This study was carried out to investigate whether relationships could be established among total P, extractable P and soil solution P under fertilized and unfertilized conditions for unburned pineapple residue management practices in pineapple cultivation on tropical peat soils. Results showed that the relationship among total P, extractable P and soil solution P for the fertilized condition was quadratic at 0-10 cm depth. There was no significant relationship at the same depth for the unfertilized condition. There was no relationship among the three forms of P for both of the fertilized and unfertilized conditions at 10-25 cm and 25-45 cm depths. This observation was attributed to low bulk density and leaching of P. Only top soil under fertilized condition affects the nature of the relationship among total, exchangeableand soil solution P in pineapple cultivation tropical peat soils.

Key words: Phosphorus fertilizers, pineapples, tropical peat soils, phosphorus leaching, soil total, extractable, solution P relationships

Introduction

One of the major constraints in the agricultural use of peat soils in the tropics is rapid crop yield declines with time after reclamation. Due to this, high amounts of fertilizers are used to ensure continued crop production on these soils (Kyuma and Vijarnsorn, 1992). For instance, as much as 36 P ha^{-1} (in the form of China phosphate rock) is used in pineapple cultivation on tropical peat in Malaysia. This high application of P has been associated with low mineral contents in the available forms (Andriesse, 1988; Funakawa *et al*., 1996; Okazaki *et al*., 1994; Okazaki and Yonebayashi, 1992) and low clay (to hold cations) in tropical peat soils (Stevenson, 1994).

Equally pertinent studies about how cultivated tropical peat soils P supplying capacity relates to available P forms are lacking. Information of this kind could be valuable to crop growers on organic soils because it may contribute to the development of efficient nutrient management strategies and the reduction of the polluting effects from excessive fertilizer applications. For instance, once nutrients in the available forms are depleted particularly under high rainfall, replenishment from the solid phase may not be rapid enough to support the nutritional requirement of plants if readily available input such as fertilizer is not timely applied to the soil. A study has shown that in spite of the high concentration of P in soil solution of uncultivated tropical peat soils, the potential capacity to supply P in these soils is not necessarily high despite the apparent high intensity of soil solution composition (Funakawa *et al*., 1996). This observation was attributed to low bulk density and low mineral contents

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in the available forms. The nature of the relationships existing among P supplying capacity and the available forms has however not yet been investigated for natural (uncultivated) and cultivated tropical peat soils. This study was carried out to investigate whether relationships could be established among soil total P, extractable P and soil solution P under fertilized and unfertilized conditions for unburned pineapple residue management practices in pineapple cultivation on tropical peat soils.

Materials and Methods

The study was conducted on an Umbro Saprists peat soil at Peninsula Malaysia Pineapple Estate in Johor. The area has an annual precipitation of about 2000 mm. Mean monthly maximum and minimum temperatures are 31 and 23°C and relative humidity ranged from 70 to 90%/month.

There were two treatments. Treatment one was on plots without P fertilizer (T1) and treatment two was on plots with P fertilization (T2). Each of the test plots was 4 m wide x 12 m long (48 m^2). Three hundred suckers of cv. Gandul (the most commonly grown variety) suckers were planted in each of the test plots. The experimental plots were laid out in a randomized complete block design with four replications.

The normal P schedule of the pineapple estate was followed. Phosphorus was applied to the fertilized plots in the form of China phosphate rock (14%), at the total rate of 36 kg ha^{-1} P. At 83 days after planting, P was applied at 11 kg ha^{-1} P. Another 11 kg ha^{-1} P was applied at 144 days after planting. At 209 days after planting, 7 kg ha^{-1} P was applied. The same rate was also applied at 263 days after planting. The normal K and N schedule of the pineapple estate was also followed. All of the other plant management procedures and schedules of the estate were also followed.

In order to monitor the movement of P in the soil profile, peat soil samples were taken at the depths of 0-10, 10-25 and 25-45 cm. Before the start of the experiment, peat soil samples (4 core samples) were taken at these depths using a peat augur. The samples were analyzed for total P, extractable P and soil solution P. The extraction methods used to analyze these forms of P were the dry ash method (Cottenie, 1980), the double acid method (Van Lierop *et al*., 1980) and the squeeze methods (Bailey *et al*., 1996). The molybdate blue method was used for the P determination. The test plots did not significantly differ in their initial P forms (total, extractableand soil solution). Subsequent peat soil samplings were done 48, 83, 144, 263, 365, 417 and 446 days after planting. The samples were also analyzed for the three P forms mentioned using the above procedures. Prior to the commencement of the experiment, peat core samplers of 7.5 cm diameter were used to collect peat soil samples at the stated depths. Standard procedures were used to determine the bulk density of the experimental plots.

At 466 days after planting, fresh fruits were harvested from the test plots excluding guard rows. The method described by Ahmed *et al*. (1999) was used for roots evaluation. Based on the plant density, a simple proportion was used to quantify the fresh fruit yield, root dry matter and root P uptake per hectare. The dry ash method (Cottenie, 1980) was used to extract P from the oven-dried root samples and the molybdate blue method used to determine the P concentration in the roots. The relationships among the three forms of P were explored by regression. The fresh fruit yield, dry root weight and root P uptake for T1 and T2 were compared by unpaired t-test. The statistical software used for these analyses was the Statistical Analysis System version 8.2 (SAS, 2001). The plot data were meaned before use in the statistical analyses.

Results and Discussion

The bulk densities at the depths of 0-10, 10-25 and 25-45 cm were 0.26, 0.17 and 0.14 g cm^{-3}, respectively and were typical of Umbro Saprists peat soil (Andriesse, 1988). As can been seen, the

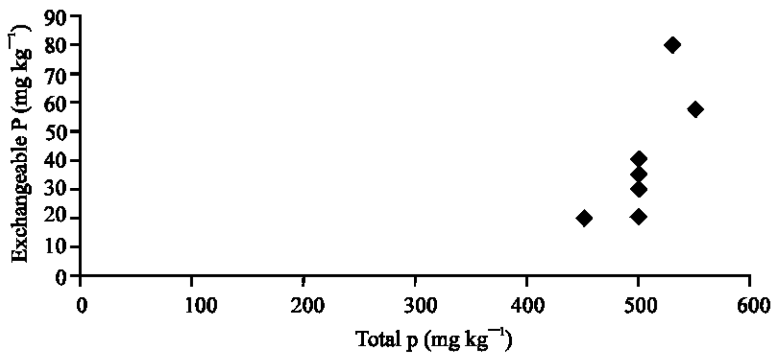

Fig. 1: Relationship between total P and extractable P at 0-10 cm for T1

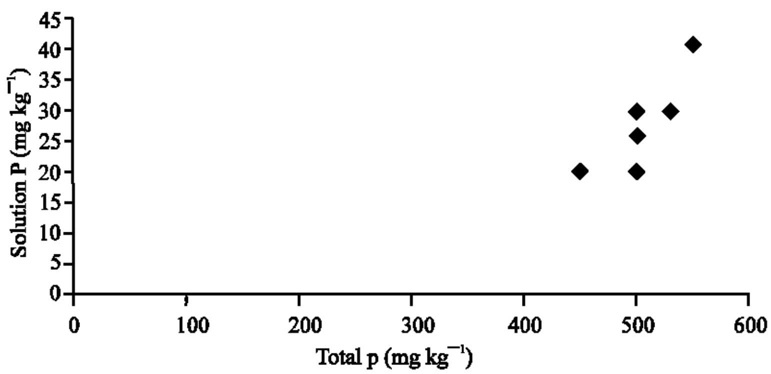

Fig. 2: Relationship between total P and Soil solution P at 0-10 cm for T1

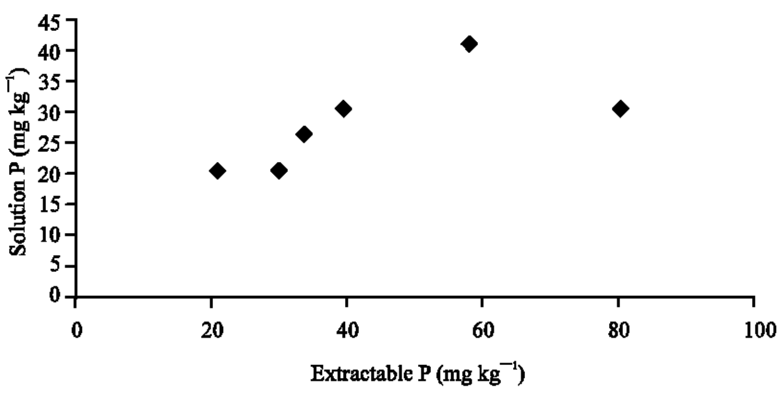

Fig. 3: Relationship between extractable P and Soil solution P at 0-10 cm for T1

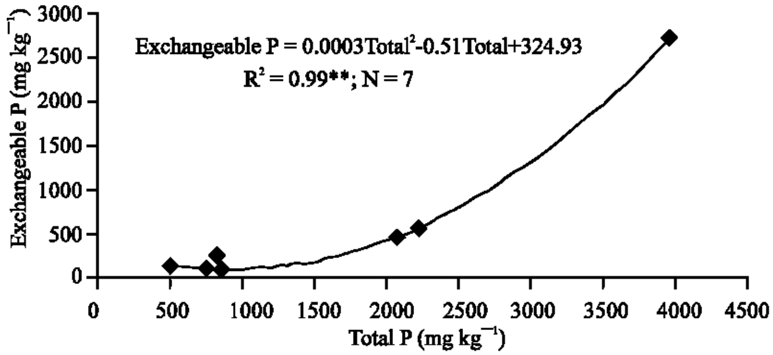

Fig. 4: Relationship between total P and extractable P at 0-10 cm for T2

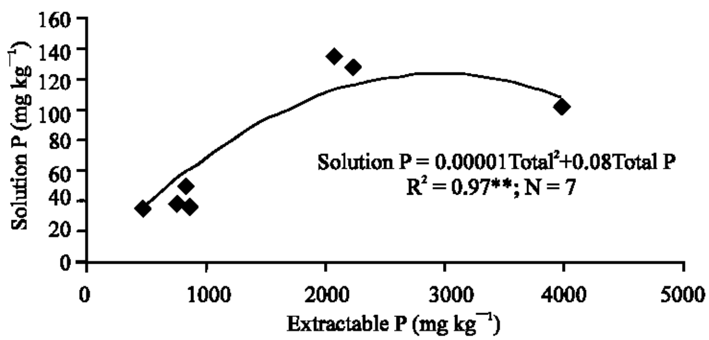

Fig. 5: Relationship between total P and Soil solution P at 0-10 cm for T2

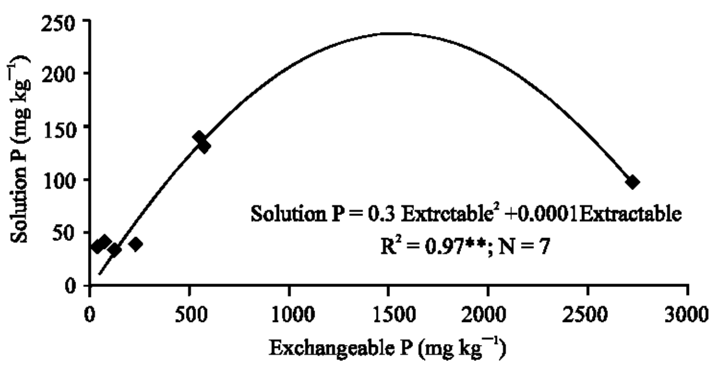

Fig. 6: Relationship between exchangeable P and Soil solution P at 0-10 cm for T2

bulk density decreased down the soil profile. The relatively high bulk density at 0-10 cm depth may be due to cultivation and compaction, subsidence of peat soil, of the surface layers upon drainage (Andriesse, 1988). The fact that the pineapple estate has been under use for about 36 years and has good drainage systems supports this observation.

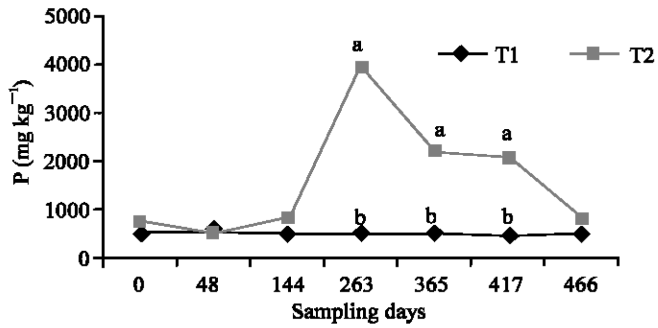

Fig. 7: Total P with time at 0-10 cm

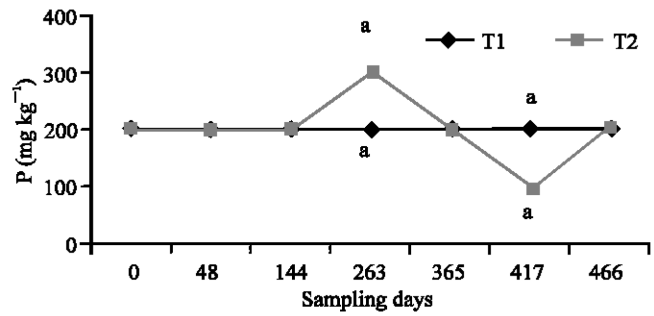

Fig. 8: Total P with time at 10-25 cm

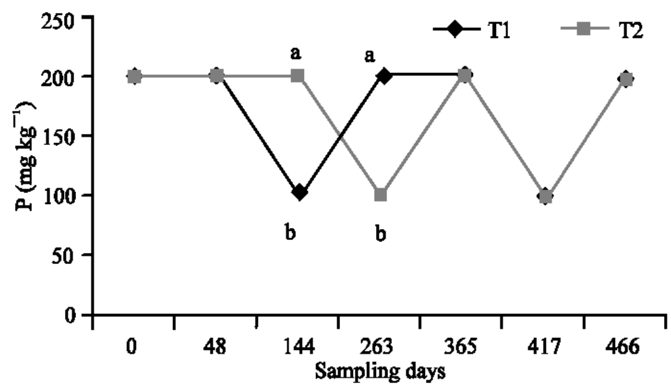

Fig. 9: Total P with time at 25-45 cm

Note: Different alphabets at sampling time indicates significant difference between means using paired t-test at $p = 0.05$. Sampling time without alphabets indicate no significant difference between means using paired t-test at $p = 0.05$

The nature of the relationships among total P, extractable P and solution P down the soil profile (0-10 cm, 10-25 cm and 25-45 cm) were explored. There was a significant quadratic relationship among total P, extractable P and soil solution P (Fig. 1-6) at 0-10 cm for only the fertilized plots. Regardless of treatment, no relationships were found at 10-25 cm and 25-45 cm depths for the 3 forms of P.

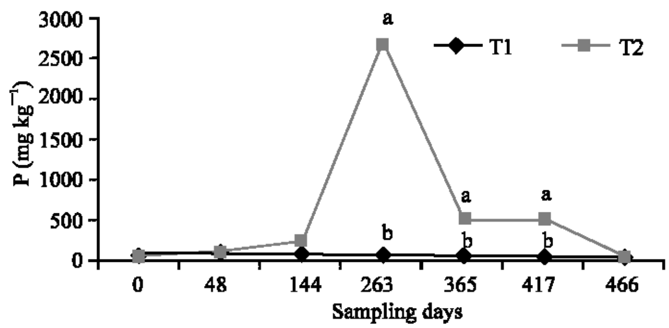

Fig. 10: Extractable P with time at 0-10 cm

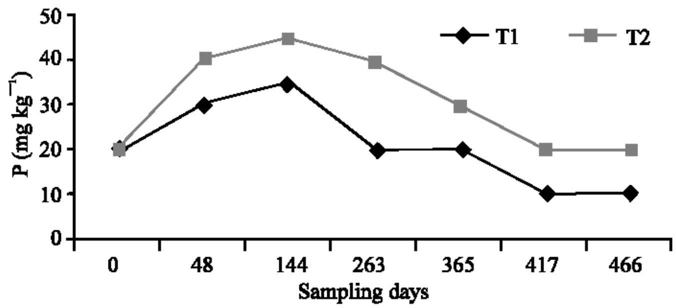

Fig. 11: Extractable P with time at 10-25 cm

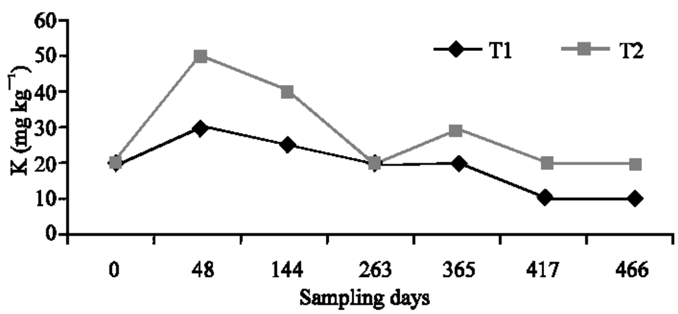

Fig. 12: Extractable P with time at 25-45 cm

Note: Different alphabets at sampling time indicate significant difference between means using paired t-test at $p = 0.05$. Sampling time without alphabets indicate no significant difference between means using paired t-test at $p = 0.05$

Increase in P intensity (due to addition of P fertilizer) and the relatively high bulk density (due to cultivation) of 0.26 g cm^{-3} at 0-10 cm might have facilitated a temporary adsorption of some of applied P in the fertilized plots at this depth. The increase in the concentration of P in the soil solution might have also created a diffusion gradient which was conducive for P uptake by the plants from the soil pool of the fertilized plots (Marschner, 1995) compared to the unfertilized plots. As P was being

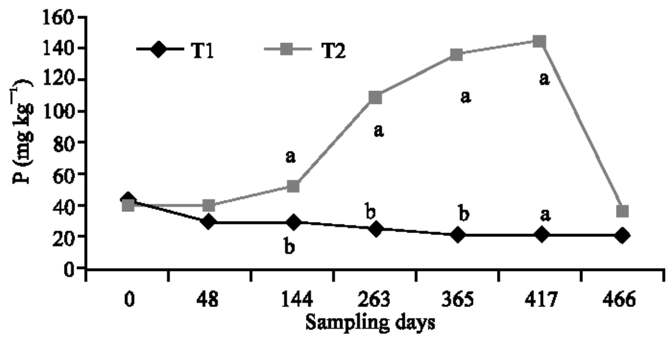

Fig. 13: Soil solution P with time at 0-10 cm

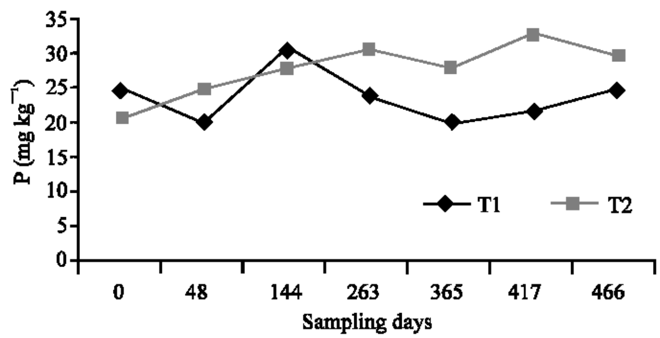

Fig. 14: Soil solution P with time at 10-25 cm

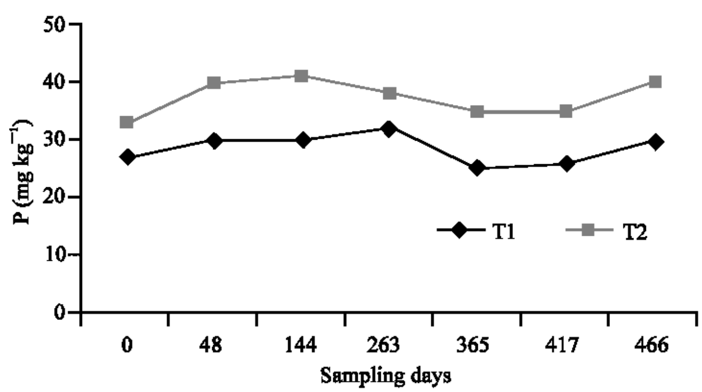

Fig. 15: Soil solution P with time at 25-25 cm

Note: Different alphabets at sampling time indicate significant difference between means using paired t-test at $p = 0.05$. Sampling time without alphabets indicate no significant difference between means using paired t-test at $p = 0.05$

Table 1: Comparison of treatment means of dry root matter production, root P uptake and fresh fruit yield

Treatments	Dry matter (Mg ha^{-1})	P uptake (kg ha^{-1})	Fresh fruit yield (Mg ha^{-1})
T1	0.35^{a}	0.07^{a}	46.27^{a}
T2	0.55^{b}	0.11^{b}	56.25^{b}

Note: Same alphabet indicates no significant difference between means by unpaired t-test at p = 0.05

depleted or taken up (from soil solution) by the plants, it was possible that a simultaneous replenishment from the adsorbed P was inevitable so as to better maintain the equilibrium concentration of this nutrient in the fertilized plots compared to the unfertilized plots (Marshner, 1995). A reflection of this can be found in Table 1 where the fresh fruit yield, root dry matter and root P uptake by the plants in the fertilized plots were significantly higher than those of the unfertilized plots.

The non existence of significant relationships among total P, extractable P and soil solution at 10-25 cm and 25-45 cm depths for the fertilized and unfertilized plots could be due low bulk density and leaching of P. The low bulk density and low clay content in tropical peat imply low P retention (Andriesse, 1988; Stevenson, 1994). This usually leads to P leaching particularly when rainfall is high (Funakawa *et al*., 1996). As shown in Fig. 7, 10 and 13, there was a sharp decrease of soil total P, extractable P and soil solution P, at 0-10 cm, particularly for the fertilized plots after 263 days after planting. This decline continued till the end of the study so that the 3 different forms of soil P at the end of the study were generally lower or equal to those before the study. There was however no evidence of significant accumulation of these P forms at 10-25 cm (Fig. 8, 11 and 14) and 25-45 cm depths (Fig. 9, 12 and 15). There seemed to be no corresponding significant accumulation of the P forms at deeper depths. Phosphorus concentrations throughout the study period were generally lower or equal to their initial status in the soil indicating leaching. Due to the low clay and absence of mineral matter (Stevenson, 1994), P fixation which is noticeable in mineral soils is almost absent in peat soils. A study has shown that almost all the P fertilizer applied to an organic soil containing essentially no clay could be removed with leaching of water (Fox and Kamprath, 1972). This loss has been attributed to the weakness of adsorption in organic soils that renders inorganic P quite mobile with respect to leaching than in mineral soils (Hortenstine and Forbes, 1972). Besides the fact that soils with organic colloids generally have low capacities to adsorb P, adsorbed P is normally very soluble (Fox and Kamprath, 1972). However, it has been noticed that the presence of appreciable level of Fe, Al, and Ca can cause P adsorption in some organic soils (Fox and Kamprath, 1972; Cogger and Duxbury, 1984).

To suggest some ways of reducing leaching, a more frequent application (foliar or soil) schedule at lower application rates need to be studied, so that a response curve could be examined and optimum rates derived. This will help to address the issue of whether sufficient or excessive P is being applied in the right formand in a sustainable way.

Conclusions

The nature of the relationship among total P, exchangeable Pand soil solution P under fertilized condition at 0-10 cm depth in pineapple cultivation on tropical peat soils is quadratic. There is no relationship among these 3 forms of P at 0-10 cm depth under unfertilized condition. There is no relationship among total P, exchangeable Pand soil solution P at 10-25 cm and 25-45 cm depths for fertilized and unfertilized conditions. The general lack of relationship after 10-25 cm and 25-45 cm depths is partly due leaching. Only top soil under fertilized condition could affect the nature of the relationship among total, exchangeableand soil solution P in pineapple cultivation tropical peat soils.

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