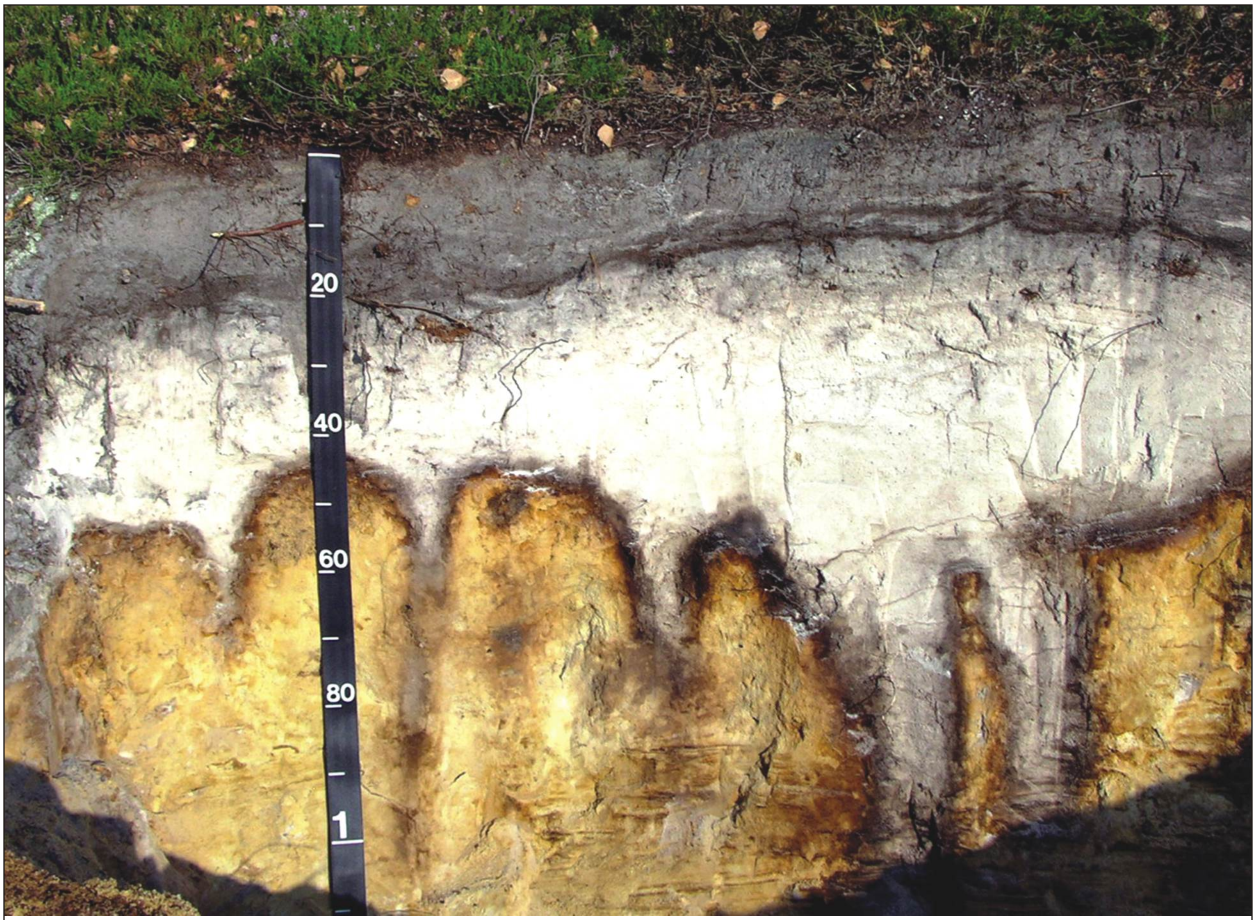

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Phosphorus Loss of Phosphorus Fertilizer Applied to Tropical Peat Soils in Pineapple Cultivation

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Abstract: This study was carried out to determine the efficiency using applied P under a conventional recommended fertilization regime in pineapple cultivation with residue removal. Results showed that P recovery from applied P fertilizer in pineapple cultivation on tropical peat soil was 53%. At 0-10 cm depth, there was a sharp decrease of soil total P, extractable P and soil solution P, days after planting for plots with P fertilizer. This decline continued till the end of the study. Soil total, extractable and solution P at the end of the study were generally equal to those before the study. There was no significant accumulation of P at 10-25 and 25-45 cm depths. However, P concentrations throughout the study period were generally lower or equal to their initial status. Recovery of P in pineapple cultivation on tropical peat soil seems to relate to P loss. As such, P loss needs to be considered in fertilizer recommendations for pineapple cultivation in organic soils.

Key words: Phosphorus fertilizers, pineapples, tropical peat soils, residues, P loss

Introduction

Commercial production of pineapples on tropical peat soils is associated with *in situ* burning of their residues before subsequent replanting. As a result of the economic loss in the agricultural sector due to fires and haze in South-East Asia (Hon, 1999; Shahwahid *et al*., 1999; Ruitenbeek, 1999), *in situ* burning of crops residues of which pineapple residues are no exception is being seriously discouraged. Research on value addition or product development from pineapple residues has shown some impressive and promising results (Ahmed *et al*., 2002a; 2003; 2004). However, the existing P fertilization regimes for this residue management practices came out of studies (Tay, 1973; Selamat and Ramlah, 1993; Razzaque, 1999; Ahmed *et al*., 2002b) that did not take into consideration P loss.

The P requirement of pineapple is low and in some cases plants can extract P from some mineral soils with low levels of this nutrient. But in peat soils, this is less significant because of the high loss of P as result of low clay content and absence of Al and Fe compounds to form relatively insoluble phosphate compounds.

There is therefore the need to quantify the total amount of P taken up by the plant, remaining in the soil after cultivation and losses through leaching or erosion from applied P fertilizers on peat soils under pineapple cultivation. This assessment will be useful in evaluating P requirements of pineapples on peat soils, thereby contributing to the reduction of environmental pollution by excessive and unbalanced P fertilizer uses. The economic significance of efficient P use to non P fertilizers producing countries such as Malaysia whose fertilizers use and import bill are high (AGRIQUEST, 2003/04),

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cannot be over emphasized. This preliminary study was carried out to determine the efficiency using applied P under a conventional recommended fertilization regime in pineapple cultivation with residue removal.

Materials and Methods

The study was conducted in a pineapple estate in Johor, Malaysia on Umbro Saprists peat soil. The area has an annual precipitation of 2000 mm. Mean monthly minimum and maximum temperatures are 23 and 31°C and relative humidity ranged from 70 to 90% per month. Two treatments were used. Treatment 1 was on plots with P fertilizer (WPF) and treatment 2 was on plots without P fertilizer (WTPF). Each experimental plot size was 4×12 m, with 300 suckers of cv. Gandul (the most commonly grown variety) planted in each plot. The experimental plots were laid out in a randomized complete block design with four replications.

Phosphorus was as applied China phosphate rock (14% P) at a total rate of 36 kg ha^{-1} P to the WPF plots. Phosphorus fertilization regimes and rates were adapted to practices in the estate. 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 to the WPF plots. The same rate was also applied at 263 days after planting. The usual N and K fertilization regimes of the pineapple estate are presented in Table 1. The normal estate N and K fertilization regimes were followed. All other plant management procedures and schedules of the estate were also followed.

Before the start of the experiment, pineapple residues were manually removed from the study area by slashing, raking and removing old plants of the previous crop. Before removing the crop residues (to ensure that the bulk density of the soil was not significantly affected during land preparation i.e., slashing, raking and residues removal), peat soil samples were (randomly in the test plots) taken at 0-10, 10-25 and 25-45 cm depths using peat soil augur. The samples were analyzed for total P, extractable P and soil solution P using the dry ash, double acid and squeeze methods (Van Lierop *et al*., 1980; Cottenie, 1980; Bailey *et al*., 1996). The molybdate blue method (Murphy and Riley, 1962) was used to determine the P concentrations in the peat samples. Subsequent peat soil samplings were done 48, 83, 144, 263, 365, 417 and 446 days after planting. These samples were also analyzed for the P forms mentioned using the aforementioned procedures.

At 466 days after planting, fresh fruits were harvested from the experimental plots excluding guard rows. From a practical point of view, a day before harvesting three plants were randomly selected from the plots, uprooted and partitioned into roots, stem, leaves, peduncle, fruit and crown. This partitioning was done to enable calculation of the total uptake of P by the plants. These parts were oven dried at 60°C until constant weights were attained and dry weights determined. The dry ash method was used to extract P from these tissues and the molybdate blue method (Murphy and Riley, 1962) used to determine the P concentrations in the tissues. Based on the plant density, a simple proportion was used to quantify P uptake in the different parts of pineapple plant per hectare. A similar calculation was done for the fresh fruits yield. The P uptake in the plant parts and fresh fruit yields for the fertilized and unfertilized treatments were compared by unpaired t-test using the Statistical Analysis System (SAS, 2001).

Table 1: Usual N and K fertilization regimes of the pineapple estate

	No. of days of application after planting				
Fertilizer rate (kg ha^{-1})	83	144	209	263	(Total)
N	176	176	176	176	(704)
K	89	89	188	188	(554)

The P recovery was calculated according to the formula of Pomares-Gracia and Pratt, 1987):

% fertilizer P recovery = (TNF) - (TNU)/R × 100 (1)

Where:

TNF = Total P uptake from fertilized plots (kg ha^{-1})

TNU = Total P uptake from unfertilized plots (kg ha^{-1})

R = Rate of fertilizer P applied (kg ha^{-1})

Note: TNF and TNU relate to WPF and WTPF, respectively in this study.

Results and Discussion

The experimental plots did not significantly differ in their initial total P, extractable P and soil solution P (data not shown). There was a sharp decrease of soil total P and extractable P at 0-10 cm after 263 days after planting for plots with P fertilizer but that of soil solution P (at same depth) rapidly declined after 417 days after planting (Table 2). 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 statistically not different from those before the study (Table 2). There was however no evidence of significant accumulation of these P forms at 10-25 and 25-45 cm depths. 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 P loss. A comparison between the initial concentrations of total, extractable and soil solution (Table 3) and those at the end of the study showed that the concentrations were generally equal. These observations suggested that the low P recovery of P could be attributed to P loss. As a result of low clay and absence of mineral matter, 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 (Razzaque, 1999). 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. 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). These observations could be some of the reasons why the P recovery in this study was not relatively high. The aspect of P recovery is subsequently discussed.

Table 2: Concentrations of three different forms of soil P at different stages of sampling for 0-10 cm depth

	Sampling stage						
	0*	48	144	263	365	417	466
Total P (mg kg^{-1})							
WPF	700	500	825	3967^{a}	2225^{a}	2067^{a}	850
WTPF	550	530	500	500^{b}	500^{b}	450^{b}	500
Extractable P (mg kg^{-1})							
WPF	60	113	233^{a}	2700^{a}	520^{a}	510^{a}	40
WTPF	58	80	40^{b}	35^{b}	30^{b}	20^{b}	40
Solution P (mg kg^{-1})							
WPF	39	38	50	102^{a}	128^{a}	136^{a}	36
WTPF	41	30	30	26^{b}	20^{b}	20^{b}	20

* Before planting. Note: Same alphabet within columns indicates no significant difference between means using paired t-test at $p = 0.05$

Table 3: Comparison for soil total, extractable and solution P before and after study

	Before study	After study
Total P (mg kg^{-1})		
Treatment		
0-10 cm		
WPF	700	850
WTPF	550	500
10-25 cm		
WPF	200	200
WTPF	200	200
25-45 cm		
WPF	150	150
WTPF	200	200
25-45 cm		
WPF	150	150
Extractable P (mg kg^{-1})		
0-10 cm		
WPF	58[a]	20[b]
WTPF	60[a]	40[b]
10-25 cm		
WPF	20[a]	10[a]
WTPF	20[a]	20[a]
25-45 cm		
WPF	20[a]	10[a]
WTPF	20[a]	20[a]
Solution P (mg kg^{-1})		
0-10 cm		
WPF	41[a]	20[b]
WTPF	39[a]	36[a]
10-25 cm		
WPF	25[a]	25[a]
WTPF	21[a]	30[a]
25-45 cm		
WPF	27[a]	30[a]
WTPF	33[a]	40[a]

Note: No significant difference within rows between means of before and after study using paired t-test at p = 0.05

Table 4: Phosphorus distribution in pineapple

Parts	WPF (kg ha^{-1})	WTPF (kg ha^{-1})
Roots	0.09	0.07
Peduncle	0.62	0.45
Crown	1.39	1.29
Stem	12.14	4.73
Leaves	13.25	7.00
Fruit	14.53	9.56
Total	42	23

Irrespective of treatment, the general trend of P uptake for both WPF and WTPF was in the order of: fruits>leaves>stem>crown>peduncle>roots (Table 4). It must be stressed that organ levels of P between treatments were not compared because optimum levels were not considered in this study. In addition, organ levels comparison may not be appropriate because pineapple will accumulate luxury levels of some nutrients, including P. Tissue levels can therefore increase with increasing applications but not necessarily be beneficial or sustainable. Several rates of application of P will be included in our subsequent studies so as to establish an optimum leaf level for Gandul. This could be useful because we are still unsure if the plant is receiving sufficient or excessive P irrespective of how much is applied and lost.

The fresh fruit yield of WPF (55 Mg ha^{-1}) was significantly ($p = 0.05$) higher than that of WTPF (45 Mg ha^{-1}). The fresh fruit yield of WPF was consistent with the average fresh fruit yield of the estate (50 t ha^{-1}). But that of WTPF was below the average fresh fruit yield of the estate which obviously indicates that without the application of P fertilizer, production will be reduced especially with time. This finding contradicts the work of (Razzaque, 1999) who reported non significant difference between the yields of P applications ranging between 0 and 52 kg ha^{-1}. Beyond an application rate of 49 kg ha^{-1} P, yield reduction has been reported (Tay, 1972). The total P uptake for WPF and WTPF were 42.02 and 23.10 kg ha^{-1} and with a total P rate of 36 kg ha^{-1}, P recovery was calculated (using the stated formula in materials and methods) to be 53%. This recovery was higher than the recovery of about 14% obtained with 42 kg ha^{-1} P in a leaching column experiment (Razzaque, 1999). This difference could be as a result of the lower amount of P (36 kg ha^{-1} P) used in this study compared to 42 kg ha^{-1} P of Razzaque (1999) as application of high amount of P to peat soils leads to its loss through leaching because of absence of fixation.

Probably without the rooting system of pineapple, this recovery would have been lower as it is known that during growth, the adventitious roots of pineapples form a short and compact system at the stem base, with numerous strong roots and limited branching. However, under ideal conditions, the soil root system could spread up to 1-2 m laterally and 0.85 m in depth (D'Eeckenbrugge and Leal, 2003). Therefore, it could be that unlike in mineral soils, the roots of pineapple in the peat soil were not very restricted or confined to the tilled area because of the relatively low bulk density. This might have allowed the roots under the fertilized condition to access larger volume of water and plants nutrients than those under the unfertilized condition. In addition, increased P diffusion gradient under the fertilized condition might have also facilitated the uptake of P in the fertilized plots (Marschner, 1995).

Conclusions and Recommendation

Recovery of P in pineapple cultivation on tropical peat soil is 53% and it seems that the recovery could be higher if P loss through for instance leaching is controlled. As such, P loss needs to be considered in fertilizer recommendations for pineapple cultivation in organic soils. Phosphorus loss from planting to harvesting needs to be studied and quantified. In order to address the issue of whether sufficient or excessive P is being applied in the right form and in a sustainable way, a number of rates of P fertilizer need to be studied, so that a response curve could be examined and optimum rates derived. To suggest some ways reducing P loss more frequent application (foliar or soil) schedule at a lower application rate needs investigation. Further investigations are needed to address the issue of how much P loss was as a result of leaching and how much was due to erosion.

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