MARDI Res. Bull., (1981) 9, 1: (49—57)

RELATIVE AVAILABILITY TO PLANTS OF PHOSPHORUS FROM ROCK PHOSPHATE AND TRIPLE SUPERPHOSPHATE IN RELATION TO LIMING ON MALAYSIAN PEAT

W.Y. CHEW*, Y.K. CHIN**, L. ISMAIL*** and K. RAMLI***

Keywords: Sorghum, Napier grass, Peat, Soil acidity, Liming pH, Phosphate availability, Phosphate carriers, Rock phosphate, Triple superphosphate, Soluble soil phosphorus

RINGKASAN

Dua percubaan di rumah kaca untuk mengkaji kesan kapur dan baja fosforus terhadap sekoi dan rumput napier di atas tanah gambut diterangkan. Pengapuran meninggikan larutan P tanah, bahan kering tanaman dan tarikan P. Sekoi didapati lebih sensitif terhadap keasidan tanah gambut dari rumput napier. Kedua-dua tanaman memberi reaksi terhadap pembajaan P cuma bila pengapuran dilakukan. Di tanah gambut yang telah dikapurkan, rumput napier memberi reaksi yang lebih baik terhadap pembajaan P daripada sekoi, dengan mengeluarkan bahan kering yang optima dengan kadar 20 kg/ha P dibandingkan dengan 10 kg/ha P diperlukan oleh sekoi. Jika dibandingkan dengan rock phosphate, triple superphosphate memberikan kesan yang lebih ke atas kedua-dua tanaman dan juga ke atas kandungan dan tarikan P. Penambahan sumber P akan menambahkan lagi bahan kering tumbuhan, kandungan P tumbuhan dan tarikan P. Tindakbalas yang positif terdapat pada sekoi tanaman pertama, manakala bagi rumput napier cuma pada penuaian pertama dan kedua sahaja. Apabila kadar P ditambah, peratus pengambilan P didapati berkurangan pada sekoi tetapi bertambah pula pada rumput napier.

INTRODUCTION

On Malaysian peat, with its extreme acidity (pH 3.0 – 3.8) and low P-fixing properties (JOSEPH *et al.*, 1971; LUCAS *et al.*, 1975), rock phosphate (RP) could prove as effective a source of P as triple superphosphate (TSP), and at a cost about 45% cheaper at current prices. Thus for pineapple which matures in one and a half years and in Malaysia is grown entirely on unlimed acid peat, TAY (1972) found no significant yield difference between RP and TSP, although TSP reduced fruit sugar content. With shorter-term crops, many research workers on peat prefer soluble phosphates, believing immediate sources of available P to be necessary. The situation is further complicated by the need to apply lime to raise peat pH in the cultivation of most annuals (CHEW, 1971); the large quantities of Ca thus supplied can appreciably depress the amount of soluble phosphates in peat (LUCAS *et al.*, 1975). The two experiments, reported here compared the relative efficacies of RP and TSP as P carriers on acid peat in relation to liming, using sorghum *(S. bicolor)* and napier grass *(Pennisetum purpureum)* as test crops.

MATERIALS AND METHODS

Peat soil (0–45 cm depth) was bulk-sampled in a forested area at the MARDI Research Station Jalan Kebun, sieved through a 20 mm wire mesh, mixed thoroughly on a cement floor and bagged at the rate of 20 kg/ha (18.51) in heavy-duty 45 x 45 cm polythene bags. From sample chemical analysis the peat was shown to be basically similar to that in a previous experiment (CHEW *et al.*, 1976), with 0.26% total P, 0.235% organic P and 30 mg/kg acid-soluble P in its dry matter.

In Expt. 1, sorghum was cropped twice on peat limed at 0 and 10 t/ha

Present addresses: *Agriculture Dept., University of Queensland, St. Lucia, Brisbane, Australia 4067.
**Monsanto Malaysia Ltd., 116 Jalan Semangat, Petaling Jaya, Selangor, Malaysia.
***MARDI Station, Jalan Kebun, Kelang, Selangor.

$CaCO_3$, factorially combined with 7 phosphate treatments consisting of a control (0 kg/ha), and 10, 20 and 40 kg/ha P, supplied as Christmas Island RP and as TSP. In Expt. 2, studying the effects of lime and phosphate fertilization on napier grass, 3 treatments on unlimed peat consisted of a control (0 kg/ha P), and 10 kg/ha P given as RP and TSP, and 5 additional treatments on limed peat (8 t/ha $CaCO_3$) consisted of a 0 kg/ha P, and 10 and 20 kg/ha P supplied as RP and TSP. Treatments were quadruplicated in a randomised complete block design with assignment of three bags to each treatment in each replicate. The lime was mixed to 15 cm depth in the sorghum experiment, 15 cm being left unlimed, while in the napier grass experiment the whole soil volume was limed. The RP (16% total P, 5% citrate-soluble and 11% insoluble) and TSP (21% total P, 3% citrate-soluble and 18% water-soluble) were applied in suspension only at the start of each experiment. Other fertilizers supplied were: at each planting of sorghum – 120 kg/ha N as urea and 85 kg K as KSO_4; and at planting and each cut of napier grass – 38 kg/ha N as urea and 21 kg K as KC1. As for micronutrients, 10 kg/ha $CuSO_4$ was given at the start of each experiment while the lime-induced Fe deficiency occasionally observed, was remedied with 0.1% $FeSO_4$ sprays.

About 20 sorghum (cv E178) seeds were sown in each bag each season, with thinning to five plants on emergence, while with napier grass (locas cv), 8 stem cuttings were planted with subsequent thinning to four plants. The bags were kept in a greenhouse and watered every 1–2 days to maintain soil moisture around field capacity.

Soil cores of the entire peat depth were taken thrice from each bag for pH analysis (with pH-meter; 1:2 soil/water ratio, volume basis) at the start (after liming), midway and the end of each experiment. Intermediate peat samples from the sorghum experiment were analysed for their acid-soluble (dilute HC1/H_2SO_4) P content.

Sorghum was cut at soil level after 95 days' growth, before flowering. Napier grass was cut at 10 cm every 6 weeks. Plant dry matter, recorded at each harvest, was analysed for P content (vanadomolybdate method), from which the P uptake was calculated.

RESULTS

Peat pH and soluble P

Peat pH increased from pH 3.25 to 4.20 with liming at 10 t/ha in Expt. 1, and from pH 3.30 to 4.00 with 8 t/ha lime in Expt. 2 *(Figure 1)*, the soil pH being well maintained throughout the experimental periods. Application of fertilizer P slightly increased soil pH but with no significant difference between RP and TSP.

Analysis of peat sampled at the end of the first sorghum crop showed that liming as well as P fertilization increased the acid-soluble P content in peat, TSP being slightly better than RP with 10 t/ha lime, but not significantly so at 0 t/ha lime *(Figure 2)*.

Plant dry matter

In both experiments and at every harvest of each crop, liming markedly improved dry matter which was otherwise negligibly low *(Figure 3)*. On unlimed peat (pH 3.2), both crops produced extremely poor growth and dry matter *(Figure 3)* and only sorghum, showed leaf yellowing. Thus, positive responses to applied P were observed only with liming, TSP being generally superior to RP. However, differences between P treatments were significant (P=0.05) only in the first sorghum crop and the first two napier grass harvests, subsequent harvests showing no significant response to applied P, either as RP or TSP.

The first sorghum crop produced optimum dry matter at 10 kg/ha P, the response being somewhat better with TSP

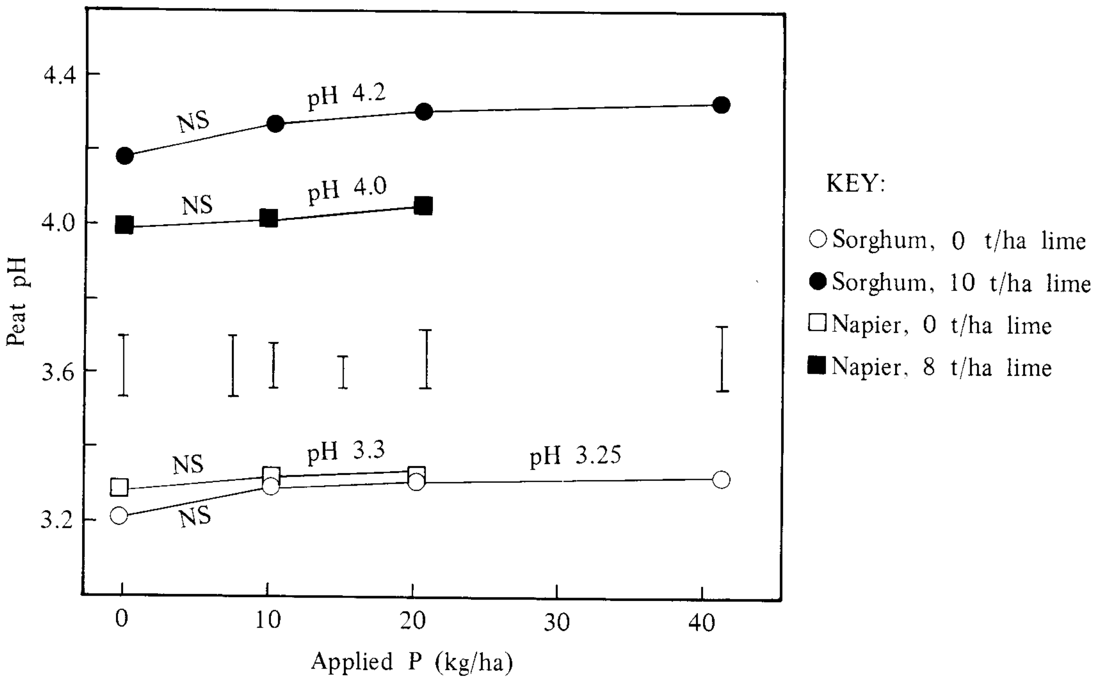


Figure 1. Peat pH in relation to liming and P fertilization.

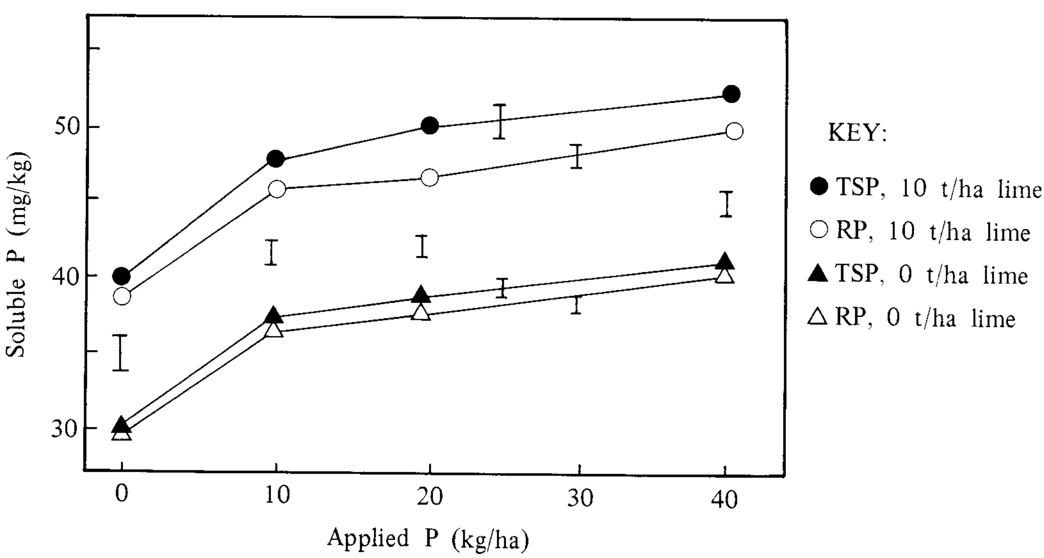
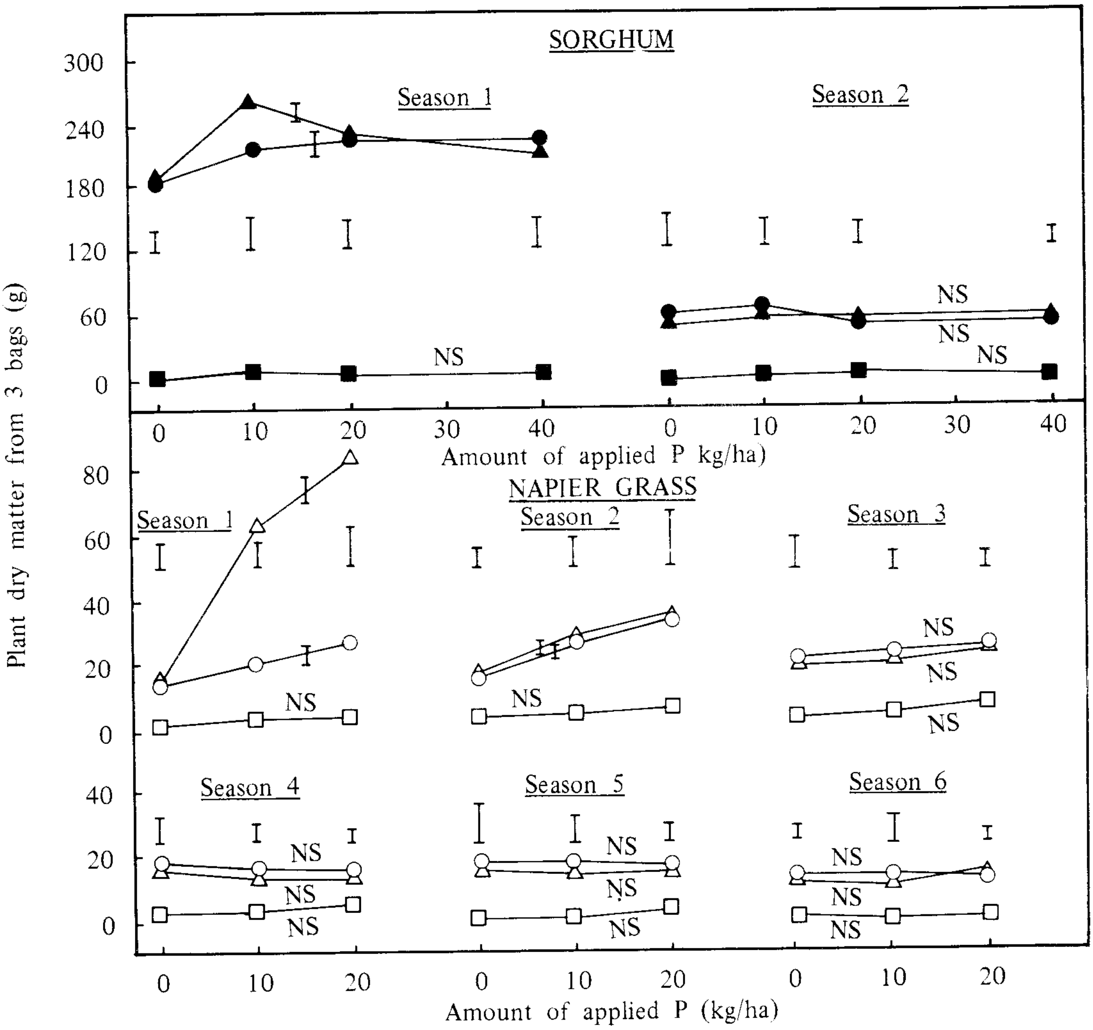


Figure 2. Acid-soluble or easily soluble P in peat in relation to liming and P fertilization (Expt 1 only).



KEY:		Lime (t/ha)	RP/TSP
▲	Sorghum	10	TSP
●	Sorghum	10	RP
■	Sorghum	0	Mean of TSP & RP
△	Napier grass	8	TSP
○	Napier grass	8	RP
□	Napier grass	0	Mean of TSP & RP

Figure 3. Dry matter of sorghum and napier grass in relation to liming and P fertilization.

than with RP. Higher rates of RP maintained yields, whereas higher rates of TSP reduced dry matter *(Figure 3)*. Similar results were obtained in the first two napier grass harvests, except that napier grass responded significantly to 20 kg/ha P, and TSP's superiority over RP, though significant only in the first harvest, was much more marked than in the case of sorghum.

Plant P concentration

On unlimed acid peat, the P concentration in dry matter was relatively high (0.4 – 0.6% in sorghum and 0.12 – 0.35% in napier grass), whereas on limed peat it was much lower (0.02 – 1.09% in sorghum and 0.08 – 0.12 in napier grass).

Liming, while increasing plant dry matter also, decreased its P concentration. However, the addition of P, either as RP or TSP to limed peat increased plant P concentration, the increment being greatest in the first harvest of each crop and decreasing with time of cropping in direct proportion to the cumulative P uptake *(Figure 4)*. Furthermore, TSP proved considerably superior to RP in improving plant P concentration over the whole range of P levels investigated and for both crops.

Plant P uptake

Plant P uptake, extremely poor on unlimed peat, improved considerably in both crops with liming. The application on increasing rates of P to limed peat, either as RP or TSP, also improved P uptake. However, the greatest response of each crop to applied P was observed in the first harvest, when sorghum showed positive parabolic responses to 40 kg/ha P as TSP, but to only 10 kg/ha P as RP; whereas napier grass responded linearly to the highest P rate investigated (20 kg/ha), irrespective of the carrier *(Figure 5)*. Thus, TSP was distinctly superior to RP in P uptake but only so in the first harvest of both crops. In subsequent harvests, there was no significant difference between increasing rates of P or between the two P carriers. However the second napier grass harvest showed a response to 20 kg/ha P but without significant difference between RP and TSP.

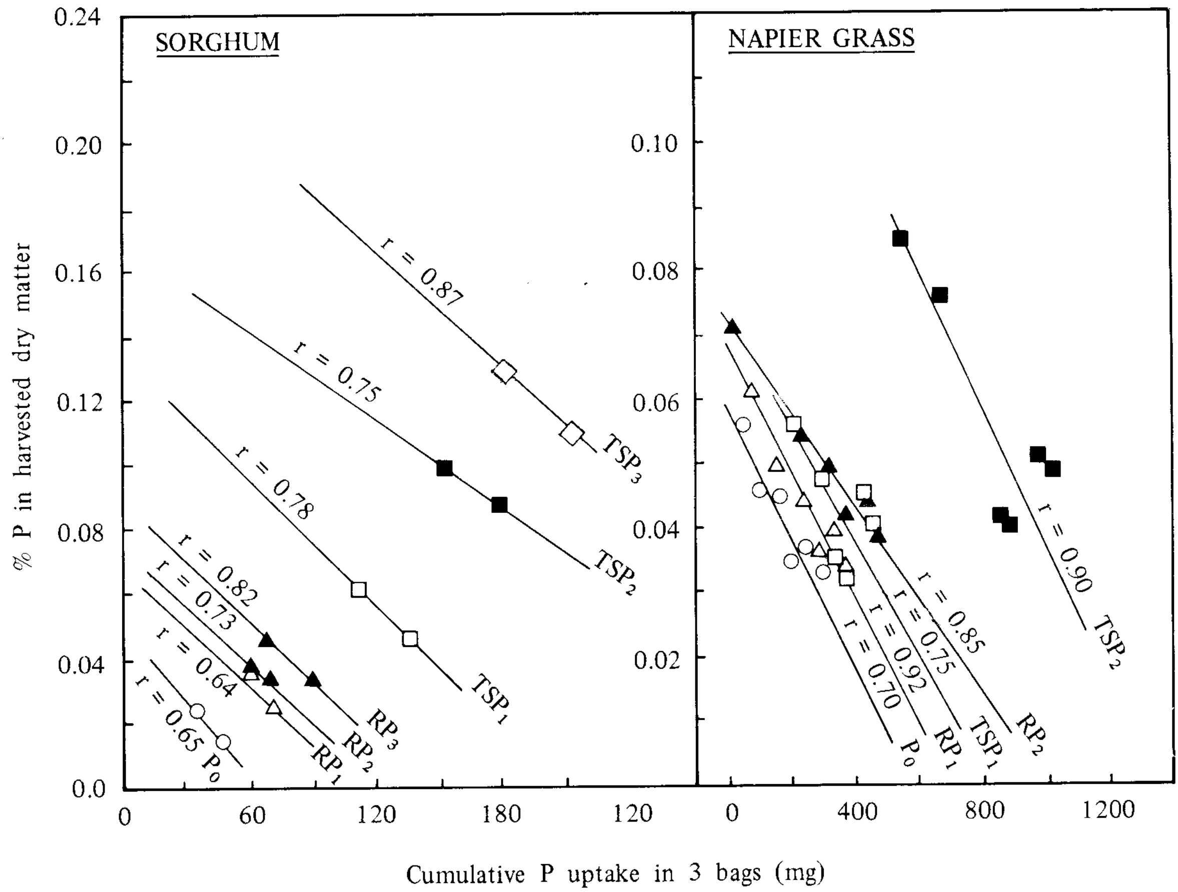
The data on cumulative P uptake *(Table 1)* confirm the above results on the effects of lime, RP and TSP. On unlimed peat, sorghum's cumulative P uptake was negligible while that of napier grass improved P uptake with P application, and more so with TSP than RP. On limed peat, and in both crops, TSP was superior to RP, although increasing rates of both carriers increased cumulative P uptake. (However, recovery of applied P was much lower in RP than TSP in both crops. In sorghum P recovery decreased, while that of napier grass increased with increasing application of either P carrier).

DISCUSSION

Effects of Lime

As in a previous paper (CHEW *et al.*, 1976) the Malaysian peat was found in these experiments to be too acidic (pH 3.3) to support normal crop growth. Without lime, growth of sorghum and napier grass was so poor that no response to applied P was detected, although the concentration of soluble P in peat was increased with P fertilization. Thus liming to pH 4.0 – 4.2 brought about remarkable improvements in crop growth, P uptake and crop response to RP and TSP. This is probably due to (a) increased mineralization of organically bound N, P and other nutrients (CHEW *et al.*, (1976), (b) greater solubility of P in peat *(Figure 2)*, and (c) increased root development and nutrient absorption (JACKSON, 1967). However, liming decreased the concentration of P in the harvested plant materials, probably because of a dilution of absorbed P in the large quantities of plant dry matter produced when lime was applied.

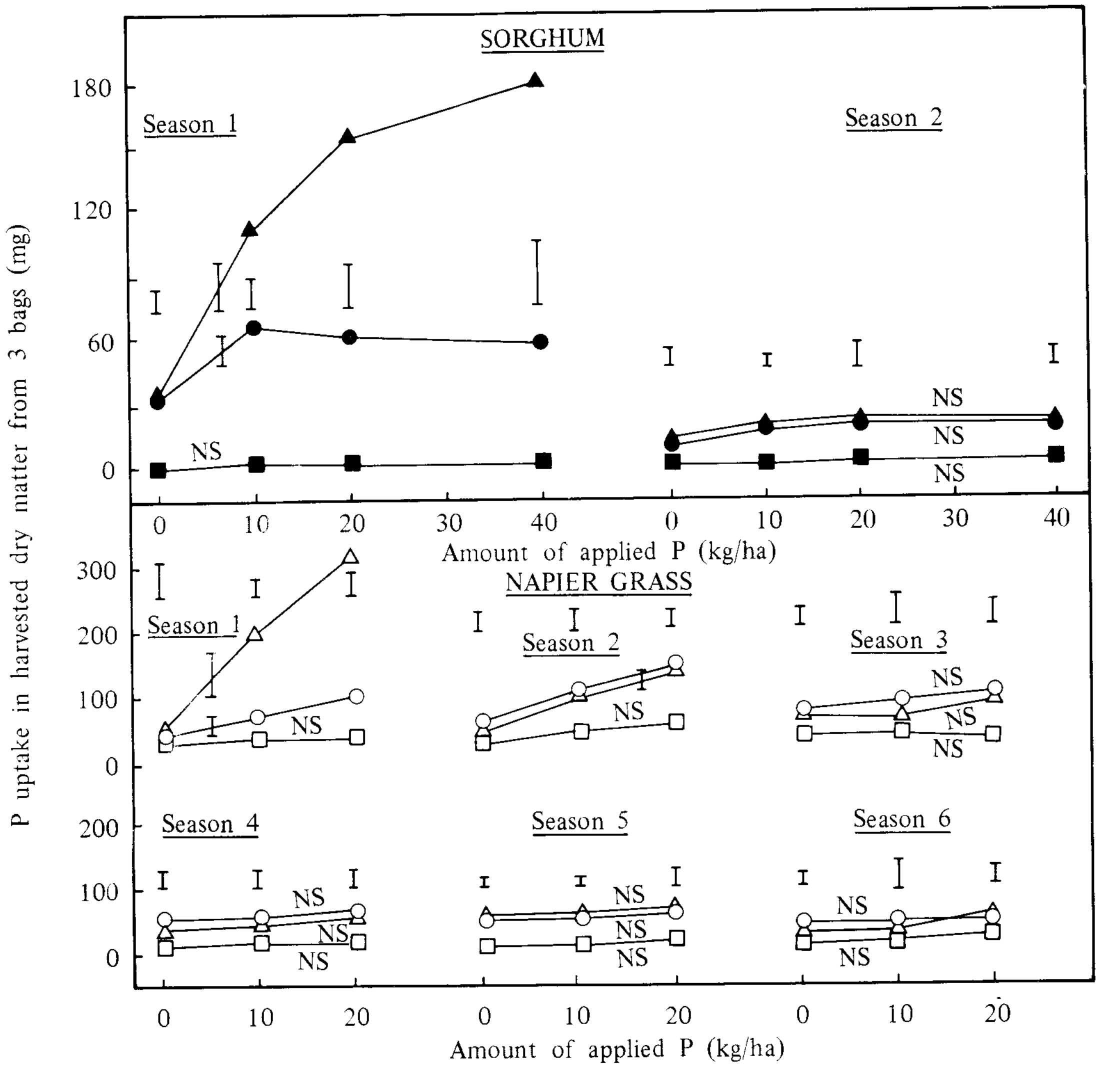
Sorghum's poorer response to applied P, compared with that of napier grass was partly due to the fact that only half of the soil



KEY:

	P (kg/ha)	TSP/RP
○	0	---
△	10	RP
▲	20	RP
▼	40	RP
□	10	TSP
■	20	TSI
◇	40	TSP

Figure 4. Concentration of P in sorghum and napier grass dry matter in relation to P fertilization with RP & TSP on limed peat.



KEY:

	Crop	Lime (t/ha)	RP/TSP
▲	Sorghum	10	TSP
●	Sorghum	10	RP
■	Sorghum	0	Mean of RP & TSP
△	Napier grass	8	TSP
○	Napier grass	8	RP
□	Napier grass	0	Mean of RP & TSP

Figure 5. P uptake of sorghum and napier grass in relation to liming and P fertilization.

TABLE 1: CUMULATIVE PHOSPHORUS UPTAKE BY SORGHUM AND NAPIER GRASS ON PEAT IN RELATION TO LIMING AND FERTILIZATION WITH ROCK AND TRIPLE SUPER–PHOSPHATES (RP & TSP)

Lime (t/ha)	Phosphorus kg/ha P	Phosphorus Carriers	Cumulative P uptake (mg/3 bags)	% recovery of applied P
			Sorghum (2 crops)	
0	0–40	RP	n	n
		TSP	n	n
10	0	–	17	–
	10	RP	105	25.7
		TSP	181	61.7
	20	RP	95	10.3
		TSP	271	52.4
	40	RP	92	4.9
		TSP	315	31.4
	LSD (P = 0.05)		15	1.9
			Napier grass (6 cuts)	
0	0	–	97	–
	10	RP	216	59.0
		TSP	273	87.3
8	0	–	295	–
	10	RP	375	39.7
		TSP	464	83.8
	20	RP	473	44.3
		TSP	661	91.0
	LSD (P = 0.05)		38	3.0

n – Denotes negligible values.

in each bag was limed. Consequently roots concentrated in the upper half of the bag because the lower soil is too acidic. This reduced root volume probably made the sorghum plants more easily susceptible to depletion of water and plant nutrients.

Effects of P Fertilizers

Increasing rates of both RP and TSP applied to limed peat increased dry matter, plant P content, and P uptake, but only in the first 12 weeks of both experiments. This indicates that when peat is limed, applied P is fairly quickly fixed because of the high Ca concentration (LUCAS *et al.*, 1975). This is confirmed by the finding that the superiority of TSP over RP in improving crop dry matter and P uptake was observed *only* in the first harvest of both crops, with subsequent harvests showing no significant difference between the two P carriers. It would appear that for annual crops similar to sorghum and napier grown on limed peat, P should be applied as TSP rather than as RP at the time of greatest crop need for even season in order to maximise its benefits. In contrast, TAY (1972) found no difference between single basal applications of RP and TSP to pineapple on acid peat. But in his experiments, no lime was applied and consequently no lime-induced P fixation occurred, since peat is extremely poor in Ca, Fe, Mn and Al.

CONCLUSION

Since sorghum remained stunted and yellow, and napier grass produced poor growth on unlimed peat (pH 3.3 in water), liming is evidently essential to increase their productivity. However, liming reduces the solubility of peat soil P and also applied soluble P, resulting in TSP not maintaining its superiority over RP as a source of fertilizer P after the first cropping of either sorghum or napier grass. Since P was applied only at the start of our experiments, without further addition subsequently, it is concluded that to optimize productivity, TSP rather than RP should be applied at optimum rates in each and every season.

SUMMARY

Two greenhouse experiments studied the effects of liming and P fertilization on sorghum and napier grass on acid peat. Liming increased soil soluble P, crop dry matter and P uptake, sorghum being more sensitive to peat acidity than napier grass. Both crops responded to applied P only with liming. On limed peat, napier grass was more responsive to applied P than sorghum producing optimum dry matter at 20 kg/ha P compared to 10 kg for sorghum. In both crops, Triple superphosphate gave greater growth, plant P content and P uptake than rock phosphate. Increasing rates of either P carrier increased plant dry matter, plant P content and P uptake but positive responses to increasing rates of P and to P carriers were observed only in the first sorghum and first two napier grass harvests, and not subsequently. The % recovery of applied P decreased in sorghum, but increased in napier grass, as P was increased.

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