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RESEARCH ARTICLE

Evaluation of Phosphorus Availability in a Lateritic Gravelly, Coconut Grown and Long Term Phosphate Fertilizer Applied Soil in Sri Lanka with an Indicator Plant

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ABSTRACT

The residual phosphorus availability and response of Ginger (*Zinigiber officinale*) to residual available phosphorus in (lateritic gravelly) Red Yellow Podzolic soil (RYP - Rhodustults) of *Andigama* soil series from Rathmalagara estate, Madampe was evaluated after 10 years of continuous application of 03 sources of phosphates to young coconut palms. A pot experiment was established using Andigama soil series which was collected from field experimental site where coconut palms were treated with 03 levels of phosphate with 03 different phosphate sources i.e., Eppawela Rock Phosphate (ERP, 30 % P_2O_5), Imported Rock Phosphate (IRP, 27.5% P_2O_5) and Triple Super Phosphate (TSP, 46 % P_2O_5) from the seedling stage up to the age of 10 years. The initial rates of phosphate applications were P_2O_5 equivalent of 50, 100 and 200 g palm^{-1}year^{-1} respectively which were annually increased by 5, 10 and 20 g respectively. Ginger was used as an indicator plant as the growth parameters, yield and the total P content in the ginger can be taken as an indication of the response to different treatments. Ginger rhizomes were planted in pots filled with 5 kg of phosphate treated soil and all the plants were treated with a basal dose of nitrogen (N) and potassium (K) at every 1 ½ month intervals for 6 months. Number of tillers per bush, height of the plants and number of leaves in bush in each pot were recorded. Six months after planting, ginger plants were uprooted and fresh and dry weight of shoots of the plants, roots and rhizomes were recorded. All the plant parts were analysed for total P. Soil samples were collected before planting the ginger and analyzed for available P by 2.5 % acetic acid method, Olsen's bicarbonate and Bray and Kurtz 1 method.

The overall result showed that the extractable P in soil treated with all 03 levels of ERP, IRP and TSP by 2.5 % HAc-P, Olsen – P and Bray – P values were above the sufficiency soil P values of 7.8 mg kg^{-1}, 8.5 mg kg^{-1} and 5.8 mg kg^{-1} respectively. The highest level of TSP, IRP and ERP treatments were significantly effective in increasing the dry weight of rhizomes and the shoots of ginger. It indicated that residual phosphorus availability of TSP, IRP and ERP was high and its effectiveness on response to ginger was more or less similar. This might be due to low dissolution of ERP and fixation of TSP in lateritic gravel soil. According to the findings of this experiment, P fertilizers can be taken out from the coconut fertilizer recommendation for a period of time by monitoring the effectiveness of the residual P status in soil and coconut leaf. Findings of this experiment can be included into site specific fertilizer recommendation programmes of the other perennial crops. By monitoring the availability of P in soil, intercrops can be grown in coconut plantations without application of P fertilizers.

Key words : Phosphate sources, residual phosphorus availability, critical soil P, response, Red Yellow Podzolic

INTRODUCTION

In Sri Lanka, Eppawela Rock Phosphate (ERP) is used as a direct application fertilizer for tea, rubber and coconut grown on acid soils (Appleton, 1994). It is used for other crops too in varying proportions together with Imported Rock Phosphates (IRP). Phosphorus in rock phosphates is available to plants grown on acidic soils, more than on neutral and alkaline soils. Rock phosphates are often recommended for slow growing crops such as tea, rubber and coconut on neutral and acidic soils (Amarasinghe and Wijewardana, 1989). The Coconut Research Institute has recommended 100% of the phosphorus requirement of adult coconut palms in Wet and Intermediate zone be supplied with ERP. The comparison of the effect of ERP with that of IRP and Triple Super Phosphates (TSP) on performance of young coconut palms showed no significant difference in leaf P concentration of the palms among treatments at the 10th year of the experiment. It implies that ERP can be equally good as IRP for young coconut palms. Rock phosphates may provide a higher residual effectiveness than super phosphate which may be of advantage for some management regimes (Khasawneh and Doll, 1978). However, long term residual effect of North Carolina and Queensland rock phosphates compared with TSP showed that rock phosphates are unlikely to be economic alternatives to super phosphate in the short or long term on most lateritic soils in South-Western Australia (Bolland and Gilkes, 1995). The objective of the present study was to evaluate the residual P availability and plant response to residual phosphorus in *Andigama* series soil after 10 years of continuous application of ERP, IRP and TSP.

MATERIALS AND METHODS

Andigama series soils used in this study was Red Yellow Podzolic soils (RYP-Rhodustults) dominant in interior part of the country (mantled plain), well drain, moderately deep lateritic gravelly soil. A pot experiment was established with surface soil (0 – 25 cm) samples collected from a field experiment where coconut palms were treated with 03 levels of phosphate with 03 different phosphate sources namely ERP (28.5 % P_2O_5), IRP (27.5% P_2O_5) and TSP (46% P_2O_5) from the seedling stage up to the age of 10 years. The initial rates of applications were P_2O_5 equivalent of 50, 100 and 200 g palm^{-1} year^{-1} respectively which were annually increased by 5, 10 and 20 g respectively. The sources of P and the levels of treatments applied in the 10th year are given in (Table 1).

Cumulative weights of phosphate fertilizer received by soil through different phosphate sources during 10 years are given in Table 2. Soil samples were collected at 0-25 cm depth from the manure circle compassing 1 m distance from base of the coconut palm of each treated plot. The soils were passed through 6 mm mesh to remove medium and coarse gravel (Davias and Jokiniemi, 2011) at field moist state and 5 kg soil were filled into plastic pots. Calculated amounts of phosphorus fertilizer added to 5 kg soil used for the pot experiment which were considered as treatments are given in the Table 3.

Collected soil samples were analyzed before planting the ginger for available P by 2.5 % acetic acid (Wijebandara, 2004), Olsen's bicarbonate (Olsen *et al.,* 1954) and Bray and Kurtz P -1 method (Bray and Kurtz, 1945). Ginger used as an indicator plant as the growth parameters, yield and the total P content in the ginger can be taken as an indication of the response to different treatments. Ginger rhizomes were planted in pots and all the plants were treated with a basal dose of nitrogen at the rate of 10 g of urea and potassium at the rate of 20 g of muriate of potash at every 1 ½ month intervals for 6 months. Treatment pots were arranged in a Completely Randomized Design with 3 replicates. Six months after planting, ginger plants were uprooted and fresh and dry weight of vegetative parts of the plants, roots and rhizomes were recorded. All the plant parts were analysed for total P through wet digestion with HNO_3 : $HClO_4$ ratio of 1 : 4 followed by colorimetric analysis with UV visible spectrophotometer. Data were analysed statistically using GLM procedure.

RESULTS AND DISCUSSION

As shown in Table 4 the residual available P contents in different treatments extracted by different extractants were significantly higher than the control. The residual available P values were above the critical soil P levels for 2.5 % Acetic acid (7.8 mg kg^{-1}), Olsen's bicarbonate (8.5 mg kg^{-1}) and Bray and Kurtz (5.8 mg kg^{-1}) (Wijebandara, 2004).

It has been noted that significantly different Bray – P, Olsen-P and 2.5 % HAc – P were observed between phosphate sources. The IRP and ERP treatments had significantly higher P values for 2.5 % acetic acid extraction than that of TSP. It is therefore evident that IRP and ERP treated soils contained significantly higher quantities of basic Ca-P fraction (apatite-P) than both TSP treated soil and control. According to Olsen-P and Bray – P values, only TSP treatments showed significantly high values compared to IRP and ERP. It indicated that a considerable amount of soluble Ca-P and Al – P were present in TSP treatment than the other two treatments. Evaluating ERP and TSP with rice, Ratnayake *et al.,* (1994) also reported that the highest Olsen – P values for TSP in RYP soil. Significantly different Bray – P and Olsen – P values between TSP levels and 2.5 % HAc values between both ERP and IRP were also observed.

Table 1: The sources of P and the levels (L) of treatments applied in the 10th year

Treatment	Level of application ($g\ palm^{-1} year^{-1}$)		
	L - 1	L - 2	L – 3
Control	0	0	0
TSP (46% P_2O_5)	326	652	1304
IRP (27.5% P_2O_5)	545	1090	2180
ERP (28.5 % P_2O_5)	500	1000	2000
P_2O_5 equivalent	150	300	600

Table 2: Cumulative weight of phosphate fertilizer received by soil through different phosphate sources during 10 years

Treatment	Cumulative amount of phosphorus fertilizer during 10 years ($g\ kg^{-1}$ soil)		
	L -1	L -2	L -3
Control	0	0	0
TSP	0.38	0.72	1.43
IRP	0.60	1.20	2.39
ERP	0.55	1.10	2.19

Table 3 : Amounts of phosphate fertilizer added to pots representing 03 levels and 03 phosphate sources as treatments

Treatment	Phosphorus fertilizer weight $g\ pot^{-1}$ (5 kg soil)
TSP-L1	1.91
TSP-L2	3.82
TSP-L3	7.64
IRP-L1	3.03
IRP-L2	6.06
IRP-L3	12.12
ERP-L1	2.77
ERP-L2	5.54
ERP-L3	11.08
Control	0

Table 4: Mean available phosphorus contents of the phosphate treated soils at the 10th year

Treatment levels	Available P (mg kg^{-1}) Bray and Kurtz	Olsen's bicarbonate	2.5% Acetic acid
TSP-L$_1$	111 (± 59)	32.9 (± 6)	27.7 (± 13)
TSP-L$_2$	261 (± 141)	126 (± 64)	100 (± 62)
TSP-L$_3$	442 (± 215)	168 (± 2)	139 (±19)
IRP- L$_1$	33.5 (± 10)	15.7 (± 4)	90.5 (± 55)
IRP- L$_2$	65 (± 11)	15.2 (± 4)	151 (± 11)
IRP- L$_3$	83 (± 10)	13.7 (± 3)	458 (± 85)
ERP- L$_1$	28.6 (± 9)	9.4 (± 1)	135 (± 23)
ERP- L$_2$	27.0 (± 5)	11.0 (± 3)	252 (± 97)
ERP- L$_3$	31.8 (± 4)	9.0 (± 1)	438 (8 ± 38
Control	13.0 (± 0.8)	5.6 (± 1)	6.0 (± 0.8)
Sources			
Control vs phosphate source	P<0.05	P<0.01	P<0.001
Between phosphate source	P<0.001	P<0.001	P<0.001
Between TSP levels	P<0.001	P<0.001	ns
Between IRP levels	ns	ns	P<0.001
Between ERP levels	ns	ns	P<0.001
Least Significant Differences (LSD)			
Control vs phosphate source	104.3	25.9	68.8
Between phosphate source	80.8	20.0	53.3
Between TSP levels	139.9	34.7	-
Between IRP levels	-	-	92.3
Between ERP levels	-	-	92.3

(Values in the parenthesis are standard error)

Only the dry weights of rhizomes were reported significantly higher for TSP, IRP and ERP treatments over the control (Table 5). It showed the good response of ginger rhizomes to residual available P of different phosphate sources. However, there were no significant differences in the dry weights of rhizomes, roots and shoots of ginger in response to different phosphate sources. This indicated the similar residual effectiveness of TSP, IRP and ERP on indicator plant response. Similar results were obtained by Arndt and McIntyre, (1963). They showed that initial effectiveness is high in soluble fertilizers and its effectiveness decreases markedly with time and less soluble fertilizers initial effectiveness is lower and the decline is progressive over a long period. Similarly, rock phosphate, though initially less effective than superphosphate, declined their effectiveness more slowly.

The TSP levels had significantly different effects on dry weight of rhizomes, roots and shoots of ginger and IRP levels had significantly different effect only on roots and shoots; but ERP levels have not shown any effect on ginger. The results indicated that residual available P in TSP levels had an effect on all plant parts than IRP and ERP

However, significant increase in the dry weight of shoots with the increased level of TSP and IRP treatments was observed. The TSP – L 3 (15.0 g) recorded significantly higher dry weight of shoots compared to TSP – L1 (5.23 g). The IRP – L3 (14.6 g) observed higher dry weight of shoots compared to IRP –L1 (3.83 g). Similar observations were recorded for the dry weights of roots. The TSP – L3 (2.84 g) recorded a significantly higher dry weight of roots as compared to TSP – L1 (1.12 g) and the IRP – L3 (3.12 g) gave higher dry weight of roots compared to IRP-L1 (1.25 g).

Phosphorus concentrations in rhizomes, roots and shoots of ginger in response to different treatment are shown in Table 6. There was a significant increase in P concentration in rhizomes, roots and shoots of ginger compared to the control. However, there was no significant increase in P concentrations of rhizomes between 03 phosphate sources and with increased phosphate levels of 03 phosphate sources. These results indicated that equal effectiveness of more soluble TSP and less soluble IRP and ERP. Similar results were obtained by Bolland *et al.*, (1988). They showed that the residual values for superphosphate and several rock phosphates in lateritic soil through yields of wheat, oats, barley or clover and found that the effectiveness of an initial application of superphosphate decreased to around 50 % of that of newly applied superphosphate between 1st and 2nd year and a decrease of 20 % over subsequent years. At low levels of application, all the rock phosphates were between 10–20 % as effective as superphosphate in the year of application.

Bolland *et al.*, (1984) measured the residual value for superphosphates and Christmas Island rock phosphate by dry matter production of subterranean clover-based pasture and bicarbonate extractable soil phosphorus. They estimated 3% and 8% as effective as superphosphate for dry matter production in the year of application and a decrease by about 70% between the first and second year after application and a decrease by a further 14% from 3rd year to 4th year.

Table 5: Mean dry weights of rhizomes, roots and shoots of ginger in response to different treatments

Treatment levels	Rhizome (g)	Roots (g)	Shoots (g)
TSP-L$_1$	4.86 (± 2)	1.12 (± 0.48)	5.23 (± 0.70)
TSP-L$_2$	5.17 (± 2)	1.79 (± 1.43)	8.31 (± 6.3)
TSP-L$_3$	9.87 (± 1)	2.84 (± 0.62)	15.0 (± 3.4)
IRP- L$_1$	5.27 (± 2)	1.25 (± 0.21)	3.83 (± 3)
IRP- L$_2$	6.17 (±1)	2.04 (± 0.34)	8.37 (± 0.92)
IRP- L$_3$	9.39 (± 2)	3.12 (± 0.96)	14.6 (± 5)
ERP- L$_1$	4.38 (± 0.81)	1.89 (± 0.95)	7.46 (± 3)
ERP- L$_2$	6.85 (± 0.50)	2.24 (± 0.48)	7.89 (± 2)
ERP- L$_3$	9.05 (± 2)	2.58 (± 0.85)	9.50 (± 4)
Control	3.51 (± 0.16)	2.30 (± 0.33)	3.21 (± 0.10)
Sources			
Control vs phosphate source	P<0.5	ns	ns
Between phosphate source	ns	ns	ns
Between TSP levels	P<0.05	P<0.05	P<0.05
Between IRP levels	ns	P<0.05	P<0.05
Between ERP levels	ns	ns	ns
Least Significant Differences (LSD)			
Control vs. phosphate source	3.1	-	-
Between phosphate source	-	-	-
Between TSP levels	3.4	1.3	6.9
Between IRP levels	-	1.3	6.9
Between ERP levels	-	-	-

(Values in the parenthesis are standard error)

The rock phosphate remained about 2% and 9% as effective as currently applied superphosphate each year. Nagarajah *et al.,* (1979) reported that ERP had very little residual value in rice soils. The significant difference in number of tillers per bush, height of the plants and number of leaves in bush were not observed with increasing levels of TSP, IRP and ERP.

The significant increase in the P concentrations in roots with increasing levels of TSP were observed. However, significant increase in the P concentrations in shoots with increasing levels of TSP and IRP treatment were also observed (Table 6)

Triple super phosphates are more soluble than rock phosphates. But residual effectiveness showed as similar in both TSP and rock phosphates (IRP and ERP). This might be due to decrease of TSP effectiveness with time and the decrease of effectiveness in TSP could be greater than that of rock phosphates. Similar results were obtained by Bolland and Gilkes (1995) as well. They noted that superphosphate was the most effective fertilizer in the year of application, and relative to freshly-applied superphosphate, the effectiveness of the superphosphate residues declined to be about 15 to 65% as effective in the year after application, and 5 to 20% as effective 9 to 10 years after application. Relative to freshly-applied superphosphate, all the rock phosphates were 10 to 30% as effective in the year of application, and the residues remained 2 to 20% as effective in the 10 years after application in lateritic soils in south-western Australia (Bolland and Gilkes (1995). They also found that the bicarbonate soil test reagent predicted a more gradual decrease in effectiveness of superphosphate of up to 70%, 10 years after application.

Total P content in the plant which is an indication of the P uptake by ginger in response to different treatments is given in Table 7. There was a significant increase in P uptake by rhizomes and shoots of ginger among 03 phosphate sources over the control. None of the plant parts showed significantly different P uptake due to different phosphate sources treatments. These results confirmed that equal residual P effect of different phosphate sources on plant response.

Also there was a highly significant increase in P uptake by rhizomes, roots and shoots of ginger between TSP-L3 and both TSP-L1 and TSP-2 levels. The P uptake by roots and shoots of ginger showed a significant increase between IRP-L3 and both IRP-L1 and IRP-L2. The response in terms of P content in roots was not significant between all the phosphate sources and the control. However, significant increase in the P content in roots with the increasing level of TSP and IRP treatment were observed.

The results indicated that dissolution of TSP is higher than rock phosphates and its effectiveness decreased with time. This might be due to the fixation of TSP in lateritic gravel soil.

Table 6: Mean phosphorus concentration in rhizomes, roots and shoots of ginger in response to different treatments

Treatment levels	Rhizomes P%	Roots P%	Shoots P%
TSP-L_1	0.18 (± 0.09)	0.15 (± 0.01)	0.21 (± 0.04)
TSP-L_2	0.25 (± 0.20)	0.25 (± 0.04)	0.26 (± 0.04)
TSP-L_3	0.27 (± 0.03)	0.33 (± 0.06)	0.28 (± 0.05)
IRP- L_1	0.15 (± 0.09)	0.16 (± 0.12)	0.20 (± 0.04)
IRP- L_2	0.02 (±0.03)	0.18 (± 0.08)	0.20 (± 0.02)
IRP- L_3	0.25 (± 0.09)	0.26 (± 0.04)	0.29 (± 0.05)
ERP- L_1	0.19 (± 0.11)	0.16 (± 0.04)	0.21 (± 0.01)
ERP- L_2	0.20 (± 0.03)	0.23 (± 0.08)	0.21 (± 0.02)
ERP- L_3	0.26 (± 0.11)	0.25 (± 0.05)	0.23 (± 0.04)
Control	0.10 (± 0.02)	0.13 (± 0.03)	0.17 (± 0.02)
Sources			
Control vs phosphate	P<0.05	P<0.05	P<0.01
sources	ns	ns	ns
Between phosphate sources	ns	P<0.05	P<0.05
Between TSP levels	ns	ns	P<0.01
Between IRP levels	ns	ns	ns
Between ERP levels			
Least Significant Differences (LSD)			
Control vs phosphate sources			
Between phosphate sources	0.102	0.072	0.43
Between TSP levels	-	-	-
Between IRP levels	-	0.097	0.058
Between ERP levels	-	-	0.058
	-	-	-

(values in the parenthesis are standard error)

Table 7: P uptake by rhizomes, roots and shoots of Ginger in response to different treatments

Treatment levels	**Rhizome ($g\ pot^{-1}$)**	**Roots ($g\ pot^{-1}$)**	**Shoots ($g\ pot^{-1}$)**
TSP-L_1	7 (± 3)	1.66 (± 0.5)	11 (± 3)
TSP-L_2	12 (± 10)	4.80 (± 4.5)	29 (± 3)
TSP-L_3	27 ± 7	9.6 (± 3.2)	43 (± 15)
IRP- L_1	9 (± 9)	2.3 (± 1.5)	12 (± 5)
IRP- L_2	13 (± 4)	3.3 (± 1.1)	17 (± 20
IRP- L_3	22 (± 12)	8.0 (± 1.0)	41 (± 15)
ERP- L_1	9 (± 5)	3.3 (± 2.5)	17 (± 10
ERP- L_2	13 (± 30	5.0 (± 2.1)	21 (± 7)
ERP- L_3	20 (± 10)	6.3 (± 2.1)	28 (± 12)
Control	5 (± 2)	3.0 (± 1.0)	11 (± 1)
Sources			
Cont. vs phosphate source	P<0.05	ns	P<0.05
Between phosphate source	ns	ns	ns
Between TSP levels	P<0.01	P<0.001	P<0.001
Between IRP levels	ns	P<0.01	P<0.001
Between ERP levels	ns	ns	ns
Least Significant Differences (LSD)			
Cont. vs phosphate source	8.7	-	10.6
Between phosphate source	-	3.6	-
Between TSP levels	11.7	3.6	14.2
Between IRP levels	-	-	14.2
Between ERP levels	-	-	-

(values in the parenthesis are standard error)

CONCLUSIONS

The overall result showed that the soil treated with all three levels of different phosphate sources showed that extractable 2.5 % HAc-P, Olsen-P and Bray-P values were above the sufficiency soil P values of 7.8 mg kg^{-1}, 8.5 mg kg^{-1} and 5.8 mg kg^{-1} respectively. The highest level (L3) of TSP, IRP and ERP treatments were significantly effective in increasing the dry weight of rhizome and the shoots of ginger. It indicated that residual phosphorus availability of TSP, IRP and ERP was high and its effectiveness on response to ginger was more or less equal. This might be due to low dissolution of ERP and higher fixation of TSP in lateritic gravel soil.

According to the findings of this experiment, P fertilizers can be taken out from the coconut fertilizer recommendation for a period of time by monitoring the effectiveness of the residual P status in soil and coconut leaf. Findings of this experiment can be included into site specific fertilizer recommendation programmes of the other perennial crops. By monitoring the availability of P in soil, intercrops can be grown in coconut plantations without application of P fertilizers.

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