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Research Article

Effects of different phosphorus sources and application rates on soils residual N and P in the rice field

Abstract

Phosphorus deficiency limits productivity of rice (Oryza sativa L.) in Tanzania. Two field experiments were conducted to determine the effects of different P sources and application rates on residuals' N and P contents in soils of irrigated rice production at Lakitatu village, Meru district, Arusha region, Tanzania. A Randomized Complete Block Design (RCBD) with three replications was adopted. Phosphorus was applied at the rates of 0, 20,40 and 60 kg P ha-1 as Minjingu Phosphate Rock (MPR), Minjingu mazao and Triple Super Phosphate (TSP). Nitrogen was applied uniformly at a rate of 60 kg N ha-1 as urea to the MPR, Minjingu mazao and TSP treatments plots taking into account the 10% N contained in the Minjingu mazao fertilizer. The P fertilizers and application rates had significant ($P<0.05$) effects on residual soils' N as well as P as the levels of P increased from 0 to 60 kg P ha-1 for all P sources. The N depletion in the soils increased significantly ($P<0.05$) with increasing rates of P application. Changes in total soil N after harvest suggested that the rice crop remove significant amount of N due to P application that improves roots elongation and architecture and therefore P fertilization improved uptake of N while contributing P residues depending to the sources and application rates used.

Keywords: Phosphorus residues, nutrients uptake, application rates, rice, nutrients depletion

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Introduction

Soils in semi arid and arid regions are often rather high in available phosphate in contrast to soils in the humid regions. However, with intensive cropping, the level of available phosphorus in soils drops and thereafter gradual reduced response to phosphate fertilizer would be expected.[1] Rice crop recovery of fertilizer N at harvest can be as low as 20 to 40% of applied N.[2] The recovery of applied phosphorus by the crop following phosphate application ranges from 5% to 20% hence 80% to 95% of the annual phosphate applications accumulate in the soil.[1] The low soil P recovery was due to P retentions, fixations and precipitations by soil clays, Al, Fe and Ca in the soils.[3] A residual effect of any fertilizer like phosphate fertilizer occurs when the fertilizer applied to one crop benefits the growth of a succeeding crop. The most precise way of assessing the residual effect of any fertilizer is to measure the rate at which the labile pool of nutrient in the fertilizer applied to soil decline after the addition of the fertilizer and by calculating the half life for the decay of the fertilizer value to the crop.[1] The residual effect of any of the fertilizer would depend on the amount of the fertilizer applied, the solubility of the fertilizer, mobility of the nutrients contained in the fertilizer in the soil and the rate or extent of retention of the fertilizer by the soil, the moisture status of the soil and the ion exchange capacity of the soil.[1] For example, the major residual phosphate compound in calcareous soils is octa calcium phosphate, which is highly insoluble hence the phosphate is immobilized, consequently unavailable to plants.

But with time, the octa calcium phosphate might be reverted to PR because it dissolves slowly as determined by the P-equilibrium in soils.[3] It has been shown that with annual application of phosphate fertilizers, reserve of available phosphate accumulate in soils to the extent that yield response to fresh applications might not be obtained.[1] Insoluble phosphate fertilizers in contrast to soluble fertilizers, require time to reach peak effectiveness as well as having a half life for immobilization.[1] In soils where the residual effects have built up, phosphate fertilizers should be applied in doses needed for maintaining adequate available phosphorus commonly refers to as maintenance application. Transformations of applied phosphorus to unavailable residual soil P is the major cause of limited P supply in most of the P-deficient soils. Although there have been a lot of attempts to apply and increase the P contents in the soils through fertilizers, very few studies highlight the effects of residues of N and P that would have reduced the recommended rates in the next season. Therefore there is a need to examine the residue effects of different P fertilizers on the rice production in northern Tanzania so as to develop appropriate recommendation by considering the initial balance after frequently applications.

Materials and methods

Initial soils were sampled from 0-30 cm depth (most of the rice plants roots concentrate in the 0-20 depth deep but significant numbers of roots extend to 30 cm hence the choice of 0-30 cm). About 500g of the composite soil samples were air dried ground to pass through a 2 mm sieve and analysed for total nitrogen (TN) and available phosphorous (P). Total nitrogen was determined by the Kjeldah method as described by Okalebo *et al.*[4] Available phosphorus was determined by the Olsen method in accordance with the procedure described by Juo.[5] The experimental treatments involved Randomized Complete Block Design (RCBD) with three replications. Prior to transplanting rice seedlings into the experimental plots, triple superphosphate (TSP), Minjingu phosphate rock (MPR) and Minjingu mazao fertilizers were applied to each treatment plots at four levels (Table 1). Nitrogen as urea was applied uniformly except for the control plots (Table 1) taking into account 10%N contained in Minjingu mazao for each level of P. Also soil samples were collected from each treatment plot after harvest for determination of residual N and P in the soils following the procedures described above. Then the increased in soils N and P below and above the initial after harvest were noted as residues or balances after crop uptake.

Table 1 Rates of the different P treatments applied to the experimental plots

MM-Urea	MPR- Urea	TSP-Urea
P_0N_0	P_0N_0	P_0N_0
$P_{20}N_{60}$	$P2_0N_{60}$	$P_{20}N_{60}$
$P_{40}N_{60}$	$P4_0N_{60}$	$P_{40}N_{60}$
$P6_0N_{60}$	$P_{60}N_{60}$	$P_{60}N_{60}$

The subscript numbers indicate the rates of the different treatments that were applied in kg ha-1.
Where: MM, Minjingu mazao; MPR, Minjingu phosphate rock; TSP, Triple supper phosphate

Statistical analysis of the data

The soil analytical data were subjected to Analysis of Variance (ANOVA) using the Gen Stat computer package. Treatments mean separation test was done using the Tukey's Test at 5% level of significance. The basic assumption in the ANOVA was that each observations (Yij) was constituted of the mean, treatment effect, block effect and random error. Thus the statistical model used was:

$$Y_{ij} = U + Ti + Bj + Eij............ (iv)$$

Where;

U = Overall mean of the experiment

Ti = The effect of ith treatments among the treatments

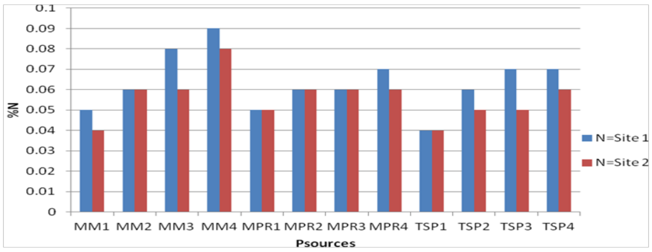
Bj = Block effect for the blocks j

Eij = Random error effect for each observations in the ith treatment and jth block

Soil parameters rating was done according to Landon.[6]

Effects of P sources and application rates on residual N in the soils

The residual total nitrogen contents in soils after harvest ranged from 0.05 to 0.07%, 0.04 to 0.07% and 0.05 to 0.09% for MPR, TSP and Minjingu mazao when applied at the rates of 0 and 60 kg P ha^{-1}, respectively at site 1 (Figure 1 & Table 3). At site 2, the residual total nitrogen contents after harvest ranged from 0.04 to 0.06%, 0.05 to 0.06% and 0.04 to 0.08% for MPR, TSP and Minjingu mazao when applied at the rates of 0 and 60 kg P ha^{-1}, respectively (Figure 1 & Table 3). These residual total N contents after harvest are very low and are comparable to initial soil total N at the trial sites (Table 2), where the %N contents in the soils was 0.08%. Phosphorus applications increased the removal of nitrogen in all sites because phosphorus is responsible for root development, hence application of P increased root growth which facilitated increased uptake of N and other nutrients by the rice plants although some amount of N might have been lost through leaching and volatilization due to frequent addition into and removal of water from the experimental plots. Therefore, the three P sources and application rates had significant ($P<0.05$) effects on N depletion in soils at both sites. This demonstrated that the residual N depended on the efficient use of P nutrient and type and source of fertilizer used.



Note: P sources ending with 1, 2, 3 and 4 indicates 0, 20, 40 and 60 kg P ha-1 respectively

Figure 1 Effects of P sources and application rates on residual total N in soils after harvest.

Table 2 The initial soil P and N of the experimental sites

Soil Parameters	Site 1	Site 2	Mean	Rating1
pH (water)	7.4	7.4	7.4	Mild alkaline
Extractable P (Olsen, mg kg-^{1})	9.1	11.2	10.15	Medium
Total nitrogen (%)	0.07	0.08	0.08	Low

Table 3 Effect of P sources and application rates on the residual N in the soils

Rate of P (kg P ha^{-1})	P source	mgPkg-^{1} (Site 1)	mgPkg-^{1} (Site 2)
0	MPR1	9.2a	10.8b
	MM1	8.9b	11.1a
	TSP1	8.6c	10.2c
20	MPR2	28.4a	27.6a
	MM2	20.6b	22.3c
	TSP2	27.5a	28.4b
40	MPR3	38.7a	37.9a
	MM3	27.1c	26.7c
	TSP3	33.8b	31.5b
60	MPR4	44.7a	42.5a
	MM4	32.3c	29.1c
	TSP4	34.9b	35.2b

Effects of P sources and application rates on residual P in the soils

The residual phosphorus in soils after harvest ranged from 9.3 to 44.7, 8.6 to 34.9 and 8.6 to 32.3 mg P kg^{-1} for MPR, TSP and Minjingu mazao when applied at the rates of 0 and 60 kg P ha^{-1}, respectively in site 1 (Figure. 2 & Table 4). At site 2, the residual phosphorus after harvest ranged from 10.8 to 42.5, 10.2 to 35.2 and 11.1 to 29.1 mg P kg^{-1} for MPR, TSP and Minjingu mazao when applied at the rates of 0 and 60 kg P ha^{-1}, respectively (Figure 2 & Table 4). The P sources and application rates had positive effects on the residual phosphorus in both sites. MPR had the highest residual phosphorus in soils at all rates in both sites while Minjingu mazao and TSP had similar residual

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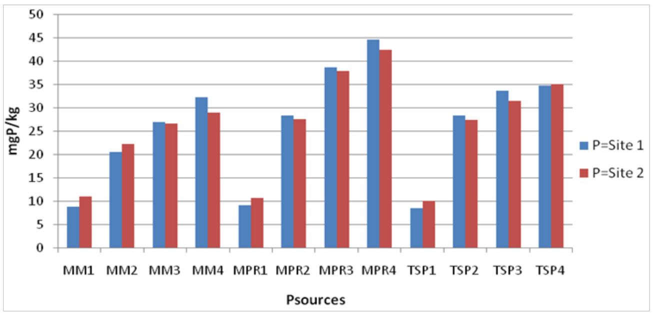
phosphorus at all rates for both sites (Figure 2 & Table 4). For both sites the application of different P sources reduced the soils' P depletion. A slightly lower residual P was observed for Minjingu mazao and TSP treatment plots because they released P rapidly to readily available form for rice plants uptake compared to MPR which released P slowly with time. However, the effect of Minjingu Mazao in terms of grain yields was higher compared to MPR and TSP hence the application of P is necessary for rice grain yield increase (data not shown). The results of this study have shown that the use of 20, 40 and 60 kg P ha-^{1} (MPR) maintained a higher positive residual P in the soils compared to Minjingu mazao and TSP. Several studies have reported P residual effects associated with the use of PR's in agriculture production.[7–9] Sometimes PR provides higher residual effects than TSP as observed with MPR by Okalebo et al.[10–11] In another experiment where MPR was evaluated for residual effects, MPR was superior to TSP in increasing grain yields.[9] The residual P after harvest increased with increasing P rates from all P sources compared to the initial value of 9.1 and 11.2 mg P kg-^{1} (Table 2) in the soils for site 1 and 2, respectively before the establishment of trials. Crop production can benefit from the residual P accumulated due to previous P fertilizer application. Further, P uptake can increase even with a reduction in P application rates.[3] Therefore, the residues of MPR, TSP and Minjingu mazao that accumulate in soils several years after their application could serve as effective sources of P which ultimately move toward a better overall balance that minimizes the application of excess P nutrient.



Note: P sources ending with 1, 2, 3 and 4 indicates 0, 20, 40 and 60 kg P ha-1 respectively

Figure 2 Effects of P sources and rates on residual P in soils after harvest.

Table 4 Effect of P sources and application rates on the residual P in the soils

Rate of P (kg P ha-^{1})	P source	mgPkg-^{1} (Site 1)	mgPkg-^{1} (Site 2)
0	MPR1	9.2a	10.8b
	MM1	8.9b	11.1a
	TSP1	8.6c	10.2c
20	MPR2	28.4a	27.6a
	MM2	20.6b	22.3c
	TSP2	27.5a	28.4b
40	MPR3	38.7a	37.9a
	MM3	27.1c	26.7c
	TSP3	33.8b	31.5b
60	MPR4	44.7a	42.5a
	MM4	32.3c	29.1c
	TSP4	34.9b	35.2b

Conclusion

The low total N of initial soil and after harvest is an indication that P fertilizers increase the uptake of N by the rice crop and hence N depletion from the soil. The application of the three P sources at different rates showed that, the MPR had the highest residual P in soils than TSP and Minjingu mazao at all P rates. Therefore, among the three different P sources applied, a rate of 60 kg P ha^{-1} should be adopted in Lekitatu village with frequent reviews so as to take care of soil P depletion with time as well as the build-up of residual P in the soils.

Acknowledgment

None.

Conflict of interest

None.

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