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RESIDUAL EFFECT AND LEVEL OF PHOSPHORUS DECLINE UNDER CEREAL BASED CROPPING SYSTEM

Obaid-ur-Rehman[1], A.M. Ranjha[2], S.M. Mehdi[3], Bashir Ahmad[1], Sher Afzal[1] and A. Hannan[4]
[1]Soil and Water Testing Laboratory, Attock, [2]University of Agriculture, Faisalabad
[3]Soil Salinity Research Institute, Pindi Bhattian
[4]Directorate of Land Reclamation, Sargodha, Irrigation and Power Department

Phosphorus (P) nutrition of the cropping system with rice crop is very important due to alternate wetting and drying cycles. A field experiment was conducted on Bhalike soil series (Typic Camborthid) to observe the residual effect of P on the succeeding crops and the level of P depletion after one crop rotation (Wheat- Sorghum Fodder-Rice). Rice was raised on the residual P. The highest significant yield of paddy (3.41 Mg ha^{-1}) and straw (3.53 Mg ha^{-1}) was found where residual P was 10.95 mg kg^{-1}. Maximum P concentration (0.15 %) in paddy was found at residual P level of 10.85 mg kg^{-1} while in straw it was maximum (0.12 %) where residual P was 9.75 mg kg^{-1}. Similarly, P uptake was significantly higher in paddy (5.33 kg ha^{-1}), straw (4.25 kg ha^{-1}) and Paddy straw (9.58 kg ha^{-1}) at residual P level of 10.95 mg kg^{-1}. Level of P depletion at the end of three crops was found at 0.004 mg kg^{-1} per annum where P was applied at 37.12 mg kg^{-1} soil and this depletion enhanced where no NPK was applied and deteriorated further where only NK was applied without P. However at the higher rates of P application, no depletion was observed.
Keywords: Rice, phosphorus, residual effect, P decline level, Pakistan

INTRODUCTION

Evaluation of the residual effect of fertilizer P has been the subject of numerous studies as the residual P is expected to build in the soil when the removal of P by the crops is lower than the applied P. Karamanos *et al.* (2007) reviewed that the recovery of P by crops in the year of fertilizer application was very low and ranged 10 to 30 % depending upon soil, crop and management factors while minor benefits to residual soil P were, so continued fertilize P use was required to achieve optimum yields. The alluvial soils are most vulnerable to P depletion and accentuation of P deficiencies as a result of imbalanced fertilization was observed. Phosphorus reserves of the Punjab soils and response of crops to P are declining over time (Malik *et al*., 1992).

Crop rotation is important for P fertilization, as crops differ in their response to applied P and their utilization of residual P. Pakistan has two principal cropping seasons i.e. kharif (summer) and rabi (winter). Major crop rotations followed are wheat-rice (irrigated), wheat-cotton and wheat–maize. Saleque *et al. (*2006) have reported that current farmer's use of P fertilizer for rice-wheat cropping sequence is inadequate and continuation of these doses would worsen P deficiency. Yadvinder-Singh *et al*. (2000) advocated application of 32 kg P to wheat and 15 kg P ha^{-1} to rice on P deficient (Olsen-P 5 kg ha^{-1}), light textured calcareous soils of northern India. A rice crop depletes about 7-8 kg ha^{-1} when P fertilizer was not used, while an application of about 20 kg ha^{-1} may cause an accretion of about 4-5 kg ha^{-1} (Dobermann *et al*., 1996). Kolar and Grewal (1989) worked on sandy loam soil in rice wheat cropping system and applied 13 kg P ha^{-1} to each crop individually to first crop and observed its residual effect on subsequent crop which was significantly inferior to its direct application and phosphorus status declined from 15.4 to 6.4 kg P ha^{-1} in the absence of P application.

The present study was planned to monitor the residual effect of P on rice yield in an alluvial clay loam soil.

MATERIALS AND METHODS

The soil of the experimental area was clay loam (Typic Camborthid) with 33 % clay, alkaline in reaction (pH_s = 8.20), free from salinity (ECe = 1.22 dS m^{-1}), calcareous in nature ($CaCO_3$ = 7.82 %), low in organic matter (0.76 %), deficient in available P (5.20 mg kg^{-1}) and poor in extractable K (145 mg kg^{-1}). Fertilizer P was applied to wheat crop varying from 40 to 300 kg P_2O_5 ha^{-1}. After wheat, sorghum crop was raised and residual P status was assessed (Table 1). Rice crop was transplanted in the same field to see the residual effect of P after harvesting sorghum. At maturity, paddy and straw yields were recorded and their respective samples were collected, oven dried and grinded for plant analysis. Soil samples were also taken at harvest for Olsen P determinations. All the chemical characteristics of the soil were determined based on the methods described by Bigham (1996) while P determination was made according to Murphy and Riley method (1962).

Statistical analysis

Analysis of variance (ANOVA) technique was used and Duncan's multiple range test (DMR) was applied to see the significance of difference among treatment means (Duncan, 1955). Necessary statistical analysis was done using MSTATC software.

RESULTS AND DISCUSSIONS

Residual P after sorghum

A maximum value of 10.95 mg kg^{-1} (see Table 1) was observed in T_{14}. Native Olsen P further dropped to 4.70 mg kg^{-1} where no NK was applied and 4.60 mg kg^{-1} where NK was applied. So imbalanced application of fertilizers caused a great reduction in native P pool of soil. Similar results were reported by Zhou *et al*. (2001). Crops seldom absorb more and often less than 20 % of fertilize P during the first cropping season after application (Tandon, 1987). P fertilizers can have long lasting residual effects on succeeding crops and due to accumulated residues, the level of soil P gradually rises contributing more to P pool available to growing plants (Harapiak and Beaton, 1986). As the sorghum fodder was raised on the residual P applied to previous wheat crop, so a marked reduction in Olsen P was observed (Table 3) and the values dropped to almost half after sorghum harvest. But still there was sufficient available P for raising another crop after sorghum.

Table 1. Rice paddy and straw yield (Mg ha^{-1})

Treatments	Residual P after sorghum	Paddy Yield	Straw Yield
	mg kg^{-1}	Mg ha^{-1}	Mg ha^{-1}
T1	4.70K	1.34 L	1.46L
T2	4.60K	1.36L	1.49L
T3	5.00J	1.38L	1.50L
T4	5.45I	1.47K	1.60K
T5	6.20H	1.57J	1.69J
T6	6.75G	1.65I	1.78I
T7	7.50F	1.81H	1.93H
T8	7.70F	1.91G	2.06G
T9	8.25E	2.13F	2.22F
T10	8.70D	2.34E	2.46E
T11	9.30C	2.49D	2.62D
T12	9.75B	2.78C	2.92C
T13	10.85A	2.95B	3.11B
T14	10.95A	3.41A	3.53A
LSD	**0.2545**	**0.7506**	**0.7506**

Means sharing same letters are statistically at par at 5% level of probability.

Rice paddy and straw yield (Mg ha^{-1})

Rice was grown on the residual P after sorghum. Paddy yield, depicted in Table 1, revealed that there was a progressive increase in the paddy yield with all the treatments. Maximum paddy yield of 3.41 Mg ha^{-1} was obtained with T_{14} (residual P 10.95 mg kg^{-1}), which was significantly higher than all the lower treatments. This might be due to the reason that no fresh P fertilizer was applied and it was the second crop on the residual P. Minimum yield of 1.34 Mg ha^{-1} was recorded in control plots but statistically at par with T_2 and T_3. Saeed *et al.* (1992) and Sahrawat *et al*. (2001) also obtained similar results.

Data regarding the rice straw yield given in Table 1 showed a similar trend as was observed in the paddy yield. Maximum straw yield of 3.536 Mg ha^{-1} was recorded with T_{14} (residual P 10.95 mg kg^{-1}) like paddy. However, the minimum yield of 1.46 Mg ha^{-1} was seen in the control plots where no NPK was applied. The reason might be due to less tillering and poor crop stand in the control plots. Reddy *et al*. (1994) found similar results on rice straw.

P concentration (%) in rice paddy and straw

Data regarding P concentration in paddy (Table 2) exhibited that maximum P concentration 0.15 % was observed with T_{13} (residual P 10.85 mg kg^{-1}) being at par with T_{14}. However, the minimum P concentration of0.08 % was seen in control plots (T_1, T_2) and where minimum P was (T_3 and T_4) applied to wheat. Duivenbooden *et al*. (1996) also reported P concentration in rice paddy between 0.10-0.27 percent. The results regarding P concentration of rice straw are given in Table 2. The data revealed that maximum P concentration (0.12) was observed in T_{12} (residual P 9.75 mg kg^{-1}). There was progressive increase in P concentration of rice straw from T_3 to T_{14}. The reason might be that due to submerged soil conditions, soils maintain solution P level and sufficiency range is attained at lower level in this heavy textured soil. Minimum P concentration (0.05 %) was observed in control plots where the least P rates (T_2 and T_3) were applied to wheat. Duivenbooden *et al*. (1996) also found similar results with respect to P concentration in rice straw.

P uptake (kg ha^{-1}) by rice

P uptake by paddy is product of paddy yield and concentration of phosphorus in paddy. The data regarding P uptake by rice paddy (Table 2) showed that maximum P uptake by paddy (5.33 kg ha^{-1}) was observed with T_{14} (residual P 10.95 mg kg^{-1}) and was significantly higher than T_{13} (residual P 10.85 mg kg^{-1}). The uptake of P by paddy was progressive in the middle order treatments. The P uptake was found minimum (1.03 to 1.23 kg ha^{-1}) and non-significant from T_1 to T_4 where minimum P rates were applied to wheat.

Table 2. P concentration (%) in rice paddy, straw and uptake (kg ha^{-1})

Treatments	P concentration (%)		P uptake (kg ha^{-1})		
	Paddy	Straw	Paddy	Straw	Total
T1	0.08I	0.05H	1.03J	0.68K	1.71L
T2	0.08I	0.05GH	1.04J	0.74JK	1.78KL
T3	0.08I	0.05GH	1.11J	0.80JK	1.91KL
T4	0.08I	0.06GH	1.23J	0.90IJK	2.13K
T5	0.09H	0.06FG	1.47I	1.01IJ	2.48J
T6	0.11G	0.07F	1.76H	1.19I	2.95I
T7	0.11FG	0.08E	2.05G	1.47H	3.53H
T8	0.12EF	0.09D	2.23G	1.78G	4.02G
T9	0.12DE	0.09D	2.63F	2.08F	4.71F
T10	0.13CD	0.10C	2.96E	2.54E	5.50E
T11	0.13C	0.11BC	3.31D	2.88D	6.19D
T12	0.14B	0.12AB	3.99C	3.41C	7.39C
T13	0.15A	0.12A	4.53B	3.83B	8.37B
T14	0.16A	0.12A	5.33A	4.25A	9.58A
LSD	**0.010**	**0.009**	**0.2056**	**0.2808**	**0.3314**

Means sharing same letters are statistically at par at 5% level of probability.

P uptake by rice straw is product of straw yield and concentration of phosphorus in straw. The data regarding P uptake by rice straw is given in Table 2. The data revealed that maximum P uptake by straw (4.25 kg ha^{-1}) was observed at T_{14} (residual P 10.95 mg kg^{-1}) and was significantly higher than T_{13} (residual P 10.85 mg kg^{-1}). The P uptake was found minimum (0.68 kg ha^{-1}) in control plots (without NPK) which were at par with T_2, T_3 and T_4.

The results regarding total P uptake by rice depicted in Table 2 revealed that maximum P uptake by rice crop (9.58 kg ha^{-1}) was observed at T_{14} (residual P 10.95 mg kg^{-1}) which was significantly higher than all the lower treatments. Minimum P uptake (1.71 kg ha^{-1}) was found in control plots without NPK and was at par with T_2 and T_3, respectively.

Residual P after rice

A decrease in Olsen-extractable P was observed after rice harvest (Table 3) but not to that extent as was observed after sorghum fodder. Maximum value observed was 6.15 mg kg^{-1} at T_{14} (residual P 10.95 mg kg^{-1} after sorghum fodder) and it remained at par with the lower treatments (T_{13} to T_{11}). However, after raising

Table 3. Phosphorus depletion level after one-year crop rotation

Solution P (mg L^{-1})	P added (mg kg^{-1})			Total P (mg kg^{-1})	Olsen P – Native P	Net available P	Annual P depletion level
	Wheat	Sorghum	Rice				
Native	0	0	0	0	4.40-5.20	-0.80	-0.154
Native	0	0	0	0	4.30-5.20	-0.90	-0.173
0.01	9.20	0	0	9.20	3.85-5.20	-1.35	-0.147
0.02	13.15	0	0	13.15	3.95-5.20	-1.25	-0.095
0.03	16.20	0	0	16.20	4.10-5.20	-1.10	-0.068
0.04	18.79	0	0	18.79	4.35-5.20	-0.85	-0.045
0.05	21.08	0	0	21.08	4.60-5.20	-0.60	-0.028
0.10	30.12	0	0	30.12	4.80-5.20	-0.40	-0.013
0.15	37.12	0	0	37.12	5.05-5.20	-0.15	-0.004
0.20	43.05	0	0	43.05	5.45-5.20	0.25	0.005
0.25	48.29	0	0	48.29	5.90-5.20	0.70	0.015
0.30	53.04	0	0	53.04	6.00-5.20	0.80	0.015
0.40	61.51	0	0	61.51	6.05-5.20	0.85	0.014
0.50	69.00	0	0	69.00	6.15-5.20	0.95	0.014

two crops on residual P, still there was considerable Olsen-extractable P in the soil which is quite higher than native soil P. Rehman *et al*. (1992) found Olsen P for 88 % relative yield of rice at 10.90 mg kg^{-1}, 95 % relative yield at 15.40 mg kg^{-1} and 99 % relative yield at 23.75 mg kg^{-1}.

Level of phosphorus depletion per annum

Data regarding annual level of P depletion are depicted in Table 3. As regards level of P depletion, maximum level (0.154 mg kg^{-1}) was observed in the plots receiving no NPK fertilizers and was accentuated (0.173 mg kg^{-1}) with plots receiving NK fertilizers without P. With the application of higher P rates, the rate of P depletion was decreased and it was observed up to solution P level of 0.15 mg L^{-1} which was 0.004 mg kg^{-1} and above this level, no net P depletion was observed but P build up was noticed.

CONCLUSIONS

The residual P can support only 2 to 3 succeeding crops. Soils are being mined per annum at 0.154 mg P kg^{-1} if no fertilizers are applied and at 0.173 mg P kg^{-1} if only NK are applied in heavy textured soils. So balanced fertilization is a pre-requisite for harvesting maximum crop yields.

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