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# Phosphorus management in rice (*Oryza sativa*) – wheat (*Triticum aestivum*) cropping system

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## ABSTRACT

The field trials on rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system were conducted during 1996–97 to 2001–2002 at Bihar Agricultural College, Sabour (Bhagalpur), for optimizing dose and frequency of phosphorus application. Rice and wheat responded significantly only up to 60 kg $P_2O_5$/ha. Average of 6 years data revealed that for getting optimum yield of wheat, P application was essential to the crop whereas in rice if the preceding wheat crop was raised with phosphorus, it was not essential to supply phosphorus to the rice crop. Application of P to both the crops every year resulted in the maximum P uptake, which was also higher with increase in P level. The same treatment (P to both the crops) fetched the maximum net return (Rs 28,738/ha) and had the highest benefit : cost ratio (1.36). Application of P only to wheat every year, however, proved to be equally good in realizing higher net return (Rs 26,466/ha). Higher P rates and its repeated application every year resulted in higher P build up in soil.

***Key words :*** Phosphorus management, Cropping system, Sustainability, Economics, Soil fertility

Amongst major nutrients used in crop production, the use efficiency of phosphorus is minimum. Phosphorus is not lost from soil and is known to leave residual effect. Slow mobility of applied P and its marked fixation results in low crop recoveries of the order of 20 to 25% (Singh, 1993). The crop response to P application is not so apparent as in case of nitrogen. This further creates reluctance on the part of farmers in use of recommended doses of P fertilizers. Thus, it is necessary to search out ways and means to develop a P-management system, which can make best use of residual phosphorus in soils thereby increasing P-use efficiency. Hasan (1999) reported that higher P rates and its repeated application every year results in higher P build up in soil. Rice is a crop in which submergence of soil due to pudding helps in greater release of both available and unavailable residual P in soil. Keeping these factors in view, the present investigation was planned to work out the more rational P management system in rice– wheat crop sequence for P economy and sustainability in yield levels.

## MATERIALS AND METHODS

The field trial was conducted for 6 consecutive years 1996–97 to 2001–02 in rice–wheat cropping systems on a fixed site in Bihar Agricultural College Farm, Sabour (Bhagalpur), with 3 levels of $P_2O_5$, viz. 30, 60 and 90 kg/ha, and 6 phases of P application, viz. $P_2O_5$ application to both rice and wheat crops every year, to rice crop only every year, to wheat crop only every year, to rice crop only in alternate years, to wheat crop only in alternate year and $P_2O_5$ application in alternate years to both rice and wheat crops. The experiment was carried out in split-plot design with P levels in main plots and phases of P application in subplots having 4 replications. The experimental soil was clay loam having pH in the netural range (7.3). Initial organic carbon was 0.43% and available P and K were 9.24 and 137 kg/ha respectively. Nitrogen and potash were applied to both the crops as per recommendation. Rice 'Sita' was transplanted by second week of July at a spacing of 15 cm × 15 cm and wheat 'UP 262' sown by last week of November with 20 cm row spacing. Post, harvest soil analysis for available P was done by the Olsen's method and P content was analysed by vanado molybdo phosphoric acid yellow colour method as per Jackson (1973). The energy values were calculated as per the procedures outlined by Mittal *et al.* (1983). Data were pooled.

## RESULTS AND DISCUSSION

### *Effect of phosphorus level*

Both rice and wheat crops responded significantly only up to 60 kg $P_2O_5$/ha. Further increase in dose of $P_2O_5$ did

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not cause significant increase in grain yield of either rice or wheat (Table 1). Based on the mean of 6 years, 60 kg $P_2O_5$/ha resulted in 7.8 and 11.5% higher yield of rice and wheat than that recorded at 30 kg level. The increase in grain yields noted at 90 kg $P_2O_5$/ha over 60 kg $P_2O_5$/ha were only 1.7 and 3.8% respectively.

### *Effect of phosphorus frequency (phases)*

Application of $P_2O_5$ to both the crops every year provided the maximum yield of rice (4,890 kg/ha) and wheat (4,099 kg/ha) (Table 1). Based on means of 6 years study, it could be inferred that in case of rice if the preceding wheat crop was raised with phosphorus, it is not essential to supply phosphorus to rice crop. A rice crop not getting P but receiving P in the preceding wheat crop performed equally good as that of a rice crop getting P in current season. Mishra and Mishra (1992) and Tandon (1987) also reported similar findings. On the other hand, wheat crop deprived off P in current season gave significantly lower yields regardless of the season or year in which they received phosphorus previously.

### *Rice-equivalent yield (REY) and economic analysis*

The maximum REY was obtained with the highest

**Table 1.** Effect of phosphorus doses and phases on grain yield and economics of rice–wheat sequence (mean data of 6 years)

| Treatment | Grain yield (kg/ha) | | Rice-equivalent yield (q/ha) | Net return (Rs/ha) | Benefit : cost ratio |
|---|---|---|---|---|---|
| | Rice | Wheat | | | |
| *P (kg/ha)* | | | | | |
| 30 | 4,211 | 3,244 | 84.69 | 21,377 | 1.07 |
| 60 | 4,569 | 3,668 | 93.83 | 24,622 | 1.16 |
| 90 | 4,649 | 3,808 | 96.47 | 24,629 | 1.10 |
| CD (P=0.05) | 177 | 191 | 4.41 | 2,180 | |
| *Phase* | | | | | |
| To both crops every year | 4,890 | 4,099 | 102.70 | 28,738 | 1.36 |
| To rice every year | 4,702 | 3,258 | 89.78 | 23,948 | 1.20 |
| To wheat every year | 4,538 | 3,793 | 95.16 | 26,466 | 1.32 |
| To rice in alternate years | 4,182 | 3,171 | 83.44 | 21,457 | 1.11 |
| To wheat in alternate years | 4,004 | 3,554 | 86.71 | 22,888 | 1.18 |
| To both crops in alternate years | 4,384 | 3,576 | 90.77 | 24,104 | 1.21 |
| CD (P = 0.05) | 332 | 348 | 6.84 | 3,080 | |

**Table 2.** Effect of phosphorus doses and phases on phosphorus uptake (pooled data) and P status of soil after 6 years of experimentation

| Treatment | Phosphorus uptake (kg/ha) | | | | Total P uptake by sequence (kg/ha) | Available P (kg/ha) |
|---|---|---|---|---|---|---|
| | Rice | | Wheat | | | |
| | Grain | Straw | Grain | Straw | | |
| *P (kg/ha)* | | | | | | |
| 30 | 10.44 | 8.24 | 7.27 | 5.71 | 31.66 | 8.50 |
| 60 | 11.56 | 9.15 | 8.51 | 6.79 | 36.01 | 6.79 |
| 90 | 11.99 | 9.70 | 9.14 | 7.36 | 38.19 | 13.13 |
| CD (P =0.05) | 1.12 | 0.94 | 1.26 | 0.68 | | |
| *Phase* | | | | | | |
| To both crops every year | 12.76 | 10.26 | 9.96 | 7.92 | 40.90 | 13.30 |
| To wheat every year | 12.08 | 9.75 | 7.56 | 6.09 | 35.48 | 12.14 |
| To wheat every year | 11.44 | 9.10 | 9.03 | 7.29 | 36.86 | 11.63 |
| To rice in alternate years | 10.37 | 8.23 | 7.17 | 5.50 | 31.27 | 8.93 |
| To wheat in alternate years | 9.81 | 7.83 | 8.17 | 6.28 | 32.09 | 9.20 |
| To both crops in alternate years | 10.96 | 8.14 | 8.26 | 6.57 | 33.93 | 10.36 |
| CD (P=0.05) | 1.36 | 1.21 | 1.53 | 0.97 | | |

Initial soil test values of available P 9.24 kg/ha

**Table 3.** Effect of phosphorus doses and phases on output : input energy ratio (mean data of 6 years)

| Treatment | Energy input (Mj/ha) | Output (Mj/ha) | | Output : input ratio | |
|---|---|---|---|---|---|
| | | Grain | Straw | Grain | Straw |
| *P (kg/ha)* | | | | | |
| 30 | 37,148 | 109,589 | 124,837 | 2.81 | 3.36 |
| 60 | 37,814 | 121,084 | 137,700 | 3.06 | 3.64 |
| 90 | 34,480 | 124,318 | 140,487 | 3.08 | 3.65 |
| *Phase* | | | | | |
| To both crops every year | 37,814 | 132,138 | 147,437 | 3.33 | 3.90 |
| To rice every year | 37,148 | 117,012 | 133,900 | 3.00 | 3.60 |
| To wheat every year | 37,148 | 122,466 | 139,825 | 3.15 | 3.80 |
| To rice in alternate years | 36,815 | 108,089 | 124,487 | 2.80 | 3.38 |
| To wheat in alternate years | 36,815 | 111,103 | 126,675 | 2.88 | 3.44 |
| To both crops in alternate years | 37,148 | 117,012 | 129,700 | 3.00 | 3.49 |

dose of $P_2O_5$ (90 kg/ha), which however was at par with that realized under the application of 60 kg $P_2O_5$/ha (Table 1). These 2 treatments significantly outyielded 30 kg $P_2O_5$/ha for rice-equivalent yield. The highest REY of 102.70 q/ha was realized with the application of P to both rice and wheat crops every year. However, the treatment involving the application of P only to wheat every year performed equally good as reflected in its statistical parity with the highest yielding treatment. Net return (Rs/ha/year) increased significantly with increasing level of P only up to 60 kg/ha. In case of phases of P application, maximum net return was realized when both the crops were supplied with P every year, which was at par with those getting P in wheat in the current year. The highest benefit : cost ratio (1.16) was obtained with the application of 60 kg $P_2O_5$/ha. As regards P-phasing, it was the maximum (1.36) when both rice and wheat were supplied with P. It was followed closely by P-phasing in which wheat crop received P in each year (1.32).

### *Phosphorus uptake*

The maximum P uptake was associated with the highest dose applied to these crops, i.e. 90 kg $P_2O_5$/ha. The P uptake by rice and wheat noted at 90 kg $P_2O_5$/ha, was to however comparable with that recorded at 60 kg $P_2O_5$/ha, but were significantly superior to those recorded with the application of 30 kg $P_2O_5$/ha.

For phases of P application, the P uptake was recorded to be maximum both in rice and wheat when it was applied to both the crops every year. In case of rice even if P was applied only to rice or only to wheat crop, the P uptake by rice was as good as that recorded for the treatment at the top in this regard. This was not true in case of wheat. For better P uptake it is essential to apply P to wheat crop. Skipping P application in rice but getting P in the current season proved to be equally good as that of the treatment in which both the crops were supplied with P.

### *Residual phosphorus*

Higher P rates along with its repeated applications resulted in higher P build up in the soil. The maximum P build up was found when both rice and wheat crops were adequately supplied with P (90 kg $P_2O_5$/ha) every year. Similar results were reported by Sharma and Mitra (1991) and Hasan (1999). Nambiar (1994) also reported that available soil P at optimal and super optimal (100-150%) NPK doses were raised from low to medium and medium to high status in various Indian soils, over a 16 years period.

### *Energy net return*

The maximum energy output of 124,318 Mj/ha was recorded with the application of 90 kg $P_2O_5$/ha (Table 3). For phases of P, P application to both rice and wheat crops every year recorded the highest energy output 132,138 Mj/ha. The output : input ratio was maximum with the application of 90 kg $P_2O_5$/ha and P application to both rice and wheat crops every year.

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