Research Article

Comparative Scheduling of Phosphorus Application for Enhancing Rice Yield and Efficiency Indices

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Abstract | Field experiments were conducted on farmers field at two locations aimed at exploring the response of phosphorus (P) applied to rice at different growth stages.Phosphorus was applied in three interval i.e. at transplanting (0 DAT), 15 days after transplanting (15 DAT), and 25 days after transplanting (25 DAT), in addition to control (no P), and farmer fertilizer practice (FFP).Results show that mean paddy yield across both sites range from 2.972 to 4.334t ha^{-1}, and maximum with P applied at 15 DAT, and contrarily the lowest with control treatment.Paddy yield increase over control was 37.3%at Sadhoke (location 1) and 40.1% at Mannoabad (location 2).Other growth parameters such as harvest index (HI) range from 37.9% to 41.7%, agronomic efficiency(AE) from 30.3 to 39.5 kg paddy yield increase kg^{-1} P applied and total P uptake (TPU) range from 12to 21.2 kg P ha^{-1}, P harvest index (PHI)ranges from 65% to 70% and Phosphorus Recovery Efficiency (PRE) range from 27% to 30%. On average the achieved paddy yield, HI, AE, TPU, PHI and PRE were statistically higher whereP applied at 15 DAT.On overall, significant differences were found in different parameters between locations.

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Keywords | Phosphorus, Growth stages, Agronomic efficiency, Phosphorus harvest index, Phosphorus recovery efficiency

Introduction

Phosphorus (P) after nitrogen (N) is the major essential plant nutrient for rice production (Panhawar and Othman, 2011; Ahmad et al., 2009) and its deficiency restrict primary productivity in cropping systems (Vance et al., 2003). In Pakistan, 90% soils are P deficient, containing <10 mg kg^{-1} Olsen P (Ahmad and Rashid, 2004; Memon, 2005), primarily suffering from moderate to severe P deficiency due to alkaline calcareous nature of soil (Iqbal et al., 2003; Rehim et al., 2012). The use of P fertilizer less than its requirement further deteriorated the P availability in the soil coupled with widen NP use ratio from 3.62 in 2013-14 to 3.39 in 2014-15 (GOP, 2015-16). Moreover, average P recovery efficiency (PRE) stands to be about 25% (Ahmad and Rashid, 2003). Major portion of applied P (0–90%) is sorbed by soil particles andso renders unavailable especially for P-inefficient plants (Jones, 1998). Such adsorption get firms with passage of time and release in soil solutions, resulting in decline of P fertilize efficiency (Vishandas et al., 2006). The P deficiency is further aggravated due to 60% lesser use of recommended P (Hussain et al., 2008).

Rice (*Oryza sativa.* L)is second major cereal crop after wheat grown on 2.8 mha area, with production capacity of 7 million tons (GOP, 2015-16) and major consumer of fertilizer including phosphate fertilizer

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in Pakistan. Profitability of rice production systems depends on the appropriate fertilizer input that is not only for getting high grain yield but also for attaining maximum profitability (Khuang et al., 2008).

Phosphorus containing fertilizer is an expensive input, determination of its economical, appropriate dose and proper time of application on specific site and specific P fertilizer application to enhance crop productivity is imperative to obtain the maximum profit for the growers (Ali et al., 2005; Khan et al., 2010; Rahim et al., 2010). It has been observed that application of P in flooded rice field ahead of rice transplanting also encourage algae growth that results unfavorable condition for rice stand establishment. In addition, algae also assimilate necessary nutrients needed for plants growth and may reduce oxygen levels (Mariraj, 2012). Phosphorus application to puddled rice at any growth stage is not questionable because of standing water in rice field. Keeping in mind the study was formulated with an objective to evaluate the appropriate time of P application at different crop growth stages of rice along with conventional practice to asses improving paddy yield and P recovery efficiencies in rice.

Materials and Methods

Field experiments were conducted on farmers field at two locations viz Sadokhe (location 1) and Mannoabad (location 2) of rice growing area to evaluate the response to P application at different growth stages. The rice cultivar *superbasmati* was used for the study. Soil of both sites show different soil chemical properties. Soil samples were collected before onset of experiments and analyzed for pH, EC, OM, $CaCO_3$, NO_3-N, P, K and Zn after extraction with a mmonium bicarbonate (AB) DTPA for determination of NO_3-N, K and Zn (Soltanpour, 1985). The soil texture of Mannoabad site was loamy having 22.4% clay, 42.7 %silt and 34.9 %s and and that of Sadhoke site was silt loam having 23.5% clay, 51.4 % silt and 25.1 % sand.The experiment was laid out in randomized complete block design having 5 treatment viz; control (no P), Farmer Practice (FP) P @ 57 kg P_2O_5 ha^{-1} at transplanting time), 0 DAT (70 kg P_2O_5 ha^{-1} at transplanting time), 15 DAT (70 kg P_2O_5 ha^{-1} at 15 days after transplanting), and 25 DAT (70 kg P_2O_5 ha^{-1} at 25 days after transplanting) and three replications. Recommended doses of N as urea, K as KSO_4 and Zn as $ZnSO_4$were applied to avoid their deficiency. The source of P was single super phosphate (SSP) and was applied as per plan @ 70 kg P_2O_5 ha^{-1}. The amount of P fertilizer applied by the FP to rice is on lower side than recommended P. Rice seedlings about 25 days were transplanted to puddled field.

Paddyand rice straw yields were recorded at physiological maturity. Grain moisture was measured after harvest and adjusted to 14±1% moisture contents. Paddy and straw samples were analyzed for P contents after digestion with HNO_3-$HClO_4$ mixed acid mixture (2:1); diluted; filtered and analyzed for P contents. Phosphorus uptake (kg ha^{-1}), P agronomic efficiency (AE) as kg paddy yield kg^{-1} P applied), harvest indexas HI (%), P harvest index as PHI (%), and P recovery efficiency as PRE (%) were calculated following the method described by Dobermann et al. (2004).

All means were statistical analysis usingstatistic 8.1 and comparisons between treatments and locations mean were made at 5% least significant difference (LSD) values.

Results and Discussion

Agronomic parameters

Paddy and straw yield: Results show that Paddy yield at both locations range from 2.972 to 4.334 t ha^{-1} whenP was applied at different crop growth stages (Figure 1). The mean maximum paddy yield at both locations stands to be 4.249 t ha^{-1} with P fertilizer applied at 15 DAT against 3.046 t ha^{-1}as minimum with control showing an increase of 39% crop. Earlier research also confirm that paddy yields highly significantly increased vis a vis P fertilizer over control (Panhawar and Othman, 2011; Yosef, 2012). While comparing P fertilizer application at different days, on over-all, yields with P application at 15 DAT were greater in all treatments and either locations. Late application of P fertilizer applicationsas much asat panicle differentiation stage ascribed to reduced yields a compare earlier applications (Slaton et al., 1998). Our results show that average paddy yield across all treatments range from 3.157 to 4.334 t ha^{-1} and from 2.972 to 4.164t ha^{-1} at Mannoabad and Sadhoke respectively. While comparing Paddy yield at either locations, yield at Mannoabad site was significantly greater than the paddy yield at Sadhoke (Figure 1). Though differences in straw yield were non-significant among P applied treatments, highest rice straw yield was also obtained with the application of P at 15 DAT. On overall P fertilizer application in all treatments produced significantly higher rice straw yield than control treatments. Differences in paddy yields between locations could be ascribed to variation in native P content which was slightly more in location 2. Application of P at 0 DAT, 15 DAT and 25 DAT produced significantly higher paddy yields compared to control and FFP treatment. The lower paddy yield in FFP make sense as farmers in this region is usually applying less than recommended P dose.

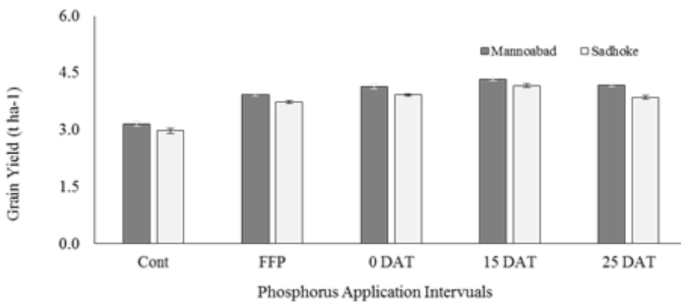

Figure 1: *Paddy yield affected by varying P application time at both locations.*

Table 1: *Soil Physico-chemical parameters of experimental site.*

Parameters	Unit	Locations	
		Mannoabad	Sadhoke
pH	(1:1)	8.32	8.51
EC	dS m^{-1}	1.15	1.32
$CaCO_3$	%	2.97	3.19
OM		0.78	0.63
P ()	mg kg^{-1}	2.92	2.27
K		116	104
Zn		0.70	0.77
Clay	%	22.4	23.5
Sand		34.9	25.1
Silt		42.7	51.4
Textural class		Loam	Silt loam

It was observed that puddling process increases P availability, however further addition of P as SSP causes a thin layer of algal growth on the surface of flooded water as proved by earlier research (Mariraj, 2012), and could possibly contribute to nutrients assimilation and affect the establishment of transplanted seedling (Panhawar and Othman, 2011). Higher response of P applied at 15 DAT as compared to other treatments may be attributed to its appropriate timing after establishment of rice seedling. On average at both locations P was deficient in soils that did not meet the requirement of plants up to 25 DAT, contributed to the reduction in paddy yield as noted with P applied at 25 DAT to accommodate for one week post transplantation shock.

Agronomic efficiency and harvest index: Agronomic efficiency (AE) as yield increase for each kg of P applied and HI as the ratio of paddy yield to biological yield were higher at both locations when P was applied at 15 DAT. However, it was observed that P application at different crop growth stages had variable effect on HI ranging from 37.9% to 41.7% but significantly increased with the application of P at 15 DAT as compared to all other treatments (Table 2). Sahrawat and Sika (2002) also reported the improvement of the HI for rice. Mean AE ranges from 30.27 to 39.48 kg paddy increase kg^{-1} P applied, as highest and highly significant with 15 DAT application of P; as compared with other treatments (Figure 2). Rest of treatments; FFP, 0 DAT and 25 DAT resulted non-significant differences in AE for P in this study.

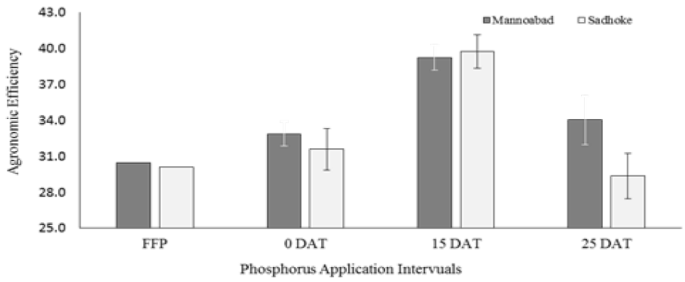

Figure 2: *Agronomic efficiency affected by varying P application time at both locations.*

Phosphorus contents of grain and straw: The mean P contents in paddy ranges from 0.256% to 0.357% and in straw from 0.084% to 0.109% showing higher concentration in paddy than straw. While comparing treatments such as FFP and 0 DAT statistically non-significant difference was observed for P concentration in paddy in both treatments.The P uptake as the product of P concentration and yields was significant different among treatments as because of yield differences as P accumulation is linked with paddy and straw yield (Shinano et al., 1995; Fageria et al., 2009).

Total P Uptake (TPU), Harvest Index (HI) and P Recovery Efficiency (PRE)

It was observed that P applied at different dates after transplanting resulted significant differences in paddy and straw Puptake. Mean P uptake across both sites

Table 2: Response of harvest index and total P uptake to P application at different growth intervals of rice.

Treatments	HI (%)			T PU (kg ha^{-1})		
	Mannoabad	Sadhoke	Average	Mannoabad	Sadhoke	Average
Control	38.02g	37.94g	37.97d	12.73f	11.36g	12.04d
FFP	38.88f	39.78e	39.33c	19.73cd	18.02e	18.87c
P at 0 DAT	40.07de	40.84bc	40.45b	21.38b	19.69cd	20.53b
P at 15 DAT	41.11b	42.20a	41.65a	22.09a	20.23c	21.16a
P at 25 DAT	40.34cd	40.39cd	40.36b	21.18b	19.62d	20.40b
LSD	39.68 b	40.23 a		19.42 a	17.78 b	

Data are mean (n=3); Means followed by different letters are significantly different from each other at p≤ 0.05; Values are means ± standard error; HI: Harvest Index; TPU: Total P Uptake.

in paddy range from 7.86-14.67 kg ha^{-1} and 4.19-6.42 kg ha^{-1}in straw. Though P uptake in treatments (0 DAT, 15 DAT and 25 DAT) were statistically similar in paddy and straw but significantly higher when comparing with FFP and control treatments. Total P uptake in FFP was significantly lower (18.87 kg ha^{-1}) than other P applied treatments except control treatment (12.05 kg ha^{-1}). Earlier research (Khan et al. 2010) also reported that P uptake by rice increased significantly with increasing P levels. Significantly greater P uptake was observed when P was applied in 15 DAT. Total P uptake differences between treatments of P applied at 0 DAT and 25 DAT were non-significant (Table 2).

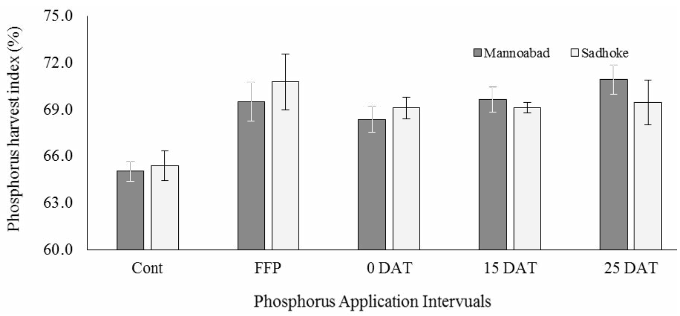

Figure 3: *Phosphorus harvest index affected by varying P application time at both locations.*

Harvest index as the proportion of total plant nutrient partitioned to the grain (Fageria, 2003). The mean values of PHI range from 65.2% to 70.2 % (Figure 3), being the maximum (70.2%) with 25 DAT. There were no significant differences in PHI values within all P applied treatments, however, PHI achieved with these treatments were significantly higher than control treatment. Results show that mean values of PRE range from 27.3 to 30.4%, being the maximum in treatment where P was applied at 15 DAT, it differed statistically from all other tested treatments. Our results show statistically identical PRE in treatments such as FFP, 0 DAT and 25 DAT (Figure 4).

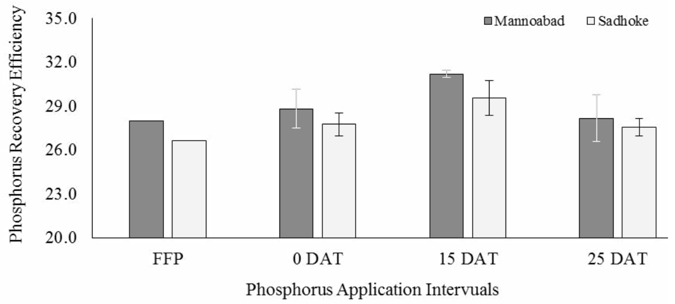

Figure 4: *Phosphorus recovery efficiency affected by varying P application time at both locations.*

Conclusions and Recommendations

Findings of this study show significant differences in paddy yield with P applied to rice at different growth stages. Paddy yield range from 2.972 to 4.333 t ha^{-1} being the maximum with treatment where P was applied at of 15 DAT.The P application at 15 DAT was considered best as all growth parameters measured such as AE, HI, P uptake, PHI and PRE significantly increased here. Based on these results it was concluded that application of P to rice at 15 DAT is more beneficial and profitable as compared to P application at 0 DAT and 25 DAT. Further, the P response was also significantly different between locations which could be ascribed to diverse soil characteristics. Such findings employ further research on large scale testing of these result including different climate regimes and diverse soils for major crops to get economically optimum yields instead of fertilizer recommendation on regional basis.

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Author's Contributions

Fayyaz Hussain: Conceived idea, planning, execution of experiment, correction and formating of draft and overall management etc.
Raza Ullah Khan: Formatting, correction of draft etc.
Asim Hayat: Experiment layout, writing data analysis etc.
Humair Ahmed: Experiment layout and writing etc.
Ahmade Khan: Correction of manuscript.

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