

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

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ABSTRACT

The trials on rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system were conducted during 1991–95 at Palampur, R.S. Pura and Varanasi centres of All-India Co-ordinated Research Project on Cropping Systems for determining the frequency of phosphorus application, so as to make judicious use of P fertilizer. Application of P_2O_5 @ 90 kg/ha to both rainy season (*kharif*) and winter (*rabi*) season crops every year gave maximum system productivity of 8.6 tonnes/ha. However, farmers may apply 60 kg P_2O_5 /ha every year to *rabi* crops with greater net returns of Rs 22,705/ha/year at Palampur, whereas application of 60 kg P_2O_5 /ha to both *kharif* and *rabi* crops every year recorded higher net returns of Rs 26,298/ha/year at R.S. Pura. Similarly, application of 60 kg P_2O_5 /ha to *rabi* crops in alternate year resulted in maximum net returns of Rs 29,213/ha/year at Varanasi.

Key words : Rice, Wheat, Phosphorus, Productivity, Economics, Soil fertility

The capacity of crops to utilize fertilizer and native phosphorus may vary greatly. Since P applied to soil is not lost out of the soil, liberal application to each crop in the system is not only uneconomic but may also deteriorate soil fertility through nutrient imbalances. Information on P management for some cropping systems has been generated but only a few practical recommendations have emerged out till now. The concept is basically sound to make suitable adjustment in fertilizer recommendations keeping in view the P needs, responses and residual effects in the

system. One possible reason why sufficient recommendations have not emerged is that many of the effects have not been quantified. Several workers suggested that P application could be done during *rabi* crop and *kharif* crop be allowed to take benefit through residue left in soil (Mishra and Mishra, 1992; Tandon, 1987), as high temperature and adequate moisture during rainy season favour the availability of residual P to *kharif* crops. Realizing the importance of rice–wheat system a work was started on centres of All-India Co-ordinated Research Project for determining

P application for judicious use of fertilizers to increase and sustain high productivity of the system.

MATERIALS AND METHODS

An experiment on rice–wheat sequence is being carried out since 1990–91 at 3 centres of AICRP on Cropping Systems Research, viz. Palampur, R.S. Pura and Varanasi, from 1991–92 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 *kharif* and *rabi* crops every year (P_1), to *kharif* crop only every year (P_2), to *rabi* crop only every year (P_3), to *kharif* crop only in alternate years (P_4), to *rabi* crop in alternate year (P_5), and P_2O_5 application in alternate years to both *kharif* and *rabi* crops (P_6). The experiment was carried out in split-plot design with P levels in main plots and phases of P applications in subplots having 4 replications. At Palampur during *kharif*, rice variety 'HPU 741' was used with 90 kg N/ha and 40 kg K_2O /ha. At R.S. Pura during *kharif* rice variety 'PC 19' was used with 100 kg N/ha, 25 kg K_2O /ha and 20 kg $ZnSO_4$ /ha. In *rabi*, wheat variety 'HD 2329' was used with 100 kg N and 25 kg K_2O /ha, while wheat variety 'HUW 234' was used with 120 kg N and 40 kg K_2O /ha. At Palampur average annual rainfall was 3,149 mm. The soil was red having pH 5.6, with initial Organic carbon (O.C.) 0.55. Available N, P and K were 576.8, 32.6 and 207.9 kg/ha respectively. At R.S. Pura, average rainfall was 1,058 mm. Texture of the soil was lowland clay with pH 7.6, electrical conductivity 0.09 dS/m and O.C. 0.40%. Available N, P and K were 214.2, 13.47 and 105 kg/ha re-

spectively. However, at Varanasi average annual rainfall was 1,113 mm. Soil was alluvial clayey, pH 7.5, electrical conductivity 0.11 dS/m and O.C. 0.39%. Available N, P and K were 151, 40 and 239 kg/ha respectively.

The data from 1991–92 to 1994–95 were analysed statistically.

RESULTS AND DISCUSSION

System productivity

The rice crop did not respond to P application beyond 30 kg P_2O_5 /ha at Palampur (Table 1). All the 6 phases of P_2O_5 application were statistically at par. Interaction was, however, significant. In *rabi*, the maximum wheat yield of 2,717 kg/ha was found significant at 90 kg P_2O_5 which was 23% and 13% higher than 30 and 60 kg P_2O_5 /ha. Interaction effect was significant. In *kharif* (rice) different doses of P_2O_5 responded differently in all phases of P_2O_5 application. Similarly, in *rabi* (wheat) with different phases of P_2O_5 application, wheat yields increased differently. With application of 90 kg/ha of P_2O_5 to both *kharif* and *rabi* crops every year, maximum yield of the system (7.4 tonnes/ha) can be realized. Application of 90 kg/ha to *rabi* crop every year will give yield of 7.2 tonnes/ha.

At R.S. Pura, application of P_2O_5 @ 90 kg/ha gave maximum rice yield and was significantly superior to 30 and 60 kg P_2O_5 by 14% and 6% respectively. Application of 90 kg P_2O_5 /ha to *kharif* crop only every year gave 4.5 tonnes/ha yield which was 0.5 tonne/ha less from application of 90 kg P_2O_5 /ha to both *kharif* and *rabi* crops every year. In *rabi* (wheat), P_2O_5 @ 90 kg/ha gave maximum yield, being significantly

Table 1. Effect of P doses and phases on grain yield of rice and wheat in rice-wheat sequence (average data of 4 consecutive years)

P phase	Rice yield (kg/ha)				Wheat yield (kg/ha)			
	30	60	90	Mean	30	60	90	Mean
<i>Palampur</i>								
P ₁	3,990	4,171	3,937	4,032	2,324	2,978	3,484	2,929
P ₂	4,344	3,896	4,085	4,108	1,630	1,945	2,189	1,922
P ₃	3,900	4,325	4,125	4,117	2,441	2,750	3,076	2,739
P ₄	4,201	4,045	4,138	4,128	1,589	2,054	2,197	1,948
P ₅	3,928	4,249	4,088	4,088	1,930	2,150	2,515	2,198
P ₆	4,129	4,247	3,579	3,985	2,378	2,603	2,839	2,607
Mean	4,082	4,155	3,992		2,049	2,413	2,717	
CD (P = 0.05)								
P doses	130				116			
P phases	NS				164			
Interaction	318				283			
<i>R. S. Pura</i>								
P ₁	4,314	4,705	5,015	4,678	3,363	3,585	3,691	3,547
P ₂	3,961	4,210	4,546	4,239	2,508	2,829	3,098	2,812
P ₃	3,663	4,015	4,175	3,951	3,178	3,356	2,482	3,339
P ₄	3,489	3,706	3,901	3,699	2,278	2,536	2,666	2,493
P ₅	3,439	3,675	3,831	3,648	2,578	2,929	3,073	2,860
P ₆	3,792	4,065	4,332	4,063	3,792	3,177	3,250	3,073
Mean	3,776	4,063	4,300		2,783	3,069	3,210	
CD (P = 0.05)								
P doses	22				15			
P phases	31				21			
Interaction	53				37			
<i>Varanasi</i>								
P ₁	3,938	4,399	4,525	4,287	3,844	4,235	4,344	4,141
P ₂	3,753	4,222	4,344	4,106	3,621	3,891	3,969	3,827
P ₃	3,650	3,947	3,984	3,860	3,710	4,038	4,100	3,949
P ₄	3,628	3,978	3,566	3,724	3,516	4,697	3,885	4,033
P ₅	3,544	3,841	3,897	3,761	3,550	4,750	3,960	4,087
P ₆	3,650	4,009	4,034	3,898	3,672	3,938	3,866	3,825
Mean	3,694	4,064	4,059		3,652	4,258	4,021	
CD (P = 0.05)								
P doses	84				73			
P phases	60				103			
Interaction	103				178			

superior to 30 and 60 kg P_2O_5 by 15% and 5% respectively.

At Varanasi in *kharif* (rice) 60 kg/ha of P_2O_5 gave maximum yield, being 10% higher than 30 kg P_2O_5 but at par with 90 kg P_2O_5 . Application of P_2O_5 to *kharif* and *rabi* crops every year provided maximum yield of rice (4,287 kg/ha). Interaction effect was significant which indicates that at 90 kg P_2O_5 /ha in *kharif* and *rabi* crop every year can give maximum yield of 4,525 kg/ha. In *rabi* (wheat), 60 kg P_2O_5 /ha gave maximum yield of 4,258 kg/ha which was 17% higher than that given by 30 kg P_2O_5 and was also superior to 90 kg P_2O_5 /ha. Application of P_2O_5 to both *kharif* and *rabi* crops every year gave maximum yield which was the highest. Interaction effect indicated that maximum yield of 4,750 kg/ha can be realized with 60 kg/ha P_2O_5 with its application to *rabi* crop in alternate years (Table 1).

Soil fertility

At Palampur available P in the soil was maximum where P_2O_5 was applied @ 90 kg/ha, being 30% more than initial value of available P in the soil (Table 2). Further, available P was 7% more in the soil than its initial value when P_2O_5 was applied to both *kharif* and *rabi* crops every year. At R.S. Pura it was noticed that application of P_2O_5 @ 30 kg/ha resulted in 14% decrease in available P of the soil below the initial value to any phase of P application. At other doses of P_2O_5 application, available P in the soil was more than its initial value in the soil (Table 2).

Economic analysis

At R.S. Pura, application of P_2O_5 @ 90

Table 2. Available P status in experimental plots at Palampur and R. S. Pura during last year of consecutive cycles

Treatment	P status (kg/ha)	
	Palampur	R. S. Pura
P_2O_5 (kg/ha)		
30	23.8	11.8
60	28.0	15.3
90	42.5	14.3
Effect of P phase		
P ₁	34.8	13.7
P ₂	35.9	12.8
P ₃	24.8	12.6
P ₄	34.1	13.4
P ₅	30.6	14.8
P ₆	28.5	15.1
Intitial	32.6	13.5

kg/ha in both *kharif* and *rabi* every year resulted in maximum net return. But benefit : cost ratio of fertilizer in this case was only 12.46 : 1. Further, application of P_2O_5 @ 90 kg/ha during *rabi* in alternate years gave 22,630/ha/year, with benefit : cost ratio of 41.91:1. At Palampur, application of P_2O_5 @ 90 kg/ha during *rabi* every year gave maximum net return, followed by application of P_2O_5 @ 60 kg/ha during *rabi* every year. However, benefit : cost ratio fertilizer was maximum when P_2O_5 @ 30 kg/ha during *rabi* in alternate year was applied, but the total net return was not maximum. However, additional benefit of about Rs 1,000/ha/year can be had by the application of P_2O_5 @ 60 kg/ha over 30 kg/ha during *rabi* in alternate year for which benefit : cost ratio of fertilizer is also high which can be advised to the medium

Table 3. Average net return of 4 years and benefit : cost ratios of fertilizer use

Doses (kg/ha)/ Phases	Average net return (Rs/ha)						Benefit: cost ratios of fertilizer use					
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆
<i>Palampur</i>												
30	20,081	18,866	20,641	18,281	18,938	21,244	27.89	52.39	57.27	50.78	105.21	118.02
60	22,390	18,359	22,705	19,220	20,557	22,273	15.55	25.50	31.53	26.69	57.10	61.87
90	22,890	19,493	22,984	19,683	21,281	20,985	10.00	18.05	21.28	18.22	39.41	38.86
<i>R. S. Pura</i>												
30	25,001	21,053	22,705	18,763	19,933	21,806	34.27	58.48	63.07	52.12	110.74	121.14
60	26,298	22,660	23,358	20,755	21,795	23,908	18.27	31.47	32.44	28.83	60.54	66.41
90	26,911	24,330	23,597	20,754	22,630	24,806	12.46	22.53	21.85	19.22	41.91	45.94
<i>Varanasi</i>												
30	25,701	24,659	24,688	23,885	23,941	24,724	35.70	68.50	68.57	66.35	133.01	137.56
60	27,850	26,732	26,465	29,063	29,213	26,631	19.34	37.13	36.76	40.37	81.15	73.98
90	27,922	27,034	26,452	24,381	26,199	26,253	12.93	25.03	24.49	22.58	48.52	48.62

Details of phases are given in Materials and Methods.

and large farmers. At Varanasi, maximum net return of Rs 29,213/ha/year was obtained with application of P_2O_5 @ 60 kg/ha during *kharif* in alternate years. However, benefit : cost ratio of fertilizer was 81.15 : 1 which is quite high but not maximum. So, this may be recommended to the medium and large farmers of that area (Table 3).

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