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Varietal differences in wheat yield and phosphorus use efficiency as influenced by method of phosphorus application

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Abstract

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Wheat varieties respond differently to phosphorus fertilization. Method of P application may influence the degree of responsiveness. Three varieties of wheat viz. Punjab-96, Inqelab-91 and Pasban-90 were grown after applying Nitrophos (23:23) @ 0 or 44 kg P ha^{-1} by two methods, (i) broadcast and incorporation at sowing and (ii) fertigation at first irrigation. Grain yield and total P uptake data obtained after crop harvest showed that wheat varieties differed significantly in grain and straw yield, harvest index and 1000-grain weight. Application of P by either method increased grain and straw yield as well as total P uptake over control. Method x P interaction effect was also significant for yield, indicating higher yield response due to fertigation compared to broadcast method of P application. Where P was applied by fertigation grain yield, total P uptake, agronomic and P fertilizer efficiency were all higher in cv. Inqelab-91 compared to cv. Pasban-90. Thus application of phosphatic fertilizer by fertigation along with selection of an appropriate variety may contribute to improve P fertilizer efficiency and increase wheat grain yield.

Key words : application methods, P fertigation, PUE, varietal differences, wheat

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Phosphorus deficiency is widespread in most of the soils of Pakistan and the application of phosphatic fertilizer is considered essential for crop production (Memon, 1996). The recommended and practiced method of P application is to broadcast and incorporate the fertilizer at sowing. However, due to alkaline and calcareous nature of these soils, the recovery by crops of P applied by this method is very low and has been attributed to rapid conversion of soluble P in forms not readily available to plants (Sharif *et al*., 1974). Several agronomic approaches such as time and method of application (Malik *et al*., 1992, Nisar *et al*., 1992) or some organic amendments such as mixing of farm yard manure with SSP or other P sources (Sharif *et al*., 1974; Ahmad Bakhsh *et al*, 1992) has been suggested to improve the P recovery. More recently we observed that applying P fertilizer through irrigation water, resulted in improved utilization of P compared to its application at sowing (Alam *et al*., 1999; 2002a). This method was easy, economical and practical for the flood irrigation system.

Wheat being the staple food, occupies more than 41% of the cropped area and consumes 45% of total fertilizer used in the country. However, the yield remained stagnant at around 2t ha^{-1} for the last many years (Twyford, 1994). Among the factors that influence wheat yield, fertilizers play an important role. Application of phosphatic fertilizer in balanced proportion at proper time and by a suitable method has great impact on crop yield (Alam *et al*., 2002, Nisar *et al*., 1992). However, plant species and even varieties within species vary in their behavior to acquire and utilize P for grain production. This property of wheat cultivars grown in Pakistan has not been fully explored. In a solution culture study some wheat varieties were found to differ in P acquisition (Gill *et al*., 1994). Similarly in another field study differences in P utilization efficiency among wheat varieties were reported (Yaseen *et al*., 1998). Comparison of wheat varieties to fertigation applied P sources showed some variation among varieties for yield and P fertilizer efficiency (Alam *el al*., 2002b). This experiment was conducted to determine the differences in yield and P use efficiency of three wheat varieties as influenced by method of P application.

Materials and Methods

A field experiment was conducted on a normal clay loam soil belonging to Bhalwal Series (Typic Ustocrept, having pH 7.74, organic matter 0.68%, $CaCO_3$ equivalent 1.05% and AB-DTPA extractable P 3.90 mg kg^{-1}). The experimental layout used was a split plot in RCBD, having P rates as main plot, methods as sub-plot and variety as sub-sub-plot. Phosphorus was applied as Nitrophos (23:23) @ 0 or 44 kg P ha^{-1} in 6×10 m plots either at sowing by broadcast and incorporation or at first irrigation by fertigation, 4 weeks after sowing. Equivalent urea-N was applied to plots not receiving P at sowing while additional N was top dressed at first irrigation to bring N rate at 150 kg ha^{-1} to all plots. Three wheat varieties viz: Punjab-96, Inqelab-91 and Pasban-90 were sown @ 120 kg ha^{-1} with tractor drill. In all, five irrigations were given and normal agronomic practices were followed. At maturity, grain and straw yield was estimated by harvesting $1.5 \times 4m^2$ area. Harvest index was calculated, and 1000 grain weight was determined. Grain and straw samples were ground in Wiley mill and one gram portions were digested in triacid mixture. Estimation of P concentration in samples was made by developing vanadomolybdate yellow color (Jackson, 1962). Statistical analysis of the data was performed on a personal computer employing MSTAT software. Agronomic efficiency (AE), has calculated as Grain yield (fertilizer)-Grain yield (control)/Amount of P applied, P fertilizer efficiency (PFE) was calculated as 100 (P uptake (fertilized) - P uptake (control)/ Amount of P applied, and P utilization efficiency was calculated as Grain yield/Total P uptake, in $kgha^{-1}$.

Results and Discussion

Grain and straw yield: Wheat varieties differed significantly in grain and straw yield,

harvest index as well as 1000 grain weight (Table 1, Figure 1). Mean highest grain yield was observed for Punjab-96 followed by Inqelab-91 and Pasban-90, while highest straw yield was obtained for Punjab-96 followed by. Pasban-90 and Inqelab-91. This resulted in equivalent but significantly higher harvest index (HI) by Punjab-96 and Inqelab-91 compared to Pasban-90. In an earlier study similar behaviour of the three varieties was observed (Alam *et al*. 2002b).

Application of P by either method significantly increased grain and straw yield over control. However, the differences in method of application were significant only for grain yield. Method x P interaction effect was also significant for grain and straw yield as well as 1000 grain weight, showing that yield improvement due to fertigation of P at first irrigation was higher compared to broadcast and incorporation of P at sowing (Figure 2). Farooq *et al*. (1994), Latif

Table 1. Effect of method of P application on yield, harvest index, 1000 grain weight, P concentration in grain and total P uptake by three wheat varieties.

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)	1000 grain weight (g)	P Conc. Grain (%)	P uptake (Grain+Straw) (kg ha^{-1})
			Broadcast and incorporation at sowing			
Punjab-96 -P	5.07	8.16	38.14	37.09	0.34	18.85
+P	5.62	8.05	41.23	38.97	0.38	22.97
Inqelab-91 -P	4.24	6.32	39.47	39.04	0.38	17.37
+P	4.81	6.77	41.50	42.47	0.41	20.97
Pasban-90 -P	3.47	7.55	32.84	32.38	0.37	14.02
+P	4.14	7.62	35.00	39.44	0.35	16.05
			Fertigation at Ist irrigation			
Punjab-96 -P	4.80	7.75	39.52	39.42	0.37	19.12
+P	6.19	9.72	38.91	40.00	0.38	26.22
Inqelab-91 -P	4.10	6.09	40.30	40.65	0.39	17.12
+P	5.69	7.55	42.51	42.27	0.42	26.62
Pasban-90 -P	3.72	6.23	37.46	34.72	0.37	15.10
+P	4.59	8.50	35.01	36.33	0.35	18.12
			ANOVA for the factors			
P	**	*	ns	ns	ns	**
Method (M)	*	ns	ns	ns	ns	*
P x M	*	*	ns	*	ns	*
Varieties (V)	**	**	**	**	**	**
P x V	Ns	ns	ns	ns	*	ns
M x V	Ns	ns	ns	ns	ns	ns
P x M x V	Ns	ns	ns	ns	ns	ns

*** Significant at P<0.05 ; ** Significant at P<0.01 ; ns non-significant as determined by DMR test.**

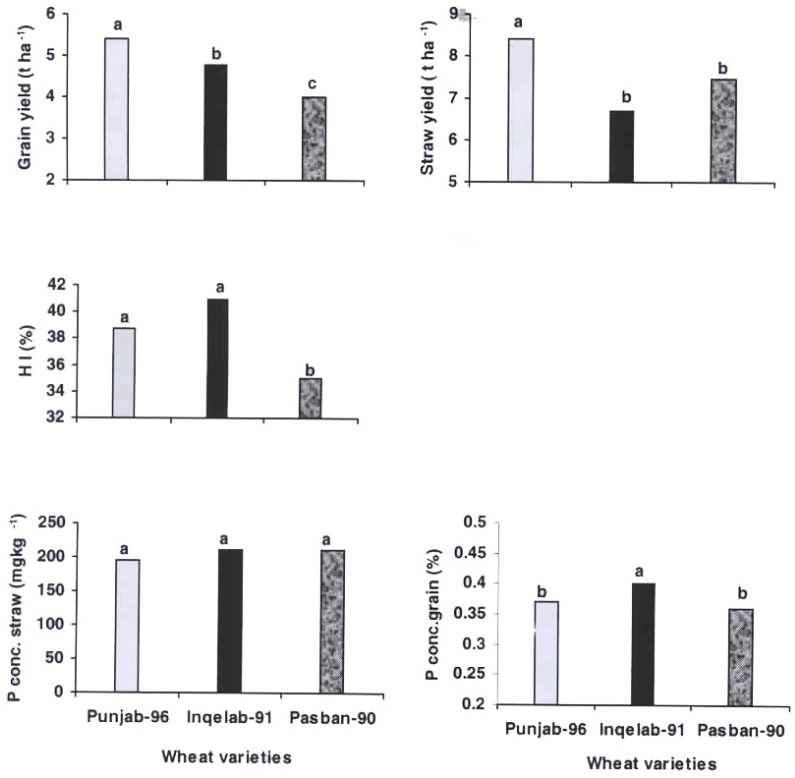

Figure 1. Differences in yield, harvest index, 1000 grain weight and P concentration in grain and straw of three wheat varieties.

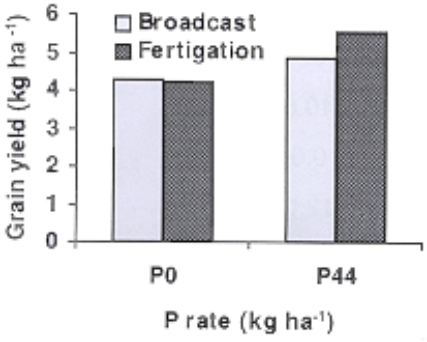

Figure 2. Method x P interaction effect on grain.

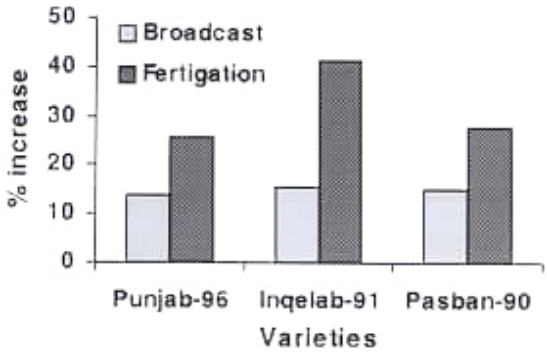

Figure 3. Extent of wheat varietal response to yield of wheat phosphorus applied by different method.

et al. (1997) and Alam *et al*. (2002a) also reported improved grain yield of wheat due to fertigation of P at first irrigation compared to its incorporation at sowing. As regards the extent of varietal response to P application by different methods, it may be observed (Table 1, Figure 3) that the behaviour of the three varieties were almost similar for both methods of application. However, Inqelab-91 had relatively greater response than to Pasban-90, that may be attributed to improved HI

and 1000 grain weight of this variety at fertigated treatment.

Phosphorus uptake

Little differences among varieties were observed for P concentration in straw, while the concentration of P in grains differed significantly (Table 1, Figure 1). The concentration of P in grain was highest in Inqelab-91 and it was similar but significantly lower in. Punjab-96 and Pasban-90. Variety x P interaction effect was significant indicating that when P was not applied, P concentration in grain of all the three varieties was similar but at applied P, the concentration of P in grain was higher in Inqelab-91 followed by Punjab-96 and Pasban-90. Total P taken up by plants was also significantly higher in Punjab-96 and Inqelab-91 while it was lower in Pasban-90. Increased total P uptake due to P application may be attributed to increased yield rather than its concentration. Correlation between yield and P uptake was observed to be higher ($r = 0.96$ for grain, $r = 0.80$ for straw, $n = 12$) while the correlation between yield and concentration was low ($r = 0.40$ for both grain and straw, $n = 12$). Method of application had significant and positive effect on total P uptake, while significant method x P interaction effect indicated increased P uptake to occur in fertigation compared to broadcast method of application (Ranjhe and Mehdi (1992) while comparing rates and time of P application on P uptake and yield of wheat found that crop dressing 1/3 of P rate at Ist irrigation produced as much yield as obtained by incorporating full rate of P at sowing. They concluded that immediate use of irrigation water after P application was the key factor in improving P fertilizer efficiency. In fact when monocalcium phosphate is added to alkaline calcareous soil, the immediate reaction products are di-calcium phosphate dihydrate (DCPD) and di-calcium phosphate anhydrate (DCPA). The conversion of these two reaction product is moisture dependent. Fertilizer P when applied at seeding may be converted more to DCPA due to less moisture and hence would be less available. At higher moisture content the conversion is towards DCPD. This product is more effective in replenishing P solution and stays for longer time before conversion to DCPA (Sauchilli, 1965). Moreover, the crown root growth at tillering has already developed close to the soil surface and crowns have been found to absorb P (Tisdale *et al.*, 1985). The demand for P at this stage of growth is also much higher compared to other stages of growth (Romer and Schilling, 1986). Therefore, provision of readily available P through fertigation to the developing roots is more likely to meet the high P demand for a longer period of time and thereby result in improved P use efficiency. In an earlier study consistent improvement of DMY and P uptake in plants sampled at different times of growth clearly showed the increased efficiency of fertigated P compared to incorporated P at sowing (Alam *et al.*, 1999).

Phosphorus efficiency

Phosphorus use efficiency of three wheat varieties was calculated for different methods of application (Table 2). Fertigation method of P application resulted in improved agronomic efficiency (AE) over broadcast method. However, the magnitude of difference varied depending on varieties tested. The differences in AE were smaller (only 30%) for Pasban-90 while it was larger for Punjab-96 (153%) and Inqelab-91 (214%), respectively. Similarly, improvement in P fertilizer efficiency (PFE) due to fertigation over broadcast method ranged from 49% in Pasban-90 to 164% in Inqelab-91. Thus Inqelab-91 proved superior to Punjab-96 and Pasban-90 in these two parameters. The P utilization efficiency (PUtE) among the varieties was not found to differ much due to method of P application, however, PUtE was slightly higher for Pasban-90 compared to Inqelab-91. In an earlier study (Alam *et al.*, 2002b) the mean PUtE of five wheat varieties across four P sources varied in the order, Punjab-96 > Pasban-90 = Pervaz-94 = Shahkar-95 > Inqelab-91. Yaseen *et al.* (1998) also reported significant differences in PUtE among 20 wheat genotypes at deficient and adequate P levels.

Table 2. Agronomic efficiency (AE), P fertilizer efficiency (PFE) and P utilization efficiency (PUtE)of three wheat varieties as effected by method of P application.

Varieties	Method of P application	AE ($Kgkg^{-1}$)	PFE (%)	PUtE ($KgKg^{-1}$)
Punjab-96	Broadcast	12.50	9.36	244
	Fertigation	31.60	16.13	236
Inqelab-91	Broadcast	12.95	8.18	229
	Fertigation	40.68	21.59	221
Pasban-90	Broadcast	15.23	4.61	258
	Fertigation	19.77	6.86	253

Conclusion

It may be concluded that wheat varieties differed significantly in yield, harvest index, total P uptake and P use efficiency and may be ranked as Punjab-96 > Inqelab-91>Pasban-90. Variety Inqelab-91 was, however, superior and Pasban-90 was inferior in responding to P applied by either method. Phosphorus applied by fertigation at first irrigation resulted in improved agronomic and P fertilizer efficiency as compared to its incorporation at sowing. Thus application of phosphatic fertilizer by fertigation along with selection of an appropriate variety may contribute to improve P use efficiency and increase wheat grain yield.

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