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Fertigation Technology for Improved Phosphorus Use Efficiency in Wheat

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The conventional method of broadcast and incorporation of P fertilizer was compared and evaluated with "fertigation" technology using the phosphatic source SSP and DAP at 22 and 44 kg P ha^{-1} rate of application. Grain yield and total P uptake by Pak-81 wheat was found to be similar irrespective of source, but rate and method of application affected them differently. Applying P by fertigation resulted in improved P fertilizer efficiency as well as agronomic efficiency compared to its broadcast application at sowing. Application of half of P rate by fertigation produced grain yield and total P uptake equivalent to that obtained by full P rate applied by the conventional method indicating the possibility of substantial saving in P fertilizer input. Thus for optimum yield and increased efficiency, fertigation technology could be economically used for both P fertilizer sources.

Key words: Fertigation, P uptake, P application, Wheat.

Introduction

The general recommendation for P application in Pakistan is that the whole quantity of it should be applied and incorporated into the soil at the time of seeding (Ahmed *et al* 1991). The recommended rate of P application for irrigated and rainfed regions however, vary from 20-120 kg P_2O_5 ha^{-1} depending on the soil test level. Since a limited quantity of phosphatic fertilizer like single superphosphate (SSP) and nitrophos (NP) are produced in the country, the demand for P is mostly met through imports as di-ammonium phosphate (DAP), nitrophos (NP) and triple super phosphate (TSP) (Ahmed *et al* 1992). The uptake efficienty of these fertilizers are generally low due to alkaline and calcareous nature of soils and may further be reduced due to time and method of application; time is more important because relative availability of more soluble fertilizer diminishes as the time between application and plant uptake increases. The recommended method of broadcast and incorporation of fertilizer before sowing allows P to react with soil particles and get converted into forms not readily available to the growing plants (Sharif *et al* 1974). To improve the efficiency of added fertilizer several procedures have been proposed, among them mixing of FYM with P before application (Sharif *et al* 1974) or banding fertilizer below the seed (Khalid and Khalid 1994) was found useful, while top dressing after plant emergence has also been advocated (Ahmed *et al* 1992). Application of P as solution along with irrigation water has been found to improve the efficiency of applied P compared to soil mixing and top dressing (Latif *et al* 1994, 1997). In a field experiment, we observed that application of NP and SSP fertilizers, irrespective of time and method of application, resulted in similar wheat grain and straw yield as well as total P uptake. This experiment was, therefore, conducted to compare the conventional method of P application with the fertigation technology and evaluate them for P use efficiency and yield of wheat using the commonly used phosphatic sources, SSP and DAP.

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Material and Methods

A field experiment was laid out at NIAB farm area, Faisalabad (Hafizabad series, Typic Ustochrept). The physicochemical properties of soil of the experimental site are given in Table 1. Wheat (cv. Pak-81) was sown at 125 kg ha^{-1} in tractor operated drills in plots measuring 8x12 meters. The treatments comprised P rates of 0, 22 and 44 kg P ha^{-1} as powder single superphosphate (SSP) and the granular diammonium phosphate (DAP). Each treatment was replicated four times in a randomized complete block design. The method employed for fertilizer application was broadcast and incorporation before sowing and fertigation where the fertilizer solution was applied along with flowing water in a flood irrigation system (4 weeks after sowing). Nitrogen as urea was top dressed to all plots in two split doses, 100 and 50 kg ha^{-1} at the first and the second irrigation i.e. 30 and 65 days after sowing. The added N in DAP was balanced with urea at the first irrigation. In all, five irrigations were given till crop maturity. Dry matter production of wheat at day 30, 65 and 90 was estimated by harvesting 0.5m^2 area from each plot while the straw and grain yield was obtained from 1x 3 m area from randomly selected

three places in a treatment. Total P in dry matter, straw and grain was estimated colorimetrically after wet digestion (Jackson 1962). The data obtained were analyzed statistically and Duncan Multiple Range test was used to separate the means (Steel and Torrie 1960). Agronomic efficiency (AE), P fertilizer efficiency (PFE) and P utilization efficiency (PUtE) were calculated (Sanders *et al* 1990).

Results and Discussion

Growth and P uptake. The effect of source, rate and method of P application on growth and P uptake by wheat harvested at 30, 65 and 90 days after sowing is given in Table 2. Source and method of application had non-significant effect on growth and P uptake in wheat harvested on 30th day after sowing. Thus application of P before sowing was of little use to the germinating wheat. Similar observations were made in an earlier study (Latif *et al* 1994). After the first irrigation, the dry matter yield (DMY) and total P uptake in plants increased significantly ($P < 0.05$) over control due to P application. At day 65, both P rates increased the DMY and total P uptake over control. The DMY was significantly ($P<0.05$) higher where SSP was applied by fertigation compared to the broadcast and incorporated P at sowing. The lower P rate applied through fertigation from either source resulted in equivalent DMY and P uptake compared to higher P rate applied as broadcast and incorporated at sowing. This indicates that fertigation applied lower P rate was more efficiently taken up and effectively utilized for vegetative growth (Qureshi 1978; Ali *et al* 1988). At day 90, fertigation applied higher P rate from both the sources increased the DMY and the total P uptake over control (Table 2). Application of fertilizer at sowing, however, showed differential response and P putake behaviour depending on source. Application of SSP increased ($P<0.05$) while DAP did not increase the DMY and P uptake over control. The plant growth rate during 65-90 days was slightly lower in DAP compared to SSP applied treatment (Table 3). The cause of lower DMY and P uptake in DAP treated plot was difficult to ascertain. However, low plant stand caused by reduced N availablity from the ammonium based phosphatic source in the alkaline medium may be involved (Tisdale *et al* 1985). The plant growth rate, DMY and P uptake was consistently higher in fertigation applied P compared to the broadcast and incorporated P at sowing.

Table 1
Soil characteristics of the experimental site

pHs	8.3
ECe	0.47 dSm^{-1}
Organic matter	0.59%
Free $CaCO_3$	1.80%
Texture	Sandy loam
Sand	67%
Silt	18%
Clay	15%
$NaHCO_3$ P	6.2 mg kg^{-1}
AB-DTPA P	3.21 mg kg^{-1}
AB-DTPA Zn	0.91 mg kg^{-1}

Table 2
Effect of source, rate and method of P application on wheat growth and P uptake

Treatment*		Days after sowing					
Rate of application (kg P ha^{-1})	Method of application	30		65		90	
		DMY	P utake	DMY	P uptake	DMY	P uptake
		kg ha^{-1}					
Control	-	79.6A	0.38A	447D	1.59D	2976C	8.11C
Single superphosphate							
22	Fertigation at 1st irrig.	80.1A	0.38A	583C	2.09C	3262BC	9.61ABC
44	Fertigation at 1st irrig.	78.3A	0.39A	684A	2.57AB	3689A	11.14A
44	Broadcast & incorporated at sowing	92.8A	0.56A	606BC	2.26BC	3563AB	10.17AB
Di-ammonium phosphate							
22	Fertigation at 1st irrig.	77.8A	0.36A	571C	2.34ABC	3271BC	9.92AB
44	Fertigation at 1st irrig.	82.3A	0.40A	667AB	2.60A	3460AB	11.01A
44	Broadcast & incorporated at sowing	99.6A	0.58A	644ABC	2.44AB	3294ABC	9.24BC

* Urea was applied to balance N rate at 150 kg N ha^{-1} in all treatments including control.
Figures with common letters within each column not differ significantly at $P<0.05$ as determined by Duncan Multiple Range test.

Grain yield and P use efficiency. Source, rate and method of P application significantly (P<0.05) increased the grain yield over control while the straw yield was not significantly affected. (Table 4). The lower P rate applied as SSP by fertigation or the higher P rate broadcast and incorporated as DAP before sowing did not increase the grain yield signifricantly (P<0.05) over control. The higher P rate applied by fertigation from both the sources, however, increased the grain yield significantly (P<0.05) over control. The fertigation-applied lower P rate produced statistically similar grain yields as obtained by applying higher P rate by broadcast and incorporation method at sowing, thus indicating the possibility of low fertilizer inputs through fertigation without a concomitant loss in wheat grain yield. Similar results were obtained in earlier studies (Latif *et al* 1997; Alam *et al* 1988).

Total P uptake at maturity increased due to rate and method of P application (Table 4). Fertigation-applied SSP at higher rate significantly (P<0.05) increased total P uptake over the lower rate as well as the control. Lower P rate from either source, when applied by fertigation, resulted in equivalent P uptake as obtained by broadcast and incorporated higher P at sowing, showing a better efficiency. The agronomic efficiency (AE) and the phosphorus fertilizer efficiency (PFE) were also higher in fertigation applied P. At equivalent rate of 44 kg ha^{-1}, PFE was 28.7 and 92.4% higher in fertigation-applied SSP and DAP, respectively, over their broadcast application at sowing. The AE and PFE were generally higher with SSP than DAP. However, at lower rate of application, DAP gave slightly higher AE and PFE than SSP. The P utilization efficiency (PUtE) was fairly uniform and not affected by P sources and rates.

Table 3

Effect of source, rate and method of P application on the growth rate of wheat during two intervals

Treatment		Growth rate (kg ha^{-1} day^{-1})	
Rate (kg ha^{-1})	Method	30-65 days	65-90 days
Control	-	10.5	101.2
Single superphosphate			
P22	Fertigation*	14.4	107.2
P44	Fertigation*	17.3	120.2
P44	Broadcast & incorporated*	14.7	118.3
Di-ammonium phosphate			
P22	Fertigation*	14.1	108.0
P44	Fertigation*	16.7	111.7
P44	Broadcast & incorporated**	15.6	106.0

*Fertigation at first irrigation; ** Broadcast and incorporated at sowing.

Conclusion

The two P sources (SSP and DAP) proved equally effective for grain and straw yield and total P uptake by wheat. However, irrespective of method of application, grain yield as well as agronomic and P fertilizer efficiency were relatively higher where the source was SSP. Applying P at lower rate by fertigation improved P fertilizer efficiency without concomitant loss in wheat grain yield. Thus for optimum yield and better P fertilizer efficiency, fertigation technology could be economically used for both P fertilizer sources.

Table 4

Effect of source, rate and method of P application on P use efficiency and yield of wheat

Treatment		Yield		Total P uptake	AE	PFE	PUtE
Rate (kg ha^{-1})	Method*	Straw (t ha^{-1})	Grain (t ha^{-1})	(kg ha^{-1})	(kg ha^{-1})	%	(kg ha^{-1})
Control	-	9.07A	6.22C	23.34C	-	-	-
Single superphosphate							
22	Fertigation*	8.90A	6.47BC	25.68B	11.32	10.64	252
44	Fertigation*	9.57A	6.83A	28.02A	13.95	10.64	244
44	Broadcast & incorporated**	9.47A	6.71AB	26.98AB	11.20	8.27	249
Di-fammonium phosphate							
22	Fertigation*	9.50A	6.59AB	25.95AB	17.14	11.86	254
44	Fertigation*	9.00A	6.60AB	26.92AB	8.70	8.14	245
44	Broadcast & incorporated**	9.59A	6.54ABC	25.20BC	7.39	4.23	259

*Fertigation at first irrigation; **Broadcast and incorporated at sowing .

N.B. Figures with similar letters in a column are not significantly different at P<0.05 as determined by DMR test.

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