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EFFECT OF PHOSPHORUS FERTIGATION IN WHEAT ON DIFFERENT SOILS VARYING IN $CaCO_3$ LEVELS

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Abstract

Low native soil phosphorus availability coupled with poor utilization of added phosphorus is one of the major constraints limiting the productivity of alkaline and calcareous soils of Pakistan. With a view of addressing this issue, a field experiment was conducted to compare the efficacy of two methods of phosphorus application; broadcast (0 and 100 kg P_2O_5 kg ha^{-1}) and fertigation (50, 75 and 100 kg P_2O_5 ha^{-1}) in calcareous soils varying in $CaCO_3$ concentrations (6, 9 and 13% $CaCO_3$). Phosphorus fertigation @ 100 kg ha^{-1} significantly enhanced the grain (4.4 tons ha^{-1}) and biological yields (11.4 tons ha^{-1}) as compared to control and broadcast at each level of $CaCO_3$%. The maximum P uptake (16.6 kg ha^{-1}) and P (10.0%) recovery were observed with fertigated P (100 kg ha^{-1}) at 6%$CaCO_3$ level in soil. The premier agronomic efficiency recorded with P fertigation at 50 kg ha^{-1}, was (147.7 %) more than broadcasted P (100 kg ha^{-1}). The results revealed that the fertigation method remained most efficient for phosphorus application compared to the conventional broadcasting method in calcareous soils.

Introduction

Wheat (*Triticum aestivum* L.) is grown on an area of 9.046 million hectares with total production of 24.033 million tons with average yield of 2657 kg ha^{-1} (Anon., 2008-2009). This average yield is lower than other wheat growing countries of the world. Besides other factors, low soil phosphorus may be one of the reasons for poor harvest. Ninety percent of Pakistan soils suffer from moderate to severe phosphorus deficiency (Malik *et al.,* 1984; Memon, 1986; Ahmed *et al.,* 1992; Memon *et al.,* 1992; Alam *et al*., 1994). Phosphorus fertilization is essential for exploiting maximum yield potentials of different crop plants (Rashid *et al*., 1994). In Pakistan, the increasing cost of phosphatic fertilizers emphasizes the need to find some methodology for improving the efficiency of added fertilizer (Twyford, 1994). In general, phosphatic fertilizers are recommended to be broadcasted and incorporated into soil before sowing (Malik, 1992). The average recovery of phosphorus fertilizer by crops is very low and varies from 15-20% on single crop basis (Rashid, 1994). This may be attributed to reversion of applied phosphates to less available forms such as octa-calcium phosphates, carbonate apatite, hydroxy apatite and flour apatite by reacting with clays and calcium compounds (Tisdale *et al.,* 1985). According to Rashid & Din (1993), degree of phosphorus fixation depends on the ratio of applied phosphorus, the fixation of broadcasted phosphorus is much greater than the phosphorus applied through bands.

Fertigation is a technique that involves application of plant nutrients through irrigation. It is an effective means of placement of fertilizers and improving fertilizer use efficiency (Latif & Iqbal, 2001). Latif *et al.,* (1994) also reported that solution of phosphate fertilizer applied along with the first irrigation produced wheat grain yield equivalent to conventional soil mixing before sowing or top dressing after plant emergence. They further narrated that P-uptake by wheat was also higher when it was applied by fertigation as compared to soil mixing (Latif *et al.,* 1997). Shah *et al.,* (2006) also demonstrated the agronomic efficiency of fertigation over broadcast method in mungbean. Earlier studies showed little utility of applied phosphorus before sowing until first irrigation to wheat crop (Latif *et al.,* 1994). Phosphorus fixation and reversion due to broadcasting could overcome by fertigation. Synchronized nutrients application through fertigation may increase the nutrient uptake and reduce the cost of crop production through savings in fertilizer expenditure. The present study was therefore, undertaken to compare the relative efficacy of broadcast and fertigation methods using wheat as a test crop.

Materials and Methods

A field experiment was designed and conducted using wheat as test crop to compare the relative efficacy of broadcast and fertigation techniques during 2008-2009 at the Experimental Farm of Nuclear Institute of Agriculture, Tando Jam on silt loam soil having an ECe of 1.2 dS m^{-1}, pH 7.8, Olsen's P 6.9 mg kg^{-1}, organic matter 0.86% and $CaCO_3$ 6-13%. Two methods of phosphorus application i.e., broadcast (0 and 100 P_2O_5 kg ha^{-1}) and fertigation (50, 75 and 100 P_2O_5 kg ha^{-1}) were evaluated. The experiment was laid out according to randomized complete block design (Steel *et al.,* 1997) with four repeats and a plot size of 5 m x 4 m. Nitrogen @120 kg ha^{-1} as urea was applied to all the treatments in two equal splits, half at sowing and the remaining half at the time of first irrigation. Phosphorus as triple super phosphate was applied by broadcasting (Phosphatic fertilizer was uniformly spread out on the soil surface and mixed in the soil with spade before sowing of crop) and by fertigation. Phosphorus through this technique was applied thirty days after crop emergence. The solution of fertilizer phosphorus was prepared at 1:5 fertilizer to water ratio in a container fitted with water tap and placed at inlet of irrigation water flowing from water channel to the sub plots. At the beginning of the irrigation, stopper of the container was opened, releasing the phosphorus solution in such a way that the entire solution was finished with the termination of irrigation water from channel.

Uniform cultural practices were carried out to each treatment plot throughout the crop growth period. The crop was harvested at maturity. Grain and straw samples were taken and dried in an oven at 70°C, ground in

Wiley's mill and 1 g of ground material was digested in HNO_3: $HClO_4$ (1:5) mixture. The acid digested material was analyzed for total phosphorus by metavanadate yellow color method as described by Jackson (1979). The agronomic efficiency was calculated as:

$$\text{Agronomic efficiency (kg kg}^{-1}\text{ P)} = \frac{\text{Yield (fertilized treatment) - Yield (control treatment)}}{\text{Fertilizer P applied (kg ha}^{-1}\text{)}}$$

The data were assessed statistically using software MSTAT-C (Russel & Eisensmith, 1983).

Results and Discussion

Biological and grain yield: Phosphorous application in combination with different levels of Calcium carbonate showed significant differences in biological and grain yield (Tables 1-2). Results showed that different level of $CaCO_3$ has drastic effect on yield if phosphorous is applied through broadcast method whereas, P availability to the plants can be increased by fertigation thus, reflecting the higher grain yield. At 6% $CaCO_3$ level, fertigation with 50 kg P ha^{-1} produced equal biological and grain yields as produced by broadcasted 100 kg P ha^{-1}. Hence, 50% fertilizer can be saved by fertigation. The highest biological (11.4 tons ha^{-1}) and grain yields (4.4 tons ha^{-1}) were recorded at 100 kg fertigated P at 6% $CaCO_3$ level. The control treatment produced the lowest biological (5.5 tons ha^{-1}) and grain yields (2.2 tons ha^{-1}). The biological and grain yields were significantly decreased with the increase of soil $CaCO_3$%. However, P fertigation at 100 kg ha^{-1} significantly improved biological (6.8 tons ha^{-1}) and grain (2.9 tons ha^{-1}) yields at 9% $CaCO_3$ as compared to control and broadcasted P. Similar trend was observed at 13% $CaCO_3$ level. This may be due to long time interaction (aging) of soluble phosphorus with soil led to its reaction with solid phase of soil, calcium carbonate and the formation of relatively insoluble reaction products with Ca, Fe and Al leading to phosphorus fixation (Brady & Weil, 2002). All these processes leading to fixation are delayed when we apply fertilizer through fertigation as plant absorbed this nutrient quickly and directly from the soil solution. Aslam *et al.,* (2009) reported that the highest seedcotton yield was obtained by phosphorus fertigation as compared to broadcast method. Similarly, Farooq *et al*., (1994), Latif *et al*., (1997) and Alam *et al*., (2001) also reported higher grain yield of wheat due to fertigation of P at first irrigation compared to its incorporation at sowing.

Table 1. Biological yield of wheat (tons ha^{-1}) as influenced by fertigation technique at different $CaCO_3$ level in soil.

Treatments (kg ha^{-1})	$CaCO_3$ (%)			Mean
	6	9	13	
P0 (Control)	5.5 f	3.9 i	3.0 j	4.1 d
P100 (Broadcast)	8.9 c	5.7 f	4.5 h	6.4 c
P50 (Fertigation)	8.9 c	5.8 f	4.9 g	6.5 c
P75 (Fertigation)	9.6 b	6.4 e	5.6 f	7.2 b
P100 (Fertigation)	11.4 a	6.8 d	5.8 f	8.0 a
Mean	8.9 a	5.7 b	4.7 c	

Means followed by similar letters do not differ significantly from each other at 5% level by DMR test

Table 2. Grain yield of wheat (tons ha^{-1}) as influenced by fertigation technique at different $CaCO_3$ level in soil.

Treatments (kg ha^{-1})	$CaCO_3$ (%)			Mean
	6	9	13	
P0 (Control)	2.2 g	1.7 h	1.1 i	1.7 e
P100 (Broadcast)	3.5 c	2.5 f	1.8 h	2.6 d
P50 (Fertigation)	3.5 c	2.6 ef	2.2 g	2.8 c
P75 (Fertigation)	3.9 b	2.8 de	2.4 f	3.1 b
P100 (Fertigation)	4.4 a	2.9 d	2.6 f	3.3 a
Mean	3.5 a	2.5 b	2.0 c	-

Means followed by similar letters do not differ significantly from each other at 5% level by DMR test

Phosphorus uptake and recovery: Phosphorus uptake and recoveries were influenced by levels of $CaCO_3$ and methods of fertilizer application (Tables 3-4). Maximum P uptake (16.6 kg ha^{-1}) and recovery (10.0%) were recorded at 6% soil $CaCO_3$, which were significantly higher than control and broadcasted P (100 kg ha^{-1}). In both methods of P application, P uptake was decreased with each increment of soil $CaCO_3$ level. Nevertheless, P fertigation (100 kg ha^{-1}) significantly enhanced the P uptake (10.4 kg ha^{-1}) at 9% $CaCO_3$. Same trend of increment in P uptake was also recorded at 13% soil $CaCO_3$. Recoveries of P fertilizer were decreased with the subsequent increase in P application, thus, reflecting the improper use of P fertilization in system. This showed that economic benefit can be increase only by applying proper P fertilizer. Shah *et al.,* (2006) reported highest P recovery (10.0%) in mungbean with lowest dose of P applied through fertigation. Similarly Iqbal *et al.,* (2003) reported that P uptake was significantly higher where P was applied as fertigation. Fertigated DAP and SSP had higher P fertilizer efficiency as compared to their broadcast application. Fertigation of acid fertilizers like SSP and TSP perform efficiently in calcareous soils (Sharma *et al.,* 1990).

Table 3. Total P uptake (kg ha^{-1}) as influenced by fertigation technique at different $CaCO_3$ level in soil.

Treatments (kg ha^{-1})	$CaCO_3$ (%)			Mean
	6	9	13	
P0 (Control)	6.6 h	4.4 j	2.9 k	4.6 d
P100 (Broadcast)	12.3 c	7.8 g	5.7 j	8.6 c
P50 (Fertigation)	11.2 d	7.8 g	6.6 h	8.5 c
P75 (Fertigation)	13.1 b	8.7 f	7.6 g	9.8 b
P100 (Fertigation)	16.6 a	10.4 e	8.9 f	11.9 a
Mean	11.9 a	7.8 b	6.3 c	-

Means followed by similar letters do not differ significantly from each other at 5% level by DMR test

Table 4. P recovery (%) as influenced by fertigation technique at different $CaCO_3$ level in soil.

Treatments (kg ha^{-1})	$CaCO_3$ (%)			Mean
	6	9	13	
P0 (Control)	-	-	-	-
P100 (Broadcast)	5.7 d	3.4 e	2.8 e	3.9 b
P50 (Fertigation)	9.2 ab	6.8 cd	7.4 c	7.8 a
P75 (Fertigation)	8.7 b	5.7 d	6.3 cd	6.9 a
P100 (Fertigation)	10.0 a	6.0 d	6.0 d	7.3 a
Mean	6.7 a	4.4 b	4.5 b	-

Means followed by similar letters do not differ significantly from each other at 5% level by DMR test

Agronomic efficiency: Data showed that P application methods and concentrations of $CaCO_3$ in the soil significantly affected the agronomic efficiency (Table 5). The highest grain harvest (26.5) was recorded with 50 kg fertigation P at 6% $CaCO_3$, which is significantly higher than both 100 kg ha^{-1} broadcasted (13.0) and fertigated P (21.5). Higher agronomic performance of P was observed at 9 and 13% soil $CaCO_3$ level with 50 kg ha^{-1} fertigated P. The results are in agreement with the findings of Shah *et al.,* (2006) who reported that agronomic efficiency (AE) of mungbean was higher with fertigation than broadcast method. Phosphorus fertigation at the rate of 22 kg ha^{-1} led 50% more agronomic efficiency as compared to full dose of P at the rate of 33 kg P ha $^{-1}$. The results of this experiment clearly demonstrate that fertigation was a more efficient method of nutrient management under different level of $CaCO_3$ than broadcast method. Latif *et al.*, 1997 and Alam *et al.*, 1999 also reported that P application through fertigation was more advantageous as compared to broadcast method.

Table 5. Agronomic efficiency of (P kg^{-1}) as influenced by fertigation technique at different $CaCO_3$ level in soil.

Treatments (kg ha^{-1})	$CaCO_3$ (%)			Mean
	6	9	13	
P0 (Control)	-	-	-	-
P100 (Broadcast)	13.0 e	7.4 f	6.1 f	8.8 c
P50 (Fertigation)	26.5 a	17.8 cd	21.3 bc	21.8 a
P75 (Fertigation)	22.8 ab	14.3 de	17.3 d	18.2 ab
P100 (Fertigation)	21.5 bc	11.8 e	14.5 de	15.9 b
Mean	16.8 a	10.2 b	11.9 b	-

Means followed by similar letters do not differ significantly from each other at 5% level by DMR test

Conclusions

It was concluded that fertigated P enhanced the grain and biological yields of wheat and improved P use efficiency as well as agronomic efficiency of P fertilizers in calcareous soils. Agronomic efficiency of fertigation P at lower rate was relatively more than its higher rates and broadcasted P. On overall basis fertigation seemed a more efficient method of P application and could save considerable amount of P fertilizer as compared to broadcast method of application.

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