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Performance of Fertigation Technique for P Usage Efficiency in Wheat

K.H. Shah, S.H. Siddiqui, M.Y. Memon, M. Aslam, M. Imtiaz and P. Khan
Nuclear Institute of Agriculture, Tandojam, Pakistan

Abstract: Low native soil P availability coupled with poor recovery of added P has become one of the major constraints limiting the productivity of crops. A field study was, therefore, conducted to compare the relative significance of fertigation and different modes of broadcast method for utilization of P when applied at the rate of 100 kg ha^{-1} in wheat crop. Compared to broadcast method, P applied through fertigation in single split was effectively utilized in terms of producing significantly higher crop harvests, P uptake, P recovery and agronomic efficiency. Owing to superiority of fertigation over broadcast method, it is being introduced to farming community for economizing fertilizer P and obtaining better crop harvests.

Key words: Fertigation, broadcast, soil mixing, phosphorus, *Triticum aestivum* L

INTRODUCTION

Phosphorus is essential to all living organisms. It does not occur by itself in elemental form in nature but is always combined with other elements to form different phosphate compounds, some of which are very complex (Johnston, 2000). Despite containing sufficiently high quantities of total soil P, majority of the soils of Pakistan are deficient (<10 μg g^{-1} Olsen's P) in P and well below the critical limit for optimal crop production (Memon *et al.*, 1992; Alam *et al.,* 1994). However, the response of crops to added P is generally inadequate with mean P recoveries varying from 10-20% on single crop basis (Rashid, 1994). Poor efficiency of applied P may partially be attributed to alkaline and calcareous nature of our soils, which favours P fixation by reverting the applied phosphate to less available calcium phosphate compounds (Halford, 1989; Rashid, 1994; Rashid *et al.*, 1994). Phosphatic fertilizer is mostly applied to crops by broadcast and subsequent ploughing method. Since P sorption maxima depends on the ratio of soil to applied phosphates, fixation of broadcast P is much greater than the fertilizer P applied in bands because of narrow soil to fertilizer ratio in the later situation (Rashid and Din, 1993; Mahmood ul Hassan *et al.*, 1993), but it is practically inconvenient for the end users to adopt placement method for P application (Memon, 1985). Fertigation is an innovative approach, where nutrients in the form of solution are applied through irrigation water to reach the crop roots rapidly and with minimal interference by the soil particles. This technique has performed most efficiently in different parts of the world (Twyford, 1994) and has also shown an edge over conventional methods in few studies in Pakistan (Alam *et al.*, 1999; Shah *et al.*, 2001). The present study was, therefore, undertaken to assess the performance and suitability of this technique for higher efficiency of P utilization using wheat as a test crop.

MATERIALS AND METHODS

The study was conducted during 2000-01 at NIA Experimental Farm, Tandojam on silt loam soil having an EC of 1.03 dS m^{-1}, pH (7.9), Olsen's P (7.2 mg kg^{-1}), O.M (0.89%) and $CaC0_3$ (12.5%). Seven treatments comprising, T_1= Control, T_2 = P through broadcast at sowing, T_3 = P through soil mixing at sowing, T_4 = Half P by broadcast at sowing + half at first irrigation, T_5 = P through broadcast after crop emergence, T_6 = P through fertigation after crop emergence, T_7 = Half P through fertigation at first irrigation and half at 2nd irrigation were arranged according to quadruplicated randomized complete block design using sub plot size of 18 m^2. Fertilizer P at 100 kg ha^{-1} as triple superphosphate was applied according to the respective protocol of each treatment. Fertilize N at 150 kg ha^{-1} was applied to all the treatments in two equal splits each at sowing and at first irrigation. Normal cultural practices were carried out throughout the growth period. The crop was sampled at maturity, separated into straw and grain and dried in an oven at 70°C to a constant weight. A uniform sub portion of the dried material was ground in Willey's mill and required quantity of the ground material was digested in HNO_3: $HClO_4$ mixture prepared in 5:1 ratio. The digested material was analyzed for total P by metavanadate yellow colour method as described by Jackson, 1962. The concentrations of P so obtained were used for calculating P uptake and P recoveries using standard formulae. Finally, the data were compiled and analyzed statistically by employing analysis of variance technique (Steel and Torrie, 1986). Differences among treatment means were compared by Duncan's new

multiple range test at 5% level of probability (Duncan, 1970).

RESULTS AND DISCUSSION

Biological and grain yield: Compared to different modes of P application, the biological and grain yields were increased significantly by fertigation technique (Table 1). The highest grain yield of 3.14 tons ha^{-1} was recorded with P fertigation in single split and the lowest (1.63 tons ha^{-1}) in the control treatment. The grain harvests recorded with single split P fertigation were accentuated over control by 93% against an increase of 65% recorded with broadcast at sowing and 77% recorded with soil mixing at sowing. The magnitude of response to fertilizer P however, was depressed with delayed application since only 45 and 31% higher yields were recorded with two split broadcast method and broadcast P at first irrigation, respectively. Comparatively higher yield response of wheat to solution P might be the outcome of enhanced and sustained P availability throughout the vegetative and productive phases of crop, which resulted into increased wheat harvests. These findings are in close conformity with those reported by Alam *et al*., 1999, where lower P rates applied through fertigation resulted in equivalent grain harvests as compared to higher P rates applied by broadcast method or soil mixing at sowing. Our results also correspond with the findings of Latif *et al.,* 1994, who found that solution of fertilizer P applied at first irrigation to wheat produced grain yield statistically similar to broadcast P at sowing but significantly higher than surface or top dressing at 1st irrigation. Higher grain harvests with solution P is possibly an indication of increased P availability at peak demand period of crop, most probably because of the lesser contacts of fertilizer P with alkaline earth carbonates and soil colloids which are partially responsible for precipitation, fixation and retention of fertilizer phosphorus (Shah *et al.,* 2001). Similar findings with fertigation P were recorded for biomass yield, which substantiate the proficiency of this technique for consistent availability of applied phosphorus.

P concentration and uptake: The concentration of P in grain and straw was affected significantly by either mode of P applications. Highest P content of 0.332% in grain and 0.028% in straw observed in single dose P fertigation treatment were significantly different from those recorded with surface broadcast or broadcast + soil mixing. Significantly lowest P contents of 0.239% in grain and 0.014% in straw, however, were found in control treatment. The results corroborate with the findings of

Table 1: Yield as influenced by fertigation and broadcast methods for P application in wheat

	Yield (tons ha^{-1})		
Treatments	Biological	Grain	Increase over control (%)
Control	7.88g*	1.63g	-
Broadcast at sowing	10.81d	2.69d	65
Soil mixing at sowing	12.08b	2.89b	77
Broadcast (2 splits)	10.42e	2.37e	45
Broadcast (1st irrigation)	9.48f	2.14f	31
Fertigation (single split)	12.57a	3.14a	93
Fertigation (2 splits)	11.07c	2.79c	71

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

Table 2: P content as influenced by broadcast and fertigation technique for P application

	P content (% of dry weight)	
Treatments	Grain	Straw
Control	0.239g*	0.014f
Broadcast at sowing	0.277d	0.022c
Soil mixing at sowing	0.287c	0.024b
Broadcast (2 splits)	0.271e	0.020d
Broadcast (1st irrigation)	0.266f	0.018e
Fertigation (single split)	0.322a	0.028a
Fertigation (2 splits)	0.293b	0.023b

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

Latif *et al.,* 1991, who reported that maize plant receiving P in solution form at first irrigation contained significantly higher P content as compared to P applied by broadcast at sowing. Our results were also upheld by Latif *et al*., 1994, who observed higher P content in solution P applied wheat followed by broadcast and surface application, and Shah *et al.,* 2001, who reported higher P concentration in berseem with solution P, while comparing the efficacy of broadcast and fertigation techniques using P at the rate of 50 and 100 kg ha^{-1}, respectively.

Uptake of any nutrient is always influenced by the yield of crop. Fertigation (single split) having produced maximum yield, also took up maximum P, which was 2.64 kg ha^{-1} in straw, 10.11 kg ha^{-1} in grain and 12.75 kg ha^{-1} in total (Table 3). Mixing of fertilizer P with soil at the time of sowing ranked next to fertigation technique with a total uptake of 10.51 kg P ha^{-1} and were significantly different from rest of the experimental treatments. Compared to control, an increase in P uptake by 168% was recorded with single split P fertigation, 121% with soil mixing and 95% with broadcast at sowing. Higher P uptake in the treatments receiving fertilizer P through fertigation transpired increased availability of solution P commensurating with the crop demand owing to lesser interaction of fertilizer P with alkaline earth carbonates and sorption by the colloidal particles. Similar findings have already been reported by Shah *et al*., 2001, while comparing the efficacy of fertigation and broadcast method for P application using wheat and berseem as test

Table 3: P uptake by wheat as influenced by broadcast and fertigation technique for P application

Treatments	P uptake (kg ha^{-1}) Straw	Grain	Total	Increase over control (%)
Control	0.87g*	3.88g	4.75g	-
Broadcast at sowing	1.78d	7.46d	9.24d	95
Soil mixing at sowing	2.20b	8.31b	10.51b	121
Broadcast (2 splits)	1.61e	6.42e	8.03e	69
Broadcast (1st irrigation)	1.30f	5.69f	6.99f	47
Fertigation (single split)	2.64a	10.11a	12.75a	168
Fertigation (2 splits)	1.95c	8.18c	10.13c	113

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

Table 4: P recovery and agronomic efficiency as influenced by broadcast and fertigation technique for P application in wheat

Treatments	P recovery (%)	Grain yield (kg kg^{-1}P)
Control	0.00 g*	0.00 g
Broadcast at sowing	4.49 d	10.62 d
Soil mixing at sowing	5.75 b	12.68 b
Broadcast (2 splits)	3.28 e	7.40 e
Broadcast (1st irrigation)	2.24 f	5.12 f
Fertigation (single split)	7.99 a	15.15 a
Fertigation (2 splits)	5.37 c	11.66 c

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

crops and by Latif *et al.*, 1994, 1997 while evaluating the relative significance of fertigation technique, broadcast method and surface application for P utilization in wheat crop.

Phosphorus recoveries and agronomic efficiency: Phosphorus recoveries were significantly affected by fertigation compared to broadcast or soil mixing method (Table 4). The P usage efficiency with fertigation technique was 7.99% against 5.75, 5.37 and 4.49% recorded with soil mixing, two split fertigation and broadcast at sowing, respectively. The difference among these treatments was statistically significant. The lowest recovery of 2.24% was observed with broadcast application of fertilizer P at the time of 1st irrigation. Low recovery of broadcast P is an indication of relatively high P fixation and conversion of applied phosphates to less available form owing to alkaline calcareous nature of the soil (Rashid, 1994; Rashid *et al.*, 1994). However, significantly higher efficiency of P utilization with the application of solution P indicates the supremacy of fertigation over broadcast application and suggests that ample amounts of fertigation P were available at the peak demand periods of the crop, which prima facie seems to be the major cause of higher P utilization. The results are in accordance with the findings of Alam *et al.*, 1999, who reported significantly higher P recoveries in wheat with fertigation technique specifically at lower P application rates.

Agronomic efficiency is an important criterion, which helps in measuring the response of certain inputs in quantitative terms. The data revealed (Table 4) that maximum agronomic efficiency of 15.15 kg, recorded with P fertigation was significantly higher than 12.68 and 10.62 kg observed in the treatment receiving P through broadcast + soil mixing and by broadcast method, respectively. Split application of fertilizer P either through broadcast or through fertigation technique depressed the agronomic performance significantly as compared to their respective single dose applications. Significantly the lowest agronomic efficiency of 5.12 kg however, was recorded in the treatment receiving P through broadcast method at 1st irrigation. Likely response was reported by Shah *et al.*, 2001, where agronomic efficiency at the rate of 50 kg P ha^{-1}in wheat was 18.3 kg with broadcast and 22.9 kg with fertigation technique.

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