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Performance of fertigation technique for phosphorus application in cotton

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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 the crops. With a view of addressing this issue, field studies were conducted to compare the relative efficacy of broadcast and fertigation techniques for phosphorus application during 2005-2006 using cotton as a test crop. Two methods of phosphorus application i.e. broadcast and fertigation were evaluated using five levels of P_2O_5 (0, 30, 45, 60 and 75 kg P_2O_5 ha $^{-1}$). Fertigation showed an edge over broadcast method at all levels of phosphorus application. The highest seed cotton yield was recorded with 75 kg P_2O_5 ha^{-1}. Fertilizer phosphorus applied at the rate of 60 kg ha^{-1} through fertigation produced 3.4 tons ha^{-1} of seed cotton yield, which was statistically identical to 3.3 tons recorded with 75 kg ha^{-1} of broadcast phosphorus. Agronomic performance of phosphorus was influenced considerably by either method of fertilizer application. The seed cotton yield per kg of fertigation phosphorus was 48% higher than the corresponding broadcast application. The results of these studies showed that fertigation was the most efficient method of phosphorus application compared with the conventional broadcast application of fertilizers.

Key words: Fertigation, broadcast, phosphorus, cotton (*Gossypium hirsutum* L.)

Introduction

Cotton (*Gossypium hirsutum* L.) is an important fiber crop in Pakistan and it is grown on an area of 3.07 m ha with total production of 12.9 m bales making an average of 711 kg ha^{-1} (Agricultural Statistics of Pakistan, 2006-07). This average yield is lower than other cotton growing countries of the world. Besides other factors, low soil phosphorus may be one of the reasons for poor harvests, since 90% soils of Pakistan suffer from moderate to severe phosphorus deficiency (Malik *et al.*, 1984; Memon, 1986; Memon *et al.*, 1992; Ahmed *et al.*, 1992; Alam *et al.*, 1994). Phosphorus fertilization is therefore, very essential for exploiting maximum yield potentials of different crop plants (Rashid *et al.*, 1994). In Pakistan, the increasing cost of phosphate fertilizer emphasizes the need to find some methodology for improving the efficiency of added fertilizer (Twyford, 1994). In general, phosphatic fertilizers are recommended to be broadcast and incorporated into soil before sowing of crop (Malik, 1992). The average recovery of fertilizer phosphorus by crops is very low and varies from 15-20 percent on single crop basis (Rashid, 1994). This may be attributed to reversion of applied phosphates to less available forms such as octo-calcium phosphates, carbonate apatite, hydroxy apatite and flour apatite by reacting with clays and calcium compounds (Tisdale *et al.*, 1993). As the degree of phosphorus fixation depends on the ratio of applied phosphorus therefore, fixation of broadcast phosphorus is much greater than the fertilizer applied in bands because of narrow soil to fertilizer ratio in the latter situation (Rashid and Din, 1993). Fertigation is a relatively new technique that involves application of plant nutrients through irrigation systems instead of the conventional broadcast method. It is an effective means of controlling the timing and placement of fertilizers and improving fertilizer use efficiency (Latif and Iqbal, 2001). Latif *et al.* (1994) 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 observed that P-uptake by wheat was also higher when phosphorus was applied by fertigation as compared to soil mixing (Latif *et al.*, 1997). In addition to these, Latif *et al.* (2003) also reported that the fertigated-P enhanced fresh and dry matter yield of onion over the broadcast phosphorus. Significantly the highest mung bean yield, P-uptake, P-recovery and agronomic efficiency were recorded with fertigation and the lowest with broadcast method (Shah *et al.*, 2006). The common and recommended practice of phosphorus application is to broadcast and mix in the soil before sowing. Earlier studies showed little utility of applied phosphorus before sowing until first irrigation to wheat crop (Latif *et al.*, 1994). This three weeks time allowed for phosphorus fixation/reversion to less soluble form, which can be avoided by fertigation which has the advantage of nutrient application at any time of plant growth. Thus application of nutrients synchronized with the plant need was expected to increase the nutrient efficiency and reduce the cost of crop production through savings in fertilizer expenditure. The present studies were therefore, undertaken to compare the relative efficacy of broadcast and fertigation methods using cotton as a test crop.

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Materials and methods

Field studies were conducted in cotton to compare the relative efficacy of broadcast and fertigation techniques during 2005-2006 at Nuclear Institute of Agriculture Experimental Farm, Tando Jam on silt loam soil having an ECe of 1.2 dS m^{-1}, pH, 7.8; Olsen's P_2O_5, 6.9 mg kg^{-1}; organic matter, 0.86% and $CaCO_3$, 10.9%. Two methods of phosphorus application i.e. broadcast and fertigation were evaluated using five levels of phosphorus (0, 30, 45, 60 and 75 kg P_2O_5 ha^{-1}). The experiment was laid out according to randomized complete block design (Steel *et al.*, 1997) with four repeats and a plot size of 5m x 4 m. Nitrogen at the rate of 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 to the treatments with the following methods.

Broadcast: Phosphatic fertilizer was uniformly spread out on the soil surface and mixed in the soil with spade before sowing of crop.

Fertigation: Phosphorus through this technique was applied thirty days after crop emergence. The solution of fertilizer phosphorus was prepared in 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. Cotton leaf samples were collected at first square stage. The sample contained at least twenty most recently matured healthy looking leaves from main stem, usually the leaf at the 4th node from the plant terminal (Cleveland and Cervantes, 2007). Leaf samples were dried in an oven at 70 ^{0}C, ground in Wiley's mill and 1 g of ground material was digested in HNO_3: $HClO_4$ mixture prepared in 5:1. The acid digested material was analyzed for total phosphorus by metavanadate yellow color method as described by Jackson (1979). The agronomic efficiency was calculated by using the following formula:

Agronomic efficiency (kg kg^{-1} P) =

$$\frac{\text{Yield (fertilized treatment) - Yield (control treatment)}}{\text{Fertilizer P applied (kg ha}^{-1}\text{)}} \times 100$$

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

Results and Discussion

Seed cotton yield

The seed cotton yield was affected significantly by rates and methods of phosphorus application (Table 1). With the increase in phosphorus level from 30 kg to 75 kg P_2O_5 ha^{-1} there was a corresponding increase in seed cotton yield regardless of its method of application. The data revealed that the seed cotton yield of 3.4 tons ha^{-1} recorded with 60 kg P_2O_5 applied through fertigation was statistically identical to 3.3 tons ha^{-1} obtained from 75 kg ha^{-1} of broadcast phosphorus. The highest seed cotton yield of 3.8 tons ha^{-1} however, was obtained from 75 kg ha^{-1} of fertigation phosphorus, which was significantly higher than the seed cotton yield of 3.3 tons ha^{-1} recorded at 75 kg ha^{-1} of broadcast phosphorus. The control treatment produced the lowest seed cotton yield. Fertigation proved to be a better mode of fertilization for the crop at all levels of phosphorus application and it elevated the crop harvest by 15% compared to broadcast method. Similarly, Stewart *et al.* (2005) observed that fertigation was effective in supplying phosphorus to the cotton crop and increased lint yield. In the present study, fertigation enhanced the availability of phosphorus in the moist soil region, where the roots of cotton plant are located and proved to be the most consistent method of increasing yield across the two years of study. These results are in line with the previous findings of Shah *et al.* (2006) who recorded significantly highest mung bean yield, P-uptake, P-recovery and agronomic efficiency with fertigation and the lowest with broadcast method.

Phosphorus concentration

Phosphorus concentration in cotton leaf at squaring stage was affected significantly by rates and methods of phosphorus application (Table 2). The highest phosphorus concentration of 2.80 g kg^{-1} in leaf was recorded with 75 kg ha^{-1} fertigation phosphorus, which was significantly higher than the phosphorus concentration recorded with 45 kg ha^{-1} fertigation phosphorus (2.59 g kg^{-1}), 30 kg ha^{-1} fertigation phosphorus (2.45 g kg^{-1}) and control (2.21 g kg^{-1}), respectively. The higher phosphorus concentration in cotton leaves with fertigation was an indication of sufficiently higher phosphorus supplies within and surrounding the rooting zone of the crop owing to lesser interaction of fertilizer phosphorus with alkaline earth carbonates and sorption by the colloidal particles. These findings corroborates with those reported by Shah *et al.* (2003) while, comparing the efficacy of fertigation with

conventional methods of phosphorus application in berseem.

Table 1. Seed cotton yield (tons ha^{-1}) as influenced by fertigation and broadcast methods for phosphorus application in cotton

Treatment	2005	2006	Mean
P0 (Control)	2.2 e	2.6 d	2.4 e
P75 (Broadcast)	3.3 b	3.3 b	3.3 b
P30 (Fertigation)	2.5 d	3.1 c	2.8 d
P45 (Fertigation)	2.9 c	3.3 b	3.1 c
P60 (Fertigation)	3.3 b	3.4 b	3.4 b
P75 (Fertigation)	3.8 a	3.8 a	3.8 a

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

Table 2. Phosphorus concentration (g kg-1) in leaf at squaring stage as influenced by fertigation and broadcast methods for phosphorus application in cotton

Treatment	2005	2006	Mean
P0 (Control)	2.12 b	2.30 c	2.21c
P75 (Broadcast)	2.54 a	2.82 a	2.68 a
P30 (Fertigation)	2.38 ab	2.52 b	2.45 b
P45 (Fertigation)	2.41 ab	2.76 a	2.59 b
P60 (Fertigation)	2.53 a	2.80 a	2.67 a
P75 (Fertigation)	2.67 a	2.93 a	2.80 a

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

Agronomic efficiency

Agronomic efficiency is an important criterion, which helps in measuring the response of certain inputs in quantitative terms. The data presented in Table 3 showed that the agronomic efficiency was affected significantly by rates and methods of phosphorus application. The highest seed cotton harvest per kg of applied phosphorus was recorded with 75 kg fertigation phosphorus (18.2) and the lowest with 75 kg broadcast phosphorus (12.3). The fertigated-P enhanced the seed cotton yield, P-concentration and agronomic efficiency significantly over the broadcast method. This may be explained that a 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 and 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. In addition, the positive effect of fertigation may also be due to optimum moisture in the soil at appropriate time along with fertilization, which facilitated maximum utilization of applied phosphorus to crops (Stewart *et al.*, 2005).

Table 3. Agronomic efficiency (kg kg-1 P) as influenced by fertigation and broadcast methods for phosphorus application in cotton

Treatment	2005	2006	Mean
P0 (Control)	-	-	-
P75 (Broadcast)	14.5 bc	10.0 c	12.3 c
P30 (Fertigation)	10.0 c	16.7 a	13.4 c
P45 (Fertigation)	16.1 ab	14.7 ab	15.4 b
P60 (Fertigation)	18.3 ab	13.1 b	15.7 b
P75 (Fertigation)	20.5 a	15.8 ab	18.2 a

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

Conclusions

Consequent upon the field experimentation for two consecutive years with cotton, it may be inferred that the fertigation is the successful technique for elevating the seed cotton harvest and it would help the farmers get more returns compared with the conventional broadcast application of fertilizers.

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