Phosphorus application strategies to improve cotton productivity under arid climatic conditions

By

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Abstract

Field experiment was conducted at Research Farm of Central cotton Research Institute, Multan, Pakistan during the years 2008-2010, to evaluate the phosphorus application techniques for improving cotton productivity under the arid climatic conditions. The treatments consisted of two methods of phosphorus fertilizer application (band placement and fertigation) either applied as a full dose at pre-plant or in three splits i.e. at sowing, 30 and 45 days after planting of the crop. Phosphorus was applied @ 50 kg P_2O_5 ha^{-1} in the form of triple super phosphate. The design of the experiment was split plot (main: application method). The whole quantity of potassium and 1/3rd nitrogen was applied at sowing. The remaining quantity of nitrogen was applied at first flower and peak flowering phases. cotton cv. CIM-557 was used as a test crop. Standard production practices were followed during the season. Composite soil samples from plough layer (0-15cm) were collected before imposition of treatments. Seed cotton yield and its components differed significantly, due to both the method and time of P-application. Among the P-application methods, fertigation proved to be better by producing 15% more seed cotton yield than band placement of P. Similarly application of P in three splits, on an average, produced 9% more yield than the full dose applied at pre-plant. A comparison among the individual treatments revealed that the maximum seed cotton yield of 2152 kg ha^{-1} was produced where P-fertilizer was applied through fertigation in three split doses. Yield contributing parameters including number of bolls per plant and boll weight also remained higher where P was applied through fertigation in 3 splits. The application of P through fertigation in 3 splits resulted in the production of maximum number of fruiting positions and intact fruit per unit land area. Fruiting positions ranged from 340 to 396 m^{-2} and intact fruits from 94 to 130 m^{-2} in different treatments. Fruit shedding decreased in either of the application techniques and time of P-application. Fruit shedding ranged from 67.2 to 71.9 % in different treatments. Furthermore, fertigation of P in 3 splits proved to better than the other application techniques by maintaining more soil P-availability during the season, producing more dry matter yield, with high P concentration in different plant parts and concurrent increase in P-uptake by the cotton plant.

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Introduction

cotton is an important cash crop of Pakistan and livelihood of millions of people (directly or indirectly) depends upon its cultivation and processing. Production of cotton reached highest of all time by attaining 14.6 million bales in 2004-05. The production level declined afterwards and is fluctuating around 12.0 million bales. Thus there is a great need to arrest decline and achieve sustainability in cotton productivity. This could only be attained by optimizing the use of available resources. Chemical fertilizers have played a significant role to boost cotton yield in the country. Almost 50% increase in yield could be ascribed to this single most important agriculture input (Malik *et el.*, 1992). Besides other fertilizers phosphorus is a key element for cotton growth and yield. Phosphorus (P) is essential macronutrient and often referred to as "The Energizer" for its role in converting the sun energy into food, fuel and fiber. Phosphorus plays a vital role in photosynthesis, metabolism of sugars, energy storage and transfer, cell division, cell enlargement, and transfer of genetic information. Adequate P availability during plant growth, hastens maturity, and promotes early boll formation and development.

Apart from other factors that limit cotton yield, low soil P may also be one of the reasons for lower yields since 90% soils of Pakistan suffer from moderate to severe P deficiency (Malik *et al.*, 1984; Alam *et al.*, 1994). Phosphorus fertilizer is, therefore, very essential for exploiting maximum yield potentials of different crop plants (Rashid *et al.*, 1994).

Conventionally phosphatic fertilizers are recommended as broadcast application and incorporated into soil before sowing of crop (Malik *et al.*, 1996). The average recovery of fertilizer phosphorus by field crops seems to be very low and varies from 15-20 percent of applied P fertilizer (Ahmed *et al.*, 1996). This may be attributed to the reversion of low grade applied phosphates to less available forms such as carbonate apatite, hydroxyl apatite, flour apatite and chlorapatite by reacting with clays and calcium compounds (Brady and Weil, 2002). 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 later situation. Fertigation is a relatively new technique that involves application of plant nutrients through irrigation systems instead of the conventional broadcast method. The fixation processes are delayed when fertilizer is applied through fertigation as plants absorb the nutrient quickly and directly from the soil solution (Shah *et al.,* 2006). Furthermore, fertigation ensures the availability of soil moisture along with fertilizer at appropriate time and facilitates utilization of applied P by the crop (Stewart *et al.,* 2005). Fertigation is an effective mean that provides the flexibility to manage fertilizer application timing for maximum utilization during the cropping season.

The increasing costs of fertilizer emphasize the need to find appropriate methodology which may help to reduce P-fixation and increase utilization of added P-fertilizer. Therefore, field studies were conducted to evaluate the best method and timing of P fertilizer application for increased cotton productivity under the arid environment.

Materials and Methods

The experiment was conducted during the cropping seasons (2009-2010) at Central cotton Research Institute, Multan, Pakistan (latitude 30^0 12'N, longitude 71^0 28'E, altitude 123m). Composite soil samples were collected before imposition of treatments at the time of planting. The analyses of soil samples were carried out as described by Ryan *et al.* (2001). The soil was silt loam having alkaline reaction (pH 8.3). It contained 0.55% organic matter, 7.12 mg kg^{-1} available soil-P, and 133 mg kg^{-1} exchangeable soil-K in the top profile. The soil is porous friable, moderately calcareous, weakly structured, and developed in an arid sub-tropical continental climate in the area of sub- recent flood plains. The soil is alluvium of mixed mineralogy, with smectites and mica being dominant clay minerals, followed by kaolinites and chlorites with various degree of weathering. The soil belongs to Miani soil series and is classified as calcaric cambisols and fine silty, mixed hyperthermic fluventic haplocambids according to FAO (1990) and Soil Survey Staff (1998), respectively.

cotton cv. CIM-557 was planted during the first week of May keeping the space of 75cm between rows and 30 cm between plants. The treatments consisted of two methods of P-fertilizer application (band placement and fertigation) either applied as a full dose or in three splits i.e. at sowing, 30 and 45 days after planting of the crop. Phosphorus was applied @ 50 kg P_2O_5 ha^{-1} in the form of triple super phosphate. The design of the experiment was split plot (main: application method). A uniform dose of 50 kg K_2O ha^{-1} at planting and 150 kg N ha^{-1} in three splits, i.e., planting, flowering and peak flowering was applied in all experimental units. Standard production practices were followed during the season. Insect population was maintained below ETL by regular sprays of recommended pesticides.

The plants were harvested from $1m^2$ and portioned into leaf, stalk and fruit parts in the laboratory. The material was dried in a forced draft oven at 70°C and dry matter estimated on a per unit land area basis. The seed cotton was hand picked in each plot and total yield was calculated on the area basis. Data on number of bolls per plant and boll weight were recorded on 10 random plants selected at maturity stage from each treatment. Data were statistically analyzed according to methods described by Gomez and Gomez (1984).

Results and Discussion

Data pertaining to the average seed cotton yield and its components for two years differed significantly due to the method and time of P-application, either through band placement or fertigation. Maximum seed cotton yield of 2152 kg ha^{-1} was obtained where phosphorus fertilizer was applied through fertigation in three split doses. The values of seed cotton yield ranged from 1717 to 2152 kg ha^{-1} in various treatments. The average across application methods split dose produced about 9% more yield over full dose. Similarly average across application doses, fertigation produced 15% more yield over band placement. The increase in seed cotton yield occurred due to increase in number of bolls per plant and

boll weight (Table 1). These results are supported by the findings of Marcus-Wyner and Rains (1982) who reported that phosphorus is required in larger amounts by reproductive organs and has a significant effect on boll development, size and time to maturity. Fertigation of P has also been reported to increase yield of corn (Hussein, 2009) and grain yield of wheat (Farooq *et al.*, 1994; Latif *et al.*, 1997; Alam *et al.*, 2002, 2003). Interaction of application methods and timing of P application did not show any significant effects, demonstrating that the each treatment behaved in independent manner.

The application of P by fertigation in split doses resulted in the production of maximum number of fruiting positions and intact fruit per unit land area. Fruiting positions ranged from 340 to 496 m^{-2} and intact fruits from 94 to 130 m^{-2} in different treatments. Fruit shedding decreased in either of the application techniques and time of application. Fruit shedding ranged from 67.2 to 72.4% in different treatments (Table 2). Application of P through fertigation in 3 split doses rendered sufficient P available for plant acquisition and translocation of photosynthates to reproductive organs which helped the cotton plants not only to produce more fruiting points but also to retain more fruit than the other application methods. The results are in conformity to the findings of Ahmad *et al.* (2007). Phosphorus is known to play an important role in the energy metabolism of the plant cells and is required in large quantity by reproductive organs (Thelander and Silvertooth, 2000).

Table-1 Effect of different methods and time of application of phosphorus fertilizer on seed cotton yield and its components (average of two years)

Application Dose	Application Method		Mean
	Band Placement	Fertigation	
	Seed Cotton yield (kg ha^{-1})		
Full dose	1717	1976	1847
3 Split doses	1867	2152	2010
Mean	1792	2064	
LSD (p<0.01)	Application Method	Application dose	Interaction
	134.5**	97.7**	ns
	Number of bolls per plant		
Full dose	17	20	19
3 Split doses	19	22	21
Mean	18	21	
LSD (p<0.01)	Application Method	Application dose	Interaction
	2.49**	1.58**	ns
	Boll weight (g/boll)		
Full dose	2.41	2.47	2.44
3 Split doses	2.52	2.59	2.56
Mean	2.47	2.53	
LSD (p<0.01)	Application Method	Application dose	Interaction
	0.04**	0.07**	ns

Table -2 Effect of different methods and time of application of phosphorus fertilizer on fruit production at maturity (average of two years)

Application Dose	Application Method		Mean
	Band Placement	Fertigation	
	Total number of fruiting points (m^{-2})		
Full dose	340	377	358.5
3 Split doses	366	396	381.0
Mean	353	386.5	
LSD (p<0.01)	Application Method	Application dose	Interaction
	25.16*	14.82**	ns
	Total number of intact fruit (m-2)		
Full dose	94	118	106.0
3 Split doses	105	130	117.5
Mean	99.5	124.0	
LSD (p<0.01)	Application Method	Application dose	Interaction
	11.09*	10.69**	ns
	Fruit shedding percentage		
Full dose	72.4	68.7	70.6
3 Split doses	71.3	67.2	69.3
Mean	71.9	68.0	
LSD (p<0.01)	Application Method	Application dose	Interaction
	3.0*	3.65**	ns

Soil P status in different application methods was monitored during the season. Chemical analysis indicated that soil-P decreased with the age of crop, beyond 60 days after planting (DAP), in either of the application techniques. Split application of P either through band placement or fertigation method maintained higher soil-P status, up to 90 DAP i.e. peak P demand period of crop, compared with the full dose (Fig.1).

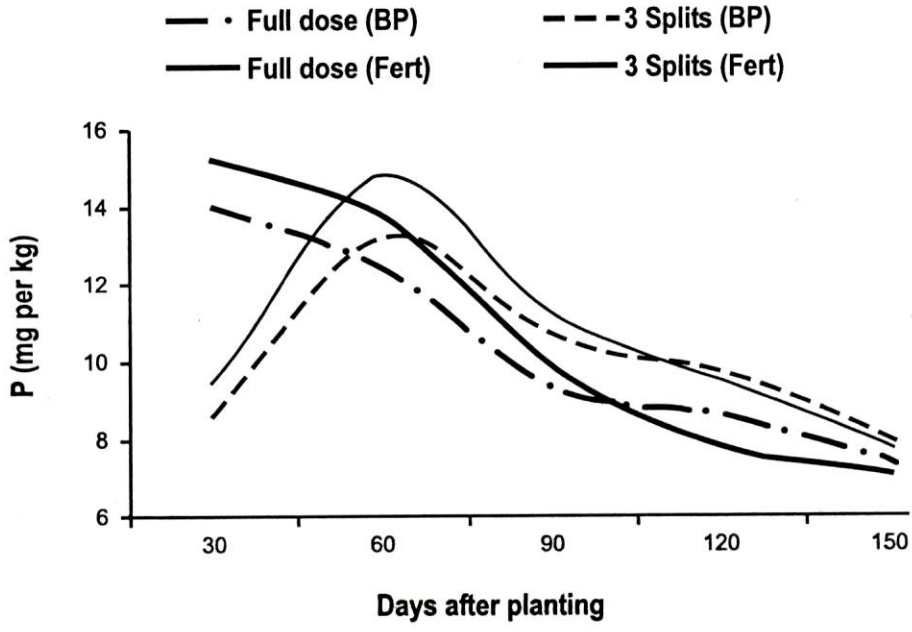

Fig. 1 Effect of different methods and time of application of phosphorus fertilizer on available soil-P during the cropping season

Results indicated that dry matter yield of leaves, stalk and fruit increased significantly with the application of fertilizer in either of the application techniques. Maximum total dry matter yield was produced where phosphorus fertilizer was applied through fertigation technique in three split doses. Values of total dry matter yield ranged from 860 to 978 g m^2 in different treatments (Fig. 2). The results are in conformity to those of Makhdum *et al.* (2001); Bibi *et al.* (2005) and Ahmad *et al.* (2007) who reported increase in total dry matter yield with the application of phosphorus to cotton.

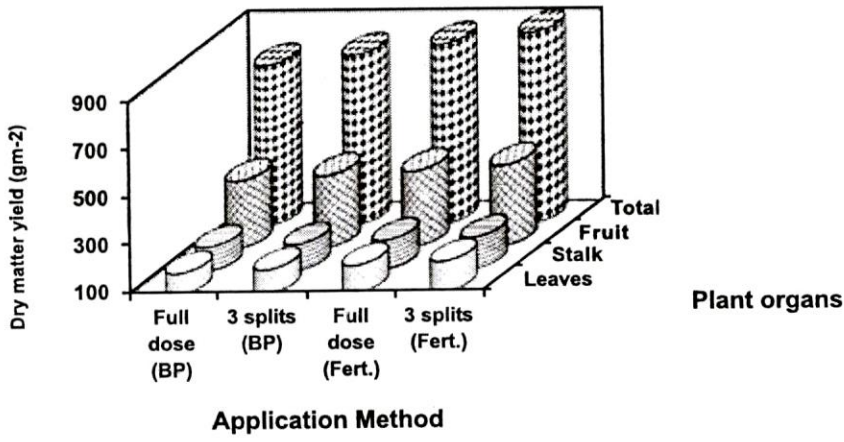

Fig. 2 Effect of different methods and time of application of phosphorus fertilizer on dry matter yield (g m^{-2}) at maturity

Phosphorus concentration in leaves, stalk, bur, seed and lint increased in either of the application method. Phosphorus concentration in different plant organs was higher in split fertigation technique compared with the other treatments. Phosphorus concentration in different plant organs was found in the order of seed > leaves > stalk > bur > lint (Fig.3). Application of P in split fertigation delayed fixation and plant absorbed this nutrient quickly and directly from the soil solution (Stewart *et al.*, 2005).

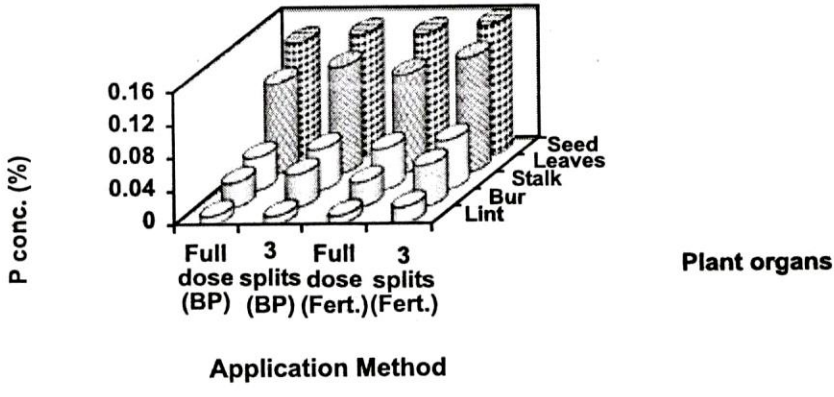

Fig. 3 Effect of different methods and time of application of phosphorus fertilizer on P concentration in plant organs at maturity

The highest P uptake by cotton plant in split fertigated plots indicates that sufficiently higher P remained available within and surrounding the rooting zones of the crop owing to lesser interaction of fertilizer P with alkaline earth carbonates and hence lesser sorption by the soil colloidal particles (Fig. 4). These results are in line with those reported by Shah et al. (2003).

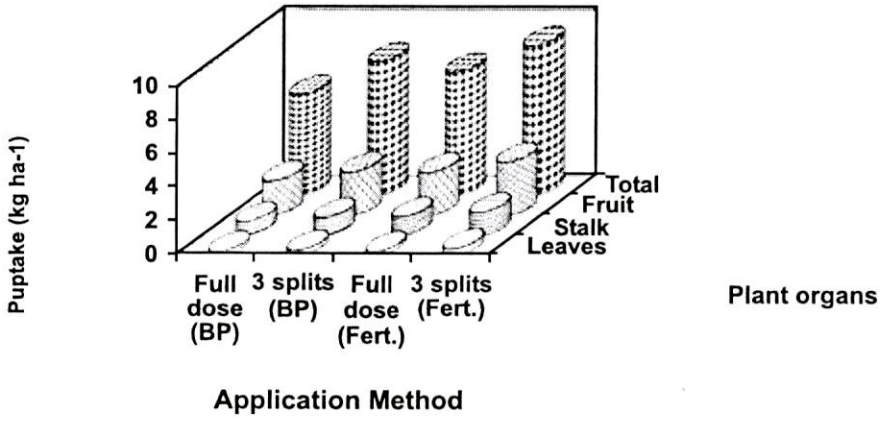

Fig. 4 Effect of different methods and time of application of P-fertilizer on P-uptake

Conclusion

Application of phosphorus fertilizer through fertigation in split doses proved to be most appropriate method as it caused significant increase in seed cotton yield, fruit production per unit area, dry biomass production and P-uptake by cotton plant as compared to other methods.

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