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Response of Wheat Crop to Phosphorus Levels and Application Methods

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ABSTRACT
A field study was carried out at New Developmental Farm of Khyber Pakhtunkhwa Agricultural University Peshawar, Pakistan during winter 2010-2011 to investigate the effect of phosphorus levels and application methods on yield and yield components of wheat. The experiment consisted of phosphorus levels (0, 50, 75, 100 and 125 kg ha^{-1}) and application methods (broadcast, single band and double band). Randomized complete block (RCB) design with split plot arrangements having four replications was used. Results indicated that application of phosphorus at the rate of 100 kg ha^{-1} through double band placement significantly ($P \leq 0.05$) enhanced plant height, productive tillers m^{-2}, grains $spike^{-1}$, 1000 grain weight, biological yield, grain yield, harvest index and agronomic phosphorus efficiency of wheat crop and reduced non productive tillers m^{-2} compared with other treatments.

Introduction
Wheat (*Trticum aestivum* L.), a member of family poaceae, is the cereal of choice in many countries of the world including Pakistan. It has been playing an important role in the development of civilization since time immemorial and is rightly known as the king of cereals. Wheat grain is directly or indirectly used in human diet and the straw is consumed as animal feed. Wheat is staple food for the people and meets the major dietary requirements, supplies about 73% of the calories and protein of the average diet (Heyan, 1987). A decrease in wheat production increases the miseries of the inhabitants and severely affects the economy of the country. Among the factors that control wheat yield, fertilizers play an important role. Application of fertilizer at proper time, in balance proportion and with appropriate method had a positive impact on crop yield (Nasir *et al.,* 1992; Alam *et al.*, 2002). Phosphorus deficiency is a yield reducing factor in fertilized soil, particularly soils high in calcium carbonate, which reduces phosphorus solubility (Ibrikei *et al.,* 2005). Phosphorus fertilizer as an important element in crop production is well established. Applied phosphatic fertilizer can only just move 3-5 cm in soil. Resultantly, it is 15-20% available to the plants (Camargo *et al.,* 2000). Phosphorus fertilizer banded with the seeds of wheat crop is generally superior to broadcasting in improving phosphorus uptake, especially at early growth stage (Matar & Brown, 1989). It has been reported that the ratio of root to fertilizer contact is a major factor in nutrient availability; the more roots come in contact with soil enriched in phosphorus, the greater is the supply of phosphorus to the plant, (Barber, 1974; Yao & Barber, 1986).

Keeping in view the significant role of phosphorus in crop production, this study was designed to find out the optimum level and best method of phosphorus application to improve yield and yield components of wheat crop.

Materials and Methods
The experiment was conducted at the New Developmental Farm of Khyber Pakhtunkhwa Agricultural University Peshawar, Pakistan during winter 2010-2011. Randomized complete block design with split plots arrangement having four replications was used. A sub plot size of 12 m^2 consisting of 10 rows of 4m length and 30cm row to row distance was maintained. Phosphorus levels (0, 50, 75, 100 and 125 kg ha^{-1}) were assigned to main plots and application methods (Broadcast, Single Band and Double Band) were kept in sub plots. Fertilizer was placed on one side of seed rows in single band and was placed on both sides of seed rows in double band at the time of sowing. SSP (18% P_2O_5) was used as source of phosphorus. Wheat (*cv.* Atta Habib) with seed rate of 120 kg ha^{-1} was sown.

Data were recorded on plant height, productive tillers m^{-2}, non productive tillers m^{-2}, grains $spike^{-1}$, thousand grains weight, biological yield, grain yield, harvest index and agronomic phosphorus efficiency (APE). Plant height was recorded by measuring height of ten randomly selected tillers from ground level to the tip of spike with the help of meter rod in each sub plot and then averaged. Productive and non productive tillers in one meter row length at three randomly selected places in each subplot were counted at physiological maturity and were converted to productive and non productive tillers m^{-2}. Number of grains $spike^{-1}$ was recorded by counting the grains of ten randomly selected spikes from each sub plot. Total grains were divided by 10 to get average number of grains $spike^{-1}$. Thousand grain weight was recorded by weighing thousand grains randomly taken from grain lot of each sub plot. For biological yield, six central rows from each subplot were harvested. The whole material was sun dried, weighed and converted in to kg ha^{-1} by using formula.

$$\text{Biological yield (kg ha}^{-1}) = \frac{\text{Biological yield}}{\text{R-R distance x row length x No. of rows}} \times 10000$$

Harvested six central rows from each sub plot were threshed, cleaned, weighed and converted into kg ha^{-1} by using the formula.

$$\text{Grain yield (kg ha}^{-1}) = \frac{\text{grain yield}}{\text{R-R distance x row length x No. of rows}} \times 10000$$

Harvest index was calculated by using the formula.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Agronomic phosphorus efficiency was calculated by using the formula out lined by Alam et al., (2003).

$$\text{APE} = \frac{\text{Yield in fertilized plot (kg ha}^{-1}) - \text{Yield in control plot (kg ha}^{-1})}{\text{Quantity of phosphorus applied (kg ha}^{-1})}$$

The data collected were subjected to analysis of variance according to the method described by Steel & Torrie (1979) and on obtaining significant differences least significant difference (LSD) test was applied at $p \leq 0.05$.

Results

Plant height (cm)

Statistical analysis of the data revealed that phosphorus levels, application methods and interaction between phosphorus levels and application methods had significantly ($p \leq 0.05$) affected plant height (Table 1). Highest plant height (101.56 cm) was attained when treated with 125 kg P_2O_5 ha^{-1} and at par with 75 and 100 kg P_2O_5 ha^{-1}. Lowest plant height (92.99 cm) was observed in the control treatments. In case of application methods, maximum plant height (100.65 cm) was recorded in double band phosphorus application as compared to the rest. Regarding interaction, plant height significantly ($p \leq 0.05$) enhanced with increase in phosphorus levels in broadcast, however, in single and double band placement, plant height increased up to 75 kg P_2O_5 ha^{-1} (Fig. 1).

Yield and yield components

Mean values of the showed significant ($p \leq 0.05$) effect of phosphorus levels and application methods on productive tillers m^{-2} of wheat while their interaction was non significantly ($p>0.05$) affected (Table 1). Maximum productive tillers m^{-2} (236.10) were recorded from 100 kg P_2O_5 ha^{-1} and statistically similar to 75 and 125 kg P_2O_5 ha^{-1}. Minimum productive tillers m^{-2} (199.64) were noted from the control plots. In case of application methods, more productive tillers m^{-2} (227.42) were recorded from double band P application and statistically at par with broadcast method. Less productive tillers m^{-2} (214.11) were recorded from single band P application. Analysis of the data indicated that phosphorus levels and application methods had a significant ($p \leq 0.05$) effect on non-productive tillers m^{-2} while their interaction showed non significant ($p>0.05$) effect (Table 1). Minimum non productive tillers m^{-2} (32.74) were recorded from 100 kg P_2O_5 ha^{-1} which was statistically at par with 75 and 125 kg P_2O_5 ha^{-1}. While maximum non productive tillers m^{-2} (46.55) were recorded from control. In terms of application methods, less number of non productive tillers m^{-2} (34.72) were noted from double band applied plots when compared with the rest. Table 2 revealed significant ($p \leq 0.05$) effect of phosphorus levels and application methods on number of grains $spike^{-1}$of wheat while interaction between phosphorus levels and application methods was non significant ($p>0.05$). Maximum grains $spike^{-1}$ (52.31) was recorded from 100 kg P_2O_5 ha^{-1} followed by 125 kg P_2O_5 ha^{-1}. Minimum grains $spike^{-1}$ (37.26) was observed from the control. In terms of application methods, highest grains $spike^{-1}$ (48.68) was produced by treatments of double banded phosphorus as compare to broadcast and single band. Significant ($p \leq 0.05$) effect of phosphorus levels and application methods on thousand grain weight of wheat was noted (Table 2). Interaction of phosphorus levels and their application methods was non significant ($p>0.05$). Heavier grains (44.50 g) were recorded from 100 kg P_2O_5 ha^{-1} and lighter grains (28.34 g) were noted from control. In case of application methods, more thousand grain weight (40.24 g) was recorded from double band phosphorus application and less (31.81 g) from single banded phosphorus application.

Grain yield of wheat is significantly ($p \leq 0.05$) affected by phosphorus and application methods (Table 2), while their interaction remained non significant ($p > 0.05$). Maximum grain yield (4172.11 kg ha^{-1}) was produced from 100 kg P_2O_5 ha^{-1} followed by 125 kg P_2O_5 ha^{-1}. Minimum grain yield (2509.89 kg ha^{-1}) was recorded from control. In case of application methods, more grain yield (3909.63 kg ha^{-1}) was recorded from double band phosphorus application when compared with rest. Phosphorus levels, application methods and their interaction had a significant ($p \leq 0.05$) effect on biological yield (Table 1). Maximum biological yield (9108.12 kg ha^{-1}) was produced by 100 kg P_2O_5 ha^{-1} which was statistically at par with 75 and 125 kg P_2O_5 ha^{-1}. Minimum biological yield (6124.97 kg ha^{-1}) was recorded from control. In case of application methods, highest biological yield (8444.14 kg ha^{-1}) was noted from double band placement which was at par with broadcast. Lowest biological yield (7635.87 kg ha^{-1}) was recorded from single band application. Biological yield increased with increasing P levels up to 100 kg ha^{-1} in all application methods, while no considerable increase occurred with further increase in P rate in any application method (Fig 1). Analysis of the data revealed that phosphorus levels and application methods showed significant ($p \leq 0.05$) effect on harvest index while interactions between phosphorus levels and the effect of application methods was non significant ($p>0.05$) (Table 2). Highest harvest index (45.64%) was recorded from 100 kg P_2O_5 ha^{-1} and least from 50 kg P_2O_5 ha^{-1} which was statistically similar with control. Maximum harvest index (45.90%) was noted from double band phosphorus application.

Agronomic phosphorus efficiency

Table 2. revealed significant ($p \leq 0.05$) effect of phosphorus levels and application methods on agronomic phosphorus efficiency while their interaction remained non significant ($p>0.05$). Maximum agronomic phosphorus efficiency (16.62) was observed from 100 kg P_2O_5 ha^{-1} and minimum (10.84) was recorded from 50 kg P_2O_5 ha^{-1}. Regarding application methods, highest agronomic phosphorus efficiency (20.37) was noted from double band phosphorus application and lower (7.95) from single band application method.

Table 1. Growth response of wheat as affected by phosphorus levels and application methods.

Phosphorus levels (kg ha^{-1})	Plant height (cm)	Productive tillers m^{-2}	Non productive tillers m^{-2}	Biological yield (kg ha^{-1})
0	92.9c	199.6b	46.5a	6125.0c
50	97.4b	208.0b	38.9ab	7616.1b
75	100.8a	232.1a	35.9b	8835.4a
100	101.5a	236.1a	32.7b	9108.1a
125	101.6a	232.3a	35.0b	8869.3a
Application methods				
Broadcast	99.5a	223.3ab	37.1ab	8252.3a
Single band	96.4b	214.1b	41.7a	7635.9b
Double band	100.7a	227.4a	34.7b	8444.1a
LSD $_{(0.05)}$ for P	2.5	22.5	8.9	434.1
LSD $_{(0.05)}$ for M	1.8	11.1	6.6	494.8
P x M	*	ns	ns	*

*represents significant & ns represents non significant P and M represents phosphorus levels and application methods respectively. Means of same category followed by same letters are not significantly different at $p \leq 0.05$ using LSD test.

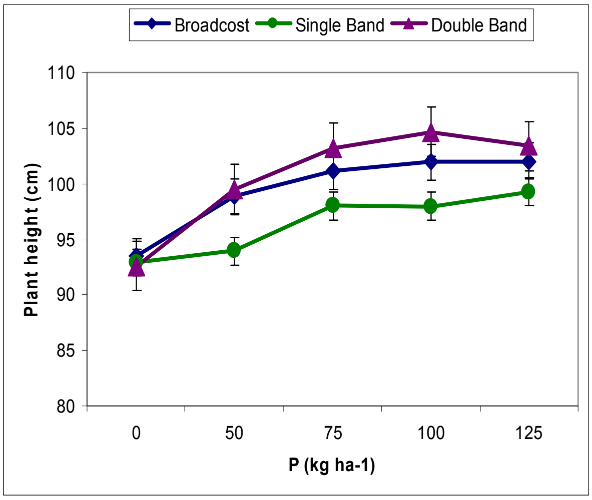

Fig. 1. Plant height of wheat as affected by phosphorus levels and application methods

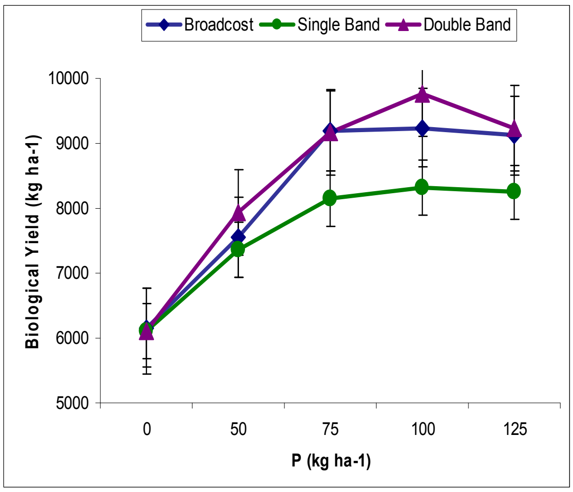

Fig. 2. Biological yield of wheat as affected by phosphorus levels and application methods

Table 2. yield of wheat as affected by phosphorus levels and application methods.

Phosphorus levels (kg ha^{-1})	Grains spike^{-1}	Thousand grains weight (g)	Grain yield (kg ha^{-1})	Harvest index	APE
0	37.3c	28.3c	2509.9d	40.9ab	-
50	42.2b	30.8bc	3051.8c	39.9b	10.8b
75	44.4bc	33.5bc	3619.3b	40.8ab	14.8ab
100	52.3a	44.5a	4172.1a	45.6a	16.6a
125	47.4ab	40.4ab	3948.6ab	44.3ab	11.5ab
Application methods					
Broadcast	43.8ab	34.5b	3383.7b	40.8b	12.0b
Single band	41.7b	31.8b	3087.8b	40.2b	7.9b
Double band	48.7a	40.2a	3909.6a	45.9a	20.4a
LSD $_{(0.05)}$ for P	7.7	10.8	534.2	5.4	8.3
LSD $_{(0.05)}$ for M	5.1	5.5	518.6	4.3	8.3
P x M	ns	ns	ns	ns	ns

* represents significant & ns represents non significant P and M represents phosphorus levels and application methods respectively. Means of same category followed by same letters are not significantly different at $p \leq 0.05$ using LSD test.

Discussion

Plant height was significantly affected by different phosphorus levels, application methods and their interactions. Taller plants were recorded in 125 kg P_2O_5 ha^{-1} through double band phosphorus application. Hussain *et al.,* (2008) stated that wheat crop with 120 kg P_2O_5 ha^{-1} produced taller plants. Similarly, Rahim *et al.,* (2010) found that plant height of wheat significantly increased with phosphorus application through band placement as compared to broadcast method of application. Maximum productive and minimum non productive tillers m^{-2} were recorded from 100 kg P_2O_5 ha^{-1} when applied through double band placement method, and minimum were recorded from control. Our results are in conformity with Jiand *et al.,* (2006) and Rahim *et al.,* (2010) who reported that number of productive tillers m^{-2} were influenced significantly with phosphorus application. Phosphorus application through intra row drilling technique gave maximum number of productive tillers m^{-2} (Ali *et al.,* 2004). Grains spike^{-1} and thousand grain weight were significantly affected by phosphorus levels and application methods while their interaction had a non significant effect. Maximum grains spike^{-1} and thousand grain weight was produced by plants that received 100 and 125 kg P_2O_5 ha^{-1} through double band placement method as compared to rest. Our results are supported by Rahim *et al.,* (2010) who stated that number of grains spike^{-1} and thousand grain weight significantly increased with phosphorus application through band placement as compared to broadcasting. Optimum application of phosphorus increased number of grains spike^{-1} and thousand grain weight of wheat (Zhang *et al.,* 1999). Similarly, Turk & Tawaha (2001) observed that thousand grain weight of wheat was significantly increased with band placement than broadcast method of phosphorus application. Contrasting results are reported by Hussain *et al.,* (2008) who found non significant effect of phosphatic fertilizer on grains spike^{-1} while significant effect on thousand grain weight of wheat. Grain yield was significantly affected by phosphorus levels and application methods while their interaction showed non significant effect. Maximum grain yield was recorded for 100 kg P_2O_5 ha^{-1} when applied through double band application method as compared to control. Similar results were also obtained by Kaleem *et al.,* (2009) and Khan *et al.,* (2010) who found that grain yield of wheat significantly increased with phosphorus application. Our results are further supported by Ali *et al.,* (2004) who concluded that maximum grain yield was obtained where phosphorus was applied at 114 kg ha^{-1} by intra row drilling technique. Grain yield of wheat significantly increased with band placement than broadcast method of phosphorus application (Turk & Tawaha 2001; Hussain *et al.,* 2008; Rahim *et al.,* 2010) Likewise, Gokman & Sencar (1999) found that application method significantly affected the grain yield of wheat and higher grain yield was obtained from band application of phosphorus 5 cm below the seed than broadcast application. Biological yield was significantly affected by phosphorus levels, application methods and their interaction. Maximum biological yield was noted for 100 kg P_2O_5 ha^{-1} when applied through double band placement method while minimum from control. Similar results were recorded by Khan *et al.,* (2010) who revealed that biological yield of wheat was significantly affected by different phosphorus sources and increased with increasing phosphorus levels. Similarly, Hussain *et al.,* (2008) found that early sowing of wheat with 120 kg P_2O_5 ha^{-1} by band placement significantly increased biological yield. Jiang *et al.,* (2006) found 108 kg P_2O_5 ha^{-1} best for higher biological yield of wheat. Our results are further supported by Alam *et al.,* (2003) who reported that application of phosphorus, method of application and their interaction significantly affected the straw yield of wheat. Harvest index was significantly affected by phosphorus levels and application methods. Maximum harvest index was recorded from 100 kg P_2O_5 ha^{-1} through double band placement. Our results are in conformity with Alam *et al.,* (2003) who observed that applications of phosphorus significantly affected the harvest index of wheat crop. However, contrasting results are reported by Hussain *et al.,*

(2008) who found non significant affect of different levels of phosphorus on harvest index of wheat. Agronomic phosphorus efficiency was significantly affected by phosphorus levels and application methods. Highest agronomic phosphorus efficiency was recorded for 100 kg P_2O_5 ha^{-1}. In case of application methods, maximum agronomic efficiency was recorded from phosphorus received through double band placement. Minimum agronomic phosphorus efficiency was observed from phosphorus applied through single band application method. Rahim *et al.,* (2010) concluded that application of phosphorus fertilizer through band placement significantly enhanced the agronomic phosphorus efficiency as compared to broadcast. The phosphorus application method and rate of phosphorus applied significantly enhances the PUE of wheat (Latif *et al.,* 1997; Alam *et al.,* 2003 & 2005). Greater phosphorus uptake was observed from banded rather than broadcast due to an increase in the probability of contact between fertilizer and roots (Matar & Brown, 1989).

Conclusion

It can be concluded from the results that 100 kg P_2O_5 ha^{-1} when applied through double band placement method significantly enhanced productive tillers, biological yield, grains $spike^{-1}$, thousand grain weight, grain yield and harvest index of wheat.

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