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Research Article

Efficacy of different methods of phosphorous and potassium fertilizer application on wheat grain yield in relation to agronomic efficiency

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Keywords

phosphorous and potassium;
application methods;
yield;
agronomic efficiency;
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Abstract

A field study was conducted at Adaptive Research Farm, Veharito investigate the efficacy of different methods of phosphorous and potassium fertilizer application on wheat grain yield in relation to agronomic efficiency in accordance with RCBD replicated thrice during 2009-10 and 2010-11.The treatments were (T_1) control, (T_2) Manual broadcasting of P and K fertilizer, (T_3) Broadcasting of P and K fertilizer with spreader and (T_4) Application of P and K fertilizer with band placement drill. Two years data revealed that productive tillers m^{-2} (325 and 341), grain yield (4.42 t ha^{-1} and 4.43t ha^{-1}) and agronomic efficiency (9.14 and 9.06 kg grain yield/kg PK applied) were recorded maximum in plots where P and K (114-62 kg ha^{-1}) was applied with band placement drill followed by productive tillers m^{-2} (314 and 321), grain yield (4.37 t $ha^{-1}$and 4.38t ha^{-1})and agronomic efficiency (8.86 and 8.77 kg grain yield/kg PK applied) from the plots where P and K were applied with spreader during 2009-10 and 2010-11, respectively. The lowest grain yield of 4.22 t $ha^{-1}$and 4.23t ha^{-1} and agronomic efficiency (8.01 and 7.94 kg grain yield/kg PK applied) was produced where manual broadcasting of P and K was carried out. Highest net return and benefit cost ratio (BCR) (Rs. 2626 and 2.25) were obtained with band placement drill for application of P and K followed by Rs. 1415 and 1.67 where spreader was used. Significant relationship (R^2= 1 and 0.999) was found between agronomic efficiency and wheat grain yield.

Introduction

Wheat is staple diet of communities living in Pakistan. In order to continue its adequate supply, it is mandatory to improve per acre yield of the crop. Among the plant nutrients, phosphorous (P) is critical to improve the yield of wheat as over 90 % soils in Pakistan are low in available P (Ahmed *et al.,* 1992). Moreover, with the passage of time, the adsorption of P gets firmer thus creating difficulties in release to soil solutions. Consequently, efficiency of fertilizer P in calcareous soils remains comparatively low (Delgado *et al.,* 2002). The recommended method of application in Pakistan is to broadcast fertilizer on the surface of the soil, followed by incorporation, before seeding of the crop. This practice enhances the conversion of soluble P to insoluble forms because of wider contact between soil particles and P (Malik *et al.,* 1992; Shah *et al.,* 2006).The seed-cum-fertilizer drills currently used inPakistan place fertilizer either too far from the seed or in direct contact with it. The crop roots utilize fertilizer very effectively, as 60-70% of the applied phosphate is utilized by wheat crop. Field experiments have confirmed that this drill saves 50% phosphate fertilizer compared with broadcast method. In addition, about 10% more grain

yield was obtained in plots where 50% fertilizer doze (18 kg P_2O_5/acre) was band placed using this drill than where full recommended phosphate doze (36 kg P_2O_5/acre) was applied through broadcast. An economic comparison of fertilizer band placement technology and the currently recommended

broadcast method of fertilizer application revealed that farmer can get a benefit of Rs 3252/ha by adopting fertilizer band placement technology for wheat (Ahmad, *et al*., 2004).

Phosphate availability in Pakistani soils is reduced due to alkaline soil conditions (pH > 7), high calcium contents (> 3 % $CaCO_3$), and large amount of calcium saturated clay. To maintain a given level of available phosphorus, it is necessary to apply adequate quantities of phosphatic fertilizers into the soil(NDFC, 2003). The agronomic practices that influence the efficiency of applied fertilizer, time and method of application are of significant importance. There is need to make P fertilizer recommendations site specific as well as crop specific on scientific basis (Ahmed *et al.*, 1992). Nisar (1985)reported that the utilization efficiency of phosphatic fertilizer by crops is very low and the recovery is also from15 to 25%.One of the reactions leading to phosphorus retention in calcareous soils is fixation of phosphate by clay of 1:1 type saturated with calcium(Tisdale *et al*., 1997). However, the soils of Pakistan contain2:1 type clay and phosphorus fixation capacity of these soils is not reported phosphorus fixing capacity (Memon& Fox,1983; Nisar, 1988). However, low P requirement within creasing clay content may be due to the buffering capacity of clay soil, which renews the P concentration in solution(Olsen & Watanab, 1970).In Pakistan, phosphate fertilizer in wheat is conventionally applied by broadcast method before sowing crop. This is a wasteful method of fertilizer application as only 15-25% of the applied phosphate is utilized by wheat crop.

P and K fertilizers should be applied at the time of seeding wheat. If these immobile nutrients are applied after planting, uptake can be hindered. The reason for this is that P and K will tend to remain above the rooting zone and thus will not be available for uptake. Broadcasting consists of uniformly distributing dry or liquid materials over the soil surface, usually before sowing. The fertilizer maybe incorporated into the soil mechanically, or left on the surface to be washed in by rainfall or irrigation (CFA, 1995). Incorporation into the Ap horizon can be by harrow(2-3 cm depth), a cultivator (4-6 cm depth) or by plough (incorporation to plough depth) (Finck, 1982). Broadcasting is the simplest and cheapestmethod and is best suited for high-speed operations and heavy application rates, especially before planting. P and K can be applied manually, trained workers achieving approximately the correct amount and uniform application. A more advanced method consists in small portable centrifugal distributors operated by hand (Finck, 1982). Problem ofK fixation can be reduced to some extent and efficiency improved by different K application methods and their time of application may affect the K recovery. Plants meet part of their K requirements from non-exchangeable pool. Also the K release rate may not keep pace with plant uptake(Grimme, 1974, Rahmatullah *et aI.,* 1996*).* The potential benefits of providing sufficient P and K for wheat, as well as other plants, often include promoting early plant maturity, resistance to diseases and other pests, stalk strength, tillering, vigorous growth, and improved yield (Slaton *et al.,*2007*).*

.In order to achieve maximum efficiency, K fertilizer may be applied in localized bands at or just prior to planting. However, when not accurate, band placement can produce a large concentration of soluble salts in the deposition zone, leading to decreased germination and plant emergence due to severe plasmolysis (Mortdvedt *et al*., 1999). Fertilizer placed in a band below (5 cm)and to the side (5 cm) of the seed usually causes less damage during germination and seedling roots develop normally. Within a short period (2weeks) and with enough soil moisture, the salt in and around the band diffuses into a larger volume of soil so that any hazard to plants no longer exists (Follet *et al*., 1981; Finck, 1982). The safe quantity of K that can be band placed depends on the crop. Fertilizer can be applied with the seed by a double-disc or similar drill that places the seed and fertilizer in a very narrow band (Follet *et al*., 1981; Finck,1982).Band placement of K can be more efficient than broadcasting, especially where soil test levels are low, where early season stress from cool or wet conditions is likely to limit root growth and K uptake and for soils likely to fix a large proportion of the added K. A higher efficiency for banded rather than broadcast K for corn was reported, but the differences decreased as thesoil test level of K increased (Follet *et al*., 1981). Other data for corn show that broadcast K was 33 to 88% as efficient as banded K when the soils tested low to medium in available K (Welch *et al*., 1966).Banding of KCl is widely practiced under no-till management. The response to banded KCl was twice as large for no-till corn as for corn grown after fall plowing (Vyn*et al.*, 1999).Modern fertilizer spreaders range from simple centrifugal types with broadcasting widths of 24 m and more, to expensive pneumatic spreaders where each outlet accurately spreads over 2 to 3 m (Möller and Svensson, 1991). Wide-sweep or full-width distributors can be of the box type or centrifugal. In the drop or box-type distributor the fertilizer drops by gravity through the distributing device operated by slots, an endless-chain ,rotating plates or grids at the bottom of the box. This type of distributor suits either fine or granulated fertilizers, and applies a fairly exact pattern limited to the distance between the wheels. The main disadvantage is the small working width, up to 5 m (McCarty and Sartain, 1995; Finck, 1982). In the centrifugal, rotary or cyclone distributor, the fertilizer drops from a conical173container onto a high-speed rotary disk with throwing bars. A baffle plate ensures that the fertilizer is spread in a semicircle only to the rear. The main advantage is the larger working width (12-14 m). The main disadvantages are that only granulated fertilizers can be spread; and they are harder to calibrate because heavier fertilizer particles are thrown farther away from the spreader(McCarty and Sartain, 1995; Finck, 1982).Another type of distributor is the row distributor for precise application in plant rows using pneumatic systems (Svensson, 1994).Ali *et al*. 2005 concluded band placement in furrows registered maximum agronomic efficiency of rice cv. 385.

At times, the indiscriminate and improper application with unfavorable conditions may not provide adequate nutrients supply because of its poor absorption and translocation in plant system. Therefore, there is an imperative need to provide the required nutrients through fertilization by appropriate method for which an attempt was made to assess the efficiency of PK nutrition by various methods in cotton-wheat cropping system of southern Punjab.

Materials and Methods

A field study was conducted at Adaptive Research Farm, Vehari to determine the influence of different methods of phosphorous (P) and potassium (K) application on the wheat grain yield in relation to agronomic efficiency for variety Sehar-2006 when sown on November, 20 and November, 14 during 2009-10 to 2010-11. The experiment was laid out in randomized complete block design with three replications, using plot size of 8x20 m. The treatments were (T_1) control, (T_2) Manual broadcasting of P and K fertilizer, (T_3) Broadcasting of P and K fertilizer with spreader and (T_4) Application of P and K fertilizer with band placement drill. Recommended dose of N-P-K fertilizer (128-114-62 kg ha^{-1}) was applied. Nitrogen and potassium were used as urea and sulphate of potash, respectively. Full P, K and half of N were applied at sowing while remaining N with first irrigation. Soil texture of the experimental site was clay loam and the chemical analysis of soil is given in Table-1. Meteorological data regarding temperature (^{0}C) and rainfall (mm) recorded during crop growth period for 2009-10 to 2010-11 is presented in Table-2. The row to row spacing was maintained as 22.5 cm using seed rate of 125 kg ha^{-1}. All other agronomic/cultural practices and plant protection measures were kept uniform for all the treatments. Productive tillers were determined from an area of one square meter marked randomly at three different locations in each plot. Wheat bundles of each sub plot were threshed with thresher and average grain yield and straw yield was recorded in kg $plot^{-1}$ and then converted into t ha^{-1}. Harvest index was calculated by using the following formula:

$$H.I = \frac{\text{Grain yield (t. ha}^{-1})}{\text{Biological yield (t. ha}^{-1})} \times 100$$

Agronomic efficiency was calculated using the experimental data as given by following formulae (Novoa and Loomis,1981).

$$\text{Agronomic Efficiency} = \frac{\text{Yield } \textit{(fertilized plot)} - \text{Yield } \textit{(unfertilized plot)}}{\text{K } \textit{applied}}$$

Recorded data were analyzed statistically according to the appropriate method for RCBD. Least Significance Difference test was applied to signify the treatment difference at 5% level of probability (Gomez and Gomez, 1984).

Table-1 Soil characteristics of experimental site

Characteristic	Unit	Value
Organic matter	%	0.57
Total nitrogen	%	0.037
Available phosphorous	ppm	1.82
Available potassium	ppm	143
pH	-	8.61
ECe	dSm^{-1}	1.82
Soil textural class	-	Clay loam

Table-2 Monthly mean maximum and minimum temperatures (^{o}C) and rainfall (mm) during crop growth period in 2009-10 and 2010-11.

Month	Temperature(^{o}C)				Rainfall (mm)	
	Max.	Min.	Max.	Min.		
	2009-10		2010-11		2009-10	2010-11
November	25.30	13.50	25.76	15.96	-	-
December	18.51	12.06	17.87	6.29	-	4
January	13.13	4.97	14.74	4.77	1	-
February	21.03	7.39	19.35	7.21	4	3
March	29.06	16.21	24.33	12.90	-	3
April	36.53	23.43	32.7	19.53	-	8.5

Results and Discussion

Yield and yield components: Different application methods of phosphorous (P) and potassium (K) influenced significantly the productive tillers m^{-2} during both the years of study (Table-3 and 4). The data indicated that maximum productive tillers of 325 and 341 were recorded in plots where band placement drill was used for application of P and K (114-62 kg ha^{-1}) followed by 314 and 321 when P and K was applied with spreader as against the minimum productive tillers of 282 and 291 from the plots where broadcasting of P and K was executed manually during 2009-10 and 2010-11, respectively. However productive tillers were statistically superior to that of control treatment. Fertilization with K results in more luxury consumption than with other nutrients causing healthy growth of crop plants.

The final yield of wheat is directly proportional to the productive tillers at harvest. During second year of study more number of tillers were noted might be due to more favourable agro climatic conditions. The experimental soil contained less amount of organic matter and had less N supplying capacity and more P in fixed form due to calcareousness. The agronomic practices that influenced the efficiency of applied fertilizer and method of application are of significant importance. The increased tillers led to establish a fact that superiority of band placement was probably due to better fertilizer efficiency as developing roots are in intimate contact with P – enriched soil adjacent to fertilizer granules. Turk and Tawaha (2001) reported that grain yield and total number of tillers m^{-2} were significantly greater with band placement than with broadcast method of P application.

The differences in grain yield with different application methods of phosphorous (P) and potassium (K) were significant during both the study years (Table-3 and Table-4). Data showed that maximum grain yield of 4.42 t ha^{-1} and 4.43t ha^{-1}were recorded in plots where band placement drill was used for application of P and K (114-62 kg ha^{-1}) followed by 4.37 and 4.38t$ha^{-1}$when P and K was applied with spreader as against the minimum grain yield of 4.22 and 4.23t $ha^{-1}$from the plots where broadcasting of P and K was executed manually during 2009-10and 2010-11, respectively. From the perusal of data it was found that higher grain yield were recorded during 2010-11 as compared to 2009-10 which might be due to favourable agro- climatic conditions which favored crop growth and grain development. Different PK application methods significantly affected grain, straw and biological yields of wheat (Table 3 and 4).

However the trend of result among different treatments during both the study years was the same except straw and biological yield obtained maximum from the plots where PK was applied with spreader. Response of P and K in terms of grain yield was improved significantly when it was applied with band placement drill. Dhindwal *et al.* (1992)reported that P and K application markedly increased wheat grain yield in normal soils with band placement method. The results are also in line with the findings of Malik *et al.,* 1992; Shah *et al.,* 2006 and Ahmad *et al*., 2004.

Table-3Efficacy of different methods of phosphorous and potassium fertilizer application on productive tillers, grain, straw, biological yield, harvest index and agronomic efficiency during 2009-10.

P – K application methods	Productive tillers (m-2)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield(t ha^{-1})	Harvest index%	Agronomic efficiency (kg seed cotton/kg PK)
Control	235 d	2.81d	3.22d	6.03d	46.60d	-
Broadcasting PK Manually	282c	4.22c	4.61b	8.83c	47.79c	8.01c
Broadcasting PK with spreader	314b	4.37b	4.66a	9.03a	48.39b	8.86b
PK Band placed	325a	4.42a	4.48 c	8.90b	49.66a	9.14a
$LSD_{(0.05)}$	9.50	0.032	0.041	0.12	0.15	0.26

Any two means not sharing a letter in common differ significantly ($p \leq 0.05$)
Recommended dose of N-P-K fertilizer (128-114-62 kg ha^{-1}).

Table-4Efficacy of different methods of phosphorous and potassium fertilizer application on productive tillers, grain, straw, biological yield, harvest index and agronomic efficiency during 2010-11.

P – K application methods	Productive tillers (m-2	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield(t ha^{-1})	Harvest index%	Agronomic efficiency(kg seed cotton/kg PK)
Control	240 d	2.83d	3.29d	6.12c	46.24d	-
Broadcasting PK Manually	291c	4.23c	4.65b	8.88b	47.63c	7.94c
Broadcasting PK with spreader	321b	4.38b	4.73a	9.11a	48.02b	8.77b
PK Band placed	341a	4.43a	4.52 c	8.95b	49.50a	9.06a
$LSD_{(0.05)}$	11.50	0.033	0.045	0.14	0.24	0.22

Any two means not sharing a letter in common differ significantly ($p \leq 0.05$)
Recommended dose of N-P-K fertilizer (128-114-62 kg ha^{-1}).

Harvest index and Agronomic efficiency: Harvest index and agronomic efficiency was significantly affected by P, K placement methods (Table 3 and 4). The highest Harvest index of 49.66 and 49.50% was calculated when PK was applied through and placement drill followed by 48.39 and 48.02% from spreader as against minimum from broad casting manually among three placement methods. However statistically lowest harvest index was recorded from control plot. The maximum agronomic efficiency of 9.14 and 9.06 was calculated when PK was applied through band placement drill followed by 8.86 and 8.77 from spreader as against minimum (8.01 and 7.94)from broadcasting manually among three placement methods. The positive response of PK application on crops has been reported by Ali *et al*. 2005.Similarly data in figure 1 and 2 indicated a significant relationship (R^2=1 and0.999) between agronomic efficiency and wheat grain yield.

Fig. 1 Relationship between agronomic efficiency and wheat grain yield during 2009-10

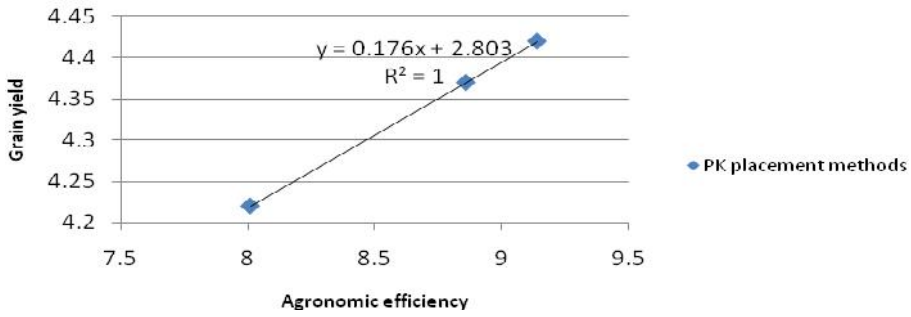
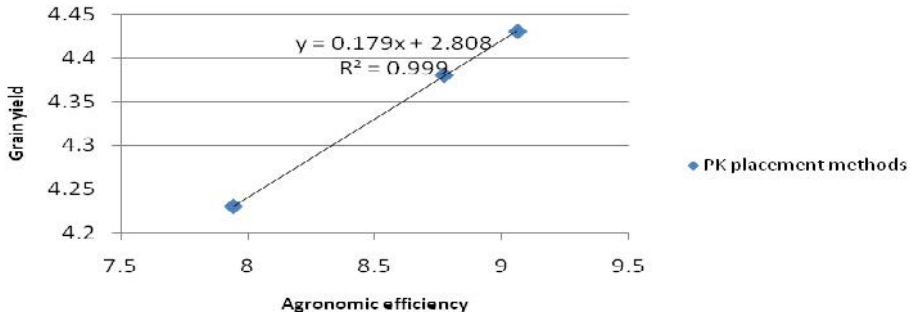


Fig. 2 Relationship between agronomic efficiency and wheat grain yield during 2010-11



Economic Analysis: From the figures presented in Table-5 for average grain yield data of both the study years, it was concluded that highest net return/BCR (Rs. 2626/2.25) was obtained where band placement drill was used for application of P and K (114-62 kg ha^{-1}) followed by Rs. 1415/1.67 where spreader was used. An economic comparison of fertilizer band placement technology and the currently recommended broadcast method of fertilizer application revealed that farmer can get a benefit of Rs 3252/ha by adopting fertilizer band placement technology for wheat (Ahmad, *et al*., 2004).

Table-5 Economic analysis of the effect of different methods of phosphorous and potassium application on wheat crop

NPK (kg ha^{-1})	Av. grain yield (kg ha^{-1})	Yield increase over control	Value of increased yield(Rs.)	Total Cost (Rs.)	Additional cost(Rs.)	Net return (Rs.)	BCR
Broadcasting Manually	4224	-	-	370	-		
Broadcasting with spreader	4372	148	3515	2470	2100	1415	1.67
Band placement drill	4423	199	4726	2470	2100	2626	2.25

Wheat grain rate = Rs. 23.75/kg
Broadcast 0.5 man day/acre =150
Spreader/acre =Rs.1000
Band placement/acre = Rs.1000

Conclusion

It may be concluded that PK application methods influenced yield , harvest index and agronomic efficiency significantly. Band placement resulted in improved agronomic efficiency as compared to rest methods. Thus application of P and K fertilizer with band placement may contribute to increase wheat grain yield.

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