Pre-plant and Placement Method for Efficient Use of P-Fertilizer in Wheat Crop

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Abstract: Poor use efficiency of phosphorus is one of the major causes to lower the yield of wheat crop. Time and method of P_2O_5 application influence the degree of responsiveness. Therefore, an investigation was carried out under field conditions to compare three times (pre-plant, at 1st irrigation and at 2nd irrigation) and two methods (broad cast and placement) of P_2O_5 applications for wheat grown in three cropping zones (central, cotton and thal zone) of Punjab province of Pakistan. The division of zones is based on agro-climatic conditions and cropping pattern followed by the farmers. The hypothesis was made to suggest best time and method of P_2O_5 application in order to enhance its use efficiency. The experiments were chalked out by applying recommended dose of N, P_2O_5 and K_2O @160, 114 and 62 Kg ha^{-1} in all treatments except control throughout study. The sources of N, P_2O_5 & K_2O were Urea, Single Super Phosphate (SSP) and Sulphtate of Potash (SOP). Three, nine and one field trials were conducted during 2008-09 at framer's fields in central, cotton and thal cropping zones of the Punjab province, respectively. It was found that time and method of P_2O_5 application significantly (P<0.05) affected the wheat grain yield in three cropping zones under study. Finally, our study suggested that application of P_2O_5 @ 114 Kgha^{-1} at the time of pre-plant with placement method produced the highest yield in central, cotton and thal zone as compared to all other times and methods of P-fertilizer application.

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1. Introduction

The Wheat (Triticum aestivum L.) is leading food grain crop of Pakistan and being staple diet of the people. It occupies a central position in GDP and formulation of agricultural policies. It contributes 14.4 percent to the value added in agriculture and 3.1 percent to GDP. During 2009-10 it was cultivated on an area of 9042 thousand hectares with the production of 23864 thousand tons in Pakistan (Economic Survey of Pakistan, 2009-10). Among all the elements required by crop, P_2O_5 is one of the most vital nutrients for sustainable crop production (Ryan, 2002). Phosphorus plays a pivotal role in root development and grain formation. Its deficiencies late in the growing season affect both seed development and normal crop maturity (Havlin et al., 2010). Judicious application of P-fertilizer is a key factor in the cereals based system of Pakistan for sustainable agriculture. Imbalanced fertilizer use, especially in terms of phosphate compared with nitrogen, has created concern as it may affect overall agricultural productivity and economic growth in Pakistan (Anon., 2006).

The soils of Pakistan are calcareous and alkaline in nature and P-fixation is a serious problem (Sharif et al., 2000). Phosphorus deficiency is invariably a common crop growth and yield-limiting factor in unfertilized soils, especially in soils having high calcium carbonate, which reduces P solubility (Ibrikci et al., 2005). The phosphorous applied to these soils is converted to insoluble calcium phosphate (49 to 59 percent), iron and aluminum phosphate (14 to 19 percent), while water soluble fraction ranges from 5 to 9 percent only (Ahmed et al., 1992). Therefore, such soils with high fixation capacity have higher demand for phosphatic fertilizer (Hussain and Haq, 2000). To produce one tone yield, wheat crop removes N, P and K @ 25, 9.0 and 33.0 kg from soil (NFDC, 2002). It is found that basal dose of P-fertilizer is foundation for establishing good crop stand because it moves very little from site of application and enhances availability to the crop (Brady et al., 2008). The critical period for phosphorous is first 5 to 6 weeks. Therefore, care should be taken regarding its time of application because deficiency results in stunted plant growth and late crop maturity leading to the severe yield losses (Ahmed et al., 1992). It was further found that placement method of P application increases its absorption, and thus fertilizer utilization, especially under low P-supplies in the soil, arid zones and high immobilization or fixation (Fink, 1982). Infact, the superiority of placement at sowing time over broadcast application for grain yield is due to high rate of P_2O_5 supply to the root zone (Barber and Koyar, 1985). Crop respond more favorably placement than to broadcast on low-fertility soils because banding puts a readily accessible phosphate

source in the root zone (Rashid et al., 1996). Placement often increases P efficiency three fold over broadcast incorporated application (IFDC, 1979).

In Pakistan, the increasing prices of phasphatic fertilizer are jeopardizing sustainable crop production. DAP and SSP price increased by 41.6% and 7.8%, respectively during 2010 as compared to the previous year. In addition, our domestic fertilizer production met only 68.8% requirement and remaining 31.2% was imported by spending huge foreign exchange (NFDC, 2009-10). Under such circumstances, system demands an efficient and accurate time and method for application of phosphatic fertilizers to crop in order to reduce its losses. Hence, present study was designed with core objective to find out the optimum time and method of phosphatic fertilizer application for wheat crop.

2. Material and Methods

A total of 13 fertilizer trials on farmers' fields were laid out using factorial arrangement under Randomised Complete Block Design (RCBD) to compare two methods (broadcast and placement) and three times (at pre-plant, at 1st irrigation and at 2nd irrigation) of phosphorous application. The experiments were conducted on wheat crop in central, cotton and thal cropping zones of the Punjab. The division of zone is based on the basis of rainfall cropping pattern followed in that regions and also on the basis of soil physic-chemical characteristic. The wheat variety planted was Inqlab-91. The plot size for treatments was 1/40th of a hectare. The sources of N, P_2O_5 and K_2O were Urea, Single Super Phosphate and Sulphate of Potash. For all treatments, control consists of treatment with no application of respective nutrient. The experiments were harvested as per standard technique i.e. cutting of three sub-plots of 3×3m, selected randomly from each treatment.

2.1 Land Preparation

The land was ploughed two times followed by leveling to ensure the even supply of nutrients, irrigation and seed. Sowing of crop was carried out in November, 2008 using automatic drill at a depth of 3cm.

2.2 Fertilizer Application

In each treatment Nitrogen was applied @160 $kgha^{-1}$ in two splits i.e. ½ N at sowing and remaining half at first irrigation. All K_2O@ 62$kgha^{-1}$ was applied at the time of sowing. Phosphorous was applied @ 114 $kgha^{-1}$ using three times (pre-plant, at 1st irrigation and at 2nd irrigation) and two methods (broadcast and placement) as shown below (Table 1):

2.3 Irrigation and Weed Control

The wheat crop was irrigated as per its water requirement using good quality water. In total, three irrigations were done. To save water, three irrigations i.e. at crown root, booting and grain development stages of wheat should be recommended (Khan et al., 2002). There was non-significant effect of method of P application on grain yield. The first irrigation was given 25 days after sowing. Subsequent irrigations were carried out at 25 days interval. The plots were kept free of all kinds of weeds during experiment.

Table 1. Time and method of fertilizer application for each treatment

Tr. No.	Fertilizer Rates			Method and time of P_2O_5 Application
	N	P_2O_5	K_2O	
	--------Kg ha^{-1}---------			
T_1	0	0	0	-
T_2	160	114	62	Pre-plant broadcast
T_3	160	114	62	Pre- plant placement
T_4	160	114	62	Broadcast at 1st Irrigation
T_5	160	114	62	Placement at 1st Irrigation
T_6	160	114	62	Broadcast at 2nd Irrigation
T_7	160	114	62	Placement at 2nd Irrigation

3. Soil Sampling and Analysis

Soil samples were collected from experimental sites prior to sowing with the help of soil auger and were analysed for their Physico-chemical characteristics in research laboratories of Soil fertility Research Institute, Punjab, Lahore. Soil textural analysis was carried out using Bouyoucos Hydrometer method as described by Black (1965) and its textural class was determined using Textural Triangle from USDA (Gee and Bauder, 1986). The pH of saturated soil paste was measured using soil pH meter having combination electrode (Mc Lean, 1982). Electrical conductivity (EC) was determined in the soil extracts taken from the saturated soil paste using a conductivity meter (Rhoades, 1982). The Exchangeable soil potassium and sodium in the extracts was determined by a flame photometer (Knudsen et al.,. 1982). Available P in the 0.5M $NaHCO_3$ (pH 8.5) extracts was determined using a spectrophotometer (Olsen and Sommers, 1982). Soil organic carbon was measured by dichromate digestion method (Page et al., 1982). Total nitrogen in soil was determined by Kjeldahl method after soil digestion with concentrated H_2SO_4 and the digestion

mixture (K_2SO_4: $FeSO_4$: $CuSO_4$: 10.0:1.0:0.5) (Buresh et al., 1982).

Table 2. Soil Physico-chemical characteristics (0-15 cm soil depth)

Parameters	Central Zone	Cotton Zone	Thal Zone
	Mean	Mean	Mean
ECe (dS m^{-1})	1.09	2.85	0.76
pH	8.1	8.3	7.9
Organic Matter (%)	0.86	0.63	0.53
Available-P (ppm)	4.4	5.4	3.8
Available-K (ppm)	144	251	120
Textural Class	Clay Loam	Sandy Loam	Sandy

The average soil analysis data (Table 2) of the experimental sites of all three zones revealed that soils are normal regarding salinity/sodicity menace. The organic matter and available phosphorous contents were poor. The available K was satisfactory in thal and central zone, while in cotton zone it was adequate.

3.1 Statistical data Analysis

Data were subjected to analysis of variance (ANOVA) according to the methods described by Steel and Torrie (1996), and treatment means were compared using the least significant (p) difference (LSD) at $\alpha \leq 0.05$.

3.2 Economic Analysis

Economic analysis of the data was carried out by the procedures described by Amanullah et al., (2010). The Value Cost Ratio (VCR) and Net Return (NR) are the economic indicators. The VCR is ratio of the value of additional crop yield to the cost of fertilizer. It was calculated by using following formula:

$$\textbf{VCR} = \frac{\textbf{Value of increased yield obtained}}{\textbf{Cost of fertilizer used}}$$

VCR is the rate of return from the money spent on fertilizer. A VCR value of 2 means 100% return from the money invested on the fertilizer. Variables tested with VCR below 2 are not recommended for the farmers, because in this case net profit decreases. The cost of fertilizer for each treatment was PKRs. 20766.0 and cost of wheat grain was PKRs.15.0 per Kg.

The net return (NR) is the value of increase yield as a result of the applied fertilizer after providing for the cost of fertilizer. This is the net cash gained due to fertilizer use. It was calculated by subtracting Cost of fertilizer from Gross return (GR):

Net Return = Gross return (GR)- Cost of fertilizer

Fertilizer use efficiency (FUE) measures the recovery of plant nutrients from mineral fertilizer application in crop husbandry (agriculture) for resource use efficiency. It was calculated by following formula:

$$\textbf{FUE} = \frac{\textbf{Increase in yield}}{\textbf{Quantity of nutrients applied}}$$

4. Results and Discussion

The yield results in Table 3, 6 and 9, respectively revealed that in central, cotton and thal zones of the Punjab application of P @ 114 Kg ha^{-1} at the times of pre-plant with placement method produced the highest yield which was statistically at par with the treatment receiving P-fertilizer at the time pre-plant with broad cast method. On contrary, P application at 1st and 2nd irrigation with both methods of application (broadcast and placement) produced significantly (P<0.05) lower wheat yield. Application of P-fertilizer at the time of pre-plant with placement and broad cast methods given about 50% more yield in each central and cotton zone and around 30% additional yield in thal zone of the Punjab. Similarly, maximum fertilizer use efficiency (FUE) and profit was also received when P-fertilizer was applied at the pre-plant time with placement method or broad cast method. The Stewart et al., (2000) also found that wheat yields were higher where P was applied by placement in soil before time of sowing. The zone wise results are discussed as under:

4.1 Central Zone

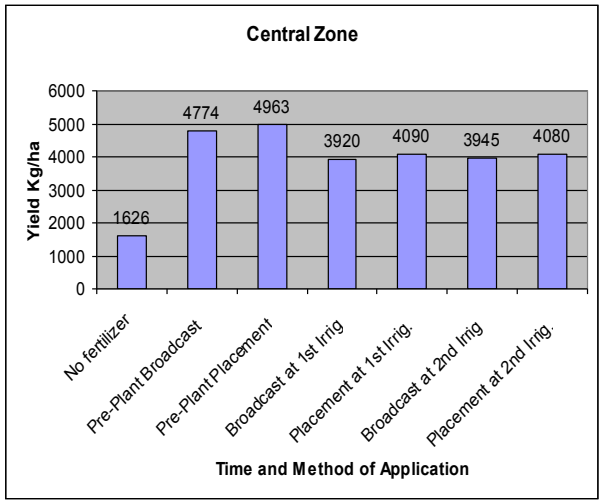
Soil texture of the central zone of the Punjab province ranges from loam to clay loam. In this zone rice- wheat and maize-wheat cropping patterns are adopted by the farmers. The minimum winter temperature is recorded 4 °C and maximum summer up to 45 °C. Its area is under canal and tube well irrigation system. The average annual rainfall is about 300 mm which is highly seasonal and half of the yearly rain is received in the months of July and August. A major portion of wheat grain is produced from this zone. Three field experiments were conducted in this zone of the Punjab province inorder

to evaluate the best time and method of phosphatic fertilizers application.

Table 3. Wheat yield as affected by times and methods of P-fertilizer application in central zone of the Punjab (2008-09)

Tr. No	Yield	Increase Yield over control	increase in yield over control
	Kg ha^{-1}	Kg	% age
T_1	1626 c	-	-
T_2	4774 a	3148	193
T_3	4963 a	3337	205
T_4	3920 b	2294	141
T_5	4090 b	2464	151
T_6	3945 b	2319	142
T_7	4080 b	2454	151
LSD at p< 0.05=550			

Figure 3a. Portrays wheat yield attained by different time and methods of P-fertilizer application in central zone.



It is evident from the wheat yield data analysis (Table 3 and Figure 3a) that application of fertilizers increased average wheat grain yield significantly (P<0.05) over control (no fertilizer). Results indicated that application of P_2O_5 fertilizer @ 114 kg ha^{-1} at the times of pre-plant with placement (T_2) and broad cast (T_2) produced significantly (P<0.05) higher yield (4963 kg ha^{-1} and 4774 kg ha^{-1}) as compared to P application at 1st and 2nd irrigation either with broadcast or placement methods of P_2O_5 application. However, pre-plan placement given 12% greater yield as compared to the pre-plant broad cast method of application. Therefore, pre-plant placement was superior among all other fertilizers treatments. It was revealed that pre-plant placement of the P-fertilizer stimulates rapid growth of the seedling and nutrient reserve for later growth stages of the plant. Primary roots develop vigorously and successfully support early plant growth. Hence, due to extensive root development, plant will be able to draw moisture from the lower depths of the soil and supports good crop stand (Ansar et al., 2008). Moreover, optimum moisture condition in the soil at pre-plant time of fertilization facilitates maximum utilization of applied P_2O_5 to crops (Stewart et al., 2005). Therefore, pre-plant time and fertilizer placement method was found as best time and method for P-fertilizer application.

Table 4. Economic analysis of wheat yield in central zone of the Punjab (2008-09)

Treatment No.	GR	NR	VCR
	PKR. ha^{-1}		
T_1	-	-	-
T_2	75552	54786	3.6
T_3	80080	59314	3.9
T_4	55056	34290	2.7
T_5	59136	38370	2.9
T_6	55648	34882	2.6
T_7	58896	38130	2.8

Economic analysis also portrayed that the highest value cost ratio (VCR) of 3.9 (Table 4) was achieved by the application of P at the times of pre-plant with placement method.

Table 5. Fertilizer use efficiency of wheat yield in central zone of the Punjab (2008-09)

Tr. No.	Increase yield over control	FUE
	Kg	
T_1	-	-
T_2	3148	9.4
T_3	3337	10
T_4	2294	6.8
T_5	2464	7.3
T_6	2319	7.0
T_7	2454	7.3

Alike, maximum fertilizer use efficiency of 10.0 (Table 5) was achieved by application of fertilizer at the time of pre-plant with placement method. Therefore, P fertilizers should be applied immediately before or at planting due to its immobility in soil. Top dressing of P is not expected to affect crop yield because the P would likely become bound near the soil surface and not migrate

to the actively growing root system. The results of our study contradicts to the findings of Rajpar et al., (2006) who revealed that there is no significant difference in use efficiency of P_2O_5 either it is applied at pre- plant time or at first irrigation. It has been profound that application of P fertilizer at a specific time is a key to achieve maximum yield especially in central zone.

4.2 Cotton Zone

The cotton zone occupies the southern region of Punjab province. The soils are sandy loam in texture. In this zone cotton-wheat cropping system is followed. The minimum winter temperature is recorded 5.8 °C and maximum summer goes up to 48°C. Like central zone, in this zone average grain yield data analysis (Table 5) of 9 field experiments on the wheat crop revealed that fertilizers treatments increased the yield over control (no fertilizer).

Table 6. Wheat yield as affected by times and methods of P-fertilizer application in cotton zone of the Punjab (2008-09)

Tr. No	Yield	Increase Yield over control	increase in yield over control
	Kg ha^{-1}	Kg	% age
T_1	1253 c	-	-
T_2	4026 a	2773	222
T_3	4130 a	2877	230
T_4	3536 b	2283	182
T_5	3588 b	2335	186
T_6	3641 b	2388	191
T_7	3747 b	2494	199

LSD at p< 0.05=257

Yield data showed that application of P_2O_5 fertilizer @ 114 kg ha^{-1} at the time of pre-plant with both methods of application (broadcast and placement) produced significantly (P<0.05) higher yield (4026 and 4130 kg ha^{-1}) as compared to P application at 1st and 2nd irrigation with both methods of application (Table 6 & Figure 6a). However, application of phosphatic fertilizer at the time of pre-plant with placement method produced 8% more yield as compared to the broadcast application at the same time. Hence, pre-plant method was preferred over all other methods and time of P application (Table 6 and figure 6a.).

Figure 6a. Portrays wheat yield attained by different time and methods of P-fertilizer application in cotton zone

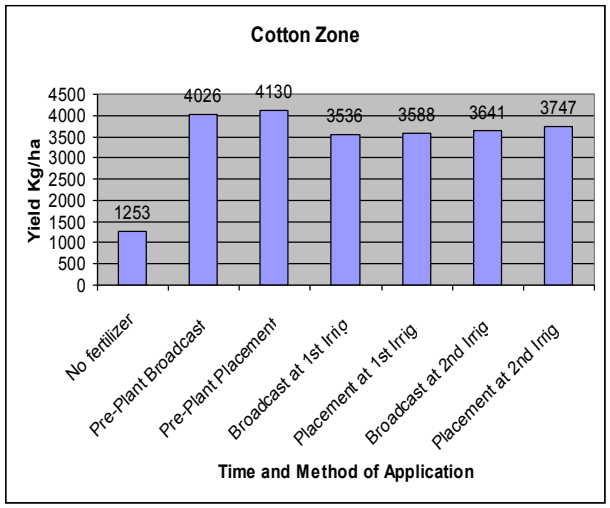


Table 7. Economic analysis of wheat yield in cotton zone of the Punjab (2008-09)

Tr. No.	GR	NR	VCR
	PKR. ha^{-1}		
T_1	-	-	-
T_2	66552	45786	3.2
T_3	69048	48282	3.3
T_4	54792	34026	2.6
T_5	56040	35274	2.7
T_6	57312	36546	2.7
T_7	59856	39090	2.9

Economic analysis indicated that the highest value cost ratio (VCR) of 3.2 and 3.3 (Table 7) and the maximum fertilizer use efficiency (FUE) of 8.3 and 8.2 (Table 8) was also achieved by the application of P at the times of pre-plant with placement or broad cast method which was recommended best time and method for economic optimum yield of wheat crop. Band placement at the time if pre-plant proved better than other methods on sandy loam soils (Alam et al., 2003). It was found preferable method for fertilizer P application to improve FUE because in top application nutrient cannot be fully utilized by the crop roots as they move laterally over long distance and fix to the soil (Alam et al., 2002). Yash et al., (1992) suggested that high pH soils adversely affect P availability to plants so P should be applied close to sowing to reduced P fixation. Too early and late application of P declined yield and net returns.

Table 8. Fertilizer use efficiency of wheat yield in cotton zone of the Punjab (2008-09)

Tr. No.	Increase yield over control	FUE
	Kg	
T_1	-	-
T_2	2773	8.2
T_3	2877	8.3
T_4	2283	6.8
T_5	2335	7.0
T_6	2388	7.1
T_7	2494	7.4

4.3 Thal Zone

Thal zone covers most of the area under rainfed farming with average annual rainfall range from 200 to 250 mm. The soils of this zone are sandy to sandy loam in texture and are inheritedly low in organic matter and phosphorous contents. In order to evaluate the best time and method of phosphatic fertilizers application, an experiment was conducted on wheat crop in this zone of the Punjab.

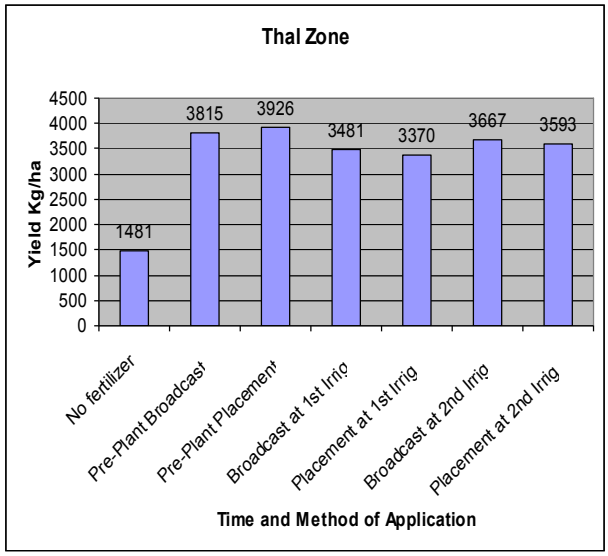
Table 9. Wheat yield as affected by times and methods of P-fertilizer application in thal zone of the Punjab (2008-09)

Tr. No	Yield	Increase Yield over control	increase in yield over control
	Kg ha^{-1}	Kg	% age
T_1	1481c	-	-
T_2	3815 a	2334	158
T_3	3926a	2445	165
T_4	3481 b	2000	135
T_5	3370 b	1889	127
T_6	3667 b	2186	148
T_7	3593 b	2112	143

LSD at $p< 0.05$=301

Data analysis (Table 9 and Figure 9a.) clearly shows that application of P_2O_5 fertilizer @ 114 kg ha^{-1} at the time of pre-plant produced highest wheat yield of 3926kg ha^{-1} which is significantly (P<0.05) at par with the treatment receiving phosphatic fertilizer broadcast method at similar application time.

Figure 9a. Portrays wheat yield attained by different time and methods of P-fertilizer application in thal zone



P application at 1st and 2nd irrigation with both methods (broadcast and placement) produced significantly (P<0.05) lower grain yield. Application of p-fertilizer at pre-plant with placement method gave 7% greater yield than its application at the same time with broad cast method. Similarly, there was around 30-35% more as compared to its application at 1st and 2nd irrigation either with broad cast or placement methods (Table 9)

Table 10. Economic analysis of wheat yield in thal zone of the Punjab (2008-09)

Tr. No.	GR	NR	VCR
	PKR. ha^{-1}		
T_1	-	-	-
T_2	56016	35250	2.7
T_3	58680	37914	2.8
T_4	48000	27234	2.3
T_5	45336	24570	2.2
T_6	52464	31698	2.5
T_7	50688	29922	2.4

Economic analysis revealed that the highest value cost ratio (VCR) of 2.8 (Table 10) was also obtained by application of phosphatic fertilizer application at pre-plant time with placement method.

Table 11. Fertilizer use efficiency of wheat yield in thal zone of the Punjab (2008-09)

Tr. No.	Increase Yield over control	FUE
	Kg	
T_1	-	-
T_2	2334	6.9
T_3	2445	7.3
T_4	2000	6.0
T_5	1889	5.6
T_6	2186	6.5
T_7	2112	6.3

Similarly, maximum fertilizer use efficiency (FUE) of 6.9 and 7.3 was also given by these two treatments (Table 11). Qureshi (1978) recommended that P fertilizers should be top dressed with first irrigation rather than applied and incorporated in the soil at sowing time. His findings are mismatched to our results. Our study suggested that top dressing exercise is not a good tool as P fertilizer is immobile in soil and has nature to fix in calcareous soils existing in thal zone of Punjab province.

Conclusion

It is concluded that time and method of P application has high impact on wheat grain yield. The application of P_2O_5 at the time of pre-plant with placement and broadcast method produced significantly (P<0.05) higher yield as compared to times of application at 1st and 2nd irrigation with the same methods in all three ecological zones of the Punjab. However, the highest yield was achieved by application of phosphorous at the time of pre-plant with placement method in all three zones, respectively. Therefore, it is recommended that phosphatic fertilizer should be applied at the time of pre-plant and preferably with placement method in agro climatic conditions of Punjab Province of Pakistan to enhance P_2O_5 use efficiency and get economic optimum yield of wheat crop.

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