PJN
ISSN 1680-5194

Pakistan Journal of Nutrition

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 11 (9): 885-890, 2012
ISSN 1680-5194

Optimizing the Method and Source of Phosphatic Nutrition for Wheat (*Triticum astivum* L.) Under Agro-Climate of Dera Ghazi Khan, Pakistan

M. Mudassar Maqbool[1], Maqbool Ahmad[1], Anser Ali[1], Rashid Mehmood[2], Muhammad Ahmad[3] and Muhammad Sarwar[1]
[1]Sub-Campus D.G. Khan, University of Agriculture, Faisalabad, Pakistan
[2]Institute of Agricultural Sciences, University of the Punjab, Lahore, Pakistan
[3]Agriculture Adaptive Research Complex, Dera Ghazi Khan, Pakistan

Abstract: In agricultural system, the application of Phosphorous (P) to the soil is essential to make sure the crop productivity as the recovery of applied P by crops becomes very low during growth period. The way, phosphorus is applied is also critical in wheat growth and development. For this purpose a field experiment was conducted to study the effect of different P fertilizers and their methods of application on wheat growth and yield. Different Phosphorus fertilizers Mono-Ammonium Phosphate (MAP), Di-ammonium Phosphate (DAP) and Triple Super Phosphate (TSP) @ 100 kg ha^{-1} were applied through: broadcasting, application with the seed, application 5 cm to the right and left of the seed and 5 cm below the seed. The effects of MAP, DAP and TSP on the characteristics examined was non-significant. However, effects of application methods on plant height, the number of plants m^{-2}, biological and grain yield were found to be highly significant. The maximum grain yield was obtained from application of phosphorus 5 cm below the seed as compare with any other method. It was concluded that the method of P application 5 cm below the seed is successful agro-technique to improve and sustain the wheat growth.

Key words: Phosphorous, application methods, wheat, growth

INTRODUCTION

Fertilizer use has played a pivotal role in increasing crop yield in Pakistan. The use of fertilizer has increased considerably from as low as 5 kg ha^{-1} in 1965-66 over 91 kg ha^{-1} during year 1989-90 (NFDC, 1990). At national level, 250500-ton phosphate is being used in wheat cultivation, which amounts to Rs. 4500 million. Fertilizers applied to soils are not fully utilized by the growing crops and large proportion of applied fertilizer goes waste (Saleem, 1992). Application of phospahtic fertilizer as major element in crop production is well established. Efficient use of phosphatic fertilizers is important from both economic view point and conservation of the world's phosphate resources. Wheat is very responsive to phosphorus fertilizers application on soils that do not provide adequate amounts of this essential nutrient. Phosphorus is the second to nitrogen as the nutrient that most commonly limits wheat growth and development. Phosphorus has been the subject of more fertility investigation than any of the other essential elements. The major problem in the use of phosphatic fertilizer in Punjab is the reduced availability of applied phosphorus to crops due to its fixation under alkaline soil conditions (Nisar and Bhatti, 1979; MinKeni and Mackenzie, 1988). Monoammonium Phosphate (MAP), Diammonium Phosphate (DAP) and Triple Supper Phosphate (TSP) are the sources of phosphatic fertilizers used in Pakistan.

As per practice in vogue, phosphatic fertilizer is broadcasted in the field. For a good crop production, phosphorus and nitrogen should be applied in 1:2 while it is 1: 4 in Pakistan. When phosphatic fertilizers added, the soil can rapidly and firmly adsorb large amount of phosphorus from soil solution, becomes unavailable to the plants and difficult to be released from the soil (Huang, 1998). On the other hand, applied phosphatic fertilizer is not totally available to plant. Phosphatic fertilizer can hardly move 3 to 5cm in soil. Resultantly, it is hardly available to the extent of 15-20% to plant. The rest goes to waste from the immediate crop being fixed in soil. Due to alkaline and calcareous nature of Pakistani soils, most of the native and applied phosphorus becomes unavailable at the growing plants (Sharif, 1985). Any measure, which helps reducing the activity of calcium, would ensure the enhanced availability of phosphorus to plants.

The efficient use of phosphatic fertilizer also depends on rate, time, methods of application and crops requirements (El-Baruni and Olsen, 1979). There are several methods of phosphorus placements in soils. Among these broadcasting is the most common and traditional method of application on wheat fields. However in soils with high phosphate fixation and low levels of available phosphorus, the application of phosphorus in bands generally increases productivity relative to broadcasting (Mater and Brown, 1989).

Corresponding Author: Anser Ali, Sub-Campus D.G. Khan University of Agriculture, Faisalabad, Pakistan

Banding under the seed or broadcast application of P does not affect the grain yield of wheat (Kashwa and Singh, 1988). The relative efficiency of phosphorus sources content as a high degree of water soluble phosphorus encourages early season growth in small cereals (Venugopalm and Ponsed, 1989). Banding below the seed at the time of planting has added the advantage of placing the fertilizer in immediate contact with the emerging radical and seminal roots during seedling establishment (Cook and Veseth, 1991). However, by drilling technique fertilizer can be placed at uniform depth and close to the seed and efficiency of the dissolved phosphorus can easily be enhanced up to 65-70%. The relative efficiency of placement was 1-4 times that of broadcast application (Vig and Singh, 1985). Drilling of phosphorus at 3-4 cm below the seed gave higher yield than applied with farmyard manur, pre-soaking irrigation and broadcast application (Uriyo *et al*., 1986). So the study was undertaken to improve the efficiency of phosphatic fertilizer in wheat through different application techniques.

MATERIALS AND METHODS

The field experiment was conducted at College of Agriculture, DG Khan, Pakistan (185 m above sea level, 31° latitude North and 73° longitude East.) to compare the effect of different phosphatic fertilizers and their methods of application on wheat crop. Soil samples were taken before sowing to a depth of 15 cm and 30 cm for physio-chemical analysis. The net plot size was 3.0 m x 5.0 m. Wheat cultivar AS-2002 was used as plant materials. Monoammnium Phosphate (MAP), Diammonium Phosphate (DAP) and Triple Super Phosphate (TSP) fertilizers were used as source of P in this experiment. Each fertilizer was applied according to four different methods; broadcasting, with the seed, 5 cm to the right and left of the seed and 5 cm below the seed. Nitrogen and potash @ 130 and 62 kg ha^{-1} were applied in the form of Urea and Sulphate of Potash (SOP) respectively, while MAP, DAP and TSP as per treatment were used as sources of phosphorus @ 100 kg P_2O_5 ha^{-1}.

The experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangement and replicated four times. Fertilizer was investigated in the main plots, while their application methods in sub-plot. Sub-plot was 1.0 x 5.0 = 5 m^{-2} in size and consisted of seven rows. Seeds were sown 17.5 cm apart in rows with a density of 500 plants per square meter. Sowing was performed manually. The total quantity of P fertilizer was applied during sowing, together with half of the N. The rest of the N was applied in the joint growth stage. Herbicide was applied in order to control both narrow and broad-leaf weeds before the joint growth stage.

Soil sample collected from experimental field was air dried ground, passed through a 2 mm stainless steel sieve and mixed thoroughly. This soil sample was used for physio-chemical analysis like soil texture, macronutrients (P, K), Electrical Conductivity (EC_e), soil pH and Organic Matter (OM) at the beginning of experiment (Table 1). The soil used for the experiment was sandy clay loam in texture, alkaline in reaction (pH = 7.82), poor in organic matter (0.64%), adequate in potassium (85 mg kg^{-1}) and low in available phosphorus (2.75 mg kg^{-1}). Particle size analysis was done by Bouyoucus Hydrometer Technique (Bouyoucus, 1962). Soil paste was prepared and saturation extract was obtained. Then the pH was determined with a pH meter (Page *et al*., 1982). Electrical conductivity was measured by using electrical conductivity meter (Page *et al*., 1982). Organic matter was determined by using Walky and Blake method (Page *et al*., 1982). Available Phosphorus was measured by using spectrophotometer (Olsen and Sommers, 1982). Extractable potassium was determined by using flame photometer (Knudsen *et al*., 1982).

The data collected for various parameters were subjected to Analysis of Variance (ANOVA) and the means obtained were compared by LSD at 5% level of significance (Steel and Torrie, 1980).

Table 1: Analysis of experimental soil

Property	Units	Value
EC	dSm^{-1}	2.14
Soil Ph		7.82
Organic matter	%	0.64
Available-P	Ppm	2.75
Available-k	Ppm	85
Saturation	%	46
Soil texture		Clay-loam

RESULTS

Growth and development: Leaf Area Index (LAI) of wheat was improved by most of the treatments. Effect of different P sources on LAI of wheat was non-significant. However, significant response was noted with respect to methods of P application. The minimum LAI (0.175) was obtained in S_0 (broadcast) treatment while, maximum LAI was recorded (0.327) in treatment S_3 (application of P 5 cm below the seed). LAI also increased by other application methods such as with the seed (S_1) and 5 cm to the right and left of the seed (S_2) treatments but they were statistically similar with each other (Table 3).

Leaf Area Duration (LAD) of wheat was influenced positively by most of the treatments however certain treatments did not affect LAD. Effect of different Phosphorus sources on LAD was non-significant. However, methods of Phosphorus applications on LAD were significant. The table clearly shows that the maximum LAD (4.87) was recorded in the plots where phosphatic fertilizers were applied 5 cm below the seed (S_3). The minimum LAD (2.64) was obtained in plots where fertilizers were broadcast (S_0). Application of

Table 2: Effect of P on various agronomic traits of wheat at $p \leq 0.05$ (The values are means of three replicates). Means sharing the common letter do not differ significantly

	Agronomic traits (As-2002)							
	Plant Height (cm)	Number of tillers m^{-2}	Number of spikelets $spike^{-1}$	Number of grains $spike^{-1}$	1000 Grain weight (g)	Biological yield $t\ ha^{-1}$	Grain yield $t\ ha^{-1}$	Harvest index (%)
Fertilizer sources								
MAP (P_1)	63.46	428.37	13.14	13.14	43.61	11.15	5.55	49.69
DAP (P_2)	63.08	419.87	13.13	13.13	43.70	10.95	5.42	49.53
TSP (P_3)	63.78	430.06	13.36	13.36	44.62	11.22	5.59	49.77
Fertilizer application methods								
Broadcast Control (S_0)	62.08c	405.08c	12.29b	53.35c	42.64c	5.32b	10.80b	49.25b
Application with seed (S_1)	59.98c	382.75d	11.53c	50.81d	39.27d	5.01c	10.23c	48.94b
5 cm R and 5 cm L to the seed (S_2)	61.96b	420.91b	12.24b	55.14b	43.79b	5.40b	10.88b	49.60b
5 cm below the seed (S_3)	69.75a	495.66a	16.80a	67.70a	50.20a	6.36a	12.51a	50.86a

Table 3: Effect of P on various growth traits of wheat at $p \leq 0.05$ (The values are means of three replicates). Means sharing the common letter do not differ significantly

	Growth traits (As-2002)			
	Leaf area index	Crop growth rate ($g\ m^{-2} day^{-1}$)	Net assimilation rate	Leaf area duration (days)
Fertilizer sources				
MAP (P_1)	0.27	0.16	2.07	6.94
DAP (P_2)	0.26	0.17	2.22	6.66
TSP (P_3)	0.26	0.19	2.11	6.76
Fertilizer application methods				
Broadcast Control (S_0)	0.22b	0.17b	2.03b	5.64b
Application with seed (S_1)	0.21b	0.17ab	2.05b	5.59b
5 cm R and 5 cm L to the seed (S_2)	0.21b	0.16b	1.89b	5.63b
5 cm below the seed (S_3)	0.40a	0.20a	2.57a	10.30a

phosphorus 5 cm below the seed significantly increased LAD over other methods including control. Increase in LAD due to other methods like broadcast (S_0), mixed with seed (S_1) and 5 cm left and right to the seed (S_2) are statistically at par with each other. Interaction between fertilizer sources and methods of application was non-significant (Table 3).

Crop Growth Rate (CGR) of wheat was influenced positively by most of the treatments however certain treatments did not affect CGR. Effect of different Phosphorus sources on CGR was non-significant. But the effect of different methods of Phosphorus application on CGR was significant. The table clearly shows that maximum CGR (0.30) was recorded in plots where phosphatic fertilizers were applied 5 cm below the seed (S_3). The minimum CGR-1 (0.21) was obtained in plots where fertilizers were applied 5 cm left and right to the seed (S_2). Application of phosphorus 5 cm below the seed significantly increased CGR over other methods including control (broadcast). Increase in CGR due to other methods like broadcast (S_0), mixed with seed (S_1) and 5 cm left and right to the seed (S_2) are statistically at par with one another. Interaction between fertilizer sources and methods of application was non-significant (Table 3).

It is clear from data (Table 3) that Net Assimilation Rate (NAR) was significantly affected by different methods of Phosphorus application. But the effect of different sources of phosphatic fertilizers on NAR of wheat was non-significant The maximum NAR (2.57) was recorded in plots where phosphatic fertilizers were applied 5cm below the seed (S_3). Minimum NAR (1.89) was recorded in plots where fertilizers were applied 5 cm left and right to the seed (S_2). Application of phosphorus 5 cm below the seed significantly increased NAR over all other methods including control (broadcast). Increase in NAR due to other methods like broadcast (S_0), mixed with seed (S_1) and 5 cm left and right to the seed (S_2) are statistically at similar with each other. Interaction between fertilizer sources and methods of application was also non-significant.

The data regarding the effect of different phosphorus sources and their methods of application on plant height are presented in the (Table 2). Analysis of variance reveals that phosphorus sources have significant effect on plant height. Application of phosphorus significantly increased the plant height over the control (broadcast). The Table 2 clearly shows that the maximum plant height (63.78 cm) was obtained in treatment where fertilizer DAP was applied (P_2). The effect of different methods of application on plant height of wheat was also significant. Maximum plant height (69.75 cm) was obtained where phosphatic fertilizer were applied 5 cm below the seed (S_3) while minimum plant height (59.98 cm) was obtained in plots where fertilizer were mixed with seed (S_1). Interaction between fertilizer sources and methods of application was non-significant.

Yield and contributing factors: Number of grain per spike is an important yield component which contributes materially towards final grain yield of wheat. Table shows significant effect of different phosphorus application methods on number of grain per spike. Effect of different phosphorus sources on number of grains per spike was non-significant. But the effect of different methods of Phosphorus application on number of grains per spike was significant. The data (Table 2) shows that the maximum number of grains per spike (67.70) was obtained in plots where phosphorus fertilizers were applied 5 cm below the seed (S_3). The minimum number of grains per spike (50.81) was obtained in the plots where fertilizers were mixed with seed (S_1). Interaction between fertilizer sources and methods of application was non significant.

The effect of different phosphorus sources on grain yield of wheat was non-significant (Table 2). But the effect of different methods of Phosphorus application on grain yield was significant. The maximum grain yield (6.36 t/ha) was obtained in plots where phosphorus fertilizers were applied 5 cm below the seed (S_3). The minimum grain yield (5.01 t/ha) was obtained in plots where Phosphorus fertilizers were mixed with seed (S_1).

The final grain yield increased significantly by application of phosphorus below the seed over control (broadcast). Grain yield in broadcast (S_0) and 5 cm left and right to the seed (S_2) are statistically similar with one another. Interaction between fertilizer sources and methods of application was non significant.

The data (Table 2) showed that the effect of different phosphorus sources on biological yield was non significant. But the effect of different methods of phosphorus application on biological yield was significant. The maximum biological yield (12.5 t/ha) was obtained in plots where phosphorus fertilizers were applied 5 cm below the seed (S_3). The minimum biological yield (10.2 t/ha) was obtained in plots where phosphorus fertilizers were mixed with seed (S_1). Application of phosphorus below the seed significantly increased the biological yield over other application methods including control (broadcast). Interaction between fertilizer sources and methods of application was non-significant.

It is obvious from the (Table 2) that the effect of different phosphorus sources on harvest index was non significant. But the effect of different methods of phosphorus application on harvest index was significant. The maximum harvest index (50.86%) was obtained in plots where Phosphorus fertilizers were applied 5 cm below the seed (S_3). The minimum harvest index (48.93%) was obtained in plots where Phosphorus fertilizers were mixed with seed (S_1). Harvest index increased significantly by a banding of Phosphorus below the seed. Harvest index obtained from broadcast (S_0), fertilizers mixed with seed (S_1) and application of Phosphorus 5 cm left and right to the seed (S_2) are statistically similar with one another. Interaction between fertilizer sources and methods of application was non-significant.

DISCUSSION

Phosphorous is an important macronutrient after nitrogen massively used for arable crops. Its application for wheat is also an essential field requirement. It is repeatedly reported that wheat responds to all phosphorus fertilizers but method of application is still in transition especially for arid area of Dera Ghazi Khan. Secondly, soils of this area do not provide an adequate available amount of this essential nutrient. Phosphorous affects the plant growth and development of wheat. The current research indicates that Leaf Area Index (LAI), Leaf Area Duration (LAD), crop growth rate, net assimilation rate and plant height of wheat were influenced by methods of applications whatever the source was used. The maximum values were recorded in application of P 5 cm below the seed. LAI is an indicator of the assimilatory system of a crop. The enhancement in LAI is possibly the result of weed suppression which increased the nutrient, water and light availability and ended in expanded assimilatory area. Increase in LAI by placement of P below the seed was also noted by Rehman and Mehdi (1996) and Memon and Puno (2005). Leaf Area Duration (LAD) represents the period of photosynthetic activity. Longer the leaves remain photosynthetically active, higher will be the LAD. Increased period of photosynthetic activity contributes directly to yield. The improved and sustained availability of growth resources due to availability of more phosphrous contributed towards the enhanced LAD. The results of the present studies corroborate the finding of Malik *et al.* (1995). The variation in growth rate under various treatments was possibly due to different P application methods. More growth rate was observed when phosphatic fertilizer was applied below the seed (S_3) at early stage. At early stage the crop might have maximum benefited resources (availability of P) to enhance its growth, while steady increase in growth rate might be due to growth regulatory effects in addition to P availability. These results are in line with those reported by Rashid *et al.* (1997), Alam *et al.* (1999), Otto and Kilian (2001) Al-Karaki and Al-Omoush (2002), Alam *et al.* (2003) Rehman *et al.* (2004), Pareek (2004), Memon *et al.* (1991), Mehdi *et al.* (2007) who concluded that crop growth is significantly affected by different methods of P application. The current research also indicated that traditional methods of phosphorus application gave low value of NAR possibly due to the less leaf area and less availability of nutrients especially phosphorus to the plants. Almost similar results were presented by Gokmen and Sencar (1999) and Alam *et al.* (2003) they reported that application of phosphorus below the seed has increased NAR significantly.

It is evident from the current research that the effect of different phosphorus application methods on plant height, number of grain per spike and final grain yield was significant whereas the effect of different phosphorus sources was non-significant. Balanced plant nutrition ensures good plant height. Increase in plant height as compared to control treatment might have been due to the fact that phosphorus stimulates root development and growth in the seedling stage and thereby helps to establish the seedling quickly. In case of phosphorus deficiency, plant growth and stem remained stunted. Application of phosphorus resulted in normal plant growth and thus plant height was increased but increase in plant height was similar in all plants except treatment 5 cm below the seed (S_3). The results are supported by the work of Alam *et al.* (1999) and Aulakh *et al.* (2003) who reported that effect of different phosphorus sources on plant height of wheat was non-significant in their field studies. The findings are also in accordance with investigations of Memon and Puno (2005) and Pareek (2004). Number of grain per spike is an important yield component which contributes materially towards final grain yield of wheat. The best P application method enables the crop to make the rapid growth and to intercept more solar radiation and thus to produce more number of grain per spike. The application of P below the seed promoted normal plant growth and as a result number of spikelets per spike was increased. When number of spikelets per spike increased, it ultimately increases number of grain per spike. Increased number of grains per spike can be attributed to greater spike length and more number of spikelets per spike. These results corroborate with the findings of Malik *et al.* (1995) and Pareek (2004). Grain yield is an important parameter used for evaluation of effectiveness of any treatment because grain production is the ultimate objective of production of cereals used for feeding of human beings in the world (Anon, 2008). The possible reason for the highest grain yield when fertilizer was applied 5 cm below the seed might be the early P uptake that increases the yield potential of the crops by stimulating the growth and development of the plants. However, Banding below the seed at the time of planting has the additional advantage of placing the fertilizer in immediate contact with the emerging radical and seminal roots during seedling establishment. Deeper placement increases the probability of root contact, since roots tend to grow at a downward angle. Another reason for increase in grain yield with application of phosphorus below the seed might be the greater number of tillers, number of spikelets per spike, number of grains per spike and 1000 grain weight which was due to higher rate of photosynthesis, better crop health, resistance to diseases and pests which ultimately increased the final grain yield. These results are in line with those reported by Otto and Kilian (2001) Al-Karaki and Al-Omoush (2002), Rehman *et al.* (2004) and Mehdi *et al.* (2007) who concluded that the final grain yield is increased by banding of Phosphorus below the seed. Biological yield is the total biomass produced by a crop from a unit area. This is made up of yield components such as number of tillers per unit area, plant height, leaf area number of grains per spike and grain weight (Qaider, 2000). The present data shows that the effect of different phosphorus sources on biological yield was non significant. But the effect of different methods of Phosphorus application on biological yield was significant. Application of phosphorus below the seed significantly increased the biological yield over other application methods including control (broadcast). Application of any phosphatic fertilizer below the wheat seed enhanced seed germination, early growth, root development and also enhanced responses to mineral nitrogen fertilizer application (Rahmatullah *et al.*, 1994; Gill *et al.*, 1994; Pareek, 2004). It is obvious that the maximum harvest index was obtained in plots where phosphorus fertilizers were applied 5 cm below the seed (S_3). The physiological efficiency of a crop to convert dry matter into economic yield is determined by the harvest index (Alam *et al.*, 2003).

It was concluded from current discussion that effects of MAP, DAP and TSP on wheat growth were not different. Fertilizers placed in contact with seed at the time of planting increased leaf area index, crop growth rate and Net assimilation rate of wheat as compare with all other application methods. It was recommended that fertilizer placed in a band below the seed may effectively prevent damage to young seedlings and increase yield for small grains grown on soils in which the texture is heavier along with higher pH.

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