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DRY MATTER PARTITIONING AND GRAIN YIELD OF WHEAT AS AFFECTED BY PHOSPHORUS AND ITS APPLICATIONS

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Abstract

The present experiment was conducted to study the effect of phosphorus levels and its application methods on wheat varieties using randomized complete block design (RCBD) with split plot arrangement. Wheat varieties (i.e. Siran-10, Atta Habib and Pirsabak-04) were assigned to main plots. Phosphorus levels (i.e. 35, 70, and 105 kg ha^{-1}) and its application methods (i.e. Broadcast, side dressed and pop-up) were allotted to sub plots. Highest leaf dry weight (0.70 g) , stem dry weight (1.74 g), spike dry weight (0.99 g), productive tiller m^{-2} (355), spike length (9.98 cm), grains spike^{-1} (48.97), grain weight spike^{-1} (2.09 g), thousand grains weight (42.85 g) and grain yield (3949 kg ha^{-1}) were recorded from Siran-10. Application of 105 kg P ha^{-1} produced maximum leaf dry weight (0.69 g) , stem dry weight (1.85 g), spike dry weight (1.06 g), productive tillers m^{-2} (386), spike length (10.09 cm), grains spike^{-1} (52.76), grain weight spike^{-1} (2.21 g), thousand grain weight (42.03 g) and grain yield (4011 kg ha^{-1}). Application method (pop-up) produced maximum leaf dry weight (0.71 g), stem dry weight (1.80 g), spike dry weight (1.02 g), productive tillers m^{-2} (370), spike length (9.87 cm), grains spike^{-1} (50.96), grain weight spike^{-1}(2.09 g), thousand grains weight (42 g) and grain yield (4068 kg ha^{-1}). It is concluded that application of phosphorus 105 kg ha^{-1} with pop-up application method produced maximum numbers of productive tillers (399), grain spike^{-1} (55) and grain yield (3949 kg ha^{-1}). Highest grain yield (3949 kg ha^{-1}) was recorded from Wheat variety (Siran-10) compared with other varieties.

Key Words: Wheat, Dry matter, Grain yield, Phosphorus, Application methods

Introduction

Wheat is an exhaustive crop which depletes soil fertility and degrades its physical condition. Wheat Production has commonly suffered due to various reasons (Khan *et al.,* 2014) and the important factor is the phosphorus deficiency as it is expensive nutrient compared to nitrogen. Phosphorus may be handled appropriately to attain maximum benefits (Malik *et al*., 1992). Adequate phosphorus is required at early growth stage of plant to attain optimum crop production (Grant *et al*., 2005). With addition of phosphorus fertilizer lodging is decreased as phosphorus provides strength to straw in cereals. It plays an essential role in cell division, nucleus formation, ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) formation which are responsible for heredity transmission. Phosphorus promotes early growth and root formation. Singh *et al*., (2000) and Zia *et al*., (2000) reported that grain yield and phosphorus accumulation increases in wheat as the rate of phosphorus increases over control. Phosphorus is immobile in soil and thus proper placement of phosphorus can make its available to roots of plants (Wahid *et al.,* 2015). Application of phosphorus with seed can boost up the yield of both spring and winter wheat compared to broadcast method of application, even the soil having higher amount of phosphorus (Jackson *et al*., 1997). The efficient placement of nutrients can enhance yield attributing traits and fertilizer use efficiency, thus maximizing net return of the farmers. With advancement in agricultural technologies fertilizer placement option have increased in the past few decades. Soils of Pakistan mostly contain <10mg kg^{-1} available phosphorus even after several decades of phosphate fertilizer use. By most standards, a soil containing 10mg kg^{-1} Olsen phosphorus is considered to be deficient. The phosphorus deficiency is widespread in most (90%) of the soils of Pakistan and the application of phosphate fertilizers is considered essential for crop production (Rashid *et al*., 1996).

The objectives of fertilizer placement are to exploit root-nutrient contact, particularly at initial developing periods of crop/roots without producing emergence problems. Nutrients placement in the area of high root density is essential to increase yield of wheat crop. Placing less soluble fertilizer like phosphorus with seed or placement with side in rows is more efficient as it was accessed earlier in growing season to roots than broadcasting. The next point is if the seminal and crown roots are well developed and the soil has enough moisture, yet there is difficulty of accessing immobile nutrients by root zone, such as phosphorus, which are placed on the surface of soil. The present study was conducted to evaluate the effects of phosphorus and phosphorus application methods on dry matter portioning and yield of wheat crop.

Materials and methods

Description of the experimental site: Field experiment was conducted at Agricultural research farms of The University of Agriculture Peshawar, Pakistan during Rabi season 2012-13. Experimental site was located at 350 m above sea level and has cool climate in winter and warm to hot in summer. Mean annual rainfall ranged from 380-550mm. The physiochemical analysis of the experimental site is presented in Table 1.

Table 1. Physico-chemical characteristics of the experimental soil.

Properties	Values
Sand	21.78%
Silt	53.42%
Clay	23.75%
Textural class	Silt Loam
pH(1:2:5)	7.75
EC(1:2:5)	0.22 dS m^{-1}
Organic matter	0.63%
Soil available phosphorus	2.23 mg kg^{-1}

Experimental design and treatments: Experiment was conducted in Randomized complete block design (RCB) with split plot arrangement. Treatments were replicated four times. Wheat varieties were assigned to main plots (Siran-2010, Atta Habib and Pirsabak-2004). Main plots were further sub divided into ten equal plots for combined application of phosphorus (35, 70 and 105 P_2O_5 kg ha^{-1}) and its application methods (Broadcast, side dressed and pop-up). Single super phosphate (SSP) was used as source of phosphorus (P_2O_5) fertilizer at the time of sowing. Recommended seed rate of 120 kg ha^{-1} was used uniformly for all wheat varieties. Nitrogen was applied in the form of urea in two splits (1/2 N before sowing and ½ N after 2nd irrigation). All other agronomic and cultural practices were carried out uniformly.

Data collection and analysis: Data was collected on dry matter partitioning (leaf, stem and spike dry weight at anthesis), productive tillers m^{-2}, spike length, grain $spike^{-1}$, grain weight $spike^{-1}$, and grain yield. For dry matter partitioning 20 tillers were randomly collected from each experimental unit, oven dried at 75^0C. Leaf, stem and spike were weighed separately and averaged for leaf, stem and spike weight data. Analysis of variance procedure was followed for the statistical analysis of recorded data according to Randomized complete block design (RCBD) with split plot arrangement. Means were compared using Least significant differences (LSD) test at $P \leq 0.05$ upon significant F-test (Steel & Torrie, 1980).

Results and Discussion

Leaf dry weight: Variation in leaf dry weight of wheat varieties was significant (Table 2). Maximum leaf dry weight (0.70 g) was recorded from Siran-10 followed by Pirsabak-2004 with leaf weight of 0.66 g which was statistically at par with Atta Habib (0.64g). Li *et al*., (2005) reported that different species and plants with in the same species vary in P uptake and its efficient use. Fu *et al*. 2006 affirmed that cultivars vary extensively in term of capability to bear phosphorus stress and the level to which their morphological and physiological traits were affected by low availability of Phosphorus. The data further revealed significant effect of phosphorus on leaf dry weight. Highest leaf dry weight (0.69g) was recorded with application of phosphorus at 70 and 105 kg ha^{-1} followed by 35 kg P ha^{-1} with the leaf dry weight of 0.66 g. Minimum leaf dry weight (0.58 g) was recorded in control. In case of application methods, pop-up produced maximum leaf dry weight (0.71 g) followed by side dressed with leaf dry weight of 0.68 g. Minimum leaf dry weight (0.64 g) was recorded from application method of broadcast. Nadim *et al*., (2012) reported that Phosphorus application as side dressed showed best performance in term of high LAI, crop growth and grain yield. Khan *et al.,* (2013) reported that NP fertilizer has increased growth of plants.

Stem dry weight: Analysis of data revealed significant difference in stem weight due to varieties, phosphorus and application methods (Table 2). Highest stem dry weight (1.74 g) was recorded from variety Siran-10 followed by Atta Habib with stem weight (1.67 g). Minimum stem weight (1.64 g) was recorded from Pirsabak-2004. Kosar *et al*., 2003 investigated variable response of cultivars in term of biomass accumulation, phosphorus uptake and phosphorus use efficiency. They reported that most efficient and responsive cultivars to phosphorus application were Chenab-2000 and Dirk among studied cultivars. In case of phosphorus, highest stem weight of 1.85 g was recorded from application of 105 kg P ha^{-1} followed by 70 kg P ha^{-1} with stem dry weight of 1.74 g. Minimum stem dry weight of 1.38 g was recorded from control. The data further showed that application method of pop-up produced highest stem dry weight of 1.80 g followed by side dressed with stem dry weight of 1.72 g compared to minimum stem dry weight of 1.63g from application method of broadcast. Increase in stem dry matter due to phosphorus may be due to maximum phosphorus uptake, better seedling growth and establishment compared with control (Fioreze *et al.,* 2012).

Spike dry weight: Analysis of data revealed significant effect of phosphorus levels and application methods on spike dry weight of wheat varieties (Table 2). Mean values of data revealed that Siran-10 produced maximum spike dry weight of 0.99 g followed by Atta Habib compared to minimum spike dry weight of 0.92 from Pirsabak-04. Variation in spike dry weight of wheat varieties may be due to their variable genetic make-up (Gutam, 2011; Dalirie *et al.,* 2010). Our results further showed that application of phosphorus at 105kg ha^{-1} produced highest spike dry weight of 1.06g compared to minimum spike dry weight of 0.97g recorded from control. In case of application methods, maximum spike dry weight of 1.02 g was produced from application method of pop-up compared to minimum spike dry weight of 0.93g recorded from application method of broadcast. Increase in spike dry weight in response to phosphorus application may be due to more dry matter partitioning to spike (Sami *et al*., 1976; Sharma & Gupta, 1994).

Table 2. Dry matter partitioning of wheat varieties as affected by phosphorus levels and its application methods.

Treatments	Leaf dry weight(g)	Stem dry weight(g)	Spike dry weight(g)
Varieties			
Siran-10	0.70a	1.74a	0.99a
Atta Habib	0.64bc	1.67b	0.97b
Pirsabak-04	0.66b	1.64b	0.92c
LSD	0.028	0.030	0.024
Phosphorus (kg ha^{-1})			
0	0.58c	1.38d	0.80d
35	0.66b	1.56c	0.89c
70	0.69a	1.74b	0.97b
105	0.69a	1.85a	1.06a
LSD	0.0281	0.035	0.046
Application Methods(AM)			
Broadcast	0.64c	1.63c	0.93b
Side dressed	0.68b	1.72b	0.97b
Pop-up	0.71a	1.80a	1.02a
LSD	0.028	0.035	0.046
Interaction			
P x AM	ns	ns	ns

Means of same category followed by same letters are not significantly different at $p<0.05$ using LSD test.

Productive tillers m^{-2}: Effect of phosphorus and application methods was significant on productive tillers m^{-2} of wheat varieties (Table 3). Interaction of phosphorus x application methods was significant (Fig. 1). Productive tillers are among the most important yield contributing traits which leads to higher grain yield. Among varieties Siran-10 produced highest number of productive tillers m^{-2} (355) compared with rest of varieties i.e. Atta Habib and Pirsbak-2004 produced 343, 333 productive tillers respectively. Similar results were reported by Mattas *et al*., (2011); Iqtidar *et al.,* (2006). Phosphorus levels revealed positive influence on productive tillers. Maximum number of productive tillers (386) was recorded from application of phosphorus at 105 kg ha^{-1} followed by 70 kg P ha^{-1}. Minimum productive tillers m^{-2} (257) was recorded in control. Application method pop-up produced highest number of productive tiller (370) compared with 356 and 334 productive tiller from side dressed and broadcast. Application methods have significant effect on plant height, number of plants ha^{-1}, and grain yield (Maqbool *et al*., 2012). Side dressed application method produced maximum LAI, productive tillers and grain spike^{-1} (Nadim *et al*., 2012). Turk *et al.,* (2002) reported superiority of pop-up due to better fertilizer use efficiency as the roots of developing crop were in contact with phosphorus granules. Application of phosphorus at 105 and 70 kg ha^{-1} coupled with application method of pop-up produced maximum productive tillers 398 and 391 respectively. Secondary tillers emergence increased linearly with application of different levels of phosphorus (Fioreze *et al*., 2012; Khan *et al*., (2007).

Spike length: Spike length was significantly affected by wheat varieties, phosphorus levels and application methods (Table 3). Among wheat varieties Siran-10 produced longest spikes (9.98 cm) followed by Atta Habib (9.46 cm) compared with lowest spike length from variety Pirsabak-2004 (9.29 cm). Variation in spike length was reported by Nasim *et al*., (2012) and Mohammad *et al*., (2011). Constant boost in spike length was observed with increase in application of phosphorus. Maximum spike length (10.09 cm) was recorded from treatment of 105 kg P ha^{-1} compared with minimum spike length of 8.76cm from control. Increase in spike length with increase of phosphorus nutrition was observed by Memon *et al*., (2011) and Laghari *et al*., (2010). Application methods of P showed positive response toward spike length. Highest spike length of (9.87 cm) was recorded from pop-up application method compared with rest of application methods. Nadim *et al*., 2012 investigated that side dressed application of phosphorus produced more productive tiller, spike length and grain spike^{-1} in wheat crop.

Grain spike^{-1}: Effect of varieties, phosphorus levels and application methods were significant on grain spike^{-1} (Table 3). Grain spike^{-1} is among important yield contributing parameters having direct effect on grain yield. Among wheat varieties, Siran-10 produced maximum number of grain spike^{-1} (48.97) compared with other varieties i.e. Atta Habib and Pirsabak-2004 with grain spike^{-1} of 46.63 and 45.36 respectively. Variation in the grain spike^{-1} of different wheat varieties may be attributed to their genetic potential. Gokmen & Sencer (1999) revealed that application of phosphorus 5cms below seed boost up grain yield and other agronomic traits of wheat. Phosphorus fertilization showed positive influence on grain spike^{-1}. Phosphorus at the rate of 105 kg ha^{-1} produced more number of grain spike^{-1} (52.76) followed by 70 kg P ha^{-1} with grain spike^{-1} of 48.92 compared with minimum grain spike^{-1} of 37.86 was recorded from control. Rahim *et al.,* 2010 reported that increasing phosphorus level from 0 to 81 kg ha^{-1} has increased grain yield from 1.6 to 3.95 Mgha^{-1}. Among different application methods, pop-up responded better producing maximum number of grain spike^{-1} (50.96). Side dressed ranked 2nd with 47.51 grain spike^{-1} compared to broadcast (45.53 grain spike^{-1}). Rahim *et al.,* (2012) reported increased grain spike^{-1} due to band placement of phosphorus which may be due to access of phosphorus fertilizer to crop roots. Interaction of P and application methods revealed that treatment 105 kg P ha^{-1} along with pop-up method produced maximum grain spike^{-1} which was statistically at par with treatment of 70 kg P ha^{-1} coupled with pop-up (Fig. 2).

Grain weight spike^{-1}: Varieties, phosphorus levels and application methods showed significant effect on grain weight spike^{-1} (Table 4). Interaction of varieties x phosphorus was significant however the rest of interactions were non-significant. Varieties showed positive effect on grain weight spike^{-1}. Highest grains weight spike^{-1} (2.09 g) was recorded from Siran-10. Atta Habib ranked 2nd (1.82 g grains weight spike^{-1}) compared with Pirsbak-2004 (1.74 g grains weight spike^{-1}). Variation in grains weight spike^{-1} may be attributed to the genetic potential of varieties for partitioning assimilates to grains (Gokmen & Sencer 1999; Shahzad *et al*., 2002). More grains weight spike^{-1} (2.21 g) was recorded from application of phosphorus at 105 kg ha^{-1} followed by 70 kg P ha^{-1} with grain weight spike^{-1} of 1.97 g. Less grains weight spike^{-1} (1.37g) was observed in control. These results are supported by findings of Turk *et al*., (2002) they reported that application of phosphorus enhanced the rate of crop development. In case of application methods, pop-up had heavier grains spike^{-1} (2.09g) compared with lighter grains spike^{-1} (1.80) from application method of broadcast. Turk *et al.,* (2002) reported that drill placement of phosphorus may increase seed weight plant^{-1} due to better fertilizer use efficiency.

Table 3. Productive tillers m^{-2}, spike length and grain spike^{-1} of wheat varieties as affected by phosphorus levels and its application methods.

Treatments	Productive tillers m^{-2}	Spike length(cms)	Grain spike^{-1}
Varieties			
Siran-2010	355a	9.98a	48.97a
Atta Habib	343b	9.46b	46.63b
Persabak-2004	333c	9.29c	45.36c
LSD	6.82	0.079	0.64
Phosphorus (kg ha^{-1})			
0	257d	8.76d	37.86d
35	310c	9.20c	42.31c
70	363b	9.72b	48.92b
105	386a	10.09a	52.76a
LSD	6.71	0.077	0.52
Application methods(AM)			
Broad cost	334c	9.48c	45.53c
Side Dressed	356b	9.66b	47.51b
Pop-up	370a	9.87a	50.96a
LSD	6.71	0.0770	0.52
Interactions			
P x AM	**	ns	**

Table 4. Grain weight spike^{-1}, 1000 grains weight and grain yield of wheat varieties as affected by phosphorus levels and its application methods.

Treatments	Grain weight spike^{-1}	1000 grains weight(g)	Grain yield(kg ha^{-1})
Varieties			
Siran-2010	2.09a	42.85a	3949a
Atta Habib	1.82b	39.54b	3745b
Persabak-2004	1.74c	38.51c	3603c
LSD	0.054	0.60	62.48
Phosphorus (kg ha^{-1})			
0	1.37d	36.14d	3147
35	1.65c	38.77c	3556
70	1.97b	41.16b	3935
105	2.21a	42.03a	4011
LSD	0.043	0.64	57.18
Application methods(AM)			
Broad cost	1.80c	39.40c	3609
Side Dressed	1.93b	40.56b	3827
Pop-up	2.09a	42.00a	4068
LSD	0.043	0.64	57.18
Interactions			
P x AM	Ns	ns	**

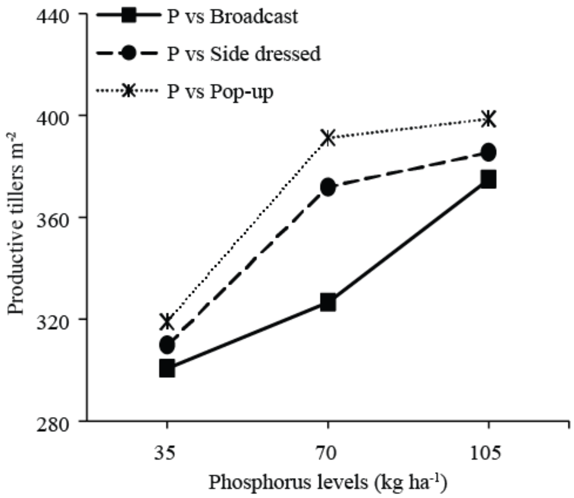

Fig. 1. Interaction of phosphorus and application methods on productive tillers m^{-2} of wheat varieties.

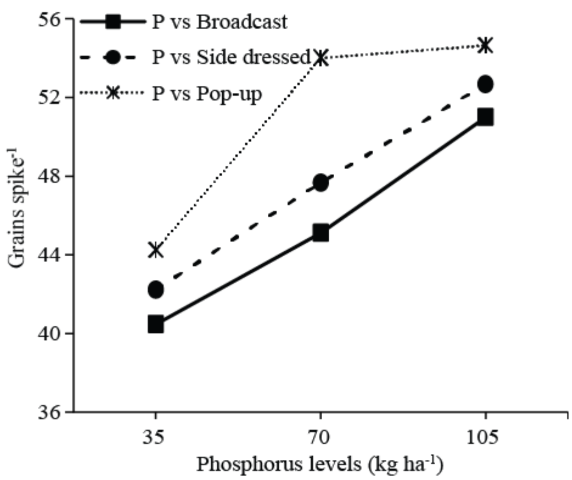

Fig. 2. Interaction of phosphorus and application methods on grain spike^{-1} of wheat varieties.

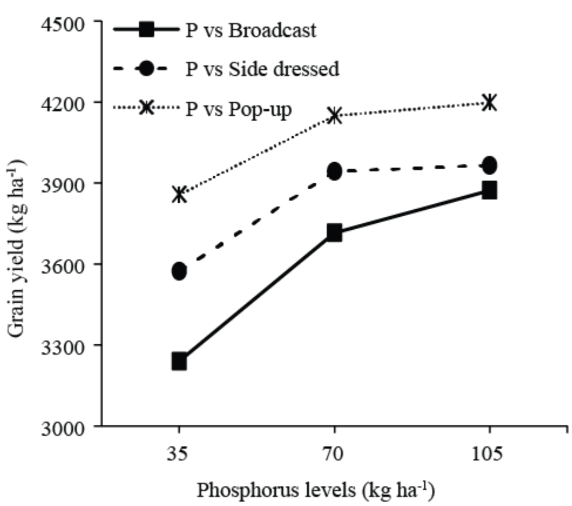

Fig. 3. Interaction of phosphorus and application methods on grain yield of wheat varieties.

Thousand grains weight: Varieties, phosphorus levels and application methods showed significant effect on thousand grains weight (Table 4). Thousand grain weight is an important agronomic trait mainly contributing to final grain yield. Highest 1000 grains weight has led to more grain yield. Among varieties, Siran-10 produced maximum 1000 grains weight (42.85 g) followed by Atta Habib with 1000 grain weight of 39.25 g while Pirsbak-2004 produced lowest grains weight (38.51 g). Difference in grain weight of wheat varieties was reported by Rahim *et al.,* (2010); Maqsood *et al.,* (2002) and Hussain *et al*., (2001). Increase in phosphorus level from 0 to 105 kg ha^{-1} has promoted thousand grain weights when more phosphorus partitioned to grains. Maximum thousand grain weight (42.03g) was recorded with application of 105 kg P ha^{-1} followed by 70 kg P ha^{-1} with 1000 grain weight of 41.16 g. Minimum thousand grain (36.14 g) weight was recorded in control. Alam *et al.,* (2003); Brennan, (1992) reported that optimum level of phosphorus promotes grain development in wheat. Heaviest grains (42 g) were recorded from application method of pop-up compared to lowest grains weight (39.40g) from broadcast. Nadim *et al.,* (2012) and Rehim *et al.,* (2012) investigated highest thousand grain weight due to maximum uptake of phosphorus with application method of pop-up which resulted better grains development.

Grain yield: Grain yield of wheat was significantly affected by varieties, phosphorus levels and application methods (Table 4). Grain yield is the result of several yield contributing traits. Among varieties Siran-10 produced highest grain yield (3949 kg ha^{-1}) followed by Atta Habib with grain yield of 3745 kg ha^{-1} compared to lowest grain yield of 3603 kg ha^{-1} from Pirsabak-2004. Alam *et al.,* (2003) investigated that cultivars vary in grain yield, phosphorus uptake and straw yield. The results further revealed maximum grain yield (4011 kg ha^{-1}) with application of 105 kg P ha^{-1} followed by 70 kg P ha^{-1} with grain yield of 3936 kg ha^{-1}. Rahim *et al.,* (2010); Hussain *et al*., (2008) and Rehman *et al.,* (2004) reported consistent raise in grain yield with gradual increase in application of phosphorus. Application method of pop-up produced highest grain yield (4068 kg ha^{-1}) compared to broadcast with grain yield of 3609 kg ha^{-1}. Blackshaw & Molnar (2009); Jackson *et al*., (1991a) and Jackson *et al*., (1997) investigated that application of phosphorus with seed can increase both spring wheat and winter wheat yield compared to deep banding or broadcasting even in the soils having high amount of phosphorus. While Afridi & Khan (2014) reported that availability nutrients increased the yield related traits of wheat. Interaction of phosphorus x application method revealed that treatments of 105 kg P ha^{-1} coupled with application method of pop-up produced highest grain yield of 4197kg ha^{-1} which wass at par with 70kg ha^{-1} P along with application method of pop-up with grain yield of 4149 kg ha^{-1} (Fig. 3). Nadim *et al.,* (2012) and Rehim *et al.,* (2012) reported highest grain yield with application of phosphorus through band placement compared with broadcast method of application. Enhanced grains grain yield of wheat with application of Hazara rock phosphate was reported by Dost & Naseer (2014); Sharif *et al*., 2013.

Conclusion

Application of phosphorus 105 kg ha^{-1} produced maximum grain yield (4011 kg ha^{-1}). Highest grain yield of 4068 kg ha^{-1} was recorded from application method of pop up. Wheat variety (Siran 2010) ranked 1st with grain production of 3949 kg ha^{-1} compared with 3745 kg ha^{-1} from Atta Habib and 3603 kg ha^{-1} from Pirsabak-2004.

References

Afridi, R.A. and M.A. Khan. 2014. Reduced herbicide doses in combination with allelopathic plant extracts suppress weeds in wheat. *Pak. J. Bot.,* 46(6): 2077-2082.

Alam, S.M., S.A. Shah and M. Akhter. 2003. Varietal differences in wheat yield and phosphorus use efficiency as influenced by method of phosphorus application. *Songklanakarin J. Sci. Tech*., 25(2): 175-181.

Amanullah, M. Zakirullah, M. Tariq, K. Nawab, A.Z. Khan, Farhatullah, Z. Shah, A. Jan, S.K. Khalil, M.T. Jan, M. Sajid, Z. Hussain and H. Rahman. 2010. Levels and time of phosphorus application influence growth, dry matter partitioning and harvest index in maize. *Pak. J. Bot*., 42(6): 4051-4061.

Azimzadeh, M. and A. Koocheki. 1999. Effects of different seeding rates and amount of phosphorus fertilizer on yield and yield components of dry land wheat in northern Khorasan. *Agric. Sci. and Tech*., 13: 131-139.

Blackshaw, R.E. and L.J. Molnar. 2009. Phosphorus fertilizer application method affects weed growth and competition with wheat. *Weed Sci.,* 57(3): 311-318.

Brennan, R.F. 1992. Effect of super phosphate and nitrogen on yield and take all of wheat. *Fert. Res*., 31(1): 43-49.

Dalirie, M.S., R.S. Sharifi and S. Farzaneh. 2010. Evaluation of Yield, Dry Matter Accumulation and Leaf Area Index in Wheat Genotypes as Affected by Terminal Drought Stress. *Not. Bot. Hort. Agrobot. Cluj.,* 38(1): 182-186.

Dost M. and M. Naseer. 2014. Diect and residual effect of Hazara rock phosphate on wheat and succeeding maize in alkaline calcareous soils. *Pak J. Bot*., 46(5): 1755-1761.

Fioreze1, S.L., G. Castoldi, L.A. Pivetta, L.G. Pivetta, D.M. Fernandes and L.T. Büll. 2012. Tillering of two wheat genotypes as affected by phosphorus levels. *Acta Scientiarum. Agro*., 34(3): 331-338.

Gokmen, S. and O. Sencar. 1999. Effect of phosphorus fertilizers and application methods on the yield of wheat grown under dryland conditions. *Tr. J. of Agri. & For.,* 23: 393-399.

Grant, C., S. Bittman, M. Montreal, C. Plenchette and C. Morel. 2005. Soil and fertilizer phosphorus: Effect on plant P supply and mycorrhizal development. *Can. J. Plant Sci*., 85: 3-14.

Gutam, S. 2011. Dry matter partitioning, grain filling and grain yield in wheat genotypes. *Comm. Biometry & Crop Sci*., 6(2): 48-63.

Hussain, N., M.B. Khan and R. Ahmad, 2008. Influence of phosphorus application and sowing time on performance of wheat in calcareous soils. *Int. J. Agri. Biol.,* 10: 399-404.

Hussain, S., A. Sajjad, M.I. Hussain and M. Saleem. 2001. Growth and yield response of three wheat varieties to different seeding densities. *Int. J. Agri. Biol.,* 03(2): 228-229.

Iqtidar, H., K.M. Ayyaz and K.E. Ahmad. 2006. Bread wheat varieties as influenced by different nitrogen levels. J. *Zhejiang Univ. Sci.,* B7(1): 70-78.

Jackson, G.D., G.D. Kushnak, G.R. Carlson, and D.M. Wichman. 1997. Correlation of the Olsen phosphorus test: Spring wheat response. *Comm. Soil Sci. Plant Anal*., 28: 813-822.

Jackson, G.D., G.D. Kushnak, G.R. Carlson, D.M. Wichman, and J. SJacobsen. 1991a. Correlation of the Olsen phosphorus soil test: Winter wheat response. *Comm. Soil Sci. Plant Anal*., 22: 907-918.

Khan, H., K.B. Marwat, M.A. Khan and S. Hashim. 2014. Herbicidal control of parthenium weed in maize. *Pak. J. Bot.,* 46(2): 497-504.

Khan, M.A., S. Kakar, K.B. Marwat and I.A. Khan. 2013. Differential response of *Zea mays* L. in relation to weed control and different macronutrient combinations. *Sains Malaysiana,* 42(10): 1405-1411.

Khan, R., A.R. Gurmani, A.H. Gurmani and M.S. Zia. 2007. Effect of phosphorus application on wheat and rice yield under wheat- rice system. *Sarhad J. Agric.,* 23(4): 851-855.

Kosar, H.S., M.A. Gill, T. Aziz, Rahmatullah and M.A.Tahir. 2003. Relative phosphorus utilization efficiency of wheat genotypes in hydroponics. *Pak J. Agric. Sci*., 40:1-2.

Laghari, G.M., F.C. Oad, S.D Tunio, A.W. Gandahi, M.H. Siddiqui, A.W. Jagirani and S.M. Oad. 2010. Growth yield and nutrient uptake of various wheat cultivars under different fertilizer regimes. *Sarhad J. Agric*., 26(4): 489-497.

Li, Y.D., Y.J. Wang, Y.P. Tong, J.G. Gao, J.S. Zhang and S.Y. Chen. 2005. QTL mapping of phosphorus deficiency tolerancew in soybean. *Euphytica*, 142: 137-142.

Malik, D.M., R.A. Chaudhry and S.J.A. Sherazi. 1992. Management of phosphorus for wheat production in Punjab. In: Proc. Symp. On the role of phosphorus in crop production. NFDC, Islamabad. Pakistan. pp. 175-195.

Maqbool, M.M., M. Ahmad, A. Ali, R. Mahmood, M. Ahmad and M. Sarwar. 2012. Optimizing methods and sources of phosphatic nutrition for Wheat under agro-climate of D.G. Khan, Pakistan. *Pak J. Nutr*., 11(9): 787-792.

Maqsood, M., A. Ali, Z. Aslam, M. Saeed and S. Ahmad. 2002. Effect of irrigation and nitrogen levels on grain yield and quality of wheat. *Int. J. of Agric. and Bio.,* 4(1): 164-165.

Mattas, K.K., R.S Uppal and R.P Singh. 2011. Effect of varieties and nitrogen management on the growth, yield and nitrogen uptake of durum wheat. *Res. J. Agric Sci.,* 2: 376-380.

Memon, M.Y., P. Khan, M. Imtiaz, J.A. Shah and N. Depar. 2011. Response of candidate wheat variety 'nia-8/7' to different levels/ratios of nitrogen and phosphorus. *Pak. J. Bot*., 43(4): 1959-1963.

Mohammad, F., I. Ahmad, N.U. Khan, K. Maqbool, A. Naz, S. Shaheen and K. Ali. 2011. Comparative study of morphological traits in wheat and triticale. *Pak. J. Bot.,* 43: 165-170.

Nadim, M.A., I.U. Awan, M.S. Baloch, E.A. Khan, K. Naveed and M. A.Khan. 2012. Response of wheat (*Triticum aestivum* L.) to different micronutrients and their application methods. *J. Anim. Plant Sci.,* 22(1): 113-119.

Nasim, W., A. Ahmed, M. Tariq and S.A. Wajid. 2012. Studying the comparative performance of wheat cultivars for growth and grains production. *Intl. J. Agron. Plant. Prod.,* 3(9): 306-312.

Rahim, A., A.M. Ranjha and Rahamtullah. 2010. Effect of phosphorus application and irrigation scheduling on wheat yield and phosphorus use efficiency. *Soil & Environ.,* 29(1): 15-22.

Rahim, A., M. Hussain, M. Abid, M.Z. Haq and S. Ahmad. 2012. Phosphorus use efficiency of *Trititicum aestivum* as affected by band placement of phosphorus and farmyard manure on calcareous soils. *Pak. J. Bot*., 44(4): 1391-1398.

Rahim. A., G.H. Abbasi, M. Rashid and A.M. Ranjha. 2007. Methods of phosphorus application and irrigation schedule influencing wheat yield. *Pak. J. Agri. Sci.,* (44): 3-5.

Rashid, R., K.S. Suleman and R. Bental. 1996. Soil Science. National Book Foundation Islamabad. pp. 300.

Rehman, O., A.M. Ranjha, S.M. Saleem and A.A. Khan. 2004. Phosphorus requirement of wheat using modified Freundlich model in Rasulpur soil series. *Pak. J. Agri. Sci.,* 41(1-2): 39-46.

Ryan, J. 1997. Accomplishments and future challenges in dry land soil fertility research in the Mediterranean area. In: *Dry Areas* ICARDA, *Int. Center for Agric. Res*., PO Box 5466, Aleppo, Syria. pp. 369.

Sami, R.C., P.K. Jana and A.K. Bhattacharyya. 1976. Levels of phosphorous and zinc on high yielding wheat variety. *Ind. J. Agric*., 19: 135-145.

Shahzad, K., J. Bakht, W.A Shah, M. Shafi and Jabeen. 2002. Yield and yield components of various varieties as influenced by sowing dates. *Asian. J. Pl. Sci.,* 1(5): 522-525.

Sharif M., M. Arif, T. Burni, F.Wahid, F.Khan, S. Khan, and A. Shah. 2014. Effect of rock phosphate composted with organic materials on yield and phosphorus uptake of wheat and mungbean crops. *Pak. J. Bot*., 45(4):1349-1356.

Sharma, P.K. and J.P. Gupta. 1994. Effect of phosphorous on the yield of wheat at different growth stages. *J. Ind. Soc. Soil Sci*., 42: 77-80.

Singh, B., S.R. Bishnoi and N.S. Dhillon. 2000. Response of Pearl Millet to phosphorus in soils of variable fertility. *J. Indian Soc. Soil Sci.,* 48(4): 845-847.

Steel, R.G.D. and J.H. Torrie. 1980. *Principles and procedures of statistic*. McGraw Hill Book Co.Inc. New York.

Tahir, M., A. Tanveer, A. Ali, M. Ashraf and A. Wasaya. 2008. Growth and yield response of two wheat (*Triticum aestivum* l.) varieties to different potassium levels. *Pak. J. life Soc. Sci.,* 6(2): 92-95.

Turk, M.A. and A.R.M. Tawaha. 2002. Impact of seeding rate, seeding date, rate and method of phosphorus application in faba bean (*Vicia faba* L. *minor*) in the absence of moisture stress. *Biotechnol. Agron. Soc. Environ.,* 6(3): 171-178.

Wahid, F., S. Muhammad, M.A. Khan, A. Ali, A.M. Khattak and A.R. Saljoqi. 2015. Wheat yield and phosphorus uptake as affected by rock phosphate added with different organic fertilizers. *Ciência e Técnica Vitivinícola J.,* 30(3): 90-100.

Zia, M. Sharif, M. Aslam, M.B. Baig and A. Ali. 2000. Fertility issues and fertilizer management in rice wheat system. *Quarterly Sci. Ver*., 5(4): 59-73.

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