International Journal of Botany Studies
ISSN: 2455-541X; Impact Factor: RJIF 5.12
Received: 08-04-2020; Accepted: 12-05-2020: Published: 18-05-2020
www.botanyjournals.com
Volume 5; Issue 3; 2020; Page No. 64-68

Effect of different levels of phosphorus on growth, yield and quality of wheat (*Triticum aestivum* L.)

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Abstract
Wheat (*Triticum aestivum* L.) is the main staple food of Pakistan. Our soils are phosphorus deficit. To study the effect of different levels of phosphorus on growth, yield and quality of wheat. Experiment was conducted at research area of College of Agriculture, University of Sargodha, Pakistan. The trial was laid out in randomized complete block design with three replications. Five phosphorus rates (0, 30, 60, 90 and 120 kg ha^{-1}) were used. The data collected were analyzed statistically using Fishers analysis of variance technique. Results indicated that phosphorus level of 90 kg ha^{-1} produced the maximum plant height (84.34 cm), number of tillers m^{-2} (340.78), spike length (11.33 cm), number of grains per spike (72.54), 1000-grain weight (36.45 g), grain yield (3955 kg ha^{-1}), biological yield (6554 kg ha^{-1}), harvest index (60.30%), crude protein (12.22%.) and fat contents (2.55%). From these results it was concluded that phosphorus level of 90 kg ha^{-1} is best for maximizing productivity and quality of wheat crop under the climatic conditions of Sargodha, Pakistan.

Keywords: wheat, soil, phosphorus, Sargodha

1. Introduction

Wheat (*Triticum aestivum* L.) is the main staple food of Pakistan and occupies a central position in agricultural policies. It contributes 14.4% to the value added in agriculture and 3.1% to Gross Domestic Product (GDP). Wheat was grown on an area of 9039 thousand hectares with a production of 25.3 million tons during 2013-2014 in Pakistan. Wheat is grown over 200 million hectares in the range of environment throughout the world with an annual production more than 650 million metric tons (Yadav *et al*., 2010) [21]. Commercially cultivated wheat is basically of two types i.e. durum wheat (*Triticum turgidum* L.) and bread wheat (*Triticum aestivum* L.) that differ in their genetic complexity, adaptation as well as use. A wide range of products are now made and consumed worldwide from both types of wheat. Wheat is used mainly for human consumption and supports nearly 35 percent of the world population. It is nutritious, easy to store and transport and can be processed into various types of food. The demand for wheat is expected to grow faster than any other major agricultural crop. Due to land limitations, the enhancement of wheat production must come from higher absolute yields, which can only be met by the concerted action of scientists involved in diverse agricultural disciplines. In addition to continuous investments, different agronomic and cultural practices should be considered for raising the yield frontier in wheat.

Soil nutrient status is important for maintaining high quality and sustainable crop production. It is very important to maintain soil nutrient at sufficient level. Application of fertilizers is optional but their costs are too high for farmer. High use of these fertilizers is not profitable (Shaheen *et al*., 2004) [15]. Almost all the soils in Pakistan have poor fertility status due to lack of organic matter. It is estimated that 80-90% of the soil falls in the range between low to medium in phosphorus and nitrogen concentration and high in calcareousness. (Zia, 1990) [23]. Soils developed under harsh climate are poor in organic matter and nutrient like nitrogen, phosphorus and sulfur. Pakistani soils are facing deficiency about 90% of N and P, 40% of K (Ahmad and Rashid, 2004) [2]. The yield potential of Pakistani wheat cultivars is about 8000 kg ha^{-1} but the average actual yield (national average) is 2500 kg ha^{-1} that is far less than the potential yield (Hussain *et al*., 2002) [7]. The gap between potential and actual yield is attributed to late sowing, wheat infestation, water crisis, soil problems, use of low-quality seed and imbalanced fertilizer applications. Supply of adequate amount of nutrient is one of the most important factors in increasing the yield of wheat (Fageria *et al*., 1997) [6]. It is estimated that in 1970s fertilizers had increased cereal yield in developing countries by 50 percent. The farming community of Pakistan is using inadequate and imbalanced plant nutrients for different crops including wheat (Ahmad and Rashid, 2004) [2]. Phosphorus is the potential component of the modern package of the fertilizer technology in wheat and accounts for 35% of the total yield increase brought about by NPK application (Tandon, 1987) [19]. Addition of only 60 kg P_2O_5 ha^{-1} gave an extra yield of 1200 to 1800 kg ha^{-1} over the nitrogen alone (Tandon, 1992) [20]. High yielding wheat varieties demand sufficient nutrient supply to produce maximum grain yield (Ali and Yasin, 1991) [4]. Present study is designed to evaluate the effect of different phosphorus levels on growth, yield and quality of wheat under semi-arid environment of Sargodha.

2. Materials and Methods
2.1 Site and soil
The experiment was conducted at the Agronomic Research area, College of Agriculture, University of Sargodha, Sargodha. The soil was loamy and has a good drainage capacity. Before sowing of crop, analysis of soil was done (Table 1).

Table 1: Physico-chemical soil analysis of crop area.

Depth (cm)	E.Ce (mS cm^{-1})	pH	Organic Matter %	Available Phosphorus (mg kg^{-1})	Available Potassium (mg kg^{-1})	Saturation %	Texture
10	0.47	7.7	1.46	3.6	86	38	Loam
15	0.52	7.8	0.69	1.3	70	38	Loam

2.2 Experimental design and the treatments
Field experiment was conducted to study the response of wheat at different phosphorus levels (0, 30, 60, 90 and 120 kg ha^{-1}) during the season 2013-14. The experiment was laid out in RCBD design with three replications.

2.3 Crop husbandry
The seed bed was prepared by cultivating the field for 2-3 times with tractor mounted cultivator each followed by planking. Wheat variety (FSD-08) was sown in lines in 29th November, 2013, using seed rate of 150 kg ha^{-1}, maintaining row to row distance of 25 cm. Nitrogen and potassium were applied at the rate of 120 and 60 kg ha^{-1}, respectively in all plots. Nitrogen, and potassium were used in form of urea and potassium sulfate. The nitrogen was used in two splits, ½ dose of nitrogen and potash fertilizer were applied at sowing. Remaining ½ of nitrogen was applied at first irrigation. All other agronomic practices such as hoeing, irrigation and plant protection measure were kept normal for the crop.

2.4 Observations
Data regarding number of tillers (m^{-2}), plant height (cm), spike length (cm), number of grains per spike, 1000- grain weight (g), grain yield (kg ha^{-1}), biological yield (kg ha^{-1}), harvest Index (%), fat contents (%) and crude protein (%) was taken. For number of tillers (m^2) quadrat was thrown and tillers were counted. For recording plant height (cm) ten plants were selected randomly and plant height was taken with the help of measuring tape and average was calculated. For spike length (cm) ten plants were selected randomly and their spike length was measured and average was calculated. For number of grains per spike ten spikes from different plants were threshed and grains were counted manually and total number of grains were counted. 1000-grains were counted from a randomly selected sample taken from a seed lot from each treatment and their weight was recorded by using electric balance and average was calculated. For grain yield (Kg ha^{-1}), dried grains were threshed manually from each plot and grains were cleaned, weighed and then converted on kg per hectare basis. The biological yield of each experimental unit was weighed after harvesting the crop and converted into kg per hectare. Harvest index percentage was calculated by using the following formula.

$$\text{Harvest Index } \% = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Crude protein percentage was determined by using the following procedure. One gram well ground homogenized sample was taken in micro Kjhaldhal distillation flask. Five gram of digestion mixture was added in the flask. Then 30 ml of conc. H_2SO_4 was added in the flask. It was placed at hot plate for 3-4 hours until solution became clear. After digestion cooled it down and made the volume 250-ml by adding distillation water. Ten mili litter of sample solution was taken in micro Kjhldhals distillation apparatus. Ten mili litter of 40% NaOH solution was added in it then boiled the whole apparatus through steam. The NH_3 was liberated, condensed and collected in a beaker having 10ml of 2-4% boric acid solution. Again, two to three drops of 0.1% methyl red indicator were added. Titration of the beaker content was done against 0.1 N H_2SO_4 till the light pink color end point. The reading was noted and calculation of the % CP was made by using following formula.

$$\text{CP (\%)} = \frac{\text{Vol of 0.1N H2SO4 used} \times \text{Dilut. of sample solution} \times 0.0014 \times 6.25}{\text{Wt. of sample} \times \text{Sample solution used}} \times 100$$

The percentage fat content of the samples was calculated with the Soxlhet extraction method and the percentage fat contents was calculated.

2.5 Statistical Analysis
The data were analyzed statistically using Fisher analysis of variance technique, Steel *et al.*, (1997) [17] and treatments means were compared by using the least significant difference test (LSD) at 0.05 probability.

3. Results and Discussion
3.1 Number of tillers (m^{-2})
Tillers plays an important role in wheat yield potential and it is affected by genotypes and environmental conditions. More tillers lead to better crop stand, which ultimately increase the yield. Mean comparisons of number of tillers effected by the application of different levels of phosphorus is presented in table 2. Data showed significant difference among the treatments. Maximum number of tillers (340.78 m^{-2}) were recorded at phosphorus level of 90 kg ha^{-1} and minimum number of tillers were observed (330.67 m^{-2}) when no phosphorus was applied (control treatment). Our results are similar with the findings of Prystupa *et al*. (2003) [14] who described that deficiency of phosphorus significantly reduced the number of tillers in barley. Takahashi and Anwar (2007) [18] reported that phosphorous fertilization has great influence on number of tillers.

3.2 Plant height (cm)
Plant height generally displays relative growth and vigor of crop plant. More plant height will produce more green area thus more photosynthetic activity that will be shared to grain yield. Mean comparison for plant height is presented in table 2. Maximum plant height was observed (84.34 cm) when phosphorus was applied @ 90 kg ha^{-1} while control (00 kg phosphorus ha^{-1}) gave least plant height (75.20 cm).

Our results are in line with the findings of Khan *et al.* (2002) [11] who reported that phosphorus levels significantly increased plant height of wheat. Islam *et al.* (2017) [8] described that 90 kg P_2O_5 gave maximum height of wheat plant and lowest was recorded in control.

3.3 Spike length (cm)

Spike length plays a key role in determining the productivity of wheat crop. More the spike length more will be the spikelet's and number of grains per spike and ultimately higher will be the yield. Table 2 present the mean comparisons for spike length of wheat at different phosphorous levels. Data showed significant difference among the treatments. Maximum spike length was observed (11.33 cm) when phosphorus was applied @ 90 kg ha^{-1} and minimum spike length (10.73 cm) was recorded when no phosphorus was applied. Our research findings are similar with the findings of Abbas *et al.* (2000) [1] who observed increased spike length of wheat in response to phosphorus fertilizer. Islam *et al*. (2017) [8] recorded maximum spike length at 90 kg P_2O_5 ha^{-1} in wheat.

3.4 Number of grains per Spike

Number of grains per spike is one of the important parameters that considerably improve the final yield of wheat. Means comparison for number of grains per spike affected by the application of phosphorus is presented in Table 4.2. Data showed significant difference among the treatments. Maximum number of grains per spike was observed (72.54) when phosphorus was applied @ 90 kg ha^{-1} and minimum number of grains per spike (63.78) was recorded when no phosphorus was applied. The results are in agreement with findings of Ponmurugan and Gopi (2006) [13] who reported increased number grains per spike in response to phosphorus fertilizer applied. Islam *et al*. (2017) [8] observed same trend in wheat and reported that 90 kg ha^{-1} gave maximum grains per spike of wheat.

3.5 1000-grain weight (g)

Grain weight is the most important component of wheat yield, which responds to the environment and fertilizer management. More the grain weight, more will be the overall yield. Table 2 present the mean comparisons for 1000-grain weight of wheat at different phosphorous levels. There were highly significant differences for 1000 grain weight among treatments. 90 kg phosphorus ha^{-1} gave maximum 1000-grain weight (36.45 g) and control (00 kg P ha^{-1}) gave lowest 1000-grain weight (35.22 g). Our findings are similar with the findings of Alam *et al.* (2003) [3] who reported significant differences for 1000-grain weight of wheat when phosphorus was applied. Masood *et al*. (2011) [12] observed that 100 kg P_2O_5 gave maximum thousand grain weight of maize.

Table 2: Effect of different levels of phosphorus on number of tillers (m^{-2}), plant height (cm), spike length (cm), number of grains per spike (g) and 1000 grain weight of wheat

Phosphorus levels	Number of tillers (m^{-2})	Plant height (cm)	Spike Length (cm)	Number of grains per spike	1000 Grain Weight (g)
0 kg ha^{-1}	330.67 d	75.20 d	10.73 d	63.78 e	35.22 d
30 kg ha^{-1}	333.78 c	78.09 c	10.95 c	66.56 d	35.63 c
60 kg ha^{-1}	336.56 b	81.41 b	11.18 b	69.21 c	36.02 b
90 kg ha^{-1}	340.78 a	84.34 a	11.33 a	72.54 a	36.45 a
120 kg ha^{-1}	335.78 b	80.50 b	11.10 b	69.41 b	36.01 b
LSD	1.0563	0.9229	0.2503	0.0775	0.1113

3.6 Grain yield (kg ha^{-1})

Grain yield is the most important attribute in wheat, as the wheat crop is basically grown for its grain. More will be the grain yield more will be the total productivity of crop and more will be the net benefit. Table 3 present the mean comparisons for grain yield of wheat grown with different phosphorous levels. The grain yield was observed highly significantly different for phosphorous levels applied. The grain yield ranged from 3955 to 3646 kg ha^{-1}. The maximum grain yield (3955 kg ha^{-1}) was observed under phosphorous level of 90 kg ha^{-1}. The grain yield was recorded minimum (3646 kg ha^{-1}) in control treatment where phosphorous level was kept 00 kg ha^{-1}. These results are in agreement with the findings of Abbas *et al.* (2000) [1] who reported increased in grain yield of in response to optimum use of phosphorus fertilizer. Masood *et al*. (2011) [12] described that 100 kg P_2O_5 gave maximum grain yield of maize and minimum was observed in control.

3.7 Biological yield (kg ha^{-1})

Biological yield is the total biomass produced by the crop from a unit area. This is made up of yield components such as number of tillers, number of grains per spike and grain weight. Mean comparisons for biological yield for phosphorous levels are presented in table 3. Maximum biological yield (kg ha^{-1}) was observed when phosphorus was applied 90 kg ha^{-1} while lowest biological yield (kg ha^{-1}) was recorded from the plot where no phosphorus was applied (control treatment). Our research findings are similar with the findings of Prystupa *et al*. (2003) [14] who reported significant difference for biological yield in wheat. Shahid (2004) [16] who reported increase in biological yield of wheat in response to optimum use of phosphorus fertilizer. Masood *et al*. (2011) [12] reported that maximum biological yield of maize was observed when 100 kg P_2O_5 and control gave the least biological results.

3.8 Harvest Index (%)

Harvest index is the ratio of economic yield and biological yield and it indicates the proportion of assimilates translocated into economic part of plant. The physiological efficiency and ability of a crop plant for converting the total dry matter into economic yield is known as harvest index. Higher the efficiency of converting the dry matter into economic part (grain), higher will be the value of harvest index. In other words, it is useful parameter to indicate the production of plant biomass conversion into grain. Harvest index changes with the availability of nutrients to plans. That the availability of nutrients to plant is influenced by changing the rate of nutrient application. Mean comparisons for harvest index are presented in Table 3. for different phosphorous levels. The harvest index was observed highly significantly different for phosphorous levels applied. Maximum harvest index (%) was observed (60.30) when phosphorus was applied 90 kg ha^{-1} and least harvest index (%) was observed in control treatment where no phosphorus was applied. Our results are quite similar with the findings of Kaleem *et al*. (2009) [10] who reported significant differences for harvest index in wheat. Jan *et al*. (2010) [9] reported that maximum harvest index of maize was observed from the plot where phosphorus was applied @ 90 kg ha^{-1}.

3.9 Fat content (%)

Mean comparison for fat content % effected by phosphorus levels are presented in Table 3. The significant difference was observed between different phosphorus levels. The maximum fat % (2.55) was recorded at phosphorus level of 90 kg ha^{-1} and the minimum (2.22%) was noticed in control treatment. Our results are quite similar with the findings of Zhu *et al.* (2012) [22] who reported increase in fat % of wheat in response to optimum level of phosphorus fertilizer.

3.10 Crude protein %

Mean comparison for crude protein % of wheat at different levels of phosphorus are presented in Table 3. The statistically significant difference for protein % was obtained. The protein % ranged from 11.62 to 12.22%. The maximum crude protein % was recorded (12.22) at 90 kg ha^{-1} phosphorus level. The minimum protein % (11.62) was noted in control treatment. Our results are quite similar with the findings of Erman *et al*. (2009) [5] who reported that maximum crude protein % in pea was recorded when phosphorus was applied @ 90 kg ha^{-1}.

Table 3: Effect of different levels of phosphorus on grain yield (kg ha^{-1}), biological yield (kg ha^{-1}), Harvest Index (%), Fat contents (%) and crude Protein (%) of wheat

Phosphorus levels	Grain yield (kg ha^{-1})	Biological yield (kg ha-1)	Harvest Index (%)	Fat contents (%)	Crude Protein (%)
0 kg ha^{-1}	3646 e	6364 e	57.27 d	2.22 d	11.62 e
30 kg ha^{-1}	3712 d	6427 d	57.73 c	2.34 c	11.79 d
60 kg ha^{-1}	3862 b	6508 b	59.31 b	2.45 b	12.02 b
90 kg ha^{-1}	3955 a	6554 a	60.30 a	2.55 a	12.22 a
120 kg ha^{-1}	3831 c	6461 c	59.25 b	2.47 b	11.99 c
LSD	22.037	14.907	0.3233	0.0306	0.0345

4. Conclusion

Research findings shows that 90 kg ha^{-1} phosphorus produced the maximum plant height, number of tillers m^{-2}, spike length, number of grains per spike, 1000-grain weight, grain yield, biological yield, harvest index, crude protein and fat contents. So, it is concluded that phosphorus level of 90 kg ha^{-1} is best for maximizing productivity of wheat crop under the climatic conditions of Sargodha, Pakistan.

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