Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.4, No.19, 2014

Effect of Different Phosphorus Levels on Growth and Yield of Wheat under Water Stress Conditions

Muhammad Zahid Mumtaz[1*] Muhammad Aslam[2] Moazzam Jamil[1] Maqshoof Ahmad[1]
1.University College of Agriculture and Environmental Sciences, The Islamia University of Bahawalpur, Pakistan
2.Agronomic Research Station, Bahawalpur, Punjab, Pakistan
*Corresponding author email: zahidses@gmail.com

Abstract
Water stress and low phosphorus availability are the limiting factors for growth and yield of wheat. Five different phosphorus levels (P = 0, 30, 60, 90, 120 kg ha^{-1}) with three water stress levels (I_1 = well-irrigated, I_2 = water stress at reproductive stage and I_3 = water stress both at vegetative + reproductive stages) were applied to check their effects on growth and yield of wheat. Higher application of phosphorus with optimum irrigation showed significant effect on growth of wheat. Higher phosphorus application rate compensate the effect of water stress conditions both at vegetative and reproductive stages. Drought stress at vegetative + reproductive stages was more drastically affected as compared to stress at reproductive stage. Lower phosphorus application rate with water stress caused maximum reduction in plant height, number of tillers, spike length, number of grains spike^{-1}, 1000 grains weight, grain yield and straw yield. It was concluded that application of phosphorus at higher rate could compensate drastic effect of water stress. On overall performance, application of phosphorus at the rate of 120 kg ha^{-1} showed better results under water stress conditions as compared to other phosphorus levels.
Keywords: - wheat, water stress, phosphorus, growth, yield

INTRODUCTION

Water shortage and phosphorus deficiency are among major abiotic stresses that limit the productivity of cereals (Usman, 2013; Yu *et al*., 2013). Applying Irrigation and fertilizer to crop is vital for enhancing crops yield (Clarke *et al*., 1990; Recio *et al*., 1999). Water shortage often causes nutrient deficiency particularly phosphorus (Haefele *et al.*, 2006). In most of arid and semi-arid regions of the world, there is limited available rainfall water for wheat (Jafar *et al.,* 2007).

Phosphorus plays an important function in plant physiology. It utilizes sugar and starch and involved in transfer of energy. It strengthen the straw and increase flower formation and fruit production (Anon., 1988). When it applied in soil it becomes fixed in soil soon after its application that limits that crop growth (Mandal and Khan, 1972). Application of phosphorus enhances drought tolerance in plant. It also stimulates root growth and photosynthesis (Singh and Sale, 2000). Application of fertilizer in dry land improve yield and increases the soil water usage (Li *et al*., 2001).

Plant growth depends on several factors, among which water is much important (Kanety *et al*., 2014). It reduces the fruit abscission at earlier growth stage (Buttar *et al*., 2014). Irrigation has a positive effect on growth of wheat (Kanety *et al*., 2014). Higher application of irrigation to plants can increase the growth and yield (Ahadiyat *et al*., 2014; Buttar *et al*., 2014). Wheat mostly absorbed water 0-60 cm from soil (Li *et al*., 2010). Application of irrigation at earlier growth stage of wheat can enhance plant height, number of tillers (Usman, 2013) and grain yield (Tahir *et al.,* 2006; Usman, 2013; Yousaf *et al*., 2014). Plant physiological and metabolic functions become reduced even at small reduction in water availability (Din *et al*., 2011). Plant height was also significantly affected by water shortage (Specht *et al.,* 2001) and 50% reduction in plant height was observed in previous studies (Heuer and Nadler, 1995). Application of phosphorus fertilizer produces taller plants (Cheema *et al.,* 2001).

Fertilizers are also important to enhance the crop yield but in some case it decreases the yield due to shortage of irrigation (Li *et al*., 2001; Rusan *et al*., 2005; Usman, 2013). Integrated effect of phosphorus and irrigation causes increase in grains weight might be due to production of maximum number of grains. Higher phosphorus application rates enhanced the grain size which increases the grain weight (Hossain *et al.,* 1996; Turk and Tawaha, 2002). Water stress causes reduction in grain weight and grain yield (Chimenti *et al.,* 2002; Erdem *et al.,* 2006; Usman, 2013). Integrated use also improves the nutrient uptake (Yousaf *et al*., 2014). Due to water shortage grain yield become reduced (Ahadiyat *et al*., 2014). Grain yield has a correlation with number of spikes in all stages of growth (Guendouz *et al*., 2014). Usman (2013) reported 26% increased in grain yield through the application of irrigation.

Irrigation is necessary for crop growth because of evaporation from plant demands more water to supply (Li *et al*., 2001; Rusan *et al*., 2005). For wheat growth and development soil moisture is needed in the root zone. Soil moisture tension becomes increase due to the reduction in soil moisture content in soil (Arora *et* *al*., 2007). The phosphorus that remained in the soil is important for long term phosphorus management practices. Phosphorus fertilizer recovery is low because of its conversion into unavailable forms of phosphorus that cannot be taken up by plants (Osborne and Rengel, 2002; Wang *et al*., 2005).

The overall irrigation scheduling can be changed significantly depending on phosphorus application (Rizzo *et al*., 1992). As a management strategy, fertilizer application and water absorption from soil water profile has been focused from long period of time to achieve higher yield (Tavakkoli and Oweis, 2004; Oweis and Hachum, 2006). In low water availability role of fertilizers is limited. Increasing crop yield depends on improvement of water availability (Li *et al*., 1998; Usman, 2013). Improvement in soil water availability also improved the fertilizers use efficiency. Keeping in view the above fact, present study was designed to evaluate the effect of different phosphorus levels on growth and yield parameters of wheat at vegetative and reproductive stages.

MATERIALS AND METHODS

Field study was conducted at Research Area of Regional Agriculture Research Station Bahawalpur, Pakistan by using split plot design with three replications. Five phosphorus levels (P_1 = 0 kg ha^{-1}, P_2 = 30 kg ha^{-1}, P_3 = 60 kg ha^{-1}, P_4 = 90 kg ha^{-1}, P_5 = 120 kg ha^{-1}) with three water stress levels (I_1 = well-irrigated, I_2 = water stress at reproductive stage and I_3 = water stress at vegetative + reproductive stages) were applied. Wheat variety (Aas-2011) was used as a test crop in this experiment. Well prepared soil was made to grow wheat crop at the rate of 125 kg ha^{-1}. Plot size was 8m × 1.8m.

All phosphorus and potassium doses were applied at the time of sowing. Nitrogen was applied at three split doses. DAP was used as a phosphorus source whereas, nitrogen and potassium were applied in the form of urea and sulphate of potash (SOP). Irrigation was stopped at the stages of vegetative and reproductive growth to maintain drought stress. Other agronomic practices were done to maintain the crop growth. At the time of physical maturity crop was harvested and the data regarding growth and yield parameters was taken.

Ten plants from each plot were select and their average plant height and spike length was taken with meter rod. From those randomly selected plants number of spikes plant^{-1} were taken. The spikes were threshed manually and grains were counted to take the data of number of grains spike^{-1}. 1000 grains were selected from each plot and their weight was taken. The total grain and straw weight was recorded from ach plot and was expressed in terms of t ha^{-1}.

The data was analyzed statistically and treatment means was compared by employing LSD test at 5% probability level (Steel *et al.,* 1997).

RESULTS

Plant height: - Data regarding the plant height revealed that plant height become increase with increasing phosphorus application rate (table 1). Highest plant height (92 cm) was observed in well irrigated field conditions with the application of 120 kg ha^{-1} phosphorus. This application rate also showed better plant height in water stress at vegetative + reproductive stage (87 cm) and reproductive stages (90 cm). In control phosphorus (P = 0 kg ha^{-1}) shortest plant height was observed in well irrigated as well as in water stress at vegetative and reproductive stages. Better results were obtained in well irrigated field whereas water stress at vegetative + reproductive stages reported lowest plant height as compared to reproductive stage.

Spike length: - Results of analysis of variance showed significantly maximum spike length with the application of phosphorus at the rate of 120 kg ha^{-1} in well irrigated conditions (table 1). With this application rate, water stress at vegetative and reproductive stages also reported better spike length as compared to other phosphorus application rate. Minimum spike length was observed in well irrigated as well as in water stress at vegetative and reproductive stages without phosphorus (P = 0 kg ha^{-1}). Shortest spike length was observed in water stress at vegetative + reproductive stage followed by reproductive stages. Better results were obtained in well irrigated field where increased spike length was observed with increasing phosphorus application rate.

Number of tillers plant^{-1}: - In the present study phosphorus application showed enhanced number of tillers plant^{-1} under well irrigated field and water stress conditions (table 2). Phosphorus application rate at 120 kg ha^{-1} showed maximum number of tillers plant^{-1} under well irrigated field as well as under water stress conditions (figure 1). Vegetative + reproductive stage showed more sensitivity with respect to number of tillers plant^{-1} as compared to reproductive stage. Minimum number of tillers plant^{-1} was observed with control phosphorus (P = 0 kg ha^{-1}) in well irrigated as well as in water stress at vegetative and reproductive stages.

Number of grains spike^{-1}: - The data regarding number of grains spike^{-1} is shown in table 2. Mean comparison showed that with the application phosphorus at the rate of 120 kg ha^{-1} showed significantly maximum number of grains spike^{-1} (37) whereas in control phosphorus lowest number of grains spike^{-1} (29) was obtained under well irrigated field conditions. Phosphorus application rate at 120 kg ha^{-1} also showed better results under water stress at vegetative and reproductive stages. It showed 30 and 34 number of grains spike^{-1} under water stress at vegetative + reproductive and reproductive stages respectively. Control phosphorus application showed lowest number of grains spike^{-1} under water stress as compared to other phosphorus application rate.

1000 grains weight: - Variation in 1000 grain weight was observed with the application of different phosphorus and water stress levels (table 3). Increased in 1000 grains weight was report by phosphorus application at 120 kg ha^{-1} under well irrigated and water stress at vegetative and reproductive stages. It showed 48 g, 44 g and 40 g of 1000 grains weight respectively. It was also observed that water stress badly affect 1000 grains weight especially at vegetative and reproductive stages. Minimum 1000 grains weight was observed by control phosphorus application in all the drought level. Under water stress more sensitivity was observed in vegetative stage with respect to 1000 grains weight as compared to reproductive stage.

Grain yield: - It was revealed that grain yield become increase with increasing phosphorus application rate (figure 2). With the application of 120 kg ha^{-1} phosphorus, maximum grain yield (3.24 t ha^{-1}) was observed in well irrigated field conditions (table 3). This application rate also showed better grain yield in water stress at vegetative + reproductive (1.79 t ha^{-1}) and reproductive stages (2.60 t ha^{-1}). Control phosphorus (P = 0 kg ha^{-1}) reported lowest grain yield under well irrigated as well as in water stress. Better results were obtained in well irrigated field whereas water stress at vegetative stages and reproductive stages showed greater loss in grain yield.

Straw yield: - In case of straw yield, under well irrigated field conditions data showed that with the application phosphorus at the rate of 120 kg ha^{-1} showed significantly maximum straw yield (5.25 t ha^{-1}) whereas in control phosphorus lowest straw yield (3.27 t ha^{-1}) was obtained. Under water stress at vegetative and reproductive stages, it also showed better results. It showed 3.32 t ha^{-1} and 4.17 t ha^{-1} straw yields under water stress respectively. Without phosphorus application, lowest straw yield under water stress was observed as compared to other phosphorus application rate. Water stress drastically affects the straw yield both at vegetative and reproductive stages.

DISCUSSION

Water stress at vegetative and reproductive stages significantly decreased the plant height and spike length. Reason could be reduction in elongation and extension of cell which reduced plant tissue development and growth. Tahir *et al.* (2006) reported 53% reduction in plant height and spike length. They also reported increase in plant height and spike length with increasing amount of irrigation. Water stress reduced growth through disturbing the balance of reactive oxygen species and antioxidant defense. Reactive oxygen species become accumulate which cause oxidative stress in protein and membrane lipids. Water stress also affects photochemical and enzymatic activities in plants (Usman, 2013). Higher application rate of phosphorus resulted in taller plant. Cheema *et al.* (2001) also described the increase in plant height and spike length with the application of phosphorus fertilizers.

Phosphorus in water stress conditions increased the number of tillers plant^{-1}. More phosphorus application at early flowering stage compensates the drastic effect of phosphorus (Ahmadi and Bahrani, 2009; Usman, 2013). Our results are similar to Rao *et al*. (2013) and Usman (2013) who reported reduction in number of tillers plant^{-1} due to water shortage. Increase in phosphorus application with optimum irrigation at critical growth stages showed increase in number of tillers. Results of Turk and Tawaha (2001) and Khan *et al.* (2002) supported our findings who reported greater number of tillers with phosphorus band application. Qadir *et al.* (1999) reported reduced number of tillers due to water stress which causes the reduction in grain yield.

Increase in phosphorus and irrigation application cause increased in number of tillers, grain spike^{-1} and grain weight. It could be due to higher phosphorus application rate which causes increased in grain size which ultimately increases number of tillers, grain spike^{-1} and grain weight (Usman, 2013). Qadir *et al.* (1999) reported reduced grain weight and grains spike^{-1} which causes the reduction in grain yield of wheat due to water stress. Hossain *et al.* (1996) and Turk and Tawaha (2002) also reported higher 1000 grain weight and number of tiller with higher phosphorus application in groundnut. Our results are also according to the finding of Maqsood *et al*. (2002) who observed maximum tillers, grains spike, 1000 grain weight and grain yield. Similar results were also reported by Chimenti *et al.* (2002) and Erdem *et al.* (2006) who indicated lower grain weight with increasing water stress. Qadir *et al*. (1999), Rao *et al*. (2013) and Usman, (2013) reported the reduction in number of tillers, grain spike^{-1} and 1000 grain weight.

It was observed that grain and straw yield increased significantly as irrigation and P application rate increases. Reduction in number of tiller, number of grains spike^{-1} and 1000 grain weight due to water stress also causes the reduction in grain yield (Qadir *et al.,* 1999; Usman, 2013). The reason could also be due to nutrient deficiency, low phosphorus solubility which caused reduction in biomass (Haefele *et al.*, 2006; Ismail *et al*., 2007; Yu *et al*., 2013). Rathke *et al.* (2005) also reported lower yield without fertilizer application. Similar results were also reported by Kang *et al*. (2002), Zhang *et al*. (2008) and Jiang *et al*. (2012). Increased in grain and straw yields were observed due to increased irrigation levels by Reddi and Reddi (1995). Turk and Tawaha (2001) and Ahadiyat *et al*., (2014) also reported higher grain and straw yield with phosphorus application.

CONCLUSION

Present study evaluates five phosphorus and three water stress levels for growth and yield of wheat. Application of phosphorus at the rate of 120 kg ha^{-1} showed better crop productivity in well irrigation as well as in water stress at vegetative and reproductive stages. Water stress drastically affects the critical growth stages of wheat. It was recommended to apply higher rate of phosphorus to compensate the drastic effect of wheat stress.

REFERENCES

Ahadiyat, Y.R. P. Hidayat and U. Susanto. 2014. Drought tolerance, phosphorus efficiency and yield characters of upland rice lines. *Emir. Journal of Food and Agriculture* 26(1): 25-34.

Ahmadi. M. and M.J. Bahrani. 2009. Yield and yield components of rapeseed as influenced by water stress at different growth stages and nitrogen levels. *American Eurasian Journal of Agricultural and Environmental Science* 5(6): 755-761.

Anonymous. 1988. Better crops with plant food. PPI, Atlanta, USA, pp. 26.

Arora, V.K., H. Singh and B. Singh. 2007. Analyzing wheat productivity responses to climatic, irrigation and fertilizer-nitrogen regimes in a semi-arid sub-tropical environment using the CERES -Wheat model. *Agricultural Water Management* 94(1-3): 22-30.

Buttar, G.S., H.S. Thind, K.S. Sekhon, B.S. Sidhu and K. Anureet. 2014. Effect of quality of irrigation water and nitrogen levels applied through trickle irrigation on yield and water use efficiency of tomato under semi-arid environment. *Indian Journal of Horticulture* 71(1): 72-76.

Cheema, M.A., M.A. Malik, A. Hussain, S.H. Shah and S.M.A Basra. 2001. Effects of time and rate of nitrogen and phosphorus application on the growth and the seed and oil yields of canola (*Brassica napus* L.). *Journal of Agronomic Crop Science* 186: 103-110.

Chimenti, C.A., J. Pearson and A.J. Hall. 2002. Osmotic adjustment and yield maintenance under drought in sunflower. *Field Crops Research* 75: 235-246.

Clarke, J.M., C.A. Campbell, H.W. Cutforth, R.M. Depauw and G.E. Winkleman. 1990. Nitrogen and phosphorus uptake, translocation, and utilization efficiency of wheat in relation to environment, and cultivar yield and protein levels. *Canadian Journal of Plant Science* 70: 965-977.

Din, J., S.U. Khan, I. Ali and A.R. Gurmani. 2011. Physiological and agronomic response of canola varieties to water stress. *Journal of Animal and Plant Science* 21(1): 78-82.

Erdem. T., Y. Erdem, A.H. Orta and H. Okursoy. 2006. Use of a crop water stress index for scheduling the irrigation of sunflower (*Helianthus annuus* L.). *Turk Journal of Agricultural and Forest* 30: 11-20.

Guendouz, A., M. Djoudi, S. Guessoum, K. Maamri, A. Hannachi, Z. Fellahi and M. Hafsi. 2014. Genotypic and phenotypic correlations among yield and yield components in durum wheat (*Triticum durum* Desf.) under different water treatments in Eastern Algeria. *Annual Research and Review in Biology* 4(2): 432-442.

Haefele, S.M., K. Naklang, D. Harnpichitvitaya, S. Jearakongman, E. Skulkhu and P. Romyen. 2006. Factors affecting rice yield and fertilizer response in rainfed lowland of Northeast Thailand. *Field Crop Research* 98: 39-51.

Heuer, B. and A. Nadler. 1995. Growth, development and yield of potatoes under salinity and water deficit. *Australian Journal of Agricultural Research* 46: 1477-1486.

Hossain, M.A., S. Begum, A.K.M.M. Rahman, S. Arabinda and A.B.M. Salahuddin. 1996. Growth analysis of mustard and rapeseed in relation to grain filling period and yield potential. *Journal of Agricultural Research* 34: 59-369.

Ismail, A.M., S. Heuer, M.J. Thompson and M. Wissuwa. 2007. Genetic and genomic approaches to develop rice germplasm for problem soils. *Plant Molecular Biology* 65: 547-570.

Jafar, M.S., M.H.E Slam, A.S.R. Amir, N. Ghorban and Z.Ghasem. 2007. The effects of water deficit during growth stages of canola (*Brassicca napus* L.). *American Eurasian Journal of Agriculture and Environmental Science* 2 (4): 417-422.

Jiang, J., Z.L. Huo, S.Y. Feng and C.B. Zhang, 2012. Effect of irrigation amount and water salinity on water consumption and water productivity of spring wheat in North-west China. *Field Crops Research* 137: 78-88.

Kanety, T., A. Naor, A. Gips, U. Dicken, J.H. Lemcoff and S. Cohen. 2014. Irrigation influences on growth, yield, and water use of persimmon trees. *Irrigation Science* 32(1): 1-13.

Kang, S.Z., L. Zhang, Y.L. Liang, X.T. Hu, H.J. Cai and B.J. Gu. 2002. Effects of limited irrigation on yield and water use efficiency of winter wheat in the Loess Plateau of China. *Agriculture Water Management* 55: 203-216.

Khan, M.B., H. Ali and M. Asif. 2002. The response of different irrigation levels to growth and yield of different wheat (*Triticum aestivum* L.) cultivars. *Journal of Research (Science)* 13(1): 71-75.

Kliewer, W.M., B.M. Freeman and C. Hosssom. 1983. Effect of irrigation, crop level and potassium fertilization on carignane vines. I. Degree of water stress and effect on growth and yield. *American Journal of Enology and Viticulture* 34(3): 186-196.

Li, F.M., J. Cao and T.C. Wang. 1998. Influence of phosphorus supply pattern in soil on the yield of spring of wheat. *Journal of plant Nutrition* 21(9): 1921-1932.

Li, F.M., Q.H. Song, H.S. Liu, F.R. Li and X.L. Liu. 2001. Effects of pro-sowing irrigation and phosphorus application on water use and yield of spring wheat under semi-arid conditions. *Agricultural Water Management* 49: 173-183.

Li, Q., B. Dong, Y. Qiao, M. Liu and J. Zhang. 2010. Root growth, available soil water, and water-use efficiency of winter wheat under different irrigation regimes applied at different growth stages in North China. *Agricultural Water Management* 97: 1676-1682.

Mandal, L.N. and S.K. Khan. 1972. Release of phosphorus from insoluble phosphatic materials in acidic low land rice soils. *Journal of Indian Society of Soil Science* 20: 19-25.

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. *International Journal of Agriculture and Biology* 4(1): 164-165.

Osborne, L.D. and Z. Rengel. 2002. Screening cereals for genotypic variation in efficiency of phosphorus uptake and utilization. *Australian Journal of Agricultural Research* 53: 295-303.

Oweis, T. and A. Hachum. 2006. Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa. *Agricultural Water Management* 80: 57-73.

Qadir, G., M. Saeed and M.A. Cheema. 1999. Effect of water stress on growth and yield performance of four wheat cultivars. *Pakistan Journal of Biological Science* 2(1): 236-239.

Rao, S.S., P.L. Regar, S.P.S. Tanwar and Y.V. Singh. 2013. Wheat yield response to line source sprinkler irrigation and soil management practices on medium-textured shallow soils of arid environment. *Irrigation Science* 31: 1-13.

Rathke, G.W., O. Christen and W. Diepenbrok. 2005. Effect of nitrogen source and rate on productivity and quality of winter oilseed rape (*Brassica napus* L.) grown in different crop rotations. *Field Crops Research* 94(2): 103-113.

Recio, B., F. Rubio, J. Lomban and J. Ibanez. 1999. An econometric irrigated crop allocation model for analyzing the impact of water restriction policies. *Agricultural Water Management* 42: 47-63.

Reddi, G.H.S. and T.Y. Reddi. 1995. Irrigation of principle crops. *In:* Efficient Use of Irrigation Water 2nd ed., Kalyani Publisher, New Delhi. pp. 229-259.

Rizzo, V., A. Castrignano, V.D. Bari and Z. Romito. 1992. A new generalized concept of crop coefficient for the use in a crop at incomplete soil covers stage. In: proceedings of second ESA congress, Warwick University, UK., July 25-29, Pp. 200-201.

Rusan, M.M., A. Battikhi and S. Zuraiqi. 2005. Enhancement of nitrogen and water use efficiency by optimizing the combination of soil, crop and nitrogen management," in *Management of Nutrients and Water in Rainfed Arid and Semi-arid Areas for Increasing Crop Production* Pp. 155-177.

Singh, D.K. and P.W.G. Sale. 2000. Growth and potentially conductivity of white clover roots in dry soil with increasing phosphorus supply and defoliation frequency. *Agronomy Journal* 92: 868-874.

Specht, J.E., K . Chase, M. Macrander, G.L. Graef, J. Chung, J.P. Markwell, M. Germann, J.H. Orf and K.G. Lark. 2001. Soybean response to water. A QTL analysis of drought tolerance. *Crop Science* 41: 493-509.

Steel, R.G.D., J.H. Torrie and D.A. Dickey. 1997. Principles and Procedures of Statistics: A Biometrical Approach. 3rd ed. McGraw Hill Co., New York, USA.

Tahir, M.H.N., S. Bashir and A. Bibi. 2006. Genetic potenial of canola (*Brassica napus*) varieties under water stress conditions. *Caderno de pesquisa Sér Bio Santa Cruz do Sul* 18(2): 127-135.

Tavakkoli, A.R. and T. Oweis. 2004. The role of supplemental irrigation and nitrogen in producing bread wheat in the highlands of Iran. *Agricultural Water Management* 65: 225-236.

Turk, M.A. and A.M. Tawaha. 2002. Impact of seedling rate, seeding date, rate and method of phosphorus application in faba bean (*Vicia faba* L. Minor) in the absence of moisture stress. *Biotechnology and Agronomic Society and Environment* 6: 171-178.

Usman, K. 2013. Effect of phosphorus and irrigation levels on yield, water productivity, phosphorus use efficiency and income of Lowland rice in Northwest Pakistan. *Rice Science* 20(1): 61-72.

Wang, Q.R., J.Y. Li, Z.S. Li and P. Christie. 2005. Screening Chinese wheat germplasm for phosphorus efficiency in calcareous soils. *Journal of Plant Nutrition* 28: 489-505.

Yousaf, M., S. Fahad, A.N. Shah, M. Shaaban, M.J. Khan, S.A.I. Sabiel, S.A.I. Ali, Y. Wang and K.A. Osman. 2014. The effect of nitrogen application rates and timings of first irrigation on wheat growth and yield. *Journal of Agricultural Innovations and Research* 2(4): 645-653.

Yu, W., C. Shu-yun, N. Tang-yuan, T. Shen-zhong and L. Zeng-jia. 2013. Coupling Effects of Irrigation and Phosphorus Fertilizer Applications on Phosphorus Uptake and Use Efficiency of Winter Wheat. *Journal*

of Integrative Agriculture 12(2): 263-272
Zhang, X.Y., S.Y. Chen, H.Y. Sun, D. Pei and Y.M. Wang. 2008. Dry matter, harvest index, grain yield and water use efficiency as affected by water supply in winter wheat. *Irrigation Science* 27: 1-10.

Table 1:- Effect of phosphorus levels on plant height and spike length under water stress

Drought levels	Phosphorus levels	Plant height (cm)	Spike length (cm)
Well-irrigated	$P_0 = 0$ kg ha^{-1}	85.0 ± 0.57	10.9 ± 0.31
	$P_1 = 30$ kg ha^{-1}	88.0 ± 0.84	11.2 ± 0.33
	$P_2 = 60$ kg ha^{-1}	89.0 ± 0.52	11.9 ± 0.34
	$P_3 = 90$ kg ha^{-1}	90.0 ± 0.85	12.8 ± 0.17
	$P_4 = 120$ kg ha^{-1}	92.0 ± 0.44	13.2 ± 0.44
Water stress at reproductive stage	$P_0 = 0$ kg ha^{-1}	84.3 ± 0.33	10.5 ± 0.51
	$P_1 = 30$ kg ha^{-1}	85.0 ± 0.66	10.9 ± 0.57
	$P_2 = 60$ kg ha^{-1}	87.0 ± 0.75	11.2 ± 0.07
	$P_3 = 90$ kg ha^{-1}	88.5 ± 0.33	11.5 ± 0.50
	$P_4 = 120$ kg ha^{-1}	90.0 ± 0.67	12.2 ± 0.54
Water stress at vegetative stage + reproductive stage	$P_0 = 0$ kg ha^{-1}	83.0 ± 0.82	10.1 ± 0.49
	$P_1 = 30$ kg ha^{-1}	83.5 ± 0.48	10.4 ± 0.17
	$P_2 = 60$ kg ha^{-1}	84.7 ± 0.58	10.6 ± 0.53
	$P_3 = 90$ kg ha^{-1}	86.0 ± 0.66	10.9 ± 0.33
	$P_4 = 120$ kg ha^{-1}	87.5 ± 0.62	11.1 ± 0.17
	LSD ($p \leq 0.05$)	**3.409**	**1.237**

Table 2:- Effect of phosphorus levels on number of tillers and grains under water stress

Drought levels	Phosphorus levels	Number of tillers m^{-2}	Number of grains spike^{-1}
Well-irrigated	$P_0 = 0$ kg ha^{-1}	103 ± 0.33	29 ± 0.93
	$P_1 = 30$ kg ha^{-1}	105 ± 0.62	30 ± 0.83
	$P_2 = 60$ kg ha^{-1}	109 ± 0.72	33 ± 1.31
	$P_3 = 90$ kg ha^{-1}	112 ± 0.57	35 ± 1.43
	$P_4 = 120$ kg ha^{-1}	114 ± 0.40	37 ± 1.22
Water stress at reproductive stage	$P_0 = 0$ kg ha^{-1}	101 ± 0.57	26 ± 1.22
	$P_1 = 30$ kg ha^{-1}	103 ± 0.82	29 ± 1.93
	$P_2 = 60$ kg ha^{-1}	105 ± 0.66	31 ± 1.72
	$P_3 = 90$ kg ha^{-1}	108 ± 0.35	32 ± 1.26
	$P_4 = 120$ kg ha^{-1}	109 ± 0.80	34 ± 0.57
Water stress at vegetative stage + reproductive stage	$P_0 = 0$ kg ha^{-1}	100 ± 0.73	23 ± 1.20
	$P_1 = 30$ kg ha^{-1}	101 ± 0.57	25 ± 0.48
	$P_2 = 60$ kg ha^{-1}	103 ± 0.33	26 ± 0.88
	$P_3 = 90$ kg ha^{-1}	106 ± 0.57	28 ± 0.94
	$P_4 = 120$ kg ha^{-1}	108 ± 0.59	30 ± 1.18
	LSD ($p \leq 0.05$)	**2.299**	**4.474**

Table 3:- Effect of phosphorus levels on yield component of wheat under water stress

Drought levels	Phosphorus levels	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Well-irrigated	P_0 = 0 kg ha^{-1}	40.50 ± 0.89	1.68 ± 0.07	3.27 ± 0.18
	P_1 = 30 kg ha^{-1}	41.60 ± 1.37	2.16 ± 0.04	3.71 ± 0.12
	P_2 = 60 kg ha^{-1}	42.40 ± 0.68	2.54 ± 0.11	4.49 ± 0.13
	P_3 = 90 kg ha^{-1}	46.12 ± 1.24	2.85 ± 0.08	4.70 ± 0.12
	P_4 = 120 kg ha^{-1}	48.50 ± 0.77	3.24 ± 0.10	5.25 ± 0.15
Water stress at reproductive stage	P_0 = 0 kg ha^{-1}	38.72 ± 0.22	1.39 ± 0.09	2.93 ± 0.19
	P_1 = 30 kg ha^{-1}	40.26 ± 0.99	1.75 ± 0.06	3.24 ± 0.16
	P_2 = 60 kg ha^{-1}	41.40 ± 0.83	1.98 ± 0.09	3.59 ± 0.20
	P_3 = 90 kg ha^{-1}	43.58 ± 1.22	2.26 ± 0.07	3.95 ± 0.16
	P_4 = 120 kg ha^{-1}	44.21 ± 061	2.60 ± 0.03	4.17 ± 0.13
Water stress at vegetative stage + reproductive stage	P_0 = 0 kg ha^{-1}	30.50 ± 0.55	1.15 ± 0.07	2.42 ± 0.17
	P_1 = 30 kg ha^{-1}	32.60 ± 1.16	1.29 ± 0.04	2.68 ± 0.12
	P_2 = 60 kg ha^{-1}	38.73 ± 1.51	1.44 ± 0.08	2.94 ± 0.11
	P_3 = 90 kg ha^{-1}	40.47 ± 0.99	1.59 ± 0.05	3.15 ± 0.20
	P_4 = 120 kg ha^{-1}	40.47 ± 0.79	1.79 ± 0.07	3.32 ± 0.19
	LSD (p≤0.05)	**3.424**	**0.293**	**0.064**

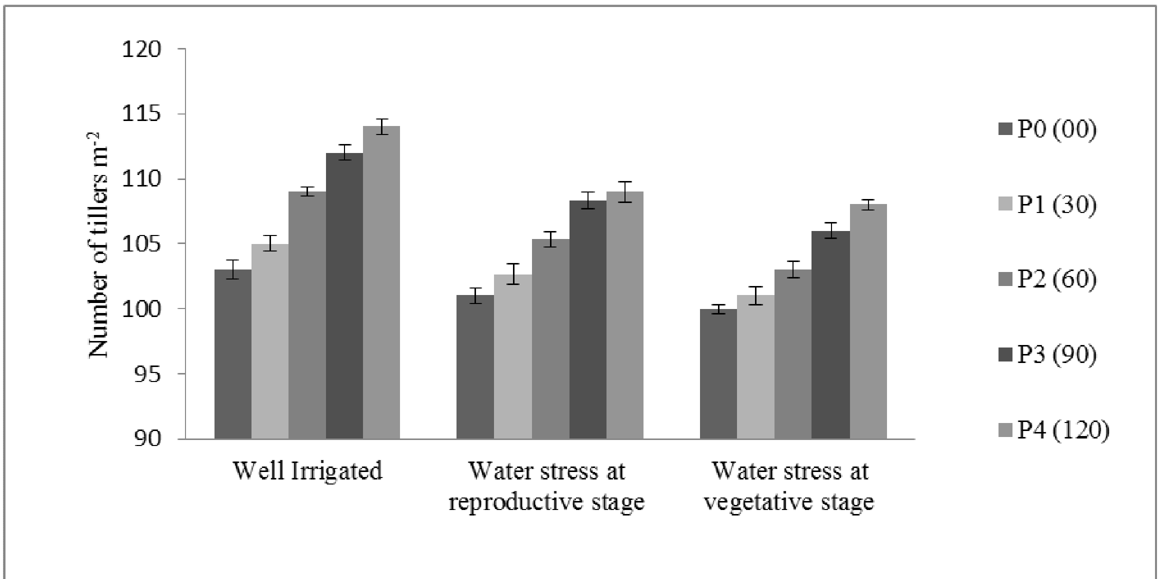

Figure 1: - Effect of different phosphorus levels on number of tillers m^{-2} of wheat

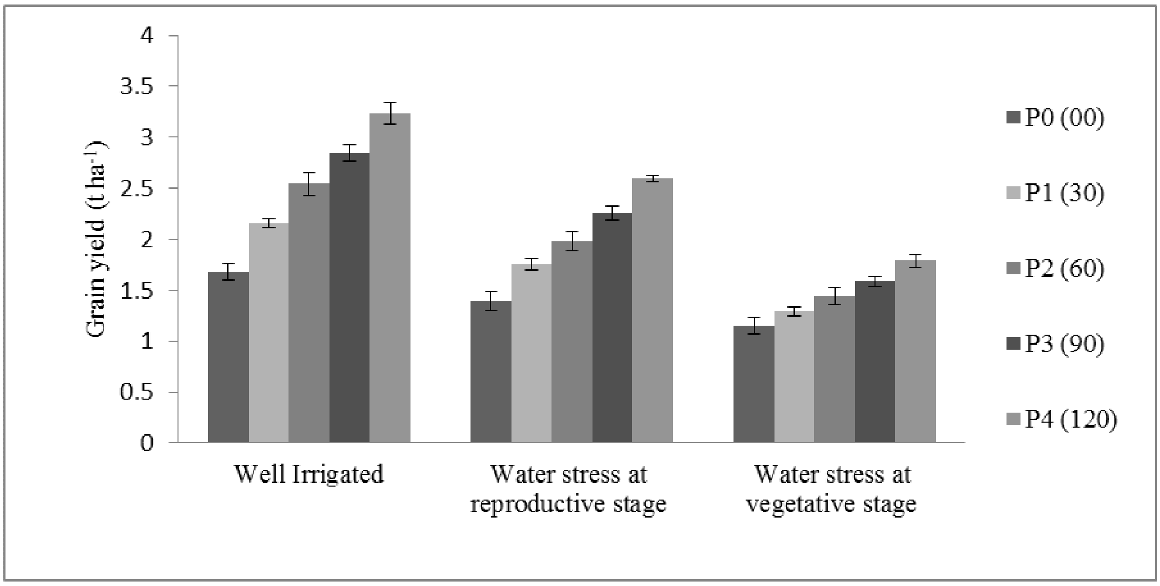

Figure 2: - Effect of different phosphorus levels on grain yield of wheat