Pak. J. Bot., 55(1): 321-326, 2023. DOI: http://dx.doi.org/10.30848/PJB2023-1(30)

IMPACT OF TILLAGE AND POTASSIUM LEVELS AND SOURCES ON GROWTH, YIELD AND YIELD ATTRIBUTES OF WHEAT

MUSHTAQ AHMAD KHAN[1], MUHAMMAD ADNAN[1*], ABDUL BASIR[1], SHAH FAHAD[2], AQSA HAFEEZ [3] MUHAMMAD HAMZAH SALEEM[4*], MANZOOR AHMAD[5], FARHANA GUL[1], DURRISHAHWAR[1], FAZLI SUBHAN[1], SAAD ALAMRI[6], MOHAMED HASHEM[6, 7], AND INAYAT UR RAHMAN[1]

[1]Department of Agriculture, University of Swabi, Anbar-Swabi, Pakistan
[2]Department of Agronomy, The University of Haripur Pakistan
[3]Department of Plant Sciences, Quaid-i-Azam University, Islamabad 45320, Pakistan; aqsahafeez@bs.qau.edu.pk (A.H)
[4]MOA Key Laboratory of Crop Ecophysiology and Farming System in The Middle Reaches of The Yangtze River, College of Plant Science and Technology, Huazhong Agricultural University, Wuhan 430070, China
[5]Department of Agriculture (Agronomy), Bacha Khan University Charsadda, Pakistan
[6]King Khalid University, College of Science, Department of Biology, Abha 61413, Saudi Arabia
[7]Assiut University, Faculty of Science, Botany and Microbiology Department, Assiut, 71516, Egypt
[*]Corresponding author's email: madnanses@uoswabi.edu.pk; saleemhamza312@webmail.hzau.edu.cn

Abstract

Appropriate tillage (T) and potassium (K) fertilizer from a suitable source can play a vital role in optimization of wheat (*Triticum aestivum*) production. Therefore, we evaluated the effect of potassium levels (of 30, 60, 90, and 120 kg K_2O ha^{-1}), sources [sulphate of potash (SOP 50% K_2O) and muriate of potash (MOP 60% K_2O)], and various tillage implement (moldboard plough, chisel plough and rotavator) on growth and yield of wheat in a field experiment during winter 2012-13. Three factorial randomized complete block design (RCBD) with split-split plot arrangement having three replications was adopted where tillage implement was assigned to main plot, sources to sub plot and K levels to sub-sub plot. Plots tilled through rotavator or moldboard and treated with 60 kg K_2O ha^{-1} as SOP produced significantly higher spikes per m^2, kernels per spike, thousand grains weight, kernel and biological yield compared to plots tilled through chisel plough and control or plots fertilized with other K levels. Crop growth rate (CGR) was at par for different tillage implements and K sources. We can conclude that rotavator and mould board plough with application of 60 kg K_2O ha^{-1} from SOP source have improved yield and yield components of wheat, and optimized wheat production.

Key words: Crop growth rate; Chisel plough; Potassium sources; Tillage practices; Wheat yield.

Introduction

Wheat (*Triticum aestivum* L.) is a major staple food cereal crop of Pakistan and the rest of the world as will. In most countries of South America, Africa and Asia wheat is major grain crop in terms of area and production (Arzadum *et al*., 2006; Basir *et al*., 2016; Mfarrej *et al*., 2021). In Pakistan the total wheat cultivated area is 9.18 million hectares, with overall production and yield of 25.478 million tones and 2775.00 kg ha^{-1} respectively in the year 2014-15 (Pakistan Economic Survey, 2014-15), where as in Khyber Pakhtunkhwa (KP), it is cultivated on an area of 0.636 m hectares which produced 1.149 m tones with an average yield of 1807 kg ha^{-1} (Bureau of statistics-KP, 2012-13). The mechanical operation of soil is called tillage and the sequence of operations to prepare the soil for crop production is called tillage system (Muqaddas *et al*., 2005; Ashraf *et al*., 2022). Soil water content and physico-chemical properties can be affected by tillage systems and thus, affect crop yield (Patra *et al*., 2004; Zahoor *et al*., 2016; Saleem *et al*., 2020b). Different tillage depths i.e., deep, conventional or reduce tillage has their own consequences on the soil. Soil porosity, moisture content, aeration and nitrates has been improved by deep and conventional tillage while it reduces weeds and soil compaction (Danilove & Kargin, 1979; Warkentin, 2000; Saleem *et al*., 2020a). While on the other hand shallow tillage is recommended for improved crop yield and soil quality as compared with more intensive tillage (Basir *et al*., 2017). Conventional tillage (20-22 cm) improved wheat yield however, wheat yield reduces by 1.4% in the reduced tillage system (10-12 cm) (Seeibutis *et al*., 2009). In contrast deep manipulation with chisel plough improved soil aeration, moisture and porosity (Malhi *et al*., 2006). Potassium is naturally found in sufficient quantity in most soils of Pakistan however, cultivating high yielding varieties, lack of rotation and continuous mono-cropping have the led the soil deficient in this essential soil nutrient (Ranjha *et al*., 1990; Tariq *et al*., 2022). Potassium is playing a very important role in many physiological processes such as photosynthesis and carbohydrates formation, and building drought tolerance in plants (Tahir *et al*., 2008). Fertilizer potassium also plays an important part in improving crop yield and quality (Mengel & Kirby, 1987; Imran *et al*., 2020). Mostly the crops meet potassium requirements from two sources i.e. SOP and MOP (David *et al*., 1986; Amanullah *et al*., 2021) however, the later one is not commonly used in Pakistan although less expensive than the SOP. One of the reasons for less use of MOP fertilizer may possibly maximize the chloride content in Pakistani soils as they are naturally abundant in chloride content however, the use of MOP is preferred due to sulphate reduction into sulphide ion in the damp conditions (Glander & Peter, 1962). Despite cheaper source of K, MOP application as inorganic sources of fertilizer in not preferred due to the detrimental effect of chloride on plant growth (Hanadi *et al*., 2002; Ahmad *et al*., 2021). Chloride concentration can be increased with application of MOP while it reduces the K content of wheat grain and straw (Khan, 1985; Hussain *et al*., 2021). Keeping in view the pros and cons of MOP and SOP the current research was planned to investigate the influence of K sources, quantities and three different tillage implements including, chisel, mould board and rotavator on growth and yield of wheat under agro-climatic condition of Peshawar, Khyber Pakhtunkhwa Pakistan.

Material and method: A research trial was conducted at research farm of the University of Agriculture, Peshawar Pakistan to determine the effect of potassium, their sources and various tillage implements on growth related aspects of wheat crop. The experiment was laid out in randomized complete block design in a split plot treatment arrangement and 3 replicates. Tillage implements [Chisel (50 cm), Mould board (30 cm) and Rotavator (15 cm)] were assigned to fixed plots, whereas potassium at the rate of 30–60–90 and 120 kg ha^{-1} and potassium sources (SOP and MOP) were assigned to sub plots each of 15 m^2 (5 x 3 m^2). Each sub-plot was consist of 10 rows with a row-to-row distance of 30 cm. Nitrogen (N) requirement of the crop were meet through application of urea at the rate of 150 kg ha^{-1}, half of the N requirement was meet at planting time and the remaining half at booting stage while full dose of phosphorus (90 kg P_2O_5 ha^{-1}) was applied at planting time. Wheat (siran 2010) was sown as test crop at a seed rate of 100 kg ha^{-1}. Productive tillers were recorded by counting the spiked tillers in m^2 area of each sub-plot. The crop growth rate (CGR) at boot and anthesis stages was determined by harvesting one meter row in each sub-plot, sun dried and worked out weight by automatic balance. The following formula described by Gardner *et al.*, (1985), was used for calculating CGR.

$$CGR= \frac{W_2 - W_1}{T_2 - T_1} \times \frac{1}{GA} \quad (g\ m^{-2}\ d^{-1})$$

W_1= Sample dry weight on boot stage
W_2= Sample dry weight on anthesis stage
T_1 = Sample collection date at the time of boot stage
T_2 = Sample collection date at the time of anthesis stage
GA = Ground Area

Numbers of grains per spike were recorded by threshing five spikes selected randomly in each plot and mean was worked out. For thousand grains weight (g) grains were picked from seed lots and weight worked out with automated balance. For biological and kernel yield four central rows in each sub-plot were harvested and sun dried. The sun dried packets were weighed for recording biological yield (BY) and then threshed with a small thresher. Biological and grain yield (GY) was weighted with the help of automatic balance and then worked out into kg ha^{-1} by the given formulas:

$$BY\ (Kg\ ha^{-1}) = \frac{\text{Pack weight of central 4 rows of each subplot}}{\text{Row wieght of central 4 rows length x No of rows harvested}} \text{x } 10000\ m^2$$

$$GY\ (Kg\ ha^{-1}) = \frac{\text{Grain wt of central 4 rows in each plot}}{\text{Row to row distance x row lenght x No of rows harvested}} \text{x } 10000\ m^2$$

Statistical analysis

Statistical analysis of the observed data were conducted by using statistical package MSTAT-C (Steel & Torrie, 1980) appropriate for three factorial split-split plot RCBD. The data were further subjected to least significant difference (LSD) test at 5% level of probability to determine significant differences among the means.

Results and Discussion

Tillage practices had significantly affected productive tillers m^{-2} Table 1. Among tillage practices rotavator had resulted statistically higher productive tiller m^{-2} (359) as compared to the rest of the tillage systems. Comparable results were described by Dolan *et al.*, (2006) who found that productive tillers were reduced by 20% when ploughing was done through chisel as compared to rotavator or mold board plough. This high number of productive tillers would be attributed to optimum water availability in the shallow tilled soil ploughed through rotavator (Chiroma *et al.*, 2006; Thomas *et al.*, 2007; Slawinski *et al.*, 2012) for thorough germination and flower commencement at reproductive stage. The applied Potassium (60 kg ha^{-1}) had significantly increased productive tillers m^{-2} (366) as compared to the control (301) however, further increase in K level reduced tillers m^{-2} Table 1. These finding are in line with the reports of Mukhtar (1975) who reported that all treatment with potassium up to 70 kg ha^{-1} resulted significantly greater number of spike tillers m^{-2} over NP alone and check treatment. Control vs rest contrast indicated that plots other than control produced maximum productive tillers m^{-2} (349) as compared with control plots (301). Application of SOP as a source of Potassium produced statistically maximum (359) productive tillers m^{-2} as compared with MOP source. These results are in consistent with those of Bakhsh *et al.*, (1986) who reported that SOP performed better as compared to K application as a MOP source.

Crop growth rate were significantly affected by potassium levels while tillage practices and K sources had non-significant effect on crop growth rate Table 1. The application of K up to 60 kg ha^{-1} had significantly increased CGR (23.57 g m^{-2} d^{-1}) however; further increase or decrease in K level had significantly reduced CGR. Similarly rest plots treated with K had resulted significantly higher crop growth rate over control plots. Nataraja *et al.*, (2006) reported comparable results and recorded that potassium fertilizer had significant influence on crop growth rate as compared with control plots.

Plots tilled with rotavator had significantly increased number of grains $spike^{-1}$ (51) as compared to chisel plough

(48) however, statistically at par with moldboard plough Table 1. The improved number of grains spike^{-1} in shallow tilled plots was due to increased soil moisture (Al-Kaisi and Yin 2005) greater N efficiency as result of less NO_3^- leaching (Bossche *et al*., 2009). Parallel results were reported by Nakamoto *et al.*, (2006) in which yield components were significantly affected by moldboard plough as compared with chisel plough. No of kernels spike^{-1} improved by augmenting K levels and maximum kernels spike^{-1} (53) were observed for 60 kg K ha^{-1} but statistically comparable with 90 kg K ha^{-1} while less kernels spike^{-1} (42) were produced in control plots. Parallel results were testified by Malik *et al.*, (1988) who studied that K applied up to 45 kg ha^{-1} as SOP had encouraging influence on yield and its attributes over Nitrophos alone. The mean values of control vs rest contrast indicated that rest plots produced statistically higher grains spike^{-1} (49) as compared with control plots grains spike^{-1} (42). Potassium source (SOP) had resulted greater grains spike^{-1} (51) as compared with MOP source of potassium. These results are in consistent with those of Rasul *et al.*, (1987) who are of the opinion that SOP source of K can perform better than MOP source of potassium in terms of grains spike^{-1}.

Significantly heavier grains were recorded in the rotavator tilled plots as compared to chisel tilled plot however, statistically at par with mold board plough plots Table 1. The greater soil moisture (Thomas *et al*., 2007) better soil nutrients (Wright & Hons, 2005; Papini *et al*., 2007) and lower bulk density (Weisskopf & Anken, 2006) had improved grain weight and other yield components in the shallow tilled plots (Hao *et al*., 2001). Comparable results were reported by Nakamoto *et al.*, (2006) who reported that yield components can be affected by different tillage practices. Potassium levels had significantly affected 1000 grains weight and plots treated with 60 kg K ha^{-1} resulted greater 1000 grains weight (45.94 g) compared to control plots (40.25 g). The results of Rasul *et al.*, (1987) support our results who investigated that pots treated with 55 kg K ha^{-1} produced significantly maximum thousand grain weight over control pots. The mean values of control vs rest contrast indicated that rest plots produced heavier 1000 grains weight (44.66 g) as compared to control plots (40.25 g). Potassium applied as SOP source had significantly increased 1000 grains weight as compared with MOP source of potassium. Similarly Rasul *et al.*, (1987) stated that SOP source of K can perform better as compared with MOP source of potassium.

Tillage practices specifically rotavator had significantly increased grain yield (4066 kg ha^{-1}) as compared to chisel plough but statistically at par with mold board plough Table 1. This maximization of grain yield in the shallow tilled plots was due to increased soil beneficial microorganisms, improved nutrients availability, improved soil structure and minimum leaching (Thomas *et al*., 2007; Wright & Hons, 2005). The application of optimum level of potassium (60 kg ha^{-1}) had statistically improved grain yield (4184 kg ha^{-1}) against the rest of K treated plots and control plot (3491 kg ha^{-1}). Control vs rest contrast indicated that plots other than control produced maximum (3972 kg ha^{-1}) grain yield against control plots (3491 kg ha^{-1}). Potassium sources had significantly affected grain yield. Sulphate of Potash source of K had resulted statistically greater grain yield (4058 kg ha^{-1}) as compared with MOP source of potassium. Rotavator as tillage implements and application of potash @ 60 kg ha^{-1} in the form of SOP fertilizer (T x K x S) had significantly increased grain yield Fig. 1. Linear increased for grain yield was observed when mold board plough or rotavator was used along with 60 kg K ha^{-1} from SOP source. However, further increase in K had slightly decreased grain yield (Fig. 1).

Table 1. Spike tillers m^{-2}, CGR, kernel spike^{-1}, 1000 kernels weight, GY and BY of wheat as influenced by tillage operations, potassium quantities and potassium sources.

Treatment	Spike tillers m^{-2}	CGR (g m^{-2} d^{-1})	Grains spike^{-1}	1000- grains weight (g)	GY (kg ha^{-1})	BY (kg ha^{-1})
Tillage Operations						
Chisel (50 cm)	332b	20.06	48b	42.89b	3847b	7869b
Mould board (30 cm)	357a	22.11	50a	45.25a	4002a	8747ab
Rotavator (15 cm)	359a	22.61	51a	45.95a	4066a	9112a
LSD $_{(0.05)}$	15.95	Ns	1.66	1.85	146	965.4
Potassium (kg ha–^{1})						
30	337b	20.85b	47b	44.41b	3912b	8435bc
60	366a	23.57a	53a	45.94a	4184a	8955a
90	354ab	21.40b	50ab	44.29b	3900b	8677ab
120	339b	20.55b	48b	44.01b	3891b	8236c
LSD $_{(0.05)}$	23.16	1.38	3.54	1.44	140.6	430.8
Control vs Rest						
Control	301b	18.20b	42b	40.25b	3491b	6774b
Rest	349a	21.59a	49a	44.66a	3972a	8576a
K Sources						
SOP (50 % K_2O)	359a	22.21	51a	45.40a	4058a	8888
MOP (60 % K_2O)	339b	21.98	48b	43.93b	3885b	8764
Interaction						
T x K	-	-	-	-	-	-
T x S	-	-	-	-	-	-
K x S	-	-	-	-	-	-
T x K x S	-	-	-	-	*	*

Means in the same category followed by different letters are significantly different at $p \leq 0.05$ levels. (-) = Non-significant; * = Significant

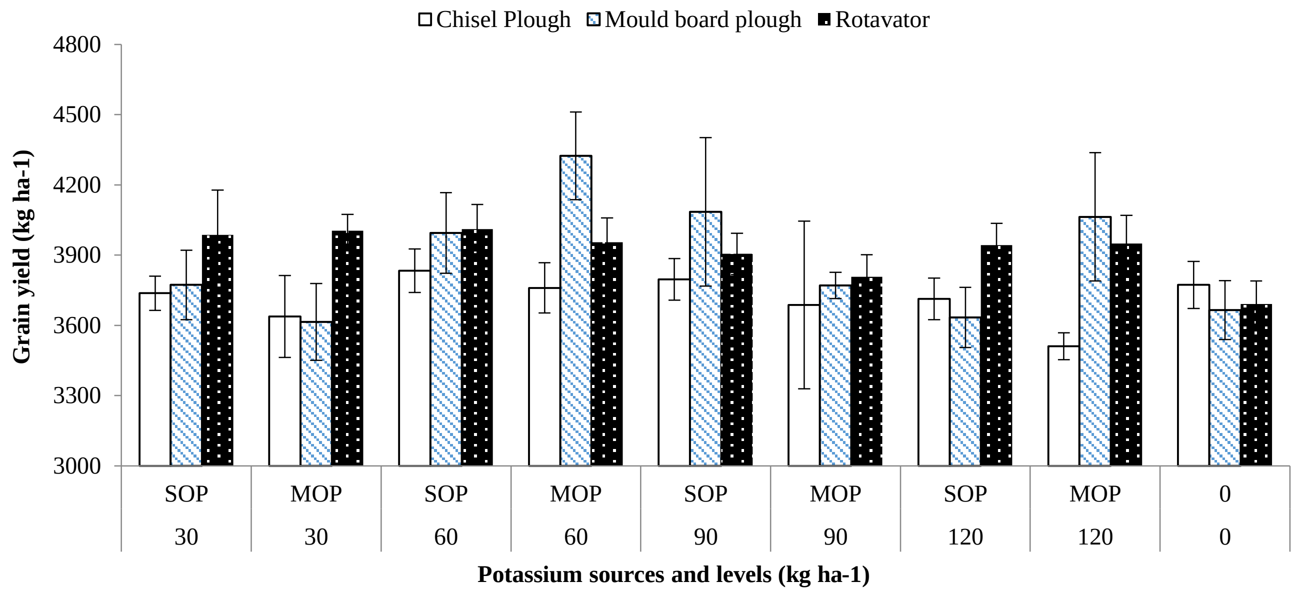

Fig. 1. Grain yield of wheat as influenced by potassium levels, sources and tillage practices.

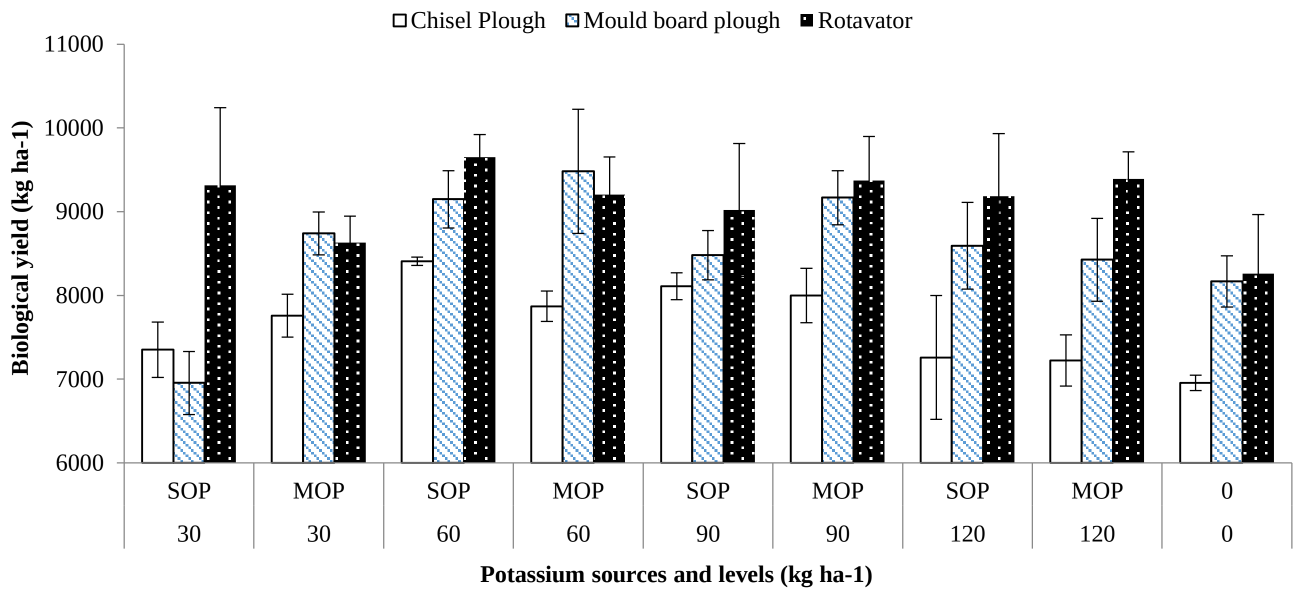

Fig. 2. Biological yield of wheat is affected by potassium levels, sources and tillage practices.

Plots tilled with rotavator had significantly improved wheat biological yield (9112 kg ha^{-1}) as compared to chisel plough (7869 kg ha^{-1}) but statistically comparable with mold board plough Table 1. These results are comparable with those of Thomas *et al*., (2007) and Ozpinar & CAY (2005), who reported that shallow tillage with rotavator resulted statistically greater biological yield as compared to deep tilled plots with chisel plough. Biological yield significantly enhanced with increasing potassium level up to 60 kg ha^{-1} further increase in K level had decreased BY. Malik *et al.*, (1988) also reported significant increase in BY with application of K level from 20 to 60 kg ha^{-1} further increase in K had non-significant effect on biological yield. The mean values of control vs rest contrast shown that plots other than control produced maximum BY (8576 kg ha^{-1}) as compared with control plots (6774 kg ha^{-1}). Rotavator when used for cultivation of wheat along with application of K up to 60 kg ha^{-1} from SOP source (T x K x S) had significantly increased biological yield (Fig. 2). A linear increasing trend was observed in terms of biological yield for mold board plough and rotavator with application of 60 kg K ha^{-1} from SOP source. Further increase in K from both sources significantly decrease biological yield.

Conclusion

Tillage with mold board plough or rotavator along with 60 kg K_2O ha^{-1} as SOP significantly improved numbers of spikes m^{-2}, grains spike^{-1}, 1000 grains weight, grain and BY in wheat. Therefore, using mould board plough or rotavator with application of 60 kg K_2O ha^{-1} as SOP is recommended for obtaining optimum wheat yield in agro-climatic conditions of Peshawar.

Acknowledgements

The author is really thankful to the Director Farm, The University of Agriculture Peshawar for conducting this study on their resources. The authors extend their appreciation to the Deanship of Scientific Research, King Khalid University for funding this work through research groups program under grant number R.G.P. 1/240/41.

References

Ahmad, K., M. Aslam, M.H. Saleem, M. Ijaz, S. Ullah, A. Hussain, M.A. El-Sheikh M. Adnan and S. Ali. 2021 Genetic diversity and characterization of salt stress tolerance traits in maize under normal and saline conditions. *Pak. J. Bot.*, 54: 3.

Al-kaisi, M.M. and X. Yin. 2005. Tillage and crop residue effects on soil carbon and carbon dioxide emission in corn–soybean rotations. *J. Environ. Qual*., 34: 437-445.

Amanullah, Y.M., S. Khalid, M.S. Elshikh, H.M. Akram, Imran, M. Adnan and A. Ali. 2021. Phenology, growth, productivity, and profitability of mungbean as affected by potassium and organic matter under water stress vs. no water stress conditions. *J. Plant Nutri*., 1-22.

Arzadun, M.J., J.I. Arroquy, H.E. Laborde and R.E. Brevedan. 2006. Effect of planting dates, clipping height and cultivars on forage and grain yield of winter wheat. *Agron. J*., 98: 1274-1279.

Ashraf, M.A., R. Rasheed, I. Hussain, M. Iqbal, M.U. Farooq, M.H. Saleem and S. Ali. 2022. Taurine modulates dynamics of oxidative defense, secondary metabolism, and nutrient relation to mitigate boron and chromium toxicity in *Triticum aestivum* L. Plants. *Envi. Sci. Pol. Res*., 11: 1-22.

Bakhhsh, A., J.K. Khattak and A.U. Bhatti. 1986. Comparative effect of potassium chloride and potassium culphate on the yield and protein content of wheat in three different rotations. *Plant Soil*, 96: 273-277.

Basir, A., M.T. Jan, M. Alam, A.S. Shah, K. Afridi, M. Adnan, K. Ali and I.A. Mian. 2017. Impacts of tillage, stubble management and nitrogen on wheat production and soil properties. *Can. J. Soil Sci*., 97: 133-140.

Bossche, A.V.D., S.D. Bolle, S.D. Neve and G. Hofman. 2009. Effect of tillage intensity on N mineralization of different crop residues in a temperate climate. *Soil Till. Res*., 103: 316-324.

Bureau of Statistics. 2013. Ground floor, benevolent fund building, saddar road Peshawar, Khyber Pakhtunkhwa Pakistan. P. 15.

Chiroma, A.M., O.A. Folorunso and A.B. Alhassan. 2006. The effects of land configuration and wood-shavings mulch on the properties of a sandy loam soil in northeast Nigeria. 2. Changes in physical properties. *Trop. J*., 24: 33-38.

Danilove, G. and I.F. Kargin. 1979. Efficiency of deepening the plow layer of leached chernozem. *Sov. Soil Sci. J*., 11: 617.

David, J.G., M. Nabhan, M.T. Saleem and N. Ahmad. 1986. Potash fertilizers in Pakistan: Sulphate and muriate of potash. NFDC, planning and development division government of Pakistan Islamabad, p. 52.

Dolan, M.S., C.E. Clapp, R.R. Allmaras, J.M. Baker and J.A.E. Molina. 2006. Soil organic carbon and nitrogen in a Minnesota soil as related to tillage, residue and N management. *Soil Till. Res*., 89: 221-231.

Gardner, F.P., R.B. Pearce and R.L. Mitchell. 1985. Physiology of crop plants. 1st Edition. Iowa State University Press, Ames, USA. pp 327.

Glander, H. and A.V. Peter. 1962. Discoveries and experience of manuring rice. Potash Res., International Potash Institute Bern, Switzerland. p. 29.

Government of Pakistan. 2015. Ministry of Finance, finance division, Pakistan Secretariat Islamabad. P. 28.

Hao, X., C. Chang, and C.W. Lindwall. 2001. Tillage and crop sequence effects on organic carbon and total nitrogen content in an irrigated Alberta soil. *Soil Till. Res*., 62: 167-169.

Hsnsdi, E.D., N. Claassenand and B. Steingrobe. 2002. Potassium efficiency mechanisms of wheat, barley and sugar beet grown on a K fixing soil under controlled conditions. *J. Plant Nutr. Soil Sci*., 165: 732-737.

Hussain, I., M.H. Saleem, S. Mumtaz, R. Rasheed, M.A. Ashraf, F. Maqsood, M. Rehman, H. Yasmin, S. Ahmed and M. Ishtiaq. 2021. Choline chloride mediates chromium tolerance in spinach (*Spinacia oleracea* L.) by restricting its uptake in relation to morpho-physio-biochemical attributes. *J. Plant Growth Reg*., 4: 1-21.

Imran, M., S. Hussain, M.A. El-Esawi, M.S. Rana, M.H. Saleem, M. Riaz, U. Ashraf, M.P. Potcho, M. Duan and I.A. Rajput. 2020. Molybdenum supply alleviates the cadmium toxicity in fragrant rice by modulating oxidative stress and antioxidant gene expression. *Biomolecules*, 10(11): 1582.

Khan, M. 1985. Differential response of potassium chloride and potassium sulphate on heat and rice under varying levels of salinity. M.Sc. Thesis, Department of Soil Science University of Agriculture Faisalabad.

Malhi, S.S., R. Lemke, Z.H. Wang and B.S. Chhabra. 2006. Tillage, nitrogen and crop residue effects on crop yield, nutrient uptake, soil quality, and greenhouse gas emissions. *Soil Till. Res*., 90: 171-183.

Malik, M.N., U. Shabab and M.I. Makhdum. 1988. Effect of potash on the growth and yield components of late sown wheat. *Sarhad J. Agric*., 4: 1-5.

Mengel, K., and E.A. Kirby. 1987. Principles of Plant Nutrition. West Publishing Company Int. potash Inst. Bern, Switzerland, 100-115.

Mfarrej, M., X. Wang, M. Hamzah Saleem, I. Hussain, R. Rasheed, M. Arslan Ashraf, M. Iqbal, M. Sohaib Chattha and M. Nasser Alyemeni. 2021. Hydrogen sulphide and nitric oxide mitigate the negative impacts of waterlogging stress on wheat (*Triticum aestivum* L.). *Plant Biology*, 660-683.

Mukhtar, A. 1975. Effect of different rates of NPK on the growth and grain yield of new wheat variety D-31. M.Sc. (Hons) Thesis. University of Agriculture Faisalabad.

Muqaddas, B., A.M. Ranjha, M. Abid and M. Iqbal. 2005. Soil physical properties and wheat growth as affected by tillage and farm manure. *Pak. J. Agri. Sci.*, 42: 56-62.

Nakamoto, T., J. Yamagishi and F. Miura. 2006. Effect of reduced tillage on weeds and soil organisms in winter wheat and summer maize cropping on Humic Andosols in Central Japan. *Soil Till. Res*., 85: 94-106.

Nataraja, T.H., A.S. Halepyati, B.T. Pujari and B.K. Desai. 2006. Influence of potassium levels and micronutrients on the physiological parameters of wheat Karnataka. *J. Agri. Sci*., 19: 685-687.

Ozpinar, S. and A. Cay. 2005. Effects of minimum and conventional tillage system on soil properties and yield of winter wheat in clay loam in the canakkale region. *Turk. J. Agric. For*., 29: 9-18.

Papini, R., G. Valboa, C. Piovanelli and G. Brandi. 2007. Nitrogen and phosphorous in a loam soil of central Italy as affected by 6 years of different tillage system. *Soil Till. Res*., 92: 175-180.

Patra, A.K., P.K. Chhonkar and M.A. Khan. 2004. Nitrogen loss and wheat yields in response to zero tillage and sowing time in a semi-arid tropical environment. *J. Agron. Crop Sci*., 190: 115-122.

Ranjha, A.M., A. Jabbar and R.H. Qureshi. 1990. Effect of amount and type of clay minerals on potassium fixation in some alluvial soils of Pakistan. *Pak. J. Agri. Sci*., 27: 187-192.

Rasul, G., J.K. Khattak and A.U. Bhatti. 1987. Comparative effect of potassium sulphate VS potassium chloride on the yield and chemical composition of maize under D.I. Khan condition. *Pak. J. Agri. Sci*., 8: 29-33.

Saleem, M.H., S. Ali, M. Rehman, M.S. Rana, M. Rizwan, M. Kamran, M. Imran, M. Riaz, M.H. Soliman and A. Elkelish, 2020a. Influence of phosphorus on copper phytoextraction via modulating cellular organelles in two jute (*Corchorus capsularis* L.) varieties grown in a copper mining soil of hubei province, china. *Chemosphere*, 248:126032.

Saleem, M.H., S. Fahad, S.U. Khan, S. Ahmar, M.H.U. Khan, M. Rehman, Z. Maqbool and L. Liu, 2020. Morpho-physiological traits, gaseous exchange attributes, and phytoremediation potential of jute (*Corchorus capsularis* L.) grown in different concentrations of copper-contaminated soil. *Ecotoxi. Environ. Safe*., 189: 109915.

Seibutis, V.I. and V. Deveikytė Feiza. 2009. Effects of short crop rotation and soil tillage on winter wheat development in central Lithuania. *J. Agri. Res*., 7: 471-476.

Slawinski, C., J. Cymerman, W.B. Witkowska and K. Lamorski. 2012. Impact of diverse tillage on soil moisture dynamics. *Int. Agrophys*. 26: 301-309.

Steel, R.G.D. and J.H. Torrie. 1980. Analysis of Covariance. In: *Principles and Procedures of Statistics*. A Biometrical Approach. 2nd Ed., McGraw-Hill New York. 401-437.

Tahir, M.A., A. Tanveer, 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: 92-95.

Tariq, M., B. Ahmad, M. Adnan, I.A. Mian, S. Khan, S. Fahad and S. Ali. 2022. Improving boron use efficiency via different application techniques for optimum production of good quality potato (*Solanum tuberosum* L.) in alkaline soil. *PloS one*, 17(1): e0259403.

Thomas, G.A., G.W. Titmarsh, D.M. Freebairn and B.J. Radford. 2007. No-tillage and conservation farming practices in grain growing areas of Queensland a review of 40 years of development. *Aust. J. Exp. Agric*., 47: 887-898.

Warkentin, B.P. 2000. Tillage for soil fertility before fertilizers. *Can. J. Soil Sci*., 80: 391-393.

Weisskopf, P. and T. Anken. 2006. Effects on no-tillage on soil structure. CAB Reviews: Perspectives in Agriculture Veterinary Science Nutrition Natural Research, 1: 051, 11.

Wright, A.L. and F.M. Hons. 2005. Tillage impacts on soil aggregation and carbon and nitrogen sequestration under wheat cropping sequences. *Soil Till. Res*., 84: 67-75.

Yaduraju, N.T. and K.N. Ahuja. 1996. NAR and CGR. In: The Illustrated Dictionary of Agric. (Eds.): Yaduraju, N.T., K.N. Ahuja. Published by Venus Publish. House, 11/298 Press Colony, Mayapuri, New Dehli, India. pp. 200/240.

Zahoor, M., N. Khan, M. Ali, M. Saeed, Z. Ullah, M. Adnan and B. Ahmad. 2016. Integrated effect of organic waste and NPK fertilizers on nutrients uptake in potato crop and soil fertility. *Pure and Appli Bio.*, 5: 601-607.

(Received for publication 17 October 2021)