International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 16, No. 6, p. 210-219, 2020

INNSPUB

RESEARCH PAPER OPEN ACCESS

Role of potassium in enhancing growth, yield and quality of maize (*Zea mays* L.)

Amjed Ali[1], Muhammad Adnan[1*], Muhammad Ehsan Safdar[1], Muhammad Asif[1], Athar Mahmood[2], Mubashar Nadeem[2], Muhammad Arshad Javed[3], Salman Ahmad[4], Rafi Qamar[1], Hafiz Muhammad Bilal[5], Bilal Ahmad Khan[1], Muhammad Mohsin Amin[1], Ali Raza[1]

[1]*Department of Agronomy, College of Agriculture, University of Sargodha, Pakistan*

[2]*Department of Agronomy, University of Agriculture, Faisalabad, Pakistan*

[3]*Department of Agricultural Extension, College of Agriculture, University of Sargodha, Pakistan*

[4]*Department of Plant Pathology, College of Agriculture, University of Sargodha, Pakistan*

[5]*Department of Horticulture, College of Agriculture, University of Sargodha, Pakistan*

Key words: Maize, Production, Nutrients, Potassium, Yield.

http://dx.doi.org/10.12692/ijb/16.6.210-219 Article published on June 29, 2020

Abstract

Maize (*Zea mays* L.) is very important crop which serve as both food and feed purpose. Its average production is very low than its potential yield due to inadequate level nutrients application particularly potassium (K). Therefore, a trial was laid out at COA, UOS, Pakistan to evaluate the effect of different doses of potassium on maize. Five different doses of potassium (0, 40, 80, 120 and 160 kg ha^{-1}) were applied under RCBD with three number of replications. Data regarding plant height (cm), cob length (cm), cob diameter (cm), no. of grains row per cob, no. of grains per row, no. of grains per cob, grain yield (kg ha^{-1}), 1000-grain weight (g), biological yield (kg ha^{-1}), harvest index (%), crude protein (%) and crude oil (%) were noted by standard procedures. Results indicated that highest plant height (210.47 cm), cob length (21.56 cm), cob diameter (6.83cm), no. of grains rows per cob (16.43), no. of grains per row (38.63), no. of grains per cob (593.43), grain yield (8089kg ha^{-1}), 1000-grain weight (439.53 g), biological yield (26015kg ha^{-1}), crude protein (7.66 %) and crude oil (3.66%) were found. It is concluded from the experiment that potassium level (160 kg ha^{-1}) is optimum for achieving maximum yield of maize crop.

*** Corresponding Author:** Muhammad Adnan ✉ mughal3368@gmail.com

Introduction

In all over the world Maize *(Zea mays* L.) crop is used both for food and feed purpose (Asif *et al.*, 2020). In Pakistan, maize ranks 3rd among the cereal crops after rice and wheat (Bukhsh *et al.*, 2011). Maize is cultivated in subtropical, tropical, and temperate provinces of all world therefore, this crop has worldwide adaptability (Khalid *et al.,* 2011). Maize crop matures more quickly because of its foliage distribution and size (Warman, 2003).

Worldwide area under the cultivation of maize crop is about 159 million hand total yield is 796.48 million (USDA, 2010). According to GOP (2013) in Pakistan area under cultivation of maize is 1.08 million hectares and total yield is 4631 thousand tons while average grain yield is about 4.26tons ha^{-1}. Punjab cover area of about 39% and gave 30% of overall production of maize; KPK shares 56% area under maize cultivation and gave63% of the overall yield production whereas Baluchistan and Sindh contribute 5% of entire area and 3% of the overall production in Pakistan (Ghulam-Nabi, 2013).

Maize crop is used as a multipurpose which provides fodder for animals, fuel and food for humans being (Afzal *et al.*, 2009). It is used in cake formation, porridge and bread making in all over the world especially in Africa, America and Asia (Bukhsh *et al.*, 2011). Kumar *et al.* (2013) described that oil present in corn embryo is also used for cooking. In Pakistan, maize yield is very poor (4.26 tons' ha^{-1}) as compare to developed countries such as USA (9840 kg ha^{-1}), France (9474 kg ha^{-1}), Italy (9668 kg ha^{-1}), Egypt (8173 kg ha^{-1}) and Canada (9193 kg ha^{-1}) (FAO, 2011). Pakistan hold 4thposition among countries which are producing corn in all over the globe (USDA, 2012).

Various factors which contributes toward slow production of corn in Pakistan are nutritional in-balance, insufficient use of fertilizer, low soil organic matter contents, inadequate plant density, weeds problem, scarce water supply, selection of unsuitable varieties and insect pest attack (Tahir *et al.*, 2008; Asif *et al.*, 2020). By proper usage of agricultural ideas, progressive cultural practices we can achieve maize potential yield (Wilson and Allison, 2004) and use of balanced amount of phosphorus, nitrogen and potassium (Kang, 1981). Balanced nutrition is an imperative feature which shows a main function in achieving quality production of maize. Presence of nutrients like magnesium, phosphorus, nitrogen and potassium in well-adjusted forms is necessary for plant growth, development and final yield (Randhawa and Arora, 2000). The research shows that application of fertilizers increases more than 50% production of crops (Braun and Roy, 1983).

Potassium is considered as most ambient macronutrients required for proper growth, development and sustainable crop yield. It is a vital element for increasing yield of maize (Bukhsh *et al.*, 2009; Bukhsh *et al.,* 2012). Maize consumed 5.2 kg P_2O_5 ha^{-1} per day during peak flowering period (White, 2000). After sowing during 38 to 52 days, the maize plants require the total potassium up to 38% for whole growing season (Rehman *et al.,* 2008). Due to calcareous nature of Pakistani soils plants cannot uptake adequate amount of potassium (Bukhsh*et al.*, 2008). It improves the overall yield of maize (Sharma *et al.*, 2005). It also helps plant to regulate the movement of stomata (Thomas and Thomas, 2009).

Potassium plays major role in stimulation of enzymes, photosynthesis, regulation of osmotic pressure, movement of the stomata's, protein synthesis, phloem transport, transfer of the energy, cation-anion balance in soil and improves resistance against stress (Marschner, 2012).

In depth of soil, potassium application in association with the other inorganic nutrients, such as phosphorus and nitrogen produce the deeper roots of plants (Kirkby *et al.,* 2009). Therefore, due to the importance and role of potassium (K) in improving both chemical and physical properties of soil, and increasing growth, development and crop yield an experiment was planned to examine the role of different levels of potassium on maize growth, yield and quality.

Materials and methods

Experimental Site and Soil

Research trial was performed at College of Agriculture (COA), University of Sargodha (UOS), Pakistan. Soil analysis was carried out before crop sowing to determine phosphorus, potassium, soil organic matter, electrical conductivity and ph. The data regarding physio-chemical analysis of soil is presented in Table 1.

Design of experiment and treatments

Experiment was arranged under RCBD with the three number of replications. Treatments consists of four different levels of potassium with one control where no potassium was applied (0,40, 80, 120 and 160 kg ha^{-1}).

Crop husbandry

Maize seeds were sown on fine and well prepared ridges. Before sowing seed, bed was prepared with cultivator and planker. Then soil was made fine by rotavator. Maize seeds were treated with "Confidor" fungicide to avoid any kind of pest attack. Ten kg seeds were used for maximum and uniform crop establishment. Different levels of potassium fertilizer were incorporated in soil and the remaining (Nitrogen and Phosphorus) fertilizer applications were applied in splits. Nitrogen in 3 doses i.e. one-third before the sowing, second dose with first irrigation and third dose at tasseling. To applied N, P, k we used Urea, DAP and MOP as sources. The different levels of potassium were applied according the treatments. We sprayed the maize crop at 2-3 leaf stage with Imidacloprid through hand sprayer to protect from the attack of shoot fly. To save the crop from stem borer attack Furadan was used @ 8 kg/acre at 4-5 leaf stage.

Observations

Different parameters of crop were recorded such as height of plant (cm), no. of grain rows per cob, no. of grains per row, no. of grains per cob, diameter of cob (cm), length of cob (cm), biological yield (kg ha^{-1}), grain yield of grain (kg ha^{-1}), 1000- grain weight (g), harvest index (%), crude oil and crude protein contents (%) by standard techniques. To observed plant height and cob length ten plants of maize crop were selected randomly and recorded by using measuring tape. Although, cob diameter was measured by Vernier caliper after that means was calculated. Similarly, no. of grains per row, no. of grains per cob and no. of grain rows per cob from all plots were recorded and mean value of grain was considered. For, 1000- Grains weight, 1000-grains were taken from every plot and dried in micro wave oven and then weighed by using digital balance and grain yield was noted and change into kg ha^{-1}. To obtain biological yield in kg ha^{-1} all plots were separately harvested and weighed then all cobs were removed and sun dried. After drying all grains were removed from cobs, weighed and yield was calculated in to kg ha^{-1}. However, Harvest index (HI) was determined in percentage by formula H.I = (Grain yield / Biological yield) x100. While the determination of crude protein was done by using the micro-kjeldhal distillation method. To determine Crude oil contents (%) in grains used Soxhlet method.

Statistical analysis

Data were analyzed by Statistics software (8.1Statistix, Tallahassee, FL, USA). However, least significant difference (LSD) test was employed to compare the treatments means at 5% probability level.

Results and discussion

Plant height (cm)

The height of any crop plant is vital vegetative trait and affected due to plant genetics, availability of nutrients, seed vigor and environmental conditions during the developmental and growth stages. Mean comparison for plant height under different treatments is given in Fig. 1(A) which showed significant difference between treatments. Highest plants (210.47) cm were noted at160 kg ha^{-1} dose of potassium. However, the lowest plant (177.87 cm) was examined where no dose of potassium was applied. Our findings are similar with Stone *et al.* (2001) who described that plants height increased with increasing in potassium doses.

Table 1. Physio-chemical analysis of soil.

Depth (cm)	ECe (mS m^{-1})	pH	O.M %	Available P (mg kg^{-1})	Available K (mg kg^{-1})	Saturation %	Texture
10	0.46	7.4	1.42	3.9	89	38	Clay Loam
20	0.55	7.7	0.74	1.7	71	38	Clay Loam

It was concluded from above results that reason for raise in plant height by potassium application might be due to fact that potassium regulates the movement of stomata and nutrition and resulted in increased plant height of maize.

Cob length (cm)

Length of cob (cm) is very ambient vegetative factor which describes the yield of maize crop. Mean comparison for cob length under different treatments is given in Fig. 1(B) which shows significant difference between treatments. The highest cob length (21.56) cm was obtained by potassium @ 160 kg ha^{-1}than other treatments and lowest length of cob (16.10 cm) was recorded where no dose of potassium was applied. Our experiment findings are supported by Ijaz *et al.* (2014) who described that different potassium doses significantly influenced the maize cob length. This increase in the length of cob at high dose of potassium might be due to role of potassium in process of photosynthesis.

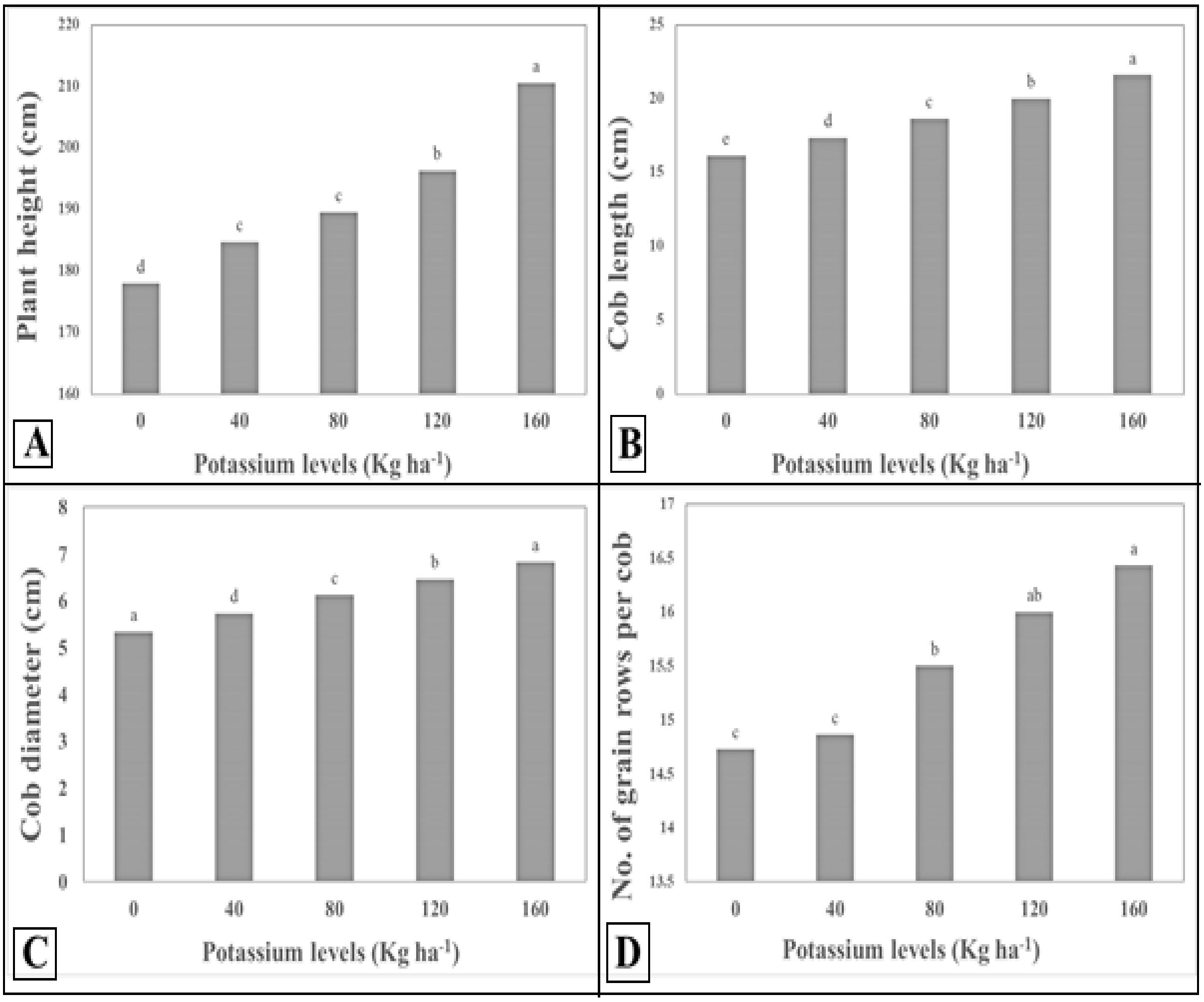

Fig 1. (A) Effect of different levels of potassium fertilizer on plant height (cm) of maize; (B) Effect of different levels of potassium fertilizer on cob length (cm) of maize; (C) Effect of different levels of potassium fertilizer on cob diameter (cm) of maize; (D) Effect of different levels of potassium fertilizer on no. of grain rows per cob of maize.

Cob diameter (cm)

Mean comparison for cob diameter under different treatments is given in Fig. 1 (C) which shows significant difference between treatments. Highest value of cob diameter (6.83 cm) was founded at160 kg ha^{-1}potassium level while, lowest diameter of cob (5.33 cm) was observed under control condition where the no potassium fertilizer was applied. Saleemi *et al.* (2013) supported our findings who stated that the maize cob diameter was significantly influenced by the various doses of potassium. The increase in diameter of cob might be due to balanced application of potassium fertilizer along with other inorganic nutrients and it produced deeper roots and uptake more nutrients (Kirkby *et al.*, 2009).

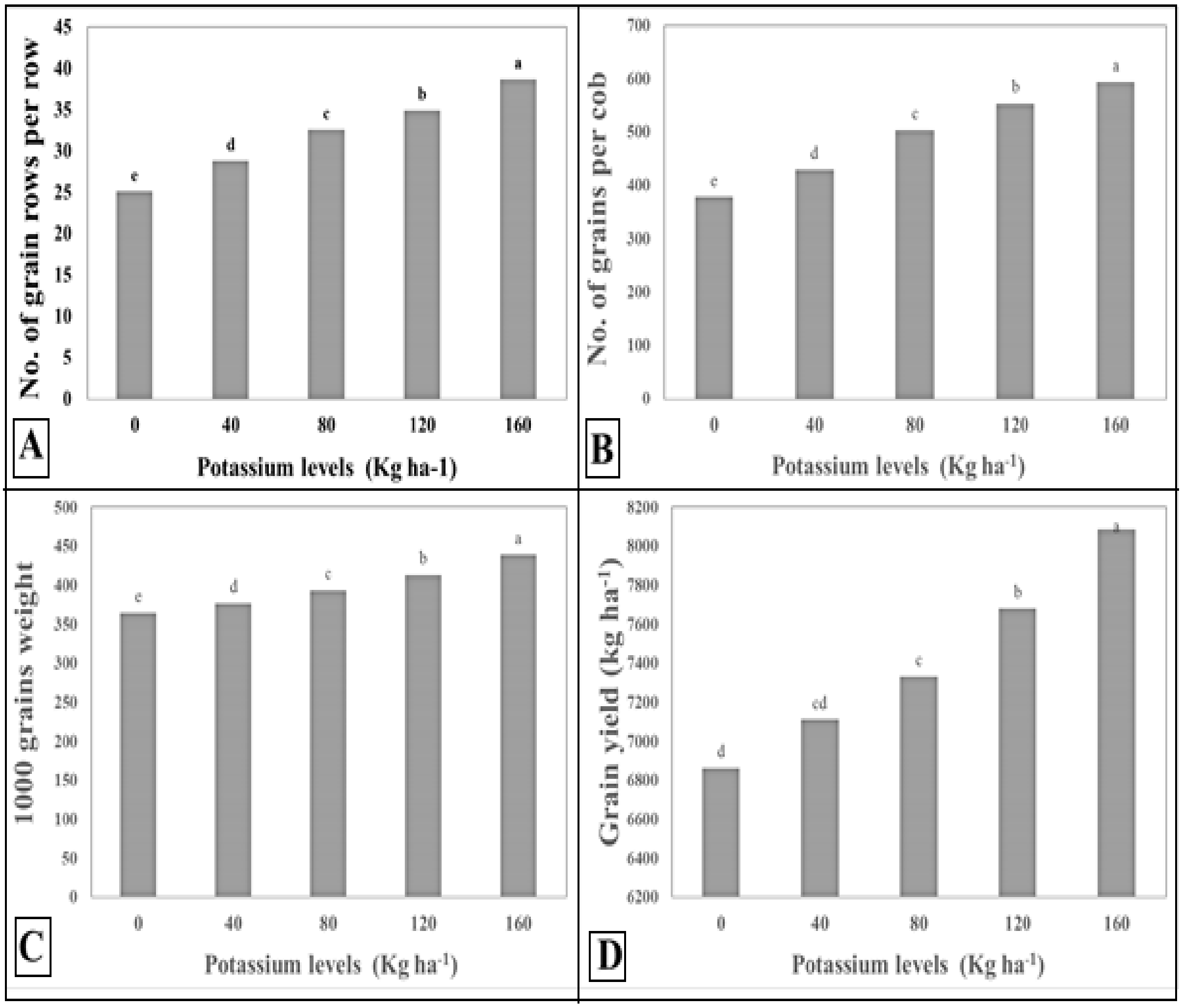

Fig. 2. (A) Effect of different levels of potassium fertilizer on no. of grains per row of maize; (B) Effect of different levels of potassium fertilizer on no. of grains per cob of maize; (C) Effect of different levels of potassium fertilizer on 1000 grain weight of maize; (D) Effect of different levels of potassium fertilizer on grain yield of maize.

Number of grain rows per cob

It is vital and basic factor that contribute toward final yield of the maize. Mean comparison for number of grain rows per cob under different treatments is given in Fig. 1(D) which shows significant difference among treatments. Maximum number of grain rows per cob (16.43) were noted at160 kg ha^{-1} dose of potassium and minimum number of grain rows per cob (16.43) were observed under control condition which was statically similar with 40 kg K ha^{-1} (14.86). Ali *et al.* (2002) described that use of potassium fertilizers significantly increased number of grains rows per cob of maize. Reason of increase in parameter may be due to potassium fertilizer improves photosynthetic movement of plant which finally stimulate to sink and produce maximum grains (Iqbal and Hidayat, 2016).

Number of grains per row

It is vital factor which ultimately affects the yield of maize. Mean comparison for number of grains per row under different treatments is given in Fig. 2(A) which shows that all treatments differ significantly. Highest number of grains per row (38.63) was achieved by application of 160 kg K ha^{-1}and lowest number of grains per row (25.00) were recorded under control treatment. Saleemi *et al.* (2013) stated that higher amount of the potassium and boron fertilizers significantly enhanced number of grains per row of the maize. This increase in parameter may be due to increase in photosynthesis is due to response of potassium fertilizer result in movement of photosynthetes from source to sink and ultimately increase in number of grains per row.

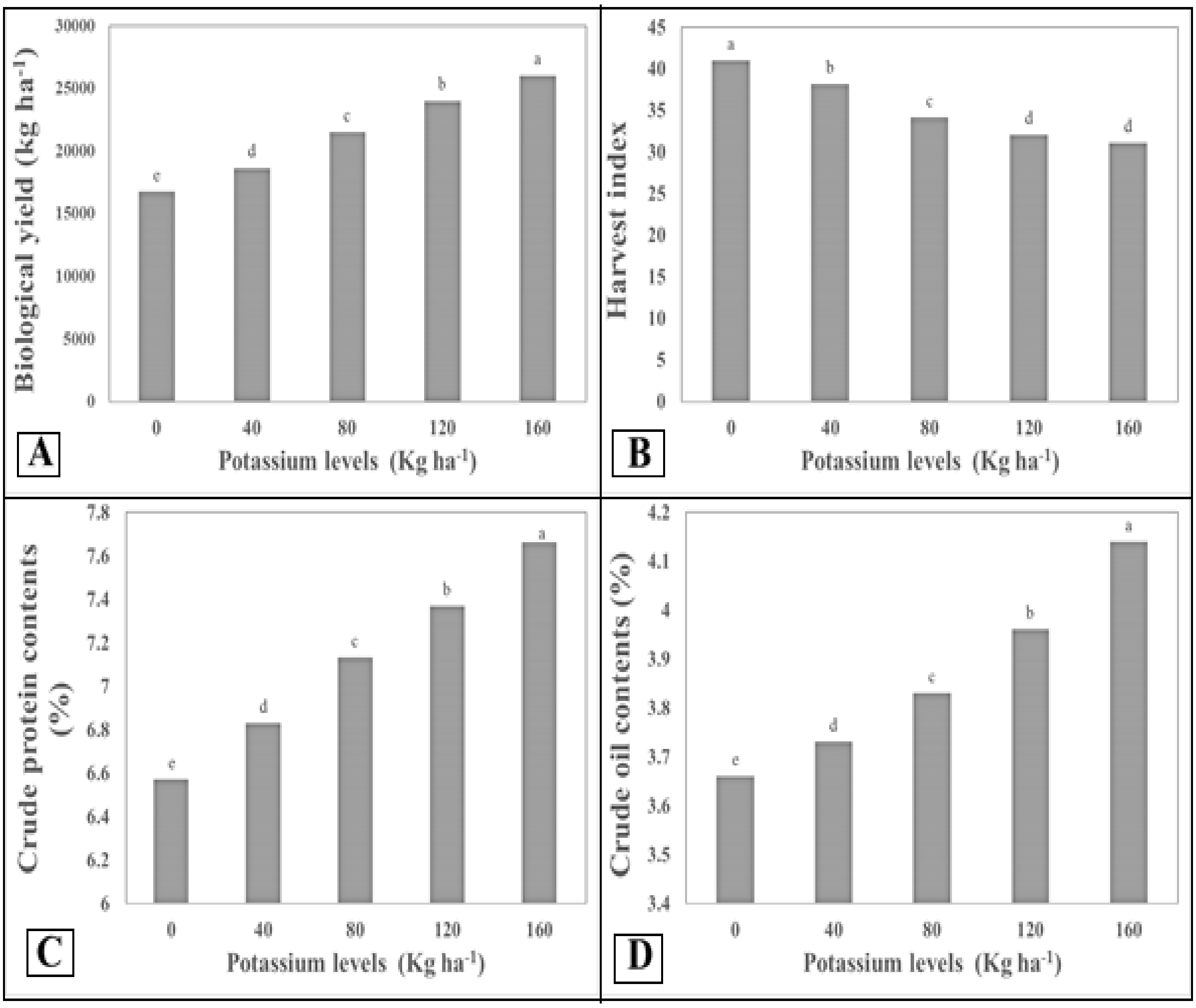

Fig. 3. (A) Effect of different levels of potassium fertilizer on biological yield (kg ha^{-1}) of maize; (B) Effect of different levels of potassium fertilizer on harvest index (%) of maize; (C) Effect of different levels of potassium fertilizer on crude protein contents (%) of maize; (D) Effect of different levels of potassium fertilizer on crude oil contents of maize.

Number of grains per cob

It is a key factor that contributes in total yield. Mean comparison for the number of grains per cob under different treatments is given in Fig. 2(B) which shows that application of potassium fertilizer significantly influences number of grains per cob. Highest number of grains per cob (593.43) noted under potassium level of 160 kg ha^{-1}while lowest number of grains per cob (378.17) found under control conditions. The number of grains per cob of maize increased significantly with increase in dose of potassium (Ijaz *et al*., 2014). The increase in number of grains might be due to more nutrient uptake and role of potassium in enzyme stimulation for protein synthesis (Meille and Pellerin, 2008).

1000-grain weight (g)

It is a major factor that directly influence the yield of *cereal* crops. Influence of different doses of potassium on 1000-grain weight of maize crop is displayed in FIG. 2 (C). Data shows that treatments differed significantly. The maximum value of 1000-grains weight (439.53) examined at 160 kg ha^{-1}potassium while, minimum value of 1000-grains weight (364.80) were noted under control (00 kg K ha^{-1}). Ijaz *et al.* (2014) directed that as doses of potassium fertilizer increased 1000-grains weight of maize significantly increased. This enhancement in 1000-grain weight might be increase in movement of photosynthates in plants due to potassium application (Sadiq and Jan, 2001).

Grain yield (kg ha^{-1})

Main purpose of maize crop is cultivation of farming community is to enhance the grain yield. Mean comparison for the grains yield under different treatments is given in fig. 2(D) which indicated significant difference between the treatments. Maximum grains yield (8089.0) kg ha^{-1}was noted at160 kg ha^{-1} dose of potassium, whereas lowest grains yield (6862.2) kg ha^{-1} was noted where no potassium fertilizer was applied. Pettigrew (2008) reported that the maize grain yield increased as doses of potassium fertilizer increases. This might be due to the role of potassium for improving assimilation of CO_2, stabilized regulation of stomata and improved enzymatic activity which produced higher carbohydrates and increased yield of grains (Nicholson *et al.,* 1999).

Biological yield (kg ha^{-1})

Biological yield of maize in response to different doses of potassium is given in Fig. 3(A). and data shows significant difference among the treatments. The highest biological yield (26015 kg ha^{-1}) achieved at 160 kg ha^{-1}of potassium however, lowest biological yield (16745 kg ha^{-1}) was recorded where no potassium was applied. Ahmad *et al.* (2015) supported our results who described that different doses of potassium influenced the yields and growth component of maize. The possible reason for this increment was the potassium fertilizer plays a significant role in enzyme activity, CO_2 assimilation, stomata closure and improved the biological yield of maize (Tababtabaei and Ranjbar, 2011).

Harvest index (%)

Harvest index of any crop is ratio of economical grains yield to total biomass production. Data shows Fig. 3(B) significant differences for harvest index under various potassium treatments. The lowest harvest index (31.067 kg ha^{-1}) produced by 160 kg ha^{-1}dose of potassium and the highest harvest index (40.96 kg ha^{-1}) noted under control conditions. Findings were contradicted with Nikju *et al.* (2015) reported that the harvest index of maize crop improved by enhancing potassium levels.

Crude protein contents (%)

Mean comparison for crude proteincontents under different treatments is given in Fig. 3(C) which showed significant difference between the treatments. The maximum crude protein contents (7.66%) achieved at potassium dose of 160 kg ha^{-1}although minimum crude protein contents (6.57%) were observed under control conditions.Crude protein contents in hybrid maize grain improved with increasing the level of potassium (Bukhsh *et al.* 2009). Increase in protein contents of grain due to higher availability of potassium to root of maize which result in more synthesis of ATPs and biosynthesis of protein (Tisdale *et al.*, 1997).

Crude oil contents (%)

Mean comparison for the crude oil contents under different treatments is given in Fig.3 (D) which shows significant difference between the treatments. More contents of crude oil (4.14%) obtained under potassium dose of 160 kg ha^{-1}and minimum (3.66%) were noted under no dose. Bukhsh *et al.* (2009)

stated that the content of crude oil in grains of maize hybrid were enhanced significantly with increasing the potassium levels. The probable reason behind the improvement in content of crude oil is might be the involvement of two enzymes acetyl-Co A carboxylase and acetyl- Co A syntheses in process of biosynthesis (Nicolson *et al.*, 1979).

Conclusion

It is concluded from the experiment that potassium level (160 kg ha^{-1}) is best for achieving higher yield of maize under semi-arid conditions of Sargodha, Pakistan.

References

Afzal M, Nasir Z, Bashir MH, Khan BS. 2009. Analysis of list plant resistance in some genotypes of maize against ChiloPartellus (Swinhoe) (Pyralidae: Lepidoptera). Pakistan Journal of Botany **41,** 421-428.

Ahmad N, Khan MB, Farooq S, Shahzad M, Farooq M, Hussain M. 2015. Potassium nutrition improves the maize productivity under water deficit conditions. Soil and Environment **34,** 15-26.

Ali T, Anwar S, Shah WA, Ahmad B. 2002. Response of maize hybrids/cultivars to various levels of potassium and irrigation frequencies. Journal of Agronomy **3,** 201-207.

Asif M, Nadeem MA, Aziz A, Safdar ME, Adnan M, Ali A, Ullah N, Akhtar N, Abbas B. 2020. Mulching improves weeds management, soil carbon and productivity of spring planted maize (*Zea mays* L.). International Journal of Botany Studies **5(2)**, 57-61.

Asif M, Nadeem MA, Aziz A, Safdar ME, Adnan M, Ali A, Ullah N, Akhtar N, Abbas B. 2020.Mulching improves weeds management, soil carbon and productivity of spring planted maize (*Zea mays* L.). International Journal of Botany Studies **5,** 57-61.

Braun H, Roy RN. 1983. Rational plant nutrition and fertilizer use for increase crop production. 7th session of the regional commission on land water use in the near East. 16-18 March.1983. FAO, Rome.

Bukhsh M, Ahmad R, Iqbal J, Rehman A, Hussain S, Ishaque M. 2011. Potassium application reduces bareness in different maize hybrids under crowding stress conditions. Pakistan Journal of Agricultural Sciences **48,** 31-37.

Bukhsh M, Ahmad A, Ishaque M. Malik A. 2009. Response of maize hybrids to varying potassium application in Pakistan. Pakistan Journal of Agricultural Sciences **46,** 179-184.

Bukhsh MA, Ahmad J, Iqbal A. Rehman S, Hussain M, Ishaque. 2011. Potassium application reduces bareness in different maize hybrids under crowding stress conditions. Pakistan Journal of Agricultural Sciences **48,** 31-37.

Bukhsh MA, Ahmad R, Cheema ZA, Ghafoor A. 2008. Production potential of three maize hybrids as influenced by varying plant density. Pakistan Journal of Agriculture Sciences **45,** 413-417.

Bukhsh MA, Ahmad R, Iqbal J, M. Maqbool M, Ali A, Ishaque M, Hussain S. 2012. Nutritional and Physiological Significance of Potassium Application in Maize Hybrid Crop Production. Pakistan Journal of Nutrition **11,** 187-202.

Bukhsh MA, Ahmad R, Ishaque M, Malik A. 2009. Response of maize hybrids to varying potassium application in Pakistan. Pakistan Journal of Agricultural Sciences **46,** 179-184.

Bukhsh MA, Ahmad ZA, Ghafoor A. 2008. Production potential of three maize hybrids as influenced by varying plant density. Pakistan Journal of Agriculture Sciences **45,** 413 417.

FAO. 2011. http//faostat.Fao.Org/site/567/desktopdefault.Aspx?

PageI.D=567.

Ghulam NA. 2013. Maize (Corn) cultivation in Pakistan. Center pivot irrigation system.Valley irrigation Pakistan (private), limited.1-8.

GOP. 2013. Economic survey of Pakistan 2012-13. Finance division, economic advisors' Wing Islamabad. 22.

Ijaz M, Mahmood A, Ullah H. 2014. Response of Maize Hybrid (*Zea mays* L.) to Different Levels of Potassium. Agricultural Research Communication **1,** 30-38.

Iqbal A, Hidayat Z. 2016. Potassium management for improving growth and grain yield of maize (*Zea mays* L.) under moisture stress condition. Scientific reports **6**, 34627.

Kang BT. 1981. Nutrient requirement and fertilizer use for maize. In Agronomy training manual for agro service agronomist NAFPP/IITA. Agriculture Lagos Federal Department 405-416.

Khalid IA, Rahman H, Rehman NU, Arif M, Khalil IH, Iqbal M, Ullah H, Afridi K, Sajjad M, Ishaq M. 2011. Evaluation of maize hybrids for grain yield stability in north-west of Pakistan. Sarhad Journal of Agriculture **27,** 213-218.

Kirkby E. A, LeBot J, Adamowicz S, Romheld V. 2009. Nitrogen in Physiology—An Agronomic Perspective and Implications for the Use of Different Nitrogen Forms. International Fertilizer Society; Cambridge, York, UK.

Kumar D, Aditya NJ. 2013. Nutritional, Medicinal and Economical importance of Corn: A Mini Review. Research Journal of Pharmaceutical Sciences **2,** 7-8.

Marschner PM. 2012. Mineral Nutrition of Higher Plants. 3rd ed. Academic Press; London, UK: 178–189.

Meille LJ, Pellerrin S. 2008. Shoot and root growth of hydroponic maize as influenced by K deficiency. Plant and Soil **304,** 157-168.

Nicholson FA, Chambers BJ, Smith KA, Harrison R. 1999. Spring applied organic manure as a source of nitrogen for cereal crops: Experiments using field scale equipment. Journal of Agricultural Science **133,** 353–363. https://doi.org/10.1017/S0021859699007133

Nicolson NC, Adee A, Stump PK. 1979. Fat metabolism in higher plants: Further characterization of wheat germ acetyl- Co A carboxylase. Archieve Biochemistry 192, 445-456. https://doi.org/10.1016/0003-9861(79)90114-0

Nikju MB, Mobasser HR, Ganjali HR. 2015. Influence of variety on biological yield, harvest index, Percent of protein in Zea mays. Biological Forum – An International Journal.7, 662-667.

Pettigrew WT. 2008. Potassium influences on yield and quality production for maize, wheat, soybean and cotton. Physiolgia Plantarum **133,** 670-681. https://doi.org/10.1111/j.1399-3054.2008.01073.x

Randhawa PS, Arora CL. 2000. Phosphorus-sulfur interaction effects on dry matter yield and nutrient uptake by wheat. Journal of Indian Society of Soil Science **48,** 536-540.

Rehman SU, Ahmad M, Haji A. Bukhsh A, Ishaque M. 2008. Comparative performance and profitability of two corn hybrids with organic and inorganic fertilizers. Pakistan Journal of Agriculture Sciences **45,** 8-12.

Sadiq SA, Jan A. 2001. Effect of graded application of potash on kharif maize sown at different fertility levels. M.Sc (Hons) Thesis. Deptt of Agron. KPK. Agric. Univ. Peshawar.

Saleemi S, Moradi Nezhad S, Abdola AR. 2013. Growth and yield response of maize (*Zea mays* L. cv.

SC704) to different rates of potassium and boron. International journal of agriculture and crop sciences **5,** 236-240.

Sharma S, Duveiller E, Basnet R, Karki CB, Sharma RC. 2005. Effect of potash fertilization on helminthosporium leaf blight severity in wheat, and associated increases in grain yield and kernel weight. Field Crops Research **93,** 142–150. https://doi.org/10.1016/j.fcr.2004.09.016

Stone PJ, Wilson DR, Jamieson PD, Gillespie RN. 2001. Water deficit effects on sweet maize canopy development. Australian Journal of Agricultural Research **52,** 115-126.

Tababtabaei SA, Ranjbar GH. 2012. Effect of different levels of nitrogen and potassium on grain yield and protein of triticale. The International Research Journal of Applied and Basic Sciences **3,** 390-393.

Tahir M, Tanveer A, Ali A, Abbas M, Wasaya A. 2008. Comparative yield performance of different maize (*Zea mays* L.) hybrids under local conditions of Faisalabad –Pakistan. Pakistan journal of life and social sciences **6,** 118-120.

Thomas TC, Thomas AC. 2009. Vital role of potassium in the osmotic mechanism of stomata aperture modulation and its link with potassium deficiency. Plant signal behavior **4,** 240–243. https://doi.org/10.4161/psb.4.3.7955

Tisdale SL, Nelson WL, Beaton JD, Havlin JL. 1997 Soil Fertility and Fertilizers: Elements required in plant nutrition, 5th Ed., Prentice Hall of India (Pvt.) Ltd., New Dehli, India p 68-96.

USDA. 2010. World of corn. 7-8.

USDA. 2012. FAS, Production, Supply, and distribution (PS&D) database. http://www.fas.usda.gov/psdonline/psdhome.aspx.

Warman A. 2003. Corn and Capitalism. How a Botanical Bastards Grew to global dominance? The University of North Carolina press, 22-35.

White J. 2000. Potassium in Agriculture. 2nd Ed. Agro Australia Publishing, Sydney, Australia. 37.

Wilson JH, Allison JCS. 2004. Production and distribution of dry matter in maize following changes in plant population after flowering. Annals of Applied Biology **90,** 121-126. https://doi.org/10.1111/j.1744-7348.1978.tb02618.x