Research Article

Maize Productivity as Influenced by Potassium under Reduced Irrigation Regimes

Salman Ali*, Inamullah, Muhammad Arif, Mehran Ali, Muhammad Owais Iqbal, Fazal Munsif and Arsalan Khan

Department of Agronomy, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan.

Abstract | Drought stress adversely affects crop growth and yield. Water availability at critical crop growth stages reduces water losses and improves water use efficiency and yield of a crop. Potassium is a major plant nutrient required in large quantity by crops and has a significant role in increasing crop growth and yield by reducing the adverse effects of drought stress. Although a large quantity of potassium can be found in soil but is mostly in an unavailable form. A field experiment was, therefore established at Agronomy Research Farm the University of Agriculture Peshawar-KP to evaluate the response of maize toward different K levels under varied irrigation frequencies, during Autumn, 2015. Randomized complete block design with split plot arrangement was used with a subplot size of 3m × 2m. Treatments consisted of six irrigation frequencies; I_0 (no irrigation), I_1 (irrigation at V_1 stage), I_2 (two irrigations; each at V_1 and V_7 stage), I_3 (three irrigations; each at V_1, V_7 and VT stage), I_4 (four irrigations; each at V_1, V_7, RT and R_2 stage) and I_5 (five irrigations; each at V_1, V_7, RT, R_2 and R_4 stage) allocated to main plot and five levels of potassium (0, 25, 50, 75 and 100 kg ha^{-1}) assigned to subplots. Results exhibited significant effects of irrigation frequencies and K levels on crop growth, yield and yield components. Increasing irrigation numbers substantially increased yield of maize crop and taller plants with higher number of grains ear^{-1}, 1000-grain weight, biological and grain yield, and harvest index were observed in plots irrigated five times. Likewise, 75 kg K ha^{-1} application resulted in higher biological (plant height and biological yield) and grain yield (grains ear^{-1}, thousand grains weight, grain yield and harvest index) components of maize. Increase in K levels beyond 75kg ha^{-1} showed a slight decrease in yield. It is concluded that water stress at each critical crop growth stage can drastically reduce crop yield, therefore, five times irrigation each at (mentioned) crop growth stage along with 75 kg ha^{-1} K is recommended for higher maize production.

Received | Febraury 21, 2018; **Accepted** | January 05, 2019; **Published** | February 10, 2019
***Correspondence** | Salman Ali, Department of Agronomy, The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan; **Email:** salmankhan@aup.edu.pk
Citation | Ali, S., Inamullah, M. Arif, M. Ali, M.O. Iqbal, F. Munsif and A. Khan. 2019. Maize productivity as influenced by potassium under reduced irrigation regimes. *Sarhad Journal of Agriculture,* 35(1): 171-181.
DOI | http://dx.doi.org/10.17582/journal.sja/2019/35.1.171.181
Keywords | Irrigation, Potassium, Drought, Stress, Maize productivity, Yield

Introduction

Maize (*Zea mays* L.) is a C_4, annual and exhaustive cereal crop which can be grown throughout the year around the world because of its photo thermo insensitive nature (Verma, 2011). It is grown mostly as an important grain crop and for fodder purpose. It is grown twice in a year (Spring and Autumn seasons) due to its short life cycle. Maize grains are used for many industrial purposes as in alcohol, starch and corn sugar industries. In Pakistan, the cultivated area under maize was 1.17 million ha while total production and average yield were 4.94 million tons and 4231 kg ha^{-1}, respectively. Similarly, in KP, the cultivated area under maize was 0.471 million ha with 0.9148 tons' annual production and 1945 kg ha^{-1} average yield (MNFSR, 2015).

Water is the fundamental part of a plant due to its pivotal role in plant growth and developmental process in plant life cycle. Availability of water at a proper growth stage in proper quantity is essential for higher and economical crop production (Aladabadi et al., 2009). Drought stress negatively affects crop yield in so many ways, therefore, the increasing deficit water scenario due to changing climatic conditions poses a serious threat to high productive agriculture and its sustainability. The damage to crop yield and production is more severe if the drought occurs at several stages of crop growth such as seedling establishment stage, vegetative stage, reproductive growth stage and grain filling stage (Reddy et al., 2004). Regarding the water requirement, the critical duration of maize growth is from the start of flowering to seed dough stage (Classen and Barber, 1977). Several researchers have shown huge losses in yield due to moisture deficit at this stage (Frootan and Yarnia, 2015). Grain yield can be reduced dramatically if drought stress occurs at flowering formation stage (Abo-El-Kheir and Mekki, 2007).

Drought stress occurs at different stage may have a different effect on yield because the physiological processes, water requirement and crop vulnerability to stress is different at each stage of crop growth (Ouda et al., 2006). For example, Pandey (2000) reported that water stress at male meiosis stage resulted in poor growth, reduced tassel development and chlorophyll contents of corn. Drought stress at vegetative stage may not affect the grain yield, but drought stress at grain filling stage can drastically reduce the grain yield by 50% or even more (Kirda et al., 2005). Innovations for saving water in irrigated agriculture by using proper method of irrigation and erasing extra and unnecessary irrigation are of great importance in water deficit regions especially arid and semiarid areas (Kisekka et al., 2015; Kirda et al., 2005). Therefore, application of irrigation water to the crop at proper growing or critical stage can reduce water losses by increasing water use efficiency without any adverse effect on yield.

Balanced fertilization of crop with recommended dose is essential for higher production. Being the lower fertility status of Pakistani soil and exhaustive nature of maize crop it is necessary to supply the required nutrients especially nitrogen (N), phosphorus (P) and potassium (K) in adequate amount (Iken and Amusa, 2004). Potassium is an essential nutrient for optimum plant growth and development (Zia-ul-hassan et al., 2011). Due to its major and important role in plant physiology and biochemistry, it is considered as one of the major plant nutrients (Nawaz et al., 2006). It promotes plant growth and enhances grain yield (Davis et al., 1996). Many studies have revealed the significant role of K fertilizers in reducing the adverse effects of drought stress on crop growth (Tabatabaii et al., 2001). In Pakistan, although most of the soils carry K in relatively large quantity but only a small fraction of it is available to plant (Zhang et al., 2014). K levels are getting depleted day after day due to extensive cultivation of high yielding and exhaustive crops and lower application of potassium to soil (0.8 kg ha^{-1} year^{-1}) which may affect adversely the growth, productivity and ultimately yield of agricultural crops (Ahmad and Rashid, 2003). Reduction in yield due to lower soil K has already been observed in many parts of the country (Aslam et al., 2014).

Therefore, our study aims to evaluate the most appropriate irrigation times during the life cycle of maize and to find out the best level of potassium for higher yield and yield attributes of the maize crop.

Materials and Methods

Description of experimental site

A field trial was carried out at Agronomy Research Farm, The University of Agriculture Peshawar, in autumn season, 2015. The experimental site exhibits subtropical climatic conditions with an annual rainfall of 350 mm. Warsak canal is used to irrigate the research area. According to FAO soil classification, the soil of experimental site is categorized as Haplic Luvisols. Physio-chemical properties of the experimental site are listed in Table 1. Data regarding rainfall, maximum and minimum temperature during the crop growth cycle is given in Figure 1.

Experimental design and treatments

Randomized complete block design with split-plots arrangement was used to test the effects of various levels of potassium under reduced irrigation. Treatments were replicated three times. Five critical crop growth stages were selected from maize growth stage described by Darby and Lauer (2000).

Treatments consisted of six irrigation frequencies; I_0 (zero or control irrigation), I_1 (irrigation at V_1 stage), I_2 (two irrigations; each at V_1 and V_7 stage), I_3 (three irrigations; each at V_1, V_7 and VT stage), I_4 (four irrigations; each at V_1, V_7, RT and R_2 stage) and I_5 (five irrigations; each at V_1, V_7, RT, R_2 and R_4 stage), allocated to main plots and five levels of potassium (0, 25, 50, 75 and 100 kg ha^{-1}) assigned to subplots. Nitrogen from urea and phosphorus from DAP (Diammonium phosphate) were applied at the rate of 120 and 90 kg ha^{-1}, respectively, whereas, the source of potassium was sulfate of potash (SOP). All the potassium and phosphorus fertilizers were applied at sowing time (19th June, 2015) of maize while nitrogen was applied in two splits; half at sowing time and a half at the V_7 stage of crop growth.

Table 1: *Soil physio-chemical properties of the experimental site.*

Property	Unit	Value
Clay	%	3.5
Sand	%	46.5
Silt	%	50
Textural class		Silty clay loam
pH		7.54
EC	dS m^{-1}	0.20
Total Potassium	mg kg^{-1}	80.63
Total Phosphorus	mg kg^{-1}	2.48
Total Nitrogen	mg kg^{-1}	18.94
Total Organic Carbon	g kg^{-1}	12.71

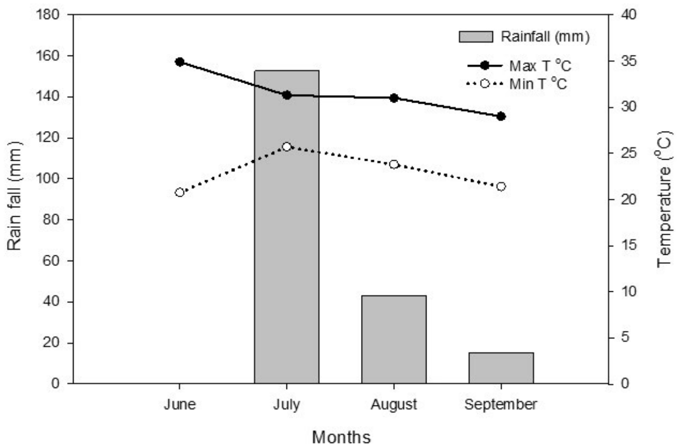

Figure 1: *Meteorological data of the experimental site during the crop growth period.*

Field experiment agronomic practices

For this experiment, a subplot size of 2 m × 3 m was used having 4 rows, each 2 m long and 0.75 m apart. The field was ploughed on 19th June with the help of cultivator followed by rotavator at field capacity. High yielding and popular maize variety of maize (AZAM) was sown at the recommended seed rate (30 kg ha^{-1}) on 19th June, 2015. Thinning was done on 6th July, 2015 after 10 days of crop emergence to maintain plant to plant distance of 25 cm and a uniform plant density (65000- 70000 plants ha^{-1}). Weeding was done twice manually with help of hand hoe 20 and 40 days after emergence. Chloropyriphos insecticide was used for controlling maize stem borers in 0.006% concentration.

Data Recording Procedure

Plant height was recorded by selecting 10 random plants in each subplot and measuring their height from base to tip of the tassel. Grains were counted in five randomly selected ears in each subplot and then averaged to get an average number of grains ear^{-1}. 1000-grain were counted and weighed from each subplot for recording thousand grains weight. Four rows of each subplot were harvested, sun-dried, weighed and then converted into biological yield kg ha^{-1} by the following formula.

$$\text{Biological yield (kg ha}^{-1}\text{)} = \frac{\text{Biological yield of harvested rows}}{\text{R-R distance (cm) x Row length (m) x Number of rows}} \text{ x 10,000 m}$$

Ears from harvested four rows were detached then dehusked and sun-dried before shelling. After proper drying, the cobs were shelled and grain yield (kg ha^{-1}) was worked out using the following formula.

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Grain yield of harvested rows}}{\text{R-R distance (cm) x Row length (m) x Number of rows}} \text{ x 10000 m}^2$$

Statistical analysis

To analyze data statistically analysis of variance techniques suitable for randomized complete block design with split plot arrangement was used. Means of the treatments were compared through the least significant differences (LSD) test at 5% probability level (Jan et al., 2009).

Results and Discussion

Plant height (cm)

Irrigation frequencies and K levels significantly affected plant height of maize (Table 2; Figure 2a, c). Increasing number of irrigations from I_1 to I_5 increased plant height by 8, 10.2, 15, 15.7 and 19.7%, respectively over no irrigated plots (I_0) and thus taller plants were recorded in plots irrigated five times (Figure 2a). Likewise, plant height increased with

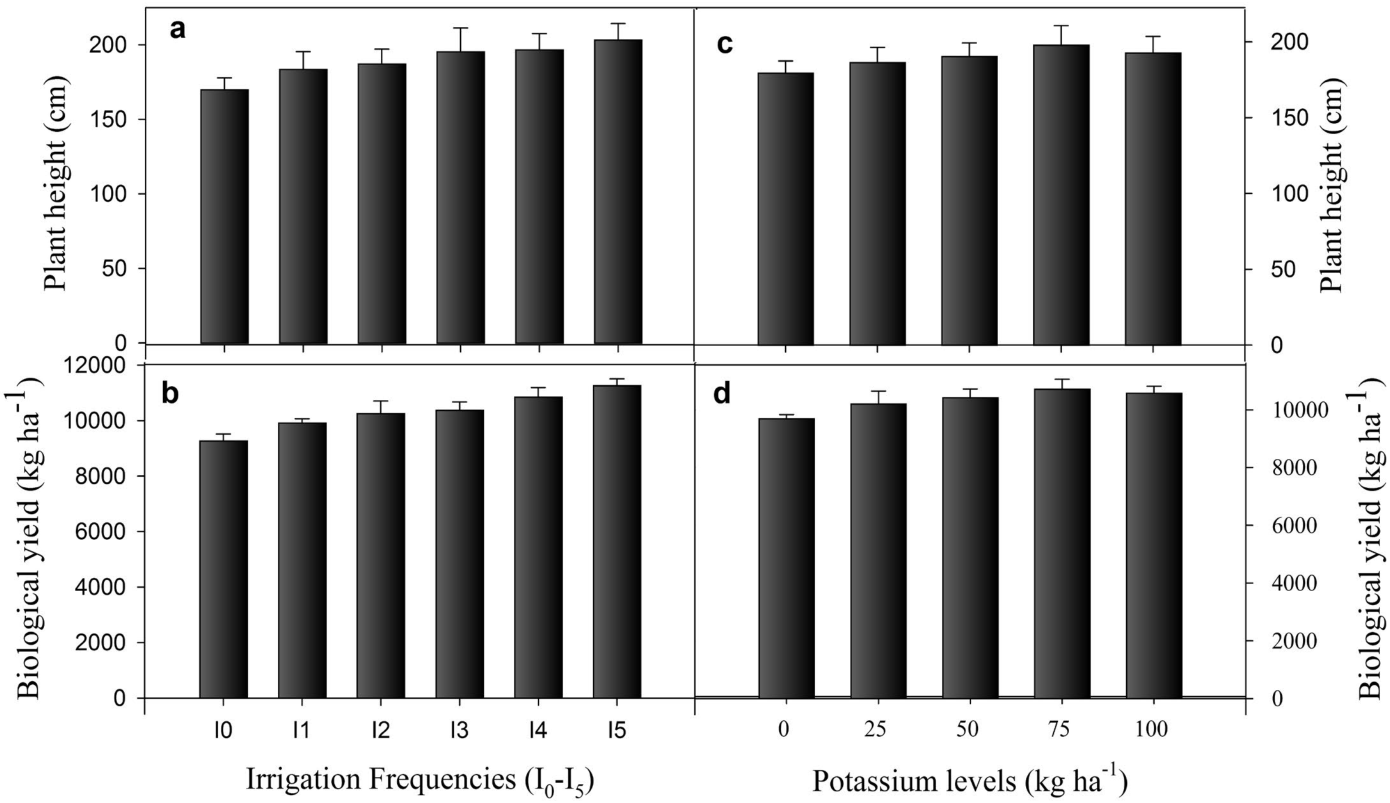

Figure 2: *Plant height and biological yield of maize as affected by irrigation frequencies and K fertilization. Data presented in each bar are the means of three replicates while Error bars are standard errors of replicated data. I_0 (zero or control irrigation), I_1 (irrigation at V_1 stage), I_2 (two irrigations; each at V_1 and V_7 stage), I_3 (three irrigations; each at V_1, V_7 and VT stage), I_4 (four irrigations; each at V_1, V_7, RT and R_2 stage) and I_5 (five irrigations; each at V_1, V_7, RT, R_2 and R_4 stage).*

increasing K levels; however, a maximum increase of 10.2% in plant height was noted with the application of 75 kg K ha^{-1} (Figure 2c). Further increase in potassium beyond 75 kg ha^{-1} did not show any noteworthy increase in plant height of maize. Short stature plants were observed in plots where no K was applied. The interaction between irrigation frequencies and K levels was not found significant (Table 2).

Grains ear^{-1}

Statistical analysis of data showed significant effects of irrigation frequencies and K levels on grains ear^{-1} of maize (Table 2; Figure 3a, c). Increase in grains ear^{-1} was observed with increasing irrigation numbers from I_1 to I_5 and significantly higher grains ear^{-1} of maize were recorded under five irrigations (I_5), while lower grains ear^{-1} were recorded with no irrigation (Figure 3a). Similarly, 75 kg ha^{-1} potassium application increased grains ear^{-1} by 22.6, 13.6, 4.5 and 5.1% over K_0, K_1, K_2, and K_4 treatments respectively, and resulted in higher grains ear^{-1}, while lower K-controlled plots resulted in lower grains ear^{-1} (Figure 3c). Interaction of irrigation frequencies and K levels indicated a linear increase in grains ear^{-1} with increasing irrigation numbers and K fertilization from 0 to 75 kg ha^{-1}. However, the increase was more prominent with five irrigation and 75 kg ha^{-1} K application, while further increase in K levels didn't show any significant increase in grains ear^{-1} (Table 2; Figure 5a).

Thousand grains weight (g)

Irrigation frequencies and K fertilization significantly varied thousand grains weight of maize (Table 2; Figure 3b, d). Mean values of the data revealed heavier grains in plots supplied with five irrigations (I_5) while lower thousand grains weight were recorded in no irrigated plots (Figure 3b). Likewise, application of 75 kg ha^{-1} K produced heavier grains with higher thousand grains weight, though lower thousand grains weight was recorded in K_0 plots (Figure 3d). Interaction of irrigation frequencies and K fertilization indicated that thousand grains weight increased significantly with increasing irrigation numbers and K levels from 0 to 75 kg ha^{-1} but further increase in K levels (from 75 to 100 kg ha^{-1}) showed no increase in thousand grains weight of maize (Table 2; Figure 5b). However, the increase was more noticeable when 75 kg ha^{-1} K was applied under five irrigations.

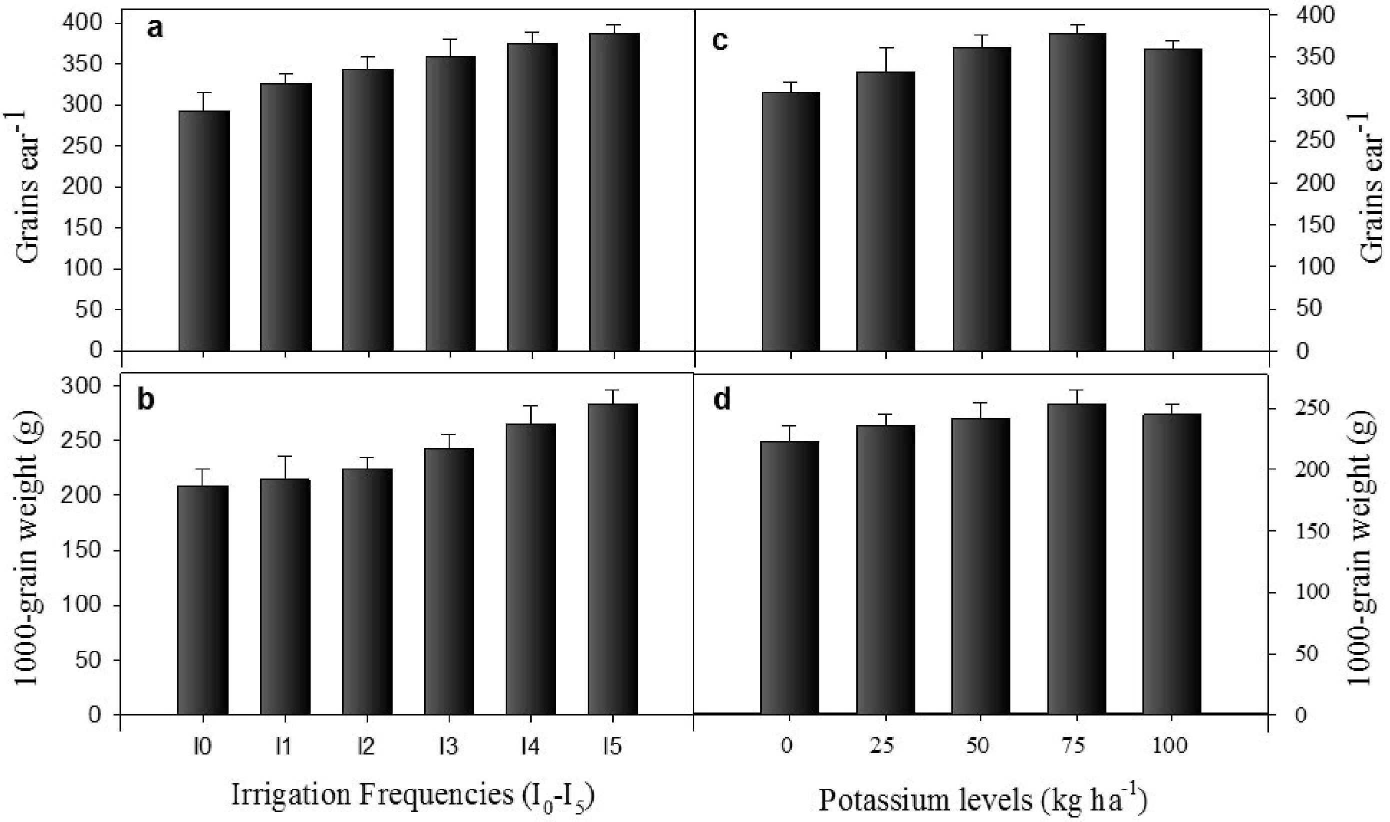

Figure 3: *Grains ear^{-1} and 1000-grain weight (g) of maize as affected by irrigation frequencies and K fertilization. Data presented in each bar are the means of three replicates while Error bars are standard errors of replicated data. I_0 (zero or control irrigation), I_1 (irrigation at V_1 stage), I_2 (two irrigations; each at V_1 and V_7 stage), I_3 (three irrigations; each at V_1, V_7 and VT stage), I_4 (four irrigations; each at V_1, V_7, RT and R_2 stage) and I_5 (five irrigations; each at V_1, V_7, RT, R_2 and R_4 stage).*

Grain yield (kg ha^{-1})

Data analysis showed that different irrigation frequencies and K application brought significant variations in grain yield of maize (Table 2; Figure 4a, c). Increasing number of irrigations from I_1 to I_5 increased grain yield by 16.9, 23.2, 25.3, 31.9 and 37.6% respectively, over no irrigated plots (I_0), and hence five times irrigated plots produced higher grain yield as compared with rest (Figure 4a). Regarding K fertilization, grain yield increased with increasing K levels, however a maximum increase of 14.2% was observed with 75 kg ha^{-1} potassium application. Further increase in K beyond 75 kg ha^{-1} showed slight but non-significant reduction in grain yield (Figure 4c) whereas control K plots resulted in lower grain yield of maize. The interaction between irrigation and K fertilization indicated linear increase as grain yield increased with increasing irrigation numbers and K levels and thus higher grain yield was recorded with five irrigations and 75 kg ha^{-1} K fertilization (Table 2; Figure 6a).

Biological yield (kg ha^{-1})

Irrigation frequencies and K fertilization significantly affected biological yield of maize (Table 2; Figure 2b, d). Increase in biological yield was witnessed with

Table 2: *Two-way analysis to find out the effects of irrigation frequencies and potassium application on maize yield.*

Treatments	Crop variables	Df	F-Value	Probability
Irrigation Frequencies	Plant height	5	6.955	<0.01
	Grains ear^{-1}	5	132.231	<0.001
	Thousand grains weight	5	98.094	<0.001
	Biological yield	5	80.112	<0.001
	Grain yield	5	51.253	<0.001
	Harvest index	5	18.220	<0.001
Potassium Levels	Plant height	4	8.636	<0.001
	Grains ear^{-1}	4	133.497	<0.001
	Thousand grains weight	4	40.327	<0.001
	Biological yield	4	63.488	<0.001
	Grain yield	4	51.377	<0.001
	Harvest index	4	8.049	<0.001
Irrigation x Potassium	Plant height	20	0.297	NS
	Grains ear^{-1}	20	2.765	<0.01
	Thousand grains weight	20	2.052	<0.05
	Biological yield	20	0.894	NS
	Grain yield	20	1.877	<0.05
	Harvest index	20	2.231	<0.01

Ns: *Non-significant.*

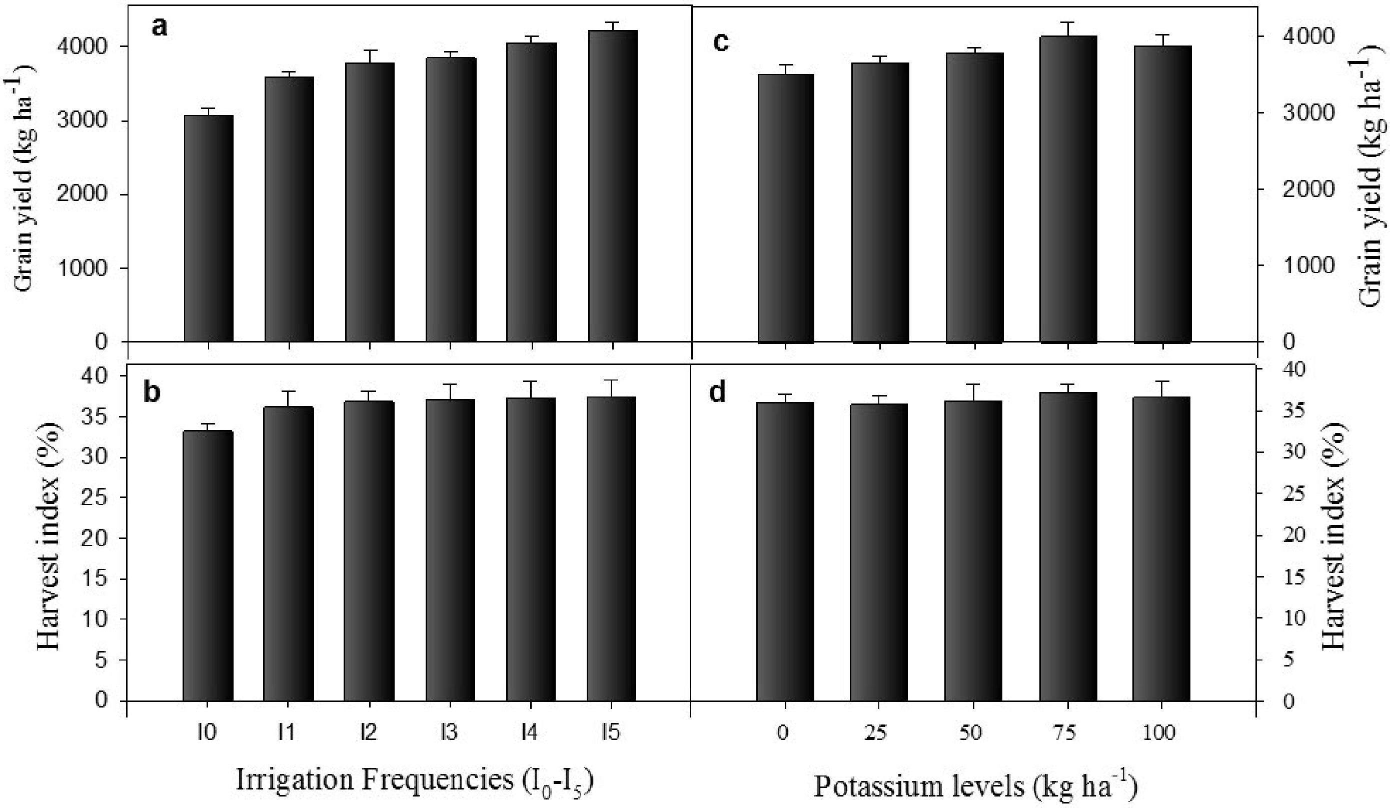

Figure 4: *Grain yield (kg ha^{-1}) and harvest index (%) of maize as affected by irrigation frequencies and K fertilization. Data presented in each bar are the means of three replicates while Error bars are standard errors of replicated data. I_0 (zero or control irrigation), I_1 (irrigation at V_1 stage), I_2 (two irrigations; each at V_1 and V_7 stage), I_3 (three irrigations; each at V_1, V_7 and VT stage), I_4 (four irrigations; each at V_1, V_7, RT and R_2 stage) and I_5 (five irrigations; each at V_1, V_7, RT, R_2 and R_4 stage).*

increasing irrigation numbers and significantly higher biological yield was noted in plots irrigated five times as compared with other treatments, whereas lower biological yield was recorded with no irrigation (Figure 2b). Similarly, K fertilization at the rate of 75 kg ha^{-1} enhanced biological yield by 10.5, 5.1, 2.7 and 2.1% over K_0, K_1, K_2, and K_4 treatments respectively, and resulted in higher biological yield. However, increasing K beyond 75 kg ha^{-1} did not show any significant changes in biological yield of maize. Plots with no potassium resulted in a lower biological yield of maize.

Harvest index (%)

Data analysis revealed significant differences in harvest index of maize in response to various irrigation frequencies and K fertilization (Table 2; Figure 4b, d). Increasing irrigation numbers from I0 to I5 significantly increased harvest index of maize and higher harvest index was recorded in five times irrigated plots (I_5), while lower harvest index was recorded in no irrigated plots (I_0) (Figure 4b). Similarly, harvest index increased with increasing K levels, however, maximum increase of 3.2% was observed with 75 kg ha^{-1} K application. Further increase in K beyond 75 kg ha^{-1} showed a slight reduction (1.6%) in harvest index (Figure 4d). Lower harvest index was recorded in plots where no K was applied. The interaction between irrigation and K fertilization indicated a linear and positive increase in harvest index with increasing irrigation numbers and K levels and thus higher harvest index was recorded with five irrigations and 75 kg ha^{-1} K fertilization (Table 2; Figure 6b).

Plant height is an important factor which reflects the active growth attained during the life cycle of crop. Increase in irrigation numbers significantly increased plant height of maize. Taller plants were observed in plots irrigated five times while short height plants were recorded in no irrigated plots. The possible reason might be the availability of water at desired crop growth stage improved water uptake, increased photosynthesis and photosynthates, resulting in better growth. Similar results were reported by Anjum et al. (2014) who reported taller maize plants with optimum supply of irrigation water. Babar et al. (2015) also reported increased plant height with application of optimum irrigation water. Taller plants were noted in plots that received 75 kg ha^{-1}K while short stature plants were recorded in control K plots.

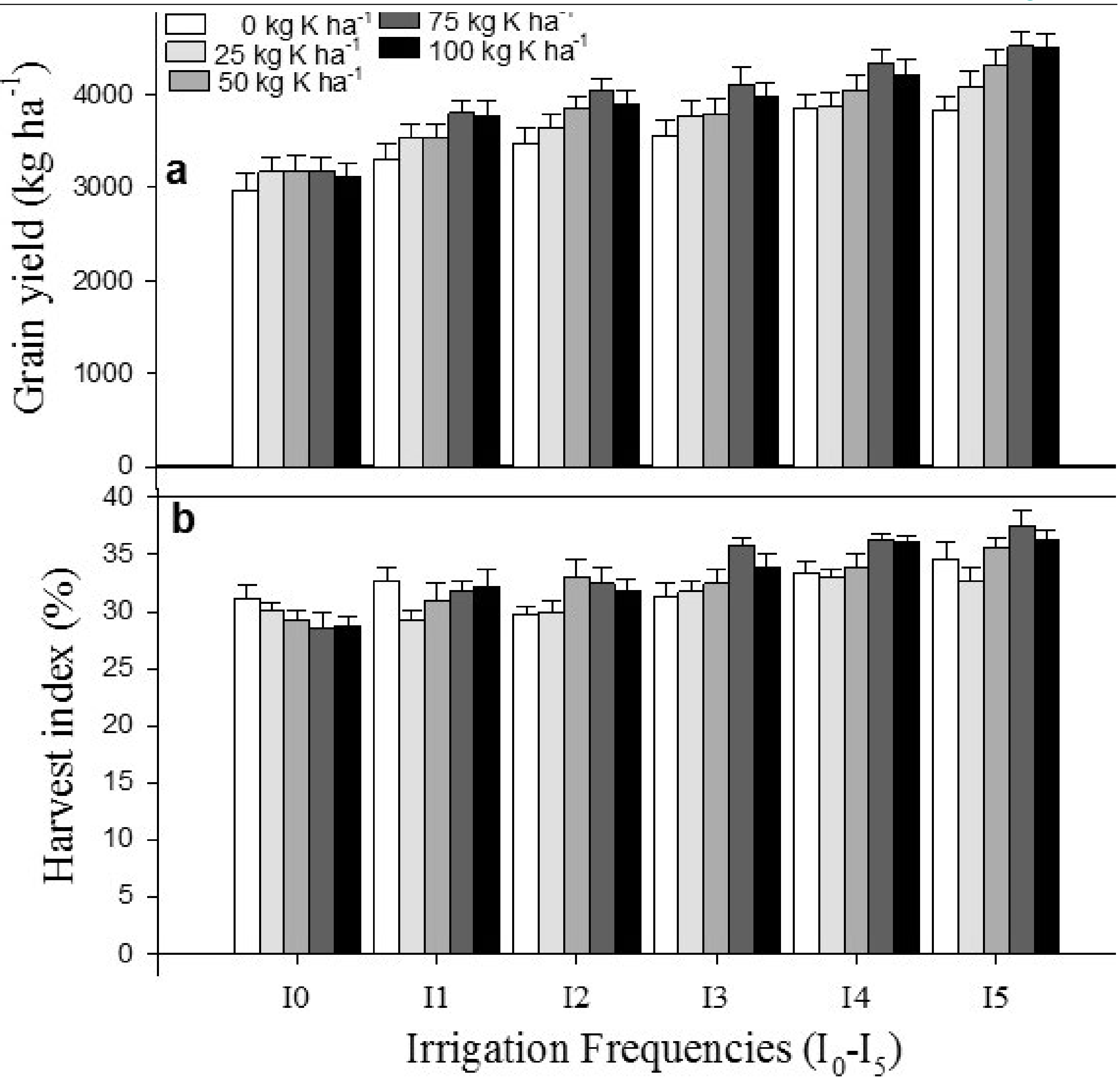

Figure 5: *Interaction of irrigation frequencies and K fertilization for a) grains ear^{-1} and b) 1000-grain weight (g) of maize. Data presented in each bar are the means of three replicates while Error bars are standard errors of replicated data. I_0 (zero or control irrigation), I_1 (irrigation at V_1 stage), I_2 (two irrigations; each at V_1 and V_7 stage), I_3 (three irrigations; each at V_1, V_7 and VT stage), I_4 (four irrigations; each at V_1, V_7, RT and R_2 stage) and I_5 (five irrigations; each at V_1, V_7, RT, R_2 and R_4 stage).*

Findings of Pettigrew (2008) and Cheema et al. (1999) agree with our results, who stated increase in plant height with increasing application of K fertilizers. Similarly, Stone et al. (2001) and Pandey et al. (2000) also stated that plant height increased with increasing irrigation frequencies and potassium application levels. Maqsood et al. (2001) and Ayub et al. (2002) also stated that plant height increased with increasing potassium fertilizers application.

Grains weight determines the seed vigor, higher the seed weight the higher will be seed vigor and so the economic yield. Plots irrigated five times produced significantly higher grains ear^{-1} and 1000-grain weight as compared with no irrigated plots. Similarly, increasing K fertilization also showed increase in 1000-grain weight and grains ear^{-1} of maize. The reason for reduction in grains ear^{-1} and 1000-grain weight in no irrigated or less irrigated plots in comparison with plots irrigated five times might be due to the water stress at different active growth stages that affected the grains formation and assimilates translocation

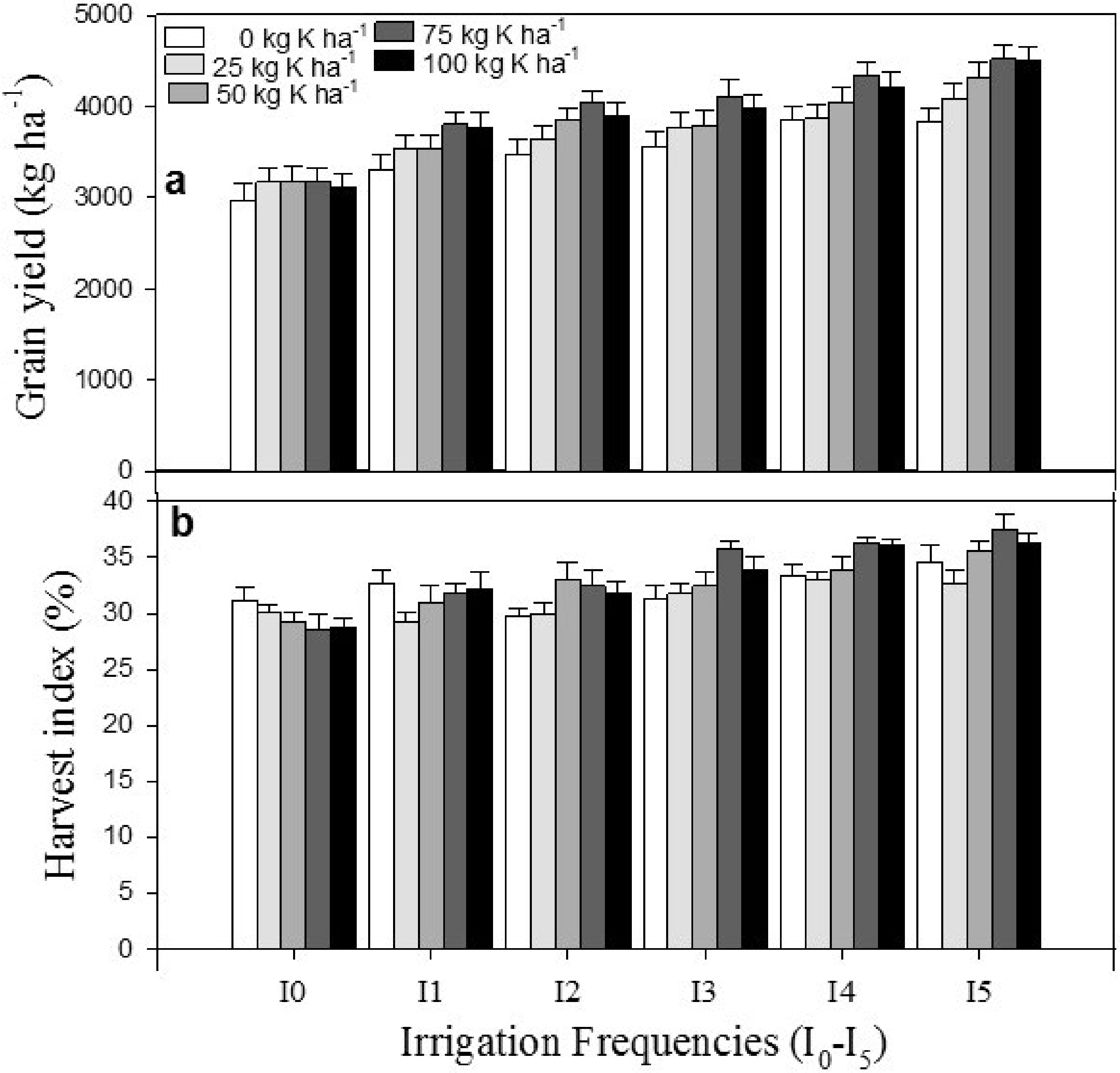

Figure 6: *Interaction of irrigation frequencies and K fertilization for a) grain yield (kg ha^{-1}) and b) harvest index (%) of maize. Data presented in each bar are the means of three replicates, while Error bars are standard errors of replicated data. I_0 (zero or control irrigation), I_1 (irrigation at V_1 stage), I_2 (two irrigations; each at V_1 and V_7 stage), I_3 (three irrigations; each at V_1, V_7 and VT stage), I_4 (four irrigations; each at V_1, V_7, RT and R_2 stage) and I_5 (five irrigations; each at V_1, V_7, RT, R_2 and R_4 stage).*

from source to grains (Ahmad et al., 2002). Kuşçu and Demir (2012) reported higher grains ear^{-1} with increasing irrigation water as compared with no irrigated plots. Aguilar et al. (2007) stated more grains ear^{-1} and higher thousand weight of maize under high irrigation frequencies. Similarly, Bahrani et al. (2012) also suggested higher 1000-grain weight of maize with frequent supply of irrigation water at proper intervals. Maqsood et al. (2013) stated significantly heavier grains and higher grains ear^{-1} with higher application of potassium. Confirmatory findings were reported by Hussain et al. (2007) and Aslam et al. (2014) who suggested increase in 1000-grain weight and grains ear^{-1} with increasing potassium fertilization.

Increasing irrigation numbers and K levels significantly increased biological yield and grain yield of maize. Higher biological and grain yield was observed in plots irrigated five times while lower biological yield were recorded in no irrigated plots. Similarly, increase in K levels also increased biological and grain yield of maize. The possible reason might be that uniform supply of moisture at critical crop growth stage resulted in better crop growth, crop stand and photosynthates formation which ultimately increased biological and grain yield of maize. Our results confirm the findings reported by Maqsood et al. (2013) and Bahrani et al. (2012), who revealed higher biological and grain yield with full irrigation as compared with reduced irrigation frequencies. The probable reason for increase in biological and grain yield with K application might be due to improved roots growth which resulted in better moisture uptake and utilization and crop survival under severe drought conditions (Pettigrew, 2008). In order to make sure that crop get all the nutrients, they must be applied in appropriate amount. Optimum level of fertilizers is that at which crop respond better and utilize it more efficiently. Deficit fertilizers application reduces crop yield while excessive fertilizers application increases input cost, environmental and water pollution and reduces crop yield resulting in very low net return per unit area. Datnoff (2007) reported that K application higher than optimal levels doesn't increase maize yield and disease resistance. The reason for decrease in maize yield with increasing K levels beyond 75 kg ha^{-1} might be that excessive K fertilization hindered the uptake of other nutrients like Zinc, iron, Manganese and Magnesium (Zhao et al., 2011). Also the genetic makeup of some cultivars make them less or more K efficient and thus making their K requirement and uptake different (Dantoff, 2007). Confirmatory results were reported by Aslam et al. (2013) who reported higher biological and grain yield with optimum application of K fertilizers. Our results are also in line with those of Bukhsh et al. (2009), Tariq et al. (2011), Cheema et al. (1999) and Maqsood et al. (2013).

Harvest index determines the potential of a crop to transform the produced dry matter to economic yield. Significantly higher harvest index was recorded in fully irrigated plots as compared with no irrigated plots. Likewise, plots fertilized with 75 kg ha^{-1} potassium produced higher harvest index as compared with plots where no K was applied. Similar results were reported by Aslam et al. (2014) who reported a higher harvest index under full irrigation at optimum intervals and proper crop growth stages as compared with deficit irrigation. Bahrani et al. (2012) and Tariq et al. (2011) also stated a higher harvest index with the increase in K application and numbers of irrigation.

Conclusions and Recommendations

In the light of results and discussion, it was concluded that water stress at each critical crop growth stage drastically decreased the growth and yield of the crop. Optimum water supply to crop considering the growth stage of crop and weather condition can increase the yield. Therefore, among all the treatments, plots received five irrigations each at V_2, V_7, VT, R_2 and R_4 stage and 75 kg ha^{-1} potassium application improved crop yield and yield components as compared with the rest of the treatments.

On the basis of higher grain yield and yield components and efficient water utilization, five irrigations each at V_1, V_7, VT, R_2 and R_4 stage with 75 kg ha^{-1} K application are recommended throughout the lifespan of maize crop for enhancing yield and productivity of maize in agro-ecological zones of KP.

Author's Contribution

Salman Ali: Conducted the field experi-ment and re-sponsible for all field work from sowing to harvesting and manuscript write up.
Inamullah: Major supervisor, responsible for overall planning and super-vision of the experiment.
Muhammad Arif: Minor field supervisor, re-sponsible for supervision of the experiment at field level.
Mehran Ali: Statistical analysis, figures and tables development.
Muhammad Owais Iqbal: Literature review and helped in results and discussion write up.
Fazal Munsif: Helped in manuscript write up and formatting, and review.
Arsalan Khan: Agronomic practices manage-ment in field including weeds and irrigation management during the course of experi-ment.

References

Abo-el-kheir, M.S.A. and B.B. Mekki. 2007. Response of maize single cross-10 to water deficits during silking and grain filling stages. J. Agric. Sci. 3(3): 269-272.
Aguilar, M., F. Borjas and M. Espinosa. 2007. Agronomic response of maize to limited levels of water under furrow irrigation in southern Spain. Span. J. Agric. Res. 5(4): 587-592. https://doi.org/10.5424/sjar/2007054-280
Ahmad, N. and M. Rashid. 2003. Fertilizers and their use in Pakistan. Ext. Bull. NDFC. Islamabad.
Ahmad, M.U.D., W.G. Bastiaanssen and R.A.

Feddes. 2002. Sustainable use of groundwater for irrigation: A numerical analysis of the subsoil water fluxes. J. Int. Comm. Irrig. Drain. 51(3): 227-241.

Aladabadi, S.A., H.A. Farahani and M.A. Khalvati. 2009. Evaluation of grain growth of corn and sorghum under K_2O application and irrigation according. Asian J. Agric. Sci. 1(1): 19-24.

Ali, M., H. Akbar, Inamullah and S. Ali. 2016. Impact of row spacing and nitrogen application methods on the performance of maize. Int. J. Agric. Environ. Res. 2(4): 282-288.

Anjum, L., N. Ahmad, M. Arshad and R. Ahmad. 2014. Effect of different irrigation and management practices on corn growth parameters. Pak. J. life Soc. Sci. 12(2): 106-113.

Aslam, M., M.S.I. Zamir, I. Afzal and M. Amin. 2014. Role of potassium in physiological functions of spring maize (Zea mays L.) grown under drought stress. J. Anim. Plant Sci. 24(5): 1452-1465.

Aslam, M., M.S.I. Zamir, I. Afzal, M. Yaseen, M. Mubeen and A. Shoaib. 2013. Drought stress, its effect on maize production and development of drought tolerance through potassium application. J. Plant Nutr. 34: 1757-1772.

Ayub, M., M.A. Nadeem, M.S. Sharar and N. Mahmood. 2002. Response of maize (Zea mays L.) fodder to different levels of nitrogen and phosphorus. Asian J. Plant Sci. 9: 352-354.

Babar, S.A., W. Bashir and M.A. Loangove. 2015. Influence of different irrigation scheduling practices on the growth and yield performance of maize (Zea mays L.). J. Bio. Agric. Healthc. 5(1): 312-319.

Bahrani, A., J. Pourreza, A. Madani and F. Amiri. 2012. Effect of PRD irrigation method and potassium fertilizer application on corn yield and water use efficiency. Bulg. J. Agric. Sci. 18(4): 616-625.

Bukhsh, M.A., R. Ahmad, M. Ishaque and A.U. Malik. 2009. Response of maize hybrids to varying potassium application in Pakistan. Pak. J. Agri. Sci. 46: 179-184.

Bukhsh, M., A.R. Ahmad, J. Iqbal, M. Maqbool, A. Ali, M. Ishaque and S. Hussain. 2012. Nutritional and physiological significance of potassium application in maize hybrid crop production. Pak. J. Nutr. 11(2): 187-202. https://doi.org/10.3923/pjn.2012.187.202

Classen, N. and S.A. Barber. 1977. Potassium influx characteristics of corn roots and interaction with N, P, Ca and Mg influx. Agron. J. 69: 860-864. https://doi.org/10.2134/agronj1977.00021962006900050034x

Cheema, M.A., M. Iqbal, Z.A. Cheema, B. Ullah and M. Rafique. 1999. Response of hybrid maize to potassium. Int. J. Agric. Bio. 4: 267-269.

Darby, H. and J. Lauer. 2000. Critical Stages in the life of a corn plant. UW Crop Scouting Manual. UWEX Publications, Madison, WI.

Darby, H. and J. Lauer. 2004. Plant physiology-critical stages in the life of a corn plant. Adv. Environ. Biol. 7(4): 17-24.

Datnoff., E. Lawrence, W.H. Elmer and D.M. Huber. 2007. Mineral nutrition and plant disease. American Phytopathological Society (APS Press)

Davis, J.G., M.E. Walker, M.B. Parker and B. Mullinix. 1996. Long term phosphorus and potassium application to corn on coastal plain soils. J. Prod. Agric. 9(1): 88-94. https://doi.org/10.2134/jpa1996.0088

FAO. 2007. Utilization of tropical foods: Food Nutr. paper 4711, FAO, Rome.

Fischer, R.A. and T.C. Hsiao. 1968. Stomatal opening in isolated epidermal strips of Viciafaba L. response to Kcl concentrations and the role of potassium absorption. Plant Physiol. 43: 1953-1958. https://doi.org/10.1104/pp.43.12.1953

Frootan, A.M. and Yarnia. 2015. Effects of soil and foliar applications of potassium sulfate on yield and yield components of maize under different irrigations levels in Iran. Adv. Environ. Biol. 9(4): 382-388.

Hussain, N., A.Z. Khan, H. Akbar, N.G. Bangash, Z.H. Khan and M. Idrees. 2007. Response of maize varieties to phosphorus and potassium levels. Sarhad J. Agric. 23(4): 172-176.

Iken, J.E. and N.A. Amusa. 2004. Maize research and production in Nigeria. Afr. J. Biotech. 3(6): 302-307. https://doi.org/10.5897/AJB2004.000-2056

Jan, M.T., P. Shah, P.A. Hoolinton, M.J. Khan and Q. Sohail. 2009. Agriculture research design and analysis. Dept. Agron. KPK Agric. Univ. Peshawar, Pakistan.

Khan, N., W. Khan, S.A. Khan, M.A. Khan and K.B. Marwat. 2012. Combined effect of nitrogen fertilizers and herbicides upon maize production in Peshawar. J. Anim. Plant. Sci. 22: 12-17.

Kirda, C., S. Topcu, H. Kaman, A.C. Ulger, A. Yazici, M. Cetin and M.R. Derici. 2005. Grain yield response and N-fertilizer recovery of maize under deficit irrigation. Field Crops Res. 93: 132–141. https://doi.org/10.1016/j.fcr.2004.09.015

Kisekka, I., F. Lamm and J.D. Holman. 2015. Response of drought tolerant and conventional corn to limited irrigation. Kansas Agric. Exp. St. Res. Rep. 1(5): 331-338. https://doi.org/10.4148/2378-5977.1088

Kuşçu, H. and A.O. Demir. 2012. Responses of maize to full and limited irrigation at different plant growth stages. Ziraat fakül. Cilt 26, Sayı 2, 15-27.

Maqsood, M., A.M. Abid, A. Iqbal and M.I. Hussain. 2001. Effect of variable rate of nitrogen and phosphorus on growth and yield of maize (golden). J. Biol. Sci. 1: 19-20. https://doi.org/10.3923/jbs.2001.19.20

Maqsood, M., M.A. Shehzad, A. Wahid and A.A. Butt. 2013. Improving drought tolerance in maize (Zea mays L.) with potassium application in furrow irrigation systems. Int. J. Agric. Biol. 15(6): 1193–1198.

MNFSR. 2013-2014. Ministry of National Food Security and Research (Economic wing) Islamabad.

MNFSR. 2014-2015. Agriculture statistics of Pakistan. Ministry of National Food Security and Research (Economic wing) Islamabad.

Nawaz, I., Zia-ul-hassan, A.M. Ranjha and M. Arshad. 2006. Exploiting genotypic variation among fifteen maize genotypes of Pakistan for potassium uptake and use efficiency in solution culture. Pak. J. Bot. 38: 1689-1696.

Ouda, S.A., F.A. Khalili and M.M. Tantawy. 2006. Prediction the impact of water stress on the yield of different maize hybrids. Res. J. Agric. Bio. Sci. 4: 27-34.

Pandey, R.K., J.W. Maranville and A. Admou. 2000. Deficit irrigation and nitrogen effects on maize in a sahelian environment. Agric. Water Manage. 46: 1–13. https://doi.org/10.1016/S0378-3774(00)00074-3

Pettigrew, W.T. 2008. Potassium influences on yield and quality production for maize, wheat, soybean and cotton. Physiol. Plant. 133: 670–681. https://doi.org/10.1111/j.1399-3054.2008.01073.x

Reddy, A.R., K.V. Chaitanya and M. Vivekanandan. 2004. Drought induced responses of photosynthesis and anti-oxidant metabolism in higher plants. J. Plant Physiol. 161: 1189-1202. https://doi.org/10.1016/j.jplph.2004.01.013

Stone, P.J., D.R. Wilson, P.D. Jamieson and R.N. Gillespie. 2001. Water deficit effects on sweet maize canopy development. Aus. J. Agric. Res. 52: 115-126. https://doi.org/10.1071/AR99145

Tabatabaii, S.E., Y.M. Ebrahimi and M.B. Khorshidi. 2011. Effect of potassium fertilizer on corn yield under drought stress condition. Am-Euras. J. Agric. Environ. Sci. 10(2): 257-263.

Tariq, M., A. Saeed, M. Nisar, I.A. Mian and M. Afzal. 2011. Effect of potassium rates and sources on the growth performance and on chloride accumulation of maize in two different textured soils of Haripur, Hazara division. Sarhad J. Agric. 27(3): 415-422.

Verma, N.J. 2011. Integrated nutrient management in winter maize (Zea mays L.) sown at different dates. J. Plant Breed. Crop Sci. 3(8): 161-167.

Zhao, D., D.M. Oosterhuis and C.W. Bednarz. 2001. Influence of potassium deficiency on photosynthesis, chloropyll content, and chloroplast ultrastructure of cotton plants. Photosynthetica. 39: 103–109

Zhang, L., M. Gao, S. Li, A.K. Alva and M. Ashraf. 2014. Potassium fertilization mitigates the adverse effects of drought on selected maize cultivars. Turk. J. Bot. 38: 713-723. https://doi.org/10.3906/bot-1308-47

Zia-ul-hassan, M., Arshad and A. Khalid. 2011. Evaluating potassium use-efficient cotton genotypes using different ranking methods. J. Plant Nutr. 34: 1957-1972. https://doi.org/10.1080/01904167.2011.610483