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GROWTH AND ECONOMIC RETURN OF MAIZE (*ZEA MAYS* L.) WITH FOLIAR APPLICATION OF POTASSIUM SULPHATE UNDER RAINFED CONDITIONS

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Benefit-cost ratio, foliar spray, growth rate, SOP, maize

ABSTRACT

Background Imbalanced plant nutrition is a major problem in profitable crop production, particularly under rainfed conditions. Farmers mostly apply nitrogen (N) and phosphorus (P) based fertilizers, while potassium (K) is rarely applied. Furthermore, K availability to plants is also very limited because of its more fixation with soil constituents due to the absence of irrigation water under rainfed conditions. Under such conditions, foliarly applied K can play an imperative role in increasing plant growth performance.

Methodology A field study was conducted to evaluate the effect of K on maize growth and economic return. Experiment was planned according to randomized complete block design in factorial arrangement with four replications. Two maize cultivars; Islamabad Gold and Azam were grown, and three levels of K_2SO_4 (0, 1 and 2%) were applied on foliage.

Results Maize cultivar Islamabad Gold performed well with foliar application of 2% K_2SO_4 solution, and depicted maximum growth rate, leaf area index, leaf area duration and net assimilation rate. Higher benefit cost ratio was also obtained by applying 2% K_2SO_4 solution in maize cultivar Islamabad Gold.

Conclusion These results suggested that the farmers of rainfed area should grow maize variety Islamabad Gold by applying 2% K_2SO_4 solution to obtain higher net benefit.

INTRODUCTION

Maize crop is the leading cereal in the world, which ranks 3rd in Pakistan after wheat and rice. The imbalanced use of chemical fertilizers is the main cause of low yield of maize (Amanullah et al. 2014). Generally, farmers rarely apply potassium (K) to cereals including maize especially under rainfed conditions in Pakistan. Potassium deficiency in our soils is widely reported due to the irregular cropping systems, and injudicious use of K fertilizers (Ahmad and Rashid 2003). Plants use K in heavy amounts (Mengel et al. 2001; White and Karley 2010), and insufficient supply of K may cause reduction in photosynthesis and resultantly causes yield reduction (Wang et al. 2015; Amanullah and Khalid 2016). It is functional component of the plant body and comprises about 1-3% weight of plant tissues, and plays a crucial role in assimilation of photosynthates and activates more than 60 different enzymes (Wang et al. 2013). Potassium application increases resistance against biotic and abiotic stresses including water stress and keeps ionic balance that helps in water absorption from the soil and improves crop yield (Wang et al. 2013). In addition, it also maintains turgor pressure, cell growth and stomatal conductance (Marschner and Rengel 2012).

Potassium also plays an important role in dry matter accumulation under water shortage in rainfed areas (Rosenstock et al. 2016) and increases photo-synthesis through stomatal regulation and ultimately enhances the plant growth (Romheld and Kirkby 2010)

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Due to its trivial application, its deficiency is very common in Pakistani soils (Ahmad and Rashid 2003). Plant growth and development including leaf area (LA), leaf area index (LAI), net assimilation rate (NAR), photosynthetic activity and dry matter accumulation is mainly affected by the K deficiency (Ebelhar and Varsa 2000; Akhtar et al. 2003; Hermans et al. 2006; Munir et al. 2007; Meille and Pellerin 2008; Thomas and Cohrane 2009). Potassium application corrects its deficiency and increases plant growth with an optimum amount but its excessive application may cause nutrient imbalance in soil and suppresses plant growth (Juame et al. 2001). Potassium has a crucial role in relative growth rate (RGR) and quality improvement of crop. Its deficiency causes stunted growth in maize (Wang et al. 2012; Ortas 2013; Murrell 2014).

Potassium is an essential macronutrient for successful crop growth and yield. It maintains the turgidity of cell that increases cell growth (Bukhsh et al. 2012). Potassium application increases the uptake of N and other essential nutrients that are necessary for the life cycle of plants (Bukhsh et al. 2010). Potassium application enhances the leaf area, increases the translocation of photosynthates, and ultimately increases the shelling percentage and yield of maize (Rengel and Damon 2008). Under rainfed conditions, being a macronutrient K plays decisive role to achieve normal plant functioning and where water is not enough for plant growth its foliar application corrects its deficiency and causes resistance against water stress, and comparatively plants can perform well (Rosenstock et al. 2016).

Potassium plays an imperative role in increasing photosynthesis, tissue enlargement, carbohydrates formation and minerals in the plant body that subsequently enhances plant growth (Pettigrew 2008). Foliar application of K enhances water uptake by the plants through stomata opening and closing that increases transpiration rate, and improves crop yield (Milford and Johnston 2002; Cakmak 2005). Plants give early response in growth to foliarly applied K and this method of K application is economically beneficial. Keeping in mind the above discussed functions of K, the present study was carried out to evaluate the impact of foliarly applied K on plant growth performance and economic return in maize under rainfed conditions.

MATERIALS AND METHODS

Experiment location

A field study was performed at Research Farm Koont, PMAS Arid Agriculture University, Rawalpindi, Pakistan (32.56°N, 72.52°E and 513 m above sea level) during summer season on sandy loam and clay soil. Soils samples were taken from upper 30 cm soil layer and tested for different properties. The experimental soil electrical conductivity (EC) was 0.7 dS m^{-1}, pH 7.14, available P 4.23 ppm, organic matter 0.43% and available K 80 ppm.

Experimental details

The experiment was replicated for 4 times with two maize cultivars Islamabad gold and Azam and three levels of K sulphate (K_2SO_4) viz. 0 (control simple water spray), 1% and 2%. The experiment was conducted according to RCBD factorial arrangement having unit plot size of 5×4.5 m^2.

Crop Husbandry

Seedbed was prepared with tractor mounted cultivator three days after rainfall. Sowing was done at 2 cm depth with hand drill at 75 cm apart row spacing with seed rate of 25 kg ha^{-1}. Plant population was maintained by manual thinning to keep plant spacing at 20 cm apart, when crop approached at 5 leaf stage. Fertilizers were applied @ 150 kg N ha^{-1} and 100 kg P ha^{-1} as a necessary fundamental dose by using source urea and DAP, respectively. Crop was cultivated under rainfed conditions and the calculated amount of fertilizers were applied at the time of sowing, while K was applied foliarly in the form of K_2SO_4 as per treatment at tasseling and silking stage. Crop was attacked by shoot borer which was controlled by applying Furadan 3G (Carbofuran) @ 8 kg ha^{-1} at 5-leaf stage. Weeds were controlled through two manual hoeings, 20 and 45 days after sowing (DAS). Harvesting was done after the appearance of black layer on cob that indicates its physiological maturity. The corn cobs were detached from the stems and permitted to dry for 10 days and then manually shelled.

Leaf area index

Starting from 45 DAS, five plants were arbitrarily picked from each experimental unit after every two weeks and their leaves were harvested. After leaf separation, leaf area was calculated after measuring length and width of leaves and using a crop factor i.e. 0.7 for maize (Gao et al. 2010). Based on the leaf area, the leaf area index (LAI) was calculated from the ratio of leaf area to land area (Watson 1947).

$$LAI = \frac{leaf\ area}{land\ area}$$

Crop growth rate

Starting from 45 DAS, 5 plants were randomly selected from each unit at time interval of 15 days, and their leaves were separated and dried in hot air oven at 70 °C until constant weight is achieved. Weighed the dried leaves with the help of a digital electronic balance. The crop growth rate (CGR) was calculated by dividing the dry weight difference of the two harvested leaves by the time interval between the two harvests using formula as proposed by Hunt (1978).

$$CGR = \frac{W2 - W1}{t2 - t1}$$

Leaf area duration

To calculate the leaf area duration (LAD), the leaf area index was measured as previously described procedure, and then the leaf area duration was calculated according to the given equation as proposed by Hunt (1978).

$$LAD = (LAI1 + LAI2)\,(t2 - t1)/2$$

Net assimilation rate

Net assimilation rate (NAR) was calculated as the ratio of total dry matter to the leaf area duration using formula as suggested by Hunt (1978).

Economic analysis

Economic analysis was performed to determine the impact of K application on net income by using the formula (CIMMYT 1988).

Net income = Gross benefit - Gross investment

Statistical analysis

The recorded data was analyzed by using Statistix software (version, Statistix, 8.1.) and at 5% probability analysis of variance technique and treatments means were compared by least significance difference (LSD) test. Moreover, data was processed in Microsoft Excel-2016 to get values of standard error as well as line graphs for graphical representation of data.

RESULTS

Results of the study showed that maize cultivars Islamabad Gold and Azam were non-significantly different from each other with respect to LAI at 45, 60 and 75 DAS (Figure 1) while foliarly applied K significantly affected maize LAI. Maximum LAI was measured in maize when 2% of K solution was applied at 45, 60 and 75 DAS. Interaction between maize cultivars and foliarly applied K had also a significant effect on LAI. At 45, 60 and 75 DAS, maximum LAI was observed in maize cultivar Islamabad Gold when 2% K solution was applied. Results of the study revealed that maize cultivars and foliarly applied K significantly improved LAD of maize crop at 45 and 60 DAS (Figure 2). Maximum LAD was calculated in maize cultivar Azam that was statistically similar to the maize cultivar Islamabad Gold at 45 and 60 DAS. Foliar application of K also significantly affected the maize LAD. Maximum LAD was observed when 2% K solution was sprayed on maize at 45 and 60 DAS. Interactive effect between maize hybrids and K application was statistically significant for the LAD. At 45 days after sowing, maximum LAD was observed in maize cultivar Islamabad Gold when 2% solution of K was sprayed, while at 60 DAS, maximum LAD was observed in maize cultivar Islamabad Gold when 2% K solution was foliarly applied.

Results presented in Figure 3 indicated that maize cultivars and foliar application of K had significant effect on CGR at 45, 60, 75 and 90 DAS. Maximum CGR was measured in cultivar Islamabad Gold. Foliar spray of K also significantly affected the CGR. Maximum CGR was calculated where 2% K was foliarly applied while the interactive effect between maize cultivars and K was also found significant. At 45, 60 and 75 DAS, maximum CGR was recorded when 2% K solution was foliarly applied on Islamabad Gold. It was found that maize hybrids and foliarly applied K had significant effect on the NAR. More NAR was calculated in maize cultivar Islamabad Gold (Table 1). Similarly, maximum NAR was observed when 1% K_2SO_4 solution was foliarly applied. Interaction between maize cultivars and foliar application of K was also found significant. More NAR was calculated in maize cultivar Islamabad Gold when 1% K solution was applied (Table 1). Economic analysis showed that foliar application of K on maize hybrids improved the benefit cost ratio (BCR), net income and gross income (Table 2). Maximum BCR, net income and gross income was observed when Islamabad Gold was grown and 2% solution of K_2SO_4 was applied at foliage.

DISCUSSION

Results of this study indicated that foliarly applied K increased the LAI (Figure 1). This increase was probably due to increase in leaf growth and cell osmotic potential. Under arid climate, K application markedly enhanced the leaf area and ultimately LAI (Aslam et al. 2014). Foliar application of K increased the constituents of cell, especially protoplasm with the consequent increase in the leaf area and LAI. Previous studies (Aslam et al. 2014) confirmed that K application improved the photosynthesis, cell division and expansion by improving leaf area and LAI. Akhtar

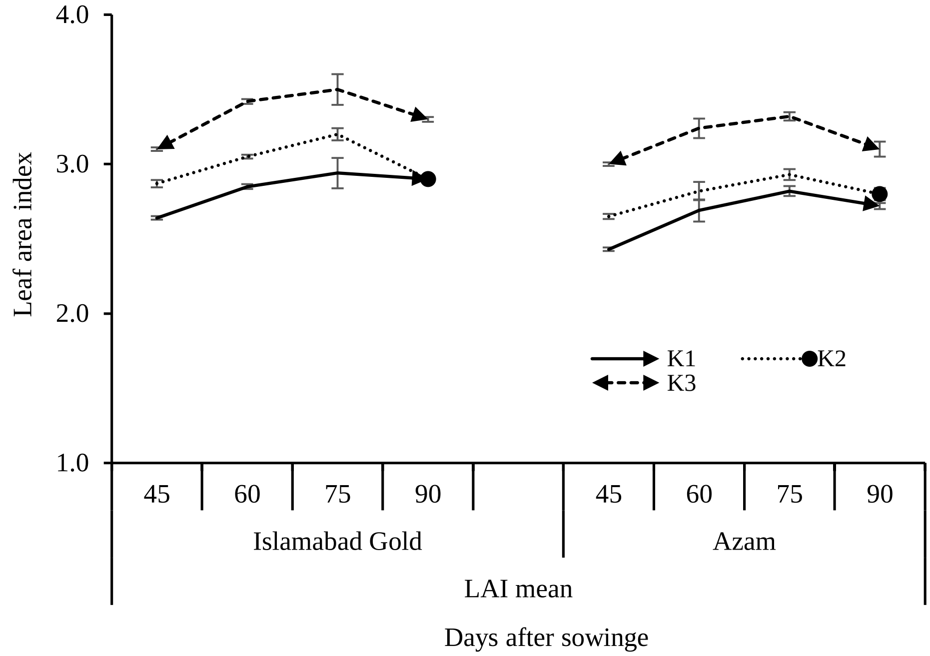

Figure 1 Effect of foliar application of K_2SO_4 on leaf area index of two maize cultivars under rainfed conditions. K_1: Control (water spray); K_2: 1% K_2SO_4; K_3: 2% K_2SO_4

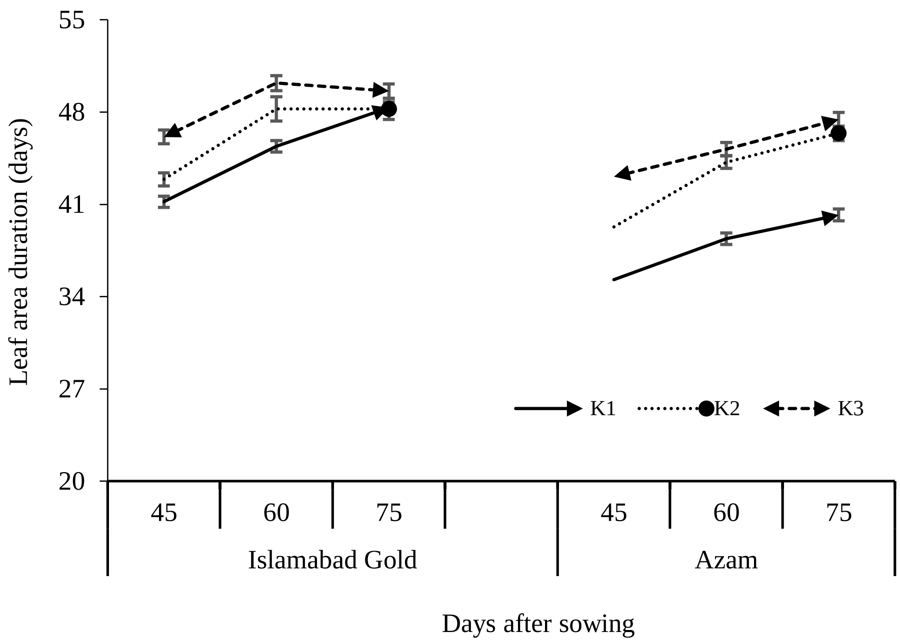

Figure 2 Effect of foliar application of K_2SO_4 on leaf area duration of maize. K_1: Control (water spray); K_2: 1% K_2SO_4; K_3: 2% K_2SO_4

et al. (2003) found that foliarly applied K activated the several enzyme, improved protein synthesis, leaf number and leaf size that ultimately increased the leaf area and LAI. Potassium application to crop stimulated the photosynthetic activity of plants and dry matter accumulation is diverted towards the areal parts of plants and hence net assimilation rate was enhanced (Hasanuzzaman et al. 2018). The results of this study

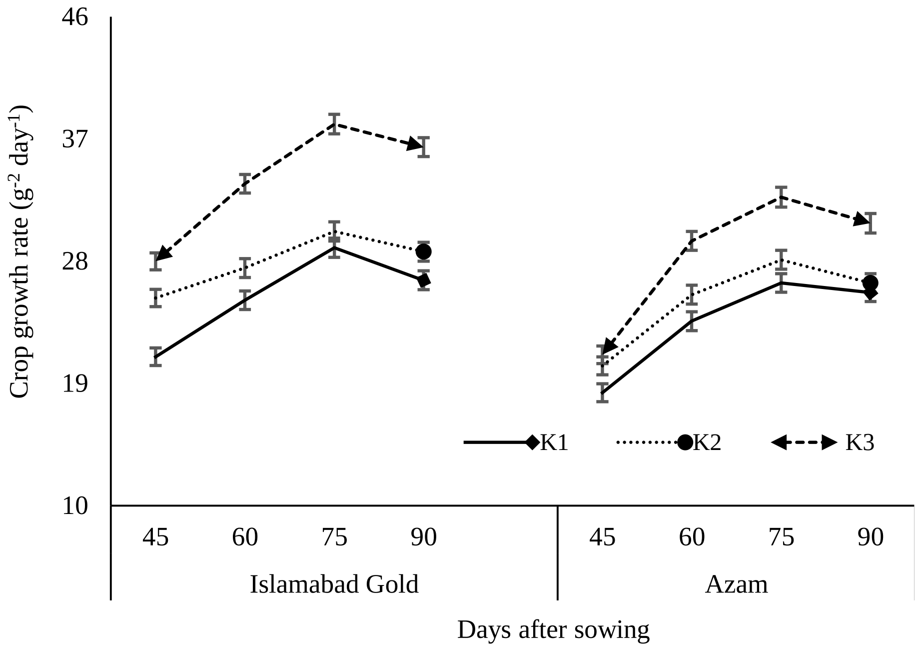

Figure 3 Effect of foliar application of K_2SO_4 on crop growth rate of maize. K_1: Control (water spray); K_2: 1% K_2SO_4; K_3: 2% K_2SO_4

Table 1 Effect of foliar application of K_2SO_4 on Net assimilation rate (NAR) (gm^{-2} day^{-1}) of two maize cultivars under rainfed conditions

Treatments	Islamabad Gold	Azam	Mean
Control (Water spray)	26.32 c	22.04 d	24.18 C
1% K_2SO_4	39.35 a	29.97 b	34.66 A
2% K_2SO_4	27.13 c	31.23 b	29.18 B
Mean	30.93 A	27.75 B	
LSD ≤ 0.05	V=0.59, K= 1.36 and V*K= 1.67		

Means not sharing the same letters in the column differ significantly from each other at $p \leq 0.05$

Table 2 Economic analysis as influenced by different levels of K_2SO_4 in rainfed maize production

Treatments	Grain yield (kg ha^{-1})	Total expenditure (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	BCR
V_1K_0	1500	34100	45000	20890	1.31
V_1K_1	1750	37100	52500	17890	1.41
V_1K_2	1913	40100	57390	18400	1.43
V_2K_0	1600	34100	48000	12400	1.40
V_2K_1	1720	37100	51600	13570	1.39
V_2K_2	1820	40100	54600	12580	1.36

BCR= benefit cost ratio, V_1, Islamabad Gold, V_2= Azam, K0: 0% K_2SO_4; K_1: 1% K_2SO_4; K_2: 2% K_2SO_4

revealed that K application increased the CGR (Figure 3). This increase in CGR was due to K application that increased enzymes and hormones activities, cell division and vegetative growth (Shah et al. 2017). Maximum crop growth was due to the accumulation of dry matter in unit area and unit time that was only due to higher photosynthetic activity (Inthichack et al. 2012). Potassium application increased the leaf area, LAI and chlorophyll contents of maize plants which resultantly increased the CGR and NAR. This increase was might be due to the maximum translocation of assimilates towards the leaves and economic portion of plants (Shah et al. 2017). Foliar application of K increased the leaf appearance, leaf elongation and therefore LAD was increased. Treatment where only water was sprayed decreased the leaf length that decreased the LAI and LAD while K application increased LAI and ultimately LAD (Meille and

Pellerin 2004). Farmers should adopt any new technology keeping in view its economic impact in terms of cost and profit ratio (Khan et al. 2012). Economic analysis of this study revealed that the combination of foliar applied K and maize hybrid Islamabad Gold was superior to achieve more net income and BCR under rainfed conditions.

CONCLUSION

Under rainfed climate, maize cultivar Islamabad Gold performed better with the foliar application of 2% K_2SO_4 solution in terms of CGR, LAI, LAD, NAR and yield than maize cultivar Azam. Therefore, rainfed farmers should grow maize hybrid Islamabad Gold by applying 2% K_2SO_4 solution as foliar spray in order to get higher grain yield of maize under rainfed conditions.

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