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To Evaluate the Better Response of Foliar Spray over Soil Application of Potassium on Hybrid Maize Yield under Rainfed Conditions

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Abstract

The field experiment was conducted to determine the response of foliar spray as compared to soil application of potassium on maize at Maize, Sorghum and Millet Program, National Agriculture Research Centre, Islamabad under rainfed environment during summer, 2014. Potassium treatments were; control (no K_2O application), Soil application @ 75 kg K_2O ha^{-1}, foliar spray application @ 1, 2 and 3% K_2O, Soil fertigation @ 75 kg K_2O ha^{-1}, and split soil application @ 75 kg K_2O ha^{-1}. Soil application of nitrogen (N) and phosphorus (P) were used @ 120 and 90 kg ha^{-1}, respectively, to all treatments at sowing. Two split foliar spray of K_2O were applied at 40 DAS (days after sowing) at 7th leaf stage and 65 DAS at tasseling stage according to research plan. The grain yield was 8.09 t ha^{-1} receiving foliar spray of 3% K_2O (13 K_2SO_4 kg ha^{-1}), followed by 2% K_2O foliar (8.6 K_2SO_4 kg ha^{-1}). Similarly plant height (188 cm) and leaf area $plant^{-1}$ (451 cm^2) were significant receiving 3% K_2O foliar. Moreover, Split soil application of potassium exhibited the grain yield (6.77 t ha^{-1}) which was at par with 1% K_2O foliar, followed by soil (6.07 t ha^{-1}) and fertigation (5.82 t ha^{-1}) of recommended soil potassium. Moreover, potassium foliar treatments was found to be economical in terms of net benefit, benefit cost ratio, and comparative greater revenue in turns of higher foliar rates as compared to soil application. All foliar treatments respond better in growth, yield and grain quality attributes followed by splitting, recommended NPK at soil and fertigation of soil applied potassium, respectively.

Key words: Foliar spray, grain yield, hybrid maize, potassium sulphate, soil application

Introduction

Maize *(Zea mays* L.*)* is often considered as “the king of grain crops” as well as important food crop of world. After wheat and rice, it ranks third as a cereal in world grain production. It nourishing the millions of the people in the form of bread, cake and porridge especially in Asia, Africa and America. Moreover, it is important food grain for feeding the human beings, livestock and poultry industry (Bukhsh et al., 2011). Maize grain contains (in per cent) about 71 starch, 9 protein, 4.5 oil, 8.5 fiber, 7 ash (Hurburgh, 1989; Chaudhary, 1993). According to an estimate, world-wide demand for maize is gradually rising especially in developing countries due to escalating population (Morris, 2002).

Potassium (K)-plays a key role for increasing the grain quality because it stimulates about 80 different enzymes, enhances the activity of stomatal aperture, supports the roots strengthening in vegetative growth, and also improves the water potential during the water stress conditions through water absorption for increasing the osmotic potential (Aziz et al., 1999). Potassium is considered as macronutrient in plant growth and sustainable crop yield and important fertilizer for increasing the maize grain yield (Bukhsh et al., 2009; Bukhsh et al., 2012). It sustains turgor pressure of cell which is important for cell enlargement. It helps in osmo-regulation of plant cell, supports in stomatal activity (Mengel and Kirkby, 1987). It is important for the activity of about 60 enzymes (Tisdale et al., 1990). Potassium plays key role on growth and development of the plant (Bukhsh et al., 2011).

Presently, Weathering process in soil cause the addition of secondary minerals e.g. Ca, Mg, S and also sulphates, carbamates and phosphates. Consequently, these minerals may affect the availability of K to growing plants (Huang, 1977). Presently, increase in cropping intensity, straw removal from the field, excessive usages of tube well water and introduction of high yielding hybrid varieties have resulted in considerable exhaust of soil K (Malik et al., 1989). Moreover, potassium fertilizers becoming high-priced and too expensive by farmers (NFDC, 2005). The above-mentioned problems of K availability compel to explore some ways to improve the K use efficiency. One such technique is to apply K fertilizer on the leaves of crop plants. Potassium fixation problem can be reduced by K foliar application techniques (Grimme, 1974). Foliar potassium is more target oriented, timely available to crop plants and inexpensive technique for increasing the fertilizer use efficiency and grain yield over soil application (Eichert and Burkhardt, 2001; Farooqi et al., 2012).

Materials and Methods

Experimental

The experiment was conducted under the rainfed conditions in area of "National Agriculture Research Centre, Islamabad" during the summer season 2014. Islamabad's climate is sub-humid to sub-tropical, receiving average annual rainfall 1045 mm, with more than 65% occurring from April to October. The mean maximum temperature ranges from 30.00 to 35.00 °C and the mean minimum temperature ranges from 15 to 20 °C during summer season. The field soil status were: pH 7.65, organic matter 2.8 g kg^{-1}, total nitrogen 0. 52 mg kg^{-1} (Kjeldahl), available phosphorus 0.95 mg kg^{-1}, extractable potassium 67 mg kg^{-1}, with sandy loam calcareous texture. Maize hybrid-2704 was cultivated in field area of Maize, Sorghum and Millet Program, Crop Sciences Institute, NARC, Islamabad. Seed bed was prepared by ploughing with cultivator and followed by planking. The treatments were allocated to different experimental units in a randomized complete block design (RCBD) with 3 replications. The maize hybrid-2704 was cultivated by row to row distance 75 cm and from plant to plant distance 20 cm. Seed rate was 25 kg ha^{-1} and a net plot size 4m × 3m. Source of potassium was potassium sulphate (K_2SO_4). Recommended dose of nitrogen and phosphorus were applied at sowing @ 120 and 90 kg ha^{-1}, respectively, to all the experimental plots. Foliar spray of K_2O @ 1, 2 and 3% concentration (4.3, 8.6 and 13.0 kg ha^{-1} K_2SO_4 respectively), were applied at 40 DAS (7th leave) and 65 DAS (tasseling stage) according to research plan.

The experiment consisted of 7 treatments viz control (no potassium), soil application of potassium @ 75 kg ha^{-1}, foliar spray @ 1% K_2O, foliar spray @ 2% K_2O, foliar spray @ 3% K_2O, potassium fertigation @ 75 kg ha^{-1}, and split soil application of recommended potassium (75 kg ha^{-1}) as half at sowing and half at initiation of flowering stage. Observations recorded were regarding agro-morphological, physiological and grain quality traits like plant height, number of leaf plant^{-1}, ear height, grain yield, ear weight plot^{-1}, number of grain rows ear^{-1}, grain number ear^{-1}, leaf area plant^{-1}, leaf area index, sub-stomatal CO_2 concentration, stomatal conductance, chlorophyll contents, grain oil and protein contents. Following data were recorded by using typical procedures as:

Data collection

The data for plant height were recorded at maturity. Measurements of maize stalk starting from the ground to the base of tassel were recorded on five randomly selected plants. Readings were taken in centimetres with a steel meter rod. Ear height was recorded from first node of ear and then average ear height was computed. For grain yield, all maize plants harvested from each plot were dried by sun and threshed manually to calculate the grain yield plot^{-1} in kg ha^{-1}. For ear weight plot^{-1}, weight of all harvested ears in each plot was recorded.

Five plants were randomly selected at crop maturity from each plot to measure the number of leaf plant^{-1}, number of grain rows ear^{-1}, grain number ear^{-1} and then averaged.

For leaf area plant^{-1}, five plants were taken randomly from each plot then measured each leaf length and width of selected plants, average length and width was calculated of each plant and multiplied with the maize correction factor (0.75) to find out the leaf area plant^{-1}.

Leaf area index (LAI) was calculated by the following formula;

$$LAI = \frac{\text{Leaf area}}{\text{Land area}}$$

Sub-stomatal CO_2 concentration, stomatal conductance and chlorophyll contents were measured in five plants randomly selected from each plot by using the instrument Infra-Red Gas Analyzer (IRGA) LC-pro plus, and the reading was averaged.

Grain oil and protein contents of maize were analyzed by Soxhlet and Kjeldhal method, respectively.

Economic analysis

Total maize production cost included the expenses on seed, soil preparation, sowing and all other agronomic operations. Net benefit, gross revenue and benefit cost ratio were calculated from the observed data.

Statistical analysis

All data were subjected to analysis of variance, and the treatment means were compared by LSD at 5% level of probability (Montgomery, 2001). All data were subjected to analysis of variance using Statistix 8.1 software.

Results and Discussion

Plant growth attributes

Higher plant height was recorded in all foliar spray treated plants as compare to soil application and fertigation of potassium (Table 1). The highest plant height was 188 cm under 3% K_2O foliar spray followed by 2% K_2O foliar. The lowest plant height (122 cm) was observed in control. Fixed number of nodes exhibited in maize crop but foliar application enlarged the inter-nodal length, as a result plant height was increased, so more accumulation of photosynthesis take place, which lead to higher production of grain yield. Number of leaf plant^{-1} is an important parameter indicating plant's photosynthetic potential. Leaf number plant^{-1} exhibited non-significant affects against various potassium treatments (Table 1). Two per cent K_2O as a foliar application gave maximum number of leaf plant^{-1} as compared to other potassium doses of fertilizer. The smallest number of leaf plant^{-1} was observed in split application of soil potassium. There is a significant difference for ear height against various potassium treatments (Table 1). The height of the ear is highly correlated to plant height. It depends on the variety or the environment, but is likely to be the same ear height within a population. The greatest value of ear height was recorded in foliar treated plots followed by soil and split dose of soil applied potassium. The lowest ear height (52.3 cm) was examined in control treatment which was at par with fertigation of soil potassium. Foliar application of potassium and urea @ 2% (both) at 65, 90, 115 DAS increased the plant height of wheat crop due to more uptake of foliar applied potassium (Amal et al., 2011). Maize plant height increased by potassium application @ 125 kg K_2O ha^{-l} (Akram et al., 2010). Dewdar and Rady (2013) suggested that recommended dose of NPK + 2 per cent K_2O to foliar sprayed at both 80 DAS and 105 DAS in cotton plants increased the number of leaf plant^{-1} due to efficient utilization of nutrients. Foliar application of KNO_3 at 0.50% at 50% flowering stage increased the ear height on grasspea because more uptake efficiency of nutrients to crop plants (Sarkar and Malik, 2001).

Table 1. Response of foliar applied potassium on plant height, number of leaf plant^{-1}, ear height

Treatments	Plant height (cm)	Number of leaf plant^{-1}	Ear height (cm)
Control (no K_2O application)	122 e*	13.3 ab*	52.3 c*
Soil application of 75 kg K_2O ha^{-1}	154 cd	13.3 ab	73.6 b
Foliar spray of 1% K_2O	166 bc	13.0 ab	76.7 b
Foliar spray of 2% K_2O	182 ab	14.0 a	87.9 a
Foliar spray of 3% K_2O	188 a	13.0 ab	89.3 a
Fertigation of 75 kg K_2O ha^{-1}	137 de	13.3 ab	57.0 c
Split application of 75 kg K_2O ha^{-1}	151 cd	12.3 b	71.1 b
LSD ($P \le 0.05$)	18.9	1.25	5.76

*Means sharing a common letter in each parameter / column did not differ significantly ($P \le 0.05$) at 5 % probability level.

Yield attributes

Data for grain yield, ear weight plot^{-1}, number of grain rows ear^{-1}, grain number ear^{-1} of maize against different potassium doses discovered significant differences (Table 2). Application of 3% K_2O as a foliar gave maximum grain yield (8.09 t ha^{-1}) in comparison to control (5.13 t ha^{-1}). The maize grain yield against 1% K_2O as a foliar spray was statistically at par with split dose of recommended soil potassium and foliar spray @ 2% K_2O. Maximum ear weight of plot^{-1} (13.4 kg) was recorded treated with foliar sprays as compared to soil application of potassium. Lowest ear weight plot^{-1} (9.0 kg) was observed in plots receiving no potassium followed by fertigation and soil applied NPK. Foliar sprays of K_2O attained higher number of grain rows ear^{-1} than soil, fertigation and split dose of soil potassium. Lowest number of rows ear^{-1} (10.0) was recorded in control followed by fertigation. Control treatment exhibited minimum grains number ear^{-1} (434) which was at par with fertigation receiving 75 kg K ha^{-1} (Table 2). Maximum number of grains ear^{-1} (717.7) was counted by 3% K_2O foliar treated plot followed by 2% K_2O. Grain yield per unit area increased by foliar potassium due to better enzymes activity and this leads to more easily translocation of photosynthates from leaf to grain (Akhtar et al., 2003; Ali et al., 2007; Mesbah, 2009; Hasina et al., 2011; John and Lester, 2011). Foliar application @ 1% K_2O at reproductive stage increased the grain yield under normal and drought conditions due to timely and efficient utilization of nutrients (Farooqi et al., 2012). Potassium @ 6.0% K_2O produced higher yield of rice comparable to the yield obtained with the soil application of K_2O @ 50 kg ha^{-1} (Ali et al., 2007). Sharma et al. (2005) stated that ear weight plot^{-1} increased by increasing the potassium use efficiency. Potassium application increased the number of grain rows ear^{-1} due to high efficiency of nutrients availability to plants (Akhtar et al., 2003; Grzebisz et al., 2003; Akram et al., 2010). Foliar application of KNO_3 @ 0.50% at 50% flowering stage increased the number of grains pod^{-1} of grasspea (Sarkar and Malik, 2001). Foliar application (once) of nitrogen, potassium and zinc @ (each 50%) increased the number of grains ear^{-1} due to timely availability of nutrients to crop plants (Hasina et al., 2011).

Table 2. Response of foliar applied potassium on grain yield, ear weight plot^{-1}, number of grain rows ear^{-1}, grain number ear^{-1}

Treatments	Grain yield (t ha^{-1})	Ear weight plot^{-1} (kg)	Number of grain rows ear^{-1}	Grain number ear^{-1}
Control (no K_2O application)	5.13 e*	9.0 f*	10.0 d*	434.00 e*
Soil application of 75 kg K_2O ha^{-1}	6.09 cd	10.7 de	11.7 bc	503.00 de
Foliar spray of 1% K_2O	6.79 bc	11.7 bc	13.0 ab	607.00 bc
Foliar spray of 2% K_2O	7.33 b	12.4 b	14.0 a	652.00 ab
Foliar spray of 3% K_2O	8.09 a	13.4 a	14.3 a	717.7 a
Fertigation of 75 kg K_2O ha^{-1}	5.82 de	9.8 e	10.3 cd	434.7 e
Split application of 75 kg K_2O ha^{-1}	6.77 bc	11.4 cd	12.3 b	539.00 cd
LSD ($P \leq 0.05$)	7.34	0.85	1.34	74.13

*Means sharing a common letter in each parameter / column did not differ significantly ($P \leq 0.05$) at 5 % probability level.

Physiological attributes

Data for leaf area plant^{-1}, leaf area index, sub-stomatal CO_2 concentration, stomatal conductance, chlorophyll contents of maize under different potassium treatments discovered significant differences (Table 3). Leaf area plant^{-1} (LAP) and leaf area index (LAI) revealed the crop growth and photosynthetic efficiency rate of plants and exhibited similar increasing and decreasing trend against the different treatments of potassium. Higher potassium use efficiency via foliar spray increased the LAP significantly, all foliar spray of K_2O observed maximum value of LAP as compared to soil, fertigation and split dose of soil potassium. High potassium use efficiency significantly increased the LAI (Table 3). The leaf area index highly increased up to 65 DAS and then decreased to the final harvesting stage. The LAI was very low in the beginning (45 days after sowing) but varied significantly in the maize hybrids under the different potassium levels. It increased with the increment of the growth period and after reaching the maximum, it stopped to the final harvest of the crop. Highest sub-stomatal CO_2 concentration rate (82.1 vpm) was recorded under 3% K_2O foliar treated plots (Table 3). Substomatal CO_2 concentration rate was recorded statistically at par under soil applied NPK, foliar spray of 1% K_2O and fertigation. Minimum sub-stomatal CO_2 concentration rate was recorded in control (no potassium). There is also significant differences in stomatal conductance against various potassium doses while control and fertigation of soil applied potassium exhibited no significant differences (Table 3). Foliar spray at 3% K_2O was recorded higher stomatal conductance (21.0), followed by soil applied potassium and foliar at 1% K_2O. Chlorophyll contents increased the photosynthetic pigments that directly relate to grain production from a unit area of land. Maximum chlorophyll contents (53.9) during the data collection were observed in 3% K_2O spray followed by 2% K_2O spray treated plot (Table 3). Soil application of potassium was statistically at par with 1% K_2O treated plot as a foliar spray. Minimum chlorophyll contents were examined in control. Fertigation of potassium showed non-significant differences with split dose of potassium in chlorophyll contents. Recommended dose of NPK plus split application of foliar spray @ 2% K_2O increased the leaf area plant^{-1} of cotton because of better enzyme activity which leads to higher photosynthetic rate (Dewdar and Rady, 2013). Potassium nutrients significantly increased the leaf area index (Ali et al., 2007; Mesbah, 2009; Akram et al., 2010). Supplemental potassium foliar increased the sub-stomatal CO_2 concentration, stomatal conductance and chlorophyll contents due to more efficiency and timely available of fertilizers (Ali et al., 2007; Zareian et al., 2013).

Grain quality attributes

Analyzed data showed that there was a significant difference for grain oil and protein contents (Table 4). Higher grain oil contents (4.30) was observed in foliar application of 3% K_2O as compared to other potassium treatments. Minimum grain oil contents were observed in control receiving-no potassium. There was non-significant difference in 1% K_2O, 2% K_2O, splitting and soil applied potassium for grain oil contents. The Application of K foliars increased the protein contents over splitting, soil and fertigation of soil applied potassium, respectively (Table 4).

Application of 1% potassium as foliar exhibited grain protein contents (7.54%) which was at par with soil and split dose of soil potassium. Similar results reported by (Minjian et al., 2007; Petttigrew, 2008 John and Lester, 2011) who suggested that grain oil and protein contents increased by increasing the higher potassium use efficiency by crop plants.

Table 3. Response of foliar applied potassium on leaf area, leaf area index, substomatal CO_2 concentration, stomatal conductance, chlorophyll contents

Treatments	Leaf area per plant (cm^2)	Leaf area index	Substomatal CO_2 concentration (vpm)	Stomatal conductance (mol /m^2s)	Chlorophyll contents (%)
Control (no K_2O application)	309 d*	25.8 d*	52.2 c*	15.1 d*	47.4 c*
Soil application of 75 kg K_2O ha^{-1}	379 bc	31.7 bc	65.7 abc	19.8 ab	50.2 abc
Foliar spray of 1% K_2O	402 b	33.6 b	66.7 abc	19.3 abc	50.8 abc
Foliar spray of 2% K_2O	411 b	34.2 b	75.1 ab	17.2 bcd	51.6 ab
Foliar spray of 3% K_2O	451 a	37.6 a	82.1 a	21.0 a	53.9 a
Fertigation of 75 kg K_2O ha^{-1}	359 c	30.0 c	65.6 abc	15.2 d	48.6 bc
Split application of 75 kg K_2O ha^{-1}	354 c	29.6 c	59.7 bc	17.0 cd	48.1 bc
LSD ($P \leq 0.05$)	39.1	3.26	21.9	2.70	3.80

*Means sharing a common letter in each parameter / column did not differ significantly ($P \leq 0.05$) at 5 % probability level.

Table 4. Response of foliar applied potassium on grain oil and protein contents

Treatments	Grain oil contents (%)	Grain protein contents (%)
Control (no K_2O application)	2.37 d*	7.08 c*
Soil application of 75 kg K_2O ha^{-1}	3.35 b	7.49 b
Foliar spray of 1% K_2O	3.32 b	7.54 b
Foliar spray of 2% K_2O	3.48 b	7.96 a
Foliar spray of 3% K_2O	4.30 a	8.12 a
Fertigation of 75 kg K_2O ha^{-1}	2.78 c	7.16 c
Split application of 75 kg K_2O ha^{-1}	3.41 b	7.52 b
LSD ($P \leq 0.05$)	0.37	0.29

*Means sharing a common letter in each parameter / column did not differ significantly ($P \leq 0.05$) at 5 % probability level.

Economic Analysis

Foliar sprays @ 1, 2 and 3 per cent at 7^{th} leaf and tasseling stage increased the economic returns comparative to that attained without them (Table 5). Economic analysis was carried out in terms of benefit cost ratio (BCR). Net benefit and benefit cost ratio were highest under foliar sprays of potassium followed by splitting and recommended dose of potassium fertilizer. Foliar spray of 3% K_2O exhibited higher BCR (4.75) followed by 2% K_2O (4.30) and 1% K_2O (3.91) due to more efficiency of hybrid maize to foliar spray and economical technique for optimum grain yield. Among soil treatments, least BCR (1.78) was found under fertigation due to low availability of potassium and other soil nutrients, followed by soil applied potassium (2.59) and control (2.67). Farooqi et al. (2012) suggested that economic yield and net benefit cost ratio was increased under both soil application of nutrients and foliar potassium spray.

Conclusions

This study indicates that recommended dose of nitrogen and phosphorus at sowing plus split foliar spray of K_2O @ 13.0, 8.6, 4.3 K_2SO_4 kg ha^{-1}) at 7^{th} leaf and tasseling stage to maize hybrid exhibited maximum growth and yield components due to more foliar efficiency and timely available of potassium nutrients as compared to different soil application of potassium. Among soil treatments, splitting at 75 kg K_2O ha^{-1} respond better and statistically at par with foliar spray of 1% K_2O in relation to grain yield.

Table 5. Economic analysis in terms of benefit cost ratio

Economic parameters	Control (no K_2O application)	Soil application of 75 kg K_2O ha^{-1}	Foliar spray of 1% K_2O	Foliar spray of 2% K_2O	Foliar spray of 3% K_2O	Fertigation of 75 kg K_2O ha^{-1}	Split application of 75 kg K_2O ha^{-1}
Urea	9,672	9,672	9,672	9,672	9,672	9,672	9,672
DAP	17,750	17,750	17,750	17,750	17,750	17,750	17,750
SOP	N/L	13,200	382	765	1,447	26,400	13,200
Other common cost (Rs ha^{-1})	25,450	25,450	25,450	25,450	25,450	25,450	25,450
Total cost (Rs ha^{-1})	52,870	66,072	53,254	53,637	54,319	79,272	66,072
Grain yield (t ha^{-1})	5.13	6.09	6.79	7.33	8.09	5.82	6.77
Grain yield revenue at Rs 30 kg^{-1} (Rs ha^{-1})	153,900	182,700	203,700	219,690	242,700	174600	203,100
Fodder yield (t ha^{-1})	8.10	11.0	11.6	13.0	14.0	9.3	11.3
Fodder yield revenue (kg ha^{-1})	40,500	55,000	58,000	65,000	70,000	46,500	56,500
Gross revenue (Rs ha^{-1})	194,400	237,700	261,700	284,690	312,700	221,100	259,600
Net benefit (Rs ha^{-1})	141530	171628	208,446	231,053	258,381	141,828	193,528
Benefit cost ratio	2.67	2.59	3.91	4.30	4.75	1.78	2.92

References

Akhtar, M.E., Saleem, M.T., Stauffer, M.D., 2003. Potassium in Pakistan Agriculture. Pakistan Agric. Research Council, Islamabad.

Akram M., Ashraf, M.Y., Ahmad, R., Rafiq, M., Ahmad, I., Iqbal, J., 2010. Allometry and yield components of maize (*Zea mays* L.) hybrids to various potassium levels under saline conditions. Arch. Bio. Sci. 62 (4): 1053-1061.

Ali A., Mahmood, I.A., Hussain, F., Salim, M., 2007. Response of rice to soil and foliar application of K_2SO_4 fertilizer. Sarhad J. Agric. 23(4).

Amal, G.A., Tawfik, M.M., Hassanein, M.S., 2011. Foliar feeding of potassium and urea for maximizing wheat productivity in sandy soil. Aus. J. Basic and App Sci. 5(5): 1197-1203.

Aziz A., Martin-Tanguy, J., Larher, F., 1999. Salt stress-induced proline accumulation and changes in tyramine and polyamine levels are linked to ionic adjustment in wheat leaf discs. Plant Sci. 145: 83-91.

Bukhsh, M.A.A.H.A., Ahmad, R., Iqbal, J., Rehman, A., Hussain, S., Ishaque, M., 2011. Potassium application reduces bareness in different maize hybrids under crowding stress conditions. Pak. J. Agri. Sci. 48: 31-37.

Bukhsh, M.A.A.H.A, Ahmad, R., Ishaque, M., Malik, A.U., 2009. Response of maize hybrids to varying potassium application in Pakistan. Pak. J. Agri. Sci. 46(3): 179-184.

Bukhsh, M.A.A.H.A., Ahmad, R., Iqbal, J., Maqbool, M.M., Ali, A., Ishaque, M., Hussain, S., 2012. Nutritional and physiological significance of potassium application in maize hybrid crop production. Pak. J. Nut. 11: 187-202.

Chaudhary, A.R., 1993. Maize in Pakistan. Punjab Agri Res Cord Board Uni. Agri. Faisalabad Pakistan.

Dewdar, M.D.H. and Rady, M.M., 2013. Influence of soil and foliar applications of potassium fertilization on growth, yield and fiber quality traits in two *Gossypium barbadense* L. varieties. African J. Agric. Research 8(19): 2211-2215.

Eichert, T. and Burkhardt, J. 2001. Quantification of stomatal uptake of ionic solutes using a new model system. J. Exp. Bot. 52: 771–781.

Farooqi, M.Q.U., Ahmad, R., Wariach, E.A., Arfan, M., 2012. Effect of supplemental foliar applied potassium on yield and grain quality of autumn planted maize (*Zea mays* L.) under water stress. J. Food Agri. Vet. Sci. 2(3): 8-12.

Grimme, H., 1974. Potassium release in relation to crop production. In: Proc. 10th Cong. IPI, Budapest, pp: 131-136.

Grzebisz, W., Baer, A., Bar óg, P., Szczepaniak, W., Potarzycki, J., 2003. Effect of nitrogen and potassium fertilizing systems on maize grain yield. Uni. Life Sci. Poznan Poland pp: 45-46.

Hasina, G., Said, A., Saeed, B., Ahmad, K., 2011. Response of yield and yield components of wheat towards foliar spray of nitrogen, potassium and zinc. Asian Res Pub Network 6(2): 23-2.

Huang, P.M., 1977. Feldspar, olivines, phronenws and amphiboles. In: Minerals in Soil Environment. Dixon, Weed (eds.) Soil Sci. Soc. Am pp. 553-602.

Hurburgh, C.R. J., 1989. The value of quality to new and existing corn users. American Society of Agric. Eng. paper 89-6016. The society: St. Joseph MI.

John, L.J. and Lester, G.E., 2011. Effect of foliar potassium fertilization and source on cantaloupe yield and quality. Better Crops 95 (1): 13-15.

Malik, D.M., Chaudhry, R.A., Hussan, G., 1989. Crop response to potash application in the Punjab. In: Role of Potassium in improving fertilizer use efficiency. Proceedings of the Workshop on the Role of Potassium in improving fertilizer use efficiency, held in Islamabad, 21-22 March 1987. National Fertilizer Development Center, Planning and Development Division pp.187-190.

Mesbah., 2009. Effect of irrigation regimes and foliar spraying of potassium on yield, yield components and water use efficiency of wheat (*Triticum aestivum* L.) in sandy soils. World J. Agric. Sci. 5(6): 662-669.

Minjian, C., Haiqui, Y., Hongkui, Y., Chungi, J., 2007. Difference in tolerance to potassium deficiency between maize inbred lines. Plant Production Sci. 10(1): 42-46.

Montgomery, D.C. 2001. Design and Analysis of Experiments. 5th ed., Wiley, New York.

Morris, M.L., 2002. Impacts of international maize breeding research in developing countries, 1966-98, CIMMYT, Mexico. Montgomery, D.C. 2001. Design and Analysis of Experiments. 5th ed., Wiley, New York.

NFDC., 2005. Fertilizer use related statistics. National Fertilizer Dev Centre, Planning Div. Govt. Pak. Islamabad.

Pettigrew, W.T., 2008. Potassium influences on yield and quality production for maize, wheat, soybean, and cotton. Physiolgia Plantarum, 133(4): 670-681.

Sarkar, R.K. and Malik, G.C., 2001. Effect of foliar spray of potassium nitrate and calcium nitrate on grasspea (*Lathyrus sativus* L.) grown in rice fallows. Department of Agronomy, University College of Agriculture, Calcutta University, Calcutta, West Bengal, India pp. 47-48.

Sharma, S., Duveiller, E., Basnet, R., Karki, C.B., Sharma, R.C., 2005. Effect of potash fertilization on Helminthosporium leaf blight severity in wheat, and associated increases in grain yield and kernel weight. Field Crops Res. 93(1): 142–150.

Tisdale, S.L., Nelson, W.L., Beaton, J.D., 1990. Soil fertility and fertilizer. Elements required in plant nutrition. 4th Ed. Maxwell McMillan Publishing Singapore pp. 52-92.

Zareian, A., Abad, H.H.S., Hamidi, A., Mohammadi, G.N., Tabatabaei, S.A., 2013. Effect of drought stress and potassium foliar application on some physiological indices of three wheat (*Triticum aestivum* L.) cultivars. Annals of Bio. Res. 4(5): 71-74.