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Full Length Article

Foliar Applied Potassium and Zinc Enhances Growth and Yield Performance of Maize under Rainfed Conditions

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Abstract

A field experiment was conducted for two years (2013 and 2014) to study the effect of foliar spray of potassium and zinc on maize crop under rainfed environment. Nine treatments were examined as: control, recommended rate of zinc (RRZn) to soil @ 15 kg Zn_2SO_4 ha^{-1}, foliar zinc spray (FZS) @ 0.1%, recommended rate of potassium to soil (RRK) @ 75 kg K_2O ha^{-1}, RRK + RRZn, RRK+ FZS, foliar potassium spray (FKS) at 1% concentration, FKS + RRZn, FKS + FZS. The experiments were arranged in split plot with three replications. All integrated and individual foliar sprays of potassium and zinc surpassed all other treatments. Among all foliar treatments, integrated use of foliar potassium and zinc spray at 25 and 50 days after sowing (DAS) @ 1.0 and 0.1%, respectively enhanced all plant growth, yield, physiological and quality traits of maize. The highest 1000 grain weight (g) and grain yield (kg ha^{-1}) were recorded under the combined foliar spray of potassium and zinc (FKS + FZS), followed by FKS + RRZn and RRK+ FZS. Greater net benefit and benefit cost ration were examined under all foliar sprays. Foliar spray of potassium and zinc is a fertilizer use efficient technique for increasing the maize yield attributes and net income under rainfed conditions. © 2016 Friends Science Publishers

Keywords: Foliar spray; Potassium and zinc; Grain yield; Crop growth rate; Maize; Rainfed conditions

Introduction

Potassium plays a vital role in enhancing the yield and quality of maize grain. Many physiological processes of plants, affecting plant growth and yield such as photosynthesis, activation of enzymes, plant water relation and assimilation are affected by potassium application. Potassium is an important nutrient as nitrogen and phosphorus for grain crops (Ahmed *et al.,* 2006; Pettigrew, 2008). It significantly affect protein synthesis, enzyme activation, osmoregulation, photosynthesis, stomatal movement, phloem transport, energy transfer, cation-anion balance and stress resistance (Marschner, 2012). The deficiency symptoms of potassium apparently have been not shown on maize crop but the yield decreases drastically, if there is severe deficiency then symptoms also can be observed (Ahmad *et al.,* 2012). Soils in Pakistan are generally considered rich in potassium but increase in cropping intensity, extensive removal of straw from the field, excessive use of tube well water and soil applied K get fixed with clay minerals have resulted in considerable exhaust of soil potassium (Malik *et al*., 1989; Abid *et al*., 2016). Moreover, the price of fertilizers is getting higher and become expensive to the farmers.

Zinc is essential for biosynthesis of the carbonic enzyme required for chlorophyll biosynthesis (Xi-Wen *et al*., 2011; Mousavi, 2011; Rehman *et al.,* 2012). Zinc availability from the soil solution to growing plants depends on the soil factors because these factors influence the sorption and desorption of zinc in the soil solution to manage the amount of zinc in the soil (Alloway, 2008). If seed has higher amount of zinc it performs many beneficial roles in the germination and in early establishment (Cakmak, 2008). Zinc application in maize improves photosynthetic rate, chlorophyll synthesis, metabolism of nitrogen and resistance to a biotic and biotic stresses (Ali *et al*., 2008; Mousavi, 2011; Yosefi *et al*., 2011). Inadequate supply of Zn drastically decreased the yield returns growing under temperate regions of maize (Subedi and Ma, 2009). Zinc deficiency is more prominent in semi-arid regions of the world having calcareous soils (Alloway, 2008; Akay, 2011). Soils with low organic matter are more susceptible to zinc deficiency (Alloway, 2009). Zn deficiency is observed in crops like rice and maize which result in reduction of crop growth and yield attributes (Mousavi, 2011; Yosefi *et al*., 2011).

The demand of macro and micro nutrients such as potash and zinc is increasing day by day because of

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amplified intensity of cropping for escalating population (Hasina *et al*., 2011). The soil application of recommended dose of these fertilizers pose financially great pressure on the economy of the country due to their expensiveness, as well as soil application causes nutrient losses through leaching, volatilization and fixation. Foliar application is a fertilizer use efficient way and increases the absorption of potassium as well as other nutrients. Foliar application enhances the potential crop yields by enhancing the nutrient use efficiency (Ogbomo and Eghrevba, 2009; Provez *et al.*, 2009; Rerkasem *et al.*, 2015) and improves the crop growth under saline soil conditions by decreasing the salts accumulation as well as by maintaining the optimum nutrient level in the root zone of plants (Mohamed *et al.*, 2010). Combined foliar spray of macro and micro nutrients significantly improved the plant growth and yield attributes of cotton crop (Pettigrew *et al.*, 2005). Mostly foliar applications of micronutrients are applied, but it can be used for the macro nutrients such as N, P and K, but these nutrients are required by crops in large amounts, therefore foliar applications, two times, fulfill the fertilizer requirements of macro nutrients of crop plants (Abid *et al*., 2016).

Hence, foliar spray application of fertilizers is more target-oriented, cost effective and fertilizer use efficient technique as well as diminish the nutrients and environmental degradation losses. Therefore, present study is planned to determine the effect of foliar spray of potassium and zinc on the plant growth, grain yield, physiological and quality traits of maize under rainfed condition and find out the economics of foliar fertilizers over soil application under rainfed conditions.

Materials and Methods

Experimental

A field experiment was carried out at Maize, Sorghum, Millet and Fodder Program, Crop Sciences Institute (CSI), National Agriculture Research Center, Islamabad, during two different years 2013 and 2014 under rainfed conditions of Pothowar. The experimental area lies in a subtropical, sub humid climatic zone. Soil conditions were alkaline in nature with pH >8.2, with less organic matter (0.5%), extractable soil potassium 65.50 mg kg^{-1} and Zinc < l.4 mg kg^{-1}. This region having latitude 32º 10′ to 34º 9′ N and longitude 71º 10′ to 73º 55′ E. Maize variety Islamabad Gold was grown in this field study. Two ploughings followed by planking was done with tractor mounted cultivator, for seedbed preparation. The field research consisted of treatments viz T_1, Control (K_0Zn_0); T_2, K_0 + RRZn (recommended rate of zinc at soil @ 15 kg Zn_2SO_4 ha^{-1}); T_3, K_0 + FZS (foliar zinc spray @ 0.1%); T_4, RRK (recommended rate of potassium to soil @ 75 kg K_2O ha^{-1}) + Zn_0; T_5, RRK + RRZn; T_6, RRK+ FZS; T_7, FKS (1% foliar K spray) + Zn_0; T_8, FKS + RRZn; T_9, FKS + FZS.

The treatments were assigned to various experimental plots in a randomized complete block design with split-plot arrangement by keeping the treatment of potassium in main plots and zinc in subplots using three replications. Potassium and zinc fertilizer were applied using source of Potassium Sulphate (K_2SO_4) and Zinc Sulphate ($ZnSO_4$) at the rate of 75 and 15 kg ha^{-1} according to research plan. Nitrogen and phosphorus were applied as a source of urea and DAP @ 120 and 90 kg ha^{-1} to all treatments at sowing. The seed rate @ 25 kg ha^{-1} were sown in lines with dibbler by maintaining 75 cm distance between rows and 20 cm between plants, in a net plot size of 4 m × 3 m. Foliar application of potash and zinc was done, twice, at 1% and 0.1% concentration respectively at 25 and 50 DAS by using knapsack sprayer. All other agronomic operations were performed uniformly for all the treatments. Two years data pertaining to plant growth, yield attributes, physiological and quality parameters were recorded for statistical analysis by adapting the following standard procedure.

Data Collection

For days to 50% pollen shedding and silking, dates were noted at 50% completion of pollen shed and silking of each experimental plot and calculated the total number of days taken from sowing.

Plant height, number of grains per ear and 1000 grain weight (g) were recorded from five plants at randomly selected from each experimental plot at maturity, then average was worked out.

For grain yield, after harvesting the maize plants of each experimental plot, sun dried and threshed manually, then grain yield per plot was calculated by following formula:

$$\text{Grain Yield } = \frac{\text{Field weight } \times (100 - \text{Moisture }) \times 0.80 \times 10000}{85 \times 12}$$

For biological yield, whole plant biomass from above ground in each experimental plot was manually harvested, sun dried for few days and weighed then changed into kg ha^{-1}.

Harvest index was calculated by using the following formula:

$$\text{Harvest Index(\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Leaf area $plant^{-1}$ of the five randomly selected maize plants from each plot was calculated manually at tasseling stage by leaf area meter and then average was worked out. Leaf Area Index (LAI) calculated by the formula given below:

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

For photosynthetic and transpiration rate, five flag leaf of maize plants were randomly selected from each treatment separately by using IRGA LC Pro Plus and then average was worked.

Crop growth rate (CGR) was determined by using formula as:

$$CGR = \frac{\mathrm{W2} - \mathrm{W1}}{\mathrm{T2} - \mathrm{T1}}$$

Where:

W_1 = Dry weight m^{-2} at 1st harvest

W_2 = Dry weight m^{-2} at 2nd harvest

T_1 = Time corresponding to 1st harvest

T_2 = Time corresponding to 2nd harvest.

Net assimilation rate (NAR) was calculated by using formula as:

$$NAR = \frac{\mathrm{TDM}}{\mathrm{LAD}}$$

TDM = Total dry matter accumulation LAD = Leaf Area Duration (interval):

$$\mathrm{LAD} = \frac{(\mathrm{LAI\ at T1} + \mathrm{LAI\ at\ T2}) \times (\mathrm{T2} - \mathrm{T1})}{2}$$

Where:

LAI_1 = Leaf area index at t_1

LAI_2 = Leaf area index at t_2.

For grain protein contents, nitrogen contents of maize grain samples were calculated by using Kjeldhal method.

For economic analysis, total cost of production was calculated by expenses of seedbed preparation, seeds cost, sowing, and all agronomic operations. The total income was calculated from grain and straw to determine the benefit cost ratio (Abid *et al*., 2016).

Statistical analysis was done for analysis of variance by using the software Statistix 8.1 and means were compared at 5% probability level by using LSD.

Results

Plant Growth Attributes

Days taken by maize crop to pollen shed are an important parameter indicating crop growth rate and span of vegetative phase. Zinc and potash either by soil or foliar application exhibited significant effect on pollen shed (Table 1). The plants fertilized with FKS + FZnS recorded less number of days (49.33) to reach 50% pollen shed, while there was no significant difference between FKS + RRZn and RRK + FZnS due to timely availability of potassium and high fertilizer use efficiency of maize. The maximum days to 50% pollen shed (57.33) was recorded in the control plots. Data indicated that days to 50% silking were significantly affected by the application of potash and zinc (Table 1). Minimum number of days (53.33) to 50% silking were taken by the maize plants under the integrated foliar spray of zinc and potassium, while non-significant differences exhibited among K_0 + RRZn, RRK + Zn_0 and FKS treatments. However, more number of days to 50% silking (62.0) was recorded in control plots having no potassium and zinc application. Integrated or sole foliar spray along with soil applied fertilizer of potassium and zinc showed significant effect on maize plant height (Table 1). Higher plant height was measured in FKS + FZnS followed by FKS + RRZn and RRK+ FZnS. The shortest plant height was recorded in control plots.

Grain Yield Attributes

Highest number of grains per ear against the treatment i.e., FKS + FZnS followed by FKS + RRZn having number of grains per ear and statistically at par with RRK+ FZS were found (Table 2). The lowest number of grains per ear was recorded in control plots followed by K_0 + RRZn and K_0 + FZS, respectively. There were significant differences in 1000-grain weight of maize among all treatments (Table 2). The plants having foliar spray with FKS+ FZS (T_9) exhibited higher 1000-grains weight (384.67 g), followed by FKS + RRZn (T_8), RRK + FZnS (T_6) and RRK + RRZn (T_5), respectively. There was also linear relationship between 1000 grain weight and maize grain yield (Fig. 1). However, the minimum 1000-grain weight was observed in control. All foliar treatments of potassium and zinc affected the grain yield significantly as compared to control. Maximum grain yield was observed with foliar spray of potassium and zinc (T_9) followed by the dosages of FKS + FZnS and RRK + FZnS. However, the minimum grain yield was recorded in control. Application of potassium and zinc either on soil or foliage showed significant effect on biological yield of maize (Table 2). The maximum biological yield was observed in maize fertilized by potassium and zinc as spray on foliage (T_9) followed by FKS + FZnS, RRK + FZnS and RRK + RRZn, respectively. Highest harvest index was exhibited with the application of FKS + FZnS followed by FKS +RRZn and RRK + FZnS, respectively. Minimum harvest index was calculated for control treatment which was statistically at par with K_0 + RRZn (T_2).

Physiological Attributes

Leaf area per plant was significantly affected by the foliar spray as compared to soil application of potassium and zinc (Table 3). Maximum leaf area per plant was recorded in maize with foliar feeding of potassium and zinc (T_9) and statistically at par with FKS + RRZn (T_8) followed by RRK + FZnS, while the smallest leaf area per plant (1962.3 cm^2) was measured in control plots. Foliar application of potassium and zinc affected leaf area index (LAI) significantly compared to control. Maximum LAI was recorded for foliar applied potassium and zinc (T_9) followed by FKS + RRZn (T_8) and RRK + FZnS (T_6) respectively. However, the minimum leaf area index was shown for control treatment (T_1). Photosynthetic rate showed significant differences among treatments (Table 3). All the treatments had higher photosynthetic rate than control. The maize plants fertilized with foliar potassium at the rate of 1% and foliar zinc at the rate of 0.1% (T_9)

exhibited maximum photosynthetic rate (25.31 μ mol m^{-2} s^{-1}) followed by FKS + RRZn (T_8) and RRK + FZnS (T_6), and RRK + FZnS was statistically at par with RRK + RRZn. However, the minimum photosynthetic rate (14.40 μ mol m^{-2} s^{-1}) was exhibited by control. Transpiration rate of maize was significantly influenced by potassium and zinc fertilization (Table 3). The crop plants fertilized with potassium and zinc as foliar spray (T_9) had the lowest transpiration rate (3.96 m mol m^{-2} s^{-1}). However, the maximum transpiration rate (6.14 m mol m^{-2} s^{-1}) was observed in the control plots (T_1), followed by sole zinc application to soil (T_2) with transpiration rate of 5.95 m mol m^{-2} s^{-1}. All the foliar treatments had significant effects on crop growth rate (CGR) as compared to soil application of potassium and zinc (Table 3). Maximum CGR was attained under FKS + FZnS followed by FKS + RRZn and RRK + FZnS. The lowest CGR was exhibited in control plots. Net assimilation rate (NAR) was significantly affected by foliar application of potassium and zinc as compared to remaining combinations (Table 3). Maximum NAR was observed in maize plants receiving both potassium and zinc fertilizers as foliar spray followed by FKS + RRZn with sole potassium foliar spray. Maize plants devoid of potassium and zinc nutrients

Table 1: Maize growth attributes as influenced by foliar treatments of potassium and zinc (average of two years data)

Treatments	Days to 50% pollen shed (days)	Days to 50% silking (days)	Plant height (cm)
T_1 Control (K_0Zn_0)	57.33 a	62.00 a	193.63 g
T_2 K_0 + RRZn	55.00 b	58.00 b	201.67 f
T_3 K_0 + FZnS	53.67 c	60.00 ab	207.83 e
T_4 RRK + Zn_0	53.00 cd	57.00 b	210.87 de
T_5 RRK + RRZn	52.00 de	55.67 bc	215.23 c
T_6 RRK+ FZnS	51.00 e	55 bc	216.87 bc
T_7 FKS + Zn_0	52.33 d	56.67 b	213.53 cd
T_8 FKS + RRZn	51.00 e	54.92 c	220.50 b
T_9 FKS + FZnS	49.33 f	53.33 d	225.33 a
LSD (0.05)	1.19	1.87	5.01

*Data in each column having similar letters are statistically same
RRZn=recommended rate of zinc; FZnS=foliar zinc spray; RRK=recommended rate of potassium; FKS=foliar potassium spray

Table 2: Maize grain yield and protein contents as influenced by foliar treatments of potassium and zinc (average of two years data)

Treatments	Number of grains ear^{-1}	1000 grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Grain protein contents (%)
T_1 Control (K_0Zn_0)	444.67 f	304.00 g	3319.0 f	9186 f	30.75 d	6.41 h
T_2 K_0 + RRZn	463.97 ef	319.00 f	3537.2 f	10550 e	31.40 d	6.64 g
T_3 K_0 + FZnS	468.74 def	329.33 e	3917.4 e	10633 e	32.00 cd	6.79 fg
T_4 RRK + Zn_0	486.85 de	338.67 de	5072.2 d	10897 de	34.12 bcd	7.01 ef
T_5 RRK + RRZn	535.34 c	346.67 d	5672.5 c	12556 c	35.43 abc	7.60 d
T_6 RRK+ FZnS	578.67 b	357.00 c	5942.9 b	13398 b	36.22 abc	8.04 c
T_7 FKS + Zn_0	505.12 cd	341.33 d	5660.7 c	11631 d	34.31 bcd	7.24 e
T_8 FKS + RRZn	609.96 b	368.33 b	6139.1 ab	13942 ab	38.30 ab	8.35 b
T_9 FKS + FZnS	684.22 a	384.67 a	6327.5 a	14390 a	38.76 a	8.65 a
LSD (0.05)	41.04	9.58	2.18	2.33	2.63	0.25

*Data in each column having similar letters are statistically same
RRZn=recommended rate of zinc; FZnS=foliar zinc spray; RRK=recommended rate of potassium; FKS=foliar potassium spray

Table 3: Maize physiological attributes as influenced by foliar treatments of potassium and zinc (average of two years data)

Treatments	Leaf area $plant^{-1}$ (cm^2)	Leaf area index (%)	Photosynthetic rate (μ mol m^{-2} s^{-1})	Transpiration rate (m mol m^{-2} s^{-1})	Crop growth rate (g m^{-2} day^{-1})	Net assimilation rate (g m^{-2} day^{-1})
T_1 Control (K_0Zn_0)	1962.3 g	13.08 h	14.40 g	6.14 a	12.98 f	6.70 h
T_2 K_0 + RRZn	2293.3 f	18.35 g	16.53 f	5.95 b	15.70 ef	6.82 h
T_3 K_0 + FZnS	2536.2 e	20.29 fg	17.35 ef	5.62 c	17.33 de	6.98 g
T_4 RRK + Zn_0	2600.0 de	21.49 ef	18.00 e	5.39 d	17.95 de	7.18 f
T_5 RRK + RRZn	3108.1 c	27.56 d	20.33 c	4.92 e	22.72 bc	7.35 e
T_6 RRK+ FZnS	3440.6 b	31.60 c	21.18 c	4.56 f	23.69 b	7.53 d
T_7 FKS + Zn_0	2730.8 d	23.42 e	19.21 d	5.14 e	19.65 cd	7.73 c
T_8 FKS + RRZn	3711.9 a	34.65 b	22.24 b	4.38 g	26.11 ab	7.92 b
T_9 FKS + FZnS	3814.3 a	37.80 a	25.31 a	3.96 h	28.14 a	8.16 a
LSD (0.05)	168.35	2.52	0.94	0.24	3.41	2.18

*Data in each column having similar letters are statistically same
RRZn=recommended rate of zinc; FZnS=foliar zinc spray; RRK=recommended rate of potassium; FKS=foliar potassium spray

exhibited smallest NAR and was statistically at par with the treatment where recommended rate of zinc was applied to soil.

Grain Protein Contents

Application of potassium and zinc had significant effects on grain protein contents of maize as compared to control treatment (Table 2). Higher proteins contents of maize grains were noted with foliar feedings of potassium and zinc fertilizers followed by FKS + RRZn and RRK + FZnS treatments. The grains of the plants which were devoid of any fertilization recorded lowest grain protein contents.

Economic Analysis

Economic analysis was carried out in terms of BCR (benefit cost ratio) (Table 4). The maximum BCR (3.80) was recorded in the treatment fertilized with FKS + FZS followed by FKS + RRZn (3.423). Lowest BCR (1.70) was recorded in control plots.

Discussion

This field experiment examined the effect of foliar spray of potassium and zinc on maize grain attributes under rainfed conditions. Present results showed that all foliar sprays of integrated potassium and zinc as well as sole spray treatments showed maximum values for maize growth and yield attributes over soil applied nutrients. The possible reason of foliar nutrients effect on maize may be attributed because of efficient utilization and timely availability of potassium and zinc fertilizers as well as other nutrients (Witold *et al*., 2008; Farooqi *et al*., 2012; Abid *et al*., 2016). Potassium foliar spray to maize crop influenced its shift from vegetative to reproductive phase (Tabri and Akil, 2010; Xu *et al.*, 2015). The early pollen shedding and silking increased grain yield of corn because grain filling period was longer which accelerated the better absorption of nutrients. Days to 50% silking were minimum when potassium applied at foliage stage (Abid *et al*., 2016). Akram *et al*. (2010) reported that zinc application both at soil and foliage led to

Table 4: Maize benefit cost ratio (BCR) as influenced by foliar application of potassium and zinc

Particulars	T1	T2	T3	T4	T5	T6	T7	T8	T9
Urea	9672	9672	9672	9672	9672	9672	9672	9672	9672
DAP	17750	17750	17750	17750	17750	17750	17750	17750	17750
SOP				13200	13200	13200			
SSFK							568	568	568
Zinc Sulfate		3000			3000			3000	
SSFZn			160			160			160
Common cost	26330	26330	26330	26330	26330	26330	26330	26330	26330
Total cost	53752	56752	53912	66952	69952	67112	54320	57320	54480
Grain yield (kg)	3319	3537	3917	5072	5672	5942	5660	6139	6327
Grain yield revenue	99570	106116	117522	152166	170175	178287	169821	184173	189825
Fodder yield (kg)	9186	10550	10633	10897	12556	13398	11631	13942	14390
Fodder yield revenue (Rs.)	45930	52750	53165	54485	62780	66990	58155	69710	71950
Gross income (Rs.)	145500	158866	170687	206651	232955	245277	227976	253883	261775
Net benefit (Rs.)	91748	102114	116775	139699	163003	178165	173656	196563	207295
Benefit cost ratio	1.707	1.799	2.167	2.086	2.330	2.655	3.197	3.423	3.805

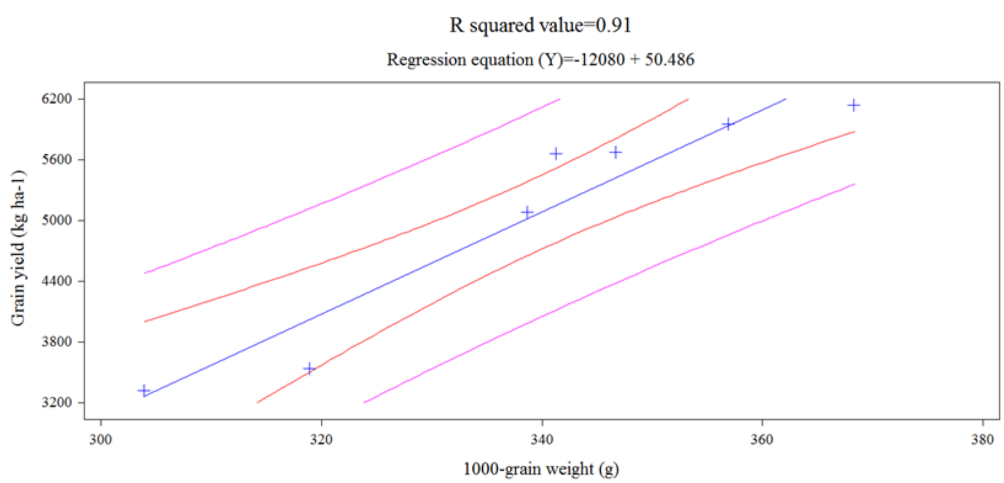

Fig. 1: Relationship between grain yield and 1000 grain weight of maize

an enhancement in plant height of maize. Ghazvineh and Yousefi (2012) concluded that integrated foliar application of potassium and zinc on maize increased the plant height when applied at 4-5 leaf stage. Maximum plant height was attained at higher potash levels might be due to better enzymes activity that leads to easy translocation of photosynthates from leaf to grain (Abid *et al*., 2016).

Number of grains per ear is a vital yield determining factor and had direct influence on grain yield. Potassium and zinc application on foliage will increase the number of grains due to better enzymes activity and leads to easy translocation of assimilates from leaf to grain (Zyayyan, 2007). Maize grain weight was increased by the foliar application of NPK due to increased nutrient use efficiency (Abd *et al*., 2012). Higher grain weight might be due to more availability of potassium and zinc by foliar spray which increases the enzyme activation and result in easily nutrients partitioning from leaf to grain (Grzebisz *et al.*, 2008). Soil application of potassium and zinc increased the grain yield (2.3%) as compared to control, while foliar application of sole zinc @ 1-1.5 kg zinc ha^{-1} in the form of $ZnSO_4$ enhanced grain yield up to 20% (Barlog and Pawlak, 2008; Grzebisz *et al.*, 2008; Maralian, 2009). This might be due to increased activity of growth promoting hormones or the crucial role of potassium in synthesis of carbohydrates, photosynthetic process, nitrogen assimilation and improved tolerance to drought and by the foliar application the more availability and uptake of zinc may enhanced the grain yield (Singh *et al*., 2005; Cakmak, 2008; Grzebisz *et al.*, 2008; Yosefi *et al*., 2011; Iqbal *et al.*, 2014). Farooqi *et al*. (2012) reported that soil and foliar applied potassium led to increment in the biological yield. This enhancement in biological yield is due to the role of potassium in translocation of photosynthates from higher concentration to low concentration (Romheld and Kirkby, 2010). It was observed that harvest index significantly enhanced with the integrated application of potassium on soil and foliage due to better enzyme activity and fertilizer use efficiency (Farooqi *et al*., 2012; Zarmehri *et al*., 2013).

Dewdar and Rady (2013) reported that leaf area per plant increased by the foliar spray of potassium and zinc. They inferred that potassium applied via foliage was more effective than soil applied potassium in relation to leaf area (Thalooth *et al*., 2006). Leaf area index enhanced with increasing the growth period, after reaching the maximum, it stopped to the final harvest of the crop. It was observed that foliar application of potassium and zinc had positive effect on biological activity, metabolism and stimulating the photosynthetic pigments and enzyme activity encouraged the vegetative growth of the plants, consequently increased the leaf area index (Thalooth *et al.,* 2006; Mohamed *et al*., 2010; Jabeen and Ahmad, 2011). Egilla *et al*. (2005) stated that foliar applied potassium @ 250 mg L^{-1} increased the photosynthetic efficiency of crop plants under drought conditions. These findings are in line with (Grzebisz *et al*., 2008; Marschner, 2012) who reported that maximum photosynthetic rate of crop plants were noted against the recommended rate of potassium and zinc as compared to without potassium. This increase in photosynthetic rate is due to increasing the performance of photo-system II by the foliar spray of zinc. Due to drought stress, transpiration rate of the plants were increased and consequently water loss occur. Potassium fertilization either applied on foliage or soil, cope the drought stress and consequently decreases the transpiration rate of crop plants (Zareian *et al.,* 2013). Pedler *et al*. (2000) resulted that zinc application increases the CGR and might be due to the role of zinc in bio-synthesis of tryptophan, a precursor of auxin hormone and mainly responsible for rapid growth rate. Application of potassium and zinc fertilizers either on soil or foliage showed that NAR had a positive linear relationship with potassium fertilizers (Szewczuk *et al*., 2009; Nadim *et al*., 2012).

Grain protein contents linearly increased under the soil as well as foliar spray application of potassium and zinc to crop plants (Farshad and Malakouti, 2000; Morshedi and Farahbakhshb, 2010). This increased grain protein contents might be due to the role of zinc in the synthesis of RNA polymerase enzyme which is involved in transformation of amino acids into protein (Rahman *et al*., 2008; Akhtar *et al*., 2009). Farooqi *et al.*, (2012) concluded that foliar application of potash and other nutrients increased the BCR by increasing the grain yield of the maize due to high fertilizer use efficiency.

Conclusion

Integrated foliar spray of potassium and zinc @ 1% and 0.1%, respectively at 25 and 50 DAS enhanced growth and yield attributes and greater economic returns of maize due to higher fertilizer use efficiency of potassium and zinc as well as other nutrients under rainfed environment. Among soil treatments, recommended dose of potassium and zinc (RRK + RRZn) at 75 and 15 kg ha^{-1} increased the grain yield and protein contents of maize as compared to sole application of potassium and zinc.

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