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INFLUENCE OF FOLIAR APPLICATION OF ZINC ON YIELD OF MAIZE (*Zea mays* L.) UNDER WATER STRESS AT DIFFERENT STAGES

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A field experiment to assess the influence of foliar application of zinc on yield of maize under skipping irrigation was conducted at water management research center, University of Agriculture, Faisalabad during 2014. Experiment comprised of two factors, foliar applied zinc concentrations (control, 0.5%, 1% and 1.5%) and irrigation levels (8 irrigations, 7 irrigations (skip irrigation at eight leaf stage) and 7 irrigations (skip irrigation at tasseling stage)). Experiment was laid out in randomized complete block design under factorial arrangement and repeated thrice. Autumn maize was sown with help of dibbler. All the agronomic practices were kept uniform except the factor under study. The observations were recorded according to standard procedures. Results shown that in foliar applied zinc concentration@ 1% with full recommended irrigationproduced best.
Keywords: Maize, skipping irrigation, Zinc, Foliar application, agronomic practices.

INTRODUCTION

Maize is the 3rd most importance staple crop after wheat and rice in the world. It has various uses such as food for humans and feed for livestock. It is processed as corn flour, snacks, porridges, pastas and bread (Ortiz-Monasterio*et al*., 2007; Menkir, 2008). Maize is 3rd important cereal crop of Pakistan, it produced 4.920 million tones on an area of 11.46 million hectares (Govt., of Pakistan, 2016).

Irrigation is vital factor for growth and development of all crop plants (Hussain *et al*., 2004). Water directly affects all the metabolic processes involved in development and survival of plants. Water frequency and intensity influence the growth and yield (Wajid *et al*., 2004). Agricultural productions in Pakistan are far less than overall world (World Bank, 2006). Maize is sensitive to micronutrient deficiency, particularly zinc; Zn application in Zn deficient soil substantially increased the maize yield (Obrador*et al*., 2003). In Pakistan, farmers only emphasis on application of nitrogen, phosphorus and potash and application of micronutrients is commonly ignored (Alloway *et al*., 2004). In sandy soils, application of zinc as foliar spray significantly improved the yield (Attia *et al*., 2011). Moreover, application of micro and macronutrients improves activation of enzymes, photosynthesis regulation, protein build up and resultantly enhance the overall production (Nguyen *et al*., 2002). Foliar application of zinc is a key factor in biofortification of zinc in maize grain (Grzebisz*et al*, 2008). Nutritional deficiency of plants can be overcome through the application of zinc. Zn application as foliar is equally effective as the soil application in maize (Silberbush, 2002). Application of Zn as foliar alone or with soil combination significantly improved the grain zinc content (Cakmak, 2008). Zinc concentration in grains was greatly increasedas a result of foliar spray (Cakmak*et al*., 2010a). Keeping in view, this experiment was planned to assess the impact of zinc application as foliar on yield of autumn maize under skipping irrigation.

MATERIALS AND METHODS

***Site description*:** The field experiment was carried out at water management research center, University of Agriculture (73° 06′ E, 31° 26′ N and at altitude of 184.4 m), Faisalabad, Punjab, Pakistan during spring season of 2014. Before carrying out the experiment, samples of soil from depth of 0-30 cm were taken from experimental unit with the help of augur. Analysis of soil samples was carried out from Ayub Agricultural Research Institute, is represented in **(**Table 1) which shows the soil properties of site. According to FAO soil classification system (FAO, 2014). Soil of experimental site is Lyallpur soil series and classified as Haplic Yermosol. While, according to USDA soil classification system (USDA, 2014) is an aridisol-fine-silty, mixed, Haplagrid and hyperthermicUstalfic.

***Experimental design and treatments*:** Experiment was designed in Randomized Complete Block design (RCBD) with factorial arrangement and replicated thrice. The net plot size of an experimental plot was 6 m × 1.8 m. This study comprised of 2 factors, foliar application of zinc (control, 0.5%, 1% and 1.5%) and irrigation levels (recommended

irrigation, skipping irrigation at eight leaf stage and skipping irrigation at tasseling stage).

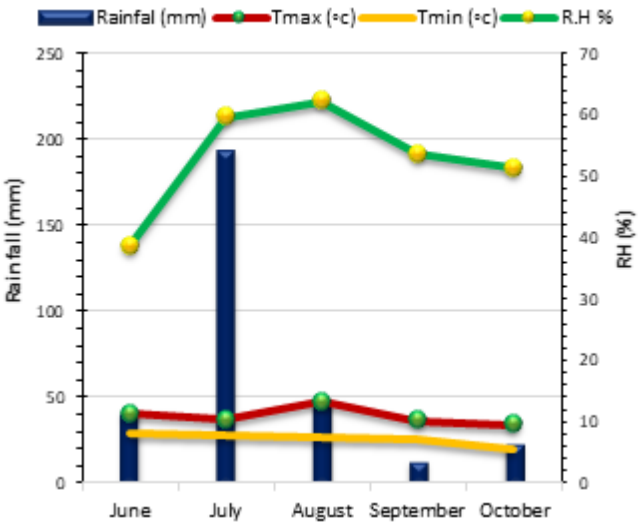

Figure 1: Meteorological data during crop season.

Table 1: Soil analysis of experimental site.

Determination	Unit	Value
Sand	%	64.00
Silt	%	17.60
Clay	%	19.40
EC	dSm^{-1}	1.56
pH		7.90
Organic matter	%	0.89
Total N	%	0.31
Available phosphorous	ppm	5.28
Available K	ppm	187.00

***Crop husbandry*:** Seedbed was prepared after pulverizing the soil with cultivators followed by planking. SNT-6521 hybrid was sown with recommended seed rate of 25 kg ha^{-1} in 3rd week of July. Recommended NPK was applied. Phosphorus and potash were applied at the time of sowing and nitrogen was applied in three splits. All practices were kept uniform except the factors under study.

***Data collection and analysis*:** Data regarding plant height (cm),randomly ten plants from each experimental unit were chosen and averaged, cob length (cm) (ten cobs were taken randomly and averaged their length), number of grains per cob randomly selected five cobs and their grains were counted using grain counter, random sample from produce of each plot were taken for 1000-grain weight (g), the whole plot produce tied in bundle and weighed for biological yield (t ha^{-1}) and threshed grain of each plots were weighed and adjusted 14% moisture for grain yield (t ha^{-1}).

***Statistical analysis*:** Data recorded on all parameters will be statistically analyzed by using Fisher's analysis of variance technique least significantly difference (LSD) test at 5% probability level will be applied to compare the treatment's means (Steel *et al*., 1997).

RESULTS AND DISCUSSION

***Plant height at maturity*:** Foliar application of zinc and irrigation levels significantly affected the plant height, while interaction between zinc application and irrigation levels was found to be non-significant. In zinc concentration levels, foliar applied zinc at 1% considerably increased the plant height and attained maximum height (149.56 cm). Lowest plant height (147.62 cm) was observed in control where no zinc was applied. Highest plant height (149.93 cm) was achieved with full irrigation application, while the lowest (148.02 cm) was observed where irrigation was skipped at tasseling stage. These results advocate the findings of Thalooth, (2006) and Attia *et al*. (2011).

***Number of plants at harvest (m^{-2})*:** Total number of plants of maize was non-significantly affected by irrigation levels and foliar zinc application. The interaction between zinc application and irrigation was also found to be non-significant. In zinc concentrations, maximum number of plants at harvest (6.00 m^{-2}) was recorded in control treatment. Maximum number of plants of maize (5.98 m^{-2}) was observed where full irrigations were applied. Kassab*et al*. (2004) reported that foliar spray of Fe, Mg, Mn and Zn considerably boosted the wheat plant population biological and grain yield. Zinc deficiency leads to reduction in leaf size, internodes and ultimately plant growth.

***Number of grains per cob*:** Foliar application of Zn at different concentrations and irrigation levels significantly affected the number of grains per cob. Interaction between these two factors also found to be significant. In foliar applications of zinc at different concentrations, foliar applied zinc at 1% considerably increased the number of grain per cob and attained maximum (390.33). Lowest number of grains per cob (382.42) was observed in control where no zinc was applied. While, in irrigation levels, highest number of grains per cob (387.80) was achieved with full irrigation application, while the lowest number of grains per cob (382.40) was observed where irrigation was skipped at tasseling stage. The interaction showed that maximum numbers of grains per cob (394.47) were obtained when full irrigations were provided with foliar application of zinc at 1%. These results are in line with the findings of Ali *et al*. (2008) who reported that foliar application of zinc significantly increases the yield and yield contributing parameters.

***Cob length*:** Effect of foliar application of zinc and irrigation levels was found to be non-significant. Interaction between these factors was also non-significant. Foliar application of zinc at 1.5% produced the maximum cob length of maize (16.0 cm), while in control treatment minimum cob length (15.42 cm) was observed. Highest cob length (15.93 cm) was

Table 2: The response of yield and yield components of maize to moisture deficits and nitrogen levels during autumn-2014.

Treatments	Plant height	Number of plants at harvest (m^{-2})	Number of grains per cob	Cob length	1000-grain weight	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index
Zinc								
Zn_0	147.62B	6.00	382.42B	15.42B	237.22D	14.49C	4.45C	30.53C
Zn_1	147.71B	5.93	383.36B	15.58AB	243.00C	14.73B	4.68B	31.01C
Zn_2	150.38A	5.95	390.33A	15.62AB	252.27A	15.67A	5.13A	32.56A
Zn_3	149.56A	5.82	383.33B	16.00A	254.11B	14.58BC	4.49C	31.85B
LSD 5%	1.366	0.240	1.148	0.566	1.754	0.198	0.1670	0.480
Irrigation								
I_1	149.93A	5.98	387.80A	15.93A	249.83A	15.49A	5.15A	33.27A
I_2	148.50B	5.91	384.38B	15.83A	243.66B	14.77B	4.57B	30.94B
I_3	148.02C	5.88	382.40C	15.20B	239.72C	14.34C	4.34C	30.27C
LSD 5%	1.183	0.208	0.994	0.490	1.519	0.172	0.0581	0.416
Interaction								
I_1Zn_0	150.60a	5.93	338.87c	14.66c	251.73b	15.56c	4.99b	32.44bc
I_1Zn_1	148.3ed	6.06	338.80de	15.40abc	244.90c	14.98d	4.77c	31.86cd
I_1Zn_2	150.87ab	6.00	394.47a	15.00bc	262.00a	16.60a	6.10a	36.73a
I_1Zn_3	148.93be	5.93	384.07de	15.73ab	240.67d	14.84de	4.75cd	32.04bcd
I_2Zn_0	148.00cd	6.00	380.87fgh	15.66ab	243.03cd	14.20gh	4.65de	32.78b
I_2Zn_1	146.80cd	5.93	382.67efg	15.60abc	242.97cd	14.20gh	4.16h	29.32f
I_2Zn_2	151.83ab	6.06	390.87b	16.00a	251.67b	15.93b	5.02b	31.55d
I_2Zn_3	146.00d	5.66	383.13e	16.06a	236.97e	14.76def	4.44fg	30.10ef
I_3Zn_0	149.07be	6.06	380.33h	15.93ab	240.57d	14.43fgh	4.40g	30.340e
I_3Zn_1	148.00cd	5.80	380.80gh	15.73ab	241.13d	14.28gh	4.55ef	31.85cd
I_3Zn_2	149.00be	5.80	385.67d	15.86ab	243.13cd	14.50efg	4.26h	29.46f
I_3Zn_3	147.93cd	5.86	382.80ef	16.20a	234.03e	14.14h	4.16h	29.42f
LSD 5%	2.366	0.416	1.989	0.980	3.038	0.344	0.116	0.832

recorded where full irrigation applied; while minimum cob length (14.13 cm) was recorded irrigation was missed at tasseling stage. These results are well advocated with finding of Fecenko and Lozek, (2006).

***1000-grain weight (g)*:** 1000-grain weight of maize significantly influenced by foliar application of zinc and irrigation levels. Interaction between zinc application and irrigation was also significantly affected 1000-grain weight. Maximum test weight (252.25 g) was recorded when foliar application of zinc was done at the rate of 1%. Minimum 1000-grain weight (237.22 g) was observed in control treatment when there was no zinc applied. Likewise, highest 1000-grain weight was recorded where recommended irrigations applied, minimum test weight (239.72 g) was obtained when irrigation was skipped at tasseling stage. Interaction showed that maximum 1000-grain weight (262.0 g) was obtained when full irrigations were provided with foliar application of zinc at 1%. The findings are strongly supported by Ali *et al*., (2008).

***Biological yield (t ha^{-1})*:** Foliar application of zinc and irrigation levels significantly affected the biological yield. Maximum biological yield (15.67 t ha^{-1}) was recorded when foliar application of zinc was done at the rate of 1%. Minimum biological yield (14.49 t ha^{-1}) was observed in control treatment when there was no zinc applied. Likewise, highest biological yield was recorded where recommended irrigations applied, minimum biological yield (15.49 t ha^{-1}) was obtained when irrigation was skipped at tasseling stage. Interaction showed that maximum biological yield (16.60 t ha^{-1}) was obtained when full irrigations were provided with foliar application of zinc at 1%. These results favored the findings of Welch, (2003), who reported that micronutrients application gave highest biomass as well grain yield. Similar finding were reported by Lana *et al*. (2007).

***Grain yield (t ha^{-1})*:** Foliar application of Zn at different concentrations and irrigation levels significantly affected grain yield. Interaction between these two factors also found to be significant. In foliar applications of zinc at different concentrations, foliar applied zinc at 1% considerably increased grain yield and attained maximum (5.13t ha^{-1}). Lowest grain yield (4.45t ha^{-1}) was observed in control where no zinc was applied. While, in irrigation levels, grain yield (5.15t ha^{-1}) was achieved with full irrigation application, while the lowest grain yield (4.34t ha^{-1}) was observed where irrigation was skipped at tasseling stage. The interaction showed that maximum grain yield (6.10t ha^{-1}) was obtained when full irrigations were provided with foliar application of zinc at 1%. While minimum grain yield (4.16t ha^{-1}) was recorded when concentration of zinc at rate of 1.5% applied with skipping irrigation at tasseling stage. These results are in

conformity with the findings of Welch, (2003) and Ali *et al*., (2008), who reported that foliar application of zinc significantly increases the yield and yield contributing parameters.

***Harvest index (%)*:** Foliar application of zinc and different levels of irrigation significantly affect the harvest index of maize. The interaction between foliar applied zinc concentrations and irrigations was also significant. Maximum harvest index (32.56%) was recorded when foliar application of zinc was done at the rate of 1%. Minimum harvest index (30.57%) was observed in control treatment when there was no zinc applied. Likewise, highest harvest index (33.27%) was recorded where recommended irrigations applied, minimum harvest index (30.27%) was obtained when irrigation was skipped at tasseling stage. Interaction showed that maximum harvest index (36.73%) was obtained when full irrigations were provided with foliar application of zinc at 1%. while the minimum value of harvest index (29.42%) was recorded in that treatment where concentration of foliar zinc at 1.5% applied with skipping irrigation at tasseling stage. These finding are in line with Sarkar *et al*. (2007) who reported that application of zinc significantly improve the yield attributes. In crux, foliar application of zinc @ 1% with recommended full irrigations increase the maize yield and yield contributing parameters.

***Conclusion*:** Maize growth and yield are adversely affected under nutrients stress conductions. Foliar application of zinc as sole or in combination improves growth, increase yield and yield components of maize under moisture stress condition, because foliar application of zinc provides the essential nutrients to the plants under dryland condition. However, the benefits of foliar, therefore, should be demonstrated to the growers under dryland condition.

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