# INFLUENCE OF ZINC UNDER DEFICIT IRRIGATION ON GROWTH AND PRODUCTIVITY OF HYBRID MAIZE

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**ABSTRACT:** Zinc (Zn) is an integral part of many enzymes and proteins required by plants for different physiological functions. The field study was conducted to determine the influence of zinc on growth and yield of maize hybrid under skipping irrigations at different growth stages. The experiment comprised of two factors, irrigation treatment viz regular irrigation system (8 irrigations, control) and skip irrigation at knee high and tasseling stages and Zn application treatments i.e. non-Zn application as control, soil application @ 9, 18 and 27 kg ha$^{-1}$. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement having three replications. The results showed that application of zinc @ 27 kg ha$^{-1}$ gave maximum leaf area index (5.16), crop growth rate (20.26 g m$^{-2}$ day$^{-1}$), 1000-grain weight (255.03 g), grain yield (5.64 t ha$^{-1}$) and harvest index (34.5%) than lower doses of zinc and minimum was recorded for control treatment. Similarly, for skipping irrigations, maximum improvement in growth and yield was observed with full irrigations, while irrigation skipped at tasseling stage negatively influenced the growth and yield of hybrid maize than at knee height stage. In conclusion, soil applied zinc at 27 kg ha$^{-1}$ and normal irrigations helped in improving the growth and yield of autumn planted maize.

**Key words:** Maize, Zinc, Water deficit, Growth and Yield.

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## INTRODUCTION

Maize being a multipurpose crop is used for human food and animal feed (Hunje *et al.,* 2011). In Pakistan, maize crop is cultivated on an area of 1144 thousand hectares, with total production of 4.301 tons per hectares (Government of Pakistan, 2016). Water has a crucial role in growth and final productivity of plants affecting all the metabolic processes (Wajid *et al.,* 2004). Conversely, the water deficiency, considerably reduce crop growth and productivity (Hussain *et al.,* 2004) and also results in substantial changes in different physiological and metabolic processes within the plant body (Jeshni *et al*., 2017). Similarly, water deficit conditions reduce seed germination, root and shoot growth and crop yield (Khakshu *et al*., 2011).

Zinc nutrition is crucial for plants growth and development as it plays a significant role in different plant physiological functions like synthesis of proteins, auxins and in energy protein synthesis (Hansch and Mendel, 2009). Moreover, zinc activates various enzymes for optimum photosynthesis, membrane integrity, and biomass production (Cakmak, 2000). Maize crop, substantially, demands micronutrients (particularly zinc) along with the macronutrients. Gupta *et al.* (2006) reported that, zinc deficiency substantially reduced the growth and productivity of maize. Moreover, Alloway, (2004) reported that zinc deficiency substantially reduced the maize crop yield up to 40% without any visible symptoms on plant leaves. High cost of zinc fertilizer and its unavailability at proper time with limited irrigation water resources not only affect the yield of maize but also raise contradict concerns in recommendation of the best level of zinc application in maize.

Zinc nutrition substantially influences the plant's drought sensitivity in different ways. Like, zinc plays a crucial role in detoxifying reactive oxygen species (ROS), and declines free radical production (Cakmak, 2000). The optimum availability of zinc protects the plants from photoxidative damage occurred due to ROS production (Wang and Jin, 2005). It is, therefore necessary to apply zinc with nitrogen, phosphorus and potassium fertilizers to reduce zinc deficiency as soils getting zinc deficient due to intensive agricultural practices. In Pakistan farmers pay attention to nitrogenous and phosphorous fertilizers and no attention to micronutrients applications especially zinc (FAO, 2004). Therefore, present study was planned to investigate the effect of soil zinc application under normal and skip irrigation at knee height and tasseling stages on growth and yield of hybrid maize.

## MATERIALS AND METHODS

**Experimental design:** The experiment was carried out at Student Research Farm, Department of Agronomy, University of Agriculture, Faisalabad, Pakistan, during autumn, 2015.

Composite soil samples were collected from the top (0–30 cm) soil layer of the experimental site prior to sowing. Samples were analyzed using the protocols described by Homer and Pratt (1961). The soil was sandy clay loam having organic matter 0.88%, pH 8.21, Electric Conductivity (EC) 0.36 dS $m^{-1}$ and Nitrogen, Phosphorus, Potash and Zinc contents were 0.07%, 4.9 mg $kg^{-1}$, 162 mg $kg^{-1}$, and 0.59 mg $kg^{-1}$respectively.

The study was conducted in randomized complete block design in split plot arrangement with three replicates. There were four Zn treatments viz. non-Zn application as control, soil application @ 9, 18 and 27 kg $ha^{-1}$. $ZnSO_4$. $7H_2O$ was used as zinc source and respective zinc application was made at sowing time. Regarding irrigations, there were three levels, recommended eight irrigations as control, seven irrigations with one skip irrigation at knee-high stage and 7 irrigations with one skip irrigation at tasseling stage.

**Crop husbandry:** Seedbed for sowing was prepared by using cultivator followed by planking. Crop was sown in the 1$^{st}$ week of August, 2015 using dibbling method. Seed of DK-6789 was used at the rate of 30 kg $ha^{-1}$ and NPK fertilizers were applied @ 250-115-125 kg $ha^{-1}$in the form of urea, single super phosphate and sulphate of potash respectively. All the dosages of phosphors (P) and potash (K) and one third of nitrogen (N) were applied at sowing, while the rest of N was used in three splits. All the agronomic practices were uniform apart from those under study.

**Data recording:** The leaf area index (LAI), crop growth rate (CGR) and net assimilations rate (NAR) were determined by standard procedures Watson (1947) and Hunt (1978) post 30, 60 and 90 days after sowing and the later on the average was calculated. For plant population at the time of harvesting the plants in one square meter area were counted. Fifteen plants were taken randomly from each treatment for determination of plan height, cob length, cob diameter, rows per cob, grains per cob, and grains rows per cob. Meanwhile crop was harvested and sun dried. The total weight of cobs and stalk was measured for determination of biological yield. Grain yield of each plot was calculated and later converted to hectare basis. Similarly, a sub sample of 1000-grains was taken to determine the 1000-grain weight.

**Statistical analysis:** Collected data was analyzed by Fisher's analysis technique, and difference among the treatments compared by honestly significant difference (HSD) test at 0.05 probability level (Steel *et al*., 1997).

## RESULTS

Different levels of soils applied zinc and skip irrigation considerably influenced the growth and agronomic attributes of autumn planted maize. The results showed that, zinc application considerably improved the leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) after 60 days of sowing (DAS) (Table-1). The maximum LAI (5.16), CGR (20.26 g $m^{-2}$ $day^{-1}$) and NAR (6.04) was observed where zinc was applied 27 kg $ha^{-1}$, while the minimum LAI (4.81), CGR (15.24 g $m^{-2}$ $day^{-1}$) and NAR (5.08) was documented in control treatment. Regarding skip irrigation maximum LAI (5.09), CGR (18.10 g $m^{-2}$ $day^{-1}$) and NAR (5.75 g $m^{-2}$ $day^{-1}$) was recorded at 60 DAS with full irrigation whereas, minimum LAI (4.93), CGR (15.64 g $m^{-2}$ $day^{-1}$) and NAR (5.39 g $m^{-2}$ $day^{-1}$) was recorded where irrigation was skipped at tasseling stage. The interactive effect of zinc and irrigation levels for these parameters was found non-significant ($p \leq 0.05$).

At all Zn levels various irrigation regimes showed significant behavior for all yield relating attributes except plant population ($m^{-2}$) and grain rows per cob. However, regarding cob length only Zn levels showed non-significant behavior (Table-2). The maximum plant height (231.9 cm), grains count per cob (483.67), 1000-grains weight (255.03 g), grain yield (5.64 t $ha^{-1}$), biological yield (17.32 t $ha^{-1}$) and harvest index (34.50%) was observed where zinc was used @ 27 kg $ha^{-1}$. The minimum plant height (201.9 cm), number of grains per cob (373.00), 1000-grains weight (238.22 g), grain yield (4.59 t $ha^{-1}$), biological yield (15.49 t $ha^{-1}$) and harvest index (29.59%) were documented in control treatment without zinc. Regarding irrigation levels tallest plants (223.0 cm), maximum grains per cob (453.48), cob length (19.70 cm), 1000-grains weight (250.15 g), grain yield (5.54 t $ha^{-1}$), biological yield (16.85 t $ha^{-1}$) and harvest index (32.78%) were observed where full irrigations was applied while minimum plant height (209.0 cm), number of grains per cob (395.98), cob length (19.05 cm), 1000-grains weight (241.95 g), grain yield (4.73 t $ha^{-1}$), biological yield (16.12 t $ha^{-1}$) and harvest index (30.82%) were observed where irrigation was skipped tasseling stage. The interactive effect of irrigations and zinc levels was found non-significant for all the growth and yield attributes (Table-2).

**Table 1. Influence of different levels of soil applied zinc and skip irrigation on growth attributes of maize**

| Factors | Growth attributes | | | |
|---|---|---|---|---|
| | Plant height (cm) | Leaf area index | Crop Growth Rate (g $m^{-2}$ $day^{-1}$) | Net Assimilation Rate (g $m^{-2}$ $day^{-1}$) |
| **Zinc levels (Zn)** | | | | |
| Control | 201.9 $^{C}$ | 4.81 $^{C}$ | 15.24 $^{C}$ | 5.08 $^{D}$ |
| 9 Kg $ha^{-1}$ | 210.6 $^{BC}$ | 5.00 $^{B}$ | 15.12 $^{C}$ | 5.44 $^{C}$ |
| 18 Kg $ha^{-1}$ | 218.9 $^{B}$ | 5.10 $^{A}$ | 16.88 $^{B}$ | 5.72 $^{B}$ |
| 27 Kg $ha^{-1}$ | 231.9 $^{A}$ | 5.16 $^{A}$ | 20.26 $^{A}$ | 6.04 $^{A}$ |
| **Irrigation Levels (I)** | | | | |
| $I_0$ Control (8 Irrigations) | 223.0 $^{A}$ | 5.09 $^{A}$ | 18.10 $^{A}$ | 5.75 $^{A}$ |
| $I_1$ (7 Irrigations)$^{*}$ | 215.5 $^{B}$ | 5.03 $^{B}$ | 16.89 $^{B}$ | 5.56 $^{B}$ |
| $I_2$ (7 Irrigations)$^{**}$ | 209.0 $^{C}$ | 4.93 $^{C}$ | 15.64 $^{C}$ | 5.39 $^{C}$ |
| HSD (Zn) ($p \leq 0.05$) | 9.55 | 0.09 | 0.83 | 0.14 |
| HSD (I) ($p \leq 0.05$) | 5.62 | 0.05 | 0.03 | 0.07 |
| Zn×I ($p \leq 0.05$) | NS | NS | NS | NS |

$^{*}$Skip one irrigation at knee high stage; $^{**}$Skip one irrigation at tasseling stage
Any two means within a column followed by same letters are not significant at $p \leq 0.05$. n = 3. NS = non-significant

**Table 2. Influence of different levels of soil applied zinc and skip irrigation on yield and yield related attributes of maize.**

| Factors | Yield attributes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | NOP ($m^{-2}$) | NGPC (cm) | NGRPC | CL (cm) | 1000-GW (g) | GY (t $ha^{-1}$) | BY (t $ha^{-1}$) | HI (%) |
| **Zinc levels (Zn)** | | | | | | | | |
| Control | 5.86 | 373.00 $^{D}$ | 13.98 | 19.39 | 238.22 $^{D}$ | 4.59 $^{D}$ | 15.49 $^{D}$ | 29.59 $^{D}$ |
| 9 Kg $ha^{-1}$ | 5.89 | 407.45 $^{C}$ | 14.05 | 19.43 | 242.61 $^{C}$ | 5.01 $^{C}$ | 16.22 $^{C}$ | 30.87 $^{C}$ |
| 18 Kg $ha^{-1}$ | 5.87 | 443.79 $^{B}$ | 14.08 | 19.46 | 247.18 $^{B}$ | 5.43 $^{B}$ | 16.85 $^{B}$ | 32.26 $^{B}$ |
| 27 Kg $ha^{-1}$ | 5.96 | 483.67 $^{A}$ | 14.18 | 19.52 | 255.03 $^{A}$ | 5.64 $^{A}$ | 17.32 $^{A}$ | 34.50 $^{A}$ |
| **Irrigation Levels (I)** | | | | | | | | |
| $I_0$ Control (8 Irrigations) | 6.04 | 453.48 $^{A}$ | 14.21 | 19.70 $^{A}$ | 250.15 $^{A}$ | 5.54 $^{A}$ | 16.85 $^{A}$ | 32.78 $^{A}$ |
| $I_1$ (7 Irrigations)$^{*}$ | 5.93 | 431.48 $^{B}$ | 14.08 | 19.59 $^{B}$ | 245.18 $^{B}$ | 5.24 $^{B}$ | 16.44 $^{B}$ | 31.82 $^{B}$ |
| $I_2$ (7 Irrigations)$^{**}$ | 5.71 | 395.98 $^{C}$ | 13.92 | 19.05 $^{C}$ | 241.95 $^{C}$ | 4.73 $^{C}$ | 16.12 $^{C}$ | 30.82 $^{C}$ |
| HSD (Zn) ($p \leq 0.05$) | NS | 6.76 | NS | NS | 3.02 | 0.09 | 0.18 | 0.65 |
| HSD (I) ($p \leq 0.05$) | NS | 6.69 | NS | 0.11 | 1.92 | 0.09 | 0.25 | 0.74 |
| Zn×I ($p \leq 0.05$) | NS | NS | NS | NS | NS | NS | NS | NS |

$^{*}$Skip one irrigation at knee high stage; $^{**}$Skip one irrigation at tasseling stage
PH = Plant height; NOP = Number of plants; NOGPC = Number of grain per cob; NGRPC = Number of grains rows per cob; CL = Cob length; 1000-GW = 1000 grains weight; GY = Grain yield; BY = Biological yield; HI = Harvest index
Any two means within a column followed by same letters are not significant at $p \leq 0.05$. n = 3. NS = non-significant

## DISCUSSION

Present study was conducted to determine influence of soil applied zinc under normal and skip irrigation on growth and productivity of hybrid maize. The optimum availability of water is the foremost factor that substantially affects the growth and productivity of hybrid maize (Hammad *et al.,* 2009). Similarly, Zn an important micronutrient required for growth and developments of plants mainly because of its role in different physiological processes (Hafeez *et al.,* 2013).

The results revealed that application of zinc and various skip irrigation treatments appreciably improved the growth and yield characters of maize hybrid. Zinc application significantly improved LAI, CGR and NAR of autumn planted maize as compared to deficit irrigation (skipping irrigation at tasseling stage). The increase in leaf area index with applied zinc is in consistence with previous results of Khan *et al.* (2009) who found use of zinc considerably enhanced the chlorophyll contents, photosynthetic rates, which led to better growth and leaf area index. Similarly, Niaz *et al.* (2009) found that application of zinc increased the intercellular $CO_2$ concentration that improved the photosynthetic rates and ultimately the crop growth and yield. Moreover, in this study, no zinc application showed significantly lesser

LAI, CGR, and NAR. This may be due to less leaf area, less fixation of carbon dioxide, and destruction of photosynthetic machine due to zinc deficiency. These findings are supported with previous results of Castrillo (2001) who found substantial decrease in LAI, CGR, and NAR under zinc deficient conditions.

The results revealed that the use of zinc @ 27 kg $ha^{-1}$ produced maximum 1000-grain weight, grain yield, biological yield and harvest index of autumn planted maize hybrid. These results are line with findings of Omidbeygi *et al*. (2006) who described that use of Zn fertilization not only increased essential oil contents but it also improved the absorption of phosphorus and nitrogen by the roots which resulted in better growth and development of the maize in terms of better yield and yield attributes.

Results of present study showed that the un-stressed plants (full irrigations) performed better in terms of growth and yield than the plants grown under stressed condition (skip irrigation either at knee height or tasseling stage). Rotundo *et al*. (2006) found that water deficiency, decreased the chlorophyll contents, LAI and photosynthetic rate that results in poor grain size and grain yield. Moreover, the results of present study revealed that, skipping irrigation at tasseling and knee height stage significantly decreased leaf area index, crop growth rate, 1000-grain weight, grain yield and harvest index of hybrid maize than normal irrigation treatment. These findings are in consistence with previous results of Smith *et al.* (2002) who found that skipping irrigation at vegetative or reproductive stages substantially, reduced the growth and productivity of maize crop. Similarly, Sajedi *et al*. (2009) reported that water shortage at any growth stage notably, reduced the growth and productivity of maize crop. Pandey *et al.* (2000) found a substantial reduction in grain yield with the skip irrigations imposed to crop at different growth stages. They found a considerable decrease of 6.6 and 11.1% in grain yield with irrigation skipped at vegetative stage, and a decrease of 22.6 and 26.5% in grain yield with irrigation skipped at vegetative and reproductive stage. Moreover, Costa and Shanmugathasan, (2002) reported that critical crop growth stage is difficult to determine and water stress at any stage considerably decreased the dry mass production and grain yield.

**Conclusion:** Soil applied zinc at the rate of 27 kg per hectare appreciably improved the growth and yield of hybrid maize. Moreover, the normal irrigation had more productivity of maize than skip irrigation treatments. It is also observed that the skip irrigation at tasseling stage (reproductive) had more pronounced negative effective on both growth and yield than skipping at knee height stage (vegetative) of maize crop.

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