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Research Article

Effects of Foliar Spraying on the Quantitative and Qualitative Characteristics of Grain Maize (*Zea mays* L.)

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Abstract

Objective: This study aims to investigate single and combined fertilizer on the quantitative and qualitative characteristics of grain corn.

Methods: The experiment design was randomized complete block at Urmia Research Station. The first factor of zinc element had four levels (0, 0.7, 1.4 and 2.1kg.ha^{-1}) and the second factor of zinc element had four levels (0, 0.3, 0.6 and 0.9kg.ha^{-1}).

Results: The effects of zinc and iron factors for the traits of stem diameter, leaf area index, thousand seed weight, number of seeds in each ear row, amount of zinc and iron in the seed, protein content and yield and seed yield showed statistically significant differences.

Conclusion: According to the obtained results and the increase in yield, it is recommended to use micronutrient fertilizers in corn fields, especially soluble Boron and zinc fertilizers in the two stages of rapid plant growth and before the appearance of crown flowers.

Keywords: corn, boron, Zn, seed yield, foliar spraying

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1 INTRODUCTION

Maize (*Zea mays L.*) is a kind of strategic crop and the third most important grain in the world after wheat and rice, which is cultivated for livestock feed, raw materials for factories and human consumption[1]. The agricultural soils of Iran are poor in organic matter and calcareous for being in all arid and semi-arid regions. In this situation, the imbalance of nutrients in the soil harms the growth and development of plants. In order to grow optimally and increase the yield and quality of the product, micronutrient elements, especially zinc and boron, should be applied in the form of foliar spraying in corn fields[2]. Micronutrient elements play an active role in the metabolic cycle of the corn plant, such as the formation and development of the cell wall of the leaves, which are directly involved in photosynthesis and transpiration. Also, they increase activities such as nitrogen fixation, enzyme activity and supply of nutrients to plant tissues[3]. Zinc is an element that corrects soil pH and increases soil organic matter. Increasing the amount of zinc improves the quality and quantity of the products[4]. Among fertilizers, zinc plays a very important role in stomatal regulation and ion balance in plant systems. Zinc reduces the effects of stresses and especially moisture stress in plants[5]. As a result of consuming zinc fertilizer and absorbing the appropriate amount of this element by the plant through the synthesis of auxin hormone, the dry matter in the plant increases. This is due to the increased regulation of stomata and chlorophyll, increased activity of enol pyruvate carboxylase and biphosphate carboxylase, and decrease in sodium concentration and accumulation in plant tissue. Under the condition of proper consumption of zinc elements, the efficiency and absorption of nitrogen and phosphorus in the plant also increase[6]. The use of zinc, magnesium, boron and copper elements in agricultural soils increases corn production. In addition to solving the lack of zinc in the soil, increasing zinc in the soil also has a positive effect on plant growth, quantity and quality of the products[7]. The lack of boron is widely seen in agricultural lands around the world, which has led to a decrease in the yield and quality of agricultural products[8]. The purpose of this research is to investigate the effects of foliar application of zinc and boron on the quantitative and qualitative characteristics of grain corn.

2 MATERIALS AND METHODS

2.1 Study Site

This experiment was conducted under the conditions of the second crop after wheat harvest in the agricultural station of Urmia city with 45˚ 52' E, 34˚ 34' N, 550m asl. Based on the results of the soil test, the tested land was lacking in zinc and iron micronutrients (Table 1).

2.2 Experiment Design

In order to investigate the effects of double foliar spraying of Boron and Zn elements (at the 7-8 leaf stage and before the emergence of the corolla) on the quantitative and qualitative characteristics of seed corn variety KSC 704, this experiment was conducted in a randomized complete block design with three replications. The first factor was zinc element at four levels (0, 0.7, 1.4 and 2.1kg.ha^{-1}) and the second factor was boron element at four levels (0, 0.3, 0.6 and 0.9kg.ha^{-1}).

2.3 Measurement of Parameters

The measurement of agricultural traits and yield components included stem diameter, leaf area index (LAI), thousand seed weight, and number of seeds in a cob row, were done on 10 plants randomly selected from the middle lines of each experimental plot. To evaluate the leaf area meter index, the leaf area meter model (CI202, made by CID in the United States of America), was used in six stages with an interval of 15 days between 30 and 105 days after planting, LAI was calculated using Watson's method[9]. To estimate the grain yield, an area of six square meters was taken from each experimental plot by removing the side lines and borders[10]. Seed protein percentage was measured based on the Kjeldahl method provided by Kenkel[11] in 1994. The concentration of Boron and zinc nutrients were measured respectively by flame atomic absorption or flame photometry with Atomic Absorption Spectroscopy model Analyst 700 and Azometin method[12].

2.4 Statistical Analysis

The obtained data were analyzed using minitab 14 software and the averages were compared using Duncan's test at the five percent probability level.

3 RESULTS AND DISCUSSION

3.1 Variance Analysis of Measurement Attributes

With the increase in the consumption of zinc element, stem diameter, LAI, number of seeds in each ear row, weight of 1000 seeds, amount of zinc and iron in seeds, protein percentage and seed yield all increased. Analysis of the variance of the measured traits showed the effects of Boron and zinc treatment for the traits of stem diameter, leaf surface index, thousand seed weight, number of seeds in a row, Boron and zinc content in corn seeds, seed protein percentage, protein yield and yield. The seed had a significant difference at the probability level of one percent, which the cob diameter trait was significant at the probability level of five percent. The interaction of these factors was significant for the traits of weight of 1000 seeds, number of seeds in a row, traits of concentration in seed, yield of seed protein and yield of seed at the probability level of one percent, and for index trait of leaf area, concentration of zinc in seed and percentage of seed protein in surface at the probability of five percent (Table 2).

The comparison of the average treatments showed that with the increase in the consumption of zinc elements, the stem diameter and grain yield increased. The highest stem diameter and seed yield (28.69mm and 9.560t.ha^{-1}) were obtained in plot with zinc fertilizer treatments at the level of 1.2kg.ha^{-1} than the control plot 25.58mm and 8.00t.ha^{-1}). It can be concluded that the consumption of zinc in the corn field is necessary like any other high-use elements. It was also found that, according to the conditions in this experiment, the corn field's need for zinc solution was more than the amount used from the highest level of zinc consumption (1.2L.ha^{-1}) in this study. It should be remembered that zinc element alone does not cause all these effects on the quantitative and qualitative characteristics of seeds, but

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Table 1. Chemical Properties ofX Farm Soil

Parameters	Soil Sampling Depth	
	0-30cm	31-60cm
pH	7.5	7.5
Electrical conductivity (ds.m^{-1})	0.5	0.75
Organic carbon (%)	0.45	0.92
(Fe) (mg.kg^{-1})	10.2	8.8
(K) (mg.kg^{-1})	268	320
(P) (mg.kg^{-1})	5.5	9
B (mg.kg^{-1})	3.9	4.2
Zn (mg.kg^{-1})	0.75	0.94
Cu (mg.kg^{-1})	8	8.2
Mn (mg.kg^{-1})	12.2	13.1

Table 2. Analysis of Variance of Yield and Yield Components for Effect of Zinc and Boron Spray

S.O.V	df	Seed P	(B Con)	(Zn Con)	KR	TKW	LAI	SDT	PYLD	YLD
Replication	2	0.2^{ns}	0.02^{ns}	0.001^{ns}	0.02^{ns}	0.03^{ns}	0.01^{ns}	0.88^{ns}	0.16^{ns}	0.001^{ns}
Zinc	3	9.24^{**}	10.62^{**}	0.28^{**}	122.1^{**}	110.1^{**}	1.03^{**}	32.44^{**}	146.2^{**}	5.00^{**}
Boron	3	45.47^{**}	3.25^{**}	0.15^{**}	102.1^{**}	105.1^{**}	0.93^{**}	16.3^{**}	51.88^{**}	5.82^{**}
Boron×Zn	9	1.42^{**}	0.41^{*}	0.02^{*}	9.54^{**}	9.50^{**}	0.08^{*}	1.42^{ns}	0.93^{*}	0.5^{ns}
Error	30	0.29	0.12	0.002	2.31	2.21	0.03	1.32	0.38	0.51
CV%		5.51	3.47	5.25	3.95	5.6	4.66	4.29	2.22	8.26

Notes: ns, * and **, non-significant and significant at 5% and 1% probability levels, respectively. Seed P=Seed protein content, B Con=Boron concentration, Zn Con=Zinc concentration, KR=Kernel per Row, TKW=Thousand Kernel Weight, LAI=Leaf area index, STD=Stem Diameter, PYLD=Protein Yield, YLD=Grain Yield.

in the presence of this element, the plant will be able to absorb other elements easily[13]. In this regard, Dornescu et al.[14] showed that the use of zinc by spraying with suitable concentrations increased the yield by 13-19% in wheat, 14-25% in corn and 30-50% in sunflower. Zinc element is one of the most important elements needed by enzymes functioning in the metabolism of carbohydrates, increasing the amount of growth regulators and helping in the metabolism of substances, affecting electron transfer reactions in the Krebs cycle, participating in the cell division of tissues. Meristem and metabolism of hydrocarbon materials, protein and their transport have an important role in reproductive processes, weight and increasing yield and seed quality[15]. The treatment of 0.6kg.ha^{-1} of fertilizer consumption had the greatest effect on the measured traits (stem diameter with 28.09mm and seed yield with 9.43t.ha^{-1}) compared to other levels under investigation. The effect of this level of fertilizer on the yield of corn compared to the control treatment showed an increase in yield by 8.46t.ha^{-1}, about one ton per hectare. By increasing the use of fertilizer (0.9kg.ha^{-1}), the amount of traits under investigation decreased. Therefore, the optimal limit of water consumption in corn fields is around 0.5 to 0.6L.ha^{-1}. The above results were consistent with the results of other researchers. Mahler[16] reported that lead was one of the essential elements in the corn plant. On the other hand, lead above the required concentration in the plant could cause poisoning and reduce the amount of corn fertility. In another report, it was stated that the deficiency or excess of elements in the corn plant disrupted the absorption of zinc, iron, copper and magnesium[17]. The interaction treatments of B and zinc, especially the treatment of 1.2 zinc fertilizer×0.6kg.ha^{-1} of fertilizer was superior to other treatments in terms of the traits of stem diameter, leaf area, number seeds in the row, amount of zinc and iron in corn seeds, seed protein percentage, protein yield and seed yield equal to 29.68mm, 4.5, 47.5cm, 34.8 and 9.07mg.kg^{-1} was 11.81%, 1.28t.ha^{-1} and 10.93t.ha^{-1}. The lowest value obtained for the aforementioned traits, including seed yield, was 7.6t.ha^{-1} which was assigned to the treatment without the use of zinc fertilizer×0.9kg.ha^{-1} of fertilizer (Table 3). According to the interaction treatments of zinc, especially the treatment of 1.2 zinc fertilizer×0.6kg.ha^{-1}, it was observed that the deficiencies in the corn plant were eliminated and the yield increased[18]. Plant growth is influenced by that food element for which the plant has a limit, so if a plant grows in favorable conditions in terms of one or more low-consumed elements. If it is limited, the use of high nitrogen, phosphorus and

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Table 3. Mean Comparison Yield and Yield Components for Effects of Zinc and Boron Spray

(YLD) (t.ha^{-1})	PYLD (t.ha^{-1})	Seed P (%)	B Con (mg.kg^{-1})	Zn Con (mg.kg^{-1})	(KR)	(TKW) (gr)	(LAI)	(STD) (mm)	(Treat) (kg.ha^{-1})
7.87^{g-i}	0.70^{h-j}	8.87^{gh}	7.20^{hi}	24.60^{h}	32.2^{g-i}	264.2^{g-i}	3.23^{gh}	25.28^{e}	$Zn_1×B_1$
8.10^{e-i}	0.72^{h-j}	8.92^{gh}	10.27^{cd}	25.3^{gh}	35.2^{e-i}	265.2^{e-i}	3.37^{f-h}	25.75^{e}	$Zn_1×B_2$
8.46^{e-g}	0.76^{g-i}	9.06^{fg}	11.47^{b}	25.73^{g}	36.8^{e-g}	266.8^{e-g}	3.50^{e-g}	26.31^{de}	$Zn_1×B_3$
7.60^{i}	0.65^{j}	9.56^{i}	13.17^{a}	21.80^{i}	33.1^{i}	263.1^{i}	3.13^{h}	25.00^{e}	$Zn_1×B_4$
8.10^{e-i}	0.75^{g-i}	9.25^{f}	8.00^{gh}	25.73^{g}	35.2^{e-i}	265.2^{e-h}	3.33^{f-h}	26.22^{de}	$Zn_2×B_1$
8.35^{e-h}	0.77^{gh}	9.27^{f}	9.47^{de}	26.87^{ef}	36.3^{e-h}	266.3^{e-g}	3.43^{f-h}	26.69^{c-e}	$Zn_2×B_2$
8.72^{de}	0.83^{fg}	9.50^{e}	10.90^{bc}	27.90^{e}	37.9^{de}	267.9^{de}	3.60^{d-f}	27.20^{b-e}	$Zn_2×B_3$
7.72^{hi}	0.68^{ij}	8.81^{h}	12.83^{a}	22.40^{i}	33.6^{hi}	263.6^{hi}	3.17^{h}	25.30^{e}	$Zn_2×B_4$
8.57^{ef}	0.87^{ef}	10.17^{d}	7.80^{g-i}	27.83^{e}	37.3^{ef}	267.3^{ef}	3.57^{d-f}	28.20^{a-d}	$Zn_3×B_1$
9.21^{cd}	0.94^{de}	10.19^{d}	8.43^{fg}	29.63^{d}	40.1^{cd}	270.1^{d}	3.80^{c-e}	28.54^{a-c}	$Zn_3×B_2$
9.60^{bc}	1.00^{cd}	10.48^{c}	10.07^{cd}	31.13^{c}	41.7^{bc}	271.7^{bc}	3.97^{bc}	28.57^{ab}	$Zn_3×B_3$
7.83^{g-i}	0.72^{h-j}	9.19^{f}	11.67^{b}	26.1^{fg}	34.1^{g-i}	264.1^{g-i}	3.37^{f-h}	25.52^{e}	$Zn_3×B_4$
9.29^{cd}	1.05^{c}	11.27^{b}	7.60^{g-i}	31.10^{c}	40.4^{cd}	270.4^{c}	3.93^{cd}	29.20^{ab}	$Zn_4×B_1$
10.00^{b}	1.14^{b}	11.33^{b}	6.90^{i}	33.10^{b}	43.7^{b}	273.5^{b}	4.17^{b}	29.60^{a}	$Zn_4×B_2$
10.93^{a}	1.28^{a}	11.81^{a}	9.07^{ef}	34.80^{a}	47.5^{a}	277.5^{a}	4.50^{a}	29.68^{a}	$Zn_4×B_3$
8.00^{fg-i}	0.76^{g-i}	10.48^{c}	10.80^{bc}	29.93^{d}	34.8^{f-i}	264.8^{f-h}	3.3^{f-h}	25.90^{e}	$Zn_4×B_4$

Notes: Mean in each column followed by similar letters are not significantly different 5% probability level, using Dancan's Multiple Range Test. The difference between the two means in the range 2, 3, etc. was examined with Dungen's test, and if the difference between the two means was greater than the ranges 2, etc., it indicated significance, otherwise it showed non-significance. Zn_1, Zn_2, Zn_3 and Zn_4 include the without fertilizer and use 0.7, 1.4 and 2.1kg.ha^{-1} of zinc treatments. B_1, B_2, B_3 and Bn_4 include the without fertilizer and use 0.3, 0.6 and 0.9kg.ha^{-1} of born treatments. STD=Stem Diameter, LAI=Leaf area index, TKW=Thousand Kernel Weight, K/R=Kernel per Row, Zn Con=Zinc concentration, B Con=Boron concentration, Seed P=Seed protein content, PYLD=Protein Yield and YLD=Grain Yield.

potash fertilizers has no effect on increasing the yield and sometimes it will also decrease the yield[19]. Zinc and Boron elements are essential components of enzymes such as dehydrogenase, proteinase, and peptidase, which play a role in carbohydrate, protein, and fat metabolism[20]. El-Badawy and Mehasen[21] reported that micronutrient elements such as zinc and iron had different biological and balance roles in the quality and quantity of corn. The application of zinc had a significant effect on the LAI. In the studies of other researchers, it has been emphasized on the effects of foliar application of zinc fertilizer on increasing the leaf surface index, the length of the green leaf period, leaf expansion and increasing the photosynthesis of corn. In this regard, Nadergholi et al.[22] reported that the increase in the LAI due to the foliar application of zinc was due to the increase in the amino acid tryptophan and the growth hormone indole acetic acid, which were the main factors in the development and expansion of the leaf area of corns. It was also reported in another study that the LAI in the corn field increased the leaf area and the amount of net photosynthesis in the corn plant with the use of zinc element foliar application. These conditions could be well represented in the field when foliar spraying was done in the early vegetative growth of the corn plant[23].

Storing zinc in the corn plant, which is absorbed by the plant during the formation and formation of corn seeds and even before this stage, in turn leads to an increase in nitrogen absorption by the corn roots during the seed formation stage. This cycle leads to an increase in the number and weight of corn kernels and increases the yield of corn kernels per unit area[24]. The highest weight of 1,000 seeds was assigned to the treatments using 1.2kg of zinc fertilizer×0.6kg.ha^{-1} of zinc fertilizer and 1.2kg.ha^{-1} of zinc fertilizer. The increase in the weight of 1000 seeds was in line with the increases in the length of the grain and in the diameter of the corn. With the use of zinc and iron elements, the absorption of other elements by the corn plant was facilitated, and thus the number of seeds in the cob and the weight of 1000 seeds, grain yield and protein increased. In this regard, Tahir et al.[25] and Kanwal et al.[26] reported that the increase in grain length, cob diameter, and 1000 seed weight in the treatment of using a higher amount of zinc element increased the yield compared to the control treatment (without the use of zinc fertilizer) produced. The effect of different levels of zinc fertilizer consumption showed a positive and significant effect on the attribute of zinc content in corn seeds. That is, with the increase in zinc consumption in the field, the amount of zinc in corn grain also increased. In the report of other researchers, it was also stated that the use of micronutrients, especially zinc, increased the amount of zinc in seeds and seed yield[27]. The highest amount of protein and corn grain yield was assigned to the treatments using 1.2kg of zinc fertilizer×0.6kg.ha^{-1} of zinc fertilizer and 1.2kg. ha^{-1} of zinc fertilizer. It should be remembered that in these treatments, the largest amount of zinc fertilizer solution was consumed in two sensitive stages of corn plant growth. The increase in the amount of protein and grain yield of corn in the condition of using only zinc fertilizer (1.2kg.ha^{-1} of zinc fertilizer) compared to the control treatment (without zinc fertilizer) was about 19.5% and the increase in protein yield was about 38.8%. This situation was equal to 47.7% and 82.8% in the treatment of 1.2% zinc fertilizer×0.6kg.ha^{-1} for grain yield and protein yield. The above results showed that when the corn plant had a proper absorption balance of elements and this proper absorption was created in the presence of zinc fertilizer consumption in the field, there would be increased quality and quantity of the product with an exponential process[28]. Mahaleh and Roshdi[29] reported, for the optimal growth of the plant and to increase the yield and quality of corn, micronutrient elements, especially zinc, should be used in the form of foliar spraying in corn fields. Micronutrient elements such as zinc play different biological roles in the quality and quantity of plant products[30]. It was reported that the use of zinc solution in corn field increases yield and yield components[31]. Generally, spraying zinc and iron elements in the necessary amount in the two initial and sensitive stages of corn plant growth will cause proper growth of the corn field. A farm with proper growth has wide and deep roots and can absorb more water and nutrients and more photosynthesis. In this situation, the corn farm has high quantitative and qualitative performance ability, along with the necessary productivity for all consumer institutions.

4 CONCLUSION

The soils of the province and even of the western region of the country are mostly calcareous with high pH and are very poor in micronutrients and especially zinc. These conditions have caused serious disturbances in the absorption of elements in growing various agricultural products, especially corn, which is one of the most high-yielding products, at different stages of the growth and development of the farm. The lack of balance and harmony in the accessible elements of the plant leads to the unfavorable growth of the farm and causes a decrease in the farm yield and the lack of efficiency of water and other consumable inputs. Therefore, according to the obtained results and the increase in yield, it is recommended to use micronutrient fertilizers in corn fields, especially soluble zinc and zinc fertilizers in the two stages of rapid plant growth and before the appearance of crown flowers.

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Conflicts of Interest

The authors declared no conflict of interest.

Author Contribution

Aghdam MZ and Jalili F performed the experiments and written the manuscript.

Abbreviation List

LAI, Leaf area index

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