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Investigating the Effect of Zinc Sulfate on Quantitative and Qualitative Characteristics of Three Varieties of Barley (*Hordeum vulgare* L.) in Khuzestan Province (Southwest of Iran)

Mehdi Sadeghi[1]*, Mysam Joodaki[2], Mohammadreza Moradi Talavat[3]

1- *Department of Agronomy, Dezful Branch, Islamic Azad University, Dezful, Iran.*

2- *Former Graduate student, Department of Agronomy, Dezful Branch, Islamic Azad University, Dezful, Iran.*

3- *Department of plant production, Ramin Agriculture and Natural Resources University, Ahvaz, Iran.*

RESEARCH ARTICLE

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ABSTRACT

BACKGROUND: Zinc is one of the low consumption elements required by plants, which plays an important role in photosynthesis.

OBJECTIVES: The purpose of this research was to determine the effect of zinc sulfate on barley crop production and introduce the best cultivar affected dry and warm climatic conditions.

METHODS: Current research was done according factorial experiment based on randomized complete block design (RCBD) with 3 replications in the research farm of Khuzestan University of Agricultural Sciences and Natural Resources (Ramin) in 2018. Treatment included four different concentrations of zinc (0, 15, 30, 45 $kg.ha^{-1}$) and three varieties of barley (Sarasari 13, Sarsari 10 and Nimrouz).

RESULT: By using 45 kg of zinc sulfate per hectare, the highest leaf area index (5.65) was obtained, which showed 31% increase compared to the treatment without zinc sulfate. Consumption of 45 kg of zinc sulfate per hectare, the highest chlorophyll index (46.8) was obtained, which showed 17% increase compared to the treatment without zinc sulfate. The highest seed yield and seed zinc percentage were obtained under the consumption of 45 kg of zinc sulfate per hectare, respectively (3325 $kg.ha^{-1}$ and 54.2 $mg.kg^{-1}$). Varieties had a significant effect on all investigated traits, except for leaf area index, seed and plant zinc content.

CONCLUSION: So that the highest seed yield was obtained in the Sarasari 10 cultivar with an average of 3327 $kg.ha^{-1}$. By increasing the consumption of zinc sulfate fertilizer, the yield and zinc content of the seed increased. The Sarasari 10 cultivar showed better reaction to zinc sulfate .

KEYWORDS: *Chlorophyll, Cultivar, Micro element, Nutrition, Seed yield.*

***Corresponding Author:** Mehdi Sadeghi ✉ me.sadeghi@iau.ac.ir

1. BACKGROUND

Barley is one of the important cereals of Iran and the world. Cultivation of this plant has a wider range than wheat and it is practiced in all temperate regions and in many cold regions (Xihan *et al*, 2008). Barley cultivation has a very long history in most of the countries that produce it, and since long ago, its seed, in addition to being used for human nutrition, is used in confectionery and its malt is also used in industry and pharmaceuticals. This plant is the least expected crop, whose range of adaptation and distribution is greater than other crops (Sharafizadeh *et al*, 2001). High-yielding cultivars of barley have lower stem height and higher harvest index than old cultivars (Evens, 1993). In Iran, high-yielding winter cultivars produce between 1.5 and 6 tons per hectare depending on the location and cultivar (ICARDA, 2004). One of the most important agricultural inputs is the correct use of chemical fertilizers, whose effect is known to increase the yield of agricultural products (Sharafizadeh *et al*, 2001). The increase in the use of fertilizers has caused the growth of food production, and scientific sources have shown that by increasing one or more of the sixteen nutrients, the yield has also increased (Mahmodian *et al*., 2002). Predicting the plant's reaction to environmental factors, especially nutrients added to the soil, plays an important role in increasing crop production and the profitability of agriculture (Khoshgoftar Manesh, 2006). Zinc deficiency is common and widespread in intensive agriculture. This phenomenon occurs due to the strong extraction of usable zinc from the root penetration zone in the soil and in some cases due to the beneficial effect of organic substances in the soil in the absorption of zinc by the plant and surface erosion, it causes zinc deficiency. On the other hand, in calcareous and alkaline soils, it is due to the high acidity of the soil (Graham *et al*, 2001). As a result of zinc deficiency in the plant, the growth is gradually stopped, and as a result, the vegetative organs, especially the leaves, have problems as a photosynthetic apparatus. As a result of this situation, the production of photosynthetic materials is disturbed and the formation of reproductive organs is damaged, so the number of seeds per spike and the seed weight decrease. Therefore, with the damage done to the yield components, the seed yield is also reduced. Zinc plays a role in the production of growth hormones (Auxin) and photosynthesis (Ravi *et al*, 2008). Zinc sulfate is used in strips in the soil at the same time as cultivation. In addition, if needed, this fertilizer can be used as a foliar spray (3-5 per thousand) in 2-3 times with intervals of 15 days. Since soil application of zinc has multi-year residual effects, it is recommended to use this fertilizer as soil (Malakouti, 2005).

2. OBJECTIVES

The purpose of this research was to determine the effect of zinc sulfate on barley crop production and introduce the best cultivar affected dry and warm climatic conditions.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This experiment was carried out in the cropping year of 2018-2019 in the research farm of Khuzestan University of Agricultural Sciences and Natural Resources (Ramin). This experiment was factorial by using randomized complete blocks design (RCBD), under three replications under two factors (zinc sulfate fertilizer and cultivar). Barley cultivars included Nimrouz (V_1), sarasari10 (V_2) and sarasari13 (V_3) and zinc sulfate levels included control (S_1), 15 (S_2), 30 (S_3) and 45 (S_4) kg.ha^{-1}. The seed density was considered to be 160 kg.ha^{-1}. The characteristics of the farm soil (loam-clay texture, acidity 7.4, nitrogen content 0.05%, phosphorus and potassium 214.7 and 214 parts per million, respectively, and the amount of zinc in the soil was 1.6 mg.kg^{-1}).

3.2. Farm Management

Each experimental plot consisted of 8 planting lines, 3 meters long and 20 cm apart. The distance between plots was about 40 cm and the number of plots in each block (repetition) was 12. The distance between the blocks was determined to be about 1.5 meters. The studied characteristics include the yield of total dry matter in the stage of seed ripening, seed yield, yield components, leaf area index and the amount of chlorophyll leaf. Cultivation was done in November 2018 after creating the atmosphere and mounds by the worker and at a depth of about 3cm.

3.3. Measured Traits

Harvesting was done manually in May 2019. Harvesting was done from lines 4 and 5, and 40 cm from the top and bottom of the plot was left as a border, and the rest, which was equal to 0.4 square meters, was harvested and all harvested plants were labeled separately and then weighed. Then the samples were transferred to the laboratory to measure the traits related to yield and yield components. Leaf area index was measured using a leaf area measuring device and chlorophyll content was measured under a chlorophyll meter model SPAD 502, made in Japan. An atomic absorption device was used to measure the amount of zinc in seeds and plants. In this way, 0.5 grams of each sample was ground and poured into test tubes. Then between 7-10 ml of concentrated sulfuric acid (95-98%) was added to the tubes. A catalytic arc was added to the equation. Then its temperature gradually reached 400 degrees Celsius, it was placed on an electric heater for 2 hours. After the digestion process, the samples were kept at normal temperature for one hour to cool down, then between 7-10 ml of distilled water was added to each of the samples and the amount of zinc was obtained by the device. It should be noted that four control samples were also prepared, which were used for device calibration before measuring the samples.

3.4. Statistical Analysis

The statistical analysis of the data was done by SAS software (Ver.9.1) and the mean comparison was also done by LSD test at 5% probability level and the required graphs were drawn by Excel software (Ver.2010).

4. RESULT AND DISCUSSION

4.1. *Leaf area index*

The findings of this study indicated that the effect of zinc sulfate on the leaf area index was statistically significant, but the cultivar effect and the interaction effect of factors had not significant effect on this trait (Table 1). By using 45 kg of zinc sulfate per hectare, the highest leaf area index (5.65) was obtained, which showed 31% increase compared to the treatment without zinc sulfate (Tables 2 and 3). Increasing the leaf area with better absorption of light by the plant can ultimately lead to increased photosynthesis and increased seed yield (Malek Mohammadi, 2011).

Table 1. Result of analysis of variance effect of treatment on studied traits

S.O.V	df	1000 weight seed	Seed yield	Number seed per spike	Number spike in m^2	Spike length
Replication	2	9.236**	45193**	49.28**	656.8^{ns}	19.58**
Zinc sulphate (a)	3	19.32*	15107**	9.11*	5496*	5.795**
Cultivar (b)	2	54.90**	29443**	13.00*	7205*	6.955**
a*b	6	2.843^{ns}	920^{ns}	1.33^{ns}	321.6^{ns}	0.781^{ns}
Error	22	5.565	993	2.42	1415.8	1.004
C.V (%)	-	8.24	11.07	6.77	8.84	7.51

^{ns}, * and **: no significant, significant at 5% and 1% probability level, respectability.

Continue table 1.

S.O.V	df	Chlorophyll index	Leaf area index	Seed zinc content	Plant zinc content
Replication	2	19.49**	1.994^{ns}	258.3**	49.07^{ns}
Zinc sulphate (a)	3	64.39**	3.231**	256.6**	38.04*
Cultivar (b)	2	106.2**	0.541^{ns}	13.27^{ns}	4.56^{ns}
a*b	6	8.681^{ns}	0.492^{ns}	13.40^{ns}	13.22^{ns}
Error	22	11.16	0.236	7.19	8.32
C.V (%)	-	7.62	9.76	5.24	9.32

^{ns}, * and **: no significant, significant at 5% and 1% probability level, respectability.

4.2. *Chlorophyll index*

The results of the analysis of variance showed that the effect of zinc sulfate and cultivar on the chlorophyll index of barley leaves was statistically significant, but the interaction effect of factors did not have a significant effect on this trait (Table 1). The results showed that consumption of 45 kg of zinc sulfate per hectare, the highest chlorophyll index (46.8) was obtained, which showed 17% increase compared to the treatment without zinc sulfate. In a research on wheat, it was stated that zinc sulfate has led to an increase in the amount of chlorophyll in wheat leaves. Zinc is one of the elements that affect the amount of chlorophyll in the leaf, which plays an essential role in the formation of its structure (Hasani *et al.*, 2010). Also, there was a significant difference between barley cultivars in terms of leaf chlorophyll index (Table 1). The highest chlorophyll index was found in the Sarasari 10 cultivar (46.5), which showed 10% increase compared to the Nimrouz cultivar (Tables 2 and 3). Kamrani *et al*. (2013) showed in a research that the consumption of zinc sulfate fertilizer can lead to an increase in leaf chlorophyll index.

Table 2. Mean comparison of $ZnSO_4$ application on studied traits

$ZnSO_4$ ($kg.ha^{-1}$)	**Zn seed ($mg.kg^{-1}$)**	**Seed yield ($kg.ha^{-1}$)**	**1000 seed weight (g)**	**Seed of spike**	**Number of spike (m^2)**
0	42.1^{c}	2100.2^{d}	25.6^{c}	18.1^{c}	350.1^{d}
15	47.2^{b}	2480.1^{c}	27.1^{b}	20.1^{b}	390.8^{c}
30	50.1^{ab}	2910.4^{b}	28.2^{b}	22.3^{ab}	410.1^{b}
45	54.2^{a}	3325.1^{a}	30.4^{a}	23.9^{a}	545.3^{a}

Mean followed by similar letters in each column are not significant different at 1% according to LSD Multiple Rang Test.

Continue table 2.

$ZnSO_4$ ($kg.ha^{-1}$)	**Seed zinc content ($mg.kg^{-1}$)**	**Length spike (cm)**	**Chlorophyll index (Spad)**	**Leaf area index**	**Plant zinc content ($mg.kg^{-1}$)**
0	42.1^{c}	10.1^{d}	30.2^{a}	3.8^{d}	25.1^{c}
15	47.2^{b}	12.9^{c}	38.1^{c}	4.4^{c}	27.8^{b}
30	50.1^{ab}	13.1^{b}	40.2^{b}	5.1^{b}	30.1^{b}
45	54.2^{a}	14.3^{a}	46.8^{a}	5.65^{a}	33.5^{a}

Mean followed by similar letters in each column are not significant different at 1% according to LSD Multiple Rang Test.

4.3. *Spike length*

The effect of zinc sulfate and cultivar on spike length was statistically significant, but the interaction effect of factors had not significant effect on spike length (Table 1). The results showed that consumption of 45 kg of zinc sulfate per hectare, the maximum length of the spike was obtained as 14.3 cm, which showed 16% increase compared to the treatment without zinc sulfate. Other researchers also believed in the effect of zinc sulfate on spike length in wheat (Molek Mohammadi, 2011). Also, according to the results of this study, spike length was significantly influenced by the type of used cultivar (Table 1). The increase in spike length is one of the most important traits that can lead to an increase in the number of seeds in a spike. The maximum length of the spike was obtained in the Sarasari10 cultivar (14 cm), which showed an increase of 12.5% compared to the Nimrouz cultivar (Tables 2 and 3). In another research on wheat, it was found that the consumption of zinc sulfate could lead to an increase in the length of the spike and finally the number of seeds per spike (Haidranjadian, 2018; Kamrani *et al*., 2019).

Table 3. Mean comparison of barley cultivars on studied traits

Cultivar	Seed yield ($kg.ha^{-1}$)	Seed per spike	Number of spike (m^2)	Length spike (cm)	Chlorophyll index (Spad)	1000 seed weight (gr)
Nimrouz	2206.1^b	18.4^c	372.3^c	10.3^c	35.2^c	25.4^c
Sarasari10	3327.1^a	24.0^a	449.4^a	14.0^a	46.5^a	30.6^a
Sarasari13	2981.1^c	20.1^b	401.1^b	12.1^b	39.1^b	27.1^b

Mean followed by similar letters in each column are not significant different at 1% according to LSD Multiple Rang Test.

4.4. *Number of spikes per square meter*

The results of the analysis of variance showed that zinc sulfate and cultivar had a statistically significant effect on the number of spikes per square meter, but the interaction effect of factors did not have a significant effect on this trait (Table 1). The findings of this study showed that the consumption of 45 kg of zinc sulfate per hectare, the highest number of spikes per square meter (454.3) was obtained, which showed 14% increase compared to the treatment without zinc sulfate. Also, the number of spikes per square meter was significantly influenced by the type of used cultivar in the experiment (Table 1). The highest number of spikes per square meter was found in the Sarasari10 cultivar (449.4 numbers), which showed 13% increase compared to the Nimrouz cultivar (Tables 2 and 3). The results obtained from the researches of other researchers also showed an increase in the number of spikes per square meter under the usage of zinc sulfate fertilizer (Mahmoudian *et al*., 2013; Kamrani *et al*., 2015).

4.5. *Number of seeds per spike*

The results of the experiment showed that the effect of zinc sulfate and cultivar on the number of seeds per spike was statistically significant (Table 1). The results showed that by using 45 $kg.ha^{-1}$ of zinc sulfate, the highest number of seeds per spike (23.9) was obtained, which showed a 13% increase compared to the treatment without zinc sulfate. Also, it was found that the highest number of seeds per spike was obtained in the Sarasari10 cultivar (24), which showed 19% increase compared to the Nimrouz cultivar (Tables 2 and 3). Some researchers reported an increase in the number of seeds per spike under the usage of zinc (Hosni *et al*., 2010; Malek Mohammadi, 2011).

4.6. *1000 seed weight*

According to the results of this study, the effect of zinc sulfate and cultivar on the 1000 seed weight was statistically significant (Table1). In this experiment, by consuming 45 kg of zinc sulfate per hectare, the maximum 1000 seed weight was 30.4 grams, which showed 20% increase compared to the treatment without zinc sulfate. In a research, it was found that zinc and copper elements had a significant effect on barley cultivars in such a way that the Sasari10 cultivar had a 1000 seed weight more than Izeh, Karun and jonoub varieties (Fathi and Qolizadeh, 2008). Also, the 1000 seed weight was significantly influenced by the type of used cultivar used (Table1). The highest 1000 seed weight was obtained in the Sarasari10 cultivar (30.6 grams), which showed a 16% increase compared to the Nimrouz cultivar (Tables 2 and 3). Kamrani *et al*. (2013) showed in a research that the consumption of zinc sulfate could lead to an increase in the 1000 seed weight.

4.7. *Seed weight*

The effect of zinc sulfate and cultivar on seed weight per spike was statistically significant, but the interaction between them was not significant (Table 1). Under the usage of 45 kg/ha of zinc sulfate, the highest seed weight per spike (0.73 g) was obtained, which showed 23% increase compared to the treatment without zinc sulfate. Also, seed weight was significantly influenced by the type of used cultivar (Table 1). The highest seed weight was obtained in the Sarasari10 cultivar (0.74 grams), which showed 28% increase compared to the Nimrouz cultivar. Some researchers reported an increase in seed weight per spike with an increase in zinc consumption. They stated the reason for this increase was the increase in chlorophyll content, followed by an increase in plant photosynthesis (Malek Mohammadi, 2013; Kamrani *et al*., 2015 and Baghi *et al*., 2007).

4.8. *Seed yield*

The results of this study showed that the effect of zinc sulfate and cultivar on seed yield was statistically significant (Table 1). The results showed that the consumption of 45 kg/ha of zinc sulfate, the highest seed yield (3325 $kg.ha^{-1}$) was obtained, which showed 40% increase compared to the treatment without zinc sulfate (Tables 2 and 3). Some researchers reported an increase in seed yield, plant dry weight and harvest index under the usage of this element in wheat (Bagi *et al*., 2007), safflower (Mohdi *et al*., 2009) and rapeseed (Baybordi and Mamedov, 2009). Also in a research reported that the use of iron and zinc elements in wheat significantly increases seed yield, 1000 seed weight, number of seeds per spike, spike length and number of spike per unit area. The reason for increased yield and its components due to the use of iron and zinc, the effect of these elements in leaf chlorophyll and auxin hormone concentration (Hemantarajan and Garj, 1988). Also, there was a significant difference between barley cultivars in terms of seed yield. The highest seed yield was produced in the Sarasari10 cultivar (3327 $kg.ha^{-1}$) was obtained, which showed an increase of 42% compared to Nimrouz cultivar. It seems that the existence of genetic differences between cultivars is the main reason for this difference in seed yield.

4.9. *Biological yield*

The effect of zinc sulfate, cultivar and the interaction effect of these factors on biological yield were statistically significant (Table 1). The findings of this study indicated that the highest zinc sulfate consumption (45 $kg.ha^{-1}$) produced the highest biological yield (7026 $kg.ha^{-1}$), which showed an increase of 26% compared to the treatment without zinc sulfate consumption. Also, the biological yield of barley was influenced by the type of used cultivar. The highest biological yield was obtained in the

Sarasari10 cultivar (7753 kg per hectare), which showed an increase compared to the Nimrouz 13 cultivar (Tables 2 and 3). In a research on barley cultivars, it was found that they differed in terms of biological yield during ripening. The highest biological yield belonged to Nusrat cultivar (13220 $kg.ha^{-1}$) and the lowest to Sahand cultivar (10500 $kg.ha^{-1}$). It was found that the biological yield changed under the usage of micro fertilizers, in such a way that the biological yield increased under the usage of three types of iron, zinc and copper fertilizers compared to the control. It seems that the reason for this is the emergence of the potential of barley cultivars and the increase of dry matter accumulation under the usage of micro-fertilizers (Mardani *et al*., 2019).

4.10. *Seed zinc content*

The effect of zinc sulfate on seed zinc concentration was statistically significant (Table 1). The results of this research showed that the consumption of 45 kg of zinc sulfate per hectare, the highest concentration of zinc in the seed was obtained (54.2 $mg.kg^{-1}$), which showed 15% increase compared to the treatment without zinc sulfate. In two separate studies on wheat and barley respectively, it was announced that the consumption of zinc fertilizer had a significant effect on the concentration of zinc in wheat genotypes. With the increase of zinc fertilizer in all consumption levels, the amount of zinc in the seed was increased, so that the highest and lowest amount of this element (with 22.52 and 13.86 $mg.kg^{-1}$ of dry matter) respectively, was obtained under the consumption of zinc fertilizer with a concentration of 0.8% and no use of fertilizer (zero) was obtained (Bagher Nejad *et al*., 2019). It was found that in most crops, increasing the application of zinc could increase its concentration in the aerial organs (Shaw and Ling, 1998 and Khan *et al*., 2003).

4.11. *Plant zinc content*

The effect of zinc sulfate on plant zinc concentration was statistically significant (Table 1). The results of this research showed that consumption of 45 kg of zinc sulfate per hectare, the highest concentration of zinc in the plant (33.56 $mg.kg^{-1}$) was obtained, which showed 14% increase compared to the treatment without zinc sulfate. During another research, it was found that the consumption of zinc increases its concentration in aerial organs and seeds. The interaction effect between zinc fertilizer and wheat genotypes was also significant and the highest amount of zinc (24 $mg.kg^{-1}$ dry matter) was obtained from 0.8% fertilizer level and the lowest amount (13.77 $mg.kg^{-1}$) was obtained from zero fertilizer level (control) (Khan *et al*., 2003).

5. CONCLUSION

The results of this study showed that zinc sulfate had a significant effect on seed yield. The highest seed yield and seed zinc percentage were obtained under the consumption of 45 kg of zinc sulfate per hectare (3325 $kg.ha^{-1}$ and 54.2 $mg.kg^{-1}$), respectively. The reason for this is the role of zinc in the formation of chlorophyll, the leaf area duration, the increase of the auxin hormone and finally the increase in the amount of photosynthesis of the plant, which was confirmed by many researchers. In general, the results of this study showed that the increase in the amount of zinc sulfate fertilizer, the yield and the amount of zinc per seed increased and the Sarasari10 cultivar showed a better response to zinc sulfate.

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FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

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