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CONTROL OF HEAT STRESS BY SILICON AND ZINC FOLIAR APPLICATION IN MAIZE CROP (*ZEA MAYS* L. CV. KSC704) AT IRANIAN TROPICAL CONDITION

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ABSTRACT

In order to study the reducing harmful effects of heat stress in maize cultivation in warm area condition and control the heat stress by minerals this field experiment was conducted in agriculture research center, Haji Abad, Iran in 2013. The experiment was conducted in split plot in the form of a randomized complete block design with three replications. Three sowing dates July 10th, July 25th and August 1st were in the main plots and foliar application were in four levels of spray with water as control, silicon, zinc, and zinc plus silicon in subplots. The results showed a significant difference between sowing date on grain yield, no. grain per row, biological yield and harvest index in %1 significant level. The highest grain yield was obtained in July 25th sowing date with zinc spraying by 12470 Kg/ha and the lowest in July 19th was 8680 Kg/ha in control. Moreover, July 19th sowing date was known that zinc and silicon have played a positive role in yield improvement, although zinc had more effectiveness. The use of these elements could improve the grain yield at the rate of 1580 Kg/ha than control treatment. In sowing date of July 10th, the silicon could improve the harvest index from %66 in control to %82. Also, we find that in heat stress conditions, zinc have outperformed silicon in the number of grain improvement and promoted the number of grain from 38 to 45 grains per row.

KEYWORDS: Heat stress, Silicon, Zinc, maize, harvest index.

INTRODUCTION

Southern regions of Iran is one of the most warm location and sources of relative problems in producing grain maize in the country. In this especially hot condition, later mature maize cultivars in late showings date is as a result for late harvest and decrease in yield quantity and quality that can be mentioned. Regarding the major changes in the southern hot in maize grain and maize harvest in December and January do not give a chance to prepare soil for planting wheat and late sowing of wheat and management remains is consequential damages of sowing maize; one of the ways to prevent this problem is early planting of corn and heat stress conditions. The importance of the corn and the area cultivated is high due to its compliance with the various weather conditions, so it is considered as the main products moderate, moderately warm, subtropical and humid regions. In conditions of high temperature and low relative humidity, tassels appeared may not have their freshness for pollen germination. Sever environmental stress during the period of pasty and stiffness of grain it can be followed by reduction of the grain yield which is often generated by first forming the black layer. The optimum temperature for the corn is between 25 to 33 degree increase ℃ during the day and 17-25 degree increase at night (Choukan 2009). The degree of thermal stress in plants is the increase of the temperature above the threshold level for a period of time that causes the damage immutable growth of plants; 10-15 in general the increase of the optimum temperature causes thermal stress and / or thermal shock (Moussa, 2006).
In moderate regions, heat is one of the most important elements and decreasing production of dry matter especially in maize (Wahid, 2007). The resistance to heat in maize is 38 degree increase during grain filling period (Wilhelm, 1999). For each 1 Celsius degree increase in temperature above the optimum temperature, reduction of 3-4% in yield occurs in wheat (Shaw, 1983), in temperature higher than 38 degree increase, the formation of seed per panicle is weak resulting from the compact high temperature direct (Carberry et al., 1986) and the dryness pollens (Schoper et al., 1986) will happen. Different methods have been suggested for controlling heat stress in plants that one of them is

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the application of minerals in plants. However, now the main solution for controlling heat is early sowing of maize and in hot weather in Haji Abad, Iran and similar regions, but finding out other methods of reducing harmful effect of heat stress is one of the objectives of this research.

Silicon after Oxygen is the most abundant element in the earth's crust (Sposito, 1989). The content of 0.2 to 100 mg of this element in one gram of dry weight has been reported (Mengle and Kirkby, 1978). Mechanism of Silicon absorption is different in various plants and also, there is no complete information in this case (Mitani and Ma, 2005). In most silicon accumulator plants, the highest silicon concentration is seen in leaf blade and the lowest in root. The absorbed silicon by roots moved towards the young leaves selectively. In conditions that silicon concentration and transpiration organs are low, more silicon are accumulated in old leaf blade. In addition, silicon in plant is a non-dynamic (Ma and Yamaji, 2006) considering that silicon consumption increases the activity of SOD and CAT enzymes and causes the protection of plant tissues from oxidative damage resulting from stress and its consequence is the increase in chlorophyll and photosynthesis stimulation (Sposito, G. 1989). The transmission of silicon in plant is conducted from inside of wooden vessel. Therefore, its distribution in foliage is determined by the severity of transpiration (Marschner, 1995). In fact, the highest silicon concentration in plant is observed where there is the highest transpiration (Henriet, 2006). Silicon absorption is done both actively and inactively (Raven, 1983). One of these elements is Zinc. The importance of zinc is due to its importance in different enzymes compound regulating metabolic activities in plants. Zinc plays an important role in constructing auxin and chloroplast and also in carbohydrates metabolism. Also, it causes the stability and structural configuration of membrane proteins (Brown et al, 1993). On the other hand, some studies have showed that the significance of silicon in heat stress control emphasizes on new dimensions. Finding useful effects of silicon application in reducing damage resulting from heat stress is one of the most important objectives of this research. Also, investigating the interactions of silicon and zinc in generating heat tolerance in maize has been another objective of this research.

MATERIALS AND METHODS

This experiment was conducted in 2013 at the Haji Abad's Agriculture Research Station, Iran (27° 13' S, 56° 22' N). Soil sample analysis was done in the first sowing date that were collected from 0-30 cm depth. Soil properties was sandy loam in texture. The Haji Abad's Agriculture Research was located in tropical region of Iran that mean of the maximum ten year temperature shown in table 1.

Table 1. maximum temperature (Haji Abad Agricultural Researches Station) ten years mean)

Month	maximum temperature (means of ten year)
January	0.25
February	24.1
March	30.3
April	40.5
May	44.8
June	47.8
July	49.5
August	48.4
September	46.1
October	41.9
November	36.2
December	28.5

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The experiment was conducted in split plot in the form of a randomized complete block design with three replications and the following treatments: Three sowing date including July 10th, July 25th and August 1st were in the main plots and foliar application were in four levels of spray with absolute water (control), spray with silicon, spray with zinc, and spray with zinc plus silicon together in sub-plots. Regarding to table 1 and local Meteorological condition the sowing date in July 10th mays crop contacts to very hot condition, in July 20th laid to recommended sowing time and in August 1st or late sowing time that over the high temperature condition. The foliar application were expose whole plant shoots by absolute water as control, nano silicon (%0.02 solution), zinc, and spray zinc plus silicon together at eight-leaf stage during two phases to the interval of 15 days at sunset time. To preparing solutions, nano silicon (SiO_2 with 64 nanometer diameter) solution was prepared with 0.02% concentration and zinc were used with 0.04% concentration. This experiment field had 36 plots. The each plot had 8 m length and 3 m width that constituted in 4 rows. The rows interval was 75 cm and the space between plants in each row was 20 cm. The seeds were sown at the depth of 2-3 cm by hand. In order to receive the optimum density while planting, the highest density was taken into consideration and plants were thinning with the space of 20 cm after the 4 leaves stage.

During the growing season all agricultural practices such as thinning, weeds control, irritation and fertilization were taken into consideration and no pest and disease were observed. On the basis of soil experiment, base fertilizers were sufficiently utilized. To prevent the drought stress, irrigation was complete and soil moisture retained to the content of field capacity in order that plants do not confront any stress other than heat. Grain and biological yield were conducted when grain moisture reached %14. To avoid the marginal effect, the six plants from middle rows of each plot were randomly harvested. Samples were cut and all traits in question such as grain number in row, the number of row, length of maize 1000-garin weight, harvest index were calculated and necessary notes were taken during the growth period. The data were calculated and statistically analyzed by SAS software and compared means by the Duncan multiple test. Excel software were used for statistical calculations.

RESULTS AND DISCUSSION

The results from analysis of variance represented that there is a significant difference between the effect of sowing date treatment levels on grain yield, grain number in row, biological yield and harvest index at %1 level (table 2). But, the effect of spraying and also treatment interactions on these traits was not significant other than grain yield. According to the results of the mean comparison, sowing date at July 10th causes the decrease in grain number per ear row from 44.8 to 41.8, heat should be caused to wasting pollen and disruption in germination. This result is in agreement with Shaw results (Shaw, 1983).

Table 2. Analysis of variance of the effect of treatments on the measured traits

SOV	DF	Mean Squar					
		Grain yield	1000-grain weight	No. row per ear	No. grain per row	Biological yield	Harvest index
Replication	2	10.01**	1266.21^{ns}	0.82^{ns}	48.03**	44.45**	171.72*
Sowing date (S)	2	12.77**	1082.61^{ns}	0.57^{ns}	44.49**	200.52**	1230.60**
Foliar application (F)	3	0.96^{ns}	274.21^{ns}	0.17^{ns}	10.18^{ns}	1.66^{ns}	24.22^{ns}
Interaction(S.F)	6	1.60^{ns}	599.90^{ns}	0.24^{ns}	10.77ns	4.07^{ns}	17.96^{ns}
Error	18	9.04	771.90	0.26	96.55	4.40	44.31
CV (%)		6.43	8.99	3.50	5.21	22.61	11.58

**,* and ns: significant in probability level of %1, %5 and non-significant, respectively.

Following this results, grain yield was reduced from 11771 Kg/ha to 9845 Kg/ha. Also, due to the treatment of heat stress, grain number in row showed the decrease from the average of 44.8 to 41.8 that can be one of the reasons of yield reduction. 1000-grain weight was not affected by heat stress and it represents the low sensitivity of this trait to stress and plant contributes a large percentage of its products to the grain in stress condition that this results is in conformity with the results of Tetiokapho and Garkent (1988) who declared that 1000-grain weight has more stability and grain number in row has more sensitivity in heat stress condition. However, heat stress caused the increase in 1000-grain weight from 310 to 317 g that was in agreement with Safa's study (1996) and due to the reduction of grain number the weight of one grain was increased (Cheikh and Jones, 1994).

Based on the obtained results a significant relationship was observed between the sowing dates regarding biological yield at %1 level and sowing date of July 10th caused 4077 Kg/ha decrease in biomass yield. It seems that reproductive growth has more sensitivity to generative growth in heat stress. According to table 2 and the study on the interactions effects the highest grain yield was obtained in sowing date on July 25th (spraying with zinc solution) to the amount of 12470 Kg/ha and the least to sowing date on July 10th in control treatment (spraying with water) to the amount of 8680 Kg/ha; i.e. yield in this condition increased to 3790 Kg/ha. In exploring the interactions effects in sowing date of July 10th that heat stress is dominated, it was known that zinc and silicon have played a significant role in yield improvement, although zinc had more effect. The use of these elements could improve the grain yield at the rate of 1580 Kg/ha to the control treatment. The interactions between treatments showed that zinc had a more role in improving this damage than silicon. Regarding that maize has a high sensitivity to zinc deficit and zinc is the main part of enzymes involved in photosynthesis including RUBP carboxylase can be a reason for more efficiency of zinc to silicon. In exploring of harvest index, it was determined that the highest harvest index is related to sowing on July 25th with the average of 64% and after that sowing date on July 10th with the average of 62.3% and the least content to that of August 1st with the average of 45%. Maize plant seems to attribute more portion of production to grain in stress condition. In different levels of spraying in sowing date on July 10th (heat stress), silicon could improve harvest index from 62% (control) to 66% (table 3). Also, the study on interactions effects showed that in heat stress condition (sowing on July 10th) zinc outperformed silicon in improving grain number and has promoted grain number from 38 (control) to 45 grains per row.

Table 3. Comparison of the means of measured traits

Treatments	Grain Yield t/ha	1000-grain Weight g	No. row per ear	No. grain per row	Biological Yield t/ha	Harvest Index %
S1	9.85 a	317.73 a	14.15 b	41.87b	6.92 b	62.40 a
S2	11.77 a	310.46 a	14.58 a	44.80 ab	7.91 b	64.15 a
S3	11.44 a	298.90 a	14.41 a	45.50 a	10.10 a	45.80 a
F1	10.78 a	316.75 a	14.22 a	42.81 b	9.36 a	57.68 a
F2	10.91 a	304.10 a	14.55 a	43.86 ab	8.79 a	59.64 a
F3	11.51 a	308.95 a	14.35 a	45.39 a	9.81 a	55.88 a
F4	10.88 a	306.31 a	14.41 a	44.18 ab	9.13 a	56.58 a
S1F1	8.68 e	312.23 a	13.88 a	38.54 b	6.19 b	62.85 a
S1F2	9.53 de	320.07 a	14.66 a	40.50 a	6.08 b	66.99 a
S1F3	10.90 bc	314.84 a	13.83 a	45.05 a	7.76 b	59.51 ab
S1F4	10.26 cd	323.76 a	14.22 a	43.31 ab	6.35 b	60.23 ab
S2F1	12.06 ab	319.57 a	14.55 a	44.74 a	6.21 b	66.50 a
S2F2	11.39 ab	315.68 a	14.44 a	44 .00a	8.54 b	65.78 a
S2F3	12.47 a	314.98 a	14.55 a	46.31 a	6.21 b	60.97 ab
S2F4	11.16 bc	291.62 a	14.77 a	44.14 a	8.54 b	63.31 a
S3F1	11.63 ab	318.47 a	14.22 a	45.13 a	6.53 b	43.66 c
S3F2	11.81 ab	276.54 a	14.55 a	47.01 a	10.54 a	46.15 bc
S3F3	11.14 bc	297.03 a	14.66 a	44.76 a	13.15 a	47.16 bc
S3F4	11.21 bc	303.54 a	14.22 a	45.10a	13.21 a	56.21 bc

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Means in a column followed by the same letter are not significantly different at P≤0.05. S as sowing dates and F as foliar application treatments

CONCLUSION

In present experiment condition the planting maize seeds on July 10th the reproductive and generative stage of maize was affected by over heat and causes 16% decreases in grain yield as heat stress effect. It was obvious that the application of zinc and silicon can improve maize grain yield in hat air conditions. Also, our studies represented that the role of zinc was more effective in compensating damage resulting from heat stress than silicon. According to the results of this experiment it is suggested that further researches be conducted about finding the role of silicon in controlling the harmful effect of heat stress on maize.

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