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The effect of irrigation-off at some growth stages and zinc sulfate spraying on grain growth rate and quantitative and qualitative yield of corn hybrid K.S.C.704

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Abstract

In order to study the effect of irrigation-off at some growth stages and Zinc Sulfate spraying on grain growth rate and qualitative yield of corn hybrid K.S.C. 704, an experiment was conducted during summer 2011-2012. The experiment was conducted in split plot based on the Randomized Complete Block Design (RCBD) with three replications. Main factors included water stress at three levels of irrigation; irrigation in all the growth stage, irrigation-off at tasselling stage, irrigation-off at milking stage, and the second factors included zinc sulfate spraying with four levels without spraying, spraying at the level of eight leaves, spraying at the level of twelve leaves and simultaneous spraying on both eight and twelve leaves. The results showed that the maximum grain yield, biological yield, harvest index, protein yield, oil percentage, and oil yield were observed on irrigation in all the growth stages treatment and the minimum amount of the factors were observed on irrigation-off at tasselling stage treatment. In the case of spraying, the maximum amount of grain yield, biological yield, harvest index, protein percentage, protein yield, oil percentage, oil yield, the dry weight of a grain, and the rate of the grain growth were observed at simultaneous spraying at both eight and twelve treatment and the minimum amount in most of the factors were observed on without spraying treatment. The interaction effect of water stress and zinc sulfate spraying was not significant except for oil yield, the rate of grain growth rate and the dry weight of a grain. Therefore, it seems that irrigation-off significantly decreases grain yield, biological yield, protein yield, oil percentage and oil yield while zinc sulfate application in the form of spraying increases the tolerance of the plant to the decrease of the above mentioned factors and consequently modified the harmful effects of water stress.

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Introduction

According to the studies which have been conducted by the Institute of Nutrition Sciences of Iran, it has been concluded that nearly 70 percent of needed daily protein is being supplied through cereals consumption. For this reason we know that corn plays an important role in diet of human being, therefore it is absolutely essential to conduct expanded researches about cultivation of this product (Sedri and Malakouti, 1998). According to protein requirement of the country and outstanding role of corn in nourishment of domesticated animals, increasing the amount of corn production is being totally essential. In order to achieve this aim, some researches must be made on appropriate usage of the soil and water resources, agricultural capacities of dry lands of the country and using improved yielding varieties (Ahmadian *et al.,* 1998).

Due to the fact that our country is located in arid and semi- arid part of the earth, and arid lands comprise more expanse of the country comparing with semi-arid, during the growth process, the plants may encounter with drought stress. As a result we witness that irretrievable damages may take place for the plant which can lead to decrease of quality and quantity of the product. Drought stress occurs when the moisture around the root of the plant decreases so much that the plant cannot absorb sufficient water anymore; in other words it can happen when transpiration is more than water absorption (Benjamin, 2007). During the stress conditions, potentialities of nourishing materials access, absorption and transferring of materials will be disturbed (Lauer, 2003). According to the studies conducted on different corn hybrids at the same conditions of dehydration, we realized that there is a positive correlation between accumulated amount of proline in them and grain yield stability (Oregan *et al.,* 1993). While studying Corn and Sorghum, it was identified that grains of products exposed to stress conditions, had high levels of nitrate and as a result had a lower quality (Mcwilliams, 2001). Pandey *et al.,* (2002) declared that, the maximum amount of water consumption in corn is when silks appear or immediately after that. The maximum decrease in grain yield occurs if the plant faces with lack of water while tassel and silk appears with a decrease in number of grains in Corn. Therefore it is concluded that, the main reason of grain yield decrease in drought stress treatments, has been significant decrease in number of grains in Corn. This conclusion has been confirmed by the other researchers too (Lack, 2006 and Mojadam, 2006). Biological yield indicates that, to what extent agronomic plant can turn its real photosynthesis to pure photosynthesis. Due to sensitivity of flowering period, lack of moisture can affect pollens and increase their barrenness; also it can dry stigma and silks and finally can lead to decrease in number of grains in Corn (Rashidi, 2005; Noormohammadi *et al.,* 2005; Hashemi Dezfouli and Herbert, 1992). Hence decrease in number of grains of Corn can provide the possibility for other grains to get use of photosynthesis materials to grain weight. It has been confirmed by researchers that, by using micronutrients especially zinc we can witness increase in grain yield of the corn (Marschner, 1993).
The reason of grain yield increase refers to inoculation, pollination improvement, no ear infertility of Corn and delay in nourishing materials absorption. Carsky and Reid (1990) declared that by getting use of zinc fertilizer, corn grain yield can be increased up to 20 percent. Thalooth *et al.,* (2006) also reported that spraying zinc solution in stress conditions of water can have positive effects on growth, yield and yield components of plants. Dry matter increase due to usage of zinc sulfate by auxin biosynthesis (Sharafi *et al.,* 2002) can lead to increase in chlorophyll density, increase in activity of phosphor enol pyruvate carboxylase and ribulose bisphosphate carboxylase decrease in sodium accumulation in plant tissues, and increase in efficiency of nitrogen and phosphor absorption in contact with zinc element (Khalil Mahaleh and Roshdi, 2008). Brown *et al.,* (1993) reported that in lack of zinc condition, the protein percentage would be decreased all over the plant, yet protein compounds almost remain without any change. Decrease of RNA and Ribosome transformation, is a

process which affect protein synthesis by lack of zinc. Mohseni *et al.,* (2006) declared that, zinc soil consumption has been effective for increasing corn yield, and zinc spraying has been effective for improving qualitative properties of the corn. Grain weight is one of the basic elements of corn yield. This element is dependent on amount of existing assimilate especially in initial process of grain growth; on the other hand it is dependent on potentiality of growing grain in using existing assimilate. Therefore rate and duration of grain filling is extremely important in determining maximum grain dry weight. Correlation between these elements is usually negative. Ecological conditions mostly affect grain filling period, yet rate of grain filling is controlled by genetic structure of the plant through physiological and descriptive features, potentiality of the plant in retransferring materials and vascular system efficiency (Naderi, 2001). Knowing all these processes plays an important role in having better field crops. This research has been conducted in different moisture conditions to determine effective qualitative and quantitative changes in corn yield, to achieve appropriate solutions that can increase efficiency of resources consumption and decrease costs in such conditions.

Materials and methods

Experiment methods

Experiment design specifications and treatments

This research has been conducted in the form of split plot based on randomized complete block design (RCBD) with three replications. This experiment was performed in summer 2011. The soil texture of the farm was silty clay. Corn hybrid K.S.C.704 belonging to the group with late growth period of 125-135 days was cultivated in the early August. The main factor included water stress at three levels of irrigation without stress (control) (I_1), irrigation-off at tasselling stage (I_2), irrigation-off at milking stage (I_3), and the second factor included zinc sulfate spraying with four levels of without spraying (control) (F_1), spraying at the level of eight leaves (F_2), spraying at the level of twelve leaves (F_2), and simultaneous spraying on both eight and twelve leaves (F_4). Spraying of fertilizer from the source of hydrated zinc sulfate ($ZnSo_4$, $7H_2o$) was done in three stages with concentration of 2.5 gr per 1000 ml of water when sunset in the three levels of eight leaves, twelve leaves, both eight and twelve leaves (simultaneously). The sprayings were done on the eve of sunset when the temperature was low so that the compounds did not evaporate immediately and, on the other hand, because of the least light at this time, bad effects of light were prevented and, until the morning, there was enough time for optimal absorption of the solution by the plants. In addition, to prevent zinc sulfate from penetrating from the plots under spraying to the other plots, a curtain with six meters long and two meters wide was put among the sub plots.

The measured traits and their measurement procedure

Analysis of grain yield

In order to analyze the grain growth influenced by different treatments, totally nine samplings were made on each minor plot. The first sampling was made ten days after pollination. Then, eight next samplings were made at time interval of five days until physiological yield examination. At each sampling, five plants were harvested from each sub plot, and in terms of relatively constant grain weight in the plant part (Ritchie and Hanway, 1977), the grains existing in the loops 16 and 17 rows were separated from the end of the maize, and weighed after drying in the oven of 72ºC for 48 hours. To calculate dry weight of a single grain in each sampling, total dry weights of the grains were divided by their numbers. After drawing the single grain weight changes curve, those points placed at the linear growth stage were specified, and the slope obtained (b) indicating the grain growth speed in the linear stage, was calculated by means of the Regression equation ($y=a+bx$). Effective filling period (EFP) of the grain was determined through dividing the final weight of grain by the grain filling speed (Lack, 2006; Naderi, 2001).

Percentage and performance of protein

To measure the nitrogen percentage, one gram of each sample was digested by using sulfuric acid and hydrogen peroxide, and then, with the aid of Kjeldahl method, its amount was determined (Sajedi, 2008). To measure the raw protein percentage of the grain, first by using the Foos machine, Kjeltec TM 2100 model, the nitrogen percentage of total grains was determined in vitro, and then, by using the coefficient of 5.65 for corn (Walton, 1990), the following equation was used.

Nitrogen Percentage × 5.65 = Protein Percentage of Total Grains (%).

Percentage and performance of oil

From the grains harvested from each plot, some 0.5-gram samples were randomly prepared and, to measure the oil percentage of the grain, first they were powdered by a mill and then were used. The oil percentage of the grains harvested was determined with the aid of ether solvents by the Soxhlet method. The oil yield per unit area was determined through multiplying the grain yield by the oil yield (Sadeghi Pour, 1996; Gholi Zadeh, 2010).

Oil Yield (Kg hec-1) = Grain Yield (Kg hec-1) × Grain Oil (%).

Biological Yield

To determine biological yield (total dry material of the organs over the soil surface), five plants were harvested from each plot, and after transferring the samples to the laboratory, they were put in the oven of 75°C for 48 to 72 hours. After drying, their weights were calculated.

Harvest Index

Harvest index was determined through dividing the grain yield by the biological yield percent.

Final harvest

Final harvest was done at physiological maturity and when the grains' humidity reached about 20%. From two middle lines of any plot, five plants were harvested and the amounts of maize weight, each grain's weight, number of grains per rows, number of grain rows, total number of grains per ear and the cob diameter were separately measured in ten plants of any plot, and the average was considered as the average of that plot. In order to determine the humidity content of different organs and the grain, as well as to determine total dry matter and the grain yield, randomized samples were harvested from the products of different parts and the grain of each plot, and were dried in 72°C for 48 hours. The first weight of the organs and the grain, total dry matter and the grain yield were corrected according to their dry weights.

Statistical analysis

To statistically analyze, SAS software was used and to correlate the factors, MSTATC software was used. In addition, to compare the averages, Duncan test was used (due to the existence of control treatment). Drawing the graphs and histograms was accomplished by means of Excel software.

Discussion and conclusions

Grain Yield

Analysis of the grain yield variance showed that the effect of irrigation treatment as well as the effect of zinc sulfate spraying, at the %1 probability level, on this factor was significant, while their interaction was not significant (Table 1). The results of the average comparison showed that the maximum amount of the grain yield was observed at the irrigation treatment (favorable irrigation) up to 9446 kg per hectare, and its minimum amount, with a difference of 20%, was observed at the irrigation-off on tasselling stage treatment up to 7559 kg per hectare (Table 2). Vazin (2010) stated that the maximum water consumption by the corn is almost when silk rating or immediately after that. Water shortages when tasselling and silk rating along with decreased grain number in the maize causes the most decrease in the grain yield. This result was also supported by the other researchers (Lack, 2006; Mojadam, 2006). Due to zinc sulfate spraying, the maximum amount of the grain yield was observed at the spraying treatment at the level of both eight and twelve leaves (simultaneously) up to 9077 kg per hectare, and the minimum amount of the grain yield, with a difference of 14%, was observed on without-spraying treatment up to 7800 kg per hectare (Table 2). Increased grain yield of the corn was proved by some researchers to be resulted by application of low-used elements specially zinc (Marschner, 1993). Carsky and Reid (1990) suggested that by using zinc fertilizer, the grain yield of the corn increased up to 20 percent. Thalooth *et al.,* (2006) reported that zinc spraying under the water stress conditions, had positive effect on the growth, yield, and yield components. The findings of this experiment conformed to the results of Sheyhbagloo *et al.,* (2009) and Sajedi *et al.,* (2010). Therefore, it seems that the main cause of decreased grain yield in the water stress treatments was significant decrease in the grain number of the maize. And increased grain yield was attributed to improved pollination and inoculation, non-hollowness of the maize, and modified absorption of nutrients.

Table 1. Summary of the results of the analysis of grain yield variance, biological yield, harvest index, qualitative traits and grain growth analysis in which mean- of square is shown.

Sources of changes	Degree of freedom	Grain yield	Biological yield	Harvest index	Protein percent	Oil percent	Oil yield	Protein yield	Grain filling rate	Effective filling period	Dry weight of single grain
		Mean-of square									
Block	2	302245.083	777628.51	9.108	1.746	0.42	2275.730	2511.87	4.34	14.32	2958.28
Irrigation	2	10972560.33**	33786291.33**	8.302$^{n.s}$	2.650$^{n.s}$	2.022$^{n.s}$	58546.79$^{n.s}$	22569.09$^{n.s}$	12.75$^{n.s}$	7.4$^{n.s}$	12308.13$^{n.s}$
Error of main plots	4	258136.92	458289.63	7.223	4.851	1.118	14529.098	19214.25	4.15	5.16	3563.52
Spraying zinc sulfate	3	2674228.85**	8246721.34**	5.137$^{n.s}$	2.137*	0.742**	19804.8**	57951.39**	28.52**	0.57$^{n.s}$	35299.71**
Irrigation * spraying	6	90236.41$^{n.s}$	615969.07$^{n.s}$	3.998$^{n.s}$	0.435$^{n.s}$	0.112$^{n.s}$	982.71**	2928.74$^{n.s}$	2.21**	1.29$^{n.s}$	2071.08**
Error	18	191780.42	313585.94	2.971	0.587	0.150	1418.41	5681.098	0.41	0.58	379.07
Coefficient of Variance (percent)		5.21	3.21	3.58	8.75	8.44	9.69	10.28	9.88	2.17	8.64

$^{n.s}$, * and ** respectively, non-significant, significant in probability level 5% and 1%.

Biological Yield

Analysis of the variances indicated that the effect of the treatments surveyed on the biological yield in the 1% probability level was significant, while their interaction on the biological yield was not significant (Table 1). The results of comparison of the averages showed that the maximum biological yield was observed on the irrigation treatment (favorable irrigation) up to 19240 kilograms per hectare, and its minimum amount, with a difference of 17%, was observed on the irrigation-off at tasselling stage treatment up to 15910 kg per hectare (Table 2). The biological yield indicates what a plant is able to change its real photosynthesis into pure photosynthesis. Decreased real photosynthesis and increased plant respiration are two factors which decrease pure photosynthesis and, as a result, the biological yield of the plant. Each of these factors by itself or together is able to decrease pure photoshynthesis and, consequently, the biological yield of the plant. One of the first effects of humidity stress on the photosynthetic system is cause by increased mesophilic resistance, so that of 50% of decrease in the photosynthesis level, two third is attributed to mesophilic resistance and the remaining one third to increased stomatal resistance (Greenway and Munns, 1980). Therefore, because water stress results in these two factors, the biological yield decreases. In the case of effect of zinc sulfate spraying, the maximum amount of the biological yield was observed on the spraying treatment at the level of eight and twelve leaves simultaneously up to 18610 kg per hectare, and the minimum amount of the biological yield, with a difference of 12%, was observed on the without-spraying treatment up to 16280 kg per hectare (Table 2). Increase in the dry material due to the application of zinc sulfate can be caused by increased auxin biosynthesis (Sharafi *et al.,* 2002), increased chlorophyll concentration, increased phosphoenolpyruvate carboxylase, and Ribolose Bisphosphate Carboxylase, decreased sodium concentration in plant textures, and increased efficiency of nitrogen and phosphorus absorption in the presence of zinc (Khalil Mahaleh and Roshdi, 2008).

Harvest Index

The effect of the treatments surveyed as well as their interaction on the harvest index was not significant (Table 1). It seems that it decreases the irrigation treatment of the grain yield and biological yield at the same extent and increases the spraying treatment of the grain yield and biological yield at the same extent. Therefore, the harvest index was not influenced by the treatments surveyed (Table 3).

Table 2. Mean comparison of the effect of interaction of irrigation cut off and zinc sulfate spraying on grain yield, biological yield, harvest index, qualitative traits and grain growth analysis using Duncan test.

Experimental treatments	quantitative traits			qualitative traits				grain growth analysis		
	Grain yield	Biological yield	Harvest index	Protein	Oil	Protein yield	Oil yield	Grain filling rate	Effective filling period	Dry weight of single grain
	(Kilogram per hectare)		(Percent)	(Percent)		(Kilogram per hectare)		(Milligram per day)	(Day)	(Milligram)
Irrigation										
Optimal irrigation (control)	9446a	19240a	49.06a	8.260a	4.913a	779.7a	465.8a	6.492a	35.47a	229.4a
Lack of irrigation while appearance of male corymb	7559c	15910c	47.50a	9.196a	4.352a	693.8a	329.7a	7.488a	34.16a	254.9a
Lack of irrigation in milk stage	8232b	17230b	47.78a	8.803a	4.492a	726.6a	370.7a	5.427a	35.57a	191.3a
Zinc Sulfate spraying										
No spraying (control)	7800c	16280c	47.86a	8.133b	4.234b	632.4c	329.8c	4.693d	35.25a	164.1d
8-leaf stage	8577b	17610b	48.70a	8.594ab	4.478ab	732.4b	386.4b	6.526b	35.13a	227.2b
12-leaf stage	8194bc	17340b	47.16a	9.129a	4.756a	739.9b	394.5b	5.769c	34.70a	198.8c
8- and 12-leaf stage	9077a	18610a	48.73a	9.156a	4.874a	828.7a	444.3a	8.890a	35.19a	310.8a

The means which have similar letters in each column do not have significant difference based on Duncan test in probability level of 5%.

Protein Percentage

The results of the variance analysis showed that the effect of irrigation treatment as well as their interaction with zinc sulfate spraying on the protein percentage was not significant, while the effect of zinc sulfate spraying on this factor, in the 5% probability level, was significant (Table 1). In the case of the effect of zinc sulfate spraying, the maximum amount of protein percentage was observed at spraying treatment at the level of eight and twelve leaves (simultaneous) up to 9.16% and the minimum amount of protein percentage, with a difference of 11%, was observed on without-spraying treatment up to 8.13% (Table 2). Brown *et al.,* (1993) reported that under zinc shortage conditions, total protein percentage of the plant decreases strictly, while the amount of protein compounds almost remain unchangeable. Decreased RNA and modified ribosomes is a mechanism which influences protein synthesis through zinc shortage. Mohseni *et al.,* (2006) suggested that soil consumption of zinc was more effective on increased yield and zinc spraying on improved qualitative properties of corn. The results of this research conformed to the findings of Sheikh Beglou *et al.,* (2009).

Protein Yield

The results of the variance analysis showed that the effect of irrigation treatment as well as its interaction with zinc sulfate spraying on protein yield was not significant, but the effect of zinc sulfate spraying in the 1% probability level was significant (Table 1). In the case of the effect of zinc sulfate spraying, the maximum amount of protein yield was observed on spraying treatment at the level of 8 and 12 leaves (simultaneous) up to 828.7 kg per hectare, and the minimum amount of protein yield, with a difference of 14%, was observed at without-spraying treatment up to 632.4 kg per hectare (Table 2). It is concluded from the results of this research that use of micronutrient fertilizers such as zinc sulfate increases protein yield that can have positive effect on the society health given corn consumption in the society.

To explain the cause of increasing protein percentage of seeds by application of micronutrient elements of zinc and boron, it should be said that zinc plays a direct role in both processes of gene expression and protein synthesis. The researchers concluded that perhaps zinc shortage prevents the activity of some antioxidant enzymes, that consequently, causes oxidative damages to protein molecules, chlorophyll, and nucleic acids (Cakmak, 2000). On one hand, zinc is one of the main ingredients in the structure of polymerase RNA, and in the absence of zinc, this enzyme becomes passive, resulting in decreased RNA amount. This element also is of the main ingredients of Ribosome, and is necessary for maintaining its structure. Decrease in protein content due to zinc shortage in the plant is attributed to decreased RNA of the plant (Lohry, 2007).

Table 3. Mean comparison of the effect of interaction of irrigation cut off and zinc sulfate spraying on grain yield, biological yield, harvest index, qualitative traits and grain growth analysis using Duncan test.

Experimental treatments	quantitative traits			qualitative traits				grain growth analysis		
Interactions (I × F)	Grain yield	Biological yield	Harvest index	Protein	Oil	Protein yield	Oil yield	Grain filling rate	Effective filling period	Dry weight of single grain
	(Kilogram per hectare)		(Percent)	(Percent)		(Kilogram per hectare)		(Milligram per day)	(Day)	(Milligram)
$I_1 \times F_1$	9028a	18420a	49a	7.937a	4.270a	716.2a	383.8dc	4.42f	36.24a	160.1h
$I_1 \times F_2$	9424a	19400a	48.57a	8.08a	4.830a	760.1a	456.7bc	6.27c	35.77a	223.9de
$I_1 \times F_3$	9328a	19060a	48.90a	8.483a	5.313a	789.8a	498.3ab	6.1cde	34.81a	212.3ef
$I_1 \times F_4$	10000a	20090a	49.77a	8.540a	5.240a	852.8a	524.5a	9.18b	35.04a	321.5b
$I_2 \times F_1$	6813a	14150a	48.13a	8.097a	4.163a	548.4a	282.6f	4.96ef	34.70a	170.9h
$I_2 \times F_2$	7765a	16360a	47.47a	9.150a	4.240a	707.8a	330.3ef	8.30b	33.60a	278c
$I_2 \times F_3$	7257a	15570a	46.60a	10.07a	4.450a	721.6a	324.1ef	6.17cd	33.94a	208.6efg
$I_2 \times F_4$	8400a	17570a	47.80a	9.463a	4.553a	797.3a	381.7de	10.52a	34.41a	362.2a
$I_3 \times F_1$	7560a	16270a	46.43a	8.367a	4.270a	632.7a	322.9ef	4.7f	34.81a	161.3h
$I_3 \times F_2$	8540a	17070a	50.07a	8.553a	4.363a	729.4a	372.1de	5def	36.01a	179.8fgh
$I_3 \times F_3$	7999a	17410a	45.97a	8.830a	4.503a	708.3a	361.2de	5.2def	35.34a	175.4gh
$I_3 \times F_4$	8829a	18170a	48.63a	9.463a	4.830a	835.9a	426.6cd	6.97c	36.12a	248.7cd

The means which have similar letters in each column do not have significant difference based on Duncan test in probability level of 5%.

I_1) Irrigation in all stages of growth (control) F_1) no spraying

I_2) Irrigation-off at tasselling stage F_2) spraying in 8-leaf stage

I_3) Irrigation-off at milking stage F_3) spraying in 12-leaf stage

F_4) spraying in 8- and 12-leaf stage

Oil Percentage

The results of the variance analysis showed that the effect of irrigation treatment as well as its interaction with zinc sulfate spraying on oil percentage was not significant, while the effect of zinc sulfate spraying on this factor was significant in the 1% probability level (Table 1). In the case of zinc sulfate spraying, the maximum amount of oil percentage was attributed to spraying treatment in the level of 8 and 12 leaves (simultaneous) up to 4.87%, and the minimum amount of oil percentage, with an almost difference of 13%, to without-spraying treatment up to 4.23% (Table 2). To explain zinc role in increasing oil content of seeds, it should be noted that perhaps zinc shortage prevents some antioxidant enzymes from activating, leading to severe and extensive damages to lipid membranes, and as a result, this element shortage decreases oil content of seeds, but in the presence of zinc, oil content of seeds increases because of improved activity of lipid membrane (Cakmak, 2000). The results of this experiment conformed to the results obtained by Morshedi and Naghibi (2004) and Ghazian Tafrishi (2004).

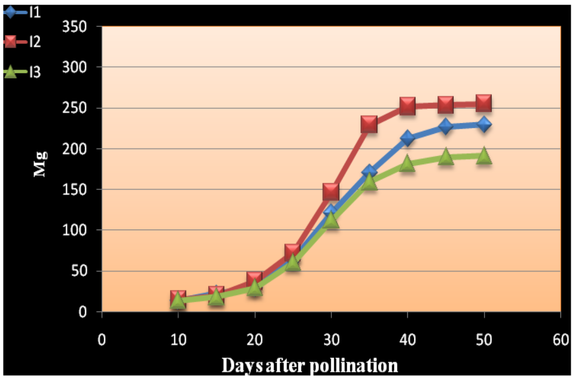

Fig. 1. Process of changes in dry material of a grain influenced by irrigation-off in different growth stages.

Oil Yield

Analysis of the variance of the data surveyed showed that the effect of irrigation treatment on oil yield was not significant, while the effect of zinc sulfate spraying as well as its interaction with irrigation treatment was significant in the 1% probability level (Table 1). In the case of the effect of zinc sulfate spraying, the maximum amount of oil yield was attributed to spraying treatment at the levels of 8 and 12 leaves (simultaneous) up to 444.3 kg per hectare, and the minimum amount of oil yield, with 26% difference, to without-spraying treatment up to 329.8 kg per hectare (Table 2). Similar results have been also reported by Houshmandfar *et al.,* (2010). In addition, the results of mean comparison of interaction of irrigation treatment and zinc sulfate spraying showed that the maximum amount of oil yield from I_1F_4 treatment (favorable irrigation and spraying at the level of 8 and 12 leaves simultaneously) up to 524.5 kg per hectare, and the minimum amount of oil yield with 46% difference from I_2F_1 treatment (irrigation-off on tasselling stage and without spraying) up to 282.6 kg per hectare (Table 3). Because oil yield is a function of grain yield, it seems that irrigation-off at tasselling stage impedes pollination and, consequently, makes hollowness in maize and decreases grain number per ear, and thereby decreasing grain yield, while spraying of low-used elements specially zinc sulfate spraying improves pollination and inoculation, non-hollowness of plan, and modified absorption of elements and increases grain yield. As a result, oil yield increases as well. The findings of this research conformed to the results obtained by Bani Abbas Shahri *et al.,* (2010).

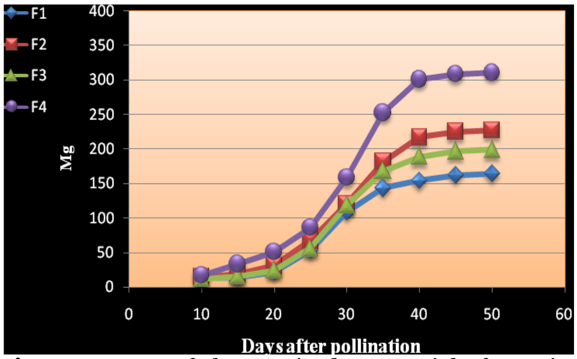

Fig. 2. Process of changes in dry material of a grain influenced by zinc sulfate spraying in different growth stages.

Grain Filling Speed

Analysis of the variance showed that the effect of water stress on the grain filling rate was not significant, while the effect of zinc sulfate spraying as well as its interaction with water stress in the 1% probability level was significant (Table 1). The most grain filling rate was attributed to simultaneous spraying treatment (8 and 12 leaves) up to 8.89 mg/day, and the least amount to without-spraying treatment up to 4.69 mg/day (Table 2). Genetic control seems to be a general phenomenon in all cultivated species. However, two possible points about this setting including availability of nutrients absorbed and other raw materials from the native plant can regulate grain growth rate. In other words, grain filling rate can be considered as a mechanism relating to seed. Indirect evidence obtained from the experiments of change in sink-source indicates that grain growth rate depends on availability of nutrients absorbed by the plant. Change in sink-source treatments may have different effects on grain growth rate depending on the plant growth stage in which these treatments are implemented because grain growth rate only responses to changes in availability of nutrients absorbed by any seed (Kafi *et al.,* 2001). The results of comparison of the average interactions indicated that the most grain filling rate was attributed to I_2F_4 treatment (irrigation-off at tasselling stage and spraying in both 8 and 12 leaves simultaneously) up to 10.52 mg/day and the least speed was attributed to I_1F_1 treatment (favorable irrigation and without spraying) up to 4.42 mg/day (Table 3). Since zinc sulfate spraying treatment had significant effect on grain filling speed, it seems that change in availability of zinc for grain may have the maximum effects on the seed's ability to aggregate dry material (Rafiee *et al.,* 2000).

Effective Period of Grain Filling

The results of analysis of variance showed that the effect of the treatments surveyed as well as their interaction on effective period of grain filling was not significant (Table 1). The results of comparison of the averages showed that the most and least effective period of grain filling were attributed to irrigation-off treatment at milky stage and irrigation-off treatment at tasselling stage with the average of 35.57 days and 34.16 days, respectively. Although these differences were not statistically significant (Table 2), in the case of effect of zinc sulfate spraying, the maximum effective period of grain filling was observed at without-spraying treatment with the average of 35.25 days and its minimum was observed on spraying treatment at the level of 12 leaves with the average of 34.70 days. These differences were not, however, statistically significant.

Grain Dry Weight

Analysis of variance of the data surveyed showed that the effect of irrigation treatment on dry weight of a grain was not significant, while effect of zinc sulfate spraying as well as its interaction with water stress in the %1 probability level was significant (Table 1). The results of comparison of the averages showed that the maximum amount of dry weight of a grain was observed on irrigation-off treatment on tasselling stage up to 254.9 mg and its minimum amount was observed on irrigation-off treatment on milking stage up to 191.3 mg. However, these differences were not statistically significant (Fig. 2). The driest weight of a gain was attributed to simultaneous spraying treatment at the level of 8 and 12 leaves with the average of 310.8 mg and its least to without-spraying treatment with the average of 164.1 mg (Fig. 1).

Irrigation-off at tasselling stage (I_2) had a higher accumulation process of grain dry matter than other levels, and irrigation-off on milky stage (I_3) was at the lowest level (Fig. 1). Sensitivity of flowering stage to humidity shortage, while influencing pollens and increasing their sterility as well as drying silks and stigma all decrease grain number per ear (Rashidi, 2005; Nourmohamadi *et al.,* 2005; Hashemi Dezfouli and Herbert, 1992). Therefore, decreased grain number helps other grains to use photosynthetic materials produced for increasing their weight. It seems that re-irrigation after irrigation-off at flowering stage increases number of grains. So, in irrigation-off treatment in flowering stage, increase in grain weights was higher than that of the other treatments. By studying the results, it can be said that significant increase in grain filling rate under full irrigation-off conditions in flowering stage, due to significant decrease of grain numbers in plant (most likely the cause of impeding in grain inoculation), can be the main factor of increased weight of a grain. Given the relations of the grain yield components, which decrease in each of the components with different degrees is compensated by increase in other yield components, increased weight of a grain can be justified (Motiee *et al.,* 1994). Despite that the grain growth curve in full irrigation treatment was lower that irrigation-off treatment in flowering stage, more number of grains in this treatment caused grain yield in treatment in all the growth stages to be at a higher level than irrigation-off treatment on milky stage, despite less weight of a grain. In milky stage, due to decreased humidity caused by irrigation-off, accumulation of dry matter in grains decreased strictly and caused grain filling rate, and finally grain weights to be decreased.

As shown in Fig. 2, spraying in two stages through supplying the zinc needed increases grain filling rate up to 8.89 mg/day. The reason for this can be considered the effect of zinc on increased nutrient accumulation speed in grain. Significant increase of filling rate in this treatment compared to other treatments made more accumulation of dry matter in this treatment, because filling period of these four treatments do not differ. Positive correlation of absorption of zinc with potassium and nitrogen percentage usually indicates the role of these elements' absorption in increasing grain filling rate. Therefore, it seems that zinc absorption by itself has no role in increasing grain filling rate, and by providing the possibility of absorption of other elements, it is effective in increasing grain filling rate.

Conclusion

Given the results obtained from the present experiment, it can stated that occurrence of water stress has a significant effect on decreasing grain yield and biological yield of corn , particularly when this stress occurs at flowering stage, a considerable decrease in yield is observed. However, since water stress decreases grain and biological yield at the same extent, effect of irrigation levels on harvest index was not significant. Tasselling stage is one of the important growth stages of corn, that by irrigation-off at this stage, grain yield and biological yield decrease significantly, while milky stage is less sensitive to irrigation-off. Supplying water needed by the corn and using micronutrient fertilizers increase grain yield, but increased water stress has negative effect on grain filling, and decreases grain inoculation through increasing time interval of pollination and appearance of silks, non-acceptance of pollens by the silk due to their humidity deficiency, and finally, decreases grain yield.

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