Effect of Water Deficit and Salinity Stress on Grain Yield of Maize

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Abstract: This research was carried out to study the effect of water deficit and salinity stress on grain yield (GY) of hybrid maize KSC-500 during different growth stages under Ahwaz climatic conditions in the growing season of 2010-2011. The research program consisted of three levels of irrigation water application, I_1, I_2, I_3 respectively 100, 75 and 50 % of plant water requirement and three levels of salinity of irrigation water, S_1, S_2, S_3 respectively salinity of river water (S_1), S_1+1 and S_1+2 ds m^{-1} during three growth stages as vegetative (Experiment 1), flowering (Experiment 2) and after flowering (Experiment 3). These experiments had three replications according to a randomized complete block design with split plot layout. Results showed that the water deficit and salinity stress had a significant effect on GY. A maximum GY was obtained from I_2 treatment in experiment 1 and from I_1 treatment in other experiments. Also, maximum GY was also obtained from S_1 in all the experiments. Collected data indicated that after flowering stage is more sensitive growth stage to water deficit and salinity stress.

Key words: Water deficit · Salinity stress · Maize · Ahwaz

INTRODUCTION

When the available water supply volume or its quality is severely limited, water deficit and salinity stress is expected to occur during the growing period. Scheduling of irrigation timings becomes more complex, because irrigation decisions have to be based not only on the relationships between grain yield, crop growing phase and crop water use, but also on water availability and its quality. These are the most important environmental stresses affecting agricultural productivity worldwide which can result in considerable yield reductions [1]. Knowledge about crop response to water deficit stress under certain environmental conditions can help develop strategies to minimize crop damage or yield reductions with limitations on water supply and quality.

Studies on the effects of water deficit stress on grain yield has shown that water deficits at certain growth stages can be helpful for increasing crop yield [2]. Under water deficit and salinity stress, reductions in grain yield due to restricted water availability depend on the degree, duration and timing of the imposed stress. Water stress imposed on maize during reproductive stage resulted in more yield reduction than that during vegetative stage, compared to fully irrigated treatment [3]. Water deficit stress during flowering stage is most harmful to the crop, while during grain filling stage, it is less so compared to the vegetative stage [4]. On the contrary of this study, is reported the effect of water deficit stress during early vegetative growth was more severe than that during the grain filling growth stage [5]. Few studies have been done for finding the effect of salinity stress on maize at different growth stages. The effect of salinity stress during and just before flowering stage is reported more severe than that during flowering and after flowering stages [6]. It is found that the yield of spring maize was not affected when electrical conductivity of saturated paste did not exceeded 1.2 dS m^{-1} [7]. Studies related to water deficit and salinity stress on maize in Iran is new. The present study was carried out with the objective of evaluating interactive effect of water deficit and salinity stress on grain yield of maize during different growth stages under Ahwaz climatic conditions.

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MATERIALS AND METHODS

Field experiments were carried out on the Agricultural Experimental Station of the faculty of water sciences engineering, Shahid Chamran University, Ahwaz, Iran (latitude 31° 20'N, longitude 48° 40'E, altitude 20m). Soil characteristics of the experimental site is shown in Table 1. The water table through the year varied between 3.1 and 4 m from the soil surface, it was always below the root zone and did not affect the crop water extraction pattern. These experiments had a net plot size of 3.0×3.0 m. Grains of maize (*Zea mays* L.) cv. Single Cross (KSC-500) was sown on August 5, 2010 on 75 cm apart furrows and harvested on around November 23, 2010. The seedling density was around 70000 plants ha^{-1}. Chemical fertilizers (P, K) were applied as base fertilizer at the rate of 60 kg ha^{-1} for both P and K. Nitrogen was applied in three periods respectively after sowing, 15 and 45 days after sowing at a rate of 350 kg ha^{-1}. The regular tillage and agricultural operations of the maize grown on this location were practiced. All other agronomic practices were identical for all the treatments. The research program consisted of three levels of the irrigation water, I_1, I_2, I_3, respectively 100, 75 and 50 percent of plant water requirement and three levels of irrigation water salinity, S_1, S_2, S_3, respectively salinity of river water (S_1), S_1+1 and S_1+2 ds m^{-1}. The experiments had three replications according to a randomized complete block design with split plot layout during vegetative (experiment 1), flowering (experiment 2) and after flowering growth stages (experiment 3).

EC values for irrigation water quality treatments are shown in Table 2. T_1 refers to Karoon river water with salinity, S1. T_2 and T_3 treatments were formulated using T_1 water as the base, to which different amounts of NaCl, Ca_2Cl and Mg_2Cl were added. T $_2$and T $_3$waters were constituently mixed with proportions of the three added salts to maintain an SAR value equal to SAR value of T_1. Ca to Mg ratio of T_2 and T_3 waters were kept close to the Ca to Mg ratio of T_1 water [8]. Chemical characteristics of the irrigation waters are shown in Table 2.

Irrigation schedule was carried out with the use of a non salinity and water stress treatment as a control plot by measuring soil moisture content using a time domain reflectometery (TDR) apparatus at 20 cm depth intervals down to 80 cm. The soil was irrigated when 50 % of the available soil water was depleted. Water deficit stress treatments were based on soil moisture deficit and the control treatment as a base by applying the following equation:

$$SMD = (\theta v_{fc} - \theta v_i) \times D \times F \qquad (1)$$

In this equation: SMD: soil moisture deficit (mm), θv_{fc} and θv_i are percent of volumetric water content in field capacity and soil water content, respectively, D: root depth (mm) and F: coefficient of treatments (%). Irrigation was conducted manually by connecting a hose to a water hydrant, with a flow meter to record the amount of water applied. Water deficit and salinity stress were performed only twice at each growth stages and other irrigations were complete without deficit.

Table 1: Soil characteristics of the experimental location

Depth (cm)	Particle size (%)			Soil texure	Bulk density (gr cm^{-3})	Fild capacity (%)	Permanent wilting Point(%)	(Ece) (ds m^{-1})
	Sand	Silt	Clay					
0-30	25.3	52.1	22.6	Silty loam	1.40	22.50	11.00	2.50
30-60	25.0	51.5	23.5	Silty loam	1.55	22.00	10.50	2.60
60-90	25.1	51.7	23.2	Silty loam	1.60	22.00	10.50	2.50

Table 2: Chemical characteristics of the irrigation water

Experiment Number	Treatment Name	EC (ds m^{-1})	Ca^{2+} (meq L^{-1})	Mg^{2+} (meq L^{-1})	Na^+ (meq L^{-1})	pH
1	T_1	2.4-2.6	10.0	3.5	12.0	7.82
	T_2	3.5-3.7	14.5	6.0	15.0	7.83
	T_3	4.5-4.7	18.0	9.0	19.0	7.83
2	T_1	2.7-2.9	12.0	4.0	13.0	7.82
	T_2	3.8-4.0	15.5	7.5	16.5	7.83
	T_3	4.8-5.0	19.0	10.5	20.5	7.84
3	T_1	2.8-2.9	12.0	5.0	14.0	7.83
	T_2	3.8-4.0	15.5	7.5	16.5	7.84
	T_3	4.8-5.0	19.0	10.5	20.5	7.84

Representative plant samples were collected from mid furrows in the polts after removing 0.5 m margins from top and bottom of furrows 110 days after sowing. After harvest, grain yield at 14 % moisture was recorded.

Analysis variance of the data were performed with MSTATC software. Duncan's Multiple Range Test (DMRT) was employed to compare the differences among the treatments means.

RESULTS AND DISCUSSION

Analysis of variance and comparison of the averages of grain yield are shown in Tables 3 and 4.

Data presented in Table 3 show that salinity stress (increasing salinity of irrigation water in two irrigations) at the vegetative growth stage significantly affected the grain yield at 1% probability level but water deficit stress (deficit irrigation in two irrigations) and the interaction of water deficit and salinity stress did not have any significant effect on grain yield. The application of I_2 treatment (use of 75% plant water requirement in two irrigations) produced the maximum grain yield and I_1 and I_3 treatments showed respectively 10.60 and 17.30 % reduction with respect to I_2, although the yield loss was significant only for I_3 treatment. As a result, the grain yield at 25 % water deficiency (75% plant water requirement in two irrigations) was high. Previous research showed that maize appears to be relatively tolerant to water deficits imposed during the vegetative and ripening periods [9]. Also, maize under vegetative water stress utilize an adaptive strategy that involve the extension of the root depth and increase water extraction from the deeper soil profile [10].

By increasing water salinity from S_1 to S_2, significant reduction was not observed in grain yield but increasing water salinity to S_3, did significantly reduced grain yield. S_1 treatment gave the maximum grain yield while the minimum was given by S_3 treatment. At S_3 and S_2 treatments, grain yield showed 10.80 and 22.50 % reduction with respect to S_1, respectively. Grain yield decreases by approximately 11% for each 1 dS m^{-1} increase in the electrical conductivity of irrigation water. Results show that water deficit stress at flowering growth stage significantly affected the grain yield at 5% probability level but salinity stress and the interaction of water deficit and salinity stress did not have any significant effect on grain yield (Table 3). However, maximum grain yield was obtained from I_1 treatment. I_2 and I_3 treatments showed respectively 7.40 and 16.0 % reduction with respect to I1 and the yield loss was

Table 3: Analysis of variance of GY

Experiment Number	Source	df	Mean Squares Grain Yield
1	Water Deficit Stress (I)	2	1.82
	Error	4	0.39
	Salinity Stress (S)	2	3.20*
	I * S	4	0.29ns
	Error	12	0.20
2	Water Deficit Stress (I)	2	1.94**
	Error	4	0.15
	Salinity Stress (S)	2	0.17ns
	I * S	4	0.05ns
	Error	12	0.12
3	Water Deficit Stress (I)	2	2.38*
	Error	4	0.06
	Salinity Stress (S)	2	8.33*
	I * S	4	0.27ns
	Error	12	0.25

*, ** Significant at 1% and 5%, respectively. ns: non significant

Table 4: Comparison of the means of GY*

Experiment Number	Treatments	Grain Yield (ton ha^{-1})
1	I_1	4.65^a
	I_2	5.20^a
	I_3	4.30^a
	S_1	5.28^a
	S_2	4.71^{ab}
	S_3	4.09^b
2	I_1	5.81^a
	I_2	5.38^{ab}
	I_3	4.88^b
	S_1	5.50^a
	S_2	5.36^a
	S_3	5.22^a
3	I_1	6.20^a
	I_2	5.42^b
	I_3	5.21^b
	S_1	6.70^a
	S_2	5.21^b
	S_3	4.90^b

* Means followed by the same letter are not significantly different at 5%

significant only for I_3 treatment. It is reported that the highest reduction in grain yield occurred at flowering growth stage due to reduction in the number of grains per ear [9]. These results are in confirmation with others [11, 12].

Data presented in Table 3 show that water deficit and salinity stress during after flowering growth stage significantly affected the grain yield at 1% probability level, but the interaction of water deficit and salinity stress did not have any significant effect on grain yield. The application I_1 treatment produced the maximum grain yield. I_2 and I_3 treatments showed respectively 12.60 and

16.0 % reduction with respect to I_1 and the yield loss was significant. As a result, this growth stage is more sensitive to water deficit and salinity stress than other growth stages. The effect of water deficit stress after flowering growth stage was demonstrated more severe than that during other growth stage [13].

By increasing water salinity from S_1 to S_3, significant reduction was observed in grain yield. S_1 treatment gave the maximum grain yield while minimum grain yield was given by S_3 treatment. At S_3 and S_2 treatments, grain yield showed 22.80 and 26.90 % reduction with respect to S_1, respectively. Grain yield decreases by approximately 13% for each 1 dS m^{-1} increase in the electrical conductivity of irrigation water. These findings are in agreement with other study who stated that the depressing effects of salinity stress were comparatively high, at after flowering growth stage [6].

CONCLUSION

The interaction of water deficit and salinity stress in all the experiments, did not have any significant effect on grain yield. It was shown that the vegetative growth stage is the least sensitive to water deficit and salinity stress and the grain yield at 25 % water deficiency (75% plant water requirement in two irrigations) was high. Grain yield decreases by approximately 11% and 13 % for each 1 dS m^{-1} increase in the electrical conductivity of irrigation water during vegetative and after flowering growth stages, respectively. Data collected showed that the after flowering stage was the most sensitive growth stage to water deficit and salinity stress.

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