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Responses to Limited Irrigation and Water Use Efficiency in new Maize Hybrids in Warm Climate of Iran

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ABSTRACT

This study was conducted in 2008 to evaluate the effects of deficit irrigation on grain yield and water use efficiency of new promising maize hybrids at Safiabad Agricultural Research Center of Dezful. The experimental design was a randomized complete block with strip plot arrangement of treatments. Irrigation was considered as the main factor at levels including: control (no water stress) and deficit irrigation during the vegetative growth, anthesis and grain filling stages. Maize hybrids were also considered as sub-factor at six levels including: H_1, H_2, H_3, H_4, H_5, H_6, and KSC704 as control. Irrigation was applied after the depletion of 45 and 65% of available water in soil. Results indicated that in control treatment, the volume of water used and grain yield were 7530.84 m^3/ha and 7088.45 kg/ha, respectively. Deficit irrigation treatments applied during the vegetative growth, anthesis and grain filling stages used 1678.7, 564.5 and1074.7m^3/ha less water than control, respectively. Grain yields in deficit irrigation treatments were also reduced by 1223.14, 827.8, 491.6 kg/ha during the similar stages compared to the control. H_4 had the highest economic efficiency in both deficit irrigation and control treatments by producing a grain yield of more than 1 kg.

KEYWORDS: maize, growth stage, tolerant, water

INTRODUCTION

Efficient water allocation in crop plants production, generally entails a correct relationship between the amount of irrigation water and the crop yield. The reduced water consumption management focuses not only on reducing the volume of water used during each stage of plant growth but also on decreasing the water consumption during the whole growth period (Sepaskha and Parand., 2006). To recommend using deficit irrigation methods without properly understanding its strategies, results in considerable yield losses and causes damage to the farmers while paying attention to the principles of deficit irrigation in a planned way would be economically useful. The primary reaction of plants when confronting drought is stomatal closure which causes a reduction in both plant's rate of photosynthesis and dry matter production (Ahmadi and Baker., 1991). The effects of deficit irrigation on grain yield in maize, varies during various growth stages. Cakir (2004), for example, reported that deficit irrigation during the early growth stages and flowering stage in maize, reduced the grain yield by 13%. According to another experiment, the effect of drought stress during the grain filling stage on final corn kernels weight, especially those located at the end of ears, was significant (Kemara et al, 2003). New maize hybrids bred for drought tolerance during the recent studies conducted throughout international research centers, demonstrate desirable responses in this regard with an up to 30% increase in dry matter production when planted in drought-stricken areas (Barzegari, 2003). Kemara *et al.* (2003) also observed that improved maize hybrids had higher tolerance to drought stress. Edmeades *et al.* (1995) reported that drought stress reduces the annual global yields of corn by 17%. According to another report, when drought stress occurs during the flowering period in maize, its effect will be much greater up to about 70% (Filintas *et al*., 2008). Westgate and Boyer (1995) demonstrated that tassels appeared later compared to normal conditions when maize plants were subjected to water stress that led kernels to become non-uniform, highly shriveled and occasionally aborted at the end of ears. Belanos and Edmeades (1993) reported that when under drought stress, the number of fertilized kernels in maize was reduced by 28% with increasing the intervals between the appearance of reproductive organs to one day while when these intervals increased to 3 and 5 days, the number of fertilized kernels was reduced by 55% and 69%, respectively. Velesker *et al.* (2007) reported that the maximum leaf length in maize under non-stress conditions was recorded during the vegetative growth stage. Joe (2003) attributed the shortening of grain filling period in maize under drought stress conditions to the accelerated aging of leaves and a reduced rate of

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current photosynthesis. Filintas *et al.* (2008) reported that under the certain circumstances of their study, the highest maize yield was obtained by irrigation in 9-day intervals followed by 12-day intervals while the lowest yield was obtained by irrigation in 15-day intervals. According to Yazar *et al.* (2002), drought stress during vegetative growth stage in maize affected all its morphological characteristics and reduced the plant height considerably, in particular. Dioudis *et al.* (2008) reported that irrigating a maize field from the time where the first strings of silk appear (initiation of fertilization) to the beginning of grain milky stage, is of particular importance. Hubick *et al.* (1990) demonstrated that grain yield in sorghum was positively correlated with its water use efficiency. Otegul *et al.* (1995) also reported an increase in water use efficiency under drought stress conditions. They attributed this to the water wastes during evapotranspiration and the vertical infiltration of water in full irrigation treatments. Saneei Nejad (2008) reported that changing the planting pattern to the furrow-bed caused a significant reduction in water used in maize and increased its water use efficiency. Majidian *et al.* (2008) stated that deficit irrigation based on 50 and 75% of plant's requirement, reduced the maize grain yield by 63 and 41%, respectively. Emam and Ranjbar (2000) investigated the impact of water deficit on maize and reported that drought stress significantly reduced both the grain yield and biomass. Majidian (2000) also reported that drought stress thwarted the desirable impacts associated by the application of N fertilizers on maize yield.

This study was carried out in Safiabad Agricultural Research Center (Khuzestan Province-Iran) in 2008 to investigate the impacts of deficit irrigation on grain yield and irrigation water use efficiency index in new maize hybrids and the possibility to reduce the amount of water used during some of the growth stages of this crop.

MATERIALS AND METHODS

This experiment was carried out in summer of 2008 in Safiabad Agricultural Research Center in a randomized complete block design (RCBD) as strip-plots with four replications comprising of four main factor and seven sub-factor levels. The climate conditions in the year of experiment and the results of soil analysis are presented in tables 1 and 2, respectively. The levels of main factor included four treatments: control deficit irrigation (I_1) and deficit irrigation during vegetative growth (I_2), anthesis (I_3) and grain filling (I_4) stages. The levels of sub-factor included six new maize hybrids: H_1, H_2, H_3, H_4, H_5 and H_6 together with SC 704 hybrid as control (H_7). Table 3 shows the parental formula of the maize hybrids used in this experiment. The bed preparation operations were conducted using plow, disc and leveler and fertilization was completed based on the soil test results (table 1) using the fertilizing sources. This was done by adding one third of required nitrogen as 75 kg ha^{-1} N from a urea source, 150 kg ha^{-1} P_2O_5 and 150 kg ha^{-1} K_2O from ammonium phosphate and potassium sulfate sources, respectively as base fertilizers. The fertilizer amounts listed above were then calculated and weighted for the area in which the experiment was conducted, broadcasted over the field after the leveling operation and mixed with the soil. The remaining two third of nitrogen was applied as top-dress at 6-leaf and reproductive organs emergence stages by weighting the required amount for the experimental plots and placing the fertilizer as strips along the rows of maize and then irrigating the field. A furrower was used after broadcasting the base fertilizer to create 75-cm rows. The maize hybrids were then planted on 23rd of July (the most suitable sowing date in North of Khuzestan). Each hybrid in this experiment was planted in six rows, 6 m long. The irrigation treatments were separated using 3 blank (not planted) rows. Irrigation treatments applied since approximately the 4-leaf stage (10 days after emergence) included:

1- Normal irrigation (control) treatment (I_1): From the emergence to seed physiological maturity after the depletion of 45% of available water in soil, 2- Deficit irrigation during vegetative growth stage (I_2): From the 4-leaf to flowering (reproductive organs emergence) stage after the depletion of 65% of available water in soil, 3- Deficit irrigation during anthesis stage (I_3): From the beginning to the end of fertilization after the depletion of 65% of available water in soil, and 4- Deficit irrigation during grain filling stage (I_4): From the end of fertilization to seed physiological maturity after the depletion of 65% of available water in soil. Soil samples were taken from the root expansion zone in 0-30 and 30-60 cm depths every two days. The available water was then calculated based on the soil water potential by weighting the samples before and after drying in the oven using the weighting method and irrigations were made accordingly. To determine the volume of water used in each round of irrigation, a hydro-flume system equipped with counters installed both parallel to the direction of pumped water flow and inside the reservoir. The inlet water flow was therefore cut-off or connected into the experimental treatments through opening and closing of hydro-flume gates. The volume of water used was recorded by writing down the number shown on the counter before and after each irrigation to calculate both economic and biological water use efficiency using the equations proposed by Alizadeh (1999). Economic and biological water use efficiencies (kg m^{-3} of water consumed) were obtained respectively by dividing the grain yield and biological yield on m^3 of consumed water. After the grain physiological maturity, two rows 4 m long were harvested and the grain yield per hectare was recorded based on 14% moisture. In order to determine the biological yield and harvest index, samples of five plants were cut from the surface and dried in 60°C oven for 48h. The 1000-kernel weight and ear characteristics including the number of kernel rows, number of kernels per row and number of kernels per ear were then measured and recorded for 5 ears selected from each treatment. Analysis of variance (ANOVA) of data was carried out using the MSTATC software and mean comparisons were made using Duncan's multiple range tests.

Table1. Chemical and physical properties of experimental field soil

Sampling depth (cm)	E.C. ($dS.m^{-1}$)	pH	Available nutrients			Soil texture	O. C (%)
			N (%)	P ($mg.kg^{-1}$)	K ($mg.kg^{-1}$)		
0-30	0.61	7.33	0.00314	8.3	152	Silty clay loam	0.88
30-60	0.52	7.50	0.002	6.2	138		0.62

Table2. Climatic and meteorological characteristics of Safiabad region (Dezful-Iran)

Month	Decade	Temperature (°C)		Wind speed ($m.s^{-1}$)	Relative humidity (%)	
		Max.	Min.		Max.	Min.
Jul.	3	48.28	27.23	5.50	50.60	10.00
Aug.	1	51.64	30.84	5.50	55.70	12.00
Aug.	2	41.52	26.31	5.09	58.09	14.82
Aug.	3	42.56	28.01	5.10	60.50	15.50
Sep.	1	44.12	28.31	7.80	78.90	33.50
Sep.	2	41.60	24.08	4.72	78.54	35.83
Sep.	3	42.76	22.60	4.84	87.12	29.92
Oct.	1	41.03	22.90	4.18	91.41	30.91
Oct.	2	36.65	17.85	4.19	81.69	29.49
Oct.	3	33.30	19.00	6.71	96.91	52.14
Nov.	1	27.39	15.16	3.52	107.14	69.30
Nov.	2	26.65	10.84	3.69	104.20	54.30

Table3. Characteristics of maize hybrids used in the experiment

Hybrid	Parent lines	Growth period (day)	Hybrid
H1	SLDE48/2/2/1× SLH2/10/25/1	116	Late
H2	SLD1/9/4/2/7/1× SLH2/10/25/1	116	Late
H3	SLD1/9/4/2/7/1× MO17	116	Late
H4 (SC Karoun 701)	SLD45/1/2/1-2 × MO17	116	Late
H5	SLD1/9/4/2/7/1 × SLH2/29/14/2	116	Late
H6	SLH H2/1/9/2/1 × SLH2/10/25/1	116	Late
H7 (SC 704)	MO17 B73 × Commercial cultivar (Control)	124	Late

RESULTS AND DISCUSSION

Results of measuring the volume of water used, ANOVA and mean comparison between deficit irrigation treatments for their impact on yield components are presented in tables 4, 5 and 6. According to the results, 1678.7, 564.5 and 1074.7 m^3 less water was used in deficit irrigation treatments applied, respectively, during vegetative growth, anthesis and grain filling stages compared to that of control treatment (Table 4) and the application of these treatments also decreased the grain yield by 1562.8, 831.2 and 476.8 $kg.ha^{-1}$, respectively (Table 6). In other words, the application of deficit irrigation treatment during the vegetative growth stage decreased water consumption by 3.22% and grain yield by 22% compared to control treatment while the application of the same treatment during the anthesis stage decreased both water consumption and grain yield by 5.7 and 11.7% compared to control treatment and finally, the same treatment applied during the grain filling stage also decreased water consumption by 14.27% and grain yield by 6.7% compared to that of control treatment. These findings, therefore, suggest that deficit irrigation during the grain filling stage caused a lower yield loss considering the amount of water saved while deficit irrigation during the anthesis stage caused the greatest loss of yield. Results obtained here in terms of different growth stages being influenced differently by deficit irrigation are in agreement with those reported by Dioudis (2008) and, Brevedan and Egli (2003) suggesting that supplying the water requirements of maize from the appearance of the first strings of silk (initiation of fertilization) to the grain milky stage, is of particular importance. Denmend and Show (1962) also reported that water stress decreased the grain yield by approximately 25, 50 and 21% when imposed before, during and after the silking in maize and as can be seen, the trend of changes in yield loss in this study is consistent with that of the current study. Results obtained in current study also suggest that some irrigation rounds during the grain filling stage could be removed while accepting yield reductions in amounts reported by applying the irrigation deficit treatment mentioned above w when e decide to adopt a deficit irrigation management in maize and if the available water becomes more limited, some of the irrigation rounds could also be removed during the vegetative growth stage but removing even one round of irrigation during the anthesis stage which equals 7.5% of total water used caused a 7.11% reduction in yield. As can be seen in table 6, while deficit irrigation had no significant effect on 1000-kernel weight and yield reductions due to deficit irrigation during the anthesis stage were lower than those of other growth stages, but imposing the deficit irrigation during the grain filling stage decreased the 1000-kernel weight by 72 g compared to control treatment and it seems that a 500 kg reduction in grain yield caused by deficit irrigation treatment during the grain filling stage compared to that in control treatment was also occurred due to the same reason. The number of kernels per row and the number of kernel rows per ear were two other traits influenced by deficit irrigation representing highly significant differences among the hybrids (Table 5). Table 6 also suggests that deficit irrigation during the vegetative growth stage caused the greatest decrease in the number of kernels per row, reducing the number of kernels per row by approximately 9 compared to control, but the effects of deficit irrigation during both vegetative and anthesis stages on decreasing the number of kernel rows per ear were the same and deficit irrigation caused a decrease in the number of kernel rows per ear from 14.5 rows in control treatment to 12. 2 and 12. 1 in deficit irrigation treatments during vegetative and anthesis stages, respectively.The numbers of kernels set and filled under drought stress accounts for most of the variation in maize grain yield under drought. Bolaños and Edmeades (1996), Edmeades *et al*. (2000), Barker *et al* (2005). Mean comparison results for maize hybrids also show that H4 was evidently superior compared to other hybrids in terms of all yield components. It had the highest number of kernel rows per ear with an average of 14 rows and was in the same statistical group along with some other hybrids in terms of the number of kernels per row and 1000-kernel weight with respective averages of 38.7 and.372.2. Table 6 also shows that the average of grain yield of H4 was 7239 kg ha^{-1}, 1000 kg more than control, while the lowest grain yield belonged to H_2 with an average of 5510.7 kg ha^{-1}. The interaction between deficit irrigation and hybrid also showed that H_4 and H_5 had the highest grain yield while H_6 and H_1 had the highest biological yield in full irrigation treatment (Table 7). H_6 and H_1 grain yields, however, were more affected by deficit irrigation during the grain filling stage compared to other hybrids. The maize hybrids studied here seem to be different in terms of physiological characteristic of carbohydrates translocation to kernels under deficit irrigation conditions during grain filling stage. However, the higher grain yields of H_4 and H_5 under both full and deficit irrigation conditions suggests their higher relative tolerance to deficit irrigation. Results obtained in the current study in terms of differences observed between hybrids for their response to deficit irrigation are consistent with those reported by Eadmedes *et al.* (1995), Stegma *et al.* (1980) and Yazar *et al.* (2002). They found that maize hybrids responses to deficit irrigation were not the same and different hybrids showed different reactions to water deficit stress due to differences in both their morphological and physiological characteristics. Banziger *et al.* (1997) and Eadmedes *et al.* (1995) also reported difference between maize lines and hybrids in terms of their tolerance to deficit irrigation. Results of deficit irrigation and hybrid interaction effect on biological yield, harvest index and economic yield and also the results of both economic and biological water use efficiency calculations are presented in table 7 (Despite no significant difference in grain yield interaction effect, this trait has also been listed in order to calculate economic and biological water use efficiencies). H_3, control and H_4 had the highest biological water use efficiency among deficit irrigation treatments while H_3 had the lowest. H_4 had the highest economic water use efficiency among both control and deficit irrigation treatment with a grain yield of more than a kg (Table 7). Maximum biological and economic yields of maize hybrids in deficit irrigation treatments presented in table 7 would also be discussed separately. H_4 and H_6 had the highest economic and biological water use efficiencies in deficit irrigation treatment during the vegetative growth stage with an average grain yield of 1.16 kg and an average biological yield of 2.28 kg per m^3 of water used. H_4 and H_1 had also the highest economic and biological water use efficiencies in deficit irrigation treatment during the anthesis stage with an average grain yield of 1.05 kg and an average biological yield of 2.09 kg per m^3 of water used. H_4 and H_5 had the highest economic and biological water use efficiencies in deficit irrigation treatment during the grain filling stage with an average grain yield of 1.12 kg and an average biological yield of 1.99 kg per m^3 of water used. As it can be seen, H_4 had the highest economic yield in all irrigation treatments. The interaction effect of deficit irrigation and maize hybrids also demonstrated that H_4 had the highest biological and grain yield under deficit irrigation during vegetative growth stage with an average of 12512.5 and 6791.5 kg ha^{-1}, respectively. H_4 had also the highest grain yield with an average of 7349.5 kg ha^{-1} under deficit irrigation during the anthesis stage while H_1 had the highest biological yield with an average of 14603 kg ha^{-1} under the same conditions. H_4 and H_5 had the highest grain and biological yields with an average of 7075 and 12890 kg ha^{-1}, respectively, under deficit irrigation treatment during the grain filling stage**.** In another study comparing varied drought-tolerant hybrids and controlled water stress treatments, hybrid differences were observed with water stress occurring 1 week prior to flowering, but not when stress was imposed 3 weeks prior to flowering (Bruce et. al, 2002). The harvest index in control and deficit irrigation treatments during vegetative growth, anthesis and grain filling stages was highest in H_4, H_5, H_6 and H_4 with an average of 40.8, 57.6, 57.6 and 59.9, respectively. It could, therefore, be suggested that H_4 may be recommended to the farmers due to its suitable economic and biological efficiencies. The differences among the maize hybrids in terms of their water use efficiency has been proven through the studies conducted by most of the researchers and the extensive maize breeding experiments conducted in international research centers in order to develop hybrids that are tolerant to deficit irrigation are based on the same idea.

Nissanka *et al.* (1997) reported that old and modern maize hybrids are significantly different in their water use efficiency. Results of the current study are also consistent with those obtained by Al-Kaisi and Xinhua (2003) in terms of the impact of deficit irrigation on biological yield in maize. They reported that drought stress reduced the water use efficiency for the production of biological yield but somewhat increased it for the production of economic yield in maize. In other words, some maize hybrids with higher water use efficiency are more tolerant to deficit irrigation and this is associated with the tolerance of their parent lines. Several breeding studies have also shown that maize lines and hybrids are genetically different in terms of their economic and biological water use efficiency. Jeanneau *et al.* (2002) demonstrated that transgenic lines of maize developed to increase the water use efficiency, had 30% higher water use efficiency due to their potential to recycle the PEP carboxylase. Lebreton *et al.* (1995) have also found during their molecular studies that there are multiple genes in maize DNA structure that regulate drought tolerance through increasing the water use efficiency. And also Edmeades *et al*. (2006) demonstrated research suggests that deeper roots are needed rather than an increase in root biomass, and variation for root depth occurs among genotypes.

Table 4. Irrigation water volume in water stress treatment of maize hybrids (2007).

Growth Stage	**Growth period (days)**	**Irrigation round**	**Control**	**Deficit irrigation during the vegetative stage**	**Deficit irrigation during the anthesis stage**	**Deficit irrigation during the grain filling stage**
			Irrigation m^3/ha			
		First	845.25	845.25	845.25	845.25
Germination to establishment	18-22	2th.	598.71	598.71	598.71	598.81
		3th.	670.20	670.20	670.20	670.20
		Total	2114.16	2114.16	2114.16	2114.16
		4th	556.33	000000	556.33	556.33
		5th	601.70	601.70	601.70	601.70
Vegetative growth stage	30-34	6th	548.18	000000	548.18	548.18
		7th	519.31	519.31	519.31	519.31
		8th	574.24	000000	574.24	574.24
		Total	2799.77	1121.01	279977	2799.77
		9th	540.41	540.41	540.41	540.41
Anthesis stage	12-15	10th	564.50	564.50	000000	564.50
		Total	1104.91	1104.91	540.41	1104.91
		11th	515.31	515.31	515.31	000000
Grain filling stage to seed maturity		12th	437.25	437.25	437.25	437.25
	50-54	13th	559.43	559.43	559.43	000000
		14th	1511.99	1511.99	1511.99	1511.99
		Total	7530.84	5852.08	6966.34	6456.09

Table 5. ANOVA of the effect of drought stress on grain yield and its components in new maize hybrids

S.O.V	**DF**	**1000 KW[1]**	**NKE[2]**	**NKR[3]**	**NRE[4]**	**HI[5]**	**GY[6]**	**BY[7]**
Replication	3	1705.58^{ns}	7797.34^{ns}	63.86^{ns}	2.38^{ns}	0.015	47911.6^{ns}	42387799.9^{ns}
Irrigation(I)	3	26217.30^{ns}	326948.10**	553.2**	51.90**	0.045*	7530211.8**	1884913350.0**
Erreor	9	13342.88	5818.49	33.48	1.14	0.007	183010.45	36387347.7
Hybrid (H)	6	2125.29*	27021,24**	63.06**	3.57**	0.045*	6641643.3**	17120689.8^{ns}
Erreor2	18	710.19	1584.91	5.18	0.59	0.067	1128443.1	15106535.3
I × H	18	488.83^{ns}	1545.56^{ns}	2.40^{ns}	0.69^{ns}	0.012*	200708.8^{ns}	30215451.6*
Erreor	54	717.49	2130.01	6.86	0.81	0.004	160858.74	17811182.7
CV (%)		12.9	9.28	7.11	6.76		6.22	16.88

ns: Non-Significant

*, **: Significant at 5% and 1% level of probability

1 = 1000-kernel weight, 2 = Number of kernels per ear, 3 = Number of kernels per row, 4 = Number of kernel rows per ear, 5 = harvest index, 6 = Grain yield, 7 = Biological Yield

Table 6. Mean comparison for grain yield and its components in maize hybrids under deficit irrigation treatments

TRE[1]	HI[2] (%)	BY[3] ($kg.ha^{-1}$)	1000 KW[4] (g)	NKE[5]	NKR[6]	NRE[7]	GY[8] ($kg.ha^{-1}$)
I1	36.38c	19479.47a	399.4a	584.7b	40.0a	14.5a	7088.45a
I2	51.18ab	11459.72b	377.3a	387.3d	31.6c	12.2b	5865.31d
I3	51.23ab	12219.38b	361.7ab	422.1c	34.7b	12.1b	6260.95c
I4	55.95a	11789.04b	326.7ab	595.87a	41.4a	14.5a	6596.92b
H1	42. 54b	14239.7 ab	351.2 c	447.50c	34.4b	12.8c	6057.6d
H2	48.43a	11378.7 ab	361.7bc	460.7bc	35.6b	13.6b	5510.7e
H3	42.47 b	14469.2 ab	355.1bc	469.3bc	35.0b	13.2 b	6145.1d
H4	42.35b	17093.9ab	372.2ab	548.4a	38.7a	14.0a	7239.3a
H5	41.12 b	17178.7 ab	384.1a	542.5a	38.6a	13.9b	7063.9b
H6	37.30 bc	17394.0a	366.6abc	525.2a	38.9a	13.3b	6493.2c
H7	42.62b	14625.5 ab	373.9ab	487.3b	37.3a	12.9c	6233.5c

Means in each column followed by the same letter are not significantly different at 5% level of probability according to Duncan's Multiple Range Test.

1 = Treatment, 2 = Harvest index, 3 = Biological yield, 4 = 1000-Kernel weight, 5 = Number of kernels per ear, 6 = Number of kernels per row, 7 = Number of kernel rows per ear, 8 = Grain yield

CONCLUSION

The first achievement of this study is the possibility to reduce water consumption (deficit irrigation) at some growth stages of maize and efficient management of water used in this important crop. In other words, if the total volume of available water is limited, some irrigation rounds could first be removed during the grain filling stage and then if more water needed to be saved, also during vegetative growth stage and in case of even further restrictions, we can still choose to remove a certain irrigation round which has a lower decreasing effect on grain yield. Another important result of this experiment was to identify the differences between maize hybrids in terms of their tolerance to deficit irrigation and their economic and biological water use efficiencies in both control and deficit irrigation treatments. This study, therefore, revealed that different genotypes of maize are different in terms of tolerating stress and there is the possibility to use the maize hybrids tolerant to deficit irrigation in regions with stressful environments. Results obtained in this study indicated the relatively higher tolerance of H_4 (Karoon 701 SC) to deficit irrigation conditions. It is therefore recommended to use this hybrid in regions facing the problem of drought stress. Results of this study also showed that it's possible to develop maize hybrids that are tolerant to drought stress. Considering the importance of water input, it is suggested to make serious attempts in order to develop drought tolerant maize hybrids.

Table 7: Mean comparisons for interaction effects of grain yield, biological yield, harvest index and, economic and biological water use efficiencies

Treatment	EWUE[1] kg/m^3 /ha	WU[2] m^3/ha	BWUE[3] Kg/m^3/ha	BY[4] (kg/ha)	GY[5] (kg/ha)	HI[6] %
I_1H_1	0.91	7530.9	2.64	19885.5ab	6852.2 ab	34.45b
I_1H_2	0.82	7530.9	2.44	18400.0b	6230.6 ab	33.86. b
I_1H_3	0.91	7530.9	2.39	18017.5 b	6813.9 ab	37.81ab
I_1H_4	1.05	7530.9	2.56	19354.0 b	7910.5 a	40.87ab
I_1H_5	1.00	7530.9	2.64	19888.7b	7731.0 a	38.87ab
I_1H_6	0.90	7530.9	2.81	21231.2a	6860.4 ab	32.31ab
I_1H_7	0.91	7530.9	2.59	19579.4 b	7220.6a	36.87ab
I_2H_1	0.86	5852.1	1.69	9937.5 def	5079.9a	51.11ab
I_2H_2	0.79	5852.1	1.81	10641.3 def	4664.7bc	43.82b
I_2H_3	0.96	5852.1	1.69	9920.0 g	5656.3 b	57.01 a
I_2H_4	1.16	5852.1	2.13	12512.5 cde	6791.7 ab	54.27a
I_2H_5	1.12	5852.1	1.95	11452.5 cde	6599.9 ab	57.62a
I_2H_6	1.07	5852.1	2.28	13350.6 cd	6315.9 ab	47.30ab
I_2H_7	1.11	5852.1	2.11	12403.7 cde	5948.8b	47.95ab
I_3H_1	0.84	6966.3	2.09	14603.1 c	5861.4b	40.13 ab
I_3H_2	0.91	6966.3	1.77	12396.2cde	5398. 8 b	43.55ab
I_3H_3	0.81	6966.3	1.58	11055.0 cde	5674.9 ab	51.33ab
I_3H_4	1.05	6966.3	1.57	10984.5 def	7349.5 a	56.60a
I_3H_5	0.98	6966.3	1.80	12587.5 cde	6849.3 ab	54.41ab
I_3H_6	0.98	6966.3	1.59	11096.9cde	6400.5ab	57.67ab
I_3H_7	0,90	6966.3	1.83	12812.5cde	6292.3 ab	49.11ab
I_4H_1	0.92	6456.1	1.69	10965.6 def	6437.3 ab	58.70.10a

I_4H_2	0.89	6456.1	1.79	11608.8 def	5749.4 ab	49.52.ab
I_4H_3	0.99	6456.1	1.81	11743.8 def	6435.5 ab	54.79ab
I_4H_4	1.12	6456.1	1.98	12843.8 cde	7705.9 a	59.99a
I_4H_5	1.11	6456.1	1.99	12890.6 cde	7075.3 a	54.88a
I_4H_6	0.99	6456.1	1.69	10968.8 def	6395.9 ab	58.30 a
I_4H_7	0.98	6456.1	1.78	11501.9 cde	6379.2 ab	55.46 ab

Means in each column followed by the same letter are not significantly different at the 5% probability level using Duncan's Multiple Range Test. 1 = Economic water use efficiency, 2 = Volume of water used, 3 = Biological water use efficiency, 4 = Biological yield, 5 = Grain yield, 6 = Harvest index.

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