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INVESTIGATION OF DROUGHT STRESS EFFECT ON MORPHOLOGIC TRAITS, YIELD AND YIELD COMPONENTS OF CORN (ZEA MAYS L.) NEW HYBRIDS

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ABSTRACT

In order to study the effect of drought stress on morphologic traits, yield and yield components of 9 new hybrids of corn (Zea maize L.), an experiment was conducted in a Randomized Complete Block Design (RCBD) with three replications under drought stress and normal irrigation based on 80 and 50 % allowing water depletion, respectively at Khorasan-Razavi Agriculture Research Center, Mashhad, Iran on June 10, 2011. The results of analyze variance showed that under normal irrigation and drought condition, there was a significant difference ($p<0.01$) between the hybrids. Mean comparison of hybrids revealed that in normal irrigation H6 and in drought stress H8 hybrid had the maximum grain yield (12.85 and 6.75 ton/ha, respectively). Under normal irrigation and water shortage, plant height and kernel no/row had the highest positive phenotypic correlation with kernel yield. In drought condition, grain yield was decreased due to the reduction cumulative effects in yield components.

INTRODUCTION

Corn (zea mays L.) is one the most important and valuable cereals in tropical and temperate regions of the world (Khavari Khorasani, 2009). According to the FAO, corn has been ranked as the first crop regarding production and after wheat and rice; maize has been classified as the third most important cereal in the world (Collado *et al.,* 2010). In Iran, corn is cultivated in 700,000 hectare of arable lands and has 2.8 percent of total cereal production (FAO, 2005). Iran with the amount of 240 mm rainfall has been classified as a dry region (Golbashy *et al.,* 2010: Shoae hosseini *et al.,* 2009). The lack of water, severe warmth and dry weather restricted crop production in such regions and drought pressure is one of the most deleterious environmental stresses which affects corn negatively (Alahdadi *et al.,* 2011; Khodarahmpour, 2011). So that, 20-25 percent of the planting area of maize is affected by drought pressure in the world (Golbashy *et al.,* 2010). Drought stress affects leaf water content, photosynthesis and water use efficiency (WUE) (Egilla *et al.,* 2005). Reports showed that in semi arid regions of Iran, drought declines season length (Magorocosho *et al.,* 2003), disturb photosynthesis and assimilate remobilization which finally reduces grain weight (Vaezi and Ahmadikhah, 2010). Corn yield components are controlled by many genes which react to the lack of water with different flexibility (Esmailiyan *et al.,* 2008) but it is affected by the environmental condition, either (Farre *et al.,* 2000). Grain yield reduction of maize due to the drought pressure is varied between 14 to 76% depending on the severity, timing and stage of occurrence (Mostafavi *et al.,* 2011; Zarabi *et al.,* 2011; Song *et al.,* 2010). Grain yield is an intricate feature which relies on various factors such as vigorous growth, enough water and nutrient supplies, increased solar radiation interception and its conversion to chemical energy and improved genetics (Eck, 1984) and it can be reduced by decreasing yield components like ear size, number of kernel per ear, or the kernel weight (Payero *et al.,* 2006). The main reason of grain yield reduction is enhancement of length of the anthesis-silking interval (ASI) (Markovic *et al.,* 2008).Under drought stress, High corn yield is correlated with a high number of fertile ears per plant (Azeez *et al.,* 2007). It has not been reported yet that drought stress affects grain in row at earlier stages of vegetative growth but it was reported that this component of yield was reduced when this pressure was appeared in ear growth and pollination (Babaogli *et al.,* 2012). The negative effect of drought pressure on flower pollination is to reduce the amount of viable pollen grain, enhancing the flowers which are unfavorable for pollinators and reducing flowers nectar production which leads to seed set failure of crops (Alqudah *et al.,* 2011). Two periods

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which are more tolerant to water shortage include vegetative and ripening periods and the flowering period is the most sensitive to water pressure, while corn has more sensitivity to water pressure at silking and tasseling stages (Rafiee *et al.*, 2011; Dagdelen *et al.*, 2008). Water stress which occurred at tassel emergence declines flowering, pollination and pollen longevity (Dolatabadian *et al.*, 2010). It was found that 2 weeks before and 2-3 weeks after silking, the number of final grain will be specified (Song *et al.*, 2010) and severe pressure before silking leads to fail to develop but water deficit stress after pollination stage can cause a restriction of the number of kernel failure (Eck, 1986). The main objective of the experiment was to identify the most important morphologic and physiologic traits affecting kernel yield in normal irrigation and drought condition and to determine the relative portion of them in order to achieving selection measures in breeding programs.

MATERIAL AND METHOD

In this experiment the effect of drought stress on agronomic features, yield and yield components of 8 new hybrids of corn (Zea maize L.) and KSC704 commercial hybrid as control resistant to drought and warm (which were bred and screened in Khozestan province condition) was assessed at Khorasan-Razavi Agriculture Research Center, Mashhad, Iran (6 km of Southeast of Mashhad, 3616N and 5938E, altitude 985 m). Climate in this region is cool and dry with average annual precipitation of 286 mm and all the rain fells in autumn and winter. The experiment was performed on June 10, 2011 as a Randomized Complete Block Design (RCBD) with three replications. The hybrids were grown in two-row plots with 3.15 m length and 0.75 cm spacing between rows. The plant density was 7500 plant/ha. In every pile, 3 seeds were planted which after seedling establishment and emergence were reduced to 1 plant. Cultivation operations except irrigation were done according to typical practices in Research Station. After seedbed preparation, 130 kg ammonium phosphate and 88 kg urea per hectare were applied and also, 88 kg urea was used at 7-leaf stage top dressing. For application of irrigation treatments, based on soil test, irrigation was applied based on 50 and 80% allowing water depletion for non stress and stress conditions, respectively. During the growth season, agronomic and morphological characteristics such as ear height, length of raceme, stem diameter, leaves no. and upper leaves no. of the genotypes were measured on 10 competitive plants in each plot randomly. At harvesting time, the number of plants and ears harvested were counted separately. Yield components (ear length and diameter, cob diameter, kernel depth, row no. /ear, kernel no. / row, total kernel no./ear and 300-kernel weight were measured. After separation of kernels by schiller and determining the humidity percentage of grains by digital handy psychrometer (Dicky John model), final grain yield in each experimental plot (based on 14 % humidity) was corrected and calculated at ton per hectare. After data collection, SAS software for variation analysis, Duncan Multiple Range Test (DMRT) for hybrids means comparison, step by step regression and phenotypic correlation between traits were used. After studying collinearity on measured variables, step by step regression analysis and combined variance analysis were done in stress and non-stress condition.

RESULTS AND DISCUSSION

1- Non-stress condition (Normal irrigation): Analyze variance showed that in non-stress condition, except for tassel length, stem diameter, leaves no, ear/plant no, 10 ear weights, total kernels no and grain yield, there was a significant difference between studied hybrids. Hybrids means comparison results showed that H6 (12.85 ton/ha) had the highest yield among studied hybrids followed by KSC704 and H1 (12.55 and 12.33 ton/ha) (table 1). Higher yield of H6 can be attributed to the length of plant, flag leaf and more kernel depth compared to the other hybrids. KSC704 (96.55 gr) and H7 (78.80 gr) had the highest and lowest 300-kernel weight. All the studied hybrids were ranked in one group regarding stem diameter, ear/plant no and 10 ear weights and there was no any statistic significant difference between them. H1 (22.03 cm) and H3 (17.20 cm) had the longest and shortest ear. Also, H3 had the minimum kernel no/row and obviously shorter ear in H3 caused lesser kernel no/row. Means comparison of hybrids revealed that H2 (52.84 mm) had the thickest ear which caused more row no/ear (17.8) in this hybrid. H4 and H3 (6.46 and 6.43 leaf) had the highest upper leaves ear. The lowest kernel yield was recorded for H8 and H2 (10.017 and 10.050 ton/ha). Lower yield of H8 can be attributed to lower kernel depth and kernels number. Also, lower yield of H2 can be due to the length of flag leaf, 300-kernel weight and kernel no/row in comparison to the other hybrids. Lorense *et al.*, (1987) reported that the number of kernels was the most susceptible yield components to water shortage. Ouattar *et al.*, (1987) found that drought pressure reduced corn kernel yield which was related to the reduction of kernel no than kernel weight. In addition, these authors indicated that drought pressure declined ear length, weight and diameter.

In order to investigate phenotypic correlation of studied traits with each other and yield, simple correlation analysis was done and the results were presented in table 2. Kernel yield had a positive and significant correlation with plant height, 300-kernel weight, flag leaf height, kernel no/row and total kernel no/ear and there was not any statistic significant difference between other traits and kernel yield (table 2). Kernel yield had the highest positive correlation with plant height (0.84) and 300-kernel weight (0.83) which was in line with the findings of Bolanos and Edemedes (1996). Dash *et al.*, (1999) reported there was a correlation between kernel yield and kernel no/row and ear length. The results of phenotypic correlation analysis between other traits in normal irrigation showed that plant height and flag leaf height had the highest positive and significant correlation (0.97), followed by flag leaf height and ear height (0.94) and maximum negative correlation was recorded between cob diameter and kernel percentage (-0.86) table 2).

Table 1 Means comparison of corn hybrids traits under normal irrigation with Duncan Multiple Range Test (DMRT)

Upper leaves no.	Leaves no.	Stem diameter (mm)	Ear height (cm)	Tassel length (cm)	Flag leaf height (cm)	Plant height (cm)	Hybrid
5.500 b	14.966ab	26.403 a	125.667 a	44.900 a	215.067a	259.967a	1
5.766 b	14.900ab	26.297 a	106.200 c	43.033 a	190.800b	233.833b	2
6.333 a	14.666ab	27.430 a	99.300 c	39.233 a	195.933b	235.167b	3
6.466 a	15.566 a	26.943 a	104.500 c	40.8.67 a	194.567b	235.433b	4
5.633 b	14.566ab	24.850 a	130.800 a	35.700 b	218.867a	254.567a	5
5.500 b	14.266 b	27.463 a	122.533ab	41.600ab	218.200a	259.800a	6
5.433 b	14.400ab	26.093 a	109.333 bc	40.200ab	196.267b	236.467b	7
5.600 b	14.133 b	26.360 a	109.767 bc	41.733ab	199.467b	241.200b	8
5.666 b	14.533ab	25.610 a	128.667 a	38.467ab	218.200a	256.667a	KSC704

Total kernel no/ear	Kernel no/row	Row no/ear	300 kernel weight (gr)	10 cob weight (Kg)	10 ear weight (Kg)	Ear no/plant	Hybrid
632.56ab	43.300 a	14.600 b	94.583ab	0.566ab	2.920 a	1.026 a	1
618.13ab	34.733 c	17.800 a	78.467 c	0.636 a	2.826 a	1.040 a	2
565.29 b	36.200 c	15.600 b	86.600abc	0.520abcd	2.546 a	1.060 a	3
639.62ab	40.000ab	16.066 b	84.650abc	0.493bcd	2.716 a	0.946 a	4
638.03ab	40.800 a	15.600 b	82.860 bc	0.556abc	2.723 a	0.976 a	5
660.59 a	41.333 a	16.000 b	92.820ab	0.460bcd	2.816 a	1.046 a	6
617.15ab	40.433ab	15.266 b	78.803 c	0.433bcd	2.390 a	1.060 a	7
564.98 b	36.900 bc	15.333 b	88.590abc	0.433cd	2.416 a	1.000 a	8
667.46 a	43.533 a	15.333 b	96.555 a	0.423 d	2.440 a	0.973 a	KSC704

Total yield (ton/ha)	Kernel percentage	Kernel depth (mm)	Cob diameter (mm)	Ear diameter (mm)	Ear length (cm)	Hybrid
12.337ab	80.66 bc	8.883 bc	30.640 bcde	48.403 bc	22.033 a	1
10.050 b	77.33 d	9.586 Abc	33.707 a	52.877 a	18.133 cd	2
10.423ab	79.66 c	9.973 ab	31.410 abcd	51.353 ab	17.200 d	3
10.233ab	82.00ab	9.680 ab	31.790 abc	51.147 ab	18.133 cd	4
10.353ab	79.66 c	8.896 Bc	32.257 ab	50.047 abc	19.966 b	5
12.857 a	83.33 a	10.506 a	28.110 e	49.117 bc	19.066 bc	6
10.317ab	81.66abc	90.113 Bc	29.137 bce	47.360 c	19.066 bc	7
10.017 b	82.00ab	8.483 c	29.773 bcde	46.733 c	18.600 bcd	8
12.557ab	82.66ab	9.583 abc	28.940 de	48.097 bc	18.500 bcd	KSC704

Means, in each column, following similar letter(s) are not significantly different at the 5% level of probability-using Duncan's Multiple Range Test

Table 2 Phenotypic correlation of corn hybrids traits under normal irrigation

10	9	8	7	6	5	4	3	2	1	Trait
									1.00	Plant height (cm)
								1.00	0.97 **	Flag leaf height (cm)
							1.00	0.26 ^{ns}	0.04 ^{ns}	Tassel length (cm)
						1.00	-0.23 ^{ns}	0.94 **	0.92 **	Ear height (cm)
					1.00	0.58 ^{ns}	0.49 ^{ns}	-0.35 ^{ns}	0.25 ^{ns}	Stem diameter (mm)
				1.00	0.14 ^{ns}	0.25 ^{ns}	0.21 ^{ns}	0.30 ^{ns}	0.27 ^{ns}	Leaves no.
			1.00	0.66 *	0.42 ^{ns}	0.62 ^{ns}	0.14 ^{ns}	0.50 ^{ns}	0.55 ^{ns}	Upper leaves no.
		1.00	-0.29 ^{ns}	0.39 ^{ns}	0.43 ^{ns}	-0.29 ^{ns}	0.35 ^{ns}	0.21 ^{ns}	0.14 ^{ns}	Ear no/plant
	1.00	0.06 ^{ns}	0.0.2 ^{ns}	0.48 ^{ns}	0.18 ^{ns}	0.23 ^{ns}	0.43 ^{ns}	0.22 ^{ns}	0.33 ^{ns}	10 ear weight (kg)
1.00	0.73 *	0.18 ^{ns}	0.12 ^{ns}	0.45 ^{ns}	-0.09 ^{ns}	-0.06 ^{ns}	0.24 ^{ns}	0.16 ^{ns}	0.11 ^{ns}	10 cob weight (kg)
-0.38 ^{ns}	0.08 ^{ns}	-0.20 ^{ns}	-0.16 ^{ns}	-0.16 ^{ns}	0.15 ^{ns}	0.53 ^{ns}	0.15 ^{ns}	0.68 *	0.75 *	300-kernel weight (gr)
0.51 ^{ns}	0.30 ^{ns}	0.08 ^{ns}	0.25 ^{ns}	0.24 ^{ns}	0.13 ^{ns}	-0.39 ^{ns}	0.10 ^{ns}	-0.47 ^{ns}	-0.46 ^{ns}	Row no/ear
-0.36 ^{ns}	0.09 ^{ns}	-0.31 ^{ns}	0.37 ^{ns}	0.02 ^{ns}	0.29 ^{ns}	0.77 *	0.10 ^{ns}	0.78 *	0.78 *	Kernel no/row
-0.04 ^{ns}	0.36 ^{ns}	-0.34 ^{ns}	-0.25 ^{ns}	0.21 ^{ns}	0.26 ^{ns}	0.68 *	-0.10 ^{ns}	0.62 ^{ns}	0.62 ^{ns}	Total kernel no/ear
0.22 ^{ns}	0.47 ^{ns}	0.0009 ^{ns}	-0.60 ^{ns}	-0.01 ^{ns}	-0.35 ^{ns}	0.67 *	0.30 ^{ns}	0.58 ^{ns}	0.68 *	Ear length (cm)
0.73 *	0.52 ^{ns}	0.02 ^{ns}	0.62 *	0.60 ^{ns}	0.22 ^{ns}	0.38 ^{ns}	-0.02 ^{ns}	0.38 ^{ns}	-0.40 ^{ns}	Ear diameter (mm)
0.84 **	0.41 ^{ns}	-0.14 ^{ns}	0.46 ^{ns}	0.58 ^{ns}	0.18 ^{ns}	0.32 ^{ns}	-0.01 ^{ns}	-0.45 ^{ns}	0.46 ^{ns}	Cob diameter (mm)
-0.02 ^{ns}	0.25 ^{ns}	0.25 ^{ns}	0.35 ^{ns}	0.13 ^{ns}	0.63 ^{ns}	-0.16 ^{ns}	-0.01 ^{ns}	0.02 ^{ns}	0.02 ^{ns}	Kernel depth (mm)
-0.82 **	-0.23 ^{ns}	0.26 ^{ns}	-0.14 ^{ns}	0.27 ^{ns}	0.22 ^{ns}	0.36 ^{ns}	0.07 ^{ns}	0.52 ^{ns}	0.52 ^{ns}	Kernel percentage
-0.23 ^{ns}	0.28 ^{ns}	0.05 ^{ns}	-0.38 ^{ns}	-0.16 ^{ns}	0.13 ^{ns}	0.66 ^{ns}	0.19 ^{ns}	0.77 *	0.84 **	Total yield (ton/ha)

Table 2 Continue

20	19	18	17	16	15	14	13	12	11	Trait
									1.00	300-kernel weight (gr)
								1.00	0.54 ^{ns}	Row no/ear
							1.00	-0.64 ^{ns}	0.62 ^{ns}	Kernel no/row
						1.00	0.73 *	0.03 ^{ns}	0.32 ^{ns}	Total kernel no/ear
					1.00	0.34 ^{ns}	0.63 ^{ns}	0.51 ^{ns}	0.32 ^{ns}	Ear length (cm)
				1.00	-0.39 ^{ns}	-0.002 ^{ns}	-0.51 ^{ns}	0.75 *	0.43 ^{ns}	Ear diameter (mm)
			1.00	0.79 *	-0.12 ^{ns}	0.23 ^{ns}	-0.55 ^{ns}	0.58 ^{ns}	-0.58 ^{ns}	Cob diameter (mm)
		1.00	-0.14 ^{ns}	0.48 ^{ns}	-0.45 ^{ns}	0.34 ^{ns}	-0.02 ^{ns}	0.40 ^{ns}	0.14 ^{ns}	Kernel depth (mm)
	1.00	0.21 ^{ns}	-0.86 **	-0.63 ^{ns}	0.10 ^{ns}	0.37 ^{ns}	0.64 ^{ns}	-0.56 ^{ns}	0.69 *	Kernel percentage
1.00	0.61 ^{ns}	0.39 ^{ns}	-0.62 ^{ns}	-0.31 ^{ns}	0.42 ^{ns}	0.73 *	0.65 *	-0.35 ^{ns}	0.83 **	Total yield (ton/ha)

**: Significant at 1%; *: Significant at 5%; ns: non significant

Table 3 Step by step regression regarding kernel yield as dependent variable and other traits as independent variables under normal irrigation

Third step		Second step		First step		
Error	**Regression**	**Error**	**Regression**	**Error**	**Regression**	
5	3	6	2	7	1	df
300-kernel weight		Kernel depth		Plant height		Entered trait
0.20	3.45	0.28	4.83	0.47	8.09	MS
16.77 **		16.84 **		17.14 **		F
0.90		0.84		0.71		r

= -14.82 + 0.05 plant height + 0.06 300-kernel weight + 0.62 kernel depth
Regression equation

**: Significant at 1%; *: Significant at 5%; ns: non significant

Step by step regression analysis under normal irrigation

After the study of collinearity on measured variables under normal irrigation and drought condition, undesirable traits were omitted (selection based on tolerance index and variance inflation factor) and Step by step regression analysis was done. The results of regression analysis regarding kernel yield as dependent variable and other traits as independent variables were presented in table 3. As the table 3 shows that the first entered trait into the model was plant height which legitimized more than 71 percent of yield variations. At second stage, kernel depth trait was entered into the model with plant height legitimized more than 84 percent of yield variations and at third stage 300-kernel weight trait was considered. All the entered traits legitimized more than 90 percent of yield variations altogether. The obtained were in line with phenotypic correlation analysis results. So that, plant height, 300-kernel weight and total kernel no/ear had the highest correlation with kernel yield (0.84 and 0.83).

2- Stress condition (Drought pressure): The results of data analyze variation revealed that there was a significant difference among the hybrids except for ear diameter in drought condition which showed genetic diversity among the hybrids. Our results were in conformity with findings of Abayomi *et al.,* (2012); Khayatnezhad *et al.,* (2011); and Dastbandan Nejad *et al.,* (2010) who observed that corn yield components were decreased by water stress in all the genotypes. Mean comparisons of hybrids by Duncan Multiple Range Test (DMRT) demonstrated H8 (6.75 ton/ha) (table 4) had the highest yield, while this hybrid had the lowest yield in normal irrigation which indicated its resistance to drought and yield stability and better flexibility that can be used in drought tension studies. Regarding table 4, it sounds that higher yield of H8 can be attributed to the ear no/plant of this hybrid (1.79). H3 (22.37 mm) had the thickest stems and H6 had the thinnest ones (14.13 mm). Maximum kernel depth was belong to KSC704 (9.01 mm) and the minimum one was belong to H1 (5.32 mm), whereas in non-stress condition H6 and H8 had the maximum and minimum kernel depth. It was recorded that H2 had the highest length of plant (180.05 cm), flag leaf (141. 7 cm) and upper leaves no (6.3) but had not considerable yield (3.39 ton/ha). H7 and KSC704 commercial hybrid (84.4 and 83.7 gr) had the maximum 300-kernel weight and H1 (61.2 gr) gad the minimum one. It was observed that H3 had the lowest yield (1.99 ton/ha) due to the row no/ear (9.7) and kernel no/row (12.01) and lesser ears weight.

The results of phenotypic correlation analysis showed that kernel yield had positive and significant correlation with kernel no/row, ear no/plant and ear length. Also, grain yield had negative and significant correlation with upper leaves no (-0.68) (table 5). Ear length of corn controls by genotype and environmental factors such as nutrients and the amount of water. Since ear contains kernel and is an important component of yield, ear lengthier leads to more kernels and yield. Golbashy *et al.,* (2010) found that there was positive correlation between grain yield and ear length. Kernel no/row and total kernel no/ear had the maximum phenotypic correlation (0.97), followed by plant height and flag leaf height (0.94). Also, ear no/plant and upper leaves no had the maximum negative and significant correlation (-0.85) (table 5).

Step by step regression analysis under drought condition: The results of regression analysis regarding kernel yield as dependent variable and other traits as independent variables were presented in table 6. As the table 6 shows that the first entered trait into the model was kernel no/row which legitimized more than 58 percent of yield variations. At second stage, ear no/plant trait was entered into the model with kernel no/row legitimized more than 87 percent of yield variations and at third stage 300-kernel weight and stem diameter were regarded which legitimized more than 99 percent of yield variations.

Combined variance analysis: The obtained results of data combined variance analysis of normal irrigation and drought condition were presented in table 7. There was a significant difference ($p < 0.01$ and 0.05) between two conditions for all the traits. Studied hybrids except for tassel length had a significant difference with each other. The interaction of hybrid and irrigation condition was non-significant for 10 ear weight, total kernel no/ear, ear diameter and cob diameter. Means comparison showed that KSC704, H6 and H8 had the highest kernel yield and H3 had the lowest one. Also, maximum kernel weight (90.142 gr) and kernel depth (9.296 mm) was belong to KSC704 hybrid (table 8).

Table 4 Means comparison corn hybrids traits under drought condition with Duncan Multiple Range Test (DMRT)

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Upper leaves no.	Leaves no.	Stem diameter (mm)	Ear height (cm)	Tassel length (cm)	Flag leaf height (cm)	Plant height (cm)	Hybrid
6.000 ab	12/850 cd	15.307 bc	80.650 ab	31.800 c	125.250 bcd	157.050 d	1
6.300 a	13/550 cb	15.920 bc	85.600 a	38.350 ab	141.700 a	180.050 a	2
6.063 ab	13/600 cb	22.377 a	83.550 a	40.100 ab	131.150 b	171.250 b	3
5.950 abc	13/250 cb	16.700 bc	72.557 cd	36.450 b	119.750 d	156.200 d	4
6.000 ab	14/850 a	15.863 bc	80.583 ab	36.350 b	129.850 bc	166.200 bc	5
5.600 cd	11/900 e	14.130 c	72.357 cd	36.450 b	123.550 cd	160.000 bc	6
6.000 ab	13/400 cb	18.357 b	66.817 d	41.350 a	110.450 e	151.800 d	7
5.400 d	12/250 ed	15.027 bc	76.350 bc	39.800 ab	128.750 bc	168.550 b	8
5.750 bcd	13/950 b	17.290 bc	76.457 bc	39.350 ab	126.050 bcd	165.400 bc	KSC704

Total kernel no/ear	Kernel no/row	Row no/ear	300 kernel weight (gr)	10 cob weight (Kg)	10 ear weight (Kg)	Ear no/plant	hybrid
281.85 a	21.350 a	13.200 a	61.260 d	0.320 bc	0.926 abc	1.183 bc	1
246.36 a	18.850 ab	12.500 a	74.460 b	0.286 bc	0.910 abc	0.950 c	2
118.19 c	12.013 c	9.700 c	66.073 cd	0.330 b	0.616 d	1.256 bc	3
299.84 a	22.467 a	13.350 a	71.550 bc	0.330 b	1.010 ab	1.270 bc	4
218.73 ab	18.150 ab	12.050 a	77.697 ab	0.453 a	1.130 a	1.250 bc	5
299.53 ab	19.050 ab	11.900 ab	64.073 d	0.250 bc	0.786 bcd	1.453 b	6
155.71 bc	15.000 bc	10.250 bc	84.460 a	0.240 c	0.730 cd	1.420 b	7
243.32 ab	20.950 a	11.600 ab	77.770 ab	0.323 b	0.980 abc	1.793 a	8
230.23 ab	18.300 ab	12.600 a	83.730 a	0.293 bc	1.010 ab	1.203 bc	KSC704

Total yield (ton/ha)	Kernel percentage	Kernel depth (mm)	Cob diameter (mm)	Ear diameter (mm)	Ear length (cm)	hybrid
4.096 bc	66.00 ab	5.326 d	20.060 bc	30.717 b	12.550 bc	1
3.390 c	67.33 a	7.576 abc	24.583 abc	39.737 ab	11.326 cd	2
1.993 d	47.33 c	5.970 cd	29.363 a	41.297 a	10.700 d	3
5.463 ab	67.66 a	6.820 bcd	26.073 ab	39.710 ab	12.200 cd	4
4.256 bc	59.00 b	6.390 bcd	20.310 bc	33.093 ab	12.830 abc	5
4.080 bc	67.66 a	7.620 abc	21.330 bc	36.567 ab	13.076 abc	6
3.796 c	67.00 a	7.260 bc	22.547 bc	37.060 ab	10.476 d	7
6.756 a	67.33 a	7.986 ab	22.707 bc	38.680 ab	14.143 ab	8
4.600 bc	7100 a	9.010 a	18.400 c	31.673 ab	14.426 a	KSC704

Means, in each column, following similar letter(s) are not significantly different at the 5% level of probability-using Duncan's Multiple Range Test

SDFD

Table 5 Phenotypic correlation in corn hybrids under drought condition

10	9	8	7	6	5	4	3	2	1	Trait
									1.00	Plant height (cm)
								1.00	0.94**	Flag leaf height (cm)
							1.00	-0.09ns	0.23ns	Tassel length (cm)
						1.00	-0.24ns	0.91**	0.81**	Ear height (cm)
					1.00	0.15ns	0.51ns	-0.05ns	0.11ns	Stem diameter (mm)
				1.00	0.38ns	0.33ns	-0.12ns	0.18ns	0.22ns	Leaves no.
			1.00	0.58ns	0.39ns	0.44ns	-0.11ns	0.26ns	0.22ns	Upper leaves no.
		1.00	-0.85**	-0.54ns	-0.17ns	-0.53ns	0.29ns	-0.41ns	-0.30ns	Ear no/plant
	1.00	-0.06ns	-0.14ns	0.33ns	-0.60ns	0.10ns	-0.38ns	0.18ns	0.05ns	10 ear weight (kg)
1.00	0.58ns	-0.11ns	0.15ns	0.61ns	0.004ns	0.47ns	-0.30ns	0.34ns	0.23ns	10 cob weight (kg)
-0.02ns	0.29ns	0.14ns	-0.08ns	0.44ns	0.07ns	-0.34ns	0.67*	-0.21ns	0.01ns	300-kernel weight (gr)
0.17ns	0.74*	-0.32ns	-0.005ns	-0.03ns	-0.68*	0.10ns	-0.70*	0.15ns	-0.07ns	Row no/ear
0.10ns	0.71*	0.09ns	-0.30ns	-0.33ns	-0.81**	-0.10ns	-0.60ns	0.01ns	-0.18ns	Kernel no/row
0.11ns	0.71*	-0.10ns	-0.14ns	-0.23ns	-0.76*	0.002ns	-0.66*	0.09ns	-0.12ns	Total kernel no/ear
0.16ns	0.65ns	0.35ns	-0.73*	-0.18ns	-0.58ns	-0.04ns	-0.21ns	0.10ns	0.03ns	Ear length (cm)
-0.19ns	0.48ns	0.15ns	0.11ns	-0.22ns	0.39ns	0.03ns	0.53ns	0.16ns	0.33ns	Ear diameter (mm)
-0.01ns	0.55ns	-0.06ns	0.34ns	-0.04ns	0.64ns	0.22ns	0.32ns	0.17ns	0.28ns	Cob diameter (mm)
-0.41ns	0.19ns	0.23ns	-0.46ns	-0.11ns	-0.23ns	-0.31ns	0.55ns	0.01ns	0.19ns	Kernel depth (mm)
-0.44ns	0.45ns	-0.09ns	-0.32ns	-0.33ns	-0.72*	-0.48ns	0.15ns	-0.27ns	-0.31ns	Kernel percentage
0.08ns	0.64ns	0.76*	-0.68*	-0.33ns	0.62ns	-0.38ns	-0.07ns	-0.20ns	-0.22ns	Total yield (ton/ha)

20	19	18	17	16	15	14	13	12	11	Trait
									1.00	300-kernel weight (gr)
								1.00	-0.16ns	Row no/ear
							1.00	0.89**	-0.14ns	Kernel no/row
						1.00	0.97**	0.95**	-0.19ns	Total kernel no/ear
					1.00	0.51ns	0.58ns	0.51ns	0.13ns	Ear length (cm)
				1.00	-0.50ns	-0.30ns	-0.28ns	-0.44ns	-0.06ns	Ear diameter (mm)
			1.00	0.89**	-0.65ns	-0.37ns	-0.39ns	-0.45ns	-0.28ns	Cob diameter (mm)
		1.00	-0.33	0.02ns	0.51ns	0.06ns	0.10ns	0.06ns	0.64ns	Kernel depth (mm)
	1.00	0.58ns	-0.62	-0.35ns	0.48ns	0.67*	0.69*	0.63ns	0.31ns	Kernel percentage
1.00	0.62 ns	0.40ns	-0.37	-0.13ns	0.69*	0.63ns	0.81**	0.47ns	0.29ns	Total yield (ton/ha)

Table 6 Step by step regression regarding kernel yield as dependent variable and other traits as independent variables under drought condition

Fourth step		Third step		Second step		First step		
Error	**Regression**	**Error**	**Regression**	**Error**	**Regression**	**Error**	**Regression**	
4	4	5	3	6	2	7	1	df
Stem diameter		300-kernel weight		Ear no/plant		Kernel no/row		Entered trait
0.03	3.46	0.05	4.56	0.29	6.09	0.83	8.16	MS
107.18**		78.74 **		20.36**		9.81 *		F
0.99		0.97		0.87		0.58		r

Regression equation = -12.06 + 0.1 stem diameter + 2.87 ear no/plant + 0.05 300-kernel weight + 0.37 kernel no/row

**: Significant at 1%; *: Significant at 5%; ns: non significant

Table 7 Combined variance analysis (means comparison) of corn different traits under stress and non-stress

Upper leaves no	**Leaves no**	**Stem diameter**	**Ear height**	**Tassel length**	**Flag leaf height**	**Plant height**	**df**	**S.O.V**
0.22*	25.62**	1246.46**	19476.52**	110.36**	84221.90**	90429.92 **	1	Irrigation condition
0.11ns	1.32**	4.77ns	426.36**	46.80**	941.36**	1354.72**	4	Main plot error
0.40**	1.72**	11.38**	253.62**	13.94ns	296.72**	233.33**	8	Hybrid
0.23**	1.17**	8.69**	267.10**	32.43**	349.47**	394.85**	4	Interaction
0.05	0.30	2.77	32.98	8.68	19.84	28.87	32	Sub plot error

ernel no/row	**Row no/ear**	**300-kernel weight**	**10 cob weight (kg)**	**10 ear weight (kg)**	**Ear no/plant**	**df**	**S.O.V**
6086.74**	197.80 **	2515.49**	0.48**	41.06**	1.17**	1	Irrigation condition
5.40 ns	0.24 ns	142.49**	0.001 ns	0.01 ns	0.01 ns	4	Main plot error
38.83**	3.91**	113.46**	0.01**	0.11 *	0.08**	8	Hybrid
21.78**	3.06**	226.68**	0.008*	0.08 ns	0.08**	4	Interaction
5.74	0.76	30.40	0.003	0.04	0.01	32	Sub plot error

Total yield	**Kernel percentage**	**Kernel depth**	**Cob diameter**	**Ear diameter**	**Ear length**	**Total kernel no/ear**	**df**	**S.O.V**
614.28**	0.36**	71.73**	825.79**	2265.92 **	579.57**	2136126.33 **	1	Irrigation condition
0.67 ns	0.001ns	0.13 ns	1.48 ns	6.48 ns	2.45*	1141.43 ns	4	Main plot error
4.38**	0.009**	2.72**	30.44**	39.15*	7.006**	9685.07**	8	Hybrid
5.09 **	0.006**	2.19**	13.99 ns	17.32ns	4.57**	4061.71 ns	4	Interaction
1.32	0.0009	0.54	6.30	15.41	0.86	1937.80	32	Sub plot error

**: Significant at 1%; *: Significant at 5%; ns: non significant

Table 8 Means comparison of corn hybrids traits under normal irrigation and drought condition with Duncan Multiple Range Test (DMRT)

Upper leaves no	Leaves no	Stem diameter (mm)	Ear height (cm)	Tassel length (cm)	Flag leaf height (cm)	Plant height (cm)	Hybrid
5.750bcd	13.908b	20.885b	103.158ab	38.350ab	170.158ab	208.508ab	1
6.033ab	14.225ab	21.108b	95.900bc	40.692a	166.250bc	206.942ab	2
6.198a	14.133ab	24.903a	91.425cd	39.667ab	163.542c	203.208b	3
6.208a	14.408ab	21.821b	88.528d	38.658ab	157.158d	195.817c	4
5.816bc	14.708a	20.356b	105.692a	36.025b	174.358a	210.383a	5
5.550cd	13.083c	20.796b	97.445bc	39.025ab	170.875ab	209.900ab	6
5.716cd	13.900b	22.225b	88.075d	40.775a	153.358d	194.133c	7
5.500d	13.191c	20.693b	93.058cd	40.767a	164.108c	204.875ab	8
5.708cd	14.241ab	21.450b	102.562ab	38.908ab	172.125a	211.033a	KSC704

Total kernel no/ear	Kernel no/row	Row no/ear	300-Kernel weight (gr)	10 cob weight (kg)	10 ear weight (kg)	Ear no/plant	Hybrid
457.21ab	32.325a	13.900bc	77.922b	1.443abc	1.923a	1.105bc	1
432.24abc	26.792de	15.150a	76.463b	0.461ab	1.868ab	0.995c	2
341.74d	24.107e	12.650e	76.337b	0.425bc	1.581bc	1.158bc	3
469.73a	31.233ab	14.708ab	78.100b	0.411cde	1.863ab	1.108bc	4
428.38abc	29.475abcd	13.825bcd	80.278b	0.505a	1.926a	1.113bc	5
445.06ab	30.192abc	13.950bc	78.447b	0.355de	1.801abc	1.250ab	6
386.43cd	27.717dc	12.758de	81.632b	0.341e	1.560c	1.240ab	7
404.15bc	28.925bcd	13.466cde	83.180b	0.378cde	1.698abc	1.396a	8
448.85ab	30.917ab	13.966bc	90.142a	0.358de	1.725abc	1.088bc	KSC704

Total yield (ton/ha)	Kernel percentage	Kernel depth (mm)	Cob diameter (mm)	Ear diameter (mm)	Ear length (cm)	Hybrid
8.216ab	73.33ab	7.105d	25.350d	39.560b	17.291a	1
6.720bc	72.33bc	8.581abc	29.145ab	46.307a	14.730de	2
6.208c	63.50d	7.971cd	30.387a	46.325a	13.950e	3
7.848ab	74.83ab	8.250bc	28.932abc	45.428a	15.166cd	4
7.305abc	69.33c	7.643cd	26.283bcd	41.570ab	16.398ab	5
8.468a	75.50ab	9.063ab	24.720d	42.842ab	16.071bc	6
7.056abc	74.33ab	8.186bc	25.842cd	42.210ab	14.771de	7
8.386a	74.66ab	8.235bc	26.240bcd	42.707ab	16.371ab	8
8.578a	76.83a	9.296a	23.670d	39.885b	16.463ab	KSC704

Means, in each column, following similar letter(s) are not significantly different at the 5% level of probability-using Duncan's Multiple Range Test

Fourth step		Third step		Second step		First step		
Error	Regression	Error	Regression	Error	Regression	Error	Regression	
4	4	5	3	6	2	7	1	df
Stem diameter		300-kernel weight		Ear no/plant		Kernel no/row		Entered trait
0.03	3.46	0.05	4.56	0.29	6.09	0.83	8.16	MS
107.18^{**}		78.74^{**}		20.36^{**}		9.81^{*}		F
0.99		0.97		0.87		0.58		r

Regression equation = -12.06 + 0.1 stem diameter + 2.87 ear no/plant + 0.05 300-kernel weight + 0.37 kernel no/row

Table 9 **The effect of drought pressure on measured traits of corn hybrids**

The variations of trait under drought to normal irrigation	Mean	Range of variations	Condition	Traits
- 33.17 %	245.5	227.5 - 268.5	normal irrigation	Plant height (cm)
	164.05	133.2 – 195.9	drought tension	
- 38.48 %	205.26	187.3 – 223.5	normal irrigation	Flag leaf height (cm)
	126.27	93.20 –151.9	drought tension	
- 7.03 %	40.63	31.5 – 45	normal irrigation	Tassel length (cm)
	37.77	28.5 – 44	drought tension	
- 32.97 %	115.19	93.2 – 143	normal irrigation	Ear height (cm)
	77.21	55.33 – 97.7	drought tension	
- 36.42 %	26.38	23 – 30.17	normal irrigation	Stem diameter (mm)
	16.77	12.32 – 25.81	drought tension	
- 9.41 %	14.66	13.5 – 16.4	normal irrigation	Leaves no
	13.28	11.10 –15.20	drought tension	
2.25 %	5.67	5.1 – 6.7	normal irrigation	Upper leaves no
	5.89	5.3 – 6.4	drought tension	
28.71 %	1.01	0.89 – 1.16	normal irrigation	Ear no/plant
	1.30	0.81 – 1.92	drought tension	
- 65.90 %	2.64	2.02 – 3.26	normal irrigation	10 ear weight (kg)
	0.90	0.45 – 1.29	drought tension	
- 38 %	0.50	0.34 – 0.68	normal irrigation	10 cob weight (kg)
	0.31	0.22 – 0.49	drought tension	
- 15.67 %	87.10	66.64 – 106.92	normal irrigation	300-kernel weight (gr)
	73.45	51.65 – 90.08	drought tension	
- 24.34 %	15.73	13.6 - 18	normal irrigation	Row no/ear
	11.90	8.50 – 14.40	drought tension	
- 53.51 %	39.69	32.9 – 44.7	normal irrigation	Kernel no/row
	18.45	10.36 – 24.50	drought tension	
- 63.88 %	622.64	531 - 705	normal irrigation	Total kernel no/ear
	224.84	90.31 – 352.80	drought tension	
- 34.54 %	18.96	17 – 22.8	normal irrigation	Ear length (cm)
	12.41	9 – 16.25	drought tension	
- 26.18 %	49.45	43.94 – 53.58	normal irrigation	Ear diameter (mm)
	36.50	21.64 – 42.23	drought tension	
- 25.55 %	30.64	27.26 – 34.99	normal irrigation	Cob diameter (mm)
	22.81	12.80 – 30.14	drought tension	
- 24.54 %	9.41	7.74 – 10.59	normal irrigation	Kernel depth (mm)
	7.10	3.53 – 9.48	drought tension	
- 20.98 %	0.81	0.76 – 0.85	normal irrigation	Kernel percentage
	0.64	0.47 – 0.75	drought tension	
- 61.21%	11.01	8.40 – 14.15	normal irrigation	Total yield (ton/ha)
	4.27	1.37 – 7.27	drought tension	

The effect of drought tension on measured traits of corn hybrids

Table 9 showed the variations by the tension on all the traits and drought pressure reduced nearly all the traits considerably. The highest percentage of reduction in drought condition than normal irrigation was recorded for 10 ear weight (-65.9 %), total kernel no/ear (-63.88 %) and kernel yield (-61.21 %). Denmead and Shaw (1990) stated that considerable reduction of yield under drought pressure was because of abnormal growth of embryo sac and pollen infertility. Kernel yield reduction was attributed to decrease in kernel growth rate and its filling period as well as decrease in cytokinin hormone (Seghatoleslami *et al.*, 2008; Jones and Brenner, 1987). The ability of kernels to use the assimilates is reduced by drought pressure because acid invertase activity is disturbed (Zinselmeier *et al.,* 1995). the yield of corn grain has a close relationship with kernel number at maturity, which being determined by the physiological status of the crop around flowering (ONeill *et al.,* 2004).

According to the table, kernel no/row was more damaged by drought (53.51 %). The main reason is that drought pressure at flowering stage delays tasseling appearance. So tassels are appeared when pollination was done and there is no any visible pollen, ovules are not fertilized and finally kernels will not being formed. Another reason is that the embryo of fertilized ovules are aborted, kernel is not formed which lead to lower kernel no/ear and kernel no/row. Drought tension increased upper leaves no and ear/ plant no. Generally, it can be concluded that total kernel no/ear (-63.88 %), kernel depth (-24.54 %) and 300-kernel weight (-15.67 %) reduced kernel yield and ear no/plant improved kernel yield (28.71 %).

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