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DIFFERENTIAL RESPONSES OF GRAIN SORGHUM GENOTYPES TO WATER STRESS AT DIFFERENT GROWTH STAGES.

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ABSTRACT

Twenty five F_1's were made in 1999 among 5 cms and 5 restorer lines of grain sorghum differing in drought tolerance . In 2000 season the parents and F_1's were evaluated at 2 locations (Assiut and Shandaweel) under 3 soil moisture regimes , i.e full irrigation (control) , water-stress at preflowering (GS2) and postflowering (GS3) stages . The objective was to study the differential responses of growth stages and genotypes of grain sorghum to soil-moisture stress . Performance of genotypes varied with water supply and location. Mean grain yield was significantly reduced by soil moisture stress at both GS2 and GS3 stages by 18.2 and 8.6 %, respectively over all parents and by 19.2 and 8.4 %, respectively over all F_1 hybrids. This indicates that the pre-flowering developmental stage (GS2) was more sensitive to soil water deficit than grain filling stage (GS3). Yield reduction was accompanied by losses in grains/panicle and grain weight. Reduction in grains/panicle was higher than reduction in grain weight when stress was imposed at GS2 , and the opposite was true under stress at GS3 . Water stress at GS2 caused 5.0 and 5.8 % delay in flowering date, 20.2 and 16.7 % reduction in plant height, for parents and F_1's respectively. Moreover, leaf area declined by 8.8 and 11.9 % for parents and 11.2 and 13.9 % for F_1's when water was withheld at GS2 and GS3, respectively. Significant differences between studied genotypes were recorded in their response to water deficit imposed at GS2 or GS3 stage. When an advantage in both absolute yield under stress or yield relative to control was taken as an index of drought tolerance in its agronomic definition, the parental lines: R-89016, R-90011 and V-112 at GS2 and B-102, R-89016, R-90011 and V-112 at GS3 stage could be regarded as the most drought tolerant lines. The crosses A-1 X V-112, A-37 X R-90011and A-102 X R-90011 at GS2 and A-1 X R-89016, A-1 X R-89022, A-1 X R-90011, A-37 X V-112, A-88006 X R-89022 and A-88006 X V-112 at GS3 could be considered the most drought tolerant hybrids. It is interesting that the parental lines R-89016, R-90011 and V-112 and the crosses A-1 X R-89016, A-1 X V-112, A-102 X R-90011 and A-102 X V-112 also excelled in their potential yield under non-stress conditions.

Key words: ***Grain sorghum, Drought tolerance, Preflowering (GS2) stress, Postflowering (GS3) stress, Genotypic differences***

INTRODUCTION

Egypt ranks first among grain sorghum (*Sorghum bicolor* L. Moench) producers in the world for the average grain yield per unit area, which reached 17.94 ardabs (2.7 tons)/feddan (6.43 tons/ha) in 1999 season (Circular No. 548 of the Central Administration of Agric. Extension, ARC, Ministry of Agric. and Land Reclamation, Egypt, 2000). According to this circular the cultivated area of grain sorghum in Egypt was about 384 thousand feddans (1 fed. = 4200 m^2) which produced about one million tons of grains in 1999. The whole grain sorghum area in Egypt is located in the Nile valley and grown under irrigation.

Grain sorghum is generally one of the qualified plants for growing in the Egyptian new reclaimed lands, where the soil is of low water-holding capacity and the atmospheric temperature is high. Grain sorghum varieties which will be grown in such areas should be characterized by high tolerance to drought and heat stresses.

Research on grain sorghum has led to identification of two most important drought responses: pre-flowering and post-flowering (Eastin and Sullivan 1974, Inuyama 1978 and Pedro *et al* 1989). The pre-flowering response occurs when the plants are stressed during the period from panicle differentiation to flowering (the GS2 stage) while the post-flowering response occurs when the plants are stressed during the grain filling period (GS3). It was found that drought stress at GS2 causes reduction in number of grain/panicle, while drought stress at GS3 causes reduction in grain weight. Moreover several investigators emphasized the role of grain sorghum genotypes in drought tolerance (Blum *et al* 1989, Saranga *et al* 1990, Donattelli *et al* 1992, Castro Nava and Huerta 1994 and Al-Naggar *et al* 1999).

To date limited number of research has been made to identify the differential response of grain sorghum genotypes to drought stress imposed by withholding irrigation at different developmental stages. Therefore, the objective of the present investigation was to study the differential effects of drought stress imposed by withholding irrigation at pre-and post-flowering stages on some agronomic and yield attributes of grain sorghum genotypes known by differences in drought tolerance.

MATERIALS AND METHODS

Ten Parents used in the current investigation were chosen based on previous experiments according to their absolute and the relative yield under drought stress and non-stress environment. The origin and status of drought reaction of the materials are presented in Table (1). The tolerant parents consisted of three restorer lines, and one cytoplasmic male sterile (cms) line. The susceptible parennts consisted of two restorer and four cms lines.

Table .1 The parental lines used their, origin and drought reaction.

	Lines	Origin	Drought reaction
	Male sterile (cms) lines		
1	ICSB-1 (A-1)	ICRISAT	S
2	ICSB-37(A-37)	ICRISAT	S
3	ICSB-102(A-102)	ICRISAT	T
4	ICSB-88005(A-88005)	ICRISAT	S
5	ICSB-88006(A-88006)	ICRISAT	S
	Restorer (R) lines		
1	ICSR-89016	ICRISAT	T
2	ICSR-89022	ICRISAT	S
3	ICSR-90011	ICRISAT	T
4	ICSV-112	ICRISAT	T
5	RTX-82BDM-499	Texas A &M	S

T = tolerant S = susceptible
ICRISAT = International Crop Research Institute for Semi – Arid Tropics-India
Texas A &M = Texas A& M University , U.S.A.

The five restorer (R) lines were crossed onto the five (cms) lines to make a total number of 25 F_1 fertile hybrids in 1999 seseaon at Giza Res. Station, FCRI, ARC. In the 2000 season, two field experiments were conducted on the 1 st of July at the Agric. Res. Station of Assiut University (Assiut Governorate) and on the 3 rd of July at Shandaweel Agric. Res. Station, FCRI, ARC (Sohag Governorate) to evaluate the 10 parental lines (5 restorer and 5 cms lines) and their 25 F_1 fertile hybrids (making a total number of 35 genotypes) under three watering regimes, i.e. pre-flowering drought stress (by withholding irrigation for 30 days from panicle initiation to anthesis), post- flowering drought stress (by withholding irrigation for 40 days from anthesis to maturity)and normal irrigation (control).

A split-plot design in a randomized complete blocks with three replications was used where the three irrigation treatments were allotted to the main plots and the 35 genotypes allotted to sub-plots. Each sub- plot consisted of one row 5 m long 70 cm wide with a total area of 3.5 square meters. Sowing was done in hills 20 cm apart along the ridges. Hills were thinned to two plants per hill after 20 days from sowing and before the first irrigation. Pest control and other agricultural practices were done as recommended.

All measurements were the average of 5 guarded plants taken randomly from each plot after heading (at the end of stress period) or at harvest time, except for days to mid - bloom, which was measured on a plot basis. Data were collected for: (1) days to 50% flowering (to mid - bloom), (2) plant height from soil surface to the top of the panicle, (3) leaf area (LA): LA = leaf length x leaf width x 0.75, using the 6^{th} leaf from the top. (4) 1000- grain weight, (5) Number of grains / panicle, and (6) grain yield / plant.

Data of each location and combined data over the two locations in absolute and relative values were subjected to a regular analysis of variance of a split plot design according to Steel and Torrie (1980).

RESULTS AND DISCUSSIONS

Combined analysis of variance for agronomic and yield traits (Table 2) showed that significant differences existed among the genotypes, parents and F_1's for all studied traits. The differences among soil moisture (irrigation) regimes were significant ($P \leq 0.01$) for all agronomic and yield traits.

All genotypes X locations, genotypes X moisture regimes and genotypes X moisture regimes X locations interactions were also significant ($P \leq 0.01$) for all studied agronomic and yield traits. Thus the performance of genotypes varies with location and water supply confirming previous results (Krieg and Hutmacher, 1986, Saranga *et al* 1990 and Al-Naggar *et al* 1999).

Differential response of growth stages:

A comparative summary of means and ranges of all studied traits over all parental lines and hybrids subjected to three soil moisture regimes are presented in Table (3). Mean grain yield per plant was significantly reduced by soil moisture stress at both GS2 and GS3 stages to 81.8 and 91.4 %, respectively, over all parents and to 80.8 and 91.6 %, respectively over all F_1 hybrids. This indicates that the developmental stage GS2 was more sensitive to soil water stress than the GS3 stage. This observation agrees with Blum (1973), Lewis *et al* (1974), Legg *et al* (1979), Mirhadi and Kobayashi (1980), Bakheit (1990) and Craufurad and Peacock (1993) who reported that soil water stress at pre-flowering stage reduced yield more than at post- flowering stage.

Yield under control ranged from 43.3 to 78.0 g/plant for parental lines and from 51.6 to 112.5 g/plant for F_1's (Table 3). Yield under water stress at GS2 ranged from 39.3 to 63.2 g/plant among parents and from 45.9 to 91.3 g/plant among hybrids. When water stress was practiced at GS3 stage, yield range was 43.4-73.5 and 44.8-99.9 g/plant for parents and hybrids

Table 2. Combined analysis of variance for agronomic and yield traits of grain sorghum genotypes evaluated under three irrigation regimes at Assiut and Shandaweel, 2000.

Source of variance	d.f.	50% flowering	Plant height	Leaf area	1000 grain weight	No. of Grains /panicle	Grain yield/ plant
Locations(L)	1	23.2**	1837.7**	182393**	676.6**	29190015**	1673.2**
Loc(Reps.)	4	35**	192.5**	511.4	27.8**	531712**	12.5
Irrigations(I)	2	866.2**	51508**	616369**	510**	14622962**	9470.2**
L X I	2	74.3**	3399**	46996**	57**	1223093**	93**
L(Reps X I)	8	2.7**	33.8	3591.4**	9.7**	225961**	4.4
Genotypes(G)	34	250.8**	23643**	119144**	180**	6883744**	3768**
Parents(P)	9	298.6**	16502**	159811**	203.7**	5509851**	1618.7*
P vs Crosses	1	726.2**	218207**	344123**	734.3**	26822131**	39259**
Crosses(F_1)	24	213.1**	18214**	94520**	148**	6568187**	3095**
G X L	34	7.3**	350**	6065.3**	57.6**	1234975**	635**
P X L	9	12.5**	473.5**	5095**	79.7**	1302616**	436.8**
P vs F_1 X L	1	0.84	1330.3**	44101**	0.05	276830*	404**
F_1 X L	24	5.6**	262.8**	4844.3**	51.7**	1249532**	719**
G X I	68	4.7**	263.4**	2249**	4.3**	280335**	165.8**
P X I	18	5.2**	470.5**	1423**	1.2	198974**	129.8**
P vs F_1 X I	2	2.5*	162.4**	8579.6**	11.1**	310740**	113**
F_1 X I	48	4.7**	190**	2295**	5.2**	309578**	181.6**
L X I X G	68	3.1**	124.7**	1513**	3.88**	242519.8**	149.8**
L X I X P	18	2.9**	167**	1075.7**	2.0	114752**	56.5**
L X I X P vs F_1	2	0.18	132.8**	4351**	1.9	60831	22.6
L X I X F_1	48	3.2**	108.5**	1559**	4.6**	298003**	190.6**
Error	408	0.63	21.4	297.5	1.95	49611	10.6
CV %		1.08	2.84	2.4	6.0	7.5	4.8

*, ** significant and highly significant at 0.05 and 0.01 probability level, respectively.

respectively, indicating higher reduction of both maximum and minimum yield range limits for parents and higher reduction of maximum yield range limits for hybrids at GS2 than at GS3. This might be attributed to the effect of high severity of soil moisture stress at GS2 stage.

Both parents and hybrids differed markedly in drought tolerance at both GS2 and GS3 stages. Drought tolerance measured by relative yield ranged from 60.5 to 108.0% at GS2 and from 80.1 to 100.2 % at GS3 among parents and ranged among hybrids from 64.5 to 94.2 % at GS2 and from 76.7 to 105.0 % at GS3 (Table 3).

Mean grain weight was reduced to 94.7 and 91.9 % at GS2 and to 89.4 and 86.7 % at GS3 for parents and hybrids, respectively as compared to control. Parents ranged for 1000-grain weight from 17.8 to 26.9 g under control, from 16.0 to 26.0 g at GS2 and from 15.7 to 24.9 g at GS3, while hybrids ranged from 20 to 31 g under control, from 19.2 to 29.0 g at GS2 and from 16.5 to 28.8 g at GS3.

Table 3. Means and ranges of different traits of grain sorghum genotypes measured und conditions of 3 soil moisture regimes (control, stress at GS2 and stress at GS *(Data are combined across Assiut and Shandaweel locations).*

Traits			Parents			Hybrids		
			Un-stressed (control)	Stressed at		Un-Stressed (control)	Stressed at	
				GS2	GS3		GS2	GS2
Days to 50% Flowering	Range	Days	65-80	66-83	65-79	63-75	67-80	64-78
		%	-	101.6-106.8	99.6-104.9	-	101.3-110.0	99.0-106.7
	Mean	Days	73.3	76.9	74.5	70.6	74.7	72.2
		%	100	105.0	101.6	100	105.8	102.2
	LSD$_{0.05}$ among stress levels			1.05			0.85	
Plant height	Range	cm.	99-203	95-180	96-186	140-259	104-218	118-245
		%	-	67.7-95.9	86.6-96.9	-	71.2-93.9	84.2-95.1
	Mean	cm	148.2	118.3	134.2	191.4	159.4	173.7
		%	100	79.8	90.5	100	83.3	90.7
	LSD$_{0.05}$ among stress levels			8.6			3.0	
Leaf area	Range	cm^2	614-832	533-773	511-763	631-888	513—800	506-768
		%	-	85.6-95.7	82.3-92.7	-	81.3-96.5	79.7-93.9
	Mean	cm^2	721	657.5	635.6	789	700.6	679.5
		%	100	91.2	88.1	100	88.8	86.1
	LSD$_{0.05}$ among stress levels			20.4			19.3	
Grains/ panicle	Range	No.	2025-3822	1782-3664	1974-3782	2073-4426	1901-3899	1972-4231
		%	-	66.2-104.7	83.1-98.9	-	66.0-101.4	86.5-99.5
	Mean	No.	2738	2319	2552	3128	2790	2958
		%	100	84.7	76.6	100	89.2	94.5
	LSD$_{0.05}$ among stress levels			243.2			255.2	
1000 grain weight	Range	gm.	17.8-26.9	16.0-26.0	15.7-24.9	20.0-31.0	19.2-29.0	16.5-28.8
		%	-	90-99	84.0-92.5	-	82.0-100	73.7-93.7
	Mean	gm.	22.6	21.4	20.2	25.6	23.5	22.2
		%	100	94.7	89.4	100	91.9	86.7
	LSD$_{0.05}$ among stress levels			1.6			1.56	
Grain yield/ plant	Range	gm.	43.3-78.0	39.9-63.2	43.4-73.5	51.6-112.5	45.9-91.3	44.8-99.9
		%	-	60.5-108	80.1-100.2	-	64.5-94.2	76.7-105
	Mean	gm.	60.2	49.1	55.0	79.7	64.4	73.0
		%	100	81.8	91.4	100	80.8	91.6
	LSD$_{0.05}$ among stress levels			3.2			3.8	

Moreover, mean number of grains per panicle of stressed plants in percent of the control plants for each genotype, was generally decreased to 84.7 and 89.2% of the control when drought was imposed at GS2, and to 93.2 and 94.5 % at GS3 for parents and hybrids, respectively. It decreased to 66 % at GS2 and to 83.1 % at GS3 in the genotype most sensitive to drought stress, while it increased up to 104.7 % at GS2 and 99.5 % at GS3 in the most tolerant genotype.

The number of grains per panicle was reduced due to water stress relatively more than grain weight for both parents and hybrids stressed at GS2 stage. In contrast, grain weight was reduced relatively more than number of grains/panicle for all genotypes stressed at GS3. Although, reduction in grain weight at GS3 stage was more than that at GS2, reduction in number of grains per panicle was more in parents than in hybrids. This result is consistent with by Mirhadi and Kobayashi (1980), Eastin *et al* (1983), Farah (1983), Eastin *et al* (1989), Bakheit (1990) and Al-Naggar *et al* (1999), who showed that reductions of sorghum grain yield due to drought stress before anthesis are related to decreases in grain number, while a smaller grain weight is responsible for yield losses from water stress after anthesis. In wheat, drought stress has been found to affect pollen activity, which reduced seed number (Saini and Aspinall 1981). Reduction in grain number of sorghum subjected to water stress regime before anthesis may be also related to inefficient pollination and fertilization, but it can also result from ovule abortion after fertilization as found in maize (Moss and Downey 1971).

Yield reduction due to drought imposed prior to and after flowering were accompanied by losses in grain number/panicle and grain weight, but reduction in each yield component, separately, was not as high as reduction in grain yield/plant. Reductions in number of grains/panicle were higher than reduction in grain weight for both parents and hybrids stressed only at GS2 stage, but reductions in grain weight were higher than reduction in number of grains/panicle for both parents and hybrids stressed at GS3 stage.

Drought stress imposed after anthesis, i.e. at the GS3 stage did not produce significant changes in the number of days to 50 % flowering. But, water stress imposed at GS2 stage caused significant delay in heading date by 3.6 and 4.1 days for parents and hybrids, respectively as compared to the controls.

Flowering date under stress at GS2 stage ranged among parents from 66 to 83 days and among hybrids from 67 to 80 days. It was delayed by water stress at GS2 by up to 5 and 5.8 % for parents and hybrids, respectively. This result agrees with Pedro *et al* (1989), Blum *et al* (1989), Craufurd *et al* (1993) and Al-Naggar *et al* (1999), who reported that drought stress at GS2 stage can delay flowering in sorghum. Moreover, Lopez-Castaneda (1979) found that anthesis was retarded in barely and wheat by moisture stress.

Plant height of parental lines under stress at GS2 stage ranged from 95 to 180 cm and for hybrids from 140 to 259 cm. It was reduced by drought stress before heading to a mean of 79.8 % with a range of 67.7 – 95.9 % across parents and a mean of 83.3 % with a range of 71.2 – 93.9 across hybrids as compared with controls. The reduction in plant height due to water stress at GS2 was also reported by Blum *et al* (1989), Blum *et al* (1992) and Al-Naggar *et al* (1999).

Leaf area (LA) declined significantly in response to water stress. It decreased at GS2 to 91.2 and 88.8 % and at the GS3 to 88.1 and 86.1 % for parental lines and hybrids, respectively. It declined to 81.3 and 79.7 % in the poorest genotypes, while it was reduced only to 96.5 and 93.9 % in the best ones, when water was withheld at GS2 and GS3, respectively as compared to controls.

Differential response of genotypes

Means of genotypes under 3 irrigation regimes in absolute and relative values to control are presented in Table (4). When an advantage in both absolute yield under stress and relative yield to control was taken as an index of drought tolerance, the parental lines: V-112, R-89016 and R-90011 at both GS2 and GS3 and B-102 at GS3 only could be regarded as the most drought tolerant lines under the conditions of this study. Moreover, the crosses A-1 X V-112, A-102 X V-112, A-102 X R-90011 and A-1 X R-90011 at both GS2 and GS3, A-37 X R-90011, A-37 X V-112 and A-102 X R-89022 at GS2 and A-8806 X R-89022, A-88006 X V-112, A-1 X R-89016 and A-1 X R-89022 at GS3 could be considered the most drought tolerant hybrids in this experiment (Table 4).

It is interesting that the parental lines V-112, R-89016 and R-90011 which excelled under stress at GS2 and GS3 and A-102 which excelled at GS3 also excelled in potential yield under non-stress conditions. But R-89016 showed low relative yield at both GS2 and GS3 stress. V-112, A-102 and R-90011 at GS3 and R-90011 at GS2 showed high relative yield. Furthermore, the crosses A-1 X V-112, A-102 X R-90011 and A-102 X V-112, which excelled under stress at GS2 and GS3 and A-1 X R-89016 which excelled under stress at GS3 also excelled in potential yield, reaching a yield level of more than 100 g/plant under control (Table 4), while these crosses exhibited low relative yield at GS2 and GS3. Only the crosses A-37 X R-90011 and A-102 X R-89016 which excelled in absolute yield under stress at GS2 and A-88006 X R-89022 and A-88006 X V-112 which excelled at GS3 excelled also in their relative yield to control (drought tolerance index).

Based on results obtained, it is evident that absolute yield under stress and relative yield as a measure of drought tolerance may be independent characters. However, we could find some genotypes, which show both high absolute yield under stress and high relative yield.

The effect of drought stress on number of grains per panicle of each genotype is presented in Table (4). The parental lines R-90011 and R-89022, RTX82 BDM-499 and V-112 stressed at GS2 stage and R-90011, R-89016, RTX 82 BDM-499 and V-112 stressed at GS3 stage exhibited high e 4. Means of studied characters for 10 parental lines and their 25 F_1 crosses of grain sorghun tested under 3 irrigation regimes (data are combined over two locations) in 2000 season.

	enotypes	Grain yield/ plant (g) Un-stressed control	Grain yield/ plant (g) Stressed at GS2	Grain yield/ plant (g) Stressed at GS3	Grains/panicle Un-stressed control	Grains/panicle Stressed at GS2	Grains/panicle Stressed at GS3	1000-grain weight (g) Un-stressed control	1000-grain weight (g) Stressed at GS2	1000-grain weight (g) Stressed at GS3
	Parents									
	ICSB-1	54.8	45.9	43.9	2555	2279	2352	21.8	20.6	18.3
	ICSB-37	54.4	45.7	53.9	2278	1975	2115	24.2	23.2	21.2
	ICSB-102	71.4	43.2	65.8	2716	1807	2256	25.8	23.9	23.4
	ICSB-88005	54.4	47.9	50.7	2109	1924	1974	26.2	25.0	23.3
	ICSB-88006	47.5	39.9	43.7	2025	1782	1985	24.0	22.3	21.9
	ICSR-89016	78.0	57.7	67.4	3438	2276	3145	21.9	20.9	19.9
	ICSR-89022	43.3	46.9	43.4	2533	2654	2472	18.0	17.9	16.3
	ICSR-90011	65.2	57.1	60.5	3822	3664	3782	17.8	16.0	15.7
	ICSV-112	76.7	63.2	73.5	2882	2381	2652	26.9	26.0	24.9
0	RTX82BDM-499	56.7	43.6	46.7	3021	2445	2785	19.0	18.0	17.1
	SD 0.05 Parents	2.50	1.22	1.44	305.6	299.2	236.6	1.87	1.60	0.99
	Parents X stress levels		3.2			243.3			1.6	
	Crosses									
1	A-1 X R-89016	102.1	68.5	82.1	3789	3014	3560	27.0	23.4	19.9
2	A-1 X R-89022	89.9	58.0	81.9	3721	2455	3219	24.4	23.6	22.2
3	A-1 X R-90011	94.9	70.5	83.4	3910	3264	3474	23.9	22.0	18.5
4	A-1 X V-112	112.5	91.3	98.8	4022	3757	3895	27.5	24.5	23.1
5	A-1x RTX82BDM	70.3	63.2	53.9	2742	2622	2650	25.8	24.0	21.6
6	A-37 X R-89016	69.5	61.6	64.5	2760	2677	2685	25.0	23.0	21.7
7	A-37 X R-89022	62.2	54.0	57.7	2771	2639	2690	22.8	20.3	18.7
8	A-37 X R-90011	83.9	75.7	79.5	4095	3899	3910	20.0	19.2	16.5
9	A-37 X V-112	86.5	70.9	80.9	2882	2444	2664	30.9	29.0	27.7
10	A-37 X RTX82BDM	55.5	47.4	52.9	2456	2230	2351	22.5	21.3	18.5
11	A-102 X R-89016	79.5	70.3	77.9	3210	2959	3095	24.5	23.7	21.7
12	A-102 X R-89022	51.6	46.7	44.8	2154	2000	2052	23.2	23.2	19.5
13	A-102 X R-90011	103.2	75.9	96.4	4426	3681	4231	23.5	20.6	21.3
14	A-102 X V-112	105.3	76.8	99.9	3445	2711	3156	30.5	28.7	28.6
15	A-102X RTX82BDM	75.0	63.4	60.1	2832	2568	2715	26.3	24.7	22.9
16	A-88005 X R-89016	75.9	66.8	67.6	2938	2725	2812	26.2	24.6	23.7
17	A-88005 X R-89022	73.8	63.3	67.2	2952	2689	2776	25.6	23.8	23.5
18	A-88005 X R-90011	72.9	68.7	73.2	3287	3334	3256	22.3	20.6	20.0
19	A-88005 X V-112	75.9	60.8	68.6	2481	2323	2310	31.0	25.8	27.6
20	A-88005XRTX82BDM	54.2	45.9	48.9	2073	1901	1972	25.5	24.2	23.1
21	A-88006 X R-89016	74.9	50.6	72.8	3111	2520	2772	24.0	23.3	22.2
22	A-88006 X R-89022	87.9	69.2	84.2	3051	2923	2980	29.9	24.6	26.2
23	A-88006 X R-90011	83.5	67.4	76.3	3819	3255	3524	22.4	20.8	19.5
24	A-88006 X V-112	84.9	67.3	82.9	2480	2468	2470	30.9	27.9	28.8
25	A-88006X RTX82BDM	66.2	56.2	69.7	2792	2705	2742	23.6	21.5	19.1
	LSD 0.05 Crosses	5.1	2.6	2.6	311.6	221.8	200.2	2.02	1.5	1.4
	Crosses X stress levels		3.8			255.2			1.56	

Table 4. Continued

	Genotypes	Leaf area (cm^2)			Days to flowering			Plant height(cm)		
		Un-stressed control	Stressed at GS2	Stressed at GS3	Un-stressed control	Stressed at GS2	Stressed at GS3	Un-stressed control	Stressed at GS2	Stressed at GS3
	Parents									
1	ICSB-1	620	575	550	73	78	74	112	97	107
2	ICSB-37	614	570	546	71	75	72	121	109	114
3	ICSB-102	580	533	511	73	76	74	149	101	130
4	ICSB-88005	641	562	541	72	76	73	126	105	111
5	ICSB-88006	795	737	710	73	78	74	136	98	119
6	ICSR-89016	832	733	733	80	83	79	195	137	169
7	ICSR-89022	826	773	763	76	80	77	164	125	148
8	ICSR-90011	785	672	646	75	79	79	177	136	162
9	ICSV-112	795	761	737	75	78	78	203	180	186
10	RTX82BDM-499	722	658	619	65	66	65	99	95	96
LSD 0.05 Parents		30.6	14.1	25.4	1.26	0.88	---	2.83	14.6	2.9
	Parents X stress levels		20.4			1.05			8.6	
	Crosses									
1	A-1 X R-89016	770	699	667	73	77	74	186	160	171
2	A-1 X R-89022	832	795	768	72	75	73	149	125	133
3	A-1 X R-90011	778	730	698	72	74	73	183	150	167
4	A-1 X V-112	888	765	765	74	76	74	189	152	170
5	A-1x RTX82BDM	631	513	506	65	69	65	140	104	118
6	A-37 X R-89016	649	569	542	75	76	75	190	145	170
7	A-37 X R-89022	870	759	742	73	77	75	177	126	155
8	A-37 X R-90011	819	709	712	73	78	75	201	152	181
9	A-37 X V-112	856	739	721	72	76	73	242	213	227
10	A-37 X RTX82BDM	707	658	650	67	71	68	149	140	139
11	A-102 X R-89016	667	607	582	70	77	73	197	158	173
12	A-102 X R-89022	840	800	765	73	80	78	169	149	151
13	A-102 X R-90011	706	661	630	71	75	73	208	180	193
14	A-102 X V-112	816	788	767	72	76	73	244	218	232
15	A-102X RTX82BDM	777	682	639	63	67	64	149	130	138
16	A-88005 X R-89016	727	650	609	70	76	73	196	156	165
17	A-88005 X R-89022	785	723	689	71	74	72	196	166	176
18	A-88005 X R-90011	803	671	661	73	77	73	209	169	186
19	A-88005 X V-112	817	694	667	71	76	72	224	200	204
20	A-88005XRTX82BDM	715	603	570	64	67	66	160	120	146
21	A-88006 X R-89016	868	783	768	73	76	75	182	152	162
22	A-88006 X R-89022	856	755	744	71	75	73	231	206	217
23	A-88006 X R-90011	843	737	716	72	77	73	205	171	184
24	A-88006 X V-112	877	733	735	74	78	77	259	218	245
25	A-88006X RTX82BDM	827	692	676	63	69	65	149	126	140
LSD 0.05 Crosses		8.3	21.6	13.4	0.91	0.84	---	2.85	3.36	1.4
	Crosses X stress levels		19.3			0.085			3.0	

absolute and relative values for grains/panicle. On the other hand, the lines B-88006 and B-102 under stress at GS2 and B-88005 and B-88006 under stress at GS3 showed both low absolute and low relative values of grains/panicle. The hybrids A-1 X V-112, A-37 X R-90011 and A-88005 X R-90011, A-102 X R-90011, A-1 X R-90011 and A-88006 X R-90011 stressed at both GS2 and GS3 had both high absolute and relative values of grains/panicle, indicating tolerance to reduction of grain number under drought stress. In contrast, the crosses A-88005 X RT X 82 BDM, A-88005 X V-112, A-102 X R-89022 and A-37 X RTX82BDM stressed at GS2 and GS3 exhibited both low absolute and low relative values for grains per panicle, indicating susceptibility to drought.

Drought stress effect on 1000-grain weight of each genotype is presented in Table (4). The tolerant lines to reduction in grain weight by water deficit, considering both absolute and relative values were V-112, B-102 and B-88005 at both GS2 and GS3. These lines excelled also in their potential grain weight. On the other hand, the parental lines R-90011, R-89022 and RTX82BDM-499 showed sensitivity to drought at both GS2 and GS3 stages measured by absolute and relative values for grain weight. The hybrids A-37 X V-112, A-102 X V-112, A-88005 X V-112 and A-88006 X V-112 were the most tolerant crosses to the effect of drought stress on grain weight, when both absolute and relative values at GS2 and GS3 stages are considered. On the contrary, the most susceptible crosses for reduction in grain weight due to water stress were A-37 X R-90011, A-37 X R-890022, and A-88006 X R-90011 at GS2 and A-1 X R-90011, A-37 X R-89022, A-37 X R-90011 and A-37 X RTX82BDM-499 at GS3.

Mean number of days to flowering of each genotype under water stress is presented in Table (4). It is obvious that date of heading of each genotype was not significantly affected by experiencing drought at GS3 while significant differences were observed due to drought at GS2 stage. The genotypes showing low absolute number of days to heading under stress coupled with the low increase in relative value (less delay) at GS2 stage which means less effect from drought and could be considered tolerant to water stress included the parental lines RT X 82BDM-499, B-37, B-88005 and B-102 and the crosses A-1 X R-90011, A-1 X V-112, A-37 X R-89016, and A-88005 X RTX82BDM-499. On the other hand, genotypes exhibiting high absolute number of days to heading under stress and high increase in the relative number (more delay) at GS2 as compared to control (which means susceptibility to water stress) were the lines R-89016, R-89022 and V-112 and the hybrids A-102 X R-89016, and A-88006 X V-112.

Mean plant height in absolute and relative values of each genotype is presented in Table (4). The most tolerant parental lines to reduction in plant height due to drought were R-89016, R-89022, R-90011 and V-112 at both GS2 and GS3. On the other hand, B-1, R-88006 and RTX82BDM-499 at GS2 and B-1 and RTX 82BDM-499 at GS3 were the most susceptible and also exhibited low values of plant height under well-watering conditions.

The most tolerant hybrids to plant height reduction by water stress were A-37 also V-112, A-102 X V-112, A-88005 X V-112, A-88006 X R-89022 and A-88006 X V-112 at both GS2 and GS3. On the contrary, A-1 also R-89022, A-1 also RTX82BDM-499, A-37 X R-89016, A-88005 X RTX82 BDM-499 and A-88006 X RTX 82BDM-499 at GS2 and A-1 x R-89022, A-1 X RTX82BDM-499, A-37 X RTX82BDM A-102 X RTX82BDM, and A-88006 X RTX82BDM-499 at GS3 were the most sensitive to reduction in plant height due to drought.

Effect of water stress on leaf area (LA) of each genotype is shown in Table (4). The most tolerant genotypes to the reduction in LA due to drought imposed at both pre-and post-flowering stages were the lines A-88006, R-89016, R-89022 and V-112 and the crosses A-1 X R-89022, A-1 X V-112, A-102 X R-89022, A-102 X V-112 and A-88006 X R-89016. On the contrary, the most susceptible genotypes to reduction in LA due to stress imposed at GS2 and GS3 stages were the lines B-1, B-37, B-102, and B-88005 and the hybrids A-1 X RTX82 BDM-499, A-37 X R-89016, A-102 X R-89016, and A-88005 X RTX82 BDM-499.

Summarizing the previous-mentioned results, it is obvious that the drought tolerance exhibited by different genotypes and expressed in terms of both high absolute yield under stress and high yield relative to control was associated with drought tolerance expressed by characters other than yield which were similar in some cases and different in other cases. The drought tolerance expressed by yield was associated with the drought tolerance expressed by number of grains/panicle. LA and plant height for the parental lines B-102, R-89016, R-90011 and V-112; days to 50% flowering, plant height, and 1000 grain weight for B-102; plant height, LA, and number of grains for R-89016; plant height and number of grains for R-90011; and plant height, number of grains and 1000 grain weight for V-112. However, it has to be kept in mind that drought tolerance will be more effective for characteristics contributing to grain yield. In addition the high-yielding genotype under the stress conditions will be favoured for use, a part from its reaction to stress.

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اختلاف استجابة التراكيب الوراثية للذرة الرفيعة للإجهاد المائى فى مراحل النمو المختلفة

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تم تركيب ٢٥ هجين F_1 من الذرة الرفيعة للحبوب عام ١٩٩٩ بمحطة بحوث الجيزة مركز البحوث الزراعية من ٥ سلالات عقيمة ذكريا و ٥ سلالات معيدة للخصب مختلفة في تحملها للجفاف . و في موسم ٢٠٠٠ تم تقييم الآباء و الهجن في موقعين (أسيوط و شندويل) تحت ظروف أنظمة إجهاد مائى مختلفة (

الري الكامل ، الجفاف في مرحلة ما قبل التزهير والجفاف في مرحلة ما بعد التزهـــير).وقـــد اختلـــف أداء التراكيب الوراثية حسب اختلاف معاملات الجفاف و المواقع التجريبية حيث نقص متوسط محصول الحبـــوب نقصا معنويا نتيجة للإجهاد المائى فى كل من مرحلة ما قبل و ما بعد التزهير بمقـــدار ١٨,٢ ,٨,٦ % علـــى التوالي كمتوسط لكل الآباء و بمقدار ١٩.٢ ،٨,٤ % على التوالي كمتوسط لكل الهجن . و يشير ذلك إلى أن مرحلة ما قبل التزهير كانت اكثر حساسية لنقص الرطوبة الأرضية عن مرحلة ما بعد التزهير (مرحلة امتـــلاء الحبوب). كان النقص فى المحصول مصحوبا بنقص فى عدد حبوب القنديل ووزن الحبة . وكان النقص فـــى عدد حبوب القنديل أعلى من النقص فى وزن الحبة عند التعرض للإجهاد المائي في مرحلة ما قبل التزهـــير و كان العكس صحيحا عند التعرض للإجهاد المائي فى مرحلة ما بعد التزهير. تسبب الإجهاد المائي فى مرحله ما قبل التزهير فى حدوث تأخير فى تاريخ التزهير بمعدل ٥ ،٥,٨ % و نقص فى ارتفاع النبات بمعـــدل ٢٠,٢ ، ١٦,٧ % بالنسبة للآباء و الهجن على الترتيب . كما أن مساحة الورقة قد نقصـــــت بمعـــدل ٨.٨ ، ١١,٩ %بالنسبة للآباء، ١١,٢ ، ١٣,٩% بالنسبة للهجن عندما منع الري فى مرحلتي ما قبل و ما بعد التزهير على التوالي .وقد سجلت اختلافات معنوية بين التراكيب الوراثية المدروسة في استجابتها للجفاف الذي تتعرض له في مرحلة ما قبل أو ما بعد التزهير. عندما وضع فى الاعتبار تميز المحصول المطلق والمحصول النسبي تحت ظروف الجفاف مقارنة بالكنترول كمقياس لتحمل الجفاف وجد أن الســــلالات الأبويـــة R-89016,R-90011 and V-112 في مرحلة ما قبل التزهير و السلالات B-102,R-89016,R-90011,V-112 في مرحلة ما بعد التزهير يمكن وصفها بأنها السلالات الأكثر تحملا للجفـــاف و الـــهجن A-1xV-112,A-37xR-90011,A-102xR-90011 في مرحلة ما قبل التزهير و الهجن A-37xR-90011 , A-102xR-90011, A-1xR-89016 ، A-1xR-89022, A-1xR-90011,A-37xV-112,A-88006xR89022,A-88006xV-112 في مرحلة ما بعـــد التزهير يمكن اعتبارها الهجن الأكثر تحملا للجفاف .كما أنه من الجدير بالذكر أن نجـــد أن الســـلالات الأبوية R-89016, ، R-90011,V-112 و الـــهجن A-1xV-112,A-102xR-90011,A-102xV-112,A-1xR-89016 قد تفوقت أيضا في محصولها تحت ظروف الري الكامل.