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HETEROSIS AND PERFORMANCE OF GRAIN SORGHUM (*Sorghum bicolor* L. Moench) UNDER DROUGH CONDITIONS

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ABASTRACT

The present study was carried out at two Experimental Farm ,Al-Azhar Univ. at Assiut and Shandaweel Research Station at Sohag .The performance and heterosis in grain sorghum with reduced water applied used were studied .Five female sterile lines (A-lines) with six Egyptian restorer lines(R-lines) released from Egyptian program at Shandaweel. The parents were crossed to produce thirty crosses .Forty two genotypes (30 hybrids and their 11 parents as well as the hybrid Shandaweel 6 as check were evaluated in summer growing season 2004 in two locations Assiut and Sohag.

The combined analysis of variance over locations, showed highly significant differences among parents and crosses. Interaction effects were significant for parents and crosses with locations for all studied traits.

Results indicated that two B-lines (BTX-89002 and ICSB-35) and two R-lines (Adv.3/2002 and Adv.4/2002) were drought tolerance genotypes and gave the highest DTI(drought tolerance index) and lowest DSI(drought susceptibility index).

The estimates of heterosis for grain yield/ plant indicated that ,the crosses (ICSA-70x RTX-2794),(ICSA-70x RTX-2895) and (ICSA-155x RTX-2895) had the best heterotic effect over the two locations under both irrigation levels. Also ,these crosses are drought tolerance and significantly outyielded the check Shandaweel -6.

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) becomes an important cereal crop particularly in the semi-arid tropic areas where it has a vital source of food for millions of people around the world . The cultivated area is about 381 thousand feddans producing about 950 thousand metric tons of grains averaging 2.49 tons/feddan (FAO 2004). In Upper Egypt, grain sorghum is a major summer crop and about seventy percent of its acreage concentrated in Assiut and Sohag governorates.

The water deficiency problem is the most important production limitation in Egypt, where has both agriculture and living area concentrated in the Nile Valley. Nile water is not sufficient to satisfy increasing water demands . Therefore, water has to be used more efficiently and wisely. Emphasis must be placed on a staple cereal, which can attain high yield under stress conditions.

Discovery of cytoplasmic male sterile help breeders to develop high yielding hybrids with high quality characters which are able to increase the water use efficiency under environments of low water supply.

Many investigations have been established in grain sorghum under stress conditions, Hovny *et al* (2001) found highly significant differences among all studied traits .Also the female line ATX-629 gave the latest ones, when they were crossed with the same restorer line Dorado-v-9.Grain yield showed a high estimate of heterosis (71.28%)over the better parent in the cross (ATX-629XR-22808-13).Abd El-Halim (2003) found wide variation in heterosis among sorghum crosses, for earliness, plant height , grain weight and grain yield /plant .Hovny et al (2005) reported that highly significant differences among parents and crosses and significant interaction of parent and crosses with locations for all the studied traits .Best parent heterosis was generally manifested for all the studied traits .The cross (SAPRU-94009 (A)XRTX-430) had the highest positive significant heterosis for 1000-grain weight and grain yield /plant .

The objectives of the present investigation are to study the possibility to improve grain sorghum through hybridization method to drought tolerance by reducing quantity of irrigation water from 100 to 40 % from the optimum irrigation levels) and its effect on yield and some related traits Also ,to identify the drought tolerance and susceptible lines and hybrids of grain sorghum. In addition to estimate heterosis under both optimum and limited water supply environments.

MATERIALS AND METHODS

The present investigation was carried out at two locations, i.e., experimental farm, Faculty of Agriculture, Al-Azhar University at Assiut governorate and Shandaweel Research station, Agriculture Research center at Sohag governorate, Egypt. The investigation was conducted during the summer growing seasons 2003 and 2004. The main objective of this work, the possibility to improve grain sorghum to drought tolerance and high production through hybridization and determined of heterosis for all studied traits. To achieve the goals of this study, six fertility restorer lines (males) and five sterile (cms) lines (females) were used in a top cross system.

In the summer season 2003 the cross between six fertility restorer lines (R-lines) and five cytoplasmic male sterile (cms) lines (A-lines) were made to produce the thirty F_1 seeds. The heads of both parents (A-lines and R-lines) were bagged at flowering time before anathesis. The pollen were collected from each of the six restorer lines and stigmas of the five male sterile lines (A-lines) were pollinated with the collected pollen .

In the summer 2004 growing season, evaluated the crosses, six R-lines and five B-lines (fertile counterpart of the A-line and maintainer of it) under two levels of irrigation, optimum (100% ET) and severe water stress, 40% of the optimum. One check ; Shandaweel-6 a drought tolerant genotype was included. The name and origin of these genotypes are shown in table (1).

The experiments were laid out in a split plot design with three replications at the two locations. The main plot consisted of irrigation treatments, while genotypes were allocated to the sub plots. Sub plot size was one ridge,4 m long, 60 cm apart. Distance between plant hills was 20 cm and thinning was done leaving two plants /hill after three weeks from sowing date. The agricultural practices were followed as recommended except irrigation throughout the growing season. Planting dates were 7 and 8 June, 2004 at Shandweel Res. St. and Experimental Farm, Faculty of Agricultural, Al-Azhar University at Assiut, respectively . The quantity of water applied was calculated (Table 2) according to modified Penman equation for estimating evapotranspiration as described by Jensen *et al*. (1990).

Table (1): The name and origin of female and male lines.

No.	Lnesi	Origin
Female lines		
1	BTX-89002	U.S.A.
2	ICSB-35	India
3	ICSB-155	India
4	ICSB-47	India
5	ICSB-70	India
Male lines		
1	RTX-2794	U.S.A.
2	RTX-2817	U.S.A.
3	RTX-2895	U.S.A.
4	Adv.3 / 2002	Egypt
5	Adv.4/ 2002	Egypt
6	Adv.6/ 2002	Egypt

Table (2): Amount of irrigation water (m^3) applied for each irrigation treatments based on ET at the two locations

Irrigation	100% ET		40% ET	
	Assiut	**Sohag**	**Assiut**	**Sohag**
Sowing irrigation	400.00	400.00	400.00	400.00
Mohayah irrigation	315.00	315.00	315.00	315.00
3	325.00	305.50	130.00	122.20
4	345.10	324.20	138.04	129.28
5	418.30	404.20	167.32	161.68
6	380.70	365.30	152.28	146.12
7	340.70	339.20	136.28	135.68
Total	2524.80	2453.40	1438.92	1410.36

The amount of water differed from irrigation to another according to the age of plant and temperature**.**

The studied characters which measured as the mean of ten random guarded plants in each plot were days to 50% flowering, plant height (cm), panicle length (cm): panicle width (cm), 1000-grain weight (gm) and grain yield/plant (gm).

Drought tolerance index and drought susceptibility index were calculated as follows:-

Drought tolerance idex (D.T.I.) was calculated according to the following equation:

$$DTI = \frac{\text{Trait mean under stress condition}}{\text{Trait mean under optimum condition}} \times 100$$

1- Drought susceptibility index (D.S.I.) was calculated according to Fischer and Maurer (1978) equation as follows:-.

$$\mathbf{DSI = (1 - Y_D/Y_W) / (1 - Y_{MD}/Y_{MT})}.$$

Where:

Y_D is yield under the drought stress.
Y_W is yield under the non-drought stress.
Y_{MD} is mean yield for all genotypes under stress irrigation
Y_{MT} is mean yield for all genotypes under optimum irrigation.
DSI values > 1.0 indicate relatively drought susceptible and <1.0 indicat relatively drought tolerance.

Statistical analysis:-

Data of each location and combined over the two locations under both irrigation levels were subjected to regular analysis of variance of a split plot in a randomized complete block design according to Gomez and Gomez (1984).

Heterosis :

Heterosis was calculated as the percentage of deviation of F_1performance over the better parent performance as described by **Bhatt (1971)**. The better parent Heterosis ($\overline{B.P}$) was calculated using the flowing equation:

Heterosis from the better- parent H($\overline{B.P}$)% $= \frac{\overline{F}_1 - \overline{B.P}}{\overline{B.P}} x100$

L.S.D. of heterosis $= \sqrt{\frac{2Mse}{r}}$ x t $\propto$

$t_\propto$ = t value according to the degree of freedom for the error.
r = number of replication.

RESULTS AND DISCUSSIONS

1-The analysis of variance:-

The combined analysis of variance for genotypes under the each level of irrigation over two locations (table 3) show significant differences between two locations for all studied traits except panicle length under 100% level of irrigation and 1000- grain weight in all irrigation levels, reflecting the sensitivity of the genotypes to fluctuations in climatic factors. The interaction between females x locations was significant for all studied traits under each level of irrigation over two locations except 1000-grain weight under 100% level of irrigation. The combined analysis of variance for female lines, male lines and their F_1 crosses under each level of irrigation over two locations (table 3) showed significant differences between two locations for all the studied traits. The interaction between male lines x locations and crosses x locations was significant for all the studied traits under each level of irrigation over two locations except plant height and panicle width for male lines x location under 100% level of irrigation .

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2-The mean performance

The mean performance of female lines table(4) manifested that the female line ICSB-70 under both levels of irrigation over the two locations gave the best results(65.67 and 68.17 days) for earliness over the two locations under 40% and 100 % levels of irrigation, respectively. The female lines ICSB-155 under all levels of irrigation over the two locations exhibited the shortest plants (113.67 and 96.00 cm). The female line ICSB-35 recorded the best results for panicle length (30.50 and 28.17 cm) , panicle width(7.33 and 6.00cm) and grain yield plant(69.00 and 59.67 gm) under each level of irrigation over the two locations. For 1000-grain weight, the female line ICSP-47 exhibited the heaviest grain weight (25.00 and 21.67 gm) under all levels of irrigation over the two locations .

The mean performance of male lines (table 4) elicited that the male line RTX-2794 exhibited earlier mean performance (66.67 and 66.17) under all levels of irrigation over the two locations. On the same time it gave best results for panicle length (32.33 and 26.83 cm) under all levels of irrigation over the two locations while, the male line RTX-2817 exhibited the shortest plants (100.34 and 83.34 cm) mean performance under all levels of irrigation over the two locations. On the other hand, Adv.4/2002 exhibited the tallest (185.84 and164.34cm) mean performance for plant height , in the same time it gave best results for panicle length(31.00 and 27.84cm) , panicle width(8.50 and 6.67 cm), 1000- grain weight (36.50 and 32.50 cm) and grain yield /plant (89.00 and 73.50 gm) under all levels of irrigation over the two locations.

The mean performance of crosses (table 4) indicated that under all levels of irrigation over the two locations the crosses ICSA-70x RTX-2794 , ICSA-47x RTX-2794 and ICSA-155 RTX-2794 exhibited earlier mean performance while, the crosses ICSA-35 x RTX-2817, ICSA-35 x Adv.3/2002 and ICSA-35 x Adv.6/2002 exhibited later mean performance over the two locations .

The cross ICSA-155x RTX-2794 recorded best result for earliness (60.33 and 60.84 days),plant height (127.17 and 113.17 cm) and panicle length (36.00 and 31.50 cm) under 100 % and 40 % levels of irrigation over the two locations .On the other hand the cross ICSA-155, RTX-2817 and ICSA-70 x RTX-2817 recorded the lowest values for plant height under 100% (125.67 and 121.00 cm) and 40% ET (110.34 and 109.84cm) levels of irrigation over the two locations.

Generally, data showed that the average of days to 50% flowering for all estimated genotypes increase under water stress condition, which means that water stress delays days to 50% flowering. Furthermore, that crosses were earlier than the parents confirming the significant contrast of parents vs. crosses. Similar results were obtained by Mahmoud (2002), El-Abd (2003) ,Hassaballa *et al* (2005),Hovny (2005) and Hovny *et al* (2005).They found that days to 50% flowering increased by increasing water stress.

Generally, mean plant height of the crosses and its parents decreased under water stress condition over the two locations.

The results for plant height are in harmony with those obtained by Wenzel (1988), El-Bakery *et al* (2000), Mahmoud (2002), El-Abd (2003)

,Hassaballa *et al* (2005),Hovny (2005) and Hovny *et al* (2005). They found that plant height of genotypes decreased when water stress increased.

Also , the mean performance of the crosses table 4 indicated that under all levels of irrigation over two locations the tallest panicle length over the two locations were the crosses ICSA-155 x Adv.4/2002, ICSA-70 x RTX-2794, ICSA-70x Adv.4/2002 and ICSA-47x RTX-2794 .

Generally , results obtained show a reduction of panicle length by increasing water stress. These results are in agreement with those obtained by Wenzel (1988)and Mahmoud (2002) They found that the reduction in panicle length increased by increasing the water stress

Moreover, the best results for 1000-grain weight(37.00 and 34.34 gm) and grain yield /plant (101.8. and 92.17 gm) obtained from the cross ICSA-70x Adv.4/2002 under 100 % and 40 % levels of irrigations over the two locations respectively .

The mean values of the crosses (table 4) showed that the crosses which exhibited the widest panicle under 100% level of irrigation were the crosses ATX-89002x Adv.4/2002, ICSA-155 x Adv.4/2002, ICSA-35 x Adv.4/2002 and ICSA-47 x Adv.4/2002. while under 40% level of irrigation over the two locations were the crosses ICSA-70 x RTX-2794and ATX-89002 x Adv.4/2002 . Generally, results indicated that mean panicle width of the crosses decreased under water stress from 100% to 40%. Similar results were obtained by Ahmed (1993)and Mahmoud (2002) They found that the reduction in panicle width increase by increasing the water stress.

The mean performance of evaluated crosses (table 4) elicited that the cross which exhibited heaviest 1000-grain weight under 100% level of irrigation over the two locations was the crosses ICSA-47 x Adv.4/2002(36.67gm) .

However ,results obtained showed reduction in 1000-grain weight by increasing water stress. Similar results were obtained by Al- Naggar *et al* (1999),El-Bakry *et al* (2000),Mahmoud (2002), El-Abd (2003) and ,Hassaballa *et al* (2005),Hovny (2005) and Hovny *et al* (2005).

In concerning twenty-three, crosses(Table 4) significantly earlier than the check hybrid (Shandaweel-6) under 100% level and twenty-three under 40% level of irrigation over the two locations. Seventeen crosses significantly shorter than the check hybrid under 100% level of irrigation over the two locations while, the tallest were nine. Under 40% level of irrigation six crosses significantly shorter than the check hybrid over the two locations while, the tallest were eleven . Ten crosses significantly taller panicle under 100% level than the check hybrid over the two locations and five crosses under 40% level of irrigation over the two locations. Five crosses under 100% level of irrigation and two crosses under 40% level of irrigation were significantly wider panicle than the check hybrid. Fifteen and twelve crosses were significantly heavier than of the check hybrid under 100% and 40% levels of irrigation over two locations, Moreover , nine crosses under 100% level of irrigation and fifteen crosses under 40% level of irrigation over two locations were significantly increased in grain yield/plant than the check hybrid.

Table (4): mean performance of all the studied traits for females, males and thirty one crosses of grain sorghum under two levels of irrigation over the two location.

	Days to 50% flowering		Plant height (cm)		Panicle length (cm)		Panicle width (cm)		1000-grain weight (gm)		Grin yield /plat (gm)	
	100%	40%	100%	40%	100%	40%	100%	40%	100%	40%	100%	40%
BTX-89002	70.67	73.17	156.00	132.17	24.17	23.67	6.17	4.50	22.50	19.67	47.17	42.67
ICSB-35	68.67	70.67	201.67	180.00	30.50	28.17	7.33	6.00	23.17	20.34	69.00	59.67
ICSB-155	67.67	68.17	113.67	96.00	30.17	25.50	6.84	4.83	22.17	17.33	37.50	26.34
ICSB-47	68.50	70.83	142.83	113.17	26.83	21.17	6.50	4.84	25.00	21.67	44.67	32.33
ICSB-70	65.67	68.17	119.00	104.00	30.17	25.00	7.00	5.33	22.50	18.84	43.67	29.84
Mean	68.23	70.20	146.63	125.06	28.36	24.70	6.76	5.10	23.06	19.57	48.40	38.17
L.S.D	0.63	1.30	18.55	11.62	1.90	0.81	0.46	0.36	2.01	0.68	3.35	5.94
RTX-2794	66.67	66.17	105.50	92.34	32.33	26.83	5.83	4.50	21.50	18.00	37.34	27.33
RTX-2817	70.67	70.17	100.34	83.34	26.84	19.17	6.00	3.33	20.50	18.50	37.67	21.34
RTX-2895	72.34	73.00	115.17	102.83	26.83	21.67	7.17	4.67	25.17	21.17	41.34	25.84
Adv.3/2002	68.17	67.67	174.50	147.50	29.34	26.17	7.34	5.84	32.84	28.34	82.50	65.00
Adv.4/2002	68.17	67.84	185.84	164.34	31.00	27.84	8.50	6.67	36.50	32.50	89.00	73.50
Adv.6/2002	72.00	71.67	126.84	106.84	23.50	18.67	6.17	4.00	25.84	23.67	54.84	41.00
Mean	69.67	69.42	134.69	116.19	28.30	23.39	6.83	4.83	27.05	23.69	57.11	42.33
L.S.D	0.56	1.68	12.61	23.08	2.24	2.54	0.81	0.35	0.71	1.39	2.25	1.86
ATX-89002xRTX-2794	61.00	60.00	138.50	119.50	32.17	28.33	7.00	5.00	19.50	17.84	42.00	32.50
ATX-89002 x RTX-2817	67.00	66.00	140.67	126.34	32.17	26.67	7.17	5.67	23.67	19.67	52.67	35.84
ATX-89002 x RTX-2895	67.67	66.00	139.34	123.84	29.67	25.83	6.67	5.34	20.00	17.50	56.00	41.84
ATX-89002 x Adv.3/2002	63.17	64.50	158.83	143.67	30.50	27.00	6.84	5.84	26.33	22.17	82.50	71.00
ATX-89002 x Adv.4/2002	63.34	63.67	187.50	161.50	33.50	27.67	8.50	6.50	28.33	26.34	94.34	79.67
ATX-89002 x Adv.6/2002	65.17	65.50	156.50	132.33	29.00	27.17	7.50	6.00	20.83	18.67	79.67	64.50
ICSA-35 x RTX-2794	66.67	67.84	136.00	120.84	34.67	29.67	7.00	5.50	21.00	18.84	62.50	42.50
ICSA-35 x RTX-2817	69.83	69.83	151.00	122.17	32.34	28.00	7.50	6.00	24.17	19.67	59.67	43.67
ICSA-35 x RTX-2895	69.50	69.50	148.84	120.00	29.67	25.84	7.17	5.50	23.67	20.34	59.17	40.00
ICSA-35 x Adv.3/2002	71.34	70.84	200.50	183.00	29.83	24.67	7.84	6.17	23.50	21.17	91.67	78.50
ICSA-35 x Adv.4/2002	68.00	69.67	207.00	186.50	34.67	29.00	8.33	6.17	30.34	26.50	95.50	84.50
ICSA-35 x Adv.6/2002	70.00	70.34	159.83	132.17	29.50	24.17	6.50	4.84	20.34	17.50	56.67	44.00
ICSA-155 x RTX-2794	60.33	60.84	127.17	113.17	36.00	31.50	7.33	5.67	22.50	20.67	65.67	51.50
ICSA-155 x RTX-2817	65.00	65.00	125.67	110.34	33.83	29.50	8.17	6.00	22.67	18.67	69.34	56.34
ICSA-155 x RTX-2895	68.50	66.84	150.84	125.00	30.67	27.84	7.00	6.34	24.17	22.00	76.00	61.00
ICSA-155 x Adv.3/2002	62.67	63.00	180.84	157.67	34.67	29.33	7.34	6.00	27.50	24.67	82.50	73.17
ICSA-155 x Adv.4/2002	63.50	63.17	182.00	144.84	35.17	30.83	8.50	6.17	35.67	32.00	95.00	80.84
ICSA-155 x Adv.6/2002	66.17	66.17	158.17	122.34	31.00	25.83	7.17	4.83	24.50	21.67	79.67	62.67
ICSA-47 x RTX-2794	60.17	60.83	134.83	126.00	33.50	32.50	7.67	6.00	27.84	23.84	64.84	55.67
ICSA-47 x RTX-2817	65.50	63.67	154.50	129.50	31.34	27.67	7.34	6.17	27.34	25.50	72.50	63.00
ICSA-47 x RTX-2895	67.00	66.17	166.50	135.34	30.00	26.84	7.50	6.00	24.00	21.67	67.34	59.67
ICSA-47 x Adv.3/2002	63.34	64.50	189.50	157.00	30.17	26.67	7.33	5.34	29.84	25.67	82.17	62.84
ICSA-47 x Adv.4/2002	64.50	65.67	200.17	153.84	31.84	29.00	8.33	6.17	36.67	31.34	91.34	77.00
ICSA-47 x Adv.6/2002	63.67	64.34	169.83	149.67	28.00	25.17	7.50	6.00	26.50	23.34	78.83	64.67
ICSA70 x RTX-2794	59.50	61.67	131.67	106.67	35.17	32.50	7.00	6.67	28.34	24.67	76.67	65.67
ICSA70 x RTX-2817	65.67	65.17	121.00	109.84	31.17	27.84	6.67	5.00	24.00	22.34	59.34	49.17
ICSA70 x RTX-2895	67.00	65.67	157.17	115.84	30.17	27.67	6.67	5.50	27.33	25.17	72.34	62.17
ICSA70 x Adv.3/2002	66.00	66.67	188.50	157.83	31.34	29.00	6.84	5.17	30.17	27.84	71.50	61.17
ICSA70 x Adv.4/2002	62.00	61.83	212.00	183.17	35.50	31.84	7.67	6.34	37.00	34.34	101.8	92.17
ICSA70 x Adv.6/2002	66.17	66.34	145.34	124.50	30.17	25.00	7.17	6.17	29.00	26.17	74.34	60.34
Sandaweel-6	68.66	68.16	169.33	130.00	32.00	28.67	7.50	6.00	25.50	23.84	76.00	58.83
Mean	65.31	65.37	160.67	136.48	31.91	28.01	7.37	5.80	26.22	23.25	73.78	60.58
L. S.D 0.05	1.43	1.35	11.04	10.58	0.84	1.91	0.42	0.36	0.57	0.55	4.33	2.77
Mean over all genotypes	66.30	66.55	155.16	132.12	30.95	26.93	7.22	5.57	25.96	22.87	68.25	55.18
L.S .D 0.05	1.88	1.54	8.64	8.24	1.64	2.46	1.02	1.01	1.25	1.26	3.23	2.85

3- The stability in performance

The stability in performance was estimated by two measures. The first, drought tolerance index (DTI), which is the percent of the mean performance of genotypes at 40% ET to its performance at 100% ET. The second, drought susceptibility index (DSI), which is the ratio of the deviation of performance at 40% from the performance at 100% ET to that of the overall mean deviation.

Drought tolerance index (DTI) for grain yield /plant (Table 5) values for the female lines ranged from 66.75% (ICSB-70) to 90.80% (BTX-89002) while, for the male lines it ranged from 52.92% (RTX-2817) to 84.75% (Adv.3/2002) .DTI values for the crosses ranged from 67.55 % (ICSA-35 x RTX-2794) to 90.38 % (ICSA-70 x Adv.4/2002)

Drought susceptibility index (DSI) values for the female lines ranged from 0.51 (BTX-89002) to 1.71 (ICSB-70) while for the male lines it ranged from 0.77 (Adv.3/2002) to 2.45 (RTX-2817). It ranged for the crosses from 0.49 (ICSA-70 x Adv.4/2002) to 1.69(ATX-89002 x RTX-2817).

Generally, results indicated that two B-lines (BTX-89002 and ICSB-35) and two R-lines (Adv.3/2002 and Adv.4/2002) were drought tolerance genotypes and gave the highest DTI and lowest DSI, while the other female and male lines were susceptible genotypes and gave the lowest DTI and highest DSI over the two locations. At severe drought (40%ET) the best stable lines are the female line BTX-89002 and male line Adv.3/2002 over the two locations (table 5) . It could be noticed that the best yielding ability lines were not the best stable lines. In this context, the sorghum breeder keen to identify the best high yielding lines under severe drought and the best stable lines to combine each other to get hopefully stable and high yielding hybrids .

At severe drought, 40% ET seven crosses significantly out yielded the check hybrid Shandaweel-6.The best crosses which gave the best yield at severe drought and out yielded the check hybrid Sandaweel-6 were seven crosses, ATX-89002 x Adv.4/2002, ICSA-35 x Adv.3/2002, ICSA-35 x Adv.4/2002, ICSA-155 x Adv.3/2002, ICSA-155 x Adv.4/2002,ICSA-47 x Adv.4/2002 and ICSA-70 x Adv.4/2002. The best B-lines over locations in yielding ability were ATX-89002 and ICSB-35, and the best restorer lines were Adv.3/2002 and Adv.4/2002, it was found that the best restorer line Adv.4/2002 shared in five out of seven superior crosses under severe drought in the two locations. Therefore, it concluded that the expression of grain yield per plant of the crosses of this particular population depended mainly upon the yielding ability of males rather than female lines.

Results in table (table 6) in generally indicated that the thirty crosses could be divided to three groups, that one which from No.1 to No 14 were drought tolerant under two locations and seven of them ATX-89002 x Adv.3/2002, ATX-89002 x Adv.4/2002, ICSA-35 x Adv.3/2002, ICSA-35 x Adv.4/2002, ICSA-155 x Adv.4/2002, ICSA-47 x Adv.4/2002 and ICSA-70 x Adv.4/2002 yielded significantly more than the check (Shandaweel-6) under each level of irrigation at two locations. Also, these crosses are drought tolerant and significantly out yielded the check hybrid (Shandaweel-6). These crosses can be used in sorghum production under drought stress condition after testing them in a large scale. Also, the male line Adv.4/2002which used in these crosses can be considered the best tolerant restorer line and it can be used in crossing with more female lines.

Table (5): Mean of grain yield /plant, drought tolerance index (DTI) and drought susceptibility (DSI) of grain sorghum genotypes under two irrigation levels over the two locations.

NO.	Genotypes	Grain yield /plant			
		100%	40%	DTI	DSI
1	BTX-89002	47.16	42.66	90.80	0.51
2	ICSB-35	69.00	59.66	86.61	0.67
3	ICSB-155	37.50	26.33	70.20	1.59
4	ICSB-47	44.67	32.33	72.75	1.44
5	ICSB-70	43.66	29.83	66.75	1.71
	Mean	48.40	38.16	0.00	0.00
1	RTX-2794	37.33	27.33	73.32	1.44
2	RTX-2817	37.66	21.33	52.92	2.45
3	RTX-2895	41.33	25.83	53.92	2.36
4	Adv.3/2002	82.50	65.00	84.75	0.77
5	Adv.4/2002	89.00	73.50	82.54	0.89
6	Adv.6/2002	54.83	41.00	74.78	1.35
	Mean	57.11	42.33	0.00	0.00
1	ATX-89002 x RTX-2794	42..00	32.50	77.49	1.21
2	ATX-89002 x RTX-2817	52.66	35.83	68.55	1.69
3	ATX-89002 x RTX-2895	56.00	41.83	74.51	1.35
4	ATX-89002 x Adv.3/2002	82.50	71.00	85.92	0.71
5	ATX-89002 x Adv.4/2002	94.33	79.66	84.38	0.81
6	ATX-89002 x Adv.6/2002	79.67	64.50	79.97	1.01
7	ICSA-35 x RTX-2794	62.50	42.50	67.55	1.67
8	ICSA-35 x RTX-2817	59.66	43.66	73.22	1.43
9	ICSA-35 x RTX-2895	59.16	40.00	68.07	1.60
10	ICSA-35 x Adv.3/2002	91.66	78.50	85.73	0.77
11	ICSA-35 x Adv.4/2002	95.50	84.50	88.32	0.60
12	ICSA-35 x Adv.6/2002	56.67	44.00	77.61	1.19
13	ICSA-155 x RTX-2794	65.66	51.50	79.23	1.06
14	ICSA-155 x RTX-2817	69.33	56.33	81.42	1.00
15	ICSA-155 x RTX-2895	76.00	61.00	80.98	1.06
16	ICSA-155 x Adv.3/2002	82.50	73.16	88.50	0.60
17	ICSA-155 x Adv.4/2002	95.00	80.83	84.92	0.77
18	ICSA-155 x Adv.6/2002	79.66	62.67	77.28	1.10
19	ICSA-47 x RTX-2794	64.83	55.66	85.83	0.75
20	ICSA-47 x RTX-2817	72.50	63.00	86.48	0.68
21	ICSA-47 x RTX-2895	67.33	59.66	88.80	0.61
22	ICSA-47 x Adv.3/2002	82.16	62.83	75.84	1.33
23	ICSA-47 x Adv.4/2002	91.33	77.00	84.30	0.84
24	ICSA-47 x Adv.6/2002	78.83	64.66	81.98	0.89
25	ICSA70 x RTX-2794	76.66	65.67	85.66	0.77
26	ICSA70 x RTX-2817	59.33	49.16	81.87	0.92
27	ICSA70 x RTX-2895	72.33	62.16	85.22	0.76
28	ICSA70 x Adv.3/2002	71.50	61.16	85.08	0.75
29	ICSA70 x Adv.4/2002	101.83	92.16	90.38	0.49
30	ICSA70 x Adv.6/2002	74.33	60.33	79.26	0.99
Mean		72.38	60.58		
Shandaweel-6		76.12	67.17		
LSD_0.05		4.33	2.75		

Table (6): The classification of thirty crosses based on their performance at two locations.

No.	Crosses	Assiut	Sohag
Group one			
1	ATX-89002 x Adv.3/2002	R	R
2	ATX-89002 x Adv.4/2002	R	R
3	ICSA-35 x Adv.3/2002	R	R
4	ICSA-35 x Adv.4/2002	R	R
5	ICSA-155 x Adv.3/2002	R	R
6	ICSA-155 x Adv.4/2002	R	R
7	ICSA-47 x RTX-2794	R	R
8	ICSA-47 x RTX-2817	R	R
9	ICSA-47 x RTX-2895	R	R
10	ICSA-47 x Adv.4/2002	R	R
11	ICSA70 x RTX-2794	R	R
12	ICSA70 x RTX-2895	R	R
13	ICSA70 x Adv.3/2002	R	R
14	ICSA70 x Adv.4/2002	R	R
Group two			
15	ATX-89002 x RTX-2817	S	S
16	ATX-89002 x RTX-2895	S	S
17	ICSA-35 x RTX-2794	S	S
18	ICSA-35 x RTX-2817	S	S
19	ICSA-35 x RTX-2895	S	S
20	ICSA-35 x Adv.6/2002	S	S
Group three			
21	ATX-89002 x RTX-2794	R	S
22	ATX-89002 x Adv.6/2002	S	R
23	ICSA-155 x RTX-2794	S	R
24	ICSA-155 x RTX-2817	R	S
25	ICSA-155 x RTX-2895	R	S
26	ICSA-155 x Adv.6/2002	S	R
27	ICSA-47 x Adv.3/2002	R	S
28	ICSA-47 x Adv.6/2002	S	R
29	ICSA70 x RTX-2817	S	R
30	ICSA70 x Adv.6/2002	S	R

Where R means drought tolerance hybrid while, S means drought susceptible hybrid .

The second group which from No. 15 to No .20 were susceptible under two locations and yielded less than the check hybrid (Shandaweel-6).The third group which from No. 21- No. 30 differed from location to location it's due to genotype by environment interaction. None of them is yielded more than the check hybrid Sandaweel-6 .

Generally ,the first and second group were stable more than the third one and the first group is the best one .These results are in harmony with those obtained by Haussmann *et al* (1998), Rao *et al* (1999), Al-Naggar *et al* (1999), Mahmoud (2002), El-Abd (2003) , and hovny (2005).

4-Heterosis :

Heterosis or hybrid vigor is a relative measure of the advantage of the F_1 hybrid over any of the parental lines. However, in sorghum heterosis would vary greatly from cross to another depending on the genetical differences between the two parental lines .Heterosis expressed as percentage deviation of F_1 performance from its better parent values for all the studied traits are presented in table (7).The high positive and highly significant percentages of heterosis would be of interest in most traits under investigation, however for days to flowering and plant height, high significant negative percentages would be useful from the breeders point of view.

Heterosis for days to 50% flowering from the earlier parent nineteen hybrids under 100% of irrigation level expressed negative significantly heterotic effects, the cross ATX-89002 x RTX-2794 recorded the best desirable value for this (-8.63%) (ATX-89002 x RTX-2794).While seventeen hybrids gave negative significantly heterotic effects under 40% level of irrigation .The cross ICSA-47 x RTX-2794 gave best results(-9.94) for this trait. These results are in accordance with those obtained by Chhina and Phul (1988) , Mahmoud (2002) , Hassaballa *et al* (2005) Hovny (2005) and Hovny *et al* (2005) they recorded differences in crosses from earlier to late for days to flowering .

For plant height all crosses except one had had positive and significant heterotic effect. The highest values 77.93 %74.93 % were obtained from the cross (ICSA70 x Adv.4/2002) under 100%and 40% of irrigation levels respectively. Similar results were obtained by Chhina and Phul (1988) ,Mahmoud (2002), Hassaballa *et al* (2005) , Hovny (2005)and Hovny *et al* (2005) .

For panicle length twenty four crosses had positive and significant heterotic effect under 100% level of irrigation .The highest value 19.87% recorded for the cross ATX-89002 x RTX-2817. Also under 40% of irrigation level twenty four crosses out of thirty had positive and significant heterotic effect values . The highest value 37.76 % recorded for the cross ICSA-47 x RTX-2817. Chhina and Phul (1988) and Mahmoud (2002) found positive and highly significant heterosis for panicle length under irrigated and limited irrigated locations.

For panicle width under 100% of irrigation level thirteen crosses out of thirty had positive and significant heterotic effect values.Best results for this trait 32.31% were obtained from the crossICSA-155x RTX-2817. Under 40% of irrigation level nineteen crosses out of thirty had positive and significant heterotic effect . The highest value 38.46% recorded for the cross ICSA-155 x RTX-2817. Similar results were obtained by Mahmoud (2002).

For 1000-grain weight and grain yield /plant under 100% and 40% of irrigation levels the cross ICSA-70 x RTX-2794 recorded 28.26 % and 32.21gm) and (86.45 and 112.5 gm) for 1000- grain weight and grain yield /plant gm under 100% and 40% of irrigation levels, respectively. For 1000-grain weight under 100% ten crosses out of thirty had positive and significant heterotic effect Also, eleven crosses out of thirty had positive and significant heterotic effect out of thirty under 40% of irrigation level . In this respect positive and highly significant heterotic effects for 1000-grain weight under irrigated and limited irrigated sorghum were obtained by Chhina and Phul (1988), Mahmoud (2002), Hassaballa *et al* (2005) Hovny (2005) and Hovny *et al* (2005) .

For grain yield/plant under 100% of irrigation level twenty crosses out of thirty had positive and significant heterotic effect values Also, under 40% of irrigation level twenty crosses out of thirty had positive and significant heterotic effect values. The crosses (ICSA-70x RTX-2794), (ICSA-70x RTX-2895) and (ICSA-155x RTX-2895) had the best heterotic effect over the two locations under both irrigation levels..Positive and highly significant heterotic effects were obtained by Mostafa (1979), El-Bakry (1998), Haussmann et al (1988) and Mahmoud (2002), Hassaballa *et al* (2005) and Hovny (2005). They indicated that heterosis was manifested in grain sorghum crosses for grain yield and its components.

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قوة الهجين والأداء الوراثي في ذرة الحبوب الرفيعة تحت ظروف الجفاف

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أجرى هذا البحث بهدف التعرف على الهجن ذات المحصول العالي المقاومة للجفاف، حيث تم التقييم تحت مستويين من الري (100% و40%) من الكمية المثلي للمياه. وذلك في موقعين هما مزرعة كلية الزراعة بجامعة الأزهر بأسيوط ومزرعة محطة البحوث الزراعية بجزيرة شندويل والتابعة لمركز البحوث الزراعية حيث تم الاختيار العشوائي لخمس سلالات عقيمة الذكر سيتوبلازمياً وستة سلالات معيدة للخصوبة.تم التهجين في محطة بحوث شندويل بسوهاج بين السلالات العقيمة ذكرياً وبين السسلالات المعيدة للخصوبة بنظام تزاوج السلالة في الكشاف فحصل على ثلاثين هجيناً ، ثم تم تقييم هذه الهجن وآبائها بالإضافة إلى هجين شندويل-6 للمقارنة وذلك لصفات 50%تزهير ،ارتفاع النبات ،طول القنديل وعرضه ،وزن الألف حبة ومحصول حبوب النبات في كلا الموقعين تحت مستويي الري 100% و 40 % من الكمية المثلي للمياه.وقد استخدم تصميم القطع المنشقة مرة واحدة في ثلاث مكرارات حيث وضعت مستويات الري في القطع الرئيسية بينما وضعت التراكيب الو راثية في القطع الشقية

وتتلخص أهم النتائج المتحصل عليها فيما يلي:

1-أوضحت نتائج تحليل التباين المشترك لنواتج المواقع أن هناك اختلافات معنوية بين الآباء وكذلك بين الهجن الناتجة منها كما كان تفاعل المواقع مع كل من الآباء والهجن معنويا لكل الصفات تحت الدراسة.

2-أوضحت النتائج أن الآباء (Adv.3/2002 and Adv.4/2002) والآباء (BTX-89002 ICSB-35)كانت أكثر الآباء تحملا للجفاف وأعطت اعلي قيم DTI واقل قيم DSI .

3-كانت قوة الهجين لأفضل الآباء واضحة لكل الصفات تحت الدراسة كما أعطت الهجن (ICSA-70x RTX-2794),(ICSA-70x RTX-2895) and (ICSA-155x RTX-2895) قوة هجين موجبة وعالية لصفتي وزن الألف حبة ومحصول حبوب النبات وتعتبر هذه الهجن أفضل الهجن الناتجة حيث كانت مقاومة للجفاف وتفوقت في إنتاجها عن هجين المقارنة شندويل-6.

Table (3): Combined mean squares of forty-two genotypes under each level of irrigation over two locations for the studied traits.

S.O.V	d.f	50%flowering		Plant height		Panicle length		Panicle width		1000-grain weight		Grain yield	
		100%	40%	100%	40%	100%	40%	100%	40%	100%	40%	100%	40%
Location	1	403.63**	939.38**	3262.59**	28688.71**	3.63	149.94*	8.60**	23.42**	0.54	5.85	4944.52**	7384.86**
Females	4	19.63**	26.53**	7471.87**	6747.55**	46.53**	39.45**	1.22*	2.05**	7.80**	15.80**	871.55**	1089.00**
F x L	4	4.33**	4.77**	334.87**	1036.38**	9.47**	19.45**	1.28*	1.72**	4.80	21.37**	106.62**	68.63**
Males	5	32.47**	41.52**	8010.96**	6255.29**	62.36**	98.91**	6.33**	8.93**	241.78**	197.83**	3221.84**	2910.20**
M x L	5	2.64**	6.76**	51.23	211.294**	6.85*	27.80**	0.58	2.04**	15.11**	8.50**	250.31**	181.51**
Crosses	30	55.01**	50.44**	3868.05**	2926.13**	28.99**	29.94**	1.81**	1.45**	128.07**	108.87**	1224.93**	1320.17**
C x L	30	24.88**	21.07**	279.99**	403.53**	3.28**	13.77**	0.69*	0.70**	12.80**	7.34**	277.67**	266.91**
Error	120	1.46	1.56	34.80	29.10	1.82	2.07	0.45	0.40	1.23	1.18	4.69	3.02

***,**Significant at 0.05and0.01probabilitylevels,respectively**

Table (7). Heterosis as a percentage of the better parent for all the studied traits over the two locations under two of irrigation levels.

Crosses	Days to 50%flowering		Plant height		Panicle length		Panicle width		1000-grain weight(gm)		Grain yield/plant	
	100%	40%	100%	40%	100%	40%	100%	40%	100%	40%	100%	40%
ATX-89002 x RTX-2794	-8.63**	-9.21**	31.30**	30.58**	8.50**	10.17**	16.37**	15.06**	-12.50**	-7.74**	-10.90**	-23.90**
ATX-89002 x RTX-2817	-6.76**	-3.74**	40.07**	51.10**	19.87**	22.83**	13.59**	28.98**	6.02**	1.64	6.91**	-17.30**
ATX-89002 x RTX-2895	-8.26**	-5.60**	21.50**	20.91**	10.84**	18.83**	-4.76**	18.94**	-18.30**	-17.90**	18.00**	-2.82*
ATX-89002x Adv.3/2002	-5.49**	-6.45**	2.09	10.61*	4.09**	4.00**	-6.11**	0.16	-19.80**	-22.30**	-0.02	1.59
ATX-89002 x Adv.4/2002	-7.41**	-5.68**	20.54**	23.83**	8.195**	4.82**	0.00	-2.50**	-22.20**	-18.50**	5.61**	8.19**
ATX-89002 x Adv.6/2002	-8.33**	-8.12**	23.51**	24.94**	18.82**	20.00**	15.48**	36.65**	-19.30**	-20.50**	44.64**	48.15**
ICSA-35 x RTX-2794	2.72**	0.03	28.92**	31.25**	8.99**	9.78**	-4.55**	-7.90**	-9.19**	-6.82**	-9.19**	-28.90**
ICSA-35 x RTX-2817	0.46	0.96	50.25**	45.50**	6.00**	5.39**	2.27**	1.54**	4.48**	-6.37**	-13.00**	-26.90**
ICSA-35 x RTX-2895	-1.73	1.19	29.59**	15.58**	-2.73*	-6.26**	-2.27**	-10.40**	-5.36**	-4.84**	-14.30**	-33.00**
ICSA-35 x Adv.3/2002	3.99**	5.27**	14.75**	24.86**	-2.18*	-6.22**	4.54**	3.56**	-28.40**	-25.70**	10.99**	12.55**
ICSA-35 x Adv.4/2002	0.48	1.96	11.31**	14.11**	11.31**	1.10	-1.93**	-7.50**	-16.80**	-17.90**	7.24**	14.77**
ICSA-35 x Adv.6/2002	-0.03	1.66	25.94**	25.02**	-3.28**	-8.75**	-11.40**	-19.00**	-21.40**	-25.60**	-17.50**	-26.30**
ICSA-155 x RTX-2794	-8.40**	-9.24**	20.60**	27.36**	15.09**	21.60**	19.01**	17.79**	0.55	12.60**	77.30**	89.32**
ICSA-155 x RTX-2817	-4.99**	-3.56**	25.32**	33.12**	12.20**	17.16**	32.31**	38.46**	5.19**	4.58**	54.29**	92.62**
ICSA-155 x RTX-2895	-1.21	0.47	35.00**	34.64**	1.73	7.95**	0.00	24.79**	-0.47	7.32**	79.54**	100.10**
ICSA-155 x Adv.3/2002	-7.51**	-6.46**	59.05**	64.87**	13.67**	14.01**	0.00	3.10**	-16.20**	-13.30**	-0.32	3.98**
ICSA-155 x Adv.4/2002	-7.55**	-5.04**	60.04**	51.47**	13.44**	12.65**	0.00	-7.50**	-2.33*	-1.39	6.70**	9.31**
ICSA-155 x Adv.6/2002	-4.29**	-0.96	39.13**	34.12**	2.84*	0.10	16.23**	7.14**	-4.92**	-7.64**	44.89**	51.18**
ICSA-47 x RTX-2794	-7.81**	-9.94**	27.81**	37.26**	11.26**	22.34**	18.03**	19.65**	11.47**	10.59**	45.15**	71.92**
ICSA-47 x RTX-2817	-8.09**	-5.18**	54.30**	54.91**	16.08**	37.76**	13.03**	27.62**	9.36**	18.06**	45.27**	93.10**
ICSA-47 x RTX-2895	-6.14**	-2.73**	45.11**	31.35**	9.77**	24.94**	7.14**	12.70**	-8.18**	-1.30*	41.79**	72.14**
ICSA-47 x Adv.3/2002	-6.73**	-5.00**	32.66**	38.46**	2.85**	1.16	0.20	-8.17**	-9.14**	-9.87**	-0.07	-8.23**
ICSA-47 x Adv.4/2002	-6.72**	-1.65	40.13**	35.57**	2.81**	5.42**	-1.93**	-7.50**	0.99	-3.02**	2.69	5.49**
ICSA-47 x Adv.6/2002	-7.62**	-8.60**	33.99**	44.26**	4.29**	30.83**	15.79**	23.818**	2.75**	-0.70	44.11**	57.31**
ICSA70 x RTX-2794	-7.67**	-7.99**	24.76**	16.18**	10.55**	23.61**	0.00	28.34**	28.26**	32.21**	86.45**	112.50**
ICSA70 x RTX-2817	-1.24	-2.13*	20.36**	31.99**	3.33**	17.90**	-4.55**	-4.058**	7.81**	20.59**	32.29**	68.53**
ICSA70 x RTX-2895	-0.18	-1.42	36.52**	14.67**	0.03	14.55**	-6.93**	8.70**	12.86**	21.90**	65.41**	113.20**
ICSA70 x Adv.3/2002	-1.19	1.95	58.26**	51.49**	3.86**	8.27**	-8.80**	-16.20**	8.08**	-2.28**	-13.50**	0.20
ICSA70 x Adv.4/2002	-7.88**	-6.60**	77.93**	74.93**	14.02**	16.87**	-9.69**	-5.00**	1.72	6.43**	14.01**	19.72**
ICSA70 x Adv.6/2002	-0.68	0.01	22.30**	24.74**	0.00	11.20**	2.50**	19.23**	12.46**	11.44**	34.92**	45.32**
L .S D at 0.05	2.56	2.65	12.52	11.45	2.86	3.05	1.42	1.34	2.35	2.30	4.59	3.68
0.01	1.94	2.00	9.48	8.67	2.17	2.31	1.07	1.01	1.78	1.74	3.48	2.79