Line X Tester Analysis and Heterosis in Grain Sorghum Hybrids Under Water Stress Conditions

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Abstract:

Twenty five F_1 grain sorghum crosses, its parents (five female lines and five male lines) and one commercial hybrid (Shandaweel-6) as check were evaluated for yield and four other characters in 2010 and 2011 seasons at Shandaweel Res. Station under two levels of irrigation (100% and 40% ET). The obtained data showed significant or highly significant differences between years, irrigation treatments and among genotypes for all studied traits except between years for 1000-grain weight. The interactions years × genotypes, irrigation × genotypes and year × irrigation × genotypes were highly significant for all studied traits except for No. of green leaves. Also, the interaction years × irrigation was significant for plant height and 1000-grain weight. Highly significant differences among crosses, and parents for all studied traits were obtained in two seasons, except for No. of green leaves in 2011 season. Mean squares due to parents vs. crosses were highly significant differences for all studied traits. Partitioning sum of squares of crosses to their contributions (females, males and males × females interaction) showed significant or highly significant differences for all studied traits in the two seasons, except males × females interaction for No. of green leaves in 2011 season. Likewise, the interactions genotypes x irrigation, parents x irrigation, crosses × irrigation and their partitions (females × irrigation, males × irrigation and males × females × irrigation) were significant or highly significant for all studied traits in the two seasons except for males × irrigation and males × females × irrigation in the two seasons for no. of green leaves. The interaction crosses vs. parents × irrigation showed highly significant differences for all studied traits in the two years. Mean days to 50% flowering of hybrids and their parents were increased by increasing water stress, but plant height, No. of green leaves, 1000-grain weight and grain yield/plant of hybrids and parents were decreased with increasing water stress. Moreover, crosses had taller plants and higher grain yield/plant than best parents under the two levels of irrigation. Also, most of the crosses were earlier than their parents.

Both additive and non additive gene effects were important in the inheritance of all studied traits, and the non-additive gene effect played the major role in the inheritance of all the studied traits. The female lines ICSB- 52 and Sh-B-13 and male line ZSV-14 were good combiners for most studies traits. Moreover, some crosses showed positive and highly significant SCA for 1000 grain weight and grain yield / plant.

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Introduction:

Grain sorghum (Sorghum bicolor L. Moench) is one of the most adaptability crops and can be grown in wide series of environments. It is mainly grown for food, feed, industrial purposes and for emerging biofuels industry. Although sorghum has an ability to cope with many types of stresses, including heat, drought, salinity and flooding (Ejeta and Knoll, 2007) but in arid and semi-arid regions, this crop is usually affected by water stress at the reproductive stage particularly post flowering stage (Tuinstra *et al*., 1997 and Kebede *et al*., 2001). Water stress is a major limitation to crop productivity worldwide and possible global climate change scenarios suggests a future increase in the risk of drought. Drought is perhaps the most important abiotic stress limiting crop productivity around the world and is certainly of great significance in the semi-arid tropics, where rainfall is generally low and its distribution is erratic. (Rosenow and Clark, 1995, Boyer 1982 and Bohnet and Jensen 1996). Grain sorghum is one of the most drought tolerant grain crops and is an excellent crop model for study mechanism of drought tolerance. Drought resistance in sorghum is a complex trait influenced by many genes coding for various traits contributing towards drought tolerance (Blum, 1979).

Developing high yielding hybrids with high quality characters under stress conditions has become less difficult after using the cytoplasmic male sterile lines. In Egypt, grain sorghum is the fourth major cereal crop .Seventy percent are concentrated in Upper Egypt at Assiut and Sohag Governorates. Many studies have been established in grain sorghum genotypes.

Ahmed (1993) found that the combined analyses of variance of two years showed significant effects of water regimes and genotypes for plant height, head width, head weight, grain yield and seed index. Furthermore, the genotypes x irrigation interaction was significant for plant height, head length, threshing rate and seed index. Skipping irrigation at an early stage of development mainly delayed flowering and reduced plant height. Grain yield and its components, head length, head width, and head weight were declined to their lowest levels when water deficit was imposed during flowering stage. Al-Naggar *et al.* (1999) found that significant reduction in grain weight, grain yield/plant, days to 50% flowering and No. of green leaves under drought stress. The differences among genotypes (parent and hybrids) were significant for all the studied traits, except number of green leaves, also the differences among moisture regimes were significant for all the studied traits. All genotypes x locations, genotypes x moisture regimes and genotypes x moisture regimes x locations interactions were significant for all traits except genotypes x locations interaction for days to 50% flowering and grain yield /plant which were not significant. El-Bakry *et al*. (2000) found that mean days to 50% flowering was delayed from 69.2 to 71.0 and 72.7 days for the respective treatments; the control, 4 and 3 irrigations. Plant height was reduced from 210.5 to 189.4 and 11.4 cm. Also, decreasing number of irrigations reduced 1000-grain weight from 33.6 to 31.9 and 30.7 g. Similarly grain yield was reduced from 21.7 for the control to 16.8 and 14.1

ard/fed. for 4 and 3 irrigation treatments, respectively. The genotypes varied significantly in their response to limited number of irrigations. The average grain yield of seven selected hybrids under the lowest number of irrigations (severe stress) was 18.2 ard/fed. compared with the average of all genotypes (14.1 ard/fed.). The seven selected hybrids were taller and had higher 1000-grain weight, while days to 50% flowering had insignificant differences among the other genotypes under severe stress (3 irrigation treatment).

Abo-Zaid (2001) reported that mean squares due to males, females and their crosses were highly significant for all studied traits (plant height, days to flowering, No. of green leaves, panicle length, panicle width, 1000 grain weight and grain yield / plant) under all irrigation treatments (well watering control, with holding irrigation at pre flowering (GS_2) and post flowering (GS_3) indicating that estimates of GCA effects were significantly for both parents males and females. Contribution of the variation due to females to the total variation was much greater than that due to males for traits studied under all irrigation treatments. Moreover, variation due to male x female interaction was also highly significant for all traits studied, suggested that SCA effects were significant at 0.01 level of probability under all treatments. Results indicated that GCA effects for both males and females and SCA effects interacted significantly with locations at 0.01 level probability for most traits under all treatments. Mahmoud (2002) reported that most of the crosses were significantly early in heading compared to earlier parents under the three levels of irrigation. Mean days to 50% flowering of the hybrids and its parents were increased by increasing water stress, but plant height, No. of green leaves, 1000-grain weight and grain yield/plant of the hybrids and its parents were decreased with increasing water stress. Moreover, the F_1 hybrids had taller plants and higher grain yield/plant than best parents under the two locations. Also, most of the hybrids were earlier than their parents. El-Abd (2003) found that the intensity of the stress applied in his study was rather moderate with reductions under stress being 23.25, 18.38, 6.07, 21.85, 12.14 and 5.61% for grain yield/plant, total biomass/ plant, plant height, green leaf area/plant, total leaf area/plant and 1000-grain weight, respectively. The average percentage of heterosis was reduced by 8% for grain yield, 17 % for total biomass/plant, 2 % for plant height and 1.5% for total leaf area /plant under water stress, it increased by 17.4% for green leaf area/plant at physiological maturity and by 5% in 1000-grain weight. Apparently the hybrids possessed greater resistance to premature leaf senescence under water stress which have contributed to enhance grain filling as indicated by the increased individual grain mass. Amir (2004) found that the combined analysis of variance over irrigation levels at each location showed highly significant differences among the crosses and their partitions (females, males and females x males) for the all studied traits. These results indicated that the additive (GCA) and non-additive (SCA) were important in the inheritance of these traits. Also, he found that days to 50% flowering for all studied genotypes increasing under water stress, means water stress delay the days to 50% flowering but, plant height, No. of green leaves, 1000-grain weight and grain yield/plant were decreased with increasing water stress for the hybrids and it parents. Mahmoud (2007) found that highly significant mean squares were found due to genotypes, crosses, parents, parents vs. crosses and males x females interaction for all studied traits (days to flowering, plant height, 1000-grain weight, number of grains/ plant and grain yield/plant). Some crosses were earlier than its parents and most of the crosses were heavier in 1000-grain weight than the better parent. Moreover, all crosses were taller, higher in number of grains/ plant and higher in grain yield/plant than the better parent in each year and combined over two seasons. Both of additive and non-additive gene effects were important in the inheritance of all studied traits. The additive gene effects played the major role in the inheritance of plant height, 1000-grain weight and grain yield/plant. Amir (2008) the results indicate that most of crosses were earlier, taller, higher in number of green leaves and higher in grain yield per plant than the best parents under two levels of irrigation (100 and 40 % ET). Some crosses showed positive and highly significant SCA for days to flowering, plant height, 1000-grain weight, number of green leaves and grain yield/plant. The female line ICSA-89002 and male line MR-812 were good combiner for most the studied traits. Moreover, some crosses showed good performance and higher yield under drought and were considered drought tolerant. El- Dardeer *et al* (2008) found that, mean square due to the interaction of genotypes x irrigation treatments was also highly significant, indicating that genotypes responded differently to irrigation treatments. Furthermore, mean squares due crosses (C), parents (P), P vs. C, females (F), males (M), F x M and their interaction with irrigation treatments were significant for all studied traits except days to 50% flowering. Tadesse *et al* (2008) revealed significant variation among entries for panicle length, seed weight, plant height and time to maturity. The entry × location effect was significant for the other observed traits indicating differential response of the genotypes in each of the locations. General combining ability (GCA) for plant height, panicle length, grain yield and seed weight was significant among male parents indicating the prevalence of additive gene action in determining these traits. Mahdy *et al* (2010) found that most of hybrids were significantly earlier, taller, heavier in grain weight and higher in grain yield compared to their parents and checks. Stability analysis for grain yield demonstrated that most of F_1 hybrids had higher yields than their parents, but the parents were relatively more stable.

The objectives of this investigation were to study effects of drought stress by reducing quantity of irrigation water from (100 to 50% ET) and its effects on yield and some related traits. In addition to estimate heterosis, general and specific combining ability effects and to identify the parental lines of the best hybrids under water stress.

Materials and Methods:

The experiments were conducted at Shandaweel Agric. Res. Station, Sohag, Egypt, during the three summer seasons 0f 2009, 2010 and 2011. In season 2009, twenty five grain sorghum crosses were developed from five introduced cytoplasmic male sterile lines (A-lines) and five restorer lines (R-lines). In 2010 and 2011 seasons, the 25 crosses, their 10 parents and one check hybrid (Shandaweel-6) were evaluated at Shandaweel Station Farm under two levels of irrigation (100 % and 40 % ET). The quantity of water applied was calculated according to the modified Penman equation for estimating evapotranspiration (ET) as described by Jensen *et al* (1990). A randomized complete block design with three replications was used. The experimental unit was one row, four meter long and 60 cm. apart and 20 cm. between hills. After full emergence, seedlings were thinned to two plants/hill. Sowing date in both of the 2010 and 2011 seasons were on 22nd and 23rd June, respectively. The recommended cultural practices of sorghum production in the two years were implemented, except water irrigation. Data were recorded on days from sowing date to 50% flowering, plant height (cm.), 1000 grain weight (gm.), number of green leaves per plant and grain yield per plant (gm.) Grain yield was adjusted with grain moisture to 14 % moister.

Drought susceptibility index and drought tolerance index were calculated

1- Drought susceptibility index was calculated according to Fisher and Maurer (1978) equation: DSI = $(1 - Y_D/Y_W) / (1 - Y_{MD}/Y_{MW})$, where;

Y_D is the drought stress yield (40% ET)

Y_W is the non-drought stressed yield (100% ET)

Y_{MW} is the mean yield for all 100% ET irrigation genotypes.

Y_{MD} is the mean yield for all 40% ET irrigation genotypes.

DSI values >1.0 indicate relatively drought susceptible and <1.0 indicate relatively drought tolerance.

Drought tolerance index (DTI):

Drought tolerance index was calculated according to the following equation:

$$DTI = \frac{\text{Mean yield under stress (40 \% ET)}}{\text{Mean yield under normal (100\% ET)}} \times 100$$

Data of each season and combined over the two seasons, under both levels of irrigation were subject to regular analysis of variance of split plot in a randomized complete block design according to Gomez and Gomez (1984). Line x tester analysis according to Steel and Torrie (1980). General combining ability (GCA) effects for females and males and specific combining ability (SCA) effects for hybrids were estimated according to Singh and Chaudhary (1977). In this analysis the mean squares for male and female parents are considered independent estimates of general combining ability (GCA) and the male × female interaction mean squares provides an estimate of specific combining ability (SCA). The proportional contribution of lines, testers and their interactions to total variance were estimated and the variance for males and females considered equivalent to GCA (additive) and the variance for lines × testers considered equivalent to SCA (non additive).

Heterosis was calculated as the percentage of deviation from better parent according to the following formula:

$$H = \frac{\overline{F}_1 - \overline{B.P}}{\overline{B.P}} x\,100$$

and its significance was tested by the LSD test.

Results and Discussion:

I- Analysis of Variance:

The combined analysis of variance over years (Table 1) showed significant or highly significant differences between years, irrigation treatments and among genotypes for all the studied traits except for 1000-grain weight between years. Indicating, the sensitivity of traits to years and drought stress and the need to evaluate the different genotypes under different soil water stress for more years. The interactions years × genotypes, irrigation × genotypes and year × irrigation × genotypes were highly significant for all the studied traits except for No. of green leaves, reflecting the differential requirements of genotypes to water. Also, the interaction years × irrigation was significant for plant height and 1000-grain weight. These results reflect the differential response of genotypes for irrigation from year to another.

Table 1. Combined analysis of variance for 36 genotypes of grain sorghum under two levels of irrigation over two years, 2010 and 2011 seasons.

S.O.V	d.f	Mean squares				
		Days to 50% flowering	Plant height (cm)	No. of green levels	1000-grain weight (g)	Grain yield per plant (g)
Years (Y)	1	32.23**	41.57**	7.78*	7.44	22.69*
Rep. / Y (Ea)	4	4.97	27.32	2.30	1.13	14.37
Irrigation (I)	1	5447.12**	9316.82**	752.08**	1960.54**	35733.89**
Y x I	1	0.75	2841.82**	10.08*	18.71	0.01
Rep. (Y x I) (Eb)	4	4.32	23.59	0.80	3.75	2.91
Genotypes (G)	35	21.66**	4557.23**	4.47**	25.48**	1250.10**
G x Y	35	12.58**	135.24**	1.73	2.87**	44.91**
G x I	35	10.64**	132.06**	1.50	6.18**	67.41**
G x Y x I	35	7.06**	154.13**	0.78	4.88**	32.53**
Error (Ec)	280	3.46	30.02	1.20	1.46	4.87

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

2- Mean performance.

The combined data over the two years under 40% 0f irrigation (Table 2) indicated that days to 50% flowering for the parental lines ranged from 73.7 (Dorado × ICSR-273) to 77.50 (NM-36565) with an average of 75.80 days. Whereas, for the crosses it ranged from 72.30 (ICSA-52 x MR-812) to 75.5. (Sh - A-2 × NM36565) with an average of 74.3 days. Under 100% of irrigation, NO. of days to 50% flowering for the parental lines ranged from 69.30 (ShB-2) to 73.20 (MR-812) with an average of 71.30 days, while, for the crosses it ranged from 68 (ICSA-52 × MR-812) to 71.5 (ICSA-52 × ZSV-14) with an average of 69.80 days. These data showed that increase in the average of days to 50% flowering over the two years for the parental lines and the crosses by decrease irrigation water from 100 to 40 % ET by 4.50 days. respectively. In general, most of the F1 crosses were earlier than their parents. While, sixteen and twenty one crosses were significantly earlier than the check hybrid Shandaweel-6 under 40% and 100% ET, respectively.

Table 2. Means of days to 50% flowering and plant height for the evaluated genotypes of grain sorghum under two levels of irrigation in two seasons and over two seasons.

Genotypes	Days to 50% flowering						Plant height					
	100% ET			40% ET			40% ET			100% ET		
	2010	2011	Com.	2010	2011	Com.	2010	2011	Com.	2010	2011	Com.
ICSA-20 × (Dorado x R-273)	69.0	70.7	69.8	73.0	74.3	73.7	181.7	185.0	183.3	171.0	155.0	163.0
ICSA-20 × ICSR-92002	67.7	75.0	71.3	71.7	79.0	75.3	200.0	208.3	204.2	188.3	173.0	180.7
ICSA-20 × MR-812	70.0	67.3	68.7	74.0	71.7	72.8	155.0	164.3	159.7	141.0	140.0	140.5
ICSA-20 × ZSV-14	67.3	69.0	68.2	73.0	73.0	73.0	192.3	194.3	193.3	179.0	160.3	169.7
ICSA-20 × NM-36565	68.7	70.0	69.3	75.0	75.3	75.2	171.7	176.3	174.0	158.3	148.3	153.3
ICSA-52 × (Dorado× R-273)	68.3	72.3	70.3	72.3	76.7	74.5	192.7	196.7	194.7	179.3	164.3	171.8
ICSA-52 × ICSR-92002	67.0	70.7	68.8	73.0	75.3	74.2	204.3	205.0	204.7	189.3	172.3	180.8
ICSA-52 × MR-812	68.0	68.0	68.0	72.7	72.0	72.3	170.0	169.7	169.8	156.7	147.0	151.8
ICSA-52 × ZSV-14	72.3	70.7	71.5	75.3	74.7	75.0	198.7	200.0	199.3	185.3	168.0	176.7
ICSA-52 × NM-36565	68.3	72.3	70.3	74.0	76.7	75.3	189.0	198.3	193.7	175.7	164.0	169.8
ShA2 × (Dorado x R-273)	71.0	71.3	71.2	73.7	75.3	74.5	185.0	163.3	174.2	162.0	146.7	154.3
ShA2 × ICSR-92002	68.7	72.7	70.7	74.0	76.3	75.2	198.0	207.3	202.7	180.0	170.7	175.3
ShA2 × MR-812	69.3	68.7	69.0	74.0	72.7	73.3	190.0	188.3	189.2	176.7	166.3	171.5
ShA2 × ZSV-14	72.0	69.0	70.5	75.0	73.0	74.0	174.3	188.3	181.3	161.0	154.0	157.5
ShA2 × NM-36565	70.3	70.7	70.5	76.3	74.7	75.5	192.0	197.3	194.7	178.7	165.0	171.8
ShA11 × (Dorado x R-273)	69.0	72.3	70.7	73.0	76.3	74.7	202.0	206.7	204.3	188.7	175.7	182.2
ShA11 × ICSR-92002	67.0	72.0	69.5	72.3	76.7	74.5	224.0	220.0	222.0	200.0	185.3	192.7
ShA11 × MR-812	69.7	69.0	69.3	74.3	73.7	74.0	182.7	195.0	188.8	167.3	160.0	163.7
ShA11 × ZSV-14	69.0	71.7	70.3	74.0	76.0	75.0	152.0	160.0	156.0	138.7	133.7	136.2
ShA11 × NM-36565	69.0	69.0	69.0	73.7	74.3	74.0	195.3	196.7	196.0	179.3	170.0	174.7
ShA13 × (Dorado x R-273)	71.0	70.7	70.8	75.0	75.7	75.3	191.7	205.0	198.3	170.7	167.3	169.0
ShA13 × ICSR-92002	69.7	71.7	70.7	75.0	75.0	75.0	168.3	168.3	168.3	155.0	143.3	149.2
ShA13 × MR-812	69.0	67.7	68.3	74.0	71.7	72.8	178.0	190.0	184.0	164.7	156.0	160.3
ShA13 × ZSV-14	70.7	68.7	69.7	76.3	74.0	75.2	177.7	201.7	189.7	161.0	160.3	160.7
ShA13 × NM-36565	68.3	69.7	69.0	73.0	74.3	73.7	211.7	210.0	210.8	193.3	183.3	188.3
Average	69.2	70.4	69.8	73.9	74.7	74.3	187.1	191.8	189.5	172.0	161.2	166.6
ICSB-20	67.0	74.0	70.5	72.3	78.0	75.2	119.3	121.7	120.5	106.0	105.0	105.5
ICSB-52	69.0	74.0	71.5	74.0	77.3	75.7	155.7	161.7	158.7	139.0	137.7	138.3
ShB2	66.0	72.7	69.3	74.0	77.7	75.8	124.3	129.0	126.7	109.3	110.7	110.0
ShB11	66.7	72.3	69.5	75.0	76.3	75.7	170.0	185.7	177.8	155.0	151.3	153.2
ShB13	70.0	71.7	70.8	74.3	75.0	74.7	150.0	155.0	152.5	136.7	130.3	133.5
(Dorado x ICSR-273)	70.0	70.3	70.2	73.0	74.3	73.7	161.0	165.7	163.3	147.7	139.0	143.3
ICSR-92002	72.0	74.0	73.0	76.7	78.0	77.3	165.7	170.0	167.8	152.3	143.0	147.7
MR-812	72.3	74.0	73.2	75.0	78.0	76.5	147.7	151.0	149.3	131.0	127.7	129.3
ZSV-14	75.3	67.7	71.5	77.7	74.0	75.8	182.3	182.0	182.2	169.0	151.0	160.0
NM-36565	71.3	74.7	73.0	76.0	79.0	77.5	153.3	161.0	157.2	136.7	134.3	135.5
Average	70.0	72.5	71.3	74.8	76.8	75.8	152.9	158.3	155.6	138.3	133.0	135.6
Shandaweel-6	69.0	70.7	69.8	73.0	74.3	73.7	181.7	185.0	183.3	171.0	155.0	163.0
LSD 0.05	1.9	2.8	2.4	1.8	2.8	2.3	8.2	7.6	7.9	7.9	6.5	7.2

Average plant height under 40% ET over the two seasons (Table 2) for the parental lines varied from 105.5 (ICSB-20) to 160.0 (ZSV-14) with an average of 135.6 cm, while for the crosses, it ranged from 136.2 (ShA-11 x ZSV-14) to 192.7 (ShA-11 x ICSR-92002) with an average of 166.6 cm. Moreover, under 100% ET irrigation, the plant height for parental lines varied from 120.5 (ICSB-20) to 182.2 (ZSV-14) with an average of

155.6 cm. while for the crosses, it varied from 156.0 (ShA11 × ZSV-14) to 222.0 (ShA-11 × ICSR-92002) with an average of 189.50 cm. Most of the crosses were taller than its parents in all cases (over two years and under the two irrigation levels), reflecting the presence of hybrid vigor. Most of the crosses were significantly taller than the check hybrid Shandweel-6, also, the parental line ICSR-92002 gave the tallest crosses compared to the other parental lines. The reduction in the average of plant height for the parental lines and the crosses under water stress was 20.0 and 22.9 cm, respectively.

Regarding number of green leaves (Table 3) for the parental lines under 40% ET over seasons ranged from 5.2 (ShB-11) to 6.30 (ICSR-92002) with an average of 5.80 leaves. Whereas, for the crosses it ranged from 5.70 (ICSA-52 × NM-36565) to 7.20 (Sh-A-2 × ICSR-92002) with an average of 6.5 leaves. Moreover, No. of green leaves for the parental lines under 100% ET over two years ranged from 5.8 (ShB-11) to 9.0 (ICSR- 92002) with an average of 7.5 leaves, while, for the crosses it ranged from 7.0 (ShA-11 × ZSV-14) to 9.8 (ICSA-20 × (Dorado × ICSR-273)) with an average of 8.6 leaves. These results indicated that the crosses had more No. of green leaves/plant than the parental lines under two levels of irrigation. Reduce water of irrigation from 100% to 40% ET lead to reductions in the average of No. of green leaves for the parental lines and crosses by 1.7 and 2.8, respectively.

Regarding 1000 grain weight (Table 3) for the parental lines under 40% ET over seasons ranged from 23.0 (Sh-B-2) to 26.8 (ICSR-92002) with an average of 23.3 gm, and for the crosses it ranged from 23.6 (SHA-11 × ICSR-92002) to 27.4 (ICSA-52 × MR-812) with an average of 23.9 gm.. Moreover, under 100% ET for the parental lines it ranged from 25.2 (Dorado × ICSR-273) to 29 .7 (ZSV-14) with an average of 27.1 gm., while, the crosses ranged from 25.7 (ICSA-20 × MR-812) to 30.5 (ShA-2 x NM-36565) with an average of 27.7 gm. The data showed, reduction in the average of 1000-grain weight for the parental lines and crosses (3.80) by decrease water irrigation from 100 to 40% ET. Ten and four crosses were significantly higher in 1000 grain weight than the check hybrid Shandaweel-6 under 100 % and 40% ET; respectively.

Grain yield for the evaluated genotypes under the two levels of irrigation in the two seasons and combined over seasons (Table 4) showed that grain yield under 40% ET over the two seasons for the parental lines varied from 33.7 (SHB-11) to 55.1 (ZSV-14) with an average of 47.6 gm., while, for the crosses varied from 40.5 (SHA-11× (Dorado × ICSR-273)) to 80.2 (ICSA-52 × (Dorado × ICSR-273) with an average of 60.0 gm. On the other hand, grain yield/plant for the parental lines under 100% ET, ranged from 51.0 (Sh-B-11) to 72.9 (ZSV-14) with an average of 64.7 gm. whereas, the crosses it ranged from 64.5 (ICSA-20 × NM36565) to 96.7 (ICSA-20 × ZSV-14) with an average of 78.8 gm. Moreover, the data showed that crosses

Table 3. Means of No. of green leaves and 1000 grain weight for the evaluated genotypes of grain sorghum under two levels of irrigation in two seasons and over two seasons.

Genotypes	No. of green leaves						1000 grain weight					
	100% ET			40% ET			100% ET			40% ET		
	2010	2011	Com.	2010	2011	Com.	2010	2011	Com.	2010	2011	Com.
ICSA-20 × (Dorado× R-273)	9.7	10.0	9.8	6.7	6.7	6.7	26.7	27.2	27.0	23.5	24.8	24.2
ICSA-20 × ICSR-92002	9.7	9.7	9.7	7.3	6.3	6.8	27.1	27.7	27.4	22.2	25.3	23.8
ICSA-20 × MR-812	8.7	9.0	8.8	6.0	6.3	6.2	25.4	26.0	25.7	23.7	24.4	24.1
ICSA-20 × ZSV-14	9.0	8.7	8.8	6.3	5.7	6.0	28.7	28.2	28.5	27.0	26.5	26.8
ICSA-20 × NM-36565	7.3	7.3	7.3	5.7	6.7	6.2	27.3	27.8	27.6	24.3	24.6	24.5
ICSA-52 × (Dorado× R-273)	8.3	8.3	8.3	7.0	7.0	7.0	28.5	28.0	28.3	25.7	25.5	25.6
ICSA-52 × ICSR-92002	7.3	7.7	7.5	6.0	6.7	6.3	27.9	28.2	28.0	25.9	26.1	26.0
ICSA-52 × MR-812	8.7	9.3	9.0	7.0	7.2	7.1	31.1	29.0	30.0	27.9	26.8	27.4
ICSA-52 × ZSV-14	8.7	8.0	8.3	7.0	6.7	6.8	28.3	28.7	28.5	26.0	24.5	25.3
ICSA-52 × NM-36565	6.7	8.0	7.3	5.0	6.3	5.7	30.1	29.2	29.7	27.5	26.8	27.2
ShA2 × (Dorado x R-273)	8.7	9.3	9.0	5.0	7.3	6.2	25.9	25.9	25.9	23.9	24.0	24.0
ShA2 × ICSR-92002	8.7	9.3	9.0	6.0	8.3	7.2	28.3	29.2	28.7	26.9	26.0	26.5
ShA2 × MR-812	8.3	8.7	8.5	5.7	7.3	6.5	27.4	28.1	27.8	26.2	24.6	25.4
ShA2 × ZSV-14	8.3	8.7	8.5	5.7	7.7	6.7	26.7	28.1	27.4	25.1	25.4	25.3
ShA2 × NM-36565	8.0	9.0	8.5	5.7	6.7	6.2	30.3	30.8	30.5	27.3	26.8	27.1
ShA11 × (Dorado × R-273)	9.0	9.3	9.2	7.0	7.0	7.0	27.0	28.1	27.6	25.0	24.5	24.8
ShA11 × ICSR-92002	8.7	9.3	9.0	6.0	6.3	6.2	26.3	26.7	26.5	23.5	23.6	23.6
ShA11 × MR-812	8.3	8.7	8.5	6.0	5.7	5.8	28.1	28.8	28.4	26.8	25.7	26.3
ShA11 × ZSV-14	6.7	7.3	7.0	5.7	6.7	6.2	29.4	28.1	28.8	27.2	24.7	26.0
ShA11 × NM-36565	8.7	8.3	8.5	7.0	6.3	6.7	28.8	28.3	28.5	26.7	26.1	26.4
ShA13 × (Dorado × R-273)	8.3	9.3	8.8	6.0	7.3	6.7	25.7	27.0	26.4	24.7	24.7	24.7
ShA13 × ICSR-92002	8.7	10.0	9.3	6.3	7.7	7.0	25.8	26.8	26.3	23.8	23.6	23.7
ShA13 × MR-812	8.0	9.3	8.7	6.0	7.0	6.5	25.6	26.3	26.0	23.5	23.9	23.7
ShA13 × ZSV-14	9.3	10.0	9.7	6.3	6.7	6.5	26.8	27.5	27.1	24.3	24.6	24.5
ShA13 × NM-36565	8.0	8.7	8.3	4.7	7.3	6.0	26.1	26.7	26.4	23.6	24.4	24.0
Average	8.4	8.9	8.6	6.1	6.8	6.5	27.6	27.9	27.7	22.7	25.1	23.9
ICSB-20	6.7	7.3	7.0	5.0	6.7	5.8	25.0	27.9	27.7	22.7	25.1	23.9
ICSB-52	5.3	8.0	6.7	6.7	5.3	6.0	25.1	26.4	25.7	23.0	24.4	23.7
ShB2	7.7	8.3	8.0	5.7	6.3	6.0	25.3	25.5	25.3	23.1	22.8	23.0
ShB11	5.7	6.0	5.8	4.3	6.0	5.2	25.8	25.8	25.5	23.9	23.2	23.6
ShB13	7.7	7.0	7.3	5.0	6.0	5.5	24.9	26.1	26.0	26.1	22.5	24.3
(Dorado × ICSR-273)	8.3	8.7	8.5	5.7	6.0	5.8	27.7	25.5	25.2	26.4	24.0	25.2
ICSR-92002	8.3	9.7	9.0	6.3	6.3	6.3	28.6	28.8	28.2	27.1	26.4	26.8
MR-812	8.7	8.0	8.3	6.3	5.3	5.8	29.5	29.4	29.0	25.6	23.4	24.5
ZSV-14	7.0	7.3	7.2	5.0	6.0	5.5	28.0	29.8	29.7	26.1	24.8	25.5
NM-36565	7.7	7.7	7.7	6.0	5.0	5.5	25.8	28.5	28.2	23.5	27.5	25.5
Average	7.3	7.8	7.5	5.6	5.9	5.8	26.7	27.4	27.1	22.2	24.4	23.3
Shandaweel-6	8.3	9	8.7	6.3	7.0	6.7	27.5	26.7	27.1	26.1	24.9	25.5
LSD 0.05	1.1	1.3	1.2	1.3	1.5	1.4	1.0	0.8	0.9	1.2	1.4	1.3

Table 4. Means of grain yield for the evaluated genotypes of grain sorghum under two levels of irrigation in two seasons and over two seasons, and drought tolerance and susceptible index.

Genotypes	100% ET			40% ET			DTI	DSI
	2010	2011	Com.	2010	2011	Com.		
ICSA-20 × (Dorado × R-273)	69.6	71.7	70.6	54.0	51.9	53.0	75.1	1.02
ICSA-20 × ICSR-92002	84.4	81.3	82.9	62.0	62.7	62.4	75.3	1.01
ICSA-20 × MR-812	76.2	73.0	74.6	54.9	51.2	53.1	71.2	1.18
ICSA-20 × ZSV-14	96.8	96.7	96.7	74.1	72.9	73.5	76.0	0.98
ICSA-20 × NM-36565	60.7	68.3	64.5	45.6	43.7	44.7	69.3	1.26
ICSA-52 × (Dorado× R-273)	85.9	84.0	84.9	46.9	51.6	49.2	58.0	1.73
ICSA-52 × ICSR-92002	79.0	76.3	77.7	56.0	54.0	55.0	70.8	1.20
ICSA-52 × MR-812	92.7	85.7	89.2	78.3	76.3	77.3	86.7	0.55
ICSA-52 × ZSV-14	69.0	72.7	70.8	52.0	50.9	51.4	72.6	1.12
ICSA-52 × NM-36565	73.8	72.0	72.9	62.1	56.6	59.4	81.5	0.75
ShA2 × (Dorado × R-273)	72.7	76.7	74.7	60.4	64.0	62.2	83.3	0.69
ShA2 × ICSR-92002	73.3	73.3	73.3	55.7	62.6	59.2	80.8	0.79
ShA2 × MR-812	66.9	76.3	71.6	52.8	55.9	54.3	75.8	0.99
ShA2 × ZSV-14	92.3	91.7	92.0	77.0	77.3	77.2	83.9	0.66
ShA2 × NM-36565	84.3	83.7	84.0	68.6	63.7	66.1	78.7	0.87
ShA11 × (Dorado × R-273)	72.7	76.3	74.5	38.6	42.3	40.5	54.4	1.87
ShA11 × ICSR-92002	68.7	72.0	70.3	47.3	43.8	45.5	64.7	1.45
ShA11 × MR-812	79.3	79.0	79.1	59.3	60.0	59.7	75.5	1.01
ShA11 × ZSV-14	71.7	66.0	68.8	53.7	53.3	53.5	77.8	0.91
ShA11 × NM-36565	73.0	76.0	74.5	57.9	65.4	61.6	82.7	0.71
ShA13 × (Dorado × R-273)	94.0	96.7	95.3	77.7	82.7	80.2	84.2	0.65
ShA13 × ICSR-92002	90.7	91.7	91.2	64.3	79.1	71.7	78.6	0.88
ShA13 × MR-812	70.3	63.7	67.0	52.7	52.3	52.5	78.4	0.89
ShA13 × ZSV-14	92.8	86.0	89.4	73.4	72.2	72.8	81.4	0.76
ShA13 × NM-36565	82.1	77.0	79.6	64.6	70.7	67.7	85.1	0.61
Average	78.9	78.7	78.8	59.6	60.7	60.1	-	-
ICSB-20	67.5	70.7	69.1	49.1	45.2	47.1	68.2	1.31
ICSB-52	63.1	63.7	63.4	49.7	44.7	47.2	74.4	1.05
ShB2	64.0	63.7	63.8	47.7	47.4	47.6	74.6	1.04
ShB11	48.7	53.3	51.0	32.5	34.9	33.7	66.1	1.39
ShB13	58.3	55.7	57.0	43.4	39.9	41.7	73.2	1.10
(Dorado x ICSR-273)	62.0	63.3	62.7	48.3	46.6	47.4	75.6	1.00
ICSR-92002	69.8	66.0	67.9	52.6	43.9	48.2	71.0	1.19
MR-812	68.0	69.7	68.8	51.3	54.0	52.7	76.6	0.96
ZSV-14	72.1	73.7	72.9	55.8	54.3	55.1	75.6	1.00
NM-36565	72.1	69.0	70.5	56.0	54.0	55.0	78.0	0.90
Average	64.6	64.9	64.7	48.6	46.5	47.6		
Shandaweel-6	76.6	78.0	77.3	58.7	59.9	59.3		
LSD 0.05	4.2	2.8	3.5	3.0	3.4	3.2		

significantly out yielded more than their parents under both levels of irrigation in two seasons and over two seasons indicating the presence of heterosis. Also, 9 and 8 crosses had significantly out yielded the check hybrid Shandaweel – 6 under 100% and 40% ET; respectively. The best crosses (ICSA-20 × ZSV-14), (ShA-2 × ZSV-14) and (ShA-13 × (Dorado × ICSR-273)) gave the highest yield over the two years under both irrigation levels. In addition, these crosses are drought tolerant and significantly out yielded check hybrid Shandaweel-6, these crosses can be evaluated in a large scale and could be considered as promising crosses under drought stress conditions. On the other hand, reduce water irrigation from 100% to 40% ET reduced the average of grain yield/plant over two years of the parental lines and crosses by 16. 7 and 19.0 gm, respectively.

Drought tolerance and susceptibility indexes (DTI and DSI)

The results of drought tolerance index and drought susceptibility index for grain yield/plant (Table 4) cleared that the different genotypes (lines and crosses) differed greatly in their response to water stress, some genotypes scored drought tolerance index over 76 % at 40 % ET which could be considered tolerant to drought and some were severely affected by drought and scored less 70 % and considered susceptible genotypes to water stress. For example the best two lines were MR-812 (76.6%) and NM-36565 (78.0%), also the best eight crosses, ICSA-52 × MR-812 (86.7%), ICSA-52 × NM-36565 (81.5%), ShA2 × (Dorado x R-273) (83.3%), ShA2 × ZSV-14 (83.9%), ShA11 × NM-36565 (82.7%), ShA13 × (Dorado × R-273) (84.2%), ShA13 × ZSV-14 (81.4%) and ShA13 × NM-36565 (85.1%). On the other hand, lines ICSB-20 (68.2 %) and Sh B-11 (66.1 %) and the crosses ICSA-52 × (Dorado× R-273) (58.0 %) and ShA11 × (Dorado x R-273) (54.4 %) indicated to their susceptible to drought.

Both of DSI and DTI at 40 % of water irrigation showed fairly the same picture, the tolerant lines and hybrids scored the highest drought tolerance index and the lowest drought susceptibility index and selection should be for high yielding genotypes at severe drought which showed DSI lower than the unity. In general, most of the drought tolerance crosses were developed from one or two drought tolerance lines, also, restorer lines MR-812 and NM 36565 had good drought tolerance. These results are in harmony with these obtained by Al-Naggar *et al.* (1999), El-Bakry *et al.* (2000), Mahmoud (2002), El-Abd (2003) and Amir (2008).

In general, mean days to 50% flowering of the hybrids and its parents were increased by increasing water stress, but plant height, No. of green leaves, 1000-grain weight and grain yield/plant of the hybrids and its parents were decreased with increasing water stress. Moreover, the F_1 hybrids had taller plants and higher grain yield/plant than best parents under the two levels of irrigations. Also, most of the hybrids were earlier than their parents. It could be noticed that the best yielding ability genotypes were not the best stable genotypes. These results are in harmony with those obtained by Al-Naggar *et al.* (1999), El-Bakry *et al.* (2000), Mahmoud (2002) (2002), El-Abd (2003) and Amir (2008).

Combining Ability:

Analysis of variance:

The combined analysis of variance of 35 genotypes (25 crosses and 10 parents) of grain sorghum over two levels of irrigation at each year for all the studied traits are presented in Tables (5 and 6).

Data cleared that, highly significantly difference between the two levels of irrigation for all the studied treats in 2010 and 2011 seasons, reflecting the sensitivity of genotypes to irrigation. Moreover, highly significantly differences among genotypes, crosses, and parents for all the studied traits in 2010 and 2011 seasons, except crosses and parents for No. of green leaves in 2011 season. Also, highly significant differences among parents vs. crosses for all the studied traits reflecting the presence of heterosis. Partitioning sum of squares of crosses to their contributions (females, males and males × females interaction) showed significant or highly significant differences for all the studied traits in 2010 and 2011 seasons, except males × females interaction for No. of green leaves in 2011 season. On the other hand, the interactions between genotypes x irrigation, parents x irrigation crosses × irrigation and their partitions (females × irrigation, males × irrigation and males × females × irrigation) were significant or highly significant for all the studied traits in the two seasons except the interaction between males × irrigation and males × females × irrigation in the two seasons for no of green leaves. The interaction between crosses vs. parents × irrigation showed highly significant differences for all the studied traits in the two years.

Partitioning sum of squares of crosses to their contributions.

The proportional contribution of sum of squares of lines, testers (as an indication to GCA or additive effects) and their interaction (as an indication to SCA or non-additive effects) to crosses sum of squares were estimated.

For days to 50% flowering in the combined over two levels of irrigation, partitioning sum of squares of crosses to their contributions accounted for 27.3 and 25.4 % in 2010 season and for 18.2 and 52.3% in 2011 season as calculated from the females and males; respectively, while they reached 47.2 and 29.3 % in 2010 and 2011 seasons; respectively, as calculated from female × male interaction. Moreover, partitioning sum of squares of crosses × irrigation to their contributions, they accounted for 19.8 and 30.1 % in 2010 season and 18.0 and 34.7 in 2011 season as calculated from the females × irrigation and males × irrigation; respectively. However;sum of squares reached 50.1 and 47.4 % in 2010 and 2011 seasons; respectively, as calculated from female × male × irrigation interaction. These results indicated that both additive and non additive gene effects controlled flowering date, and generally the non-additive were more pronounced than the additive effects.

For plant height, partitioning sum squares of crosses to their contributions, the sum of squares accounted for 22.1 and 37.9 % in 2010 season and counted 29.8 and 27.2 in 2011 season as calculated from females and males; respectively. However;they reached 40.0 and 43.0 % in 2010 and 2011 seasons; respectively, as calculated from female × male interaction. As well as, partitioning sum squares of crosses × irrigation to their contributions, they reached 22.2 and 37.0 % in 2010 season and 23.9 and 29.6 in 2011 season as calculated from females × irrigation and males × irrigation; respectively, however; they reached 40.8 % and 46.5 % in 2010 and 2011 seasons; respectively, as calculated from female × male × irrigation interaction. These results indicated that both additive and non additive gene effects controlled plant height and the non-additive gene effect played the major role in plant height inheritance.

For No of green leaves per plant, partitioning sum of squares of crosses to their contributions, indicated that GCA accounted for 11.1 and 24.0 % in 2010 season and accounted 28.2 and 25.7 in 2011 season as calculated from females and males, respectively, while the SCA reached 65.1 % and 46.1 % in 2010 and 2011 seasons respectively, as calculated from female × male interaction. As well as, partitioning sum squares of crosses × irrigation to their contributions, it could be indicated that GCA accounted for 28.7 and 14.8 % in 2010 season and accounted 32.7 and 15.5% in 2011

Table 5. Combined analysis of variance of 25 F_1's and 10 parents over two levels of irrigation in 2010 studied season.

S.O.V	d.f	Mean squares				
		Days to 50% flowering	Plant height (cm)	No. of green leaves	1000-grain weight (g)	Grain yield per plant (g)
Irrigation (I)	1	361995.17**	2031693.73**	3685.95**	252010**	319226.38**
Rep (irrigation)	4	0.52	58.18	1.8	1.92	3.98
Genotypes (G)	34	9.62**	2091.46**	2.37**	5.55**	462.55**
Parents (P)	9	18.27**	1513.49**	2.35**	6.69**	193.19**
Parents vs. Crosses	1	19.37**	32989.73**	18.44**	37..37**	4582.94**
Crosses (C)	24	5.97**	1020.77**	1.70**	3.79**	391.88**
Female (F)	4	9.79**	1354.25**	1.53*	6.32**	811.45**
Male (M)	4	9.1**	2319.48**	2.05**	3.83*	631.75**
F × M	16	4.23**	612.72**	1.66*	3.15*	227.01**
G ×I	34	7.48**	1058.71**	2.27**	14.48**	278.25**
P × I	9	15.33**	760.26**	3.15**	14..51**	100.08**
P vs. C × I	1	9.89**	16496.69**	12.66**	80.15**	2413.63**
C × I	24	4.43**	527.37**	1.51*	11.74**	256.09**
F × I	4	5.27**	701.98**	2.6**	22.15**	506.99**
M × I	4	8.00**	1170.68**	1.34	8.97**	405.21**
F ×M × I	16	3.33**	322.9**	1.27	9.82**	156.08**
Error b	136	1.36	25.24	0.58	1.52	5.09

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Table 6. Combined analysis of variance of 25 F1's and 10 parents over two levels of irrigation in 2011 studied season.

S.O.V	d.f	Mean squares				
		Days to 50% flow-ering	Plant height (cm)	No. of green leaves	1000-grain weight (g)	Grain yield per plant (g)
Irrigation (I)	1	377978.56**	2012990.58**	4198.71**	396.11**	319245.60**
Rep (irrigation)	4	0.65	61.69	1.5	3.08	8.71
Genotypes (G)	34	20.65**	1738.66**	2.02**	4.13**	473.34**
Parents (P)	9	14.80**	1288.49**	1.34	5.16**	153.71**
Parents vs. Crosses	1	88.84**	27256.75**	27.63**	10.79**	5602.34**
Crosses (C)	24	20.00**	844.22**	1.2	3.47**	379.49**
Female (F)	4	21.78**	1509.14**	2.03**	4.00*	862.32**
Male (M)	4	62.77**	1379.78**	1.85*	3.50.*	640.87**
F × M	16	8.86**	544.09**	0.83	3.33**	193.44**
G ×I	34	10.89**	923.92**	2.23**	15.74**	294.33**
P × I	9	8.55**	685.87**	2.45**	12.82**	93.18**
P vs. C × I	1	44.42**	13937.72**	13.95**	37.72**	2802.31**
C × I	24	10.36**	470.95**	1.66**	15..92**	265.26**
F × I	4	11.18**	674.08**	3.26**	39.7**	621.33**
M × I	4	21.56**	837.27**	1.54	7.29**	326.78**
F ×M × I	16	7.36**	328.59**	1.29	12.14**	160.87**
Error b	136	3.1	19.57	0.77	1.41	3.8

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

season as calculated from females × irrigation and males × irrigation, respectively, while the SCA reached 56.1 % and 51.8 % in 2010 and 2011 season respectively, as calculated from female × male × irrigation interaction. These results indicated that both additive and non additive gene effects controlled No of green leaves per plant. The effect of SCA and its reaction with irrigation was more pronounced than that of GCA.

Regarding 1000 grain weight, partitioning sum of squares of crosses to their contributions, showed that GCA accounted for 27.8 and 16.8 % in 2010 season and accounted 19.2 and 16.8 in 2011 season as calculated from females and males, respectively, while the SCA reached 55.4 % and 64.0 % in 2010 and 2011 seasons respectively, as calculated from female × male interaction. As well as, partitioning sum squares of crosses × irrigation to their contributions, showed that GCA accounted for 31.5 and 12.7 % in 2010 season and accounted 41.6 and 7.6 in 2011 season as calculated from females × irrigation and males × irrigation, respectively, while the SCA reached 55.8 % and 50.8 % in 2010 and 2011 season respectively, as calculated from female × male × irrigation interaction. These results indicated that both additive and non additive gene effects controlled 1000 grain weight. The effect of SCA and its reaction with irrigation was more pronounced than that of GCA.

Regarding grain yield per plant, partitioning sum of squares of crosses to their contributions, indicated that sum of squares were 34.5 and 26.9 % in 2010 season and 37.9 and 28.1% in 2011 season as calculated from females and males; respectively, while they were 38.6 and 34.0 % in 2010 and 2011 seasons; respectively, as calculated from female × male interaction. Likewise; partitioning sum squares of crosses × irrigation to their contributions, sum of squares were 33.0 and 26.4 % in 2010 season and 39.0 and 20.5% in 2011 season; respectively as calculated from females × irrigation and males × irrigation. However; they reached 40.6 % and 40.4 % in 2010 and 2011 seasons; respectively, as calculated from female × male × irrigation interaction. These results indicated that both additive and non additive gene effects controlled grain yield per plant and the non-additive gene effect played the major role in grain yield inheritance.

A- General combining ability (GCA):

General combining ability (GCA) effects of the female and male lines for each irrigation level in 2010, 2011 and combined over two years are presented in Table (7).

GCA effects for days to 50% flowering showed that the female line ICSB-20 had negative (favorable) GCA effects under two irrigation levels in the two seasons and combined over two seasons. Also, the male line MR-812 had negative (favorable) and significant GCA effects under two irrigation levels in 2011 season and combined over two seasons. These lines were the best combiners for earliness.

For plant height the lines ICSR-92002, NM- 36565, ICSB-52 and Sh B-11 had positive and significant GCA effect under two irrigation levels in 2010 and 2011 seasons and combined over two seasons. These lines had favor gene for tallness. On the other hand, the female lines ICSB-20 and the male line MR-812 and ZSV-14 had negative and significant GCA effects under two irrigation levels in 2010 and 2011 seasons and over two seasons. These lines had favor gene for shortness.

For No. of green leaves per plant the female lines ICSB -20 and ICSB -52 and the male line ICSR-92002 had positive and insignificant (GCA) effects for No. of green leaves under two irrigation levels in 2010 and 2011 seasons and over two seasons. These lines had favor gene for stay green.

For 1000-grain weight the female lines ICSB- 52 and the male line NM-36565 had positive and significant or highly significant GCA effect under two irrigation levels in 2010 and 2011 seasons and over two seasons. These lines had favor gene for heavier 1000 grain weight.

Regarding grain yield per plant, GCA effects showed that the female line Sh-B- 13 and the male line ZSV-14 had positive and significant or highly significant GCA effects under two irrigation levels and over two levels of irrigation. Also, the female line Sh-B- 2 had positive and significant or highly significant GCA effects under stress condition in 2010 and 2011 seasons and combined over two season. These lines would be considered best combiners for grain yield/plant.

In general, the female lines ICSB- 52 and Sh-B-13 and male line ZSV-14 were good combiners for most studies traits. Similar results were obtained by Mahmoud (2002), El-Abd (2003), Amir (2004) and Amir (2008). They concluded that general combining ability effects were significant in some parental lines for some studied characters.

B- Specific combining ability (SCA).

Specific combining ability (SCA) was calculated for each irrigation level in 2010 and 2011 seasons and over two seasons (Table8).

Combined data over two years for days to 50% flowering showed that, the crosses No. 3, 5, 7, 8, 13, 15, 18, 23 and 25 had negative and significant SCA effects under water stress only. Indicating that these crosses could be considered the best combinations for earliness. While the cross No. 20 had positive and significant SCA effects under two irrigation levels.

For plant height the crosses No. 2, 4, 9, 13, 16, 17, and 25 had positive and highly significant SCA effects under two irrigation levels. Indicating that these crosses could be considered the best combinations for tallness. On the other hand, the crosses no.3, 8, 11, 19 and 22 had negative and significant SCA effects

For No. of green leaves the crosses No. 2, 8, 20 and 24 had positive SCA effects under two irrigation levels. While cross no.20 had positive and significant SCA effects under 40 % ET irrigation level means this cross would be considered good combinations for No. of green leaves under water stress.

Regarding SCA for 1000-grain weight, the crosses No. 4, 8, 12, 15, 18 and 21 had positive and significant under 100% ET irrigation levels. Moreover, crosses No. 4, 12 and 21 had positive and significant SCA effects under two irrigation levels. These crosses were considered as best combinations for heavier 1000-grain weight.

Regarding grain yield per plant, crosses No. 2, 4, 8, 14, 15, 18, 20, 21 and 22 had positive and significant SCA effect under two irrigation levels. These crosses were considered as best combinations for grain yield.

In general, crosses which had negative significant SCA effects for days to 50% flowering were early in flowering. Moreover, most of the crosses which had positive significant SCA Effect for 1000 grain weight and grain yield per plant were high in grain yield. These results were agreement with the obtained by Mahmoud (2002), El-Abd (2003), Amir (2004) and Amir (2008) Found that crosses had negative significant specific combining ability effects were early flowering. Moreover, general and specific combining ability effects were effective in predicting hybrid performance in all traits.

Table 8. Continue

No.	Genotypes	Grain yield/plant					
		100% ET			40% ET		
		2010	2011	Comb.	2010	2011	Comb.
1	ICSA-20 × (Dorado × R-273)	-7.99**	-8.89**	-8.44**	-0.03	-2.42*	-1.23
2	ICSA-20 × ICSR-92002	6.56**	2.91**	4.73**	6.41**	6.44**	6.43**
3	ICSA-20 × MR-812	0.49	-2.03*	-0.77	-3.22**	-3.82**	-3.52**
4	ICSA-20 × ZSV-14	13.67**	14.57**	14.12**	9.54**	11.74**	10.64**
5	ICSA-20 × NM-36565	-12.73**	-6.56**	-9.65**	-12.71**	-11.94**	-12.32**
6	ICSA-52 × (Dorado× R-273)	5.73**	3.51**	4.62**	-8.09**	-3.97**	-6.03**
7	ICSA-52 × ICSR-92002	-1.35	-2.03*	-1.69	-0.52	-3.46**	-1.99
8	ICSA-52 × MR-812	14.45**	10.71**	12.58**	19.27**	20.15**	19.71**
9	ICSA-52 × ZSV-14	-16.68**	-9.36**	-13.02**	-13.52**	-11.50**	-12.51**
10	ICSA-52 × NM-36565	-2.15	-2.83**	-2.49*	2.86**	-1.22	0.82
11	ShA2 × (Dorado × R-273)	-5.29**	-6.03**	-5.66**	1.62	1.47	1.54
12	ShA2 × ICSR-92002	-4.91**	-7.23**	-6.07**	-4.67**	-1.87	-3.27**
13	ShA2 × MR-812	-9.18**	-0.83	-5.00**	-10.15**	-7.30**	-8.73**
14	ShA2 × ZSV-14	8.83**	7.44**	8.13**	7.66**	7.93**	7.79**
15	ShA2 × NM-36565	10.56**	6.64**	8.60**	5.54**	-0.23	2.65*
16	ShA11 × (Dorado × R-273)	-0.40	0.11	-0.15	-8.68**	-8.48**	-8.58**
17	ShA11 × ICSR-92002	-4.69**	-2.09*	-3.39**	-1.53	-8.99**	-5.26**
18	ShA11 × MR-812	8.05**	8.31**	8.18**	7.93**	8.56**	8.25**
19	ShA11 × ZSV-14	-7.01**	-11.76**	-9.39**	-4.13**	-4.32**	-4.22**
20	ShA11 × NM-36565	4.05**	5.44**	4.75**	6.40**	13.24**	9.82**
21	ShA13 × (Dorado × R-273)	7.95**	11.31**	9.63**	15.19**	13.41**	14.30**
22	ShA13 × ICSR-92002	4.39**	8.44**	6.42**	0.30	7.88**	4.09**
23	ShA13 × MR-812	-13.81**	-16.16**	-14.98**	-13.84**	-17.59**	-15.71**
24	ShA13 × ZSV-14	1.20	-0.89	0.15	0.44	-3.85**	-1.70
25	ShA13 × NM-36565	0.27	-2.69**	-1.21	-2.09**	0.14	-0.98

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

Heterosis:

Estimates of heterosis for days to 50% flowering, plant height, No. of green leaves/ plant, 1000 grain weight and grain yield per plant for 25 crosses as a percentage of the better parent under two levels of irrigation water (100 and 40 % ET) in 2010 and 2011 seasons and combined over two seasons are presented in Tables 9 and 10.

The combined data over the two years under water stress (Table 5) showed that heterosis for days to 50 % flowering ranged from - 4.35 to 2.83 %, three crosses out of twenty five crosses had negative and significant heterosis (earliness)-. Whereas, under optimum irrigation heterosis values for days to 50 % flowering ranged from -3.70 to 6.47 %, two crosses out of twenty five crosses had negative and significant heterosis (earliness). It is noted that, these crosses had negative and significant SCA.

Under water stress condition heterosis for plant height ranged from -14.81 to 38.97 %, nineteen crosses out of twenty five crosses had positive and significant heterosis, while one out of twenty five had negative and significant heterosis. On the other hand, under optimum irrigation heterosis values for plant height ranged from -15.23 to 34.24 %. Twenty crosses had positive and significant heterosis, while one cross had negative and significant heterosis.

For No. of green leaves per plant heterosis ranged from -18.03 to 28.83 % and –18.62 to 27. 83 % under stress and optimum irrigation, respectively. Moreover, seven and five crosses had positive and significant heterosis under stress and optimum water irrigation, respectively.

For 1000-grain weight heterosis ranged from -11.10 to 10.06 % and from -12.58 to 3.60 % under stress and optimum water irrigation, respectively. Most of crosses had negative and significant heterosis for 1000-grain weight. This indicates that the increase in grain yield may be attributed to the increased number of grains.

Regarding grain yield / plant under water stress, heterosis values ranged from -26.45 to 55.05 %, While, under optimum irrigation it ranged from 5.53 to 54.38 %. eighteen and sixteen crosses out of twenty five crosses had positive and significant heterosis for grain yield/plant under stress and normal irrigation, respectively. It is noted that, the high positive value of heterosis were also high positive and significant SCA. In general, some crosses were earlier, taller, higher green leaves, 1000-grain weight and grain yield/plant than the better parents. These results are in harmony with those obtained by El-Bakry (2000), Mahmoud (2002), El-Abd (2003), Amir (2004) , Mahmoud (2007)and Amir (2008).

Table 10: Heterosis of twenty five crosses for grain yield per plant in percentages from the better parent under two levels of irrigation in 2010, 2011 and combined over two seasons.

No.	Genotypes	100% ET			40%ET		
		2010	2011	Com.	2010	2011	Com.
1	ICSA-20 × (Dorado × R-273)	3.16	1.42	2.29	10.08**	11.43**	10.76**
2	ICSA-20 × ICSR-92002	33.77**	27.75**	30.76**	24.95**	34.6**	29.78**
3	ICSA-20 × MR-812	19.01**	14.66**	16.84**	13.84**	7.98*	10.91**
4	ICSA-20 × ZSV-14	56.13**	52.63**	54.38**	53.59**	56.49**	55.04**
5	ICSA-20 × NM-36565	-2.15	7.89**	2.87	-5.50	-6.17	-5.84*
6	ICSA-52 × (Dorado× R-273)	23.02**	18.87**	20.95**	-10.81**	14.07**	1.63
7	ICSA-52 × ICSR-92002	13.18*	15.66**	14.42**	6.56*	20.91**	13.74*
8	ICSA-52 × MR-812	32.76**	29.80**	31.28**	49.05**	61.04**	55.05**
9	ICSA-52 × ZSV-14	-1.15	10.10**	4.48	-1.12	15.86	7.37*
10	ICSA-52 × NM-36565	5.73	9.09**	7.41**	18.12**	26.69**	22.41**
11	ShA2 × (Dorado × R-273)	6.86*	8.49**	7.68**	17.73**	18.58**	18.16**
12	ShA2 × ICSR-92002	7.75*	5.26*	6.51**	8.52**	15.99**	12.26**
13	ShA2 × MR-812	-1.67	9.57**	3.95	2.78	3.55	3.17
14	ShA2 × ZSV-14	35.78**	31.58**	33.68**	50.00**	43.21**	46.61**
15	ShA2 × NM-36565	24.02**	20.10**	22.06**	33.64**	17.87**	25.76**
16	ShA11 × (Dorado × R-273)	0.83	3.62	2.23	-30.81**	-22.09**	-26.45**
17	ShA11 × ICSR-92002	-4.81	-2.26	-3.54	-15.18**	-19.46**	-17.32**
18	ShA11 × MR-812	9.89**	7.24**	8.57**	6.34*	10.48**	8.41**
19	ShA11 × ZSV-14	-0.65	-10.41**	-5.53*	-3.77	-1.84	-2.81
20	ShA11 × NM-36565	1.2	3.17	2.19	3.86	20.3**	12.08**
21	ShA13 × (Dorado × R-273)	30.43**	36.79**	33.61**	38.77**	53.1**	45.94**
22	ShA13 × ICSR-92002	25.81**	32.85**	29.33**	14.95	46.43**	30.69**
23	ShA13 × MR-812	-2.41	-7.73**	-5.07	-5.78*	-3.11	-4.45
24	ShA13 × ZSV-14	28.77**	24.64**	26.71**	31.22**	33.79**	32.51**
25	ShA13 × NM-36565	13.97*	11.59**	12.78**	15.48**	30.95**	23.22**

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

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تحليل السلالة x الكشاف و قوة الهجين فى هجن الذرة الرفيعة للحبوب تحت ظروف الإجهاد المائي

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تم تقييم عدد 25 هجين من ذرة الحبوب الرفيعة و آبائهم (5 سلالات عقيمة A lines و عدد 5 أباء معيدة للخصوبة R- lines) والهجين التجاري شندويل 6 للمقارنة وذلك لصفة محصول الحبوب وأربع صفات أخرى وذلك فى موسمى 2010 و 2011 فى محطة بحوث شندويل تحت مستويين من الرى (100% و40% بخر – نتح). وقد أظهرت النتائج إختلافات معنوية أو عالية المعنوية بين السنوات وبين معاملات الرى وداخل التراكيب الوراثية بالنسبة لجميع الصفات محل الدراسة عدا صفة وزن الآلف حبة بين السنوات.كان التفاعل بين السنوات و التراكيب الوراثية وبين معدلات الرى والتراكيب الوراثية وكذلك بين معدلات الرى والتراكيب الوراثية و السنين عالى المعنوية لجميع الصفات محل الدراسة عدا صفة عدد الأوراق الخضراء كما كان التفاعل بين السنين و مستويات الرى معنويا بالنسبة لصفتى طول النبات و وزن الألف حبة. . كما كانت هناك تباينات عاليه المعنوية بين الآباء وبين الهجن خلال الموسمين و ذلك بالنسبة لجميع الصفات محل الدراسة عدا صفة عدد الأوراق الخضراء. كما اظهر تباين الآباء ضد الهجن اختلافات معنوية عالية لجميع الصفات المدروسة. اظهر تجزئة مجموع مربعات التباينات الى مكوناتها (females, males and female × male) اختلافات معنوية أو عالية المعنوية لجميع الصفات المدروسة فى الموسمين عدا صفة عدد الأوراق الخضراء للتفاعل female × male فى موسم 2011. من ناحية اخرى كانت التفاعلات بين التراكيب الوراثية فى معدلات الرى و الآباء فى معدلات الرى و الهجن فى معدلات الرى وكذلك تجزئة الهجن فى معدلات الرى الى مكوناتها (الأمهات فى معدلات الرى و الآباء فى معدلات الرى و الآباء فى الأمهات فى معدلات الرى) معنوية أو عالية المعنوية لجميع الصفات المدروسة فى كلا الموسمين عدا التفاعل بين الآباء فى معدلات الرى والتفاعل بين الآباء فى الأمهات فى معدلات الرى بالنسبة لصفة عدد الأوراق الخضراء.
أدى انخفاض معدل الرى من 100% بخر- نتح الى 60% بخر نتح الى زيادة عدد الأيام من الزراعة الى 50% تزهير بينما أدى الى انخفاض ارتفاع النباتات و عدد الأوراق الخضراء ووزن الألف حبة ومحصول الحبوب لكل نبات بالنسبة لكلا من الآباء والهجن. علاوة على ذلك كانت بعض الهجن مبكرة مقارنة بالآباء و كانت معظم الهجن أطول من الآباء كما كانت أزيد فى عدد الأوراق الخضراء و وزن الألف حبة وأعلى فى محصول الحبوب لكل نبات مقارنة بأحسن الأبوين و ذلك خلال موسمي التقييم وتحت مستويي الرى.

أظهرت النتائج أن كلا من فعل الجين التجميعى والغير تجمعى هام لتوريث الصفات محل الدراسة وان فعل الجين السيادي يلعب الدور الرئيسى فى توريث كل الصفات محل الدراسة. أظهرت السلالة الأم ICSA- 52 وSh-A-13 و السلالة الأب ZSV-14 قدرة إئتلافية عالية بالنسبة لمعظم صفات المدروسة ويدل ذلك أنه يمكن استعمال هذه الآباء فى برنامج التربية لتحسين محصول الذرة. علاوة على ذلك أظهرت بعض الهجن قدرة ائتلافية خاصة عالية موجبة و معنوية بالنسبة لصفة محصول الحبوب لكل نبات و صفة وزن الآلف حبة.