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COMBINING ABILITY AND HETEROSIS STUDIES IN GRAIN SORGHUM HYBRIDS UNDER DROUGHT CONDITIONS

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ABSTRACT

Twenty F_1 grain sorghum crosses, their parents (five CMS A-lines and four male R-lines) and one commercial hybrid (H-305) as a check were evaluated for grain yield/plant and some other traits in 2017 and 2018 seasons at Shandaweel Agric. Res. Station, Sohag, Egypt under two irrigation levels (100% and 40% from optimum water irrigation level). The combined analysis of variance across two years showed significant or highly significant differences between years, irrigations and genotypes for all the studied traits, indicating genetic variability for all the studied traits. However, the interaction between years × irrigations showed significant mean squares for 1000-grain weight and grain yield per plant. While, mean squares due to the interactions between years × genotypes and irrigations × genotypes were highly significant for all the studied traits, except panicle length, reflecting the differential response of genotypes under conditions of drought stress. Also, the interactions mean squares between years × irrigations × genotypes were highly significant for 1000 grain weight and grain yield per plant. Highly significantly differences were found among genotypes, crosses, and parents for the entire studied traits in 2018 and 2019 seasons. Similarly, highly significant mean squares were obtained for crosses vs. parents for all the studied traits in the two seasons, reflecting the presence of heterosis for all the studied traits. Partitioning sum of squares of crosses into their contributors (females, males and females x males interaction) showed highly significant variances for all the studied traits in 2018 and 2019 seasons. These results reflect that both additive and non-additive gene effects were important in the inheritance of all studied traits and that additive gene effect played the major rule for inheritance of most studied traits. Mean number of days to 50% flowering of the hybrids and their parents were increased by increasing water stress, but plant height, panicle length, 1000 grain weight and grain yield per plant of the hybrids and their parents were decreased. Moreover, the F_1 hybrids had taller plants and higher grain yield per plant than the best parent under the two irrigation levels. The female line A-SH-9 and the male line ICSR93001 were good combiners for grain yield per plant. Moreover, some crosses had positive and highly significant SCA effects under two levels of irrigation for 1000 grain weight and grain yield per plant.

Key words: ***Sorghum bicolor, CMS lines, R-lines, combining ability.***

INTRODUCTION

Grain sorghum (*Sorghum bicolor* L. Moench) became 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. It is used for feeding animals, as an industrial raw material in addition to, complementing other cereals as a primary food grain for human beings.

Improving drought tolerance in sorghum would be a major contribution toward increasing and stabilizing grain sorghum yield as a food production in harsh environmental areas worldwide where increasing populations and food demands are big problems that are likely to worsen with time. The small farmer is the first who feels the dual pressures of increased demand and limited supply of production resources. Therefore, improving sorghum yields and increasing its production efficiency at the same time are especially vital to him.

In Egypt, grain sorghum is the fourth cereal crop ranking after wheat, maize and rice. In 2017 the cultivated area was about 147,961 hectares produced about 727648 tons of grains (FAO 2017). Seventy percent of this area is located in Assiut and Sohag Governorates.

Drought is a serious problem which causes crop yield loss. This problem may be alleviated by developing new cultivars or hybrids resistant to drought and adapted to dry condition such as the new reclaimed soils at Toshky and Darb El-Arbain in Upper Egypt. Grain sorghum is one of the most drought tolerant grain crops and is an excellent crop model for studying mechanisms of drought tolerance.

Sorghum ability to survive and tolerate water stress conditions make it the most promising crop for improving water use efficiency among other cereal crops. It is decisive to develop and adapt new technologies to expose variability among sorghum genotypes for stress resistance and to identify the best genotypes, which are able to increase the water use efficiency under environments of low water supply. Improving breeding programs for increased water use efficiency in grain sorghum is critical in order to utilize Egypt`s water resources more efficiently.

Developing high yielding hybrids with high quality characters under stress conditions, has become less difficult after using the cytoplasmic male sterile lines. 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. Several cross combinations showed significant positive heterosis for 1000-grain weight, significant negative heterosis for days to heading and good performance. El-Dardeer (2011) found that the cross (ICSA-610x ICSR-31) had highest positive significant heterosis for grain yield (66.97%). Crosses (ICSA-364 x ICSR-66), (ICSA-364xICSR-66) and (ICSA-490 x ICSR-66) had higher grain yield than the check shandweel-1 and it should be produced commercially after testing on a large scale. Mahmoud *et al* (2013) found that, some crosses were earlier, taller, higher green leaves, 1000-grain weight and grain yield/plant than the better parents. Also, they found that 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 the male line ZSV-14 were good combiners for most studies traits. Moreover, some crosses showed positive and highly significant SCA effects for 1000 grain weight and grain yield/plant. Padmashree *et al* (2014) showed that, the differences in GCA are mainly due to additive effects and higher order additive interactions while differences in SCA may be attributed to non-additive gene effects. Therefore, several sorghum reports indicated that general (GCA) and specific (SCA) combining ability effects for some parental lines (male and female) and hybrids were positive and highly significant for grain yield and its components trait under normal and drought environments. Hassaballa *et al* (2015) stated that the combined analysis across the three levels of irrigation at each of the two years showed highly significant mean squares due to irrigation levels, and genotypes and their interaction for all studied traits, indicating genetic variability for all studied traits. They reported that, the important roles of both additive and non-additive in the inheritance of number of days to 50% flowering, plant height, 1000-grain weight and grain yield/plant. Female lines ASH-6, ASH-11, ICSA-37 and ICSA-88003 and the male lines ICSR-92003 and ICSV-273 had positive and highly significant general combining ability effects for grain yield under the three irrigation levels across the two seasons. These lines had favorable genes and would be considered good combiners for high yielding ability. The crosses (ASH-8 × ICSR-89028) and (ICSA-37 × ICSR-92003) had positive and highly significant SCA effects under the three of irrigation treatments over the two seasons and would be considered the best combinations for grain yield. Menezes *et al* (2015) reported that, some parents were identified having high positive GCA for grain yield and its components and negative for days to 50% flowering which were considered as good combiners under normal and drought environments. However, high positive heterosis in grain yield and its components were found for more than half of the hybrids. Chikuta *et al* (2017) indicated that the F_1 hybrids under normal and drought environments showed range of heterosis with negative and positive values which indicated the potential for devoloping hybrids superior to their mid and better parent for earleness, plant height, No. of green leaves, leaf area/plant, panicle length, panicle width, 1000 grain weight and grain yield. El-Sherbeny (2019) *et al* found that highly significant variances were found among environments, genotypes (parents and crosses), lines and line x tester interaction for all studied characters. They added that the best top crosses were (L5 x T3) and (L3 x T3) which significantly out yielded the crosses means, were also tolerant to drought (low DSI). In this respect, one top cross was the most promising hybrid with the maximum desirable heterotic values of 7 traits out of 8 over mid and better parents. Also, they reported that both additive and non-additive gene actions played an important role in the expression of studied traits.

In this study attempts were made to verify the following goals (1) Identify the best lines from both restorer and cytoplasmic male sterile lines under water stress conditions to be included in a crossing program. (2) Estimate the heterosis and combining ability in the crosses under optimum and limited water supply environments.

MATERIALS AND METHODS

The present investigation was carried out at Shadnaweel Res. Station, Agric. Res. Cent. during the summer seasons of 2016, 2017 and 2018. In season 2016 twenty grain sorghum crosses were developed between five introduced cytoplasmic male sterile lines (A-lines) and four restorer lines (R-lines) in a line × tester mating design. In 2017 and 2018 seasons, twenty crosses, their parents and one check hybrid H-305 were evaluated at Shandaweel Station Farm under two levels of irrigations (100% and 40% ET). The quantity of water given at each irrigation was determined by a water counter every 15 days after the first irrigation according to modified Penman equation for estimating evapotranspiration as described by Jensen *et al* (1990). A randomized complete block design (RCBD) of three replications was used for each irrigation level. The experimental unit was one row, four meter long and 60 cm apart and the sowing was done with 20 cm between hills, two plants/hill after thinning. Sowing date in both of the 2017 and 2018 seasons was on 21st and 25th June, respectively. The recommended cultural practices of sorghum production in the two years were implemented except the amount of irrigation water after the first irrigation. Data were recorded on days from sowing date to 50% flowering (days), plant height (cm), panicle length (cm), 1000-grain weight (g) and grain yield per plant (g). Grain yield was adjusted with grain moisture to 14%. Drought tolerance index and drought susceptibility index were calculated as follows:-

1- Drought tolerance index (DTI):

Drought tolerance index was calculated according to the following equation.

$$DTI = \frac{\text{Trait mean under stress condition (40\% Et)}}{\text{Trait mean under optimum condition (100\% Et)}}$$

2- Drought susceptibility index (DSI):

Drought susceptibility index was calculated according to Fischer and Mourer (1978) equation as follows:

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

where: Y_D = yield under the drought stress.

Y_W = yield under the non-drought stress.

Y_{MD} = mean yield for all genotypes under optimum irrigation.

Y_{MT} = mean yield for all genotypes under stress irrigation.

DSI values > 1.0 indicate relatively drought susceptible and < 1.0 indicates relatively drought tolerant.

Data of each season and combined over the two seasons, under both levels of irrigation were subjected to a regular analysis of variance of a randomized complete blocks design according to Gomez and Gomez (1984). Line × tester analysis was performed according to Kembthorn (1957). General combining ability (GCA) effects for females and testers and specific combining ability (SCA) effects for hybrids were estimated according to Singh and Chaudhary (1985). 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 (H) was calculated as the percentage of deviation from better parent according to following formulas:

$$H = \frac{\overline{F}_1 - \overline{B.P}}{\overline{\overline{B.P}}} x100$$

Where: Bp two parents mean, F_1 average of cross and its significant was tested by LSD test.

RESULTS AND DISCUSSION

Analysis of variance

The combined analysis of variance across two years (Table 1) showed significant or highly differences between years, irrigations and genotypes for all the studied traits, indicating genetic variability for all the studied traits. However, the interaction between years × irrigations showed significant for 1000-grain weight and grain yield per plant. While, the variances due to interactions between years × genotypes and irrigations × genotypes were highly significant for all the studied traits, except panicle length, reflecting the differential requirements of genotypes under conditions of drought stress. Also, The interactions between years × irrigations × genotypes were highly significant for 1000 grain weight and grain yield per plant.

Table 1. Combined mean squares of thirty genotypes under two irrigation levels across two years for the studied traits.

SOV	df	Mean squares					
		Days to 50% flowering	Plant height	Panicle length	Panicle width	1000 Grain weight	Grain yield per plant
Years (Y)	1	89.40**	4124.96**	128.52**	18.54*	72.30**	291.10**
R (Y)	4	12.22	101.93	7.40	0.69	3.61	22.83
Irrigation (I)	1	1978.71**	37177.47**	2661.79**	740.46**	1461.08**	23103.72**
YI	1	0.98	305.44	1.01	1.19	75.18**	90.50*
Error	4	2.71	55.41	4.35	1.69	1.68	6.11
Genotypes (G)	29	29.58**	8445.87**	462.13**	45.79**	142.67**	3946.28**
YG	29	28.69**	153.87**	6.55**	2.388**	1.89**	19.32**
IG	29	7.23**	40.63**	2.10	1.94**	2.66**	10.29**
Y IG	29	2.00	27.62**	2.76	0.35	1.77**	8.60**
Error	232	2.63	45.71	2.11	0.59	0.80	5.21

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

Mean performance

The combined data across two seasons (Table 2) indicate that days to 50% flowering for the parental lines under 40% of irrigation ranged from 74.83 days (BSH-13) to 78.00 days (RSH-14) days with an average of 76.31 days.

Table 2. Mean performance of days to 50% flowering and plant height for twenty grain sorghum crosses, their parents and check H-305 under two irrigation levels in 2017, 2018 seasons and across two seasons.

Genotypes	Days to 50% flowering						Plant height					
	100% ET			40% ET			100% ET			40% ET		
	2017	2018	Com	2017	2018	Com	2017	2018	Com	2017	2018	Com
ASH-9× RSH-14	73.33	68.83	71.08	78.60	75.67	77.13	171.67	183.33	177.50	157.00	171.20	164.10
A-SH-11 RSH-14	69.83	72.00	70.92	75.87	74.10	74.98	169.33	177.67	173.50	154.00	168.00	161.00
ASH-12× RSH-14	73.53	67.77	70.65	76.47	71.67	74.07	163.33	171.67	167.50	146.00	153.33	149.67
ASH-13× RSH-14	68.73	62.10	65.42	79.17	70.97	75.07	170.00	175.67	172.83	151.00	163.33	157.17
ASH-18× RSH-14	68.97	73.33	71.15	76.63	76.00	76.32	175.00	178.33	176.67	152.67	161.67	157.17
ASH-9× RSH-39	71.33	66.27	68.80	78.10	72.73	75.42	185.00	172.33	178.67	161.00	161.27	161.13
A-SH-11× RSH-39	69.77	63.60	66.68	78.60	70.83	74.72	191.67	190.00	190.83	171.00	168.33	169.67
ASH-12× RSH-39	65.67	67.67	66.67	70.80	73.67	72.23	190.00	194.00	192.00	170.33	181.37	175.85
ASH-13× RSH-39	70.17	64.87	67.52	77.27	71.23	74.25	190.67	196.67	193.67	168.00	175.17	171.58
ASH-18× RSH-39	68.77	66.33	67.55	74.20	71.53	72.87	190.00	193.33	191.67	166.67	174.00	170.33
ASH-9× RSH-79	69.63	71.00	70.32	72.37	74.67	73.52	225.00	230.67	227.83	198.33	213.33	205.83
A-SH-11× RSH-79	67.50	71.00	69.25	71.60	74.33	72.97	225.00	237.50	231.25	204.00	211.00	207.50
ASH-12× RSH-79	70.80	70.00	70.40	74.87	72.67	73.77	191.33	205.00	198.17	170.33	183.33	176.83
ASH-13× RSH-79	72.47	70.67	71.57	75.13	73.33	74.23	201.67	208.33	205.00	179.00	190.00	184.50
ASH-18× RSH-79	69.37	72.33	70.85	74.10	74.67	74.38	211.67	200.00	205.83	177.67	178.33	178.00
ASH-9× ICSR93001	69.37	74.00	71.68	73.50	77.67	75.58	182.33	189.33	185.83	162.67	171.67	167.17
A-SH-11×	71.87	68.00	69.93	75.53	73.33	74.43	173.33	187.33	180.33	153.00	168.33	160.67
ASH-12×	70.43	69.00	69.72	75.93	74.67	75.30	175.00	180.00	177.50	156.33	161.00	158.67
ASH-13×	71.97	70.67	71.32	75.83	75.00	75.42	178.33	208.33	193.33	157.33	188.83	173.08
ASH-18×	72.73	70.67	71.70	75.67	74.67	75.17	201.67	205.67	203.67	171.67	195.00	183.33
Average	70.31	69.01	69.66	75.51	73.67	74.59	188.10	194.26	191.18	166.40	176.93	171.66
BSH-9	73.67	70.33	72.00	77.20	77.00	77.10	130.67	132.33	131.50	106.00	111.67	108.83
B-SH-11	72.63	74.33	73.48	75.17	77.33	76.25	118.33	123.33	120.83	91.00	100.00	95.50
BSH-12	70.40	69.67	70.03	75.60	74.37	74.98	135.00	135.00	135.00	117.00	120.00	118.50
BSH-13	69.43	70.67	70.05	74.60	75.07	74.83	141.67	134.67	138.17	117.00	123.33	120.17
BSH-18	71.07	72.00	71.53	75.67	76.43	76.05	130.00	138.33	134.17	111.67	117.33	114.50
RSH-14	72.70	75.33	74.02	76.33	79.67	78.00	158.33	165.33	161.83	129.67	145.00	137.33
RSH-39	72.27	73.00	72.63	75.77	76.33	76.05	163.67	165.00	164.33	141.00	143.33	142.17
RSH-79	72.23	74.00	73.12	77.00	78.33	77.67	168.00	170.00	169.00	145.00	135.00	140.00
ICSR93001	73.73	70.67	72.20	76.53	75.20	75.87	165.33	170.33	167.83	144.33	150.00	147.17
Average	72.01	72.22	72.12	75.99	76.64	76.31	145.67	148.26	146.96	122.52	127.30	124.91
H-305	71.50	69.00	70.25	75.57	73.50	74.98	183.67	185.00	184.34	161.00	165.87	163.43
LSD 0.05	2.40	2.89	2.63	2.28	3.06	2.67	13.12	11.32	12.13	9.67	10.20	9.84

Moreover, for the crosses ranged from 72.23 days (ASH-12×RSH-39) to 77.13 days (ASH-9×RSH-14) with an average of 74.59 days. Days to 50% flowering for the parental lines under 100% ET of irrigation, ranged from 70.03 days (BSH-12) to 74.02 days (RSH-14) with an average of 72.12 days, While for the crosses ranged from 65.42 days (ASH-13× RSH-14) to 71.70 days (ASH-18 × ICSR-93001) days with an average of 69.66 days. Moreover, the data showed that increase in average number of days to 50% flowering across the two years for the parental lines and crosses by decreased irrigation from 100% to 40% by 4.19 and 4.93 days, respectively. In general, most of the F_1 crosses were earlier than the their parents. While, one and five crosses out of twenty crosses were earlier significantly compared to the check hybrid H-305 in the combined data across two seasons under 40% and 100% ET, respectively.

Average plant height under 40% ET across two seasons (Table 2) for the parental lines ranged from 95.50 cm (BSH-11) to 147.17 cm (ICSR-93001) with an average of 124.91 cm. Furthermore for the crosses ranged from 149.67 cm (ASH-12×RSH-14) to 207.50 cm (ASH-11×RSH-79) with an average of 171.66 cm. Besides, the plant height for the parental lines under 100% of irrigation ranged from 120.83 cm (BSH-11) to 169.00 cm (RSH-79) with an average of 146.96 cm, while for the crosses ranged from 167.50 cm (ASH-11× RSH-14) to 231.25 cm (ASH-11× RSH-79) with an average of 191.18 cm. The reduction in the average of plant height for the parent lines and crosses under 40% combared to 100% ET was 22.05 and 19.52 cm, respectively. Most the crosses were taller than the their parents in all cases (across two years and the two irrigation levels), reflecting the presense of hybrid vigor. Also, the parentel lines ASH-11 and RSH-79 gave the tallest crosses compared to the parental lines. While, seven and six crosses out of twenty crosses were taller significantly compared to the check hybrid H-305 in the combined data across two seasons under 40% and 100% ET, respectively.

Regrading panicle length (Table 3) for thr parentel lines under 40% of irrigation ranged from 15.40 (BSH-12) to 27.07 (RSH-79) with an average of 21.75 cm. Additionally, for the crosses ranged from 28.06 cm (ASH-13 × RSH-14) to 41.23 cm (ASH-12×ICSR93001) with an average of 32.93 cm.

Table 3. Mean performance of panicle length and 1000 grain weight for twenty grain sorghum crosses, their parents and check H-305 under two irrigation levels in 2017, 2018 seasons and across two seasons.

Genotypes	Panicle length						1000 Grain weight					
	100% ET			40% ET			100% ET			40% ET		
	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb
ASH-9×	36.00	36.00	36.00	28.33	31.50	29.92	28.37	27.32	27.85	24.43	23.11	23.77
A-SH-11	34.67	37.33	36.00	28.90	30.07	29.48	23.67	23.37	23.52	20.53	18.68	19.60
ASH-12×	35.33	38.00	36.67	27.37	32.17	29.77	25.63	25.97	25.80	23.38	21.44	22.41
ASH-13×	35.00	35.67	35.33	28.87	28.33	28.60	24.91	25.37	25.14	20.72	20.46	20.59
ASH-18×	35.67	38.00	36.83	30.60	31.17	30.88	23.10	22.32	22.71	19.73	18.64	19.19
ASH-9×	42.00	42.00	42.00	37.50	34.57	36.03	25.94	25.25	25.60	23.73	20.94	22.34
A-SH-11×	37.67	38.00	37.83	32.53	33.90	33.22	24.90	22.31	23.61	20.23	18.41	19.32
ASH-12×	35.33	37.33	36.33	29.57	31.43	30.50	24.37	25.37	24.87	22.31	19.51	20.91
ASH-13×	40.67	41.00	40.83	35.20	35.30	35.25	24.50	25.27	24.89	21.18	19.71	20.45
ASH-18×	34.67	37.00	35.83	29.53	31.87	30.70	23.94	23.72	23.83	20.36	19.09	19.72
ASH-9×	35.00	37.00	36.00	31.17	31.33	31.25	24.90	23.97	24.44	21.08	18.44	19.76
A-SH-11×	35.00	37.00	36.00	29.83	32.20	31.02	26.10	25.37	25.74	21.88	21.08	21.48
ASH-12×	41.00	42.00	41.50	34.90	36.23	35.57	24.60	24.47	24.54	20.93	19.84	20.39
ASH-13×	36.00	37.67	36.83	30.93	33.13	32.03	24.50	24.92	24.71	20.78	18.51	19.65
ASH-18×	36.33	37.33	36.83	30.57	32.40	31.48	23.87	22.77	23.32	19.63	18.11	18.87
ASH-9×	39.33	41.00	40.17	34.17	36.67	35.42	20.34	22.29	21.31	21.46	18.54	20.00
A-SH-11×	38.67	41.00	39.83	33.87	36.77	35.32	19.07	22.59	20.83	20.00	18.41	19.20
ASH-12×	44.67	45.67	45.17	41.67	40.80	41.23	23.77	23.06	23.41	20.53	19.08	19.81
ASH-13×	40.00	40.67	40.33	32.00	35.67	33.83	23.63	23.47	23.55	21.03	20.31	20.67
ASH-18×	41.33	41.67	41.50	37.67	36.67	37.17	23.70	21.50	22.60	20.75	18.74	19.75
Average	37.72	39.07	38.39	32.26	33.61	32.93	24.19	24.03	24.11	21.23	19.55	20.39
BSH-9	24.33	23.00	23.67	19.97	16.50	18.23	32.97	32.27	32.62	28.68	26.76	27.72
B-SH-11	20.67	23.00	21.83	16.33	17.67	17.00	30.27	32.70	31.49	27.63	26.71	27.17
BSH-12	21.67	22.67	22.17	11.70	19.10	15.40	31.60	33.80	32.70	28.18	27.13	27.66
BSH-13	26.00	28.00	27.00	20.23	22.20	21.22	30.00	31.71	30.86	28.51	26.18	27.35
BSH-18	24.00	22.67	23.33	18.13	17.83	17.98	32.84	33.04	32.94	28.85	27.20	28.03
RSH-14	32.67	31.33	32.00	27.10	26.67	26.88	31.24	30.37	30.80	27.73	24.48	26.10
RSH-39	31.33	32.67	32.00	26.20	25.60	25.90	31.94	30.97	31.45	27.43	24.98	26.20
RSH-79	30.67	31.00	30.83	26.53	27.60	27.07	30.10	29.37	29.74	26.38	24.48	25.43
ICSR93001	31.00	33.00	32.00	24.00	28.10	26.05	31.07	31.82	31.45	28.28	24.64	26.46
Average	26.93	27.48	27.20	21.13	22.36	21.75	31.34	31.78	31.56	27.96	25.84	26.90
H-305	35.67	36.33	36.00	30.63	31.60	31.12	26.37	26.02	26.20	22.34	20.84	21.59
LSD 0.05	2.67	2.29	2.46	2.36	2.26	2.29	1.69	1.61	1.63	1.41	1.81	1.60

Moreover, the panicle length for the parental lines under 100% of irrigation ranged from 21.83 cm (BSH-11) to 32.00 cm (ICSR93001) with an average of 27.20 cm, while for the crosses it ranged from 35.33 cm (ASH-13× RSH-14) to 45.17 cm (ASH-12× ICSR93001) with an average of 38.39 cm.The reduction in the average of panicle length for the parent lines and crosses under 40% combared to 100% ET was 5.45 and 5.46 cm, respectively. Most of the crosses had longer panicle length compared to the parents,reflecting the presense of hybrid vigor. Also, the parentel lines ASH-12 and ICSR93001 gave the best crosses compared to the parental lines. While, 7 crosses out of twenty crosses had longer panicle length significantly than the check hybrid H-305 in the combined data across the two seasons under 40% and 100% ET.

Regrading 1000 grain weight (Table 3) for the parentel lines under 40% of irrigation ranged from 25.43 g (RSH-79) to 28.03 g (BSH-18) with an average of 26.90 g. Also, for the crosses ranged from 18.87 g (ASH-18×RSH-79) to 23.17 g (ASH-9×RSH-14) with an average of 20.39 g. Moreover, the 1000 grain weight for the parentel lines under 100% of irrigation ranged from 29.74 g (RSH-79) to 32.94 g (BSH-18) with an average of 31.56 g, while for the crosses ranged from 20.83 g (ASH-11× ICSR93001) to 27.85 g (ASH-9× RSH-14) with an average of 24.11 g. The reduction in the average of 1000 grain weight for the parent lines and crosses under 40% combared to 100% ET was 4.66 and 3.72 gm, respectively. Also, the parentel lines ASH-9 and RSH-14 gave the best crosses compared to the parental lines. While, the cross ASH-9× RSH-14 was higher significantly compared to the check hybrid H-305 in the combined data over two seasons under 40% and 100% ET.

Grain yield for the evaluated genotypes under the two irrigation levels in the two seasons and combined over seasons (Table 4) showed that grain yield per plant over the two seasons under 40% ET for the parenel lines ranged from 28.77 g (BSH-12) to 51.47 g (RSH-39) with an average of 42.00 g. Also, for the crosses it ranged from 56.28 g (ASH-11×RSH-79) to 87.78 g (ASH-13× ICSR93001) with an average of 76.09 g. Moreover, the grain yield per plant for the parental lines under 100% of irrigation ranged from 44.90 g (BSH-12) to 65.97 g (RSH-39) with an average of 56.99 g, while for the crosses it ranged from 75.01 g (A-SH-11 × RSH-79) to 105.00 g (A-SH-11 × ICSR93001) with an average of 92.53 g.

Table 4. Mean performance of grain yield per plant for twenty grain sorghum crosses, their parents and check H-305 under two irrigation levels in 2017, 2018 seasons and across two seasons, and drought tolerance and susceptible index.

Genotypes	Grain yield per plant						DTI%	DSI
	100% ET			40% ET				
	2017	2018	Com	2017	2018	Com		
ASH-9× RSH-14	87.33	88.17	87.75	71.53	72.80	72.17	82.25	0.90
A-SH-11 RSH-14	84.67	86.93	85.80	62.97	71.50	67.23	78.36	1.10
ASH-12× RSH-14	92.08	87.47	89.78	74.20	71.64	72.92	81.22	0.96
ASH-13× RSH-14	90.14	92.73	91.44	72.47	75.65	74.06	80.99	0.97
ASH-18× RSH-14	99.15	95.63	97.39	82.67	83.59	83.13	85.36	0.75
ASH-9× RSH-39	105.51	100.80	103.16	85.77	83.67	84.72	82.12	0.91
A-SH-11× RSH-39	91.33	94.07	92.70	78.97	84.10	81.53	87.95	0.61
ASH-12× RSH-39	83.10	86.33	84.72	68.70	69.87	69.28	81.78	0.93
ASH-13× RSH-39	86.60	88.20	87.40	68.57	75.10	71.83	82.19	0.91
ASH-18× RSH-39	97.37	95.53	96.45	81.10	83.50	82.30	85.33	0.75
ASH-9× RSH-79	82.25	87.83	85.04	64.03	73.43	68.73	80.82	0.98
A-SH-11× RSH-79	74.15	75.87	75.01	53.25	59.30	56.28	75.03	1.27
ASH-12× RSH-79	95.13	97.00	96.07	75.83	79.63	77.73	80.91	0.97
ASH-13× RSH-79	74.67	81.90	78.28	63.97	63.43	63.70	81.37	0.95
ASH-18× RSH-79	84.67	88.63	86.65	66.40	70.20	68.30	78.82	1.08
ASH-9× ICSR93001	101.83	103.73	102.78	83.80	84.76	84.28	82.00	0.92
A-SH-11 × ICSR93001	105.17	104.83	105.00	87.20	87.70	87.45	83.29	0.85
ASH-12 × ICSR93001	100.33	97.40	98.87	82.37	81.43	81.90	82.84	0.87
ASH-13 × ICSR93001	102.50	107.00	104.75	86.87	88.70	87.78	83.80	0.83
ASH-18 × ICSR93001	100.70	102.53	101.62	84.27	88.50	86.38	85.00	0.76
Average	91.93	93.13	92.53	74.75	77.43	76.09	-	-
BSH-9	57.17	55.10	56.13	39.13	45.57	42.35	75.45	1.25
B-SH-11	52.67	53.50	53.08	37.50	37.67	37.58	70.80	1.49
BSH-12	44.13	45.67	44.90	28.70	28.84	28.77	64.08	1.83
BSH-13	57.03	52.80	54.92	39.43	41.50	40.47	73.69	1.34
BSH-18	49.88	48.30	49.09	35.40	35.30	35.35	72.01	1.43
RSH-14	65.13	64.87	65.00	49.83	52.97	51.40	79.08	1.07
RSH-39	67.00	64.93	65.97	48.67	54.27	51.47	78.02	1.12
RSH-79	59.85	63.47	61.66	42.30	47.63	44.97	72.93	1.38
ICSR93001	61.45	62.80	62.13	42.60	48.73	45.67	73.51	1.35
Average	57.15	56.83	56.99	40.40	43.61	42.00		
H-305	91.77	94.60	93.18	75.53	77.07	76.30		
LSD 0.05	4.05	4.16	4.06	3.20	3.58	3.36		

Drought tolernace and suscesptibility indexes (DTI and DSI)

The results of drought tolerance index and stress susceptibility index for grain yield/plant (Table 4) cleared that the different genotypes (lines and crosses) differed greatly in their response to water sress Most genotypes scored drought tolernace index over 80% at 40% ET which could be considered tolerance to drought and some were severely affected by drought and some were severely affected by drought and scored less than 80% and considered susceptible genotypes to water stress. For example the best eight crosses were A-SH-11 × RSH-39 (87.95%), ASH-18× RSH-14(85.36%), A-SH-18 × RSH-39, (85.33%), ASH-18 × ICSR93001 (85.00%), ASH-13 × ICSR93001(83.80%), A-SH-11 × ICSR93001 (83.29%), ASH-12 × ICSR93001, (82.84%) and A-SH-9 × RSH-14 (82.25%). On other hand, all the crosses and parental lines ASH-18 × RSH-79 (78.82), A-SH-11, RSH-14 (78.36%) and A-SH-11× RSH-79 (75.03) indicate to their suscesptibility to drought. Both of DSI and DTI at 40% ET showed farily the same picture, for the tolerante hybrids scored the heighest drought tolernace index and the lowest susceptibility index and selction should be for high yielding genotypes at sever a drought which should DSI lower than the unity. Results are in harmony with those obtained by EL-Abd (2003), Hassaballa *et al* (2005), Al-Naggar *et al* (2007), Hafez (2010), Mahmoud *et al* (2013) and EL-Kady (2015).

In general, mean days to 50% flowering of the hybrids and its parents were increased by increasing water stress, but plant height, panicle length, 1000 grain yield grain yield per plant of the hybrids and its parents were decreased with increasing water stress. Morover, the F1 hybrids had taller plants and higher grain yield per plant than the best barents. These results are in harmony with those obtained by EL-Abd (2003), Hassaballa *et al* (2005), Al-Naggar *et al* (2007), Hafez (2010), Mahmoud *et al* (2013) and EL-Kady *et al* (2015).

Combining ability

Analysis of variance

The combined analysis of variance of 29 genotypes (20 crosses and 9 parents) of grain sorghum across two irrigations levels at each season are presented in Tables (5 and 6). Results indicated highly significant mean squares among two irrigations levels for all the studied traits in 2018 and 2019 seasons reflecting the sensitivity of genotypes to irrigation.

Table 5. Combined analysis of variance of 20 F_1's and 9 parents across two levels of irrigation in 2017 season.

SOV	df	Mean squares				
		Days to 50% Flowering	Plant height	Panicle length	1000 Grain weight	Grain yield per plant
Seasons (S)	1	49.60	3420.76**	73.52**	1490.26**	352.08**
Reps/(S)	4	10.80**	60.5	2.2	0.69	5.66
Genotypes (G)	28	11.69**	4328.3**	244.59**	64.47**	1961.28**
Parents (P)	8	7.20*	1852.92**	129.86**	4.69**	331.06**
P vs. C	1	110.21**	81092.18**	4566.34**	1565.32**	43262.14**
Crosses (C)	19	8.40**	1330.36**	65.44**	10.65**	473.96**
Female (F)	3	8.20**	338.46**	17.73**	17.65**	178.05**
Male (M)	4	23.48**	5472.66**	243.31**	10.83**	1814.33**
F x M	12	4.70	625.42**	36.88**	8.27**	273.50**
G × S	28	14.49**	91.55**	5.39	0.97	14.73**
P × S	8	3.42	67.79	9.72**	1.25	11.27*
P vs. C x S	1	57.89**	327.46**	3.87	1.44	2.64
C × S	19	17.53**	89.13**	3.66	0.83	16.29**
F × S	3	13.18**	43.98	0.94	1.95	16.65**
M × S	4	36.05**	186.36**	0.61	0.38	13.37**
F× M × S	12	14.35**	79.88*	5.32	0.58	16.90**
Error b	112	2.72	37.20	3.44	0.89	4.30

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

Highly significant variances among genotypes, crosses, and parents were found for all the studied traits in 2018 and 2019 seasons. Similarly, highly significant variances were found for crosses vs. parents for all the studied treats in the two seasons, reflecting the presence of heterosis for all the studied traits. Partitioning sum of squares of crosses to their contributions (females, males and females x males interaction) showed highly significant variances for all the studied traits in 2018 and 2019 seasons.

Table 6. Combined analysis of variance of 20 F_1's and 9 parents across two levels of irrigation in 2018 season.

SOV	df	Mean squares				
		Days to 50% Flowering	Plant height	Panicle length	1000 Grain weight	Grain yield per plant
Seasons (S)	1	30.46	1110.12*	52.97	0.44	22.89
Reps/(S)	4	4.31	98.45	12.01**	4.43**	22.97**
Genotypes (G)	28	26.35**	4404.45**	233.07**	86.25**	2084.20**
Parents (P)	8	11.79**	2062.62**	122.95**	6.56**	316.31**
P vs. C	1	225.40**	72809.60**	4661.52**	2065.71**	47054.86**
Crosses (C)	19	22.01**	1790.22**	46.36**	15.62**	461.69**
Female (F)	3	11.33**	448.83**	22.28**	14.67**	157.97**
Male (M)	4	70.78**	8250.31**	149.50**	43.15**	1572.29**
F x M	12	13.38**	622.33**	28.59**	9.05**	240.29**
G × S	28	16.65**	94.94*	2.07	2.80**	14.23**
P × S	8	6.85*	31.03	3.54	2.85**	8.64
P vs. C x S	1	21.34**	118.38	5.88	3.40	21.41
C × S	19	20.53**	120.61**	1.25	2.75**	16.21**
F × S	3	15.49**	140.65*	1.22	1.83	18.68*
M × S	4	26.83**	192.23*	0.70	1.42	30.34**
F× M × S	12	20.64**	96.03	1.41	3.39**	11.85*
Error b	112	2.62	55.63	2.23	1.01	6.31

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

On other hand, the interactions between genotypes x irrigations showed significant or highly significant variances for days to 50% flowering, 1000 grain weight and grain yield per plant in 2017 and 2018 seasons except for 50% flowering in 2018 season. The interaction between crosses × irrigation showed significant or highly significant mean squares for days to 50% flowering, 1000 grain weight and grain yield per plant in 2017 season. The interaction between female × irrigation showed significant mean squares for 1000 grain weight in 2017 season only. The interaction between male × irrigation was significant for 50% flowering, 1000 grain weight and grain yield per plant in 2017 and 2018 seasons, except for grain yield per plant in 2017 season. The interaction between female × male × irrigation showed highly significant mean squares for 50% flowering and grain yield per plant in 2017 season only. The interaction between parents × irrigation showed insignificant variances for all the studied traits in 2018 and 2019 seasons. The interaction of crosses vs. parents × irrigation showed significant or highly significant variances for 50% flowering in 2017 season, while, in 2018 season showed highly significant differences for 1000 grain weight and grain yield per plant.

Partitioning sum squares of crosses to their contributors

Mean squares due to 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).

For days to 50% flowering, in the combined across two levels of irrigation partitioning sum squares of crosses to their contributors accounted GCA accounted for 9.58% and 22.82% in 2017 season and for 19.53% and 41.96% in 2018 season as calculated from the females and males, respectively, while SCA reached to 67.59% and 38.69% in 2017 and 2018 respectively, as calculated from males x females interaction. Regarding to plant height, partitioning sum squares of crosses to their contributors, GCA accounted for 6.90% and 75.13% in 2017 season and for 4.71% and for 60.52% in 2018 season as calculated from the females and males, respectively, while the SCA as calculated from males x females interaction reached 17.97% and 34.76 % in 2017 and 2018, respectively.

For panicle length, partitioning sum squares of crosses to their contributions, it could be indicated that GCA accounted for 6.11% and 50.16 % in 2017 and for 9.28% and 59.58% in 2018 season as calculated from the females and males, respectively, while, the SCA as calculated from males x females interaction reached for 43.73% and 31.14% in 2017 and 2018 seasons respectively.

For 1000 grain weight, partitioning sum squares of crosses to their contributors, it could be indicated that GCA accounted for 24.84% and 28.38% in 2017 and for 30.31% and 25.47% in 2018 season as calculated from the females and males, respectively, while, the SCA as calculated from males x females interaction reached 46.77% and 44.21% in 2017 and 2018 seasons respectively.

Regarding to grain yield per plant, partitioning sum squares of crosses to their contributors, it could be indicated that GCA accounted for 8.74% and 59.56% in 2017 and for 6.77% and 59.89% in 2018 season as calculated from the females and males, respectively, while, the SCA as calculated from males x females interaction accounted for 31.70% and 33.34% in 2017 and 2018 seasons respectively. These results indicate that both additive and non-additive gene effects were important in the inheritance of all studied traits, and the additive gene effects played the major role in the inheritance of most studied traits. These results are in harmony with those obtained by Amir (2004) and Mahmoud (2007) who reported that both of additive and non-additive gene effects were important in the inheritance of all the studied traits, and the additive gene effects played the major role in inheritance of plant height, 1000 grain weight and grain yield per plant. Mohamed (2014) found that both of additive and non-additive gene effects were important in the inheritance of all the studied traits, and the additive gene effects played the major role in inheritance days to 50 % flowering, panicle length, panicle width, 1000 grain weight and grain yield per plant.

General combining ability

The estimates of general combining ability effects of the male and female lines for days to 50% flowering, plant height, panicle length, 1000 grain weight, and grain yield per plant under two irrigation levels and across two seasons are presented in (Tables 7, 8 and 9).

General combining ability (GCA) effects for days to 50% flowering showed that the female lines A-SH-11and A-SH-12 and the male lines RSH-39 and RSH-79 had negative and insignificant GCA effects each irrigation level and across two seasons. These lines can be considered best combiners for earliness which means that these lines had favorable gene action for earliness.

Table 7. Estimates of general combining ability (GCA) effects for days to 50% flowering and plant height of 5 CMS-lines and 4 restorers under two irrigation levels and across two seasons.

No.	Genotypes	Days to 50% flowering						Plant height					
		100% ET			40% ET			100% ET			40% ET		
		2017	2018	Comb	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb
Female lines													
1	A-SH-9	0.61	1.02*	0.81	0.13	1.51**	0.82	2.90	-0.34	1.28	3.53*	2.44	2.99
2	A-SH-11	-0.57	-0.36	-0.46	-0.11	-0.52	-0.32	1.73	3.87	2.80	3.37	1.99	2.68
3	A-SH-12	-0.20	-0.40	-0.30	-1.00*	-0.50	-0.75	-8.18**	-6.59**	-7.39**	-5.47**	-7.17**	-6.32**
4	A-SH-13	0.52	-1.93**	-0.70	1.34**	-1.037	0.15	-2.93	2.99	0.03	-2.38	2.41	0.01
5	A-SH-18	-0.35	1.66**	0.65	-0.36	0.55	0.09	6.48**	0.08	3.28	0.95	0.33	0.64
S.E (g_i)		0.43	0.50	0.47	0.40	0.54	0.48	2.31	1.98	2.15	1.74	1.78	1.76
S.E. (g_i-g_j)		0.60	0.71	0.66	0.56	0.77	0.67	3.27	2.80	3.05	2.47	2.51	2.49
Male lines													
1	RSH-14	0.57	-0.20	0.19	1.84**	0.01	0.92*	-18.23**	-16.93**	-17.58**	-14.08**	-13.42**	-13.75**
2	RSH-39	-1.17**	-3.26**	-2.22**	0.28	-1.67**	-0.69	1.37	-4.99	-1.813	1.18	-4.90**	-1.86
3	RSH-79	-0.36	2.00**	0.82	-1.90**	0.26	-0.82	22.83**	22.04**	22.44**	18.92**	18.28**	18.60**
4	ICSR93001	0.96*	1.46**	1.21**	-0.22	1.40**	0.59	-5.97**	-0.13	-3.05	-6.02**	0.04	-2.99
S.E$_{(gi)}$		0.38	0.45	0.42	0.36	0.49	0.43	2.07	1.77	1.93	1.56	1.59	1.57
S.E. (g_i-g_j)		0.54	0.63	0.59	0.50	0.69	0.60	2.92	2.51	2.72	2.21	2.24	2.23

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

Table 8. Estimates of general combining ability (GCA) effects for panicle length and 1000 grain weight of 5 CMS-lines and 4 restorers under two irrigation levels and across two seasons.

No.	Genotypes	panicle length						1000 grain weight					
		100% ET			40% ET			100% ET			40% ET		
		2017	2018	Comb	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb
Female lines													
1	A-SH-9	0.37	-0.07	0.15	0.53	0.51	0.52	0.70*	0.67*	0.68*	1.64**	0.71*	1.17**
2	A-SH-11	-1.22*	-0.73	-0.98*	-0.98	-0.53	-0.75	-0.75*	-0.62*	-0.69*	-0.62**	-0.41	-0.52
3	A-SH-12	1.37**	1.68**	1.53**	1.12	1.40*	1.26	0.40	0.68*	0.54	0.50*	0.42	0.46
4	A-SH-13	0.20	-0.32	-0.06	-0.51	-0.65	-0.58	0.20	0.72*	0.46	-0.36	0.20	-0.08
5	A-SH-18	-0.72	-0.57	-0.64	-0.17	-0.73	-0.45	-0.54	-1.46**	-1.00**	-1.17**	-0.91**	-1.04**
S.E $_{(gi)}$		0.46	0.40	0.43	0.64	0.40	0.54	0.30	0.28	0.29	0.23	0.31	0.27
S.E.(g_i-g_j)		0.65	0.57	0.61	0.90	0.56	0.76	0.42	0.40	0.41	0.33	0.44	0.39
Male lines													
1	RSH-14	-2.38**	-2.07**	-2.23**	-3.45**	-3.11**	-3.28**	0.94**	0.84**	0.89**	0.67**	0.91**	0.79**
2	RSH-39	0.35	0.01	0.18	0.61	0.26	0.43	0.54*	0.35	0.45	0.28	-0.02	0.13
3	RSH-79	-1.05*	-0.87*	-0.96*	-0.78	-0.70	-0.74	0.61*	0.27	0.44	-0.42*	-0.36	-0.39
4	ICSR93001	3.08**	2.93**	3.01**	3.62**	3.56**	3.59**	-2.09**	-1.46**	-1.77**	-0.53*	-0.54	-0.53*
S.E $_{(gi)}$		0.41	0.36	0.39	0.58	0.36	0.48	0.27	0.25	0.26	0.21	0.28	0.24
S.E.(g_i-g_j)		0.58	0.51	0.55	0.81	0.51	0.68	0.38	0.35	0.37	0.30	0.39	0.35

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

Table 9. Estimates of general combining ability (GCA) effects grain yield per plant of 5 CMS-lines and 4 restorers under two irrigation levels and over two seasons.

No.	Genotypes	Grain yield / plant					
		100% ET			40% ET		
		2017	2018	Comb	2017	2018	Comb
Female lines							
1	A-SH-9	2.30**	2.00**	2.15**	1.54*	1.24	1.39*
2	A-SH-11	-3.10**	-2.71**	-2.90**	-4.15**	-1.78**	-2.96**
3	A-SH-12	0.73	-1.08	-0.18	0.53	-1.78**	-0.63
4	A-SH-13	-3.46**	-0.67	-2.06**	-1.78*	-1.70**	-1.74**
5	A-SH-18	3.54**	2.45**	3.00**	3.86**	4.02**	3.94**
S.E $_{(gi)}$		0.71	0.74	0.73	0.57	0.63	0.60
S.E.(g_i-g_j)		1.00	1.04	1.03	0.80	0.89	0.85
Male lines							
1	RSH-14	-1.26	-2.94**	-2.10**	-1.98**	-2.39**	-2.18**
2	RSH-39	0.85	-0.14	0.35	1.87**	1.82**	1.85**
3	RSH-79	-9.76**	-6.88**	-8.32**	-10.05**	-8.23***	-9.14**
4	ICSR93001	10.17**	9.97**	10.07**	10.15**	8.79**	9.47**
S.E $_{(gi)}$		0.64	0.66	0.65	0.51	0.56	0.54
S.E.(g_i-g_j)		0.900	0.93	0.92	0.72	0.80	0.76

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

For plant height, GCA showed that the male line RSH-79 had positive and highly significant GCA effects under each irrigation level and across the two seasons. Also, the female lines A-SH-11 and A-SH-18 had positive and insignificant GCA effects under each irrigation level and across the two seasons. These lines can be considered the best combiners for tallness which means that these lines had favorable gene action for tallness. On other hand, the female line A-SH-12 and the male line RSH-14 had negative and highly significant GCA effects under each irrigation level and across the two seasons. These lines had favorable gene action for shortness.

Regarding to panicle length, GCA showed that the male line ICSR93001 had positive and highly significant GCA effects under each irrigation level and across the two seasons. Also, the female line A-SH-12 had positive and highly significant GCA effects in the two seasons and combined across two seasons under 100% ET and in the second season under stress irrigation. These lines can be considered the best combiners for panicle length.

For 1000 grain weight, GCA showed that the female line A-SH-9 and the male line RSH-14 had positive and highly significant or significant GCA effects under two irrigation levels and across two seasons. Also, the male line RSH-14 had positive and highly significant GCA effects under two irrigation levels and across two seasons. These lines had favorable gene action for heavier 1000 grain weight.

Regarding to grain yield per plant, GCA showed that the female lines A-SH-9 and A-SH-18 had positive and highly significant or significant GCA effects under two irrigation levels and across two seasons, except A-SH-9 under stress irrigation in 2018 season. Also, the male line ICSR93001 had positive and highly significant GCA effects under two irrigation levels and across the two seasons. Moreover, the male line RSH-39 had positive and highly significant GCA effects under stress irrigation level in the two seasons and across two seasons. These lines can be considered the best combiners for grain yield.

B - Specific combining ability

Estimates of specific combining ability effects for days to 50% flowering, plant height, panicle length, 1000 grain weight, and grain yield per plant under two irrigation levels and across two seasons (Tables 10, 11 and 12).

The combined data across two seasons over two showed that specific combining for days to 50% flowering showed that, the cross No. 4 had negative and highly significant SCA effects under normal irrigation but had negative and insignificant SCA effects under stress irrigation. Also, the crosses No. 8, 10, 11, 12 and 17 had negative and insignificant SCA effects under the two levels of irrigation. Indicating that these crosses were considering the best combinations for earliness.

For plant height, the crosses No. 8, 11, 12 and 20 had positive and significant or highly significant SCA effects under two levels of irrigation, indicating that, these crosses were conceder the best combinations for tallness. On other hand, the crosses No. 6, 15 and 17 had negative and significant or highly significant SCA effects under two levels of irrigation indicating that these crosses were conceder the best combinations for shortens.

Table 10. Estimates of specific combining ability (SCA) effects for days to 50% flowering and plant height under two irrigation levels and across two seasons.

No.	F_1 cross	Days to 50% flowering						Plant height					
		100% ET			40% ET			100% ET			40% ET		
		2017	2018	Comb	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb
1	ASH-9× RSH-14	1.85*	-0.99	0.43	1.12	0.47	0.80	-1.10	6.34	2.62	1.33	5.25	3.29
2	A-SH-11 RSH-14	-0.48	3.55**	1.54	-1.37	0.94	-0.21	-2.27	-3.53	-2.90	-1.50	2.50	0.50
3	ASH-12× RSH-14	2.86**	-0.64	1.11	0.12	-1.51	-0.70	1.65	0.93	1.29	-0.67	-3.01	-1.84
4	ASH-13× RSH-14	-2.67**	-4.78**	-3.72**	0.48	-1.68	-0.60	3.07	-4.66	-0.80	1.25	-2.58	-0.67
5	ASH-18× RSH-14	-1.56	2.87**	0.65	-0.35	1.77	0.71	-1.35	0.93	-0.21	-0.42	-2.17	-1.29
6	ASH-9× RSH-39	1.59	-0.50	0.54	2.18**	-0.78	0.70	-7.37	-16.59**	-11.98**	-9.93**	-13.20**	-11.57**
7	A-SH-11× RSH-39	1.20	-1.79	-0.30	2.92**	-0.65	1.14	0.47	-3.13	-1.33	0.23	-5.69	-2.73
8	ASH-12× RSH-39	-3.27**	2.32*	-0.48	-4.00**	2.17	-0.91	8.72	11.33**	10.02*	8.4*	16.51**	12.45**
9	ASH-13× RSH-39	0.51	1.05	0.78	0.14	0.27	0.20	4.13	4.41	4.27	2.98	0.73	1.86
10	ASH-18× RSH-39	-0.02	-1.08	-0.55	-1.23	-1.01	-1.12	-5.95	3.99	-0.98	-1.68	1.65	-0.02
11	ASH-9× RSH-79	-0.93	-1.02	-0.97	-1.38	-0.78	-1.08	11.17*	14.71**	12.94**	9.67**	15.69**	12.68**
12	A-SH-11× RSH-79	-1.88*	0.36	-0.76	-1.90*	0.92	-0.49	12.33**	17.33**	14.83**	11.83**	13.81**	12.82**
13	ASH-12× RSH-79	1.05	-0.60	0.22	2.25**	-0.76	0.74	-11.42*	-4.71	-8.06	-9.33**	-4.70	-7.02
14	ASH-13× RSH-79	1.99*	1.60	1.79	0.18	0.44	0.31	-6.33	-10.96**	-8.65*	-3.75	-7.61*	-5.68
15	ASH-18× RSH-79	-0.23	-0.33	-0.28	0.85	0.19	0.52	-5.75	-16.38**	-11.06*	-8.42*	-17.19**	-12.80**
16	ASH-9× ICSR93001	-2.51**	2.51*	0.00	-1.92*	1.09	-0.42	-2.70	-4.46	-3.58	-1.07	-7.74*	-4.40
17	A-SH-11× ICSR93001	1.16	-2.11*	-0.47	0.35	-1.21	-0.43	-10.53*	-10.67**	-10.6*	-10.57**	-10.63**	-10.60**
18	ASH-12× ICSR93001	-0.64	-1.07	-0.85	1.64*	0.10	0.87	1.05	-7.54	-3.25	1.60	-8.80*	-3.60
19	ASH-13× ICSR93001	0.17	2.13*	1.15	-0.80	0.97	0.09	-0.87	11.21**	5.17	-0.48	9.46*	4.49
20	ASH-18× ICSR93001	1.81*	-1.46	0.18	0.74	-0.95	-0.11	13.05**	11.46**	12.25**	10.52**	17.71**	14.11**
SE(sij)		0.85	1.01	0.93	0.80	1.09	0.95	4.62	3.96	4.31	3.49	3.55	3.52
S.E.(s_{ij}-s_{kl})		1.21	1.43	1.32	1.13	1.54	1.35	6.54	5.60	6.09	4.93	5.03	4.98

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

Table 11. Estimates of specific combining ability (SCA) effects for panicle length and 1000 grain weight under two irrigation levels and across two seasons.

No.	F_1 cross	Panicle length						1000 Grain weight					
		100% ET			40% ET			100% ET			40% ET		
		2017	2018	Comb	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb
1	ASH-9× RSH-14	0.30	-0.93	-0.32	-1.01	0.35	-0.33	2.54**	1.78**	2.16**	1.83**	1.94**	1.88**
2	A-SH-11 RSH-14	0.55	1.07	0.81	1.06	-0.06	0.50	-0.71	-0.88	-0.79	-0.80	-1.38*	-1.09*
3	ASH-12× RSH-14	-1.37	-0.68	-1.03	-2.56	0.12	-1.22	0.09	0.42	0.26	0.92	0.56	0.74
4	ASH-13× RSH-14	-0.53	-1.02	-0.78	0.56	-1.6633	-0.55	-0.42	-0.22	-0.32	-0.88	-0.20	-0.54
5	ASH-18× RSH-14	1.05	1.57	1.31	1.95	1.25	1.60	-1.50*	-1.09	-1.30*	-1.06*	-0.92	-0.99
6	ASH-9× RSH-39	3.57**	3***	3.28**	4.1**	3.05**	3.57**	0.51	0.19	0.35	0.53	0.70	0.62
7	A-SH-11× RSH-39	0.82	-0.33	0.24	0.64	0.41	0.53	0.93	-1.45*	-0.26	-0.71	-0.71	-0.71
8	ASH-12× RSH-39	-4.10**	-3.42**	-3.76**	-4.42**	-3.98**	-4.20**	-0.76	0.30	-0.23	0.24	-0.44	-0.10
9	ASH-13× RSH-39	2.40*	2.25**	2.33**	2.84*	1.94*	2.39*	-0.42	0.16	-0.13	-0.03	-0.02	-0.02
10	ASH-18× RSH-39	-2.68**	-1.50	-2.09*	-3.17*	-1.41	-2.29*	-0.25	0.79	0.27	-0.04	0.46	0.21
11	ASH-9× RSH-79	-2.03*	-1.13	-1.58	-0.85	-2.24**	-1.54	-0.59	-1.00	-0.80	-1.42**	-1.46*	-1.44*
12	A-SH-11× RSH-79	-0.45	-0.47	-0.46	-0.67	-0.34	-0.50	2.06**	1.69**	1.88**	1.64**	2.29**	1.97**
13	ASH-12× RSH-79	2.97**	2.12*	2.54**	2.30	1.77*	2.04	-0.60	-0.51	-0.55	-0.43	0.23	-0.10
14	ASH-13× RSH-79	-0.87	-0.22	-0.54	-0.04	0.72	0.34	-0.49	-0.10	-0.30	0.28	-0.88	-0.30
15	ASH-18× RSH-79	0.38	-0.30	0.04	-0.75	0.07	-0.34	-0.39	-0.07	-0.23	-0.06	-0.18	-0.12
16	ASH-9× ICSR93001	-1.83	-0.93	-1.38	-2.24	-1.16	-1.70	-2.46**	-0.97	-1.71**	-0.93	-1.18	-1.06
17	A-SH-11× ICSR93001	-0.92	-0.27	-0.59	-1.03	-0.02	-0.53	-2.28**	0.63	-0.82	-0.13	-0.20	-0.17
18	ASH-12× ICSR93001	2.5**	1.98*	2.24**	4.68**	2.09*	3.38**	1.26*	-0.21	0.53	-0.73	-0.36	-0.54
19	ASH-13× ICSR93001	-1.00	-1.02	-1.01	-3.37*	-1.00	-2.19*	1.34*	0.17	0.75	0.63	1.10	0.87
20	ASH-18× ICSR93001	1.25	0.23	0.74	1.96	0.09	1.02	2.14**	0.38	1.26*	1.16*	0.63	0.90
SE(sij)		0.92	0.80	1.29	1.29	0.80	1.07	0.60	0.56	0.58	0.47	0.62	0.55
S.E.(s_{ij}-s_{kl})		1.30	1.32	1.22	1.82	1.13	1.51	0.84	0.79	0.82	0.66	0.87	0.77

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

Table 12. Estimates of specific combining ability (SCA) effects for grain yield per plant under two irrigation levels and across two seasons.

No.	F1 cross	Grain yield/plant					
		100% ET			40% ET		
		2017	2018	Comb	2017	2018	Comb
1	ASH-9× RSH-14	-5.64**	-4.02**	-4.83**	-2.77*	-3.48**	-3.12*
2	A-SH-11 RSH-14	-2.91*	-0.58	-1.73	-5.65**	-1.76	-3.71**
3	ASH-12× RSH-14	0.68	-1.64	-0.48	0.90	-1.61	-0.35
4	ASH-13× RSH-14	2.92*	3.22*	3.07*	1.48	2.32	1.90
5	ASH-18× RSH-14	4.94**	2.99*	3.97**	6.04**	4.53**	5.28**
6	ASH-9× RSH-39	10.43**	5.81**	8.12**	7.61**	3.18*	5.39**
7	A-SH-11× RSH-39	1.66	3.79*	2.72	6.50**	6.63**	6.56**
8	ASH-12× RSH-39	-10.41**	-5.57**	-7.99**	-8.45**	-7.60**	-8.02**
9	ASH-13× RSH-39	-2.72	-4.12**	-3.42*	-6.27**	-2.44s	-4.36**
10	ASH-18× RSH-39	1.05	0.09	0.57	0.62	0.23	0.42
11	ASH-9× RSH-79	-2.22	-0.42	-1.32	-2.20	2.99*	0.40
12	A-SH-11× RSH-79	-4.92**	-7.68**	-6.30**	-7.30**	-8.12**	-7.71**
13	ASH-12× RSH-79	12.23**	11.83**	12.03**	10.61**	12.22**	11.41**
14	ASH-13× RSH-79	-4.05**	-3.68*	-3.86**	1.05	-4.06**	-1.51
15	ASH-18× RSH-79	-1.04	-0.07	-0.56	-2.16	-3.02*	-2.59*
16	ASH-9× ICSR93001	-2.57	-1.37	-1.97	-2.64*	-2.70*	-2.67*
17	A-SH-11× ICSR93001	6.16**	4.44**	5.30**	6.45**	3.26*	4.85**
18	ASH-12× ICSR93001	-2.50	-4.62**	-3.56*	-3.06**	-3.00*	-3.03*
19	ASH-13× ICSR93001	3.85**	4.57**	4.21**	3.75**	4.19**	3.97**
20	ASH-18× ICSR93001	-4.94**	-3.02*	-3.98**	-4.50**	-1.74	-3.12*
SE(sij)		1.42	1.48	1.45	1.13	1.26	1.20
S.E.(s_{ij}-s_{kl})		2.01	2.09	2.05	1.60	1.78	1.69

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

Regarding to panicle length, the crosses No. 6, 9 and 18 had positive and significant or highly significant SCA effects under the two levels of irrigation these crosses can be considered the best combinations for panicle length.

For 1000 grain weight, the crosses No. 1 and 12 had positive and highly significant SCA effects under the two levels of irrigation. These crosses can be considered the best combinations for 1000 grain weight.

Regarding to grain yield per plant, the crosses No. 5, 6, 13, 17 and 19 had positive and highly significant SCA effects under the two levels of irrigation. Also, the cross No 7 had positive and highly significant SCA effects under stress irrigation. Indicating that these crosses are considered the best combinations for grain yield per plant.

In general, crosses which had positive and significant SCA effects for grain yield per plant were high in grain yield per plant. These results are in line with those reported by Haussmann *et al* (1999), Mahmoud (2002), Amir (2004), Mahmoud (2007), Amir (2008) and Mahmoud *et al* (2013), who concluded that general and specific combining ability effects were effective in predicting hybrids performance in all traits.

Heterosis

Estimates of heterosis for days 50% flowering, plant height, panicle length, 1000 grain weight, and grain yield per plant under two irrigation levels and across two seasons (Tables 13, 14 and 15).

The combined data across two seasons under water stress showed that heterosis for days 50% flowering ranged from -4.65% to 0.78%. Four crosses out of twenty crosses had negative and significant or highly significant heterosis. Whereas, under optimum irrigation, heterosis ranged from -8.19% to 2.17%; seven out twenty crosses had negative and significant or highly significant heterosis it is noticed that most of these crosses had negative and insignificant SCA.

Under water stress conditions heterosis for plant height ranged from 7.81% to 47.02%; nineteen of twenty had positive and significant or highly significant heterosis. While, under optimum irrigation heterosis for plant height ranged from 3.5% to 36.83%; sixteen out of twenty crosses had positive and significant or highly significant heterosis.

For panicle length, heterosis value ranged from 6.45% to 51.87% and from 10.42% to 41.15% under stress and optimum irrigation, respectively. Moreover, most crosses had positive and highly significant heterosis for panicle length.

Table 13. Heterosis of days to 50% flowering and plant height in percentage from the better parent under two irrigation levels and across two seasons.

No.	F_1 cross	Days to 50% flowering						Plant height					
		100% ET			40% ET			100% ET			40% ET		
		2017	2018	Comb	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb
1	ASH-9× RSH-14	0.87	-2.13**	-1.27	2.97**	-1.73*	0.04	8.42**	10.89**	9.68*	21.08**	18.07**	19.49**
2	A-SH-11 RSH-14	-3.85**	-3.14**	-3.49*	0.93	-4.18**	-1.66	6.95**	7.46**	7.21	18.77**	15.86**	17.23**
3	ASH-12× RSH-14	4.45**	-2.73**	0.88	1.150*	-3.63**	-1.22	3.16*	3.83*	3.50	12.60**	5.75**	8.98*
4	ASH-13× RSH-14	-1.01	-12.12**	-6.61**	6.12**	-5.46**	0.31	7.37**	6.25**	6.80	16.45**	12.64**	14.44**
5	ASH-18× RSH-14	-2.95**	1.85**	-0.54	1.28*	-0.57	0.35	10.53**	7.86**	9.17*	17.74**	11.49**	14.44**
6	ASH-9× RSH-39	-1.29*	-5.78**	-4.44*	3.08**	-4.72**	-0.83	13.03**	4.44**	8.72*	14.18**	12.51**	13.34**
7	A-SH-11× RSH-39	-3.46**	-12.88**	-8.19**	4.57**	-7.21**	-1.75	17.11**	15.15**	16.13**	21.28**	17.44**	19.34**
8	ASH-12× RSH-39	-6.72**	-2.87**	-4.81*	-6.35**	-0.94	-3.67*	16.09**	17.58**	16.84**	20.80**	26.53**	23.69**
9	ASH-13× RSH-39	1.06	-8.21**	-3.62	3.57**	-5.11**	-0.78	16.50**	19.19**	17.85**	19.15**	22.21**	20.69**
10	ASH-18× RSH-39	-3.24**	-7.87**	-5.57**	-1.94**	-6.29**	-4.19**	16.09**	17.17**	16.63**	18.20**	21.40**	19.81**
11	ASH-9× RSH-79	-3.60**	0.95	-2.34	-6.02**	-3.03**	-4.65**	33.93**	35.69**	34.81**	36.78**	58.02**	47.02**
12	A-SH-11× RSH-79	-6.55**	-4.05**	-5.29**	-4.75**	-3.88**	-4.31*	33.93**	39.71**	36.83**	38.16**	56.30**	46.9**
13	ASH-12× RSH-79	0.57	0.48	0.52	-0.97	-2.29**	-1.62	13.89**	20.59**	17.26**	17.47**	35.80**	26.31**
14	ASH-13× RSH-79	4.37**	0.00	2.17	0.71	-2.31**	-0.80	20.04**	22.55**	21.30**	23.45**	40.74**	31.79**
15	ASH-18× RSH-79	-2.39**	0.46	-0.96	-2.07*	-2.31*	-2.19	25.99**	17.65**	21.79**	22.53**	32.10**	27.14**
16	ASH-9× ICSR93001	-5.84**	5.21**	-0.44	-3.96**	3.28**	-0.37	10.28**	11.15**	10.72**	12.70**	14.44**	13.59**
17	A-SH-11× ICSR93001	-1.06	-3.77**	-3.14	0.49	-2.48*	-1.89	4.84**	9.98**	7.45*	6.00**	12.22**	9.17*
18	ASH-12× ICSR93001	0.05	-0.96	-0.45	0.44	0.40	0.42	5.85**	5.68**	5.76	8.31**	7.33**	7.81
19	ASH-13× ICSR93001	3.65**	0.00	1.81	1.65**	-0.09	0.78	7.86**	22.31**	15.19**	9.01**	25.89**	17.61**
20	ASH-18× ICSR93001	2.35**	0.00	0.23	0.00	-0.71	-0.92	21.98**	20.74**	21.35**	18.94**	30.00**	24.58**

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

Table 14. Heterosis of panicle length and 1000 grain weight in percentage from the better parent under two irrigation levels and across two seasons.

No.	F_1 cross	panicle length						1000 Grain weight					
		100% ET			40% ET			100% ET			40% ET		
		2017	2018	Comb	2017	2018	Comb	2017	2018	Comb	2017	2018	Comb
1	ASH-9× RSH-14	10.20 **	14.89 **	12.50 **	4.68 *	18.13 **	11.35 *	-13.95 **	-15.34 **	-14.64 **	-11.33 **	-13.64 **	-12.45 **
2	A-SH-11 RSH-14	6.12 **	19.15 **	12.50 **	6.77 **	12.75 **	9.74	-24.22 **	-28.54 **	-25.30 **	-25.96 **	-30.08 **	-27.85 **
3	ASH-12× RSH-14	8.16 **	21.28 **	14.58 **	1.11	20.63 **	10.79	-18.89 **	-23.18 **	-21.10 **	-17.03 **	-20.96 **	-18.96 **
4	ASH-13× RSH-14	7.14 **	13.83 **	10.42 **	6.65 **	6.25 **	6.45	-20.26 **	-19.99 **	-18.53 **	-27.33 **	-21.84 **	-24.7 **
5	ASH-18× RSH-14	9.18 **	21.28 **	15.10 **	13.05 **	16.88 **	14.95 *	-29.65 **	-32.45 **	-31.06 **	-31.60 **	-31.47 **	-31.54 **
6	ASH-9× RSH-39	34.04 **	28.57 **	31.25 **	46.68 **	46.74 **	46.71 **	-21.33 **	-21.74 **	-21.54 **	-17.26 **	-21.74 **	-19.42 **
7	A-SH-11× RSH-39	20.21 **	16.33 **	18.23 **	27.25 **	32.42 **	29.84 **	-22.02 **	-31.77 **	-25.02 **	-26.78 **	-31.07 **	-28.89 **
8	ASH-12× RSH-39	12.77 **	14.29 **	13.54 **	15.65 **	22.79 **	19.22 **	-23.69 **	-24.94 **	-23.95 **	-20.83 **	-28.09 **	-24.39 **
9	ASH-13× RSH-39	29.79 **	25.51 **	27.60 *	37.68 **	37.89 **	37.79 **	-23.28 **	-20.31 **	-20.88 **	-25.72 **	-24.71 **	-25.24 **
10	ASH-18× RSH-39	10.64 **	13.27 **	11.98 **	15.51 **	24.48 **	20.00 **	-27.10 **	-28.22 **	-27.66 **	-29.44 **	-29.84 **	-29.63 **
11	ASH-9× RSH-79	14.13 **	19.35 **	16.76 **	19.87 **	13.53 **	16.60 **	-24.47 **	-25.72 **	-25.09 **	-26.50 **	-31.08 **	-28.71 **
12	A-SH-11× RSH-79	14.13 **	19.35 **	16.76 **	14.74 **	16.67 **	15.73 **	-13.77 **	-22.42 **	-18.26 **	-20.81 **	-21.09 **	-20.95 **
13	ASH-12× RSH-79	33.70 **	35.48 **	34.59 **	34.23 **	31.28 **	32.71 **	-22.15 **	-27.60 **	-24.97 **	-25.73 **	-26.86 **	-26.28 **
14	ASH-13× RSH-79	17.39 **	21.51 **	19.46 **	18.97 **	20.05 **	19.53 **	-18.60 **	-21.41 **	-19.91 **	-27.12 **	-29.30 **	-28.16 **
15	ASH-18× RSH-79	18.48 **	20.43 **	19.46 **	17.56 **	17.39 **	17.48 **	-27.31 **	-31.09 **	-29.20 **	-31.95 **	-33.43 **	-32.67 **
16	ASH-9× ICSR9300	26.88 **	24.24 **	25.52 **	30.41 **	30.49 **	30.45 **	-38.32 **	-30.93 **	-34.66 **	-25.16 **	-30.71 **	-27.84 **
17	A-SH-11× ICSR9300	24.73 **	24.24 **	24.48 **	29.26 **	30.84 **	30.08 **	-38.62 **	-30.92 **	-33.85 **	-29.29 **	-31.07 **	-29.32 **
18	ASH-12× ICSR9300	44.09 **	38.38 **	41.15 **	59.03 **	45.20 **	51.87 **	-24.79 **	-31.79 **	-28.40 **	-27.39 **	-29.68 **	-28.39 **
19	ASH-13× ICSR9300	29.03 **	23.23 **	26.04 **	22.14 **	26.93 **	24.62 **	-23.94 **	-26.24 **	-25.10 **	-26.23 **	-22.42 **	-24.41 **
20	ASH-18× ICSR9300	33.33 **	26.26 **	29.69 **	43.77 **	30.49 **	36.89 **	-27.81 **	-34.93 **	-31.39 **	-28.08 **	-31.10 **	-29.55 **

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

Table 15. Heterosis of grain yield per plant in percentage from the better parent under two irrigation levels and across two seasons.

No.	F1 cross	Grain yield/plant					
		100% ET			40% ET		
		2017	2018	Comb	2017	2018	Comb
1	ASH-9× RSH-14	34.08**	35.92**	35.00**	43.55**	37.44**	40.40**
2	A-SH-11 RSH-14	29.99**	34.02**	32.00**	26.35**	34.99**	30.80**
3	ASH-12× RSH-14	41.38**	34.84**	38.12**	48.90**	35.25**	41.87**
4	ASH-13× RSH-14	38.39**	42.96**	40.67**	45.42**	42.83**	44.08**
5	ASH-18× RSH-14	52.23**	47.43**	49.83**	65.89**	57.82**	61.73**
6	ASH-9× RSH-39	57.48**	55.24**	56.37**	76.23**	54.18**	64.60**
7	A-SH-11× RSH-39	36.32**	44.87**	40.53**	62.26**	54.98**	58.42**
8	ASH-12× RSH-39	24.03**	32.96**	28.42**	41.16**	28.75**	34.62**
9	ASH-13× RSH-39	29.25**	35.83**	32.49**	40.89**	38.39**	39.57**
10	ASH-18× RSH-39	45.32**	47.13**	46.21**	66.64**	53.87**	59.91**
11	ASH-9× RSH-79	37.43**	38.39**	37.92**	51.38**	54.16**	52.85**
12	A-SH-11× RSH-79	23.89**	19.54**	21.65**	25.89**	24.49**	25.15**
13	ASH-12× RSH-79	58.95**	52.84**	55.80**	79.28**	67.18**	72.87**
14	ASH-13× RSH-79	24.76**	29.04**	26.96**	51.22**	33.17**	41.66**
15	ASH-18× RSH-79	41.46**	39.65**	40.53**	56.97**	47.38**	51.89**
16	ASH-9× ICSR93001	65.72**	65.18**	65.45**	96.71**	73.93**	84.56**
17	A-SH-11× ICSR93001	71.14**	66.93**	69.01**	104.69**	79.96**	91.5**
18	ASH-12× ICSR93001	63.28**	55.10**	59.14**	93.35**	67.10**	79.34**
19	ASH-13× ICSR93001	66.80**	70.38**	68.61**	103.91**	82.01**	92.23**
20	ASH-18× ICSR93001	63.87**	63.27**	63.57**	97.81**	81.6**	89.16**

***, ** significant at the 0.05 and 0.01 levels of probability, respectively.**

For 1000 grain weight, heterosis value ranged from -32.67% to -12.45% and from -34.66% to -14.64% under stress and optimum irrigation, respectively. Moreover, all crosses had negative and highly significant heterosis for 1000 grain weight.

Regarding to grain yield per plant, heterosis value ranged from 30.80% to 92.23% and from 21.65% to 69.01% under stress and optimum irrigation respectively. Moreover, all crosses had positive and highly significant heterosis for grain yield per plant. It is noted that, the high positive heterosis were also high positive and significant SCA. In general, some crosses were earlier, taller, plants, longer, panicle, higher in 1000 grain weight and grain yield per plant than the better parents. Similar results were obtained by Hovny *et al* (2001), Mahmoud (2002), Abd El-Halim (2003), Hafez (2010) , Abd-El-Mawgoud *et al* (2012), Abd-Elrheem (2012), Mohamed (2014) and El-Kady *et al* 2015. They found that heterosis was manifested in grain sorghum crosses for grain yield and its components.

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دراسة القدرة علي الائتلاف وقوة الهجين في هجن الذرة الرفيعة للحبوب تحت ظروف الاجهاد المائي

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تم تقييم عدد ٢٠ هجين من ذرة الحبوب الرفيعة و آبائهم (٥ سلالات عقيمة A lines و عدد ٤ أباء معيدة للخصوبة R lines) والهجين التجاري ٣٠٥ للمقارنة وذلك لصفة محصول الحبوب وأربع صفات أخرى وذلك في موسمي ٢٠١٧ و ٢٠١٨ في محطة البحوث الزراعية بجزيرة شندويل تحت مستويين من الري (١٠٠ % و ٤٠ % بخر – نتح). وقد أظهرت النتائج اختلافات معنوية أو عالية المعنوية بين السنوات وبين معاملات الري وبين التراكيب الوراثية بالنسبة لجميع الصفات محل الدراسة. كان التفاعل بين السنوات و التراكيب الوراثية وبين معدلات الري والتراكيب الوراثية عالي المعنوية لجميع الصفات محل الدراسة. كما كان التفاعل بين السنين و مستويات الري معنويا بالنسبة لصفتي وزن الألف حبة ومحصول النبات الفردي. وبالنسبة الي التفاعل بين التراكيب الوراثية ومعدلات الري والسنوات كان عالي المعنوية لصفات طول النبات و وزن الألف حبة ومحصول النبات الفردي. و كما كانت هناك تباينات عالية المعنوية بين الآباء وبين الهجن خلال الموسمين و ذلك بالنسبة لجميع الصفات محل الدراسة. كما كان التباين الراجع الي الاباء مقابل الهجن عالي المعنوية خلال الموسمين بالنسبة لجميع الصفات محل الدراسة مما يعطى مؤشرا عن وجود قوة الهجين. اظهر تجزئة مجموع مربعات التباينات الى مكوناتها (آباء وأمهات وآباء × أمهات) اختلافات معنوية أو عالية المعنوية لجميع الصفات المدروسة فى الموسمين عدا صفة عدد الايام من الزراعة حتي ٥٠% تزهير بالنسبة الي آباء × أمهات في موسم ٢٠١٧. أدي انخفاض معدل الري من ١٠٠% بخر – نتح الي ٤٠% بخر – نتح الي انخفاض في طول النباتات و طول القنديل ووزن الالف حبة ومحصول الحبوب لكل نبات بينما ادى لزيادة عدد الايام من الزراعة وحتى التزهير. علاوة على ذلك كانت بعض الهجن مبكرة مقارنة بالآباء و كانت معظم الهجن أطول من الآباء كما كانت اعلي فى طول الكوز و وزن الألف حبة و كذلك أعلى فى محصول الحبوب لكل نبات مقارنة بأحسن الأبوين و ذلك خلال موسمي التقييم وتحت مستويي الري. أظهرت النتائج أن كلا من فعل الجين المضيف وغير المضيف هام لتوريث الصفات محل الدراسة وان فعل الجين المضيف يلعب الدور الرئيسي في توريث كل الصفات محل الدراسة. أظهرت السلالة الأم A-SH- 11 و السلالة الأب ICSR-93001 قدرة إئتلافية عالية بالنسبة لصفة محصول الحبوب لكل نبات ويدل ذلك أنه يمكن استعمال هذه الآباء في برنامج التربية لتحسين محصول الحبوب. علاوة على ذلك أظهرت بعض الهجن قدرة ائتلافية خاصة عالية موجبة و معنوية بالنسبة لصفة محصول الحبوب لكل نبات و صفة وزن الالف حبة.

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