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COMBINING ABILITY AND HETEROSIS FOR GRAIN SORGHUM LINE x TESTER MATING DESIGN

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ABSTRACT

Twenty F_1 grain sorghum crosses, their parents (four sterile female tester and five male lines) and one commercial check hybrid (Shandaweel-305) were evaluated for yield and five other characters in 2019 and 2020 seasons at Arab El-Awamer Station, Assiut, Egypt. The obtained data showed highly significant differences between genotypes and their partition, crosses, parents and crosses vs parents for all studied traits except for parents for grain yield/plant and crosses vs parents for panicle width, 1000-grain weight and grain yield/plant. Meanwhile, mean squares due to lines, testers and their interaction were significant or highly significant for all traits except for 1000- grain weight of lines. Most of the crosses were earlier and had higher grain yield/plant than their parents. The best parents for general combining ability effects were BSH-1 and ICSR-89016 for grain yield/plant. Thus, these two lines can be used in sorghum breeding program for improving grain yield. Moreover, the best crosses for specific combining ability were (ICSR-89031 X Ash-1 and ICSR-89031 X Ash-11) for grain yield/plant. Two crosses (ICSR-89016 X Ash-3 and ICSR-89016 X Ash-11) out-yielded the check. The best crosses for heterosis relative to better parent were (ICSR-89016 X Ash-1 and ICSR-89031 X Ash-3).

Key words: ***Sorghum bicolor, heterosis, GCA, SCA, Line x Tester***

INTRODUCTION

Grain sorghum is one of the most adaptable crops and can be grown in a wide series of environments. It is mainly grown for food, feed, industrial purposes and for emerging biofuels industry. The cultivated area from sorghum crop at Assuit and Sohag governorates is about 70% from the entire area, 400.000 feddan (feddan = 4200 m^2) (FAO 2017). The importance of sorghum increased more and more after adding 20% from the sorghum for making bread. Grain sorghum is a substitute for wheat and is great for those requiring a gluten-free diet. Sorghum is also the greatest crop for surviving in the tough conditions prevalent in Upper Egypt. Although sorghum grain can withstand a variety of conditions such as heat, drought, salt, and flooding (Ejeta and Knoll, 2007). Sorghum grain has a high concentration of potassium and starch, it is less acidifying and is easily absorbed and tolerated by the Sick and diabetics, adults and even children. It is rich in antioxidants (Dy Kes and Rooney, 2006), which is believed to help lower the risk of cancer, diabetes, heart disease and some neurological diseases. The discovery of cytoplasmic male sterile (CMS) lines in sorghum facilitates the production of hybrids. Development of hybrids in Egypt is still depending on exotic CMS and restorer lines. Selection among these lines to produce hybrids depends on their good performance of general and specific combining abilities as a first step for hybrid program step for hybrid program. El- Menshawy (1996), Amir (1999), Bakheit *et al* (2004), Abo-Elwafa *et al* (2005) and Mohamed (2014) reported that the hybrids were earlier, taller and had higher 1000 grain weight and grain yield than their better parents. General combining ability was found to be more important than specific combining for plant height and grain weight (Radwan *et al*, 1997). Combining ability evaluations can help with the selection of appropriate parents for a successful hybridization programme. "Heterosis" has been regarded as the most significant breakthrough in plant breeding. Exploitation of heterosis on commercial scale and the systematic varietal improvement through hybridization are the main tools to increase the sorghum production (Menezes *et al* (2015).The success in the development of superior hybrids and/or varieties depends on the choice of parents for hybridization, the amount and the type of genetic variability presence in the base population to be improved. The aim of this study was to assess the potential of some grain sorghum genotypes and hybrids, as well as to estimate general and specific combining abilities, as well as heterosis in the resulting hybrids.

MATERIALS AND METHODS

The experiments were conducted during the three summer seasons 2018, 2019 and 2020. Four introduced cytoplasmic male sterile lines (BSH-1, BSH- 3, BSH-6, BSH-11) were crossed with five tester lines (ICSR-89016, ICSR-89031, ICSR-890012, ICSR-MR12 and ICSR-MR1)) in line x tester mating design to produce twenty hybrids at Shandweel Agric. Res. Station in 2018 season. The origin of the four male sterile lines and four restorers are presented in Table (1). The resulting twenty crosses along with their nine parents and one check (Sh-305) were evaluated for various yield contributing traits of sorghum at Arab El-Awamer Agric. Res. Station, Assiut, Egypt, in 2019 and 2020 seasons. 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 secure two plants / hill. The other recommended cultural practices of sorghum production in the two years were implemented in the right time.

Data were recorded on plant height (cm), days from sowing date to 50% flowering (days), panicle length (cm), panicle width (cm), 1000-grain weight (g) and grain yield per plant (g). Data of each season and combined across the two seasons, were subject to regular analysis of variance of randomized complete block design according to Gomez and Gomez (1984). Line by tester analysis was performed according to Kempthorne (1957) and Steel and Torrie (1980). Heterosis was calculated as the percentage of deviation from better parent according to the following formula:

$$H = m\,F_1 - m\,B.P\ /\ m\,B.P \times 100$$

Where, m $F_1$and m B.P are means for the F_1 hybrid and best parent, respectively. Test of significance was made by using LSD.

Table 1. Origin of the parental lines and the check.

No.	Origin
Cytoplasmic male sterile lines (CMS lines)	
1- BSH-1	**Egypt**
2- BSH-3	**Egypt**
3- BSH-6	**Egypt**
4- BSH-11	**Egypt**
Restorer lines (R-lines)	
1- ICSR-89016	**India**
2- ICSR-93031	**India**
3- ICSR-930012	**India**
4- ICSR-MR12	**India**
5- ICSR-MR1	**India**
Check (Shandaweel-305)	**Egypt**

RRESULTS AND DISUCSSION

Analysis of variance

The combined analysis of variance for six traits across two years Table (2) showed highly significant differences exist among genotypes for all the studied traits.

Table 2. Combined analysis of variance for 30 genotypes of grain sorghum for six traits across 2019 and 2020 seasons.

SOV	df	Mean squares					
		Plant height	Days to 50% flowering	Panicle Length	Panicle Width	1000-grain weight	Grain yield per plant
Years (Y)	1	137.9	0.022	5.933	0.032	10.65	0.280
Rep./Y (a)	4	67.9	2.711	2.687	0.153	3.129	4.709
Genotypes (G)	29	4212.8**	75.20**	23.25**	2.030**	31.45**	143.3**
G x Y	29	26.52	2.746	2.433	0.125	3.178	1.608
Error (b)	116	23.99	2.998	2.160	0.115	3.839	6.140

**** Significant at 0.01 level of probability.**

Mean performance

The combined average across the two years (Table 3) indicated that plant height (cm) for the crosses ranged from 168.4 cm (MR1xAsh-6) to 208.0 cm (MR12 x Ash-3) with an average of (191.9 cm). While, the parental lines ranged from121.3 cm (BSH-11) to 167.5 cm (ICSR-890012) with an average of (142.7cm). Days to 50% flowering for the crosses ranged from 70.67 day (MR1x Ash-6) to 89.67 day (ICSR-89031x Ash-1) with an average (83.32 day). For the parental lines, the average across two years ranged from 81.17 day (BSH-1) to 88.50 day (ICSR- 890012) to with an average of (85.41 day).

For panicle length (cm), the crosses ranged from 20.99 cm (MR12 x Ash-3) to 26.78 cm (MR1xAsh-1) with an average of (24.19 cm). While, the parental lines ranged from 20.67 cm (ICSR- MR12) to 25.54 cm (ICSR-89016) with an average of (22.24 cm).For panicle width, the crosses ranged from 5.300 cm (MR-12 x Ash-1) to 8.05 cm (ICSR-89016 x Ash-11) with an average of (6.63 cm). While the parental lines ranged from 5.65 cm (ICSR- 890012) to7.434 cm (ICSR-89031) with an average of (6.51 cm). For1000-grain weight, the crosses ranged from 22.07 g (ICSR-89016 x Ash-1) to 32.10 g (MR1 x Ash-1) with an average of (26.4 g). While, for the parental lines the average ranged from 21.72 g (ICSR- 89016) to 27.80 g (ICSR-89031) with an average (26.07g). For grain yield/plant, the crosses ranged from 34.92 g (MR12 x Ash-3) to 55.52 g (ICSR- 89016 x Ash-11) with an average of (45.72g).While, the parental lines ranged from 41.57 g

(ICSR- 89016) to 48.07g (BSH-11) with an average of (44.78 g). Five crosses insignificantly out – yielded the check SH-305.

Table 3. Means performance of 30 genotypes for six traits across two years.

Genotypes	Plant height (cm)	Days to 50% flowering	Panicle Length (cm)	Panicle Width (cm)	1000-grain weight (g)	Grain yield per plant (g)
	Com.	Com.	Com.	Com.	Com.	Com.
ICSR-89016 x Ash-1	186.8	81.83	23.09	5.984	22.07	54.25
ICSR-89016 x Ash-3	187.5	83.34	25.64	6.800	30.05	55.22
ICSR-89016 x Ash-6	202.8	85.17	25.32	6.500	27.20	52.64
ICSR-89016 x Ash-11	186.0	85.67	23.12	8.050	27.50	55.52
ICSR-89031 x Ash-1	202.3	89.67	26.77	6.367	26.15	45.50
ICSR-89031 x Ash-3	197.5	85.67	21.83	7.250	23.64	43.65
ICSR-89031 x *Ash-6	181.4	84.67	22.90	6.650	26.37	45.45
ICSR-89031 x Ash-11	182.4	82.50	21.55	6.500	25.45	44.07
ICSR-890012 x Ash-1	192.0	86.67	21.75	6.900	25.50	44.95
ICSR-890012 x Ash-3	204.2	84.00	23.62	5.767	26.72	45.20
ICSR-890012 x Ash-6	194.7	83.33	26.02	6.967	26.39	40.82
ICSR-890012 x Ash-11	202.0	84.00	24.20	5.700	27.10	41.18
MR12 x Ash-1	190.9	85.67	23.70	2020	28.35	41.15
MR12 x Ash-3	208.0	83.50	20.99	5.900	23.57	34.92
MR12 x Ash-6	202.8	83.84	23.55	7.000	24.37	40.70
MR12 x Ash-11	195.8	83.33	24.80	6.267	25.17	43.24
MR1 x Ash-1	192.6	84.00	26.78	8.167	32.10	52.32
MR1 x Ash-3	180.2	76.67	25.94	6.533	23.78	43.15
MR1 x Ash-6	168.4	70.67	26.49	7.367	27.15	44.90
MR1 x Ash-11	180.7	82.17	24.43	6.667	29.85	45.57
ICSR-89016	134.0	82.00	25.54	6.767	21.72	41.57
ICSR-89031	165.4	87.17	22.57	7.067	27.80	44.20
ICSR-890012	167.5	88.50	21.37	5.633	24.10	43.95
ICSR- MR12	167.2	87.00	20.67	7.200	25.04	46.34
ICSR- MR1	149.7	87.00	21.88	5.567	27.50	46.04
BSH-1	127.2	81.17	21.54	6.150	25.50	44.14
BSH- 3	128.3	83.67	20.92	6.067	27.58	44.07
BSH-6	123.8	86.67	23.08	6.900	27.74	44.68
BSH-11	121.3	85.50	22.62	6.817	27.67	48.07
SH-305	162.9	83.00	26.83	6.400	27.39	54.59
LSD 0.05	5.6	1.98	1.68	0.386	2.24	2.83

Combining ability

The line x tester of variance of twenty nine genotypes (20 crosses and 9 parents) of grain sorghum in season 2019 for all the six traits is presented Table (4). Data cleared highly significant differences among genotypes and crosses for all the studied traits, except for 1000-grain weight. Also, highly significant mean squares due to parents vs. crosses was shown for all six traits (plant height, days to 50% flowering and panicle length) reflecting the presence of average heterosis. Partitioning sum of squares of crosses to their contributors (line, tester and line × tester interaction) showed highly significant variances for all traits, except panicle length for lines and 1000- grain weight for lines, testers and lines x testers interaction.

Table 4. Analysis of variance of 20 F_1 and 9 parents for six traits in 2019 season.

SOV	df	Mean squares					
		Plant height	Days to 50% flowering	Panicle length	Panicle width	1000-grain weight	Grain yield per plant
Rep.	2	61.47	0.10	4.54	0.06	23.79	1.15
Genotypes (G)	28	2110.**	40.53**	11.20**	0.93**	20.94	65.28**
Crosses (C)	19	313.5**	45.99**	8.81**	1.03**	22.02	90.64**
Crosses vs. parents	1	43684.2**	85.33**	105.0**	0.01	7.70	21.92
Parents (P)	8	1180.9**	21.98**	5.17	0.83**	20.03	10.48
Lines effects	3	134.9**	30.98**	2.93	1.27**	3.99	31.27**
Testers effects	4	681.8**	101.5**	13.61**	0.62**	21.09	341.6**
Line X tester effects	12	235.3**	31.24**	8.68**	1.10**	26.83	21.82**
Pooled error	56	16.92	3.47	3.08	0.13	16.37	6.56

**** Significant at 0.01 level of probability**

In season 2020, highly significant differences existed among genotypes, crosses and parents for all the studied traits, except crosses vs parents for panicle width, 1000-grain weight and grain yielz/plant and parents for grain yield per plant Table(5). The mean squares due to lines, testers and their interaction were significant or highly significant for all studied traits, except lines for 1000-grain weight.

Table 5. Analysis of variance of 20 F_1 and 9 parents for six traits in 2020 season.

SOV	df	Mean squares					
		Plant height	Days to 50% flowering	Panicle height	Panicle width	1000-grain weight	Grain yield per plant
Rep.	2	85.77	4.59	1.35	0.320	0.22	6.95
Genotypes (G)	28	2240.6**	39.90**	13.15**	1.29**	16.70**	67.41**
Crosses (C)	19	354.4**	46.31**	13.17**	1.50**	17.28**	94.08**
Crosses vs. parents	1	46646.3**	77.55**	35.93**	0.01	0.290	11.58
Parents (P)	8	1169.4**	19.98**	10.24**	0.96**	138.9**	11.07
Line effects	3	118.8**	59.80**	10.88**	1.06**	9.78	29.80**
Tester effects	4	750.2**	92.48**	21.38**	1.02**	14.72*	361.1**
Line X tester effects	12	281.4**	27.55**	11.01**	1.77**	20.01**	21.14**
Pooled error	56	30.94	2.67	1.36	0.10	4.36	6.00

**** Significant at 0.01 level of probability**

General combining ability effects (GCA)

General combining ability (GCA) effects of the lines and testers for all studied traits in 2019 and 2020 seasons are presented in Table (6). For plant height, the line BSH- 3 in 2019 had positive and highly significant GCA effects, this line have might favorable genes for tallness. The testers ICSR-890012 and ICSR- MR12 had positive and highly significant GCA effects in two seasons. These testers had favorable genes for tallness. GCA effects for days to 50% flowering showed that the line BSH-6 had negative (favorable) and highly significant GCA effects in two seasons. Also, the tester line ICSR- MR1 had negative (favorable) and significant GCA effects in two seasons. These lines were the best for earliness. For panicle length, the lines BSH-1 and BSH-6 had desirable GCA effects in 2020 season while, the tester line ICSR- MR1 had positive and highly significant GCA effects in two seasons. These lines may have favorable genes for panicle length and could be considered as good combiners for panicle length elongation. Regarding panicle width, the lines BSH-11and the tester line ICSR-89016 had positive and highly significant GCA effects. These lines may have favorable gene action for increasing panicle width and could be considered as good combiners for this trait.

Table 6. Estimates of general combining ability effects for all studied traits in 2019 and 2010 seasons.

Genotypes		Plant height		Days to 50% flowering		Panicle length	
		2019	2020	2019	2020	2019	2020
Line	BSH-1	-0.073	2.03	1.867**	2.633**	-0.060	0.648*
	BSH- 3	4.247**	2.797	-0.80	-0.567	-0.333	-0.711*
	BSH-6	-1.74	-2.117	-1.40**	-2.167**	0.640	0.821**
	BSH-11	-2.433*	-2.71	0.333	0.100	-0.247	-0.759*
Tester	ICSR-89016	1.07	-3.41*	0.983	0.383	0.5733	-0.244
	ICSR-89031	-2.0*	-0.043	2.233**	2.383**	-0.460	-1.260**
	ICSR-890012	7.087**	5.465**	1.15*	1.217*	0.090	-0.544
	ICSR- MR12	5.72**	9.157**	0.733	0.800	-1.51**	-0.219
	ICSR- MR1	-11.78**	-11.17	-5.1**	-4.783**	1.307*	2.266**
Genotypes		Panicle width		1000-grain weight		Grain yield per plant	
		2019	2020	2019	2020	2019	2020
Line	BSH-1	-0377**	-0.267**	0.375	0.446	1.862**	1.968**
	BSH- 3	-0.063	-0.120	-0.718	-1.027	-1.312	-1.272*
	BSH-6	0.143	0.033	-0.0317	-0.226	-0.952	-0.685
	BSH-11	0.297**	0.353**	0.375	0.806	0.402	-0.012
Tester	ICSR-89016	0.317**	0.280**	0.728	-0.1653	8.482**	8.89**
	ICSR-89031	0.0333	0.280**	-1.455	-0.590	-0.860	-1.243
	ICSR-890012	-0.217*	-0.187*	0.253	-0.247	-2.577**	-2.785**
	ICSR- MR12	-0.225*	-0.387**	-1.213	-0.907	-5.827**	-5.61**
	ICSR-MR1	0.092	0.013	1.687	1.910**	0.782	0.748

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

For 1000-grain weight the tester line ICSR- MR1 had positive and highly significant GCA effects in 2020 season. This line had favor gene for heavier 1000-grain weight. For grain yield per plant, the line BSH-1 had positive and highly significant GCA effects in two seasons. The tester line ICSR-89016 had positive and highly significant GCA effects for grain yield. These lines would be considered as the best combiners for grain yield / plant.

Specific combining ability (SCA) effects

Specific combining ability (SCA) was calculated for the two seasons Table (7). Among the twenty crosses, some of them showed significant or highly significant and positive SCA effects for plant height, (the crosses No. 3, 4, 5, 10, 12, 15 and 17 in 2019 and the crosses No. 3, 5, 14 and 17 in 2020). For days to 50% flowering, the crosses No. 1, 15 and 17 had negative and significant or highly significant SCA effects in the two seasons, indicating that these crosses could be considered the best for earliness. In general, crosses which had negative significant SCA effects for days to 50% flowering were early in flowering. These results were in agreement with those obtained by Mahmoud (2002), Amir (2004) and Mahmoud *et al* (2013) who 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 7. Estimates of specific combining ability effects for 20 crosses for all studied traits in 2019, 2020 seasons.

No.	Genotypes	Plant height (cm)		Days to 50% flowering		Panicle height (cm)	
		2019	2020	2019	2020	2019	2020
1	ICSR-89016 X Ash-1	-2.51	-7.296*	-4.783**	-4.05**	-1.607	-1.390*
2	ICSR-89016 X Ash-3	-6.497**	-7.063*	1.967	1.617	3.127**	3.294**
3	ICSR-89016 X Ash-6	13.82**	14.02**	0.3833	-0.55	-2.29*	-2.589**
4	ICSR-89016 X Ash-11	4.817*	0.343	-0.533	-0.80	0.043	0.252
5	ICSR-89031 X Ash-1	8.857**	12.00**	2.967**	3.783**	0.727	0.434
6	ICSR-89031 X Ash-3	1.937	4.237	1.217	-1.183	1.500	2.236**
7	ICSR-89031 X Ash-6	-4.477	-10.68	0.6333	0.817	-0.833	-0.981
8	ICSR-89031 X Ash-11	-6.317*	-5.556	-0.617	0.983	0.217	0.269
9	ICSR-890012 X Ash-1	-9.527**	-4.838	-0.533	0.733	-1.850	-1.656*
10	ICSR-890012 X Ash-3	4.82*	0.062	-0.700	-1.350	0.967	0.132
11	ICSR-890012 X Ash-6	-4.127	0.975	3.15**	2.75**	0.293	0.3037
12	ICSR-890012 X Ash-11	8.833**	3.802	0.900	0.750	-1.307	-0.880
13	MR12 X Ash-1	-7.827**	-11.10**	1.317	-0.083	1.377	1.404*
14	MR12 X Ash-3	2.853	7.27*	1.067	2.00*	0.243	-1.121
15	MR12 X Ash-6	4.773*	5.95	-6.433**	-5.417**	-0.607	0.294
16	MR12 X Ash-11	0.200	-2.123	0.417	2.483*	-0.187	-1.150
17	MR1 X Ash-1	11.01**	11.23**	-3.50*	-3.183**	-0.987	-1.433*
18	MR1X Ash-3	-3.113	-4.505	-1.083	-0.350	0.697	0.917
19	MR1 X Ash-6	-9.993	-10.26	0.00	-1.933*	1.563	2.525**
20	MR1X Ash-11	2.100	3.535	4.167**	2.983**	-1.087	-0.860

Table 7. Cont.

No.	Genotypes	Panicle Width (cm)		1000-grain weight (g)		Grain yield per plant (g)	
		2019	2020	2019	2020	2019	2020
1	ICSR-89016 X Ash-1	-0390	-0.667**	-4.875*	-5.221**	-1.928	-2.210
2	ICSR-89016 X Ash-3	0.0267	-0.0333	-0.325	1.004	-1.353	-0.810
3	ICSR-89016 X Ash-6	0.81**	0.967**	-1.233	-1.440	0.263	-0.268
4	ICSR-89016 X Ash-11	-0.682**	-0.533**	3.400	1.754	-1.22	-0.310
5	ICSR-89031 X Ash-1	0.235	0.267	3.033	3.904**	4.238**	3.598*
6	ICSR-89031 X Ash-3	-0.170	0.287	5.185*	3.252**	1.245	2.963*
7	ICSR-89031 X Ash-6	0.647**	0.653**	-0.298	-1.490	0.220	0.330
8	ICSR-89031 X Ash-11	-0.337	-0.613**	1.260	1.067	3.737*	3.172*
9	ICSR-890012 X Ash-1	-0.295	-0.447*	-1.473	-0.373	-3.313*	-4.27**
10	ICSR-890012 X Ash-3	0.155	0.120	-4.673	-2.456*	-1.888	-2.195
11	ICSR-890012 X Ash-6	-0.243	-0.60**	0.998	0.251	-0.348	-1.557
12	ICSR-890012 X Ash-11	-0.060	-0.20	0.715	1.476	1.993	1.210
13	MR12 X Ash-1	0.290	0.80**	-0.560	0.739	-0.990	-1.815
14	MR12 X Ash-3	0.298	0.20	-1.093	-0.641	1.260	1.777
15	MR12 X Ash-6	-0.285	-0.20	-0.060	-1.824	-1.915	0.385
16	MR12 X Ash-11	0.803**	0.98**	-1.308	1.719	1.032	0.803
17	MR1 X Ash-1	-0.613**	-0.42*	-0.0917	-0.990	-0.860	-0.730
18	MR1X Ash-3	-0.763**	-1.153**	0.533	-0.366	-3.01*	-1.088
19	MR1 X Ash-6	0.678**	0.78**	-0.833	-0.740	3.273*	2.803
20	MR1X Ash-11	-0.105	-0.187	1.70	0.377	-0.435	-1.788

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

For panicle length, the cross No. 2 had positive and highly significant SCA effects in two seasons and the crosses No.6, 13 and 19 had positive and significant or highly significant SCA effects in 2020. These crosses were considered as best combinations for panicle length.

For panicle width, the crosses No. 3, 7, 16 and 19 had positive and highly significant SCA effects in two seasons. These crosses were considered as best combinations for panicle width. For 1000-grain weight, cross No.6 had positive and significant or highly significant SCA effects in two seasons. The crosses No. 5 and 8 had positive and significant or highly significant in two seasons for grain yield/plant, but the cross No. 6 had positive and significant SCA effects in 2020 only. These results were in agreement with those obtained by Mahmoud (2002), Amir (2004), Mahmoud et al (2013), Tag El-Din (2015) and Hussien (2015**)** who found that crosses had negative and significant specific combining ability effects for early flowering. Moreover, general and specific combining ability effects were effective in predicting hybrid performance in all traits. The magnitude of SCA effects of the crosses along with the mean performances indicated that the highest SCA effects with highest mean grain yield per plant was recorded in the cross No 5. Also, cross No 8, showed significant and positive SCA effects for grain yield/plant with desirable mean grain yield/plant. The results of the current studies are in conformity with the findings of Amsalu and Bapat (1990), Rafiq *et al* (2002) and Kaul *et al* (2003).

Heterosis

Estimates of combined heterosis across the two seasons for, plant height, days to 50% flowering, panicle length, panicle width, 1000- grain weight and grain yield per plant for twenty crosses as a percentage of the better parent in the two seasons are presented in Table (8). All crosses had positive and highly significant heterosis for plant height in the two seasons. For days to 50% flowering, most crosses in two seasons had negative and highly significant heterosis (earliness). For panicle length in the two seasons, ten crosses from twenty had positive and highly significant heterosis and may be considered best combination for such trait.

The crosses No. 3, 6, 16 and 19 were positive and highly significant heterosis for panicle width in the two seasons and may be considered the best combinations for such trait. For 1000-grain weight, two crosses out of twenty crosses No 4 and 5 had positive and highly significant heterosis in the two seasons and may be considered as the best combinations for 1000-grain weight. For grain yield/plant, crosses No. 1, 5, 6, 11 and 16 in two seasons showed positive and highly significant. Thus, these crosses could be considered as the best combinations for grain yield/plant. These results are in harmony with those obtained by El-Bakry *et al* (2000), Mahmoud (2002), Amir (2004), Mahmoud (2007) and Mahmoud *et al* (2013).

Table 8. Heterosis of twenty crosses for six traits as a percentage relative to the better parent in 2019, 2020 seasons.

No.	Genotypes	Plant height (cm)		Days to 50% flowering		Panicle length (cm)	
		2019	2020	2019	2020	2019	2020
1	ICSR-89016 X Ash-1	42.36**	36.54**	-2.01**	0.410	-4.23*	-14.50**
2	ICSR-89016 X Ash-3	42.61**	37.28**	2.68**	3.05**	23.40**	14.08**
3	ICSR-89016 X Ash-6	53.38**	49.26**	-2.99**	-1.14*	0.15	-3.91**
4	ICSR-89016 X Ash-11	38.85**	38.69**	-0.78	-2.27**	9.73**	10.38**
5	ICSR-89031 X Ash-1	21.51**	23.14**	-4.23**	-2.67**	17.83**	22.41**
6	ICSR-89031 X Ash-3	19.91**	18.98**	1.60*	-2.38**	7.38**	-6.00**
7	ICSR-89031 X Ash-6	12.28**	7.18**	-1.92**	-1.53**	4.10	-10.20**
8	ICSR-89031 X Ash-11	10.72**	9.88**	-7.09**	-3.04**	10.23**	8.92**
9	ICSR-890012 X Ash-1	11.26**	18.06**	-3.88**	-4.17**	-0.640	0.00
10	ICSR-890012 X Ash-3	22.29**	21.48**	-11.54**	-12.21**	17.68**	19.41**
11	ICSR-890012 X Ash-6	13.47**	19.07**	-1.15	-2.32**	6.42**	-7.50**
12	ICSR-890012 X Ash-11	20.72**	20.41**	-2.30**	-3.44**	0.430	-3.16*
13	MR12 X Ash-1	13.25**	15.10**	-5.60**	-6.08**	14.35**	11.05**
14	MR12 X Ash-3	22.25**	26.51**	-3.83**	-4.55**	2.580	1.45
15	MR12 X Ash-6	19.81**	22.79**	-19.16**	-18.70**	11.05**	18.46**
16	MR12 X Ash-11	16.65**	17.62**	-1.16	1.57**	0.820	-18.87**
17	MR1 X Ash-1	25.83**	31.47**	-5.36**	-5.34**	0.440	-12.36**
18	MR1X Ash-3	19.34**	21.38**	-6.34**	-3.80**	10.29**	3.69*
19	MR1 X Ash-6	10.82**	14.20**	-1.94**	-6.44**	7.06**	12.26**
20	MR1X Ash-11	18.37**	23.09**	-4.62**	-6.49**	7.79**	8.27**

Table 8. Cont.

No.	Genotypes	Panicle Width (cm)		1000-grain weight (g)		Grain yield per plant (g)	
		2019	2020	2019	2020	2019	2020
1	ICSR-89016 X Ash-1	-3.70*	-8.29**	-30.61**	-18.06**	23.82**	22.04**
2	ICSR-89016 X Ash-3	-15.84**	-12.89**	-11.53**	0.00	3.81*	1.26
3	ICSR-89016 X Ash-6	10.38**	13.98**	3.840	-3.74	3.58*	0.15
4	ICSR-89016 X Ash-11	-18.65**	-21.46**	16.42**	6.06**	-11.28**	-11.1**
5	ICSR-89031 X Ash-1	-5.83**	3.14*	21.97**	12.00**	12.85**	14.47**
6	ICSR-89031 X Ash-3	4.76**	8.81**	-3.520	4.190	22.52**	28.12**
7	ICSR-89031 X Ash-6	-3.17*	-1.78	-15.25**	-14.92**	-0.90	-3.41*
8	ICSR-89031 X Ash-11	0.00	-9.63**	-2.13	-4.190	3.16*	1.36
9	ICSR-890012 X Ash-1	-7.77**	-18.05**	-17.06**	-11.96**	-22.78**	-26.46**
10	ICSR-890012 X Ash-3	-2.43	3.14*	-18.13**	-15.11**	-7.07**	-5.44**
11	ICSR-890012 X Ash-6	-3.35*	-8.29**	-14.10**	-6.48**	18.48**	17.10**
12	ICSR-890012 X Ash-11	-9.95**	-11.11**	-9.31*	-3.60	2.83	-0.15
13	MR12 X Ash-1	-3.35*	5.37**	-4.69	-5.02*	-7.68**	-9.63**
14	MR12 X Ash-3	-3.35*	-6.34**	-11.91**	-12.36**	-12.01**	-12.30**
15	MR12 X Ash-6	-7.18**	-6.34**	2.29	-10.15**	-6.35**	1.54
16	MR12 X Ash-11	17.82**	18.36**	-19.84**	3.02	15.79**	15.21**
17	MR1 X Ash-1	-15.38**	-9.78**	-10.71**	-8.32**	-7.55**	-9.10**
18	MR1X Ash-3	-13.37**	-19.32**	0.720	-4.83*	-15.58**	-13.06**
19	MR1 X Ash-6	7.92**	5.80**	-9.51*	-8.56**	-9.28**	-10.83**
20	MR1X Ash-11	-0.970	-2.42	10.11*	1.040	-3.25*	-7.15**

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

In general, most crosses were earlier, taller plants, 1000-grain weight and grain yield per plant than the mid and the better parents, which reflecting the importance role of non-additive genetic variance in the inheritance of these traits. Heterosis was reported by several researchers for the economic traits in sorghum, Justin *et al* (2015), Erin *et al* (2016), Chikuta *et al* (2017) and El-Sherben *et al* (2019).

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القدرة الأئتلافية وقوة الهجين في محصول الذرة الرفيعة للحبوب باستخدام تصميم السلالة في الكشاف

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تم تقييم عدد ٢٠ هجين من الذرة الرفيعة للحبوب و أبائهم (٤ سلالات عقيمة ذكريا و ٥ سلالات معيدة للخصوبة) والهجين التجاري شندويل- ٣٠٥ للمقارنة وذلك لصفة محصول الحبوب وخمس صفات أخري في محطة عرب العوامر بأسيوط وذلك خلال موسمي ٢٠١٩ و ٢٠٢٠. وقد أوضحت النتائج اختلافات عالية المعنوية لكل الصفات محل الدراسة لجميع التراكيب الوراثية بأجزائها ما عدا الأباء لصفة المحصول والهجن مقابل الاباء لكل من صفة عرض الكوز ووزن الألف حبة وصفة المحصول . علاوة علي ذلك كانت بعض الهجن متفوقة عن أحسن الاباء وذلك لصفتي التبكير في التزهير و المحصول .أظهرت بعض الأباء قدرة ائتلافية عامةعالية مما يدل علي امكانية استخدام هذه الأباء في برنامج التربية لتحسين محصول الذرة الرفيعة ومنهم BSH-1 وICSR-8901z لصفة المحصول . أفضل الهجن بالنسبة للقدرة الأئتلافية الخاصة كان (ICSR-89031 x Ash-1 and ICSR-89031 x Ash-11). أثنين من الهجن الأقل محصولا من الهجين التجاري شندويل ٣٠٥ (ICSR-89016 X Ash-3 and ICSR-89016 X Ash-11). والهجن التي أوضحت قوة الهجين بتفوقها علي أحسن الأباء كانت (ICSR-89016 x Ash-1 and ICSR-89031x Ash-3) ويجب تقييم هذه الهجن في تجارب موسعة لكي يتم إنتاجها على نطاق تجاري.

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