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Study of heterosis in single-cross hybrids of sunflower

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ABSTRACT

This study was conducted to estimate the genetic variability and heterosis of 40 F_1 hybrids of sunflower for seed yield and its components over two seasons (summer and winter) in 2007 at Sennar Research Station Farm in central Sudan. The plant material consisted of 14 sunflower parents (4 females and 10 males) and their 40 F_1-hybrids. The experiment was arranged in a randomized complete block design with three replicates. The traits measured were days to 50% flowering, plant height, head diameter, number of seeds per head, one thousand seed weight and seed yield. Hybrids showed high genetic variability for all traits studied than their parents which suggested some degree of hybrid vigor. The direction and magnitude of heterosis varied from cross to cross. Over two seasons, the average mid-parent heterosis in preferred direction and magnitude depicted that the hybrid SA2 x SR41 followed by SA3 x SR41 for days to flowering, SA1 x SR14 for plant height, SA2 x SR14 for head diameter, SA2 x SR13 followed by SA3 x SR13 for number of seeds per head, and SA3 x SR7 for one thousand seed weight. With regard to seed yield, the best hybrids with positive average heterosis were SA3 x SR41 (53.42%), SA4 x SR45 (52.75%), SA4 x SR1 (52.25%) and SA3 x SR10 (40.63%) which also combined with high seed yield of 1581 kg/ha, 1479 kg/ha, 1474 kg/ha, and 1457 kg/ha, respectively. These hybrids (involving the female line SA3 or SA4 and the male lines (SR10, SR13, SR41 and SR45) can be used in our breeding program in an attempt to develop local sunflower hybrid (s) with high seed yield and other important agronomic traits and for testing their yield potential and stability across locations and seasons.

INTRODUCTION

In the Sudan, sunflower (*Helianthus annuus* L.) is a potential oilseed crop. The crop is grown both as a summer and winter crop under irrigated system and as a summer crop under rainfed system. Sunflower as a non-traditional crop provides an excellent alternative to cover large areas in the production of oil crops beside the major oil crops, sesame (*Sesamum indicum* L.), groundnut (*Arachis hypogaea* L.) and cotton seed (*Gosspium* sp. L.). Moreover, sunflower is a highly cross pollinated crop, which makes it useful for development of both hybrids and open pollinated varieties.

The discovery of cytoplasmic male sterility by Leclercq (1966) and fertility restoration (Kinman, 1970) has been the land mark events in sunflower hybrid production. These opened new vistas in sunflower breeding, which shifted attention from population breeding to heterosis breeding. The favorable character of hybrids like uniform growth and maturity, high self-fertility, suitability to high input management and production stability shifted the focus towards heterosis breeding. Moreover, utilization of heterosis has allowed sunflower to become the major oilseed in many countries of Eastern and Western Europe, Russia and South America, and as an important crop in the USA, Australia, South Africa, China, India and Turkey (Wani *et al.*, 2010).

In the Sudan, the value of hybrids and the importance of heterosis breeding in this crop were not recognized quite enough. In the recent years, sunflower has been evolved as a program, in the Agricultural Research Corporation (ARC) of the Sudan, to network the crop improvement in many aspects. Development of sunflower hybrids involves crossing of a cytoplasmic male sterile line as the female parent (A-line) to a fertility restorer line as the male parent (R-line). Therefore, modern sunflower breeding is particularly associated with the exploration of heterosis in the production of sunflower hybrids and the magnitude of heterosis is determined by the combining ability of the parents. Developing inbred lines that have high general combining ability (GCA) and specific combining ability (SCA) for important yield components is a main objective of sunflower breeding. The second objective is using and crossing these inbred lines to obtain superior hybrids with stable and high yield.

Sunflower hybrids yield about 50% more than the best open pollinated varieties (Miller, 1987). The most useful and widely accepted definition of heterosis is the superiority of an F_1 hybrid over the mean performance of its superior inbred parent (Welsh, 1981; Fehr, 1987). The exploitation of hybrid vigor or heterosis (which mainly depends upon its direction and magnitude) is one of the methods of plant breeding for development of hybrids with high yielding potential. Therefore, development of hybrid sunflower for Sudan conditions is an important step towards narrowing down the gap between demand and supply of seeds. Hence, boosting sunflower production and productivity and also, producing their seeds locally would reduce the cost of seed in addition to seed viability and ensure the seed supply at the optimum time.

The present study of line x tester analysis, which involves four cytoplasmic male sterile lines and ten fertility restorers, was undertaken to determine the degree of mid-parent heterosis in 40 F_1- crosses or hybrids of sunflower for seed yield and its components over two seasons in an attempt to develop local sunflower hybrid(s) with high seed yield and other important agronomic traits for irrigated conditions in the Sudan..

MATERIALS AND METHODS

Four cytoplasmic male sterile lines, SA1, SA2, SA3 and SA4 and ten fertility restorer lines, (SR1, SR2, SR3, SR6, SR7, SR10, SR 13, SR14, SR41 and SR 45) improved by Sunflower Breeding Program of ARC, Sudan, were crossed in all possible combinations in 2005 and 2006. These 40 F_1 hybrids (line x tester) along with 14 parents (including 4 lines and 10 testers) were tested at Sennar Research Station Experimental Farm for two seasons, summer and winter of 2007, respectively, on the clay 34̀ E and 421 masl). The soil is the vertisol with ̊ 33́ N, 33̊plains of central Sudan (13 60% clay content, pH of 7.8-8.5, about 0.4-0.5% organic carbon and 0.05% total nitrogen. The region has a semi-arid climate with summer rainfall ranging from 300 to 600 mm.

The materials were tested in a randomized complete block design with three replicates on the 15th of July for summer season and on the 13th of November for winter season. Three seeds per hill were sown to ensure uniform stand which was later thinned to one plant per hill. The plot size consisted of four rows per plot, each of 5 m in length with row to row and

plant to plant distances of 0.80 m and 0.30 m, respectively. Nitrogen was applied at 80 kg urea per ha. Irrigation was applied at intervals of 12-14 days
depending on weather conditions. Hand weeding was carried out to keep the crop weed free. The harvest was done during the first and second weeks of December and March for summer and winter seasons, respectively.

Data were recorded on ten randomly selected plants from the middle inner two rows in each plot from each replicate for the following traits; days to 50% flowering, plant height (cm), head diameter (cm), number of seeds per head, 1000-seed weight (g), and seed yield (kg/ha).

Data were analyzed using the IRRISTAT statistical analysis package for windows (2006). The analysis of variance was carried out for each season for the six traits and then combined. Means were separated using Duncan's Multiple Range Test (DMRT). The amount of average heterosis over mid parent (MP) was computed for all traits measured, using the following formula:

Heterosis over mid parent (MP) = $[(F_1 – MP) \times 100]/MP$

F_1 = the mean of hybrid variety, Where:

MP = mean of two parents involved in the crosses.

RESULTS AND DISCUSSION

The performance of the four cytoplasmic male sterile lines (A-line) and ten fertility restorer lines (R-line) tested for five traits in sunflower was high over the two seasons. The 14 parents (lines and testers) and their 40 F_1- hybrids (crosses) used in present study provided a wide range of expression for six traits under both seasons and their combining as evident from their significant variation that indicated the diversity in the material tested. The results obtained from mean separation and ranking of the 14 parents and their 40 F_1-hybrids for each character are discussed in the following paragraphs.

Table 1. Mean performance of 14 sunflower parents for the measured traits over two seasons of 2007.

Parent	DF	PH	HD	NSH	SW	SY
SR1	64	121	12	1158	29	958
SR2	67	123	11	1123	28	893
SR3	64	108	13	1205	30	1018
SR6	67	109	11	1067	38	1095
SR7	64	112	13	1170	35	849
SR10	69	106	13	1113	43	1002
SR13	65	111	12	1160	36	1086
SR14	68	106	11	1120	34	930
SR41	65	101	13	1180	28	1111
SR45	67	110	12	1087	47	1035
SA1	75	107	12	1189	42	1054
SA2	80	112	12	1215	40	1042
SA3	62	115	17	1191	46	1087
SA4	65	105	15	1235	43	1057
Mean	67	110	13	1159	37	1016
SE $\pm$	0.65	1.82	0.35	16.05	2.23	27.29
CV (%)	1.7	2.9	4.8	2.4	10.4	4.7

Where, DF = days to 50% flowering, PH = plant height (cm), HD = head diameter (cm), NSH = number of seeds per head, SW = 1000-seed weight (g) and SY = seed yield (kg/ha).

Days to 50% flowering

The number of days required for 50% of the plants in a genotype to flower is a definite indication of the duration of genotype. Days to maturity is often closely correlated with days to flowering, although genetic differences in the duration required from flowering to maturity exists. Thus, highly significant differences were detected among the parents and their crosses for days to 50% flowering in combined analysis over two seasons with general mean being 67 days. The parents mean ranged between 62 to 80 days for SA3 and SA2, respectively (Table 1). The hybrid means ranged between 62 days for SA3x SR13 to 80 days for SA2 x SR1 (Table 2). The breeding for earliness is of a vital importance in hybrids with good agronomic traits to suit semi-arid tropics such as the Sudan. Also, earliness was a desirable trait, especially under rainfed conditions that represented the bulk areas of sunflower production in the country. Hence, there were 30 hybrids having mean of days to flowering lower than their crosses general mean and the earliest hybrids were SA4 x SR45, SA3 x SR41, SA4 x SR2 and SA4 x SR41 (Table 2).

Plant height

Development of dwarf or medium plant height is the recent trend in breeding work to avoid lodging of sunflower hybrids. The mean plant height for the studied parents and their crosses showed highly significant differences with the general mean being 110 cm. The parent's mean ranged between 101 cm (SR41) to 123cm (SR2) (Table 1). The hybrids (crosses) mean varied from 105 cm for SA1 x SR3 to 164 cm for SA2 x SR1. The tallest hybrids across seasons were SA2 x SR1, SA2 x SR6, SA3 x SR45, SA2 x SR10 and SA2 x SR14. While crosses SA1 x SR3, SA4 x SR3, SA1 x SR2 and SA4 x SR2 were the shorter hybrids (Table 2). Therefore, the moderate plant height and strong stem with large stem diameter are useful traits when dealing with lodging.

Moreover, in the current study, most of the hybrids were slightly taller than their parents which indicated some degree of hybrid vigour.

Head diameter

Head diameter is an important factor in determining seed yield of sunflower. The parents, as expected, had smaller head size than hybrids in both seasons. Over two seasons, the mean head diameter for parents varied from 11 cm (SR2) to 17 cm (SA3) with a general mean being 13 cm (Table 1), whereas for crosses or hybrids, means varied from 13 cm (SA1x SR2) to 19 cm (SA4 x SR45) with a general mean being 16 cm (Table 3). However, among the hybrids SA4 x SR45, SA3 x SR2, SA4 x SR10, SA3 x SR45 and SA4 x SR1 performed better than other crosses for this trait.

Number of seeds per head

Number of seeds per head is an important yield component in sunflower. The variation among the studied parents and their crosses having a general mean being 1159 and 1179 seeds, respectively. The parents ranged between 1067 for SR6 to 1235 for SA4 and the crosses varied from 1087 for SA2 x SR6 to 1301 for SA4 x SR10 (Tables 1 and 3). Among the parents, SA4, SA2, SR3, SA3, SA1 and SR41 had the maximum number of seeds per head (Table 1). Whereas, among the crosses, SA4 x SR10, SA3 x SR13, SA1 x SR41, SA2 x SR10 and SA3 x SR13 had the highest number of seeds per head (Table 3). On the other hand, the parents SR6 and their crosses SA2 x SR6 had the minimum number of seeds per head. The results indicated that number of seeds per head was important for increased seed yield and that

fertility of females (lines) depended upon good combining males (testers) with stable fertility restorers.

1000-seed weight:

Generally, 1000-seed weight of most oilseed sunflower cultivars grown currently ranged from 40g to 100g. There was a substantial variation among the studied parents and their crosses in seed weight over two seasons. Thus, the mean 1000-seed weight for parents across the two seasons varied from 28g (SR41) to 47g (SR45) with a general mean of 37g, whereas for crosses, the means varied from 36g (SA2 x SR1) to 61 g (SA3 x SR41) (Tables 1 and 4). Among the hybrids, SA3 x SR41, SA4 x SR45, SA3 x SR13, SA3 x SR10 and SA4 x SR10 performed better than other crosses for this trait.

Seed yield

It is the most important character in which the breeder is interested. The ultimate aim of any breeding program is to increase the yield. In the present study, mean seed yield for parents ranged from 849 kg/ha for SR7 to 1111 kg/ha for SR41 with the general mean being 1016 kg/ha. The top parents for
seed yield were SR41, SR6, SA3 and SR13 (Table 1). However, the hybrids (crosses) varied from 1081 kg/ha (SA2 x SR6) to 1581 kg/ha (SA3 x SR41) with a general mean of 1245 kg/ha. The top ranking and the best yielder hybrids across two seasons were SA3 x SR41, SA3 x SR45, SA3 x SR10, SA3 x SR13 and SA3 x SR41 (Table 4). SA3 was involved in four superior hybrids; indicating its value in cross-combinations to produce commercial hybrids. It is noteworthy that most of the cross-combinations (hybrids) were superior in seed yield compared to parents confirming the fact that hybrids produce higher seed yield than lines or open pollinated varieties in sunflower crop. These results agreed with those of Miller (1987), who pointed to the fact that

sunflower hybrids yield about 50% more than the best open pollinated varieties. Also, agreed with the fact that one of the most effective ways of increasing the yield of sunflower per unit area is the use of heterosis through two line hybrids (Skoric, 1992). Thus, hybrid vigor has been the main driving force for acceptance of this oilseed crop in the Sudan and other countries around the world.

Heterosis

Heterosis (hybrid vigour) plays a major role in improving crop productivity and quality. Accordingly, farmers prefer hybrids due to their high yield performance, quality and uniformity. In the present study, superiority of the hybrids was estimated over mid-parent for six traits combined over two seasons. Hence, the ranges of heterosis over mid-parent with per se performance in respect of each of the character studied are presented in Tables 2, 3 and 4, respectively. The observed effect of heterosis on the different traits is described as follows.

Days to 50% flowering

Early flowering provides sufficient time for seed formation process and good seed filling period. Hence, for early flowering, negative heterosis is desirable. The average mid parent heterosis over two seasons ranged from -1.01% to – 14.67% in the desirable direction and from 0.25% to 19.05% in the opposite direction (Table 2). Out of 40 F_1 hybrids, there were 23 hybrids with negative heterosis. The highest and negative mid parent heterosis was obtained by SA2 x SR41 (-14.67%), SA3 x SR41 (-14.35%), SA4 x SR41 (-14.35%), SA2 x SR10 (-11.94%), and SA1 x SR41 (-7.62%) and with three different female parents having the SR41 as the common parent and best combiner for early flowering. These hybrids (when involving the male line SR41 in their crosses) appear to be early in terms of maturity that would be suitable for water utilization efficiency and as a technique to escape the drought.

Table 2. Performance of 40 crosses and their average mid parent heterosis (MHP%) for days to 50% flowering in sunflower over two seasons of 2007.

Female	SA1		SA2		SA3		SA4	
Male	Mean	MPH%	Mean	MPH%	Mean	MPH%	Mean	MPH%
SR1	63	-2.56	80	19.50	65	0.77	63	-3.34
SR2	65	-1.01	66	-2.45	63	-4.28	62	-5.79
SR3	66	-1.25	66	-3.16	63	-5.50	64	-3.50
SR6	69	7.49	68	2.27	65	2.07	63	-2.59
SR7	67	3.08	74	12.00	66	1.80	68	4.88
SR10	66	-5.04	63	-11.94	64	-7.21	64	-7.21
SR13	68	3.80	67	0.25	62	-5.58	68	4.06
SR14	66	0.25	64	-5.68	67	2.03	64	-2.03
SR41	66	-7.62	63	-14.67	62	-14.35	62	-14.35
SR45	69	9.24	66	2.83	67	6.35	61	-3.18
C.V.%	1.76							
SE ±	0.65							

Plant height

Short plants of sunflower are desirable for resistance to lodging and easy combine harvesting, therefore, for plant height, heterosis in the negative direction is desirable. The results of heterosis in Table 3 revealed that in some crosses considerable height reduction occurred in the hybrids, while in other crosses little reduction was observed. Across seasons, only four hybrids demonstrated negative heterosis for plant height (Table 3).These were SA1 x SR3 (-6.90%), SA1 x SR2 (-5.14%), SA4 x SR3 (-1.83%), and SA1 x SR13 (-1.74%). These results suggest the complex genetic control of plant height as well as genotype x environment interaction. Similar results were reported by Yilmaz and Emiroglu (1994), Goksoy *et al.* (1999) and Hladni *et al.* (2005).

Table 3. Performance of 40 crosses and their average mid parent heterosis (MHP%) for plant height in sunflower over two seasons of 2007.

Female	SA1		SA2		SA3		SA4	
Male	Mean	MPH%	Mean	MPH%	Mean	MPH%	Mean	MPH%
SR1	132	13.36	164	39.77	143	30.79	138	23.40
SR2	108	-5.14	132	15.24	134	25.12	110	0.92
SR3	105	-6.90	133	15.82	126	17.63	107	-1.83
SR6	124	9.87	161	41.19	124	16.43	116	7.03
SR7	112	0.90	139	24.04	141	35.14	112	5.15
SR10	124	8.48	145	25.43	143	33.23	131	19.88
SR13	124	7.34	141	20.91	114	4.12	113	0.90
SR14	113	-1.74	145	24.93	117	8.31	122	10.38
SR41	119	2.15	137	16.27	132	20.18	112	0.00
SR45	120	1.83	136	14.09	151	35.43	116	1.75
C.V.%	7.3							
SE ±	5.41							

Head diameter

Large head diameter or size often bears high sterile zone and maximum number of empty seeds. Therefore, medium head size is required for seed filling. For head diameter, positive heterosis values are desirable because it is an effective yield related parameter. In this experiment, the estimates of mid parent heterosis over two seasons varied from 2.54% to 56.68% in a desirable direction. All the cross-combinations (hybrids) showed positive heterosis of which five crosses scored above 41% of mid parents heterosis. These were SA2 x SR14 (56.68%), SA3 x SR2 (49.93%), SA2 x SR41 (47.95%), SA4 x SR10 (45.36%) and SA4 x SR1 (41.57) (Table 4). These results are in agreement with those reported by Goksoy *et al.* (1999) and Hladni *et al.* (2005). Hence, all of hybrids exhibited positive mid-parent heterosis, suggesting predominance of non-additive gene action in determining the trait.

Table 4. Performance of 40 crosses and their average mid parent heterosis (MHP%) for head diameter in sunflower over two seasons of 2007.

Female	SA1		SA2		SA3		SA4	
Male	Mean	MPH%	Mean	MPH%	Mean	MPH%	Mean	MPH%
SR1	14	12.62	16	38.13	15	17.76	18	41.57
SR2	13	10.59	15	36.98	19	49.93	17	34.88

SR3	14	10.27	15	25.17	15	15.54	15	18.22
SR6	14	3.22	16	23.46	15	2.54	17	20.23
SR7	16	26.48	14	18.55	17	28.17	16	24.65
SR10	15	21.76	16	37.20	16	23.14	19	45.36
SR13	16	31.00	14	22.86	16	27.89	14	14.78
SR14	14	14.53	18	56.68	15	21.61	16	34.97
SR41	15	20.16	17	47.95	17	33.42	18	38.82
SR45	16	7.00	18	26.90	18	18.67	19	31.45
C.V.%	3.8							
SE ±	0.36							

Number of seeds per head

The number of seeds per head has a direct relationship with seed yield, and the positive values of mid-parent heterosis are desirable. The average of mid-parents heterosis in the combined analysis ranged from 0.84% to 14.65% in the desirable direction and from – 0.47% to –7.68% in the opposite direction. This wide range of mid-parent heterosis for number of seeds per head (-7.68% to 14.65%) indicated that, there are many seeds in the sunflower head (capitulum), but some of them are chaffy and do not contribute to yield. Among the 40 F_1 hybrids, 23 hybrids displayed positive heterosis. The five highest positive mid parents heterosis crosses were SA2 x SR13, SA3 x SR13, SA4 x SR10, SA2 x SR14 and SA2 x SR2 (Table 5). Thus, SA2 could be considered as a best combiner for number of seeds per head. Also, similar results were reported by Yilmaz and Emiroglu (1994), and Limbore *et al.* (1998).

Table 5. Performance of 40 crosses and their average mid parent heterosis (MHP%) for number of seeds per head in sunflower over two seasons of 2007.

Female	SA1		SA2		SA3		SA4	
Male	Mean	MPH%	Mean	MPH%	Mean	MPH%	Mean	MPH%
SR1	1184	1.42	1150	3.28	1097	-7.68	1216	2.41
SR2	1139	0.84	1193	7.39	1253	6.65	1186	0.95
SR3	1135	-2.00	1169	5.93	1140	-1.38	1128	-0.61
SR6	1120	-7.26	1087	-7.53	1140	-6.96	1190	-1.38
SR7	1215	4.73	1104	-4.48	1153	-1.26	1145	-5.36
SR10	1179	-0.69	1263	6.55	1254	3.98	1301	10.29
SR13	1165	4.89	1249	14.65	1283	13.52	1196	1.70
SR14	1198	5.34	1164	9.28	1136	-0.47	1184	4.72
SR41	1274	6.01	1201	2.97	1207	-0.68	1251	4.60
SR45	1124	-5.81	1097	-5.85	1179	-1.72	1186	0.97
C.V.%	4.7							
SE ±	32.05							

One thousand seed weight

Seed weight is one of the most important yield components and, therefore, highly significant and positive heterosis is desirable. In this study, all the hybrids over two seasons were showing positive mid parent heterosis values. However, there were eight hybrids showing positive heterosis above 63% over mid-parent values for 1000-seed weight in their combined analysis. While the percentage of heterosis for this trait ranged from 7.18 to 87.16 in the desirable direction. The highest percentage of heterosis above 71% were given by SA3 x SR7 (87.16%), SA2 x SR7 (79.32%), SA3 x SR41 (74.18%), SA2 x SR14 (73.54%) and SA3 x SR2 (71.81%) for 1000-seed weight (Table 6). The positive heterosis values obtained indicated the possibility of improving this character and consequently seed yield. The data obtained were in accordance with Cruz and Dela (1986) and Khan *et al.* (2004) who observed significant and positive heterosis for 1000-seed weight; Chaudhary and Anand (1984) reported 66.33% and Goksoy *et al.* (1999) reported heterosis values ranging from 12.3 to 93.0% in sunflower.

Table 6. Performance of 40 crosses and their average mid parent heterosis (MHP%) for 1000-seed weight(g) in sunflower over two seasons of 2007.

Female	SA1		SA2		SA3		SA4	
Male	Mean	MPH%	Mean	MPH%	Mean	MPH%	Mean	MPH%
SR1	41	26.20	36	11.81	53	59.80	56	57.76
SR2	41	29.54	51	63.53	55	71.81	45	30.17
SR3	44	22.07	47	30.93	51	41.05	49	26.59
SR6	43	20.15	47	31.18	47	28.06	51	29.42
SR7	40	40.32	51	79.32	55	87.16	43	35.81
SR10	48	36.57	47	33.61	59	65.98	59	54.61
SR13	52	36.31	52	36.14	60	56.06	44	7.18
SR14	40	20.03	57	73.54	51	49.58	55	52.12
SR41	54	56.62	57	65.65	61	74.18	54	44.58
SR45	44	16.02	52	40.60	57	48.76	60	49.03
C.V.%	5.1							
SE ±	1.49							

Seed yield

Yield is a complex trait which is determined by many components and the relative importance of each component is determined by its contribution to final yield. In sunflower breeding, the ultimate objective is to obtain maximum seed yield per unit area. Therefore, heterosis over mid parent values in the positive direction is desirable. In combined analysis, the mid parents heterosis ranged from 6.14 to 53.42% in a favorable direction (Table 7). All of the hybrids had positive heterosis and recorded higher seed yield than the mean of the parents. This result indicates that the mechanism of expression of heterosis was different in various crosses under different environments and suggesting predominance of non-additive gene action in determining seed yield of the hybrid. Maximum increase of 53.42% in seed yield over mid parent was given by SA3 x SR41 followed by SA4 x SR45 (52.73%), SA4 x SR1 (52.25%), and SA3 x SR10 (40.63%). Therefore, there was a wide range of genetic variability and magnitude of mid-parent heterosis for traits including seed yield when involving the female line SA3 or SA4 in their crosses. However, Chaudhary and Anand (1984) reported heterosis for seed yield ranging from 47% to 206%, while Limbore *et al.* (1998) recorded heterosis ranging from -53.03% to 114.79% for seed yield. Similarly Hladni *et al.* (2005) estimated heterosis for seed yield ranging from 98.4% to 274.1%.

Table 7. Performance of 40 crosses and their average mid parent heterosis

(MHP%) for seed yield (kg/ha) in sunflower over two seasons of 2007.

Female	SA1		SA2		SA3		SA4	
Male	Mean	MPH%	Mean	MPH%	Mean	MPH%	Mean	MPH%
SR1	1131	10.63	1103	11.49	1271	20.77	1474	52.25
SR2	1118	18.38	1237	35.73	1355	39.05	1119	25.78
SR3	1100	12.24	1148	21.21	1186	17.42	1224	32.20
SR6	1106	9.73	1081	10.96	1243	19.84	1236	29.63
SR7	1113	11.72	1198	24.31	1354	31.90	1093	16.01
SR10	1274	26.61	1197	22.94	1457	40.63	1311	37.70
SR13	1180	14.07	1251	24.90	1447	35.90	1245	26.99
SR14	1090	6.14	1376	38.45	1141	7.99	1260	29.57
SR41	1235	23.45	1258	30.06	1581	53.42	1324	40.01
SR45	1152	12.63	1254	26.71	1384	31.48	1479	52.75
C.V.%	6.1							
SE ±	43.95							

CONCLUSION

Development of high yielding single-cross hybrids with high vigor is the ultimate objective of sunflower breeding and the success depends largely on the identification of the best parents (females and males) to ensure maximum heterosis for hybrid production. Thus, based on the results obtained in this study, it could be concluded that variability and magnitude of heterosis was present in the evaluated material for seed yield. The direction and magnitude of heterosis varied from cross to cross. This indicates that the mechanism of expression of heterosis was different in the various crosses under different environments. However, heterotic studies depicted that SA2 x SR41 followed by SA3 x SR41 for days to flowering, SA1 x SR14 for plant height, SA2 x SR14 for head diameter, SA2 x SR13 followed by SA3 x SR13 for number of seeds per head, and SA3 x SR7 for 1000-seed weight. However, with regard to seed yield the best desirable cross combinations were SA3 x SR41, SA4 x SR45, SA4 x SR1 and SA3 x SR10, which were coupled with high SCA effects over two seasons.

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دراسة قوة الهجين للهجن المفردة في محصول زهرة الشمس (*Helianthus annuus* L.)

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الخلاصة

أجريت هذه الدراسة بهدف تقدير التباين الوراثي و قوة الهجن للإنتاجية ومكوناتها لأربعين هجين مفرد من محصول زهرة الشمس، نتجت من تهجين أربعة أمهات ذات عقم ذكرى سايتوبلازمى مع عشرة آباء معيدة للخصوبة. أجريت التجربة بمحطة بحوث سنار فى وسط السودان بالقطاع المروي لموسين (صيف وشتاء2007). أستخدم تصميم القطاعات العشوائية الكاملة بثلاثة مكررات. كانت الصفات المدروسة هى عدد الايام حتى 50% إزهار، طول النبات، قطر القرص، عدد البذور بالقرص، وزن الآلف حبة، وانتاج البذور. أظهرت النتائج فروقات معنوية لكل الصفات في الموسمين مع تفوق الهجن وتباينها وراثياً مقارنة بالآباء. وفي التحليل المشترك لحساب قوة الهجين لكل الصفات كنسبة زيادة أو نقصان من متوسط الأبويين، ظهر أنّ الهـجينين SA2 x SR41 وSA3 x SR 41 هما الأفضل للإزهار والنضج المبكر، الهجين SA1 x SR14 لطول النبات، الهـجين SA2 x SR14 لقطر القرص ، الهجينين SA2 x SR13 و SA3 x SR13 لعدد البذور بالقرص، الهجين SA3 x SR7 لوزن الألف بذرة. أما بخصوص إنتاجية البذور أظهرت بعض الهجن نسبة قوة هجين موجبة SA3 x SR41 (53.42%)، SA4 x SR45 (52.73%)، SA4 x SR1 (52.25%) و SA3 x SR10 (40.63%) وإنتاجية بذور تقدر بـ 1581 كيلوجرام للهكتار، 1479 كيلوجرام للهكتار، 1474 كيلوجرام للهكتار و1459 كيلوجرام للهكتار علي التوالي. ويستنتج من هذه الدراسة ان الهجن التي يدخل في تركيبها الأم SA3 أو الأم SA4 مع الآباء SR41 ، SR45، SR13 و SR10 هى هجن متفوقة لإنتاجية البذور والصفات الأخرى ، ويمكن استخدام تلك الأمهات والآباء في تطوير هجن محلية مفردة من محصول الزهرة واختبار ثبات إنتاجيتها عبر المواسم والمواقع المختلفة.