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ESTIMATES OF HETEROBELTIOSIS AND COMBINING ABILITY IN GRAIN SORGHUM

M.M. El-Menshawi and M.H. El-Bakry

Grain Sorghum Research Department, Field Crops Research Institute, Agricultural Research Center, Giza

ABSTRACT

Three exotic cytoplasmic male sterile lines (A lines): ICSA14, ICSA88015 and ATX623 and seven restorer lines (R lines); ICSR16, ICSR21, ICSR89022, ICSR89038, ICSR90001; ICSR93001 and Dorado of grain sorghum, were crossed to produce 21 (A x R) F_1's. Parents and hybrids were evaluated in field trials in 2003 at 3 locations. Mean squares due to parents were significant for all studied characters at all locations except panicle width at Assuit. Mean squares due to hybrids were also significant for all characters at all location. Data indicated that the contribution of variation due to interaction males x females was higher for all studied traits than either the contribution of that due to males or females, suggesting that to improve these traits breeder should use the heterosis breeding. Exceptions were for 50 % heading at South Tahrir and Assuit, panicle length at South Tahrir and panicle width at Assuit and Shandaweel, where the contribution of parents was the highest. The cms line (ATX623) and the restorer (ICSR89038) had the highest positive and significant GCA effects for grain yield at South Tahrir and Assuit and ICSA14, ICSR21 at Shandaweel. SCA variance was more important than that of GCA for grain yield and its components. The best SCA effect for grain yield was exhibited in (ATX623 x ICSR93001) and (ICSA14 x ICSR 89038) at South Tahrir; (ATX623 x ICSR93001), (ICSR88015 x ICSR21) at Assuit and (ICSA14 x ICSR90001), (ICSA88015 x ICSR89038) and (ATX623 x ICSR 93001) at Shandaweel.

Heterosis as a percentage of the better parent was manifested for all studied traits. The highest positive and significant heterosis for grain yield was 41.41 % (ICSA14 x ICSR89038) at South Tahrir, 75.59 % (ATX623 x ICSR89038) at Assuit and 34.04 % (ICSA88015 x ICSR89053) at Shandaweel. The hybrid ATX623 x ICSR93001 outyielded other tested hybrids under different environments and thus we recommend further testing of this hybrid in the evaluation trails in order to release it as a commercial hybrid.

Key words: *Grain, Sorghum, Heterobeltiosis, Combining ability*

INTRODUCTION

The major objective of grain sorghum [*Sorghum bicolor* L. Moench] breeders is to derive parental lines that will produce high yielding hybrids while maintaining or improving other agronomic characters. Information on the relative importance of general and specific combining ability is of value

in the development of efficient breeding programs in crop species which are amenable to commercial production of F_1 hybrid seed. Additional basic information is needed on heterosis in sorghum to aid the breeder in developing hybrids. The grain sorghum hybrid program starts with testing various parental lines for their combining ability and heterotic effects in order to identify the best ones in hybrid combinations. Grain yield improvements in the small grained cereals have been achieved largely by increasing harvest index without a significant change in biomass (Hanson, 1970). Sorghum hybrid produce more biomass as compared with their parents (Quinby, 1974). Heterosis in sorghum grain yield results mainly from heterosis expressed in a large number of kernels per panicle, mostly in the lower panicle branches (Blum, 1970). The large panicle in the hybrid is initiated earlier and develops faster than in its parents Perez (1986) found that heterosis for grain yield depended on heterosis for grains/panicle and panicle length. Hybrids were found to flower several days earlier than their parents. El-Menshawi (1996), Mahmoud (1997), Amir (1999), Hovny *et al* (2001) and Mostafa and El-Menshawi (2001) used male sterile lines to produce hybrids. They reported that hybrids were earlier, taller, had higher 1000-grain weight and higher grain yield than their best parents.

Andrews *et al* (1997) found that both grain sorghum and pearl millet F_1 single crosses whether were made by using cytoplasimc male sterility (CMS) or by other ways were much better than their parental lines in grain yield as well as grain quality. They also reported the importance of early generation testing to select for combining ability. Combining ability in grain sorghum was studied by several workers using line x tester analysis (Reddy and Joshi, 1993, El-Menshawi, 1996, Mahmoud, 1997, Amir, 1999, Mostafa and El-Menshawi, 2001 and Hovny *et al*, 2001). They reported that general (GCA) and specific (SCA) combining ability were important in the inheritance of grain yield and other related components in some crosses.

The objectives of the present investigation were: 1. to evaluate the agronomic performance and breeding behavior of some lines selected from grain sorghum program, 2. to estimate combining ability and heterobeltiosis effects as they should be useful in understanding the inheritance of the studied characters and so in determining the most appropriate breeding programs in sorghum to improve such traits and 3. to identify the best parental lines in hybrid combinations.

MATERIALS AND METHODS

Three exotic cytoplasmic male sterile line (A lines) ICSA14, ICSA88015 and ATX623 and seven restorer lines (R lines) of sorghum; ICSR-16, ICSR21, ICSR89022, ICSR89038, ICSR90001; ICSR93001 and the variety Dorado, were used to produce 21 single crosses at Giza Agricultural Research Station in 2002 season. Crossing was done by bagging the panicles of both parents (A and R lines) just before anthesis to prevent contamination from foreign pollen. Pollen were collected from each male parent and placed on the stigma of the female parent and were bagged the pollinated female panicles.

Both A and R parental lines and their respective crosses were evaluated in a field trail at three locations: South Tahrir, Assuit and Shandaweel Agricultural Research Stations in 2003 growing season. The experimental design used was a randomized complete block design with three replications at each location. Single-rows plot of 6.0 m long and 0.7 m apart were used in these experiments. Planting was done in hills of 20 cm apart. Thinning was done after three weeks of sowing (date of sowing was nearly at mid of June for all locations) by leaving two plants/hill. All other agronomic practices were done as recommended for grain sorghum production.

Data were recorded for days to 50 % heading, plant height, panicle length, panicle width, 1000-kernel weight and grain yield (ard/fed.). Data of each location were subjected to the analysis of variance of randomized complete block design (R.C.B.D) according to Steel and Torrie (1980).

Line x tester analysis according to Kempthorne (1957) as shown by Singh and Chaudhary (1977) was used to estimate general and specific combining ability effects at each location. The fixed model was considered in the statistical analysis. Percentage of heterobeltiosis was determined by using the following equation:

$$\text{Heterobeltiosis \%} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where $\overline{F_1}$ and $\overline{BP}$ are the means of the F_1 and better parent, respectively. Heterosis percentage exceeding the least significant difference between two means (LSD) in percent of the better parent mean was considered significant.

RESULTS AND DISCUSSION

Mean Performance

Means of all studied traits at the three locations are presented in Tables (1 and 2). Number of days to 50 % heading for parents ranged from 90 (Dorado) to 105 days (ICSA14) at South Tahrir, 64 (ATX623) to 74 days (ICSA14 and Dorado) at Assuit, 66 (ATX623) to 74 days (ICSR90001) at Shandaweel, while for hybrids ranged from 90 (ICSA14 x Dorado) to 104 days (ICSA14 x ICSR93001) at South Tahrir, 62 (ATX623 x ICSR90001) to 74 days (ICSA14 x ICSR93001) at Assuit and 66 (ATX623 x ICSR89038) to 72 days (ICSA88015 x ICSR89038) at Shandaweel. In general most of the crosses flowered earlier than their parents. The female ATX623 was the earliest line at the three locations. ICSA88015 was the second earliest line at Assuit. It was observed that most of the crosses involving ICSR16 showed lateness at Shandaweel, but, showed earliness at Assuit and South Tahrir except with the line ICSA88015 at Tahrir. The earliest hybrid across the three locations was ATX623 x ICSR93001.

For plant height parents ranged from 102 cm (ICSR89022) to 136 cm (ICSR89038) at South Tahrir, 133 cm (ATX623) to 191 cm (ICSR93001) at Assuit and 130 cm (Dorado) to 207 cm (icsr21) at Shandaweel, while for crosses it ranged from 90 cm (ICSA14 x ICSR93001) to 162 cm (ATX623 x ICSR93001) at South Tahrir, 132 (ICSA14 x ICSR93001) to 233 cm (ICSA88015 x ICSR93001) at Assuit and from 159 cm (ICSA14 x ICSR93001) to 243 cm (ICSA88015 x ICSR89022) at Shandaweel. Hybrids were generally taller than the parental lines indicating the role of hybrid vigor in plant height.

With respect to panicle length, the parents ranged from 19 to 30 cm, 26 to 34 cm and 26 to 42 cm while for hybrids ranged from 20 to 29 cm, 26 to 32 cm and 28 to 38 cm at South Tahrir, Assuit and Shandaweel, respectively. Some of hybrids had longer panicle length than their parents.

Concerning panicle width the means across the parental lines were 6.2, 6.1 and 5.6 cm while for hybrids were 6.0, 6.8 and 5.9 cm for South Tahrir, Assuit and Shandaweel, respectively.

For 1000-kernel weight at South Tahrir the parental lines ranged from 17.33 g (ICSR90001) to 31.33 g (ICSR93001) with an average of 25.59 g and for hybrids from 18 g (ICSA14 x ICSR93001) to 32 g (ATX623 x ICSR93001). Most of crosses had heavier 1000 kernel weight than their respective parental lines. The crosses (ICSA14 x ICSR89038), (ATX623 x Dorado) and (ICSA88015 x ICSR93001) had the heaviest 1000 kernel

Table 1. Average performance of 10 parental lines and their 21 hybrids for days to 50 % heading, plant height (cm) and panicle length (cm) for three locations, 2003 South Tahrir (L_1), Assuit (L_2) and Shandaweel (L_3).

Genotypes	Days to 50 % heading (days)			Plant height (cm)			Panicle length (cm)		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
ICSR16	101	71	69	122	187	183	22	30	27
ICSR21	101	73	74	129	172	207	23	29	25
ICSR89022	102	72	71	102	175	203	19	29	40
ICSR89038	100	73	67	136	144	170	22	28	25
ICSR90001	100	72	75	115	175	169	21	29	42
ICSR93001	94	72	67	120	191	189	20	26	26
Dorado	90	74	70	122	162	130	19	28	28
Mean males	**98.3**	**72.4**	**70.42**	**120.8**	**172.3**	**178.7**	**20.85**	**28.92**	**30.4**
ICSA14	105	74	70	122	169	162	29	28	30
ICSA88015	93	68	70	108	142	137	30	34	36
ATX623	92	64	66	122	133	150	30	28	30
Mean females	**96.7**	**68.7**	**68.7**	**117.3**	**148.0**	**149.67**	**29.6**	**30.0**	**32.0**
Mean of parental lines	**97.0**	**71.3**	**69.9**	**119.8**	**165.0**	**170.0**	**23.5**	**28.9**	**30.9**
ISCA14 x ICSR16	92	70	69	129	191	218	20	29	30
X ICSR21	98	71	69	128	202	240	28	29	31
X ICSR89022	101	72	68	114	162	174	20	30	31
X ICSR89038	102	71	65	104	147	153	26	29	30
X ICSR90001	101	70	64	129	172	200	26	29	34
X ICSR93001	104	74	72	90	132	159	21	29	33
X Dorado	96	71	70	125	185	206	24	28	28
ISCA88015 x ICSR16	100	68	69	135	207	200	20	31	31
X ICSR21	102	67	65	143	210	215	29	30	32
X ICSR89022	95	69	69	132	204	243	21	29	35
X ICSR89038	101	62	72	132	192	212	26	30	38
X ICSR90001	98	69	68	117	182	201	24	30	33
X ICSR93001	104	68	66	132	233	220	27	29	30
X Dorado	101	63	70	125	181	200	21	32	36
ATX623 x ICSR16	92	69	70	127	177	197	20	30	31
X ICSR21	86	69	70	132	200	208	26	26	30
X ICSR89022	92	70	68	141	183	225	23	28	34
X ICSR89038	83	64	66	117	198	185	24	30	33
X ICSR90001	82	62	68	128	173	231	22	31	31
X ICSR93001	85	65	63	162	197	195	25	31	35
X Dorado	86	69	66	125	175	172	22	30	32
Mean of hybrids	**95.3**	**68.2**	**67.9**	**115.42**	**177.52**	**194.38**	**23.28**	**29.52**	**32.38**

Table 2. Average performance of 10 parental lines and their 21 hybrids for panicle width (cm), 1000-kernel weight (g) and grain yield (ard/fed.) for three locations, 2003 South Tahrir (L_1), Assuit (L_2) and Shandaweel (L_3).

Genotypes	Panicle width (cm)			1000-kernel weight (g)			Grain yield (ard/fed.)		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
ICSR16	6	7	6	25.00	26.47	30.60	7.30	28.13	21.67
ICSR21	6	6	5	30.67	20.73	23.83	6.47	26.13	12.37
ICSR89022	7	6	5	20.33	24.37	23.00	4.43	23.60	19.23
ICSR89038	7	6	6	26.00	22.93	25.13	6.20	22.40	17.63
ICSR90001	6	6	5	17.33	24.17	24.03	5.83	23.03	21.63
ICSR93001	7	6	5	31.33	30.00	31.23	6.53	23.73	19.53
Dorado	6	6	6	28.67	30.40	34.33	7.80	32.37	19.57
Mean males	**7.4**	**6.1**	**5.42**	**25.48**	**22.31**	**27.45**	**5.65**	**22.28**	**18.80**
ICSA14	6	6	6	20.30	23.93	25.43	7.57	22.10	19.37
ICSA88015	5	6	5	26.30	20.40	21.13	7.20	17.50	15.17
ATX623	6	6	7	30.00	18.20	20.03	6.13	18.37	17.37
Mean females	**5.6**	**6.0**	**6.0**	**25.50**	**20.80**	**22.20**	**6.90**	**19.32**	**17.30**
Mean of parental lines	**6.2**	**6.1**	**5.60**	**25.59**	**24.16**	**25.87**	**6.54**	**23.75**	**18.05**
ISCA14 x ICSR16	5	6	7	24.00	28.93	32.77	6.03	28.46	26.13
X ICSR21	5	6	7	28.00	28.60	32.20	7.32	29.20	25.63
X ICSR89022	5	7	6	26.00	25.30	27.43	7.63	35.90	22.13
X ICSR89038	6	6	7	30.00	28.03	28.47	9.70	32.17	21.83
X ICSR90001	6	6	6	31.00	28.16	31.07	7.10	30.23	27.43
X ICSR93001	5	6	6	18.00	25.43	27.93	5.13	17.77	16.13
X Dorado	6	6	7	28.00	27.23	29.57	9.17	35.73	24.70
ISCA88015 x ICSR16	6	6	5	25.00	25.40	23.90	7.07	28.40	19.33
X ICSR21	6	7	7	30.00	25.90	27.93	5.23	35.77	19.43
X ICSR89022	6	7	7	20.00	18.13	18.43	6.70	35.57	22.23
X ICSR89038	4	6	7	28.00	27.53	35.17	6.23	29.07	23.63
X ICSR90001	4	6	5	27.00	26.33	29.97	6.00	25.63	20.53
X ICSR93001	7	7	5	30.00	25.33	25.03	6.33	25.07	20.53
X Dorado	6	6	5	26.00	29.37	25.17	5.33	29.97	19.30
ATX623 x ICSR16	5	7	6	22.00	28.03	28.63	7.20	28.60	24.57
X ICSR21	6	5	6	26.00	27.30	30.63	6.87	23.57	27.73
X ICSR89022	6	7	5	24.00	27.87	31.53	6.07	38.47	21.83
X ICSR89038	8	6	6	28.00	25.87	29.90	7.43	39.33	22.40
X ICSR90001	7	6	4	29.00	40.80	35.00	7.10	34.10	17.50
X ICSR93001	7	7	6	32.00	22.40	27.03	9.00	38.10	23.33
X Dorado	6	6	5	30.00	28.73	31.60	8.20	28.20	24.97
Mean of hybrids	**6.0**	**6.28**	**5.95**	**26.77**	**26.18**	**29.04**	**7.14**	**30.58**	**22.44**

weight. At Assuit parental lines ranged for 1000-kernel weight from 18.2 g (ATX623) to 30.4 g (Dorado) with an average of 24.16 g while the hybrids ranged from 18.13 g (ICSA88015 x ICSR89022) to 29.37 g (ATX623 x Dorado). The best crosses for 1000-kernel weight at Assuit were (ICSA14 x ICSR16), (ATX623 x Dorado). At Shandaweel the parents ranged for 1000-kernel weight from 20.03 g (ATX623 x Dorado) to 34.33 g with an average of 25.87 g, while the hybrids ranged from 18.43 g (ICSA x ICSR89022) to 35.17 g (ICSA88015 x ICSR89038). The best hybrids at Shandaweel for 1000-kernel weight were (ATX623 x ICSR90001), (ICSA14 x ICSR21) and (ICSA14 x ICSR16).

For grain yield (ard/fed.) at South Tahrir the female lines ranged from 6.13 (ATX623) to 7.57 ard/fed (ICSA14), the males ranged from 4.43 (ICSR91022) to 7.80 ard/fed (ICSR93001) and the hybrids ranged from 5.13 (ICSA14 x ICSR93001) to 9.70 ard/fed. (ICSA14 x ICSR89038) with an average of 7.14 ard/fed. At South Tahrir most of hybrids had higher grain yield than their respective parents. The crosses (ICSA14 x ICSR89038), (ICSA14 x Dorado) and (ATX623 x ICSR93001) had the highest grain yield at South Tahrir. At Assuit the grain yield of female parents ranged from 17.5 (ICSA88015) to 22.1 ard/fed. (ATX623), male parents from 22.4 (ICSR89038) to 32.37 ard/fed. (Dorado) and hybrids from 17.77 (ICSA14 x ICSR93001) to 39.33 ard/fed (ATX623 x ICSR89038). Most of F_1 crosses had higher grain yield than their parents at Assuit. The crosses (ATX623 x ICSR89038), (ATX623 x ICSR93001) and (ATX623 x ICSR89022) had the highest grain yield at Assuit. At Shandaweel grain yield of female parents ranged from 15.17 (ICSA88015) to 19.37 ard/fed (ICSA14), males from 17.63 (ICSR89038) to 22.37 ard/fed (ICSR21) and hybrids from 16.13 (ICSA14 x ICSR93001) to 27.73 ard/fed (ATX623 x ICSR21). At Shandaweel the best crosses for grain yield were (ICSA14 x ICSR90001), (ICSA14 x ICSR16) and (ATX623 x ICSR21). Most of hybrids had also higher grain yield than their parents at Shandaweel. In general, the cross showing the highest grain yield was ATX623 x ICSR93001 at two locations (South Tahrir and Assuit) and ICSA14 x ICSR90001 at Shandaweel. Therefore, it is recommended that the cross ATX623 x ICSR93001 should be further tested in the evaluation trials in order to release it as new improved commercial hybrid.

Heterobeltiosis

Heterobeltiosis estimates for 21 hybrids at each location for the studied traits are presented in Tables (3 and 4).

Table 3. Heterosis as a percentage of the better parent of 21 hybrids for days to heading, plant height and panicle length at three locations, 2003.

Hybrids	Days to 50 % heading (days)			Plant height (cm)			Panicle length (c		
	L1	L2	L3	L1	L2	L3	L1	L2	
ISCA14 x ICSR16	11.78**	-5.41	-9.96**	6.03**	2.14	19.53**	-32.95**	-4.40*	
X ICSR21	6.05**	-4.50*	-10.39**	-0.26	17.02**	16.13**	-25.00**	0	-
X ICSR89022	-3.50**	-3.15*	-12.12**	-6.58**	-7.62**	-13.98**	-30.68**	5.81*	-2.
X ICSR89038	-2.55*	-3.60*	-15.15**	-25.06**	-13.39**	-9.63**	-10.23**	1.18	1
X ICSR90001	-3.50*	-4.95*	-17.32**	6.03**	-1.90	18.34**	-11.36**	0	-19
X ICSR93001	0.64	0	-6.49*	-26.03**	-31.18**	-15.70**	-27.27**	1.18	8
X Dorado	-8.24**	-4.05*	-8.65*	5.19*	9.25**	27.63**	-18.18**	0	-6.
ISCA88015 x ICSR16	-0.66	-6.45*	-1.43*	10.96**	10.71**	9.49*	-34.07**	-9.71**	-15
X ICSR21	1.32	-5.19*	-12.11**	11.40**	21.86**	4.03	-5.49*	-12.62**	-12
X ICSR89022	-6.38**	-6.76**	-3.74	21.54**	16.57**	19.74**	-30.77**	-16.50**	-11.
X ICSR89038	0.67	-12.74**	2.85	-2.94	32.79**	24.75**	-14.29**	-13.59**	5.
X ICSR90001	2.98*	-6.33*	-9.78**	2.03	3.81*	18.93**	-20.88**	-11.65**	-20.
X ICSR93001	9.50**	-4.67*	-6.19*	10.03**	21.95**	16.40**	-9.89*	-16.50**	-17.
X Dorado	8.99**	-12.50**	0	2.19	11.75**	46.34**	-29.67**	-7.77*	-0.
ATX623 x ICSR16	-8.61**	4.61*	1.93	4.11*	-5.36	7.66*	-34.07**	0	2.
X ICSR21	15.18**	-2.83	-5.38*	2.33	16.05**	0.81	-15.38**	-12.50**	-1.
X ICSR89022	9.48**	-5.41*	-5.14*	15.62**	4.76	11.02**	-25.27**	-2.33**	-15.
X ICSR89038	16.67**	-8.96**	-1.0	-14.00**	37.40**	9.04*	-20.88**	5.88*	7.6
X ICSR90001	18.87**	-15.84**	-9.78**	4.93	-0.95	36.49**	-28.57**	5.68*	-26.9
X ICSR93001	-10.21**	-8.88**	-6.40*	32.88**	2.79	3.17	-17.58**	10.59**	15.3
X Dorado	6.16*	-3.70*	-4.78*	2.46	8.25**	14.44**	-28.57**	5.88*	13.1

*** and ** indicate significance at 5 and 1 % level of probability, respectively.**

4. Heterosis as a percentage of the better parent of 21 hybrids for panicle width, 1000-kernel weight and grain yield ard/fed at three locations, 2003.

ids	Panicle width (cm)			1000-kernel weight (g)			Grain yield (ard/fed.)		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
ı14 x ICSR16	-26.32**	-5.56*	11.11**	-4.0*	9.32**	7.08*	-20.26**	2.96	21.08**
X ICSR21	-21.05**	-10.00**	23.53**	-8.70**	19.50**	26.61**	23.79**	11.03**	14.61**
X ICSR89022	-28.57**	10.52**	0	29.51**	3.83*	7.86*	0.88	51.90**	14.29**
X ICSR89038	-5.00*	5.88*	11.11**	15.38**	17.13**	13.84**	41.41**	43.60**	12.74**
X ICSR90001	-10.53**	-5.56*	11.76**	52.46**	16.55**	22.15**	-6.16**	31.26**	26.81**
X ICSR93001	-23.81**	5.56*	0	-42.55**	-15.22**	-10.56**	-32.16**	-25.14**	-17.41**
X Dorado	5.88*	0	5.80*	-1.16	-10.42**	-13.88**	17.52**	-11.48**	26.24**
A88015 x ICSR16	0	5.56*	11.11**	-5.06**	-4.03*	-21.90**	-3.20	0.94	-10.77**
X ICSR21	-5.26*	0	0	-2.17	24.92**	17.34**	-27.31**	35.99**	-13.11**
X ICSR89022	-14.29**	10.52**	33.33**	-25.32**	-25.58**	-19.86**	-6.94*	50.49**	15.59**
X ICSR89038	-35.00**	11.76**	16.62**	6.32*	20.06**	39.92**	-13.43**	29.76**	34.03**
X ICSR90001	-31.58**	-5.56*	-6.25*	3.80*	8.97*	12.21**	-16.67**	11.29**	-5.08*
X ICSR93001	-4.76*	11.11**	-6.25*	-4.26*	-15.56**	-19.85**	-12.04**	5.62*	-5.11*
X Dorado	5.88*	-5.26*	17.65**	-9.30**	-3.40*	-26.70**	-31.62**	-33.20**	-1.36
X623 x ICSR16	-15.79*	5.26*	-28.52**	-12.87**	5.92*	-6.43*	-1.37	1.66	13.38**
X ICSR21	-5.26*	-20.0**	-19.05**	-15.22**	31.67**	28.53**	6.19*	-10.39**	23.99**
X ICSR89022	-14.29**	5.26*	-14.29**	-6.49*	14.36**	37.10**	-1.09	62.76**	13.52**
X ICSR89038	15.00*	-10.53**	-23.81**	7.69*	12.79**	18.97**	19.89**	75.59**	27.03**
X ICSR90001	10.52**	-10.52**	-9.52**	14.29**	68.83**	45.63**	15.76**	48.05**	-19.11**
X ICSR93001	0	5.26*	-47.62**	2.13	-25.33**	-13.44**	37.76**	66.22**	19.45**
X Dorado	0	0	-19.04**	4.65*	-5.48*	-7.96*	5.13*	-28.82**	27.60**

ıd ** indicate significance at 5 and 1 % level of probability, respectively.

At South Tahrir heterobeltiosis was manifested for days to 50 % heading, plant height, 1000-kernel weight and grain yield. Most hybrids at South Tahrir were earlier, taller, had heavier seed weight and higher yield than their respective better parents. For panicle width, 4 crosses exhibited significant and positive heterobeltiosis estimates; the highest estimate (15.0 %) was shown by the cross ATX623 x ICSR89038. But, for panicle length, panicle width heterobeltiosis was not manifested. For grain yield there was a wide range of heterobeltiosis estimates at South Tahrir. The best estimate of heterobeltiosis at South Tahrir was –16.67 % for earliness (ATX623 x ICSR89038), 32.88 % for plant height (ATX623 x ICSR93001), 52.46 % for 1000-kernel weight (ICSA14 x ICSR89038) and 41.40 % for grain yield (ICSA14 x ICSR90001).

At Assuit heterobeltiosis estimates for number of days to heading were negative for all hybrids except one, (ATX623 x ICSR16) which showed positive and significant heterosis. For plant height, 12 crosses showed positive and significant heterobeltiosis values while six showed negative ones. The highest heterobeltiosis for plant height (32.79 %) was shown by (ICSA88015 x ICSR89038) at Assuit. For panicle length, five crosses showed positive and significant values of heterobeltiosis; the highest (10.59 %) was shown by the cross (ATX623 x ICSR93001) at Assuit. For panicle width ten crosses showed positive and significant heterobeltiosis values at Assuit; the highest (11.76 %) was exhibited by the cross (ICSA88015 x ICSR89038). Heterobeltiosis for 1000-kernel weight at Assuit were positive for 13 crosses; the highest positive value was 68.83 % for the cross (ATX623 x ICSR90001). For grain yield heterobeltiosis at Assuit, ranged from –33.20 % to 75.59 %. The highest estimate of heterobeltiosis for grain yield at Assuit was 75.59 % for the cross (ATX623 x ICSR89038) and 66.22 % for (ATX623 x ICSR93001).

At Shandaweel heterobeltiosis for days to 50 % heading were negative in the majority of crosses and ranged from –17.32 to 2.85 %. The best hybrid for heterobeltiosis regarding earliness was ICSA14 x ICSR93001 at Shandaweel. For plant height 18 out of 21 hybrids showed positive and significant heterobeltiosis at Shandaweel. For panicle length 4 crosses in Shandaweel showed positive and significant heterosis value the highest heterobeltiosis (15.38 %) was exhibited by (ATX623 x ICSR93001). For panicle width 9 crosses showed positive and heterobeltiosis estimates. The highest estimate 33.33 % was manifested by (ICSA88015 x ICSR89022). Concerning 1000-kernel weight in Shandaweel heterobeltiosis were positive in 12 crosses, the highest positive estimate 45.63 % was

exhibited by (ATX623 x ICSR90001). For grain yield at Shandaweel the heterobeltiosis estimates ranged from –19.91 % (ATX623 x ICSR90001) to 34.03 % (ICSA88015 x ICSR89038). Fourteen crosses at Shandaweel showed significant positive values of heterobeltiosis for grain yield, the highest positive estimate was 34.03 % for the cross ICSA88015 x ICSR89038.

In general, heterosis above the better parent in this study was manifested for all studied traits. The existence of heterosis for different characters in grain sorghum crosses using either cytoplasmic male sterile and restorer lines or varietal crosses had been demonstrated by several workers (Nandanwankar, 1990; Mostafa *et al.* 1992; Reddy and Joshe, 1993 and El-Menshawi, 1996). Most of these workers reported significant magnitudes of heterosis for grain yield and its components.

The three crosses (ICSA14 x ICSR89038), (ATX623 x ICSR89038) and (ATX623 x ICSR93001) gave positive favourable and significant heterosis values for grain yield/plant and most studied traits under conditions of the three locations (South Tahrir, Assuit and Shandaweel). In addition to exhibiting the highest heterobeltiosis, these 3 crosses are also amongst the highest yielding genotypes under the 3 locations. These crosses are recommended for further large scale studies for yield and other traits performance before releasing as new variety.

Analysis of Variance

Analysis of variance for studied traits at each location is presented in Table (5). Highly significant mean squares due to genotypes, crosses, parents *vs* crosses were observed for all studied characters at all locations except mean squares due to parents for panicle width and due to parents *vs* crosses for panicle length at Assuit. The significance of mean squares due to parents *vs* crosses for most studied traits indicates that the crosses performed significantly better than their respective parents, and therefore heterotic effects are present.

Partitioning the sum of squares due to crosses into their components by using line x tester analysis showed that mean squares due to females (A lines) and males (R lines) were highly significant for all traits at all locations except for plant height, panicle length, and panicle width for female parents at South Tahrir and panicle width for male parents at Assuit which were not significant. The highly significance of mean squares due to males and females reveals that variances due to GCA of both males and females played important role in the inheritance of studied traits. At the same time,

Table 5. Analysis of variance of the genotypes for studied traits at South Tahrir (L_1), Assuit (L_2) and Shandaweel (L_3), season 2003.

S.O.V.	df	Mean squares								
		Days to 50 % heading (days)			Plant height (cm)			Panicle length (cm)		
		L1	L2	L3	L1	L2	L3	L1	L2	L3
Reps.	2	4.01	2.78	11.75	334.91	411.39	56.90	10.46	0.66	0.52
Genotypes	30	131.52	36.28	32.68	540.83	1636.12	2498.16	33.67	8.05	48.82
Parents	9	77.42	29.69	54.96	276.20	1140.28	2020.53	64.37	14.03	119.06
P vs crosses	1	126.85	164.42	113.67	1089.1	8677.33	2178.17	1.79	4.88	39.65
Crosses (C)	20	156.10	32.84	18.59	632.49	1507.19	1741.09	21.45	15.52	18.62
Males (M)	6	15.32	19.14	10.60	273.54	827.22	1703.94	41.33	4.41	13.17
Females (F)	2	1190.78	148.77	5.53	1528.83	5142.02	2070.92	9.63	4.43	34.97
F x M	12	54.04	20.37	24.76	662.58	1241.37	1704.68	13.49	6.40	18.61
Error	60	3.46	1.58	1.87	67.53	75.28	48.33	1.67	0.88	1.48
Contribution of male		2.94	17.49	17.73	24.17	16.40	29.36	57.79	22.44	21.20
Contribution of females		76.28	45.30	2.98	12.97	34.10	11.84	4.49	7.85	18.78
Contribution Males x females		20.77	37.24	79.39	62.85	49.42	58.75	37.72	69.66	59.44
S.O.V.	df	Panicle width (cm)			1000-kernel weight (g)			Grain yield (ard/fed.)		
		L1	L2	L3	L1	L2	L3	L1	L2	L3
Reps.	2	0.08	0.10	1.11	10.68	1.59	5.93	2.99	1.92	0.19
Genotypes	30	1.94	1.09	2.05	47.73	52.58	55.81	5.42	125.74	30.57
Parents	9	0.95	1.72	1.96	63.63	47.12	65.25	2.95	122.65	14.72
P vs crosses	1	3.41	3.07	2.34	55.92	184.88	185.76	7.11	802.6	194.78
Crosses (C)	20	2.31	0.71	2.28	40.15	48.41	45.06	6.45	93.44	29.49
Males (M)	6	0.95	1.44	2.39	50.51	63.24	126.40	2.50	93.27	16.54
Females (F)	2	6.33	0.39	4.39	4.88	57.37	33.68	17.19	77.43	47.74
F x M	12	2.33	0.39	1.87	40.85	39.50	24.94	6.63	95.93	32.94
Error	60	0.71	0.31	0.32	1.53	2.83	1.18	0.55	3.01	1.50
Contribution of male		12.32	60.94	31.36	37.73	39.19	27.04	11.64	24.09	6.81
Contribution of females		27.31	5.54	19.26	1.21	11.85	28.05	26.15	8.30	16.98
Contribution Males x females		60.37	33.48	19.37	61.05	48.96	44.85	61.71	61.70	66.29

mean squares due to the males x females interaction were highly significant for all studied traits except 50 % heading and 1000-kernel weight at Shandaweel and panicle width at Assuit which were not significant indicating that the specific combining ability (SCA) variance also played important role in the inheritance of most studied traits. These results are in agreement with those obtained by El-Menshawi (1996), Mohamed (1997), Amir (1999) and Hovny *et al.* (2001).

Combining ability

Analysis of variance (Table 5) indicates that the contribution of variation due to the interaction between males x females was higher for all traits than either the contribution of that due to males, or females. Exceptions were for 50 % heading at South Tahrir, Assuit and Shandaweel and panicle width at Assuit and Shandaweel where the contribution of parents was the highest. Non additive played more important role than additive gene effects in the inheritance of most studied traits.

General combining ability effects (GCA)

The GCA effects of the parental lines for the studied traits at the 3 locations were presented in Table (6). For days to 50 % heading the negative (favorable) significant GCA effects were observed for the lines ATX623, ICSR90001, ICSR16 and Dorado at South Tahrir, ICSR88015 and ICSR89038 at Assuit and ATX623, ICSR90001 and ICSR93001 at Shandaweel. The negative GCA effects for these lines indicate their superiority in giving early flowering hybrids.

For plant height, positive and significant GCA effects were exhibited by the lines ICSA14, ICSA88015, ICSR16, ICSR21 in all locations. ICSA14, ATX623 and Dorado at South Tahrir and ICSR89022, ICSR90001 at Shandaweel.

Positive (favourable) and significant estimates of GCA effects for panicle length were shown by ICSR89038 at South Tahrir and Shandaweel, ICSR21 and ICSR93001 at South Tahrir, ICSR16 and Dorado at Assuit and ICSR89022 at Shandaweel. The female line ICSA88015 had positive and significant effects for panicle length at all locations.

For panicle width the positive and significant GCA effects were exhibited by the lines ATX623 and ICSR93001 at South Tahrir, ICSA88015, ICSR89022 and ICSR93001 at Assuit and ICSA14, ICSR16, ICSR89022 and Dorado at Shandaweel.

Table 6. General combining ability effects at Tahrir (L_1), Assuit (L_2) and Shandaweel (L_3), 2003.

Parent	Days to 50 % heading (days)			Plant height (cm)			Panicle length (cm)		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
Females									
	**	**		**	**	**	**	**	**
ICSA14 (F1)	3.94	3.06	0.22	9.78	-15.87	-9.49	-0.46	-0.43	-1.34
	**	*	*	*	**	**	**	**	**
ICSA88015 (F2)	4.75	-1.75	0.36	3.84	15.41	10.31	0.78	0.48	1.22
	**		**	*			*		
ATX 623 (F3)	-8.68	-1.32	-0.58	5.93	0.46	-0.83	-0.32	0.05	0.13
± S.E. gi (female)	**0.41**	**0.27**	**0.29**	1.79	1.89	1.52	**0.28**	**0.20**	**0.27**
	*		**	*	**	*	**	*	**
ICSR16 (M1)	-0.52	0.67	1.59	3.31	5.60	2.41	-3.38	0.59	-1.84
				**	**	**	**	**	**
ICSR21 (M2)	0.14	0.56	0.25	7.52	18.16	18.52	2.17	-1.19	-1.39
	*	*				**	**	*	**
ICSR89022 (M3)	0.81	2.00	0.03	1.75	-2.73	11.41	-1.94	-0.52	1.16
		**		**	**	**	**		**
ICSR89038 (M4)	0.03	-2.44	-0.19	-10.25	-6.84	-49.25	2.17	-0.07	1.38
	**		**		**		*	**	
ICSR90001 (M5)	-1.86	-1.11	-1.63	-2.25	-10.17	7.97	0.62	0.69	0.16
	**		*			**	**		
ICSR93001 (M6)	2.25	0.78	-0.96	0.85	1.49	-11.14	1.29	0.03	0.16
	*		*	*	**		*	*	
Dorado (M7)	0.86	-0.44	0.92	0.92	-5.50	-9.92	-0.94	0.48	0.38
± S.E. gj (males)	**0.61**	**0.42**	**0.46**	2.73	2.89	2.32	**0.28**	**0.32**	**0.41**
S.E. (gi – gj)	**0.87**	**0.59**	**0.64**	3.87	4.09	3.28	**0.61**	**0.44**	**0.57)**
	Panicle width (cm)			1000-kernel weight (g)			Grain yield (ard/fed.)		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
Females									
	**		**	*		**	**	**	**
ICSA14 (F1)	-0.43	-0.08	0.41	-0.30	0.21	1.09	-0.74	-0.84	0.99
	*	*			**	**	**	*	**
ICSA88015 (F2)	-0.19	0.16	0.07	-0.25	-1.78	-2.81	-1.00	-1.34	-1.73
	**		**	**	**	**	**	**	**
ATX 623 (F3)	0.62	-0.08	-0.49	0.56	1.54	1.72	0.27	2.19	0.74
± S.E. gi (female)	**0.18**	**0.13**	**0.12**	**0.27**	**0.37**	**0.14**	**0.16**	**0.38**	**0.27**
	**		*	**		**	*	**	*
ICSR16 (M1)	-0.41	0.11	0.24	-3.05	0.28	-0.47	-0.37	-2.19	0.93
		*		**		**		**	**
ICSR21 (M2)	-0.19	-0.22	0.09	1.17	0.09	1.37	0.02	-1.33	1.81
		**	*	**	**	**	*	**	
ICSR89022 (M3)	-0.19	0.67	0.23	-3.49	-3.41	-3.10	-0.34	5.80	-0.38
		*	**	**		**	**	**	
ICSR89038 (M4)	0.25	-0.22	0.46	1.84	-0.03	2.44	0.98	2.67	0.17
		**		**	**	**	**	*	*
ICSR90001 (M5)	-0.19	-0.50	0.02	2.39	4.59	2.11	-0.40	-0.86	-0.62
	**	*	**		**	**	*	**	**
ICSR93001 (M6)	0.47	0.33	-1.09	-0.16	-2.78	-2.23	-0.32	-3.73	-2.45
			*	**	*		**	*	*
Dorado (M7)	0.25	-0.18	0.23	1.29	1.27	-0.12	0.43	-0.37	0.53
± S.E. gj (males)	**0.28**	**0.20**	**0.19**	**0.41**	**0.57**	**0.21**	**0.25**	**-0.29**	**0.41**
S.E. (gi – gj)	**0.40**	**0.26**	**0.27**	**0.68**	**0.62**	**0.43**	**0.34**	**0.81**	**0.60**

*** and ** indicate significance at 5 and 1 % level of probability, respectively.**

For 1000-kernel weight the positive and significant GCA effects were shown by ATX623, ICSR90001 at the three locations, ICSR89038 and ICSR21 at South Tahrir and Shandaweel, Dorado at South Tahrir and Assuit. These results indicated that these lines seem to be good general combiners for increase of grain weight of hybrids.

For grain yield the positive (favourable) and significant GCA effects were exhibited by ATX623 at all locations, ICSR89038 at Assuit and South Tahrir and ICSR21 at Shandaweel. In general, ATX623 and ICSR89038 showed the highest significant GCA effects for grain yield indicating that these lines are good combiners for increasing grain yield of their hybrids.

5. Specific Combining Ability (SCA)

Estimates of SCA effects are presented in Tables (7 and 8). At South Tahrir significant SCA effects were shown in 14 crosses for days to 50 % heading and plant height, 12 for panicle length, 11 for panicle width, 15 for 1000-kernel weight and 18 for grain yield, positive and significant SCA effects were exhibited by 8 crosses for days to 50 % heading, 5 for plant height, 6 for panicle length, 7 for panicle width, 8 for 1000-kernel weight and 9 crosses for grain yield. While, 6 crosses had negative and significant SCA effects for days to 50 % heading. The best SCA effects for grain yield at South Tahrir were shown by the crosses (ATX623 x ICSR93001), (ICSA14 x ICSR89038) and (ICSA14 x ICSR16).

At Assuit the favourable significant SCA effects were shown by 8, 7, 1, 8 and 9 crosses for plant height, panicle length, panicle width, 1000-kernel weight and grain yield, respectively. But for days to 50 % heading seven crosses had negative and significant SCA effects. At Assuit (ATX623 x ICSR93001) (ICSA88015 x ICSR21), (ICSA14 x Dorado) showed the best SCA effects for grain yield.

At Shandaweel the favourable significant SCA effects were shown by 8, 9, 8, 8, 9 and 10 crosses for days to 50 % heading, plant height, panicle length, panicle width, 1000-kernel weight and grain yield, respectively. The best SCA effects for grain yield at Shandaweel were shown by (ICSA14 x ICSR90001) and (ICSA88015 x ICSR 89038) and (ATX623 x ICSR93001). Combining ability in grain sorghum was studied by several workers using line x tester analysis. It was reported that both GCA and SCA were important in the inheritance of grain yield and its components (Jagadeshawer and Shinde 1992) and Reddy and Joshi (1993). Other workers pointed out that SCA effects were of considerable magnitude (Hugar *et al* 1980, Mostafa *et al* 1992 and El-Menshawi 1996).

Table 7. Specific combining ability effects for days to heading, plant height and panicle length at Tahirir (L_1), Assuit (L_2) and Shandaweel (L_3), 2003.

Genotypes	Days to 50 % heading (days)			Plant height (cm)			Panicle length (cm)		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
ISCA14 x ICSR16	-6.38**	-.195*	0.44	8.56**	15.21**	22.83**	0.24	-0.68*	0.79*
X ICSR21	-1.05	-1.17*	0.55	3.67	13.65**	28.38**	-2.98**	1.42**	1.68**
X ICSR89022	0.95	-1.62*	0.56	-5.22*	-5.46*	-30.17**	-0.54	1.76**	-0.87*
X ICSR89038	2.73**	2.49**	-2.67**	-5.22*	-11.35**	-20.51**	1.35*	-0.34	-2.09**
X ICSR90001	3.62**	0.16	-2.89**	14.11**	11.98**	-1.06	2.57**	-0.46	2.46**
X ICSR93001	2.51**	1.94**	4.78**	0.28	-39.68**	-22.62**	-2.76**	-0.46	1.46**
X Dorado	-2.38**	0.16	1.22**	12.11**	20.65**	23.16**	2.13*	-1.24**	-3.42**
ISCA88015 x ICSR16	0.48	0.52	-0.92*	0.94	-0.08	-15.32**	-0.67	0.42	-1.11**
X ICSR21	2.14**	-0.03	-3.25**	5.05*	-9.30**	-16.43**	2.44**	1.19**	-0.56
X ICSR89022	-5.86**	0.52	0.30	-0.84	5.59*	18.35**	-1.11	-0.81	0.56
X ICSR89038	0.59	-2.37**	3.88**	11.16**	-2.63	18.01**	-0.22	-0.25	3.33**
X ICSR90001	-0.52	3.63**	0.97*	-11.17**	-9.30**	-19.87**	-0.67	-0.37	-0.44
X ICSR93001	1.37*	0.75*	-1.69**	0.05	30.69**	18.24**	0.2**	-1.37**	-3.78**
X Dorado	1.80*	-3.03**	0.75	-5.17*	-14.97**	-2.98	-1.78*	1.19**	2.00**
ATX623 x ICSR16	5.90**	1.43**	1.37*	-9.49**	-15.13**	-7.51*	0.43	0.27	0.32
X ICSR21	-1.10	1.21**	2.70**	-8.71*	-4.35	-11.95**	0.54	-2.61**	-1.13**
X ICSR89022	4.90**	1.10**	0.25	-6.06*	-0.13	11.83**	1.65*	-0.95*	0.32
X ICSR89038	-3.32**	-0.12	-1.19**	-5.94*	18.98**	2.49	-1.13*	0.60*	-1.24**
X ICSR90001	-3.10**	-3.79**	1.92*	-2.93	-2.68	20.93**	-1.90*	0.82*	-2.02**
X ICSR93001	-3.87**	-2.68**	-3.08**	27.95**	8.98**	4.38*	0.76*	1.83**	2.32**
X Dorado	0.57	2.87**	-1.97*	-6.94*	-5.68*	-20.17**	-0.35	0.05	1.43**
SE (S_{ij}-S_{kl})	**1.07**	**0.73**	**0.79**	**4.74**	**5.01**	**4.01**	**0.75**	**0.54**	**0.70**
SE (sca effects)	**1.51**	**1.03**	**1.11**	**6.71**	**7.08**	**5.68**	**1.06**	**0.77**	**0.99**

*** and ** indicate significance at 5 and 1 % level of probability, respectively.**

Table 8. Specific combining ability effects for panicle width, 1000-kernel weight and grain yield/fed at Tahirir (L_1), Assuit (L_2) and Shandaweel (L_3), 2003.

Genotypes	Panicle width (cm)			1000-kernel weight (g)			Grain yield (ard/fed.)		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
ISCA14 x ICSR16	-0.35	-0.48*	0.14	0.52	1.27*	3.24*	-1.47**	1.16*	1.86*
X ICSR21	-0.24	0.08	0.81**	0.30	1.23*	0.84*	1.47**	0.54	0.37
X ICSR89022	0.24	0.19	-0.86**	3.30*	1.32*	0.54*	1.00**	0.10	-0.93
X ICSR89038	0.65**	0.08	-0.08	1.63*	0.67	-3.47*	1.84**	-0.51	-1.78*
X ICSR90001	0.43	0.08	0.03	2.02*	-3.80**	-1.03*	-0.37	1.09*	4.62**
X ICSR93001	-0.57*	-0.14	0.48*	-8.32**	0.83	0.18	-2.42**	-8.50**	-4.86**
X Dorado	0.32	0.19	-0.52*	0.52	-1.42*	-0.30	0.86*	6.10**	0.72*
ISCA88015 x ICSR16	1.08**	-0.05	0.48	1.47*	-0.31	-1.72*	1.31*	1.09*	-2.31*
X ICSR21	0.52*	-0.51	-1.19**	2.25*	0.38	0.51	-0.91*	7.60**	-3.10*
X ICSR89022	0.52*	-0.05	0.48*	-3.41*	-3.89*	-4.56**	0.91*	0.27	1.90*
X ICSR89038	-1.59**	0.17	0.59*	-0.41	2.14*	6.63**	-0.88*	-3.11**	2.75**
X ICSR90001	-1.14**	-0.16	-0.97**	-1.63*	-3.69*	-1.23*	0.28*	-3.06**	0.45
X ICSR93001	0.52*	-0.05	0.14	3.59**	2.69	1.18*	0.52*	-0.70	2.27**
X Dorado	0.07	-0.38*	0.48*	-1.86*	2.67*	-0.81	-1.22**	-2.16**	-9.95**
ATX623 x ICSR16	-0.73*	0.52*	-0.62*	-2.00*	-0.96	-1.52*	0.16	-2.25**	0.45
X ICSR21	-0.28	-0.59*	0.38*	-2.56*	-1.50*	-1.35*	-0.50*	-8.14**	2.72**
X ICSR89022	-0.28	-0.14	0.38*	0.11	2.56*	4.01**	-1.00*	-0.38	-0.97
X ICSR89038	0.93*	-0.25	-0.51*	-1.22*	-2.82*	-3.16**	-0.96*	3.61*	-0.96
X ICSR90001	0.71*	-0.08	0.94**	-0.44	7.80**	2.27	0.10	1.91*	-5.06**
X ICSR93001	0.05	0.19	-0.62*	4.78**	-3.53*	-1.35*	1.91**	9.19**	2.59*
X Dorado	-0.39	0.19	0.05	1.33*	-1.25*	1.10*	0.36*	-3.94*	1.24*
SE (sca effects)	0.49	0.35	0.33	0.71	0.98	0.37	0.42	1.00	0.71
SE (S_{ij}-S_{kl})	0.69	0.49	0.46	1.01	1.39	0.53	0.60	1.42	1.00

* and ** indicate significance at 5 and 1 % level of probability, respectively.

In general, the restorer line ICSR93001 was a good combiner with the female line ATX623. Moreover, the parental lines (males) used in this study had the ability to restore fertility of the hybrids and therefore, these male lines may be classified as restorer lines as suggested by Murty *et al.* (1994) and therefore, can be used commercially in hybrid seed production on grain sorghum.

REFERENCES

Amir, A.A. (1999). Line x tester analysis for combining ability in grain sorghum (*Sorghum bicolor* (L.) Moench]. M. Sc. Thesis, Fac. Agric. Assuit Univ., Egypt.

Andrews, D., G. Ejeta, M. Gibbert, P. Gaswami, K.A. Kumar, A.B. Maunder, K. Porter, K.N. Rai, Y.F. Rejewski, V.S.B. Reddy, W. Stemgmeir and B.S. Talukar (1997). Breeding hybrid parents. P. 173-187. In Proceeding of the International Conference on Genetic Improvement of Sorghum and Pearl millet, Wbbock, Texas, USA.

Blum, A. (1970). Nature of heterosis in grain production by the sorghum panicle. Crop Sci. 10: 28-31.

El-Menshawi, M.M.S. (1996). A study on the production of grain sorghum hybrids. Ph.D. Thesis, Fac. Agric. Cairo Univ., Egypt.

Hanson, W.D. (1970). Genotypic stability. Theor. Appl. Gen. 40: 226-231.

Hovny, M.R.A., M.M. El-Menshawi and O.O. El-Nagouly (2000). Combining ability and heterosis in grain sorghum (*Sorghum bicolor* (L.) Moench]. Bull. Fac. Agric. Cairo Univ. 52: 47-60.

Hugar, C.B., R. Parameswarappa and J.V. Goud (1986). Genetic evaluation on new male sterile lines in (*Sorghum bicolor* (L.) Moench]. Mysore J. Agric. Sci. 20: 262-275.

Jagadeshwar, K. and V.K. Shinde (1992). Combining ability in rabi sorghum (*Sorghum bicolor* (L.) Moench]. Indian J. Genet. Plant Breed. 52: 22-25.

Kempthorne, O. (1957). An introduction to genetic statistics. John Wiley and Sons, New York.

Mahmoud, K.M. (1997). Combining ability and heterosis studies in grain sorghum (*Sorghum bicolor* (L.) Moench]. M.Sc. Thesis, Fac. Agric. Assuit Univ. Egypt.

Mostafa, M.S.A and M.M. El-Menshawi (2001). Combining ability estimates from diallel crosses among grain sorghum (*Sorghum bicolor* (L.) Moench]. Restorer lines. Egypt. J. Appl. Sci., 16 (4): 142-149.

Mostafa, M.S.A., F.I. El-Attar, A.M. El-Kady and M.I. Bashir (1992). Combining ability studies for grain yield and some agronomic characters in grain sorghum. Egypt. J. Appl. Sci. 7: 871-882.

Murty, D.S., R. Tabo and O.Ajayi (1994). Sorghum hybrid seed production and management. Information Bulletin No. 41. (ICRISAT)

Nan danwankar, K.G. (1990). Heterosis studies for grain yield characters in rabi sorghum (*Sorghum bicolor* (L.) Moench]. Indian J. Genet. Plant Breed. 50: 83-85.

Perez-Cabrero, C.J. (1986). Combining ability and heterosis studies for adaptation in newly developed male and female inbreds of sorghum (*Sorghum bicolor* (L.) Moench]. Dissertation Abstracts International Sciences and Engineering. 46:10, 3332 B.

Quinby, J.R. (1963). Manifestations of hybrid vigor in sorghum. Crop Sci. 3: 288-291.

Reddy, J.N. and P. Joshi (1993). Heterosis, inbreeding depression and combining ability in sorghum. Indian. J. Genet. Plant. Breed. 53: 138-146.

Singh, R.K. and B.D. Chaudhary (1977). Line x tester analysis. In: Biometrical methods in quantitative genetic analysis 178-185. Kalyani Pub. New Delhi.

Steel, R.G.D and J.H Torrie (1980). Principles and Procedures of Statistics. Second Ed. McGraw. Hill Book Co., New York.

تقدير قوة الهجين وقدرة الائتلاف لمحصول الذرة الرفيعة للحبوب

ميرفت متري المنشاوى – محمد حسن البكرى

قسم بحوث الذرة الرفيعة-معهد بحوث المحاصيل الحقلية-مركز البحوث الزراعية-الجيزة

أجريت هذه الدراسة لتقدير القدرة العامة والخاصة على التالف وقوة الهجين لـ ٢١ هجين من الذرة الرفيعة حيث تم إنتاجهم فى محطة بحوث الجيزة عام ٢٠٠٢ وذلك بالتهجين بين ثلاثة سلالات عقيمة عقماً ذكريا سيتوبلازميا ICSA14, ICSA88015 and ATX623 وسبعة سلالات معيدة للخصب ICSR16, ICSR21, ICSR89022, ICSR89038, ICSR90001; ICSR93001 and Dorado. وفى موسم ٢٠٠٣ تم تقييم الـ ٢١ هجين وآبائهم العشرة فى تصميم قطاعات كاملة العشوائية فى ٣ محطات تجارب تابعة لمركز البحوث الزراعية (جنوب التحرير- أسيوط- شندويل). تم تحليل النتائج لكل محطة على حدة نظرا لوجود اختلافات بيئية بين هذه المناطق وبعضها. وقد تم حساب القياسات الوراثية باستخدام نظام (Line x tester) واوضحت النتائج لكل منطقة وجود تباين معنوى

عالى فى اغلب الصفات المدروسة بالنسبة للآباء والهجن والآباء مقابل الهجن مما يؤكد وجود تأثير لقوة الهجين.

أوضح جدول تحليل التباين ان مدى مساهمة التفاعل بين الآباء والأمهات كانت أعلى ما يمكن فى اغلب الصفات تحت الدراسة مما يوضح أهمية الاستفادة بقوة الهجين بين الآباء لتحسين هذه الصفات عدا صفة ٥٠ % طرد قناديل فى جنوب التحرير وأسيوط وعرض القنديل فى أسيوط وشندويل حيث كانت مساهمة الآباء أعلى ما يمكن مما يدل على ان الانتخاب للسلالات الأبوية المبكرة هى المسئولة عن تحسين هذه الصفات المدروسة.

وقد اظهرت النتائج ان التأثير السيادى يلعب دورا أساسيا فى توارث اغلب الصفات المدروسة وان التأثير المضيف له دور فى توريث صفة ٥٠ % طرد قناديل وعرض القنديل. ووجد ان الهجين ATX623 x ICSR93001 اظهر تفوقا فى المحصول ومكوناته تحت الظروف البيئية المختلفة فى الثلاث مناطق تحت الدراسة وان الهجين ICSA14 x ICSR89038 تفوق فى جنوب التحرير وان الهجين ICSA88015 x ICSR21 متفوق فى محطة بحوث أسيوط اما فى شندويل فان الهجينين ICSA14 x ICSR90001, ICSA88015 x ICSR89038 اظهرا تفوقا ملحوظا عن باقى الهجن.

وتراوحت قوة الهجين مقارنة بأفضل الابوين بالنسبة لمحصول الحبوب ما بين -٣٢,١٦ % الى ٤١,٤١ % فى جنوب التحرير وبين -٣٣,٢٠ % الى ٧٥,٥٩ % فى أسيوط و -١٩,١١ % الى ٣٤,٠٤ % فى شندويل.

وعلى ضوء تلك النتائج نجد بان الهجين ATX623 x ICSR93001 هجينا مبشرا وقد أعطى اكبر محصولا عن الهجن الأخرى تحت الدراسة فى مختلف البيئات ويوصى بإدخاله فى تجارب المقارنة الموسعة لتأكيد أداءه للمحصول والصفات الأخرى قبل التوصية لتسجيله كصنف جديد.