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Heterosis and Combining Ability in Grain Sorghum (*sorghum bicolor* (l.) Moench) Under Normal and Water Stress Conditions.

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Abstract:

Seven CMS and seven restorer lines of grain sorghum [(*Sorghum bicolor* (L.) Moench)], their forty nine single cross hybrids and the check hybrid Shandaweel-1 were evaluated in two field experiments in 2007 season. The first experiment was irrigated normally as recommended, while in the second experiment, one irrigation was skipped after every normal irrigation (water stress). Combined analysis over the two irrigation treatments showed highly significant differences between the two irrigation treatments and among genotypes. Mean square due to the interaction of genotypes x irrigation treatments was also highly significant, indicating that genotypes responded differently to irrigation treatments. Furthermore, mean squares due crosses (C), parents (P), P vs. C, females (F), males (M), F x M and their interaction with irrigation treatments were significant for all studied traits except days to 50% flowering. Line x tester analysis indicated that the linesICSA-364and ICSR-66 showed the highest significant GCA effects for grain yield/ plant. The GCA effect for days to 50% flowering of lines ICSA- 363, ICSA-572 and ICSR- 102 and were negative and significant over the two irrigation treatments and they considered good combiners for earliness. Better parent heterosis was generally manifested for plant height panicle length and width and grain yield/plant. The cross (ICS.A-610 x ICS.R-31) had highest positive significant heterosis for grain yield (66.97%).Crosses (ICSA-364x ICSR- 66), (ICSA-364x ICSR- 102) and (ICSA-490x ICSR- 66) had higher grain yield than the check (Shandaweel-1) and it should be produced commercially after tested on a large scale.

Introduction :

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the oldest cultivated cereals and it is one of the major cereal crops in the world that ranks the fifth after wheat ,rice, maize and barley .The cultivated area in the world was 44 million hectares producing around 63 million Tons of grains (FAO 2009). In Egypt, grain sorghum is the fourth

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Cereal, ranking after wheat, maize and rice, the cultivated area is about 158 thousand hectares producing 880 thousand tons of grains (FAO 2009). Most of these areas are concentrated in Upper Egypt at Assiut and Sohag Governorates.

The discovery of cytoplasmic male sterile lines in sorghum facilitates the production of hybrids. The development of hybrid sorghum in Egypt began in 1990 and is dependent on exotic CMS and restorer lines that show good adaptation for the prevailing local conditions. Water deficiency is a serious limitation to crop production in large areas of the world. Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important crops in arid and semi-arid regions where precipitation is low and highly variable. For sorghum production in these areas, the cultivars are expected to be tolerant limited irrigation. The demand for cereals in Egypt calls for an increase in the production of sorghum that comes mainly from increased yield per unit area. Developing high yielding and adapted sorghum hybrid is one approach to resolve cereal grain deficits. The improvement of sorghum production was mainly achieved through breeding of high yielding cultivars coupled with improved agronomic practices. The general combining ability (GCA) of each parent should be examined when the objective is the development of superior genotypes. The estimation of GCA under different treatments of irrigation will be helpful to decision regarding the commitment of breeding resources to develop and evaluated efficient methods of producing commercial F1 hybrids under different treatments of irrigation. Parent that will contribute favorable combination of genes for yield and other agronomic traits are the most sougth.

Hovny *et al* (2000) found that significant better parent heterosis was observed for flowering date, plant height and 1000-grain weight. Twelve crosses out of eighty had positive significant specific combining ability effects for grain yield.

Abd El-Halim, (2003) found wide variations in heterosis among crosses for earliness, plant height, 1000-grain weight and grain yield/plant. Mahmoud (2002) found that most of the studied crosses were significantly earlier in flowering compared to the earlier parent at two locations and under three levels of irrigation. Mean days to 50 % flowering of the hybrids and their parents were increased while plant height and 1000-grain weight were decreased with increasing water stress. However, the F1 hybrids had taller plants and higher grain yield /plant than the best parent under the two irrigation treatments. EL-Abd (2003) found a reduction of 23.25, 6.07, 12.14 and 5.61 % for grain /plant, plant height, leaf area /plant and 1000-grain weight, respectively, under water stress. However, the percentage of heterosis was reduced by 8 % for grain /plant, 2 % for plant height and 1.5 % for leaf area /plant under water stress. Bakheit *et al* (2004) found the lines ICSA-88003, ICSR-237 and ICSR-92003 showed the highest significant GCA effects for grain yield. Mahmoud and Ahmed (2010) found that under clay soil and surface irrigation, female line B11 and male line R-272 were the best general combiner for grain yield/plant while under sandy soil and drip irrigation, the female line B93 and male line R-273 were the best general combiner for grain yield/plant. Mahdy *et al* (2011) found some parents having significant negative gca for days to heading and significant positive for plant height, 1000-grain weight and grain yield were considered as good combiners. They added that significant positive heterosis in grain yield heterosis was found for more than half of the hybrids studied. Several cross combinations showed significant positive 1000-grain weight heterosis, significant negative days to heading heterosis and good performance.

The present study used 7 CMS and 7 restorer lines to evaluate agronomic performance, assess the general combining ability of the parents and heterosis and specific combining ability of their crosses.

Materials and Methods

Seven cytoplasmic male sterile lines (CMS-lines) i.e., ICS.A-363, ICS.A-364, ICS.A-490, ICSA-572, ICSA-605, ICSA-610 and ICSA-63 and seven restorer lines i.e., ICSR-31, ICSR-59, ICSR-66, ICSR-89037, Dorado and ICSR-89035 exotic from ICRISAT

Forty –nine CMS x restorer single crosses were produced in 2005 and 2006 seasons, the forty-nine hybrids, their parents and the check (Shandaweel -1) were evaluated in two experiments at Shandaweel Agric. Res. Sohag, Egypt. The first experiment was irrigated normally (6 irrigations) while in the second experiment, one irrigation was skipped after every normal irrigation (3 irrigations). The randomized complete block design with three replications was used in the two experiments. Plot size was one row 5meters long and 70cm apart planting was done in hills spaced 20 and thinned two plants/hill after hoeing and after three weeks from planting. Cultural practices were followed as recommended for growing grain sorghum. Data were recorded on days to 50 % flowering, plant height (cm), panicle length and width, 1000 grain weight and grain yield /plant adjusted to 14% moisture content. A combine statistical analysis over the two experiments was done according to Gomez and Gomez (1984) .Means of genotypes were compared by Revised LSD. General (G.C.A.) and specific combining ability (S.C.A.) effects were estimated according to Kempthorne (1957) and as illustrated by Singh and Chaudhry (1977).

Significance of GCA and SCA was tested by

$$t(gca) = \frac{gca \quad effect}{SE.gca}$$

$$t(sca) = \frac{sca \quad effect}{SE.sca}$$

Heterosis was calculated as the percentage deviation of F1 mean from the mean of its better parent and its significance was tested by the appropriate LSD test.

Results and Discussion

A-Mean performance of parents and crosses

The combined analysis of variance including the check over the two irrigation treatments (Table 1) indicated highly significant differences between environments (E), among genotypes (G) as well as GxE for all studied traits. Separate analysis of variance for each environment revealed significant differences among genotypes, crosses, females (F), males (M), FxM interaction (Tables2 and 3).

The data presented in Table (4) showed highly significant differences between environments and genotypes, among males, females and males x females for all studied traits. However, the mean square values for males were higher than those of males x females for all studied traits. These higher values indicated the large effect of the testers on cross performances in all studied traits. The interaction between males with irrigation were highly significant for all studied traits except plant height .The interaction between males x females with irrigation were significant for all studied traits except days to 50% flowering. Also, the interaction between females and irrigations was significant for all studied traits.

Results in Table (6) showed that, 15, 22, 13, 5, 8 and 12 out of 49 crosses were significantly superior to the check hybrid in flowering date, plant height, panicle length, panicle width, 1000-grain weight and grain yield/plant, respectively. The female parents ICSA- 630 and ICSA-572gave the earliest crosses compared with other female parent, Also, the male parents ICSR-102 and ICSR-59 gave the earliest crosses, and the female parent ICSA-363 gave the tallest plant height, Also, the male parent ICSR-31 had the tallest plant when crossed with the female parents. The female parent ICSA-364 had longer panicle length than other female parent. The female parent ICSA-363 had the heaviest 1000-grain weight when crossed with any of the male parent. The female ICSA-364 had the highest grain yield /plant when crossed with any of the male parents, also, the male parent ICSR-66 had the highest grain yield /plant when crossed with any of the female parents. Hussein (2001), Mahmoud (2002) Abd- EL-Halim (2003), Abo- Elwafa *et al* (2005) and Mahmoud and Ahmed 2010), reported that most CMS x restorer crosses were taller, earlier, had longer panicles and outyielded their parents.

Table (1): Combined analysis of variance of all genotypes for studied traits over two irrigation treatments.

Source of variation	D.F.	Mean Squares					
		Days to 50% flowering	Plant height	Panicle length	Panicle width	1000-grain weight	Grain yield /plant
Environment(E)	1	3734.391**	44118.38**	1265.491**	265.0026**	1107.042**	33756.56**
Reps/Env.	4	0.360677	9.203125	1.369792	0.238464	0.774479	13.03415
Genotypes (G)	63	151.9224**	6098.143**	32.0204**	4.018821**	50.34585**	1442.571**
G x E	63	5.740482**	58.16865**	7.411233**	0.998213**	6.101296**	144.9723**
Error	252	3.389778	38.38566	1.863019	0.335686	1.49557	23.24878**

**, Significant at 0.01 probability level.

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Table(2):Mean squares for the studied traits under normal irrigation.

Source of variation	D.F.	Mean Squares					
		Days to 50% flowering	Plant height	Panicle length	Panicle width	1000-grain weight	Grain yield /plant
Replication(Rep.)	2	0.3426	5.9854	1.78	0.343	0.239	14.55
Genotypes (G)	62	75.74**	3195.42**	20.14**	3.02**	30.23**	671.67**
Parents (P)	13	98.78**	3054.55**	17.62**	4.22**	38.52**	836.93**
P vs. C	1	45.64**	12654.42**	82.46**	4.84**	15.84**	2342.82**
Crosses (C)	48	70.12**	3036.50**	19.52**	2.66**	28.28**	592.09**
Females (F)	6	39.95**	6955.85**	30.89**	7.60**	50.75**	1170.05**
Males (M)	6	414.56**	12689.85**	51.12**	4.56**	30.05**	428.35**
F x M	36	17.75**	774.39**	12.35**	1.51**	24.24**	523.06**
Error	124	3.43	37.66	2.18	0.33	1.78	21.36

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

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Table (3):Mean squares for the studied traits under water stress.

Source of variation	D.F.	Mean Squares					
		Days to 50% flowering	Plant height	Panicle length	Panicle width	1000-grain weight	Grain yield /plant
Replication(Rep).	2	0.4934	9.160	0.5516	0.294	1.66	43.51
Genotypes (G)	62	84.06**	3059.54**	18.26**	1.85**	26.91**	811.99**
Parents (P)	13	90.63**	3043.51**	21.22**	1.18**	35.75**	818.32**
P vs. C	1	3.03	14375.68**	125.52**	5.74**	7.71**	7780.46**
Crosses (C)	48	83.07**	2828.13**	15.22**	1.75**	24.91**	665.19**
Females (F)	6	85.44**	5261.01**	5.62**	4.62**	78.73**	711.27**
Males (M)	6	483.94**	13088.34**	22.86**	2.51**	8.88**	909.92**
F x M	36	17.07**	712.62**	15.55**	1.14**	18.63**	616.60**
Error	124	3.38	39.33	1.57	0.34	1.20	25.09

**, Significant at 0.01 probability level.

Table (4):Combined mean squares of all genotypes without checks for the studied traits over irrigations.

Source of variation	D.F.	Days to 50% flowering	Plant height	Panicle length	Panicle Width	1000-grain weight	Grain yield /plant
Environment(E)	1	3721.15**	43747.15**	1346.78**	349.75**	828.59**	39944.58**
Reps/Env.	4	0.42	7.57	1.05	0.45	1.22	29.03
Genotypes (G)	62	154.11**	61916.448**	31.22**	4.07**	60.84**	1288.34**
Parents (P)	13	188.38**	6065.871**	34.25**	4.38**	76.26**	1330.44**
P vs. C	1	12.58	27002.701**	36.21**	15.66**	5.85*	9331.09**
Crosses (C)	48	147.78**	5798.349**	23.5**	3.74**	57.83**	1109.38**
Females (F)	6	117.91**	12120.4**	23.47**	9.01**	105.99**	1708.47**
Males (M)	6	879.44**	25720.82**	25.27**	4.67**	93.12**	1198.57**
F x M	36	30. 81**	1424.20**	23.21**	2.71**	43.93**	994.67**
G x E	62	5.69**	58.508*	6.22**	0.73**	6.94**	195.31**
P x E	13	1.03**	32.185	13.74**	0.62*	5.53**	324.81**
P vs C x E	1	36.09**	27.43	0.06	0.46	6.84**	792.18**
C x E	48	6.32**	66.284**	4.31**	0.76**	7.32**	147.81**
F x E	6	7.48*	96.45**	7.72**	1.11**	12.5**	172.85**
M x E	6	19.05**	57.38	0.92	0.91*	13.51**	139.69**
F x M x E	36	4	62.74*	4.3**	0.68**	5.43**	144.99**
Error	248	3.41	38.50	1.40	0.32	1.33	23.23

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

Table (5): Mean performance of the parental lines over the two irrigation treatments.

No	Parents	Days to 50% flowering	Plant height (cm)	Panicle length(cm)	Panicle width(cm)	1000-grain weight(g)	Grain yield /plant (g)
Female lines							
1	ICS.A-363	64.50	169.17	25.75	5.93	29.08	50.20
2	ICS.A-364	73.92	175.92	23.25	5.04	27.00	52.72
3	ICS.A-490	77.08	117.08	23.42	4.5	26.58	56.45
4	ICS.A-572	66.08	109.58	24.67	5.10	28.75	32.42
5	ICS.A-605	74.67	145.50	23.12	5.22	19.48	47.08
6	ICS.A-610	72.83	129.58	24.42	7.25	27.83	49.88
7	ICS.A-630	61.33	57.08	24.85	5.17	18.15	35.28
Male lines							
1	ICS.R-31	63.75	162.08	28.98	5.48	22.29	72.35
2	ICS.R-59	65.42	105.00	27.53	4.68	21.71	52.39
3	ICS.R-66	74.50	170.42	21.07	6.82	24.98	43.98
4	ICS.R-102	71.58	138.33	21.77	5.80	24.67	56.08
5	ICS.R-89037	79.17	122.08	25.87	6.92	27.52	58.92
6	Dorado	72.67	128.33	25.92	6.60	27.51	53.23
7	ICS.R-89035	75.50	125.00	23.50	5.30	25.17	57.96

Table (6): Mean performance of crosses and check variety over tow irrigations.

No	Crosses	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width(cm)	1000-grain weight(gm)	Grain yield /plant (gm)
1	ICS.A-363 x ICS.R-31	68.92	191.25	28.15	5.15	27.17	69.30
2	ICS.A-363 x ICS.R-59	68.25	193.33	25.42	5.90	29.52	75.98
3	ICS.A-363 x ICS.R-66	67.08	186.67	25.77	7.17	30.13	78.56
4	ICS.A-363 x ICS.R-102	65.00	190.58	25.85	5.92	29.83	78.28
5	ICS.A-363xICS.R-89037	70.33	172.00	25.00	6.40	29.93	87.02
6	ICS.A-363 x Dorado	69.83	207.92	24.53	6.20	26.87	88.07
7	ICS.A-363xICS.R-89035	71.67	159.58	25.98	5.02	24.06	49.04
8	ICS.A-364 x ICS.R-31	73.00	195.83	28.67	7.10	26.92	80.02
9	ICS.A-364 x ICS.R-59	70.25	187.42	26.17	6.33	25.92	83.19
10	ICS.A-364 x ICS.R-66	74.08	195.00	28.83	7.08	25.45	90.64
11	ICS.A-364 x ICS.R-102	70.83	191.75	28.67	6.25	29.08	89.98
12	ICS.A-364xICS.R-89037	72.58	142.50	26.08	6.67	27.03	88.81
13	ICS.A-364 x Dorado	71.92	184.17	26.90	7.25	27.06	81.46
14	ICS.A-364xICS.R-89035	70.08	178.33	25.72	5.67	25.72	66.33
15	ICS.A-490 x ICS.R-31	72.00	167.83	28.08	5.75	23.85	30.33
16	ICS.A-490 x ICS.R-59	74.17	145.42	24.92	6.00	26.53	74.62
17	ICS.A-490 x ICS.R-66	72.92	191.08	27.28	7.27	27.25	89.78
18	ICS.A-490 x ICS.R-102	75.58	122.92	25.63	5.67	24.03	63.31
19	ICS.A-490xICS.R-89037	76.00	108.75	25.00	6.70	24.81	77.21
20	ICS.A-490 x Dorado	76.92	119.17	24.63	6.15	22.47	68.04
21	ICS.A-490xICS.R-89035	75.33	126.75	24.00	6.93	25.82	69.98
22	ICS.A-572 x ICS.R-31	62.25	176.67	28.92	7.23	26.83	80.75
23	ICS.A-572 x ICS.R-59	62.25	114.17	24.32	5.60	27.87	60.33
24	ICS.A-572 x ICS.R-66	70.17	161.25	26.17	6.85	27.63	88.33

Table (6): cont

No	Crosses	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle width(cm)	1000-grain weight(g)	Grain yield /plant (g)
25	ICS.A-572 x ICS.R-102	62.67	140.00	27.92	5.97	25.17	75.47
26	ICS.A-572xICS.R-89037	70.92	122.92	24.98	6.08	22.92	45.93
27	ICS.A-572 x Dorado	66.25	146.25	24.17	6.62	25.37	65.65
28	ICS.A-572xICS.R-89035	62.75	123.75	22.17	6.55	29.38	83.62
29	ICS.A-605 x ICS.R-31	75.75	175.42	29.33	7.72	21.39	56.50
30	ICS.A-605 x ICS.R-59	75.33	135.42	20.98	6.50	20.73	67.51
31	ICS.A-605 x ICS.R-66	73.42	193.67	28.42	7.82	28.93	90.90
32	ICS.A-605 x ICS.R-102	70.50	128.75	20.27	7.50	29.25	88.78
33	ICS.A-605xICS.R-89037	77.67	157.92	27.75	7.52	29.20	80.62
34	ICS.A-605x Dorado	75.58	137.50	27.92	6.80	26.71	84.64
35	ICS.A-605xICS.R-89035	75.08	150.42	27.60	5.08	24.41	75.41
36	ICS.A-610 x ICS.R-31	72.92	178.08	28.90	6.00	21.47	86.64
37	ICS.A-610x ICS.R-59	72.17	131.75	27.65	5.83	20.59	49.83
38	ICS.A-610 x ICS.R-66	74.33	168.25	27.12	5.92	26.22	73.47
39	ICS.A-610 x ICS.R-102	72.42	147.17	25.17	5.93	21.13	72.60
40	ICS.A-610xICS.R-89037	75.33	142.42	26.57	6.33	28.21	70.85
41	ICS.A-610 x Dorado	76.50	170.92	26.65	6.38	23.68	64.39
42	ICS.A-610xICS.R-89035	76.00	121.67	28.17	5.87	25.95	69.14
43	ICS.A-630 x ICS.R-31	61.50	128.33	27.50	5.30	23.90	70.20
44	ICS.A-630x ICS.R-59	62.58	102.50	26.42	5.15	23.32	67.22
45	ICS.A-630x ICS.R-66	71.17	156.67	28.92	5.75	20.83	57.95
46	ICS.A-630 x ICS.R-102	60.17	93.75	25.00	4.92	24.18	67.45
47	ICS.A-630xICS.R-89037	66.25	101.67	22.40	5.83	20.15	46.41
48	ICS.A-630 x Dorado	65.92	111.25	30.33	5.27	26.57	79.53
49	ICS.A-630xICS.R-89035	59.42	112.50	28.33	5.50	24.52	61.37
	Shandweel-1	72.25	147.58	28.50	7.67	26.67	73.38
	RevLSD %5	2.63	8.80	1.99	0.86	1.74	6.85
	RevLSD%1	3.40	11.39	2.56	1.38	2.25	8.87

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B-Heterosis:

1- Days to 50 % flowering: The heterotic values over irrigation treatments ranged from -5.19 for (ICSA- 364 x ICSR-89035) to 18.82 % for (ICSA-630 x ICSR-31). Seven crosses had negative and significant heterosis values. The crosses (ICSA-364 x ICSR-89035), (ICSA-572 X ICSR-31) and (ICSA-572 X ICSR-102) showed the highest negative value of heterosis over the best parent under both irrigation treatments. The results showed that these crosses were earlier than the earliest parent Table (7).

2- Plant height: Based on the combined over the two irrigations treatments, it ranged from -36.19 (ICSA-605 x ICSR-66) to 74.98 % (ICSA-572 x ICSR-59). Most of the F1 crosses had positive heterosis for plant height, which indicates that these crosses were taller than the tallest parent. Twenty –seven of these crosses had positive and highly significant heterosis values under the two irrigations treatments. While 17 cross had negative and highly significant heterosis values under the two irrigations treatments. The crosses (ICSA-490 x ICSR-59), (ICSA-490 x ICSR-89037), (ICSA-572 x ICSR-59) and (ICSA-630 x ICSR-59) gave positive and high heterotic values for plant height compared with the best parent. Generally positive and significant values of heterosis, indicated that these crosses were taller than the tallest parent Table (7).

3 - Panicle length: Based on combined of the two irrigation treatments, the panicle length ranged from -23.79 (ICSA-605 x ICSR-59) to 24.01%for (ICSA-364 x ICSR-66). Thirteen crosses had highly significantly positive heterosis values. Twelve cross showed highly significant heterosis values under the irrigation treatments which indicates that these crosses had longer panicle length than their best parent and that may contribute to yield and yield potential. The crosses (ICSA-364 x ICSR-66) and (ICSA-364 x ICSR-102) gave positive and high heterotic values for panicle length compared with the best parent, Table (7)

4- Panicle width: Heterotic values for the combined data over irrigations treatments (Table 7) ranged from -20.2 for (ICSA-630 x Dorado) to 40.73% for (ICSA- 605x ICSR- 31). Ten crosses had positive and highly significantly heterosis values. The crosses,(ICSA-364 x ICSR-31),(ICSA-364 x ICSR-59),(ICSA-364 x Dorado),(ICSA-490 x ICSR-89035),(ICSA-572 x ICSR-31),(ICSA-572 x ICSR-89035),(ICSA-605 x ICSR-31), (ICSA-605 x ICSR-59) and (ICSA-605 x ICSR-102) showed high values of the heterosis over the best parents under both irrigation treatments, which may contribute to yield potential of these crosses. Generally, positive and significant indicating that these crosses wider panicle than the best parents.

5- 1000-grain weight: The combined data over two irrigation treatments indicated that heterotic values ranged from -27.77 (ICSA- 630 x ICSR-89037) to 18.58% (ICSA-605 x ICSR-102).Five crosses had positive and highly significant heterosis values. Most of crosses had negative heterosis values under both irrigation treatments, indicating that these crosses had lower 1000-grain weight than the best parent. The crosses (ICSA-364 x ICSR-102), (ICSA-605 x ICSR-66), (ICSA-605 x ICSR-102), (ICSA-605 x ICSR-89037) and (ICSA-630 x ICSR-31) gave positive and high heterotic values for 1000-grain weight compared with the best parent, table (7).

6- Grain yield / plant (g): Heterotic values for grain yield/plant over the two irrigation treatments (Table 7) varied from - 64.62 (ICSA-630 x ICSR-89035) to 66.97% (ICSA-610 x ICSR- 31). Twenty crosses had significantly positive heterosis values. The crosses (ICSA-363 x ICSR- 89037) (ICSA-363 x Dorado), (ICSA-572 x Dorado), (ICSA-605x ICSR- 102), (ICSA-605 x Dorado), (ICSA-610 x ICSR- 31) and (ICSA-610x ICSR- 89037) showed high and highly significant heterosis values. The crosses,(ICSA-363 x Dorado),(ICSA-364 x ICSR-66),(ICSA-364 x ICSR-102), (ICSA-572 x Dorado),(ICSA-605 x ICSR-31),(ICSA-605 x ICSR-66),(ICSA-605 x ICSR-102),(ICSA-605 x Dorado), (ICSA-610 x ICSR- 31), (ICSA-610 x Dorado) and (ICSA-630 x Dorado) gave the highest heterosis values over the best parent under the two irrigation treatments. El-Menshawy (1996) reported that heterosis values for grain yield over better parent up to 26.0% and heterosis over better parent for 1000- grain weight and plant height up to 24.2%, 69.6%, respectively. Radwan *et al* (1997) showed that heterosis for grain yield was 26 % above the value of the better parent. Abd- El-Halim (2003) found heterosis values for 1000-grain weight and grain yield/plant up to 22.49% and 106.8%, respectively. Abo-Elwafa *et al* (2005) found that heterosis values of the best parent ranged from -12.37% for earliness to 106.82% for grain yield/plant.

Table (7): Heterosis as a percentage of the better parent for forty nine crosses average over irrigations.

No	Crosses	Days to 50% flowering	Plant height	Panicle length	Panicle width	1000-grain weight	Grain yield /plant
1	ICS.A-363 x ICS.R-31	8.1**	13.05**	-2.88	-13.2**	-6.59**	0.04
2	ICS.A-363 x ICS.R-59	13.18**	15.76**	-7.69**	-0.56	1.49	6.48
3	ICS.A-363 x ICS.R-66	11.63**	-1.52	0.06	5.13	3.61	-7.53*
4	ICS.A-363 x ICS.R-102	-3.49**	4.43**	0.39	-0.28	2.58	9.86*
5	ICS.A-363xICS.R-89037	17.44**	3.69**	-3.35	-7.47	2.92	28.03**
6	ICS.A-363 x Dorado	13.05**	5.27**	-5.34	-6.06	-7.62**	32.27**
7	ICS.A-363xICS.R-89035	-4.65**	-24.14**	0.91	-15.45**	-17.28**	-35.91**
8	ICS.A-364 x ICS.R-31	7.06**	9.9**	-1.09	29.48**	-0.31	7.27
9	ICS.A-364 x ICS.R-59	7.39**	6.54**	-4.96	32.4**	-4.01	11.53**
10	ICS.A-364 x ICS.R-66	0.34	-17.34**	24.01**	3.91	-5.74*	13.81**
11	ICS.A-364 x ICS.R-102	-13.04**	-35.1**	23.3**	7.76	7.72**	20.62**
12	ICS.A-364xICS.R-89037	1.92*	-23.02**	0.84	-3.61	-1.79	19.84**
13	ICS.A-364 x Dorado	-0.69	-25.11**	3.79	9.85*	-1.64	9.21*
14	ICS.A-364xICS.R-89035	-15.33**	-41.73**	9.43**	6.92	-2.59	-11.07**
15	ICS.A-490 x ICS.R-31	5.23**	15.17**	-3.11	4.86	-10.28**	9.34*
16	ICS.A-490 x ICS.R-59	13.25**	66.55**	-9.5**	19.6**	-0.22	-24.45**
17	ICS.A-490 x ICS.R-66	-2.13*	12.13**	16.51**	6.6	2.51	11.83**
18	ICS.A-490 x ICS.R-102	-1.98*	16.57**	9.47**	-2.3	-9.59**	-23.17**
19	ICS.A-490xICS.R-89037	-4.76**	58.63**	-3.35	-3.13	-9.84**	-6.3
20	ICS.A-490 x Dorado	2.29*	31.1**	-4.95	-6.82	-18.33**	-17.43**
21	ICS.A-490xICS.R-89035	-5.74**	25.33**	2.13	30.82**	-2.88	-15.08**

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

Table (7):Cont

No	Crosses	Days to 50% flowering	Plant height	Panicle length	Panicle width	1000-grain weight	Grain yield /plant
22	ICS.A-572 x ICS.R-31	1.96	17.58**	-0.23	31.91**	-6.67**	-17.97*
23	ICS.A-572 x ICS.R-59	8.28**	74.98**	-11.68**	11.63*	-3.07	-46.21**
24	ICS.A-572 x ICS.R-66	14.38**	-27.87**	6.08	0.49	-3.88	-25.64**
25	ICS.A-572 x ICS.R-102	-5.17**	1.2	13.18**	2.87	-12.46**	-16.87**
26	ICS.A-572xICS.R-89037	6.68**	5.46**	-3.41	-12.05**	-20.29**	8.34
27	ICS.A-572 x Dorado	9.58**	14.68**	-6.75*	0.25	-11.77**	45.32**
28	ICS.A-572xICS.R-89035	-8.95**	-25**	-10.14**	23.58**	2.2	-46.71**
29	ICS.A-605 x ICS.R-31	10.33**	6.12**	1.21	40.73**	-4.04	20.6**
30	ICS.A-605 x ICS.R-59	10.96**	-2.06	-23.79**	24.6**	-4.49	-1.9
31	ICS.A-605 x ICS.R-66	2.01*	-36.19**	22.93**	14.67**	15.81**	12.03**
32	ICS.A-605 x ICS.R-102	-0.93	-15.52**	-12.33**	29.31**	18.58**	29**
33	ICS.A-605xICS.R-89037	4.02**	8.53**	7.28*	8.67*	6.12*	13.73**
34	ICS.A-605x Dorado	3.67**	-2.12	7.72*	3.03	-2.91	23**
35	ICS.A-605xICS.R-89035	-11.27**	-30.13**	17.45**	-4.09	-3.01	-4.27
36	ICS.A-610 x ICS.R-31	9.54**	28.28**	-0.29	-17.24**	-22.87**	66.97**
37	ICS.A-610x ICS.R-59	9.94**	42.12**	0.42	-19.54**	-26.02**	-13.59*
38	ICS.A-610 x ICS.R-66	5.61**	-30.07**	11.06**	-18.39**	-5.81*	-18.95**
39	ICS.A-610 x ICS.R-102	-7.45**	5.72**	3.07	-18.16**	-24.07**	0.8
40	ICS.A-610xICS.R-89037	3.78**	6.11**	2.71	-12.64**	1.35	9.64*
41	ICS.A-610 x Dorado	5.28**	31.9**	2.83	-11.95**	-14.94**	24.09**
42	ICS.A-610xICS.R-89035	-9.5**	-14.15**	15.36**	-19.08**	-6.77*	-3.95
43	ICS.A-630 x ICS.R-31	16.85**	-1.54	-5.12	-3.34	7.21*	10.45
44	ICS.A-630x ICS.R-59	14.27**	69.84**	-4.06	-0.32	7.41*	-32.63**
45	ICS.A-630x ICS.R-66	22.83**	-25.62**	16.36**	-15.65**	-16.64**	-28.58**
46	ICS.A-630 x ICS.R-102	2.31*	-10.54**	0.6	-15.23**	-1.96	-27.63**
47	ICS.A-630xICS.R-89037	22.42**	23.21**	-13.4**	-15.66**	-26.77**	-34.53**
48	ICS.A-630 x Dorado	23.91**	-5.19**	17.04**	-20.2**	-3.42	19.59**
49	ICS.A-630xICS.R-89035	-3.12**	-10**	14.02**	3.77	-2.58	-64.62**

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

C-Combining ability:

C-I-General combining ability:

General combining ability (GCA) effects of the parental lines over the two irrigation treatments are presented in table (8). GCA, for days to 50% flowering, the female lines ICSA-363, ICSA-364and ICSA-572 had negative and highly significant GCA effects, also for male lines ICSR-31 and ICSR-102 had negative and highly significant GCA effects indicating that these genotypes had favorable gene action for earliness. For plant height, the female line ICSA-363 and male line ICSR-31 had positive and highly significant GCA effects, indicating that these genotypes had favorable gene action for tallness. For panicle length, ICSA-364, the male line ICSR-31 and ICSR-66 had positive and highly significant GCA effects, indicating that these genotypes had desirable gene action for increasing length of panicle. For panicle width, ICSA-605 had positive and highly signification. For 1000-grain weight two female lines ICSA-363and ICSA-490 and male line ICSR-102 had positive and highly significant GCA effects. For grain yield/plant three female line ICSA-364 and male line ICSR-66 had positive and highly significant GCA effects. The female lineICSA-364 had favorable gene action for earliness and high yield. The male lineICSR-102 had favorable gene action for earliness and high 1000-grain weight. Different general combining ability effects among male and females lines are frequently reported by Mahmoud (1997), Hoveny *et al* (2000), Abd-El-Halim (2003) and Mahmoud and Ahmed (2010).

Table (8) Estimates of general combining ability effects for studied traits of seven restorers and CMS-lines over two irrigations.

No	Parents	Days to 50% flowering	Plant height	Panicle length	Panicle width	1000-grain weight	Grain yield /plant
Female line							
1	ICS.A-363	-1.0136**	20.4915**	-0.5388	-0.2884	1.6963**	2.4968
2	ICS.A-364	-1.2041**	-8.5561**	0.9374*	0.3687*	0.4058	10.2361**
3	ICS.A-490	1.3912**	26.0391**	-0.7031	0.0997	-1.174**	-5.0735*
4	ICS.A-572	-2.3231**	-7.7942**	-0.834	0.1616	2.2427**	-1.2413
5	ICS.A-605	2.2364**	-17.7252**	-0.315	0.7378**	0.0772	5.0825*
6	ICS.A-610	1.3554**	1.0272	0.8207	-0.2146	-2.0776**	-3.1223
7	ICS.A-630	-0.4422	-13.7823**	0.6327	-0.8646**	-1.1704**	-8.3782**
Male line							
1	ICS.R-31	-1.7636**	33.0629**	2.1541**	0.0687	-1.3799**	-5.0044*
2	ICS.R-59	1.3316**	29.301**	-1.2293**	-0.3503*	-0.2311	-4.2997
3	ICS.R-66	4.2126**	-12.568**	1.1469**	0.583**	-0.7204	8.6932**
4	ICS.R-102	-5.1684**	-12.1276**	-0.8531*	-0.2313	2.6046**	3.8694
5	ICS.R-89037	4.2721**	1.3129	-0.9554*	0.252	1.132**	-1.7044
6	Dorado	3.7483**	-1.3776	0.0946	0.1282	-1.6442**	3.2872
7	ICS.R-89035	-6.6327**	-37.6037**	-0.3578	-0.4503**	0.2391	-4.8413*
S.E		0.368	1.180	0.422	0.155	0.384	2.157

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

C-II-Specific combining ability effects:

Estimates of SCA effects (Table 9) revealed that six crosses had negative and significant SCA effects for days to 50%flowering. For plant height eleven crosses had positive and highly significant SCA effects. For panicle length three crosses had positive and significant SCA effects. For panicle width three crosses had positive and significant SCA effects. For 1000-grain weight eight crosses had positive and significant SCA effects. Six crosses showed positive and significant SCA effects for grain yield/plant, whereas seven crosses had negative effects for grain yield/plant.

Similar results were obtained by Pillai *et al* (1995),Mahmoud (1997), Hoveny *et al* (2000), Abd-El-Halim (2003) and Abo El-Wafa *et al* (2005). They reported that specific combining ability differed in magnitude among hybrids for most of studied traits.

Table (9): Specific combining ability effects of forty nine crosses for studied traits over irrigations

No	Crosses	Days to 50% flowering	Plant height	Panicle length	Panicle width	1000-grain weight	Grain yield /plant
1	ICS.A-363 x ICS.R-31	1.2041	-15.1582**	0.1816	-0.883*	0.3311	-0.8741
2	ICS.A-363 x ICS.R-59	2.1922*	-6.8129*	0.8316	0.2861	1.5323	5.1044
3	ICS.A-363 x ICS.R-66	-1.6888	7.0561*	-1.1946	0.6194	2.6383*	-5.3134
4	ICS.A-363 x ICS.R-102	-2.0578*	15.449**	0.8888	0.1837	-0.9867	-0.7646
5	ICS.A-363xICS.R-89037	2.0017*	0.7585	0.1412	0.1837	0.5859	13.5425*
6	ICS.A-363 x Dorado	-0.3078	6.1156	-1.3755	0.1075	0.2954	9.6009
7	ICS.A-363xICS.R-89035	-1.3435	-7.4082*	0.5269	-0.4973	-4.3963**	-21.2956**
8	ICS.A-364 x ICS.R-31	0.7279	15.9847**	-0.7779	0.4099	1.3716	2.1032
9	ICS.A-364 x ICS.R-59	-0.3673	13.8299**	0.1054	0.0622	-0.7772	4.5735
10	ICS.A-364 x ICS.R-66	0.6684	13.699**	0.3959	-0.1211	-0.7546	-0.9694
11	ICS.A-364 x ICS.R-102	-1.8673	-17.9915**	2.2293	-0.1401	-0.4463	3.1878
12	ICS.A-364xICS.R-89037	1.7755	-10.182**	-0.2517	-0.2068	-1.032	7.5949
13	ICS.A-364 x Dorado	-0.8673	-11.1582**	-0.485	0.5003	0.4276	-4.7468
14	ICS.A-364xICS.R-89035	-0.0697	-4.182	-1.216	-0.5044	1.2109	-11.7432*
15	ICS.A-490 x ICS.R-31	-3.034**	-25.3367**	0.2793	-0.6711	3.018**	-32.2706**
16	ICS.A-490 x ICS.R-59	0.8707	-13.2415**	0.4959	-0.002	1.4109	11.308
17	ICS.A-490 x ICS.R-66	-3.1769**	24.7109**	0.4864	0.3313	-0.2582	13.4735*
18	ICS.A-490 x ICS.R-102	3.4541**	-5.5629	0.8364	-0.4544	0.9668	-8.1694
19	ICS.A-490xICS.R-89037	-2.7364**	13.4133**	0.3054	0.0956	-1.6689	11.3044
20	ICS.A-490 x Dorado	-1.2959	-9.3129**	-1.1112	-0.3306	-3.701**	-2.8539
21	ICS.A-490xICS.R-89035	5.9184**	15.3299**	-1.2922	1.0313*	0.2323	7.208

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

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Table(9) : cont

No	Crosses	Days to 50% flowering	Plant height	Panicle length	Panicle width	1000-grain weight	Grain yield /plant
22	ICS.A-572 x ICS.R-31	-1.4031	12.5323***	1.2435	0.7503	-0.5486	14.3139*
23	ICS.A-572 x ICS.R-59	1.335	17.4609***	0.0269	-0.4639	2.7026*	-6.8075
24	ICS.A-572 x ICS.R-66	3.2041**	-9.5034**	-0.4993	-0.1473	-3.3748**	8.1997
25	ICS.A-572 x ICS.R-102	-0.3316	7.1395*	3.2507**	-0.2163	-3.3165**	0.1568
26	ICS.A-572xICS.R-89037	-1.9388	-17.551***	0.4197	-0.583	-0.4772	-23.8027***
27	ICS.A-572 x Dorado	0.5017	3.5561	-1.4469	0.0741	4.6323***	-9.0777
28	ICS.A-572xICS.R-89035	-1.3673	-13.6344***	-2.9946**	0.5861	0.3823	17.0175**
29	ICS.A-605 x ICS.R-31	-0.6293	3.4847	1.1412	0.6575	-4.9915***	-16.2599**
30	ICS.A-605 x ICS.R-59	-1.4745	-22.2534***	-3.8255**	-0.1401	-1.0653	-5.9563
31	ICS.A-605 x ICS.R-66	-0.9388	-14.1344***	1.2316	0.2432	3.0573**	4.4425
32	ICS.A-605 x ICS.R-102	3.3588**	-0.4082	-4.9184**	0.7408	1.3156	7.1413
33	ICS.A-605xICS.R-89037	0.6684	21.1514***	2.6673*	0.2741	2.3549*	4.5568
34	ICS.A-605x Dorado	-1.1412	8.3418**	1.784	-0.3187	1.7561	3.5901
35	ICS.A-605xICS.R-89035	0.1565	3.818	1.9197	-1.4568**	-2.4272*	2.4854
36	ICS.A-610 x ICS.R-31	-0.2483	20.9728***	-0.4279	-0.1068	-2.5284*	22.0866***
37	ICS.A-610x ICS.R-59	-1.2602	0.9847	1.7054	0.1456	-2.0022	-15.4349**
38	ICS.A-610 x ICS.R-66	0.8588	-22.1463***	-1.2041	-0.7044	2.4954*	-4.7861
39	ICS.A-610 x ICS.R-102	-0.4269	4.4966	-1.1541	0.1265	1.0537	-0.8289
40	ICS.A-610xICS.R-89037	-0.534	-17.6939***	0.3483	0.0432	2.6347*	2.9949
41	ICS.A-610 x Dorado	0.9065	18.4133***	-0.6184	0.217	-1.3724	-8.4551
42	ICS.A-610xICS.R-89035	0.7041	-5.0272	1.3507	0.2789	-0.2808	4.4235
43	ICS.A-630 x ICS.R-31	3.3827***	-12.4796***	-1.6398	-0.1568	3.3478**	10.9009
44	ICS.A-630x ICS.R-59	-1.2959	10.0323**	0.6602	0.1122	-1.801	7.2128
45	ICS.A-630x ICS.R-66	1.0731	0.318	0.784	-0.2211	-3.8034***	-15.0468*
46	ICS.A-630 x ICS.R-102	-2.1293*	-3.1224	-1.1327	-0.2401	1.4133	-0.723
47	ICS.A-630xICS.R-89037	0.7636	10.1037**	-3.6303**	0.1932	-2.3974*	-16.1908**
48	ICS.A-630 x Dorado	2.2041*	-15.9558***	3.2531**	-0.2497	-2.0379	11.9425*
49	ICS.A-630xICS.R-89035	-3.9983***	11.1037***	1.7054	0.5622	5.2787***	1.9044
	S.E	0.974	3.123	1.116	0.411	1.017	5.706

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

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قوة الهجين والقدرة على الأئتلاف فى الذرة الرفيعة للحبوب تحت الرى المنتظم والإجهاد المائى

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أستخدمت هذه الدراسة سبعة سلالات عقيمة ذكريا سيتوبلازميا وسبعة سلالات معيده للخصوبة من الذرة الرفيعة للحبوب وكذلك هجنهم الفردية (تسعه وأربعون هجين) وتم تقييم هذه الهجن وآبائها وهجين شندويل -1للمقارنة فى تجارب حقلية عام 2007 في مزرعة محطة البحوث الزراعية بشندويل تحت تجربتى الرى المنتظم واسقاط رية وذلك لصفات 50% تزهير و ارتفاع النبات و وزن 1000 حبه ومحصول النبات الفردى وذلك بهدف تقدير القدرة الأئتلافية العامة للأباء وقوة الهجين والقدرة الأئتلافية الخاصة وكانت أهم النتائج كما يلى:

أشار التحليل المشترك للتجربتين أن تباين الآباء والهجن كان عالى المعنويه لجميع الصفات المدروسة ، كما كان التفاعل بين الهجن والتجربتين معنويا لكل الصفات المدروسة .

أشار تحليل السلالة X الكشاف أن السلالات ICSA-364 and ICSR-66 كانت عالية المعنوية للقدرة العامة على الأئتلاف فى محصول الحبوب للنبات .كما لوحظ ان السلاتICSA-363,ICSA- 572 ICSR-31وICSR-102 كانت معنويه وسالبه للقدره العامه على الائتلاف بالنسبه لصفه 50% تذهير

لوحظت قوة الهجين بالنسبة لوزن 1000 حبه فى عدد قليل من الهجن وكانت أعلى قيمة موجبة ومعنوية لقوة الهجين هى (66.97%) ناتجة من الهجين (ICS.A-610 x ICS.R-31) لصفة محصول الحبوب للنبات .

كان متوسط محصول الحبوب للهجن ,(ICSA-364 x ICSR-102) ,(ICSA-364 x ICSR- 66) (ICSA-490 x ICSR-66) مرتفع بالمقارنة بالهجين شندويل - 1 ويقترح إعادة تقيمها لأستخدام على نطاق تجارى واسع .