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STUDIES ON COMBINING ABILITY AND HETEROSIS FOR SOME TRAITS OF ROOT AND YIELD CHARACTERS OF SOME RICE GENOTYPES UNDER NORMAL AND WATER DEFICIT CONDITIONS

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ABSTRACT

Eight genotypes cultivars of rice were crossed to obtain 15 F_1 crosses, through line x tester mating design was employed for this purpose. The experiment was carried out using line x tester mating design, during 2021 and 2022 rice growing seasons at the experimental farm of Sakha Research Station, Sakha, Kafr El-Sheikh, Egypt. Both GCA and SCA variances were found to be significant or highly significant for all studied traits. The estimates of GCA effects indicated that, the parent IR 12 G 3222 was a good general combiner for root length, number of roots/plant, and flag leaf area under both conditions. In addition, GZ 1368 was a good combiner for root volume under both conditions. While the line IR 69432 was a good combiner for root/shoot ratio under water deficit condition. The line 11 L 236 for chlorophyll content, number of filled grains/panicle, grain yield/plant and the tester Giza 178 for relative water content and grain yield/plant were good combiners under both conditions. On the other hand, the cross combinations, IR 69432 X GZ 1368 was found to be the best specific combinations for root length, number of roots/plant, root volume and root/shoot ratio under two conditions. The cross combination, IR 12 G 3213 X Giza 178 was the best specific combinations for relative water content, flag leaf area and chlorophyll content under both conditions . The cross combination, IR 12 G 3222 X Giza 178 was the best specific combination for 1000-grain weight and fertility % under both conditions. In addition, the cross combination, IR 69432 X GZ 1368 under normal and IR 69432 X Nerica 7 under water deficit were the best specific combinations for grain yield/plant. On the other hand, the crosses, IR 69432 X GZ 1368, IR 6500-127 X Nerica 7, IR 12 G 3222 X GZ 1368, 11 L 236 X GZ 1368 and11 L 236 X Nerica 7 exhibited highly significant positive estimates of heterosis as a deviation from mid and better parent for most of the studied traits under normal and water deficit condition.

Conclusively, from these results it could be concluded that *IR 12 G 3222, GZ 1368, 11 L 236 and Giza 178 were the best general combiners and the crosses IR 69432 × GZ 1368 and IR12G3222 × GZ1368 were the best crosses for estimates of SCA and heterosis effects relative to the mid- and better- parents for most of the studied traits under water deficit and normal conditions.*

Key words: Rice, root traits, physiological characters, combining ability, heterosis.

INTRODUCTION

Rice (*Oryza sativa* L.) is staple of more than 3.5 billion people to obtain 20% of their daily calorie intake. Water is essential for growth and development of rice plants (Yang 2012 and Ghoneim 2020). More than 75% of the world rice is produced under continuous flooding practices (Van *et al.* 2001). Rice production area in Egypt changes yearly based on the available irrigation water and occupies about 20% with the total production of 5.5 million tons. About one-third of total cultivated area is exposed to water shortage annually in Egypt (Abdallah *et al.* 2016). Hence, irrigation water is the most limiting factor for expanding rice cultivation area in Egypt Hassan *et al.*, (2023) and Shehab *et al*., (2023).

Drought, like many other environmental stresses, has adverse effects on crop yield. Low water availability is one of the major causes for crop yield reductions affecting the majority of the farmed regions around the world. As water resources for agronomic uses become more limiting, the development of drought-tolerant lines becomes increasingly more important Daher (2018) and Shehab *et al*., (2023).

Environmental stresses, such as water deficit and temperature rises are major factors limiting plant growth and productivity. Yield insurance can only be attained depending on the processes determining plant development and its responses to stress. Among the crops, rice as a semi aquatic crop, is probably more susceptible to drought stress than most other plant species. The shortage of irrigation water is one of the major obstacles for increasing rice production not only in Egypt but also in the worldwide AbdAllah *et al.*, (2013) and Sakran *et al.*, (2022).

The success of a plant breeding program greatly depends on right choice of parents for hybridization and the gene action of different economic traits. Combining ability analysis provides such information so as to frame the breeding program effectively. The Line x tester analysis gives reliable information about the nature and magnitude of gene action and combining ability effects present in the genetic materials. Dhillon. (1975) pointed out that the combining ability gives useful information on the choice of parents in terms of expected performance of the hybrids and their progenies. The line x tester analysis method is used to breed both self and cross-pollinated plants and to estimate favorable parents and crosses, and their general and specific combining abilities (Kempthorne, 1957).

Therefore, the aim of this study estimate combining ability and heterosis for some traits of root and yield characters of some rice genotypes under normal and water deficit conditions.

MATERIALS AND METHODS

The experiment was carried out using line x tester mating design, during 2021 and 2022 rice growing seasons at the Experimental Farm of Sakha Research Station, Sakha, Kafr El-Sheikh, Egypt. The experimental material of the present study comprised five lines, namely, IR 69432, IR 6500-127, IR 12 G 3222, IR 12 G 3213 and 11 L 236 and three testers namely, Gz 1368-S-5-4, Nerica 7 and Giza 178, which provided from the pure genetic stock of the Rice Research Section, Field Crops Research Institute, Agricultural Research Center, Egypt. In 2021, the five lines and three testers were grown at RRTC farm in three successive dates of planting with ten days intervals in order to overcome the differences in flowering time between parents. At flowering time, hybridization between the parents was done; 30 days old seedlings of each parent were individually transplanted in the permanent field in seven rows following the technique proposed by Jodon (1938) to produce their F1 using line x tester mating design.

In 2022 season, seeds of the line x tester F1 Hybrids and their parents were sown in dry seedbed. After thirty days from sowing, seedlings of each F1 hybrids and their parents were evaluated in two separate irrigation experiments, the first experiment (normal condition) was irrigated every 4 days (6000 m^3 /fed), and the plots of this experiment were kept saturated with water from transplanting up to 2 weeks before harvesting. However, the second experiment (water stress condition) was irrigated every 10 days (3800 m^3/fed) according to Gaballa (2021). The two experiments were designed in randomized complete blocks with three replications. Each replicate comprised of 5 rows of each parents and 3 rows for F_1 hybrids. The row was 5 m long and 20x20 cm was maintained between rows and seedlings. Recommended cultural practices were followed for the two conditions. For root measurements, 20 rice plants from each F_1 hybrids and their parents were grown in plastic bag, one plant/bag. The bag was 20 cm in diameter and 0.5 m in height with holes on the top and down two sides. Bags were placed with water deficit treated basin. The studied traits, root length (cm), number of roots/plant, root volume (cm^3) and root/soot ratio, chlorophyll content, number of panicles/plant, number of filled grains/ panicle, fertility percentage (%), 1000-grain weight (g) and grain yield/plant (g) were scored according to IRRI (1996). Relative water content % (R.W.C): It was determined by the method of Barrs and Weatherly (1962). Flag leaf area (cm^2): It was measured at the flowering stage following the manual method proposed by Yoshida *et al*. (1962).

Combining ability analysis was done using line x tester. The variances for general combining ability and specific combining ability were tested against their respective error variances derived from ANOVA reduced to mean level. Significance test for GCA and SCA effects were performed using T-test. The following variance components were estimated based on the expectations of mean squares according to Kempthorne (1957). Heterosis was estimated according to Folconer and Mackay (1996). Furthermore, appropriate L. S. D. values were calculated to test the significance of heterotic effects according to the formula suggested by Wynne *et al.* (1970).

RESULTS AND DISCUSSION

Analysis of variance

The mean square estimates of root, yield and its components and some physiological traits, *i.e.* root length, number of roots/plant, root volume, root/shoot ratio, flag leaf area, chlorophyll content, relative water content, number of panicles/plant, number of filled grains/panicle, 1000-grain weight (g), fertility percentage and grain yield/plant (g), under water deficit and normal irrigation conditions are presented in Table (1). Significant and highly significant mean square estimates were recorded for genotypes, parents, crosses and the interaction among them for all these traits under both water deficit and normal conditions, except root/shoot ratio under both conditions for all sources of variance, chlorophyll content and relative water content under water deficit and 1000-grain weight under normal condition for parents vs. crosses which were insignificant. These results agree with those obtained by Saleem *et al., (*2010), El-Hity *et al.,* (2015), Daher (2018), Abdelaty *et al.,* (2022) and Hassan *et al.,* (2023). Estimates of both general (GCA) and specific combining ability (SCA) variances were found to be highly significant for all root traits, yield and its components and some physiological traits under both water deficit and normal irrigation conditions, except root/shoot ratio under both conditions and root length for testers under water deficit condition which were insignificant, indicating the importance of additive and non-additive genetic variances in determining the inheritance of these studied traits. Similar results were obtained

Table (1): Mean square estimates of ordinary and combining ability analysis for root characteristics, some physiological, yield and yield components under water deficit and normal conditions.

S.O.V	d.f	Root length		Number of roots/plant		Root volume		Root /shoot ratio	
		N	D	N	D	N	D	N	D
Replications	2	0.85	0.87	2.89	2.13	2.36	1.84	0.09	0.01
Genotypes	22	43.80**	21.15**	11991.76**	6405.60**	1104.61**	452.45**	0.62	0.26
Parents	7	41.45**	22.49**	3540.14**	926.14**	185.95**	47.52**	0.74	0.04
Parents vs. Crosses	1	11.91**	5.54*	115897.00**	78144.12**	2846.74**	2087.03**	1.90	0.18
Crosses	14	47.25**	21.59**	8795.77**	4021.14**	1439.51**	538.17**	0.46	0.37
Lines (female gca)	4	24.08**	18.70**	4181.20**	4857.50**	245.17**	96.19**	0.60	0.22
Testers (male gca)	2	38.25**	2.57	9504.80**	6068.60**	4633.09**	1762.02**	0.48	0.31
Lines x Testers (sca)	8	61.09**	27.80**	10925.80**	3091.10**	1238.28**	453.19**	0.39	0.46
Error	45	0.39	0.43	2.08	1.46	2.59	2.42	0.10	0.04

*and ** significant at 0.05 and 0.01 probability levels, respectively

Table (1): Cont….

S.O.V	d.f	Flag leaf area		Chlorophyll content		Relative water content		No. of panicles /plant	
		N	D	N	D	N	D	N	D
Replications	2	0.17	1.94	1.75	1.62	2.05	2.79	1.09	0.39
Genotypes	22	267.77**	92.75**	34.19**	36.49**	513.90**	636.62**	162.75**	19.54**
Parents	7	257.53**	75.97**	36.60**	40.39**	421.22**	972.68**	51.38**	11.79**
Parents vs. Crosses	1	115.92**	19.53**	96.40**	0.94	620.39**	1.41	1430.01**	42.61**
Crosses	14	283.74**	106.37**	28.54**	37.07**	552.64**	513.96**	127.91**	21.77**
Lines (female gca)	4	36.60**	90.37**	29.44**	8.56**	387.24**	150.75**	35.70**	16.20**
Testers (male gca)	2	1169.40**	90.98**	53.06**	13.64**	679.51**	229.69**	704.60**	34.20**
Lines x Testers (sca)	8	185.89**	118.21**	21.96**	57.19**	603.61**	766.64**	29.85**	21.45**
Error	45	0.07	0.63	1.65	1.69	0.87	0.77	0.97	2.16

Table (1): Cont…

S.O.V	d.f	1000 grain weight		No. of filled grains / panicle		Fertility %		Grain yield/ plant	
		N	D	N	D	N	D	N	D
Replications	2	0.16	0.68	0.54	0.70	1.08	2.23	1.20	0.97
Genotypes	22	20.75**	19.39**	3961.30**	4254.78**	23.62**	262.80**	225.07**	231.84**
Parents	7	22.96**	18.53**	3712.23**	7769.95**	24.98**	121.88**	144.00**	104.04**
Parents vs. Crosses	1	1.53	48.40**	122.96**	126.39**	8.95**	120.49**	3064.78**	2308.08**
Crosses	14	21.01**	17.75**	4359.99**	2792.09**	23.98**	343.42**	62.77**	147.44**
Lines (female gca)	4	30.04**	12.03**	2142.92**	2105.80**	37.13**	230.85**	58.16**	33.85**
Testers (male gca)	2	37.83**	21.78**	12020.62**	2568.20**	8.60**	51.97**	162.76**	478.03**
Lines x Testers (sca)	8	12.30**	19.61**	3553.37**	3191.20**	21.26**	472.57**	40.07**	121.59**
Error	45	0.37	1.94	7.01	6.10	2.07	1.29	2.63	3.03

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

previously by Rahimi *et al.,* (2010), El-Hity *et al.,* (2015), Daher (2018) and Devi *et al.,* (2018) and Sakran *et al. (*2022).

Mean performance of parents and their F_1 generation

Table (2) shows that the highest mean values of root length and root volume were recorded by parent IR 69432 under water deficit and normal conditions. Moreover, Giza 178 gave the highest mean values for number of roots/plant under both conditions. On the other hand, the highest mean values of root length were recorded by cross, IR 69432 X GZ 1368 (23.3, 29.4 cm) under water deficit and normal conditions, respectively.

On the other hand, the results showed that the cross namely, IR 12 G 3222 X Giza 178 (225 and 330 roots) under water deficit and normal conditions, respectively recorded the highest mean values of number of roots/plant. While, the cross, IR 69432 X GZ 1368 under water deficit and the cross IR 69432 X GZ 1368 under normal condition gave the highest mean values for root volume trait. Concerning to root/shoot ratio, the highest mean values were detected by the genotype Nerica 7 under both conditions. The results also revealed that the F1 hybrid, IR 69432 X GZ 1368 exhibited the highest mean values (1.50 and 1.46) for root/shoot ratio under water deficit and normal conditions, respectively. For flag leaf area, Table (2) shows that the variety, IR 6500-127 recorded the highest mean values under water deficit and normal conditions, respectively.

On the other hand, the highest mean values were recorded by cross, IR 6500-127 X Nerica 7 under both conditions. In the case of, chlorophyll content data in Table (2) exhibited that among parents IR 6500-127 and IR 69432 scored the highest mean values under water deficit and normal conditions (47.1 and 41.5 SPAD), respectively. Among hybrids 11 L 236 X Nerica 7 under water deficit and normal conditions scored the highest mean values for this trait. For relative water content, among parents the highest mean values under water deficit and normal conditions were obtained by Nerica 7 and Giza 178. On the other side, among hybrids IR 69432 X Giza 178 recorded the highest mean values under both conditions for this trait. On the other hand, the crosses, IR 12 G 3213 X Nerica 7 under water stress, and IR 12 G 3222 X Nerica 7
under normal conditions exhibited the highest mean values for number of filled grains/panicle.

The cross, IR 6500-127 X Nerica 7 exhibited the highest mean values for 1000-grain weight (27.2 g, and 29.1 g) under water deficit and normal conditions, respectively. While, the crosses, IR 6500-127 X GZ 1368 under water deficit and 11 L 236 X GZ 1368, under normal conditions gave the

Table (2): Mean performance of the eight parents and their F_1 generation for root characteristics, some physiological traits, yield and yield components traits under water deficit and normal conditions

Crosses	Root Length (cm)		Number of roots/plant		Root volume (cm^3)		Root /shoot ratio	
	N	D	N	D	N	D	N	D
IR 69432 X GZ 1368	29.4	23.3	220	100	100.0	43	1.46	1.05
IR 69432 X Nerica 7	18.0	17.7	182	120	30.0	23	0.79	0.25
IR 69432 X Giza 178	21.9	18.0	140	90	30.3	15	0.85	0.15
IR 6500-127 X GZ 1368	25.7	13.1	150	95	51.0	32	0.85	0.23
IR 6500-127 X Nerica 7	20.2	18.6	240	130	31.3	15	0.68	0.62
IR 6500-127 X Giza 178	24.1	20.5	150	100	40.0	29	0.46	0.31
IR 12 G 3222 X GZ 1368	29.1	18.8	192	120	75.0	61	0.60	0.24
IR 12 G 3222 X Nerica 7	29.1	21.1	150	115	25.0	17	0.70	0.59
IR 12 G 3222 X Giza 178	22.9	22.2	330	225	37.0	20	0.63	0.30
IR 12 G 3213 X GZ 1368	26.1	22.4	190	120	67.0	35	1.60	0.24
IR 12 G 3213 X Nerica 7	29.0	18.4	190	140	60.0	34	0.79	0.40
IR 12 G 3213 X Giza 178	20.2	17.2	270	190	31.0	19	0.79	0.18
11 L 236 X GZ 1368	19.2	16.0	160	99	45.0	35	0.31	0.26
11 L 236 X Nerica 7	28.0	17.4	150	136	70.0	46	0.71	0.26
11 L 236 X Giza 178	24.6	19.0	240	130	29.0	17	0.82	0.22
IR 69432	27.2	21.5	160	90	50.0	24	0.26	0.42
IR 6500-127	21.2	15.0	160	48	28.0	16	0.31	0.28
IR 12 G 3222	24.5	16.0	98	52	37.0	20	0.21	0.31
IR 12 G 3213	22.4	20.2	112	60	26.0	20	0.04	0.31
11 L 236	26.9	21.2	100	35	30.0	13	0.21	0.12
GZ 1368	23.8	18.2	80	65	40.0	21	0.51	0.21
Nerica 7	27.1	19.5	64	38	30.0	13	0.81	0.45
Giza 178	25.2	19.8	235	165	36.0	22	0.89	0.23
LS D at 0.05	1.02	1.08	2.38	2.00	2.66	2.57	0.52	0.35
at 0.01	1.37	1.44	3.18	2.67	3.55	3.43	0.69	0.46

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

Table (2): Cont.

Crosses	Flag leaf area, (cm^2)		Chlorophyll content (SPAD)		Relative water Content		No. of panicle /plant	
	N	D	N	D	N	D	N	D
IR 69432 X GZ 1368	47.1	25.5	48.6	37.3	73.9	41.2	27	11
IR 69432 X Nerica 7	51.6	16.8	44.0	42.2	60.4	56.1	19	17
IR 69432 X Giza 178	26.7	23.3	48.3	36.8	88.7	97.2	29	17
IR 6500-127 X GZ 1368	37.7	31.0	46.1	31.6	86.4	66.7	23	11
IR 6500-127 X Nerica 7	57.8	34.8	43.3	40.7	50.5	73.2	26	12
IR 6500-127 X Giza 178	26.8	17.6	47.9	39.1	43.3	63.2	30	14
IR 12 G 3222 X GZ 1368	53.9	33.3	43.0	40.9	75.0	75.2	28	16
IR 12 G 3222 X Nerica 7	40.3	32.2	42.3	35.4	70.1	68.4	20	11
IR 12 G 3222 X Giza 178	27.8	19.7	44.9	38.6	70.2	61.4	33	16
IR 12 G 3213 X GZ 1368	42.7	24.6	43.5	41.9	61.3	60.4	23	19
IR 12 G 3213 X Nerica 7	37.5	29.7	39.3	33.1	73.7	63.9	22	12
IR 12 G 3213 X Giza 178	30.2	24.9	47.4	36.6	75.3	72.2	31	17
11 L 236 X GZ 1368	39.1	20.9	42.4	41.2	64.9	89.0	24	16
11 L 236 X Nerica 7	40.3	18.1	50.1	42.8	43.9	66.4	29	12
11 L 236 X Giza 178	36.3	26.8	48.6	34.3	73.5	70.0	28	15
IR 69432	45.3	29.6	47.1	39.8	77.6	42.9	17	11
IR 6500-127	54.8	31.8	45.5	41.5	80.3	67.8	11	10
IR 12 G 3222	33.4	30.5	39.9	36.6	53.4	70.1	16	14
IR 12 G 3213	46.7	22.4	46.2	39.5	68.8	66.4	21	14
11 L 236	51.8	22.0	40.2	38.2	62.5	71.3	17	14
GZ 1368	30.3	28.9	37.1	30.1	74.7	47.0	21	13
Nerica 7	44.9	17.7	43.8	36.4	91.1	86.1	13	11
Giza 178	46.3	37.9	42.9	41.1	81.2	97.3	23	16
LS D at 0.05	0.44	1.31	2.12	2.14	1.54	1.45	2.01	2.42
at 0.01	0.58	1.76	2.83	2.87	2.05	1.93	2.68	3.24

*and ** significant at 0.05 and 0.01 probability levels, respectively

Table (2): Cont.

Crosses	1000-grain Weight, (g)		No. of filled grains/ panicle		fertility (%)		Grain yield /plant, (g)	
	N	**D**	**N**	**D**	**N**	**D**	**N**	**D**
IR 69432 X GZ 1368	25.0	19.7	184	139	92.7	89.1	51.4	30.8
IR 69432 X Nerica 7	22.0	20.0	163	133	91.3	87.4	45.3	35.3
IR 69432 X Giza 178	28.0	19.1	157	128	86.8	74.2	55.0	39.8
IR 6500-127 X GZ 1368	28.0	19.8	185	139	92.1	90.2	49.5	30.8
IR 6500-127 X Nerica 7	29.1	27.2	208	125	90.6	81.2	47.2	33.3
IR 6500-127 X Giza 178	28.4	20.8	200	182	89.6	70.9	55.3	39.2
IR 12 G 3222 X GZ 1368	23.0	19.2	171	120	86.8	68.7	48.0	38.4
IR 12 G 3222 X Nerica 7	25.0	20.2	245	210	90.5	84.8	56.1	20.0
IR 12 G 3222 X Giza 178	28.9	24.8	154	130	93.5	87.0	57.7	39.6
IR 12 G 3213 X GZ 1368	23.0	20.2	171	164	92.8	90.0	47.9	42.0
IR 12 G 3213 X Nerica 7	22.0	18.2	274	208	88.2	80.1	56.8	21.7
IR 12 G 3213 X Giza 178	26.0	22.2	170	150	91.5	83.8	57.4	40.0
11 L 236 X GZ 1368	22.0	19.2	245	188	97.1	87.5	53.0	44.5
11 L 236 X Nerica 7	27.0	23.2	223	170	94.1	86.0	59.4	32.5
11 L 236 X Giza 178	25.0	21.2	148	131	93.9	85.9	57.3	37.0
IR 69432	26.0	19.0	212	168	91.5	89.1	41.0	21.5
IR 6500-127	28.5	24.2	203	122	91.7	76.2	31.0	17.0
IR 12 G 3222	27.0	24.0	237	219	93.7	91.8	43.5	31.0
IR 12 G 3213	24.0	22.8	280	210	91.6	91.6	45.2	29.3
11 L 236	23.0	21.8	245	188	90.2	75.5	42.6	27.1
GZ 1368	22.0	19.8	174	113	93.5	86.1	38.7	18.7
Nerica 7	26.0	23.8	135	88	85.0	81.6	26.3	14.9
Giza 178	21.0	19.8	185	135	88.2	84.6	45.0	31.3
LS D at 0.05	1.00	2.26	4.37	4.07	2.37	1.87	2.67	2.87
at 0.01	1.34	3.02	5.84	5.45	3.17	2.50	3.57	3.83

*and ** significant at 0.05 and 0.01 probability levels, respectively

lowest mean values of sterility %. Regarding to grain yield/plant, the variety, IR 12 G 3213 recorded the highest mean values under normal condition. While, the variety Giza 178 gave the highest mean values of grain yield under water deficit condition.

On the other hand, the highest mean values were recorded by cross, 11 L 236 x GZ 1368 under water deficit condition and 11 L 236 x GZ 1368 under normal condition.

General and specific combining ability effects:

Table (3) shows that the estimates of GCA effects indicated that the parent IR 12 G 3222 was a good combiner for root length, number of roots/plant and flag leaf area under both conditions. The parent GZ 1368 was a good combiner for root volume under both conditions. Moreover, the parent, IR

Table(3): Estimates of general combining ability (GCA) effects for root characteristics, some physiological traits, yield and yield components traits under water deficit and normal conditions

Genotypes	Root Length		Number of roots /plant		Root volume		Root /shoot ratio	
	N	D	N	D	N	D	N	D
L1-IR 69432	-1.50**	0.75**	-16.27**	-24.00**	5.33**	-2.42**	0.21*	0.23**
L2-IR 6500-127	-1.16**	-1.53**	-16.93**	-19.00**	-7.33**	-3.98**	-0.16	0.05
L3-IR 12 G3222	2.50**	1.78**	27.07**	26.00**	-2.44**	3.24**	-0.18	0.00
L4-IR 12 G3213	0.72**	0.43	19.73**	22.67**	4.56**	-0.09	0.35**	-0.13
L5- 11 L236	-0.57*	-1.43**	-13.60**	-5.67**	-0.11	3.25**	-0.21*	-0.15*
S.E (g_i)	0.21	0.22	0.48	0.40	0.54	0.52	0.10	0.07
S.E (g_i-g_j)	0.29	0.31	0.68	0.57	0.76	0.73	0.15	0.10
L.S.D at 0.05	0.42	0.44	0.97	0.81	1.09	1.05	0.20	0.14
at 0.01	0.57	0.59	1.30	1.08	1.46	1.40	0.27	0.19
T1- GZ 1368	1.34**	-0.20	-14.53**	-20.53**	19.49**	11.84**	0.21*	0.09
T2-Nerica 7	0.43*	-0.28	-14.53**	0.87**	-4.84**	-2.42**	-0.09	0.07
T3-Giza 178	-1.77**	0.48**	29.07**	19.67**	-14.64**	-9.42**	-0.11	-0.17**
S.E (g_i)	0.16	0.17	0.37	0.31	0.42	0.40	0.08	0.05
S.E (gt-g_i)	0.23	0.24	0.53	0.44	0.59	0.57	0.11	0.08
LSD at 0.05	0.32	0.34	0.75	0.63	0.85	0.81	0.16	0.10
at 0.01	0.43	0.46	1.00	0.84	1.13	1.08	0.22	0.14

*and** significant at 0.05 and 0.01 probability levels, respectively

Table 3 : Cont.

Genotypes	Flag leaf area		Chlorophyll content		Relative water content		No. of panicles /plant	
	N	D	N	D	N	D	N	D
L1-IR 69432	2.07**	-3.41**	1.63**	0.80	6.91**	-3.47**	0.80	0.60
L2-IR 6500-127	1.08**	2.51**	0.45	-1.03*	-7.34**	-0.61*	-1.87**	-2.07**
L3-IR 12 G3222	0.95**	3.13**	-1.91**	0.14	4.36**	0.04	0.13	-0.07
L4-IR 12 G3213	-2.93**	1.12**	-1.89**	-0.97*	2.72**	-2.80**	1.80**	1.60**
L5- 11 L236	-1.16**	-3.35**	1.73**	1.07*	-6.64**	6.84**	-0.87	-0.07
S.E (gi)	0.09	0.27	0.43	0.43	0.31	0.29	0.44	0.49
S.E (gi-gj)	0.12	0.38	0.61	0.61	0.44	0.41	0.63	0.69
L.S.D at 0.05	0.18	0.55	0.87	0.87	0.63	0.59	0.88	0.98
at 0.01	0.24	0.73	1.16	1.16	0.84	0.78	1.18	1.32
T1- GZ 1368	4.38**	1.77**	-0.60	0.40	4.89**	-1.81**	-0.20	0.20
T2-Nerica 7	5.79**	1.05**	-1.51**	0.69	-7.68**	-2.68**	-1.40**	-1.60**
T3-Giza 178	-10.16**	-2.81**	2.11**	-1.09**	2.79**	4.49**	1.60**	1.40**
S.E (gi)	0.07	0.21	0.33	0.34	0.24	0.23	0.34	0.38
S.E (gt-gi)	0.09	0.29	0.47	0.47	0.34	0.32	0.49	0.54
LSD at 0.05	0.14	0.42	0.67	0.69	0.49	0.46	0.69	0.77
at 0.01	0.19	0.57	0.89	0.92	0.65	0.62	0.92	1.03

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

Table 3 : Cont.

Genotypes	1000-grain Weight		No. of filled grains/ panicle		Fertility %		Grain yield/ plant	
	N	D	N	D	N	D	N	D
L1-IR 69432	-0.49*	-1.41**	-25.18**	-21.13**	-1.16*	1.78**	-2.58**	0.31
L2-IR 6500-127	3.01**	1.59**	4.49**	-5.80**	-0.68	-1.02*	-2.49**	-0.56
L3-IR 12 G 3222	0.14	0.40	-3.29**	-1.13	-1.16*	-8.27**	0.78	-2.33**
L4-IR 12 G 3213	-1.83**	-0.79	11.82**	19.53**	-0.60	2.83**	0.88	-0.43
L5- 11 L 236	-0.83**	0.21	12.16**	8.53**	3.60**	4.68**	3.41**	3.01**
S.E (g_i)	0.20	0.46	0.88	0.82	0.48	0.38	0.54	0.58
S.E (g_i-g_j)	0.29	0.66	1.25	1.16	0.68	0.53	0.76	0.82
L.S.D at 0.05	0.44	0.92	1.78	1.66	0.97	0.77	1.09	1.17
at 0.01	0.54	1.24	2.38	2.21	1.30	1.03	1.46	1.57
T1- GZ 1368	-1.29**	-1.39**	-1.78**	-4.47**	0.87*	-0.68*	-3.20**	2.31**
T2-Nerica 7	-0.48**	0.77*	29.16**	14.73**	-0.50	2.11**	-0.19	-6.43**
T3-Giza 178	1.77**	0.62	-27.38**	-10.27**	-0.37	-1.43**	3.38**	4.13**
S.E (g_i)	0.16	0.36	0.68	0.64	0.37	0.29	0.42	0.45
S.E (g_t-g_j)	0.22	0.51	0.97	0.90	0.53	0.41	0.59	0.64
LSD at 0.05	0.32	0.72	1.37	1.29	0.75	0.59	0.85	0.91
at 0.01	0.43	0.97	1.84	1.73	1.00	0.78	1.13	1.22

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

12 G 3213 was a good combiner for root/shoot ratio under normal condition and IR 69432 was a good combiner for root/shoot ratio under water deficit conditions. The parent IR 69116 was a good general combiner for chlorophyll content under normal condition.

11 L 236 under both conditions was found to be good combiners for chlorophyll content. Moreover, Giza 178 under both conditions was the best general combiner for relative water content. While, the tester Giza 178 was the best general combiner for number of panicles/plant. In addition, IR 6500-127 was the best general combiner for 1000-grain weight under both conditions and 11 L 236 rice line was a good general combiner for increasing number of filled grains/panicle and fertility % under both conditions. While, the genotypes 11 L 236 and Giza 178 were the best general combiners for grain yield/plant under water deficit and normal conditions. Generally, IR 12 G 3222, GZ 1368, 11 L 236 and Giza 178 were the best ones, since it possessed significant and desirable GCA effects for most of the studied traits under water deficit and normal conditions.

The estimates of specific combining ability of fifteen crosses for root, physiological and grain yield characters are presented in Table (4). Highly significant positive estimates of specific combining ability effects were recorded in six crosses under water deficit and seven crosses under normal conditions for root length. The highest positive values were estimated for the cross, IR 69432 x GZ 1368 under both conditions. Highly significant and positive estimates of specific combining ability effects were detected for seven crosses under water deficit and six crosses under normal conditions for number of roots/plant. highly significant positive estimates of specific combining ability effects were detected for five crosses under water deficit and six crosses under normal conditions for root volume, The highest positive value was estimated for the crosses IR 69432 x GZ 1368, IR 6500-127 x Giza 178, IR 12 G 3222 x GZ 1368, IR 12 G 3213 x Nerica 7 and 11 L 236 x Nerica 7 under both conditions. Significant and highly significant positive estimates of specific combining ability effects were detected for two crosses under water deficit and normal conditions for root/shoot ratio. Generally, the highest positive value was estimated by the cross IR 69432 x GZ 1368 for all root traits under both condition.

Highly significant positive estimates of specific combining ability effects were detected for nine and seven crosses for flag leaf area under water deficit and normal conditions, respectively. The estimates of SCA showed that significant and highly significant positive (SCA) values were recorded in three crosses under normal condition for chlorophyll content and eight crosses under water deficit condition showed highly significant positive estimates of (SCA) effects for this trait. Significant and highly significant positive estimates of

Table (4): Estimates of specific combining ability (SCA) effects for the studied traits under water deficit and normal conditions

Crosses	Root Length		Number of roots /plant		Root volume		Root /shoot ratio	
	N	D	N	D	N	D	N	D
IR 69432 X GZ 1368	4.81**	3.86**	53.87**	17.20**	27.07**	4.16**	0.52**	0.77**
IR 69432 X Nerica 7	-5.45**	-1.72**	15.87**	15.80**	-18.60**	-1.58	-0.15	-0.46**
IR 69432 X Giza 178	0.65	-2.14**	-69.73**	-33.00**	-8.47**	-2.58**	-0.07	-0.31*
IR 6500-127 X GZ 1368	1.04**	-4.12**	-15.47**	7.20**	-9.27**	-4.96**	-0.02	-0.31*
IR 6500-127 X Nerica 7	-3.55**	1.47**	74.53**	20.80**	-4.60**	-8.02**	0.11	0.28*
IR 6500-127 X Giza 178	2.51**	2.65**	-59.07**	-28.00**	13.87**	12.98**	-0.39*	0.03
IR 12 G 3222 X GZ 1368	0.72	-1.75**	-17.47**	-12.80**	9.84**	16.49**	-0.25	-0.25*
IR 12 G 3222 X Nerica 7	1.63**	0.67	-59.47**	-39.20**	-15.82**	-13.24**	0.15	0.18
IR 12 G 3222 X Giza 178	-2.35**	1.08**	76.93**	52.00**	5.98**	-3.24**	0.10	0.07
IR 12 G 3213 X GZ 1368	-0.49	3.27**	-12.13**	-9.47**	-5.16**	-6.18**	0.55**	-0.13
IR 12 G 3213 X Nerica 7	3.75**	-0.64	-12.13**	-10.87**	12.18**	7.09**	-0.29	0.05
IR 12 G 3213 X Giza 178	-3.25**	-2.63**	24.27**	20.33**	-7.02**	-0.91	-0.27	0.07
11 L 236 X GZ 1368	-6.08**	-1.26**	-8.80**	-2.13**	-22.49**	-9.51**	-0.51**	-0.08
11 L 236 X Nerica 7	3.63**	0.22	-18.80**	13.47**	26.84**	15.76**	0.19	-0.06
11 L 236 X Giza 178	2.44**	1.04**	27.60**	-11.33**	-4.36**	-6.24**	0.32	0.14
S.E (S_{ij})	0.36	0.38	0.83	0.70	0.93	0.90	0.18	0.12
S.E (S_{ij} - S_{ik})	0.51	0.53	1.18	0.99	1.31	1.27	0.26	0.17
LS D at 0.05	0.73	0.77	1.68	1.41	1.88	1.82	0.36	0.24
at 0.01	0.97	1.03	2.24	1.89	2.51	2.43	0.49	0.32

*and ** significant at 0.05 and 0.01 probability levels, respectively

Table 4 : Cont.

Crosses	Flag leaf area		Chlorophyll content		Relative water content		No. of panicles /plant	
	N	D	N	D	N	D	N	D
IR 69432 X GZ 1368	0.93**	1.87**	2.23**	-2.08**	-5.35**	-21.82**	-3.80**	-4.20**
IR 69432 X Nerica 7	4.03**	-6.13**	-1.48*	3.18**	-6.23**	-6.05**	3.40**	3.60**
IR 69432 X Giza 178	-4.95**	4.26**	-0.75	-3.09**	11.58**	27.87**	0.40	0.60
IR 6500-127 X GZ 1368	-7.44**	1.40**	0.95	-5.95**	21.46**	0.76	-1.13	-1.53
IR 6500-127 X Nerica 7	11.25**	5.97**	-0.94	2.86**	-1.89**	8.20**	1.07	1.27
IR 6500-127 X Giza 178	-3.80**	-7.37**	-0.01	3.09**	-19.57**	-8.96**	0.07	0.27
IR 12 G 3222 X GZ 1368	8.85**	3.14**	0.16	2.18**	-1.65**	8.68**	1.87**	1.47
IR 12 G 3222 X Nerica 7	-6.13**	2.77**	0.46	-3.55**	6.04**	2.77**	-1.93*	-1.73*
IR 12 G 3222 X Giza 178	-2.72**	-5.92**	-0.62	1.37	-4.39**	-11.45**	0.07	0.27
IR 12 G 3213 X GZ 1368	1.49**	-3.60**	0.69	4.31**	-13.68**	-3.30**	3.20**	2.80**
IR 12 G 3213 X Nerica 7	-5.07**	2.30**	-2.61**	-4.80**	11.25**	1.11*	-2.60**	-2.40**
IR 12 G 3213 X Giza 178	3.57**	1.31**	1.92*	2.49**	2.43**	2.19**	-0.60	-0.40
11 L 236 X GZ 1368	-3.83**	-2.81**	-4.03**	1.55*	-0.78	15.69**	-0.13	1.47
11 L 236 X Nerica 7	-4.08**	-4.91**	4.58**	2.31**	-9.15**	-6.04**	0.07	-0.73
11 L 236 X Giza 178	7.91**	7.72**	-0.55	-3.85**	9.93**	-9.65**	0.07	-0.73
S.E (S_i)	0.15	0.46	0.74	0.75	0.54	0.51	0.77	0.85
S.E (S_i - S_{ij})	0.21	0.65	1.05	1.06	0.76	0.72	1.09	1.20
LSD at 0.05	0.30	0.93	1.50	1.52	1.09	1.03	1.56	1.72
at 0.01	0.41	1.24	2.00	2.03	1.46	1.38	2.08	2.30

*and ** significant at 0.05 and 0.01 probability levels, respectively

Table 4 : Cont.

Crosses	1000 grain Weight		No. of filled grains/ panicle		Fertility %		Grain yield/ plant	
	N	D	N	D	N	D	N	D
IR 69432 X GZ 1368	1.29**	1.46	17.78**	10.13**	1.56	6.21**	4.02**	-6.81**
IR 69432 X Nerica 7	-2.52**	-0.37	-34.16**	-15.07**	1.53	1.73*	-5.09**	6.43**
IR 69432 X Giza 178	1.23**	-1.08	16.38**	4.93**	-3.10**	-7.94**	1.07	0.37
IR 6500-127 X GZ 1368	0.79*	-1.43	-10.89**	-5.20**	0.48	10.11**	2.03*	-5.94**
IR 6500-127 X Nerica 7	1.06**	3.87**	-18.82**	-38.40**	0.30	-1.67*	-3.28**	5.30**
IR 6500-127 X Giza 178	-1.85**	-2.44**	29.71**	43.60**	-0.78	-8.44**	1.25	0.64
IR 12 G3222 X GZ 1368	-1.34**	-0.80	-16.11**	-28.87**	-4.34**	-24.10**	-2.74**	3.43**
IR 12 G3222 X Nerica 7	-0.16	-1.96*	24.62**	41.93**	0.73	9.18**	2.36*	-6.23**
IR 12 G3222 X Giza 178	1.50**	2.76**	-8.51**	-13.07**	3.60**	14.91**	0.38	2.81**
IR 12 G3213 X GZ 1368	0.63	1.39	-32.22**	-5.53**	1.10	6.06**	-2.94**	5.13**
IR 12 G3213 X Nerica 7	-1.19**	-2.77**	39.84**	19.27**	-2.13*	-6.67**	2.96**	-6.43**
IR 12 G3213 X Giza 178	0.56	1.38	-7.62**	-13.73**	1.04	0.61	-0.02	1.31
11 L 236 X GZ 1368	-1.37**	-0.61	41.44**	29.47**	1.20	1.71*	-0.37	4.19**
11 L 236 X Nerica 7	2.81**	1.23	-11.49**	-7.73**	-0.43	-2.57**	3.06**	0.93
11 L 236 X Giza 178	-1.44**	-0.62	-29.96**	-21.73**	-0.76	0.86	-2.68**	-5.13**
S.E (S_{ij})	0.35	0.80	1.53	1.43	0.83	0.66	0.94	1.00
S.E ($S_{ij} - S_{kl}$)	0.50	1.14	2.16	2.02	1.17	0.93	1.32	1.42
LSD at 0.05	0.71	1.62	3.09	2.89	1.68	1.33	1.90	2.02
at 0.01	0.95	2.16	4.13	3.86	2.24	1.78	2.54	2.70

*and ** significant at 0.05 and 0.01 probability levels, respectively

specific combining ability were inventoried for seven crosses under water deficit and six crosses under normal conditions for relative water content.

Generally, the best hybrid combinations was IR 12 G 3213 x Giza 178 for flag leaf area, chlorophyll content and relative water content under both conditions. Highly significant positive estimates of specific combining ability effects were recorded in 2 crosses under water deficit and 3 crosses under normal conditions for number of panicles/plant, The highest positive values were estimated for the crosses, IR 69432 x Nerica 7 and IR 12 G 3213 x GZ 1368 under both conditions. The cross combination IR 12 G 3222 x Giza 178 exhibited that highly significant and positive estimates of specific combining ability effects for 1000-grain weight and fertility % under both conditions. Highly significant and positive estimates of specific combining ability effects were detected for 6 crosses under water deficit and 6 crosses under normal condition for number of filled grains/panicle. Moreover, IR 69432 x GZ 1368 under normal condition and IR 69432 x Nerica 7 under water stress condition were the best cross combination for grain yield /plant. Significant and highly significant positive estimates of specific combining ability effects were recorded in six, five crosses for grain yield/plant under water deficit and normal conditions, respectively, the highest positive values were estimated for the crosses, IR 69432 x Nerica 7 under water deficit condition and IR 69432 x GZ 1368 under normal condition.

The results revealed that there is a preponderance of non-additive gene action for root and some vegetative characters in the hybrids resulted in high amount of vigor in F_1, selection can be postponed to later generation. These findings were in agreement with those of Gaballah (2009), El-Naem (2010), El-Hity *et al.,* (2015), Abo-Zeid (2016), Ghazy (2017) and Daher (2018).

Estimates of heterosis

A large number of crosses exhibited high estimates of heterosis in a desirable direction for different traits under study. The estimates of mid-parent and better parent heterosis for different traits are presented in Table (5). A greater magnitude of heterosis when it measured as a deviation from mid-parent and better parent was observed in IR 69432 x GZ 1368, IR 12 G 3222 x GZ 1368, IR 12 G 3222 x Nerica.7, and IR 12 G 3213 x GZ 1368 rice crosses for root length and number of roots/plant under both conditions. The availability of sufficient hybrid vigor in several crosses in respect of root length and number of roots/plant suggests that a hybrid breeding program could profitably be undertaken in rice under normal and water deficit conditions. The crosses IR 69432 x GZ 1368, IR 6500-127 x GZ 1368, IR 6500-127 x Giza 178, IR 12 G 3222 x GZ 1368, IR 12 G 3213 x GZ 1368, IR 12 G 3213 x

Table (5): Estimates of heterosis as a deviation from mid and better parent of the fifteen rice crosses for root characteristics, physiological traits, yield and yield components traits under normal and deficit water conditions

No.	Genotype	Root Length				Number of roots/plant			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	14.87**	17.51**	8.02**	8.70**	83.33**	29.03**	37.50**	11.11**
2	IR 69432 X Nerica 7	-33.47**	-13.85**	-33.61**	-17.70**	62.45**	86.91**	13.75**	33.33**
3	IR 69432 X Giza 178	1.28	-0.74	-18.89**	-16.15**	2.56**	16.13**	-12.50**	0.00
4	IR 6500-127 X GZ 1368	14.36**	-21.40**	8.27**	-28.39**	25.00**	68.14**	-6.25**	46.15**
5	IR 6500-127 X Nerica 7	-16.27**	7.56**	-25.33**	-4.95*	114.22**	200.91**	50.00**	170.83**
6	IR 6500-127 X Giza 178	28.63**	37.67**	13.49**	36.76**	9.89**	76.99**	-6.25**	53.85**
7	IR 12 G3222 X GZ 1368	20.49**	9.52**	18.72**	2.78	115.73**	105.13**	95.92**	84.62**
8	IR 12 G3222 X Nerica 7	12.71**	18.64**	7.28**	7.88**	85.11**	154.42**	53.06**	121.15**
9	IR 12 G3222 X Giza 178	12.47**	44.46**	-6.48**	39.04**	212.80**	284.62**	192.04**	246.15**
10	IR 12 G3213 X GZ 1368	12.95**	16.49**	9.70**	10.73**	97.92**	92.00**	69.64**	84.62**
11	IR 12 G3213 X Nerica 7	18.80**	-7.42**	8.51**	-9.02**	115.82**	184.54**	69.64**	133.33**
12	IR 12 G3213 X Giza 178	7.94	-3.33	-9.79**	-15.11**	281.25**	425.00**	138.94**	216.67**
13	11 L 236 X GZ 1368	-24.17**	-18.87**	-28.59**	-24.60**	77.78**	98.00**	60.00**	52.31**
14	11 L 236 X Nerica 7	3.73*	-14.59**	3.34	-18.01**	82.85**	270.56**	50.00**	254.14**
15	11 L 236 X Giza 178	14.15**	5.42*	-8.47**	-10.57**	125.35**	160.00**	112.39**	100.00**
L.S.D	0.05	0.89	0.93	1.02	1.08	2.06	1.73	2.38	2.00
	0.01	1.19	1.25	1.37	1.44	2.75	2.31	3.18	2.67

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

Table (5): Cont.

No.	Genotype	Root volume				Root /shoot ratio			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	122.22**	91.11**	100.00**	79.17**	279.22**	373.68**	186.27**	257.14**
2	IR 69432 X Nerica 7	-25.00**	24.32**	-40.00**	-4.17	12.86	-42.53	-30.70	-44.44
3	IR 69432 X Giza 178	-29.46**	-25.00**	-39.33**	-37.50**	5.59	-52.82	-37.04	-63.49
4	IR 6500-127 X GZ 1368	50.00**	74.77**	27.50**	53.97**	183.33*	-6.76	66.67	-17.86
5	IR 6500-127 X Nerica 7	8.05*	3.45	4.44	-6.25	10.57	119.18**	-40.35	77.78
6	IR 6500-127 X Giza 178	25.00**	81.25**	11.11**	81.25**	-36.11	21.57	-65.93**	10.71
7	IR 12 G3222 X GZ 1368	94.81**	197.56**	87.50**	190.48**	66.67	-8.28	17.65	-22.58
8	IR 12 G3222 X Nerica 7	-25.37**	3.03	-32.43**	-15.00*	3.70	71.05	-38.60	44.44
9	IR 12 G3222 X Giza 178	1.37	11.11	0.00	0.00	-19.23	12.35	-53.33**	-2.15
10	IR 12 G3213 X GZ 1368	103.03**	70.73**	67.50**	66.67**	481.82**	-8.28	213.75**	-22.58
11	IR 12 G3213 X Nerica 7	114.29**	106.06**	100.00**	70.00**	33.90	5.26	-30.70	-11.11
12	IR 12 G3213 X Giza 178	0.00	10.00	-13.89**	-5.00	13.67	-58.06	-41.48*	-41.94
13	11 L 236 X GZ 1368	28.57**	105.88**	12.50**	66.67**	-13.89	56.00	-39.22	21.88
14	11 L 236 X Nerica 7	133.33**	253.85**	133.33**	253.85**	5.19	-8.77	-37.72	-42.22
15	11 L 236 X Giza 178	-12.12**	17.24*	-19.44**	6.25	5.13	25.71	-39.26*	-4.35
L.S.D 0.05		2.30	2.22	2.66	2.57	0.45	0.30	0.52	0.35
0.01		3.07	2.97	3.55	3.43	0.60	0.40	0.69	0.46

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

Table (5): Cont.

No.	Genotype	Flag leaf area				Chlorophyll content			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	24.62**	-12.89**	3.90**	-13.88**	15.43**	6.58*	3.22	-6.41*
2	IR 69432 X Nerica 7	14.45**	-29.02**	13.85**	-83.22**	-3.25	12.41**	-6.59**	7.54**
3	IR 69432 X Giza 178	-31.41**	-19.26**	-41.14**	-21.28**	7.39**	-9.15**	2.66	-10.58**
4	IR 6500-127 X GZ 1368	-11.28**	1.84	-31.16**	-2.80	11.69**	-11.87**	1.43	-23.98**
5	IR 6500-127 X Nerica 7	16.05**	40.57**	5.51**	9.27**	-2.97	4.43	-4.73*	-2.05
6	IR 6500-127 X Giza 178	-38.50**	-41.32**	-51.04**	-44.73**	8.32**	-5.33*	5.28*	-5.78*
7	IR 12 G 3222 X GZ 1368	69.29**	12.12**	61.26**	9.28**	11.56**	22.49**	7.64**	11.61**
8	IR 12 G 3222 X Nerica 7	3.05**	33.86**	-10.08**	5.71*	1.17	-2.92	-3.33	-3.25
9	IR 12 G 3222 X Giza 178	-15.63**	-32.88**	-16.84**	-35.47**	8.41**	-0.77	4.62	-6.20*
10	IR 12 G 3213 X GZ 1368	10.90**	-4.36	-8.61**	-15.13**	4.44*	20.43**	-5.84*	6.16*
11	IR 12 G 3213 X Nerica 7	-18.03**	48.40**	-19.64**	32.65**	-12.67**	-12.80**	-14.94**	-16.22**
12	IR 12 G 3213 X Giza 178	-23.67**	-3.43	-35.30**	-11.52**	12.51**	-18.78**	2.68	-11.02**
13	11 L 236 X GZ 1368	-4.60**	-18.08**	-24.41**	-27.85**	9.73**	20.47**	5.52*	7.68**
14	11 L 236 X Nerica 7	-16.61**	-8.99**	-22.16**	2.28**	19.31**	13.19**	14.38**	10.42**
15	11 L 236 X Giza 178	-13.77**	6.96**	-29.83**	-4.62	16.97**	-13.61**	13.26**	-16.64**
L.S.D	0.05	0.38	1.14	0.44	1.31	1.83	1.86	2.12	2.14
	0.01	0.51	1.52	0.58	1.76	2.45	2.48	2.83	2.87

*and ** significant at 0.05 and 0.01 probability levels, respectively

Table (5): Cont.

No.	Genotype	Relative water content				No. of panicles/plant			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	-3.02**	-8.35**	-4.83**	-12.38**	57.89**	-8.33	42.86**	-15.38
2	IR 69432 X Nerica 7	-28.40**	-12.99**	-33.70**	-43.89**	26.67**	54.55**	11.76	54.55**
3	IR 69432 X Giza 178	11.68**	38.66**	9.20**	-0.10	65.00**	25.93**	43.48**	6.25
4	IR 6500-127 X GZ 1368	11.49**	16.14**	7.60**	-1.62	43.75**	-4.35**	9.52	-15.38
5	IR 6500-127 X Nerica 7	-41.09**	-4.81**	-44.58**	-14.93**	116.67**	14.29	100.00**	9.09
6	IR 6500-127 X Giza 178	-46.41**	-23.39**	-46.71**	-35.02**	111.76**	7.69	56.52**	-12.50
7	IR 12 G3222 X GZ 1368	17.13**	28.41**	10.40**	7.26**	51.35**	23.08**	33.33**	23.08*
8	IR 12 G3222 X Nerica 7	-2.92**	-12.37**	-23.03**	-20.49**	37.93**	-8.33	25.00**	-15.38
9	IR 12 G3222 X Giza 178	4.27**	-26.67**	-13.61**	-36.91**	94.87**	10.34	65.22**	0.00
10	IR 12 G3213 X GZ 1368	-14.55**	6.48**	-17.90**	-9.08**	15.00**	40.74**	9.52	35.71**
11	IR 12 G3213 X Nerica 7	-7.85**	-16.15**	-19.11**	-25.71**	37.50**	-4.00	15.79**	-14.29
12	IR 12 G3213 X Giza 178	0.92	-29.11**	-7.23**	-25.80**	147.37**	28.57	52.17**	6.25
13	11 L 236 X GZ 1368	-5.40**	50.52**	-13.15**	24.92**	10.53*	18.52*	0.00	14.29
14	11 L 236 X Nerica 7	-42.79**	-15.56**	-51.78**	-22.82**	33.33**	-4.00	17.65**	-14.29
15	11 L 236 X Giza 178	2.29*	-16.96**	-9.52**	-28.07**	55.00**	0.00	34.78**	-6.25
L.S.D	0.05	1.33	1.25	1.54	1.45	1.74	2.10	2.01	2.42
	0.01	1.78	1.67	2.05	1.93	2.32	2.81	2.68	3.24

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

Table (5): Cont.

No.	Genotype	1000 grain weight				No. of filled grains/ panicle			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	4.17*	1.43	-3.85	3.51	1.66	-1.07	-11.11**	-17.26**
2	IR 69432 X Nerica 7	-15.38**	-6.50	-15.38**	-15.90**	-4.68**	3.91**	-21.26**	-20.83**
3	IR 69432 X Giza 178	3.70*	-10.55*	0.00	-19.54**	-15.59**	-6.23**	-24.15**	-23.81**
4	IR 6500-127 X GZ 1368	6.75**	-14.05*	-8.07**	-24.64**	7.25**	18.30**	-2.63*	13.93**
5	IR 6500-127 X Nerica 7	3.05	27.38**	-4.49**	12.68**	28.00**	19.05**	9.47**	2.46
6	IR 6500-127 X Giza 178	-2.75	-16.92**	-6.68**	-20.83**	12.68**	60.35**	5.26**	49.18**
7	IR 12 G3222 X GZ 1368	-6.12**	-14.16**	-14.81**	-23.12**	-7.53**	-27.71**	-20.74**	-45.21**
8	IR 12 G3222 X Nerica 7	-5.66**	-17.10**	-7.41**	-19.12**	38.45**	36.81**	12.29**	-4.11*
9	IR 12 G3222 X Giza 178	5.13**	1.60	3.25	-0.88	-19.37**	-19.75**	-29.03**	-40.64**
10	IR 12 G3213 X GZ 1368	0.00	-4.98	-4.17	-11.24*	-11.40**	1.55	-25.97**	-21.90**
11	IR 12 G3213 X Nerica 7	-12.00**	-21.74**	-15.38**	-23.38**	49.73**	39.60**	18.61**	-0.95
12	IR 12 G3213 X Giza 178	0.00	-9.31	-7.14**	-6.56	-24.24**	-7.14**	-26.41**	-28.57**
13	11 L 236 X GZ 1368	-2.22	-7.51	-4.35	-11.75*	29.63**	24.92**	9.87**	0.00
14	11 L 236 X Nerica 7	10.20**	1.93	3.85	-2.35	24.58**	23.19**	0.00	-9.57**
15	11 L 236 X Giza 178	-1.96	-6.85	-10.71**	-10.77*	-23.71**	-10.58**	-33.63**	-30.32**
L.S.D 0.05		1.95	1.99	1.00	2.26	3.78	3.53	4.37	4.07
0.01		2.61	2.66	1.34	3.02	5.06	4.72	5.84	5.45

*and ** significant at 0.05 and 0.01 probability levels, respectively

Table (5): Cont.

No.	Genotype	Fertility %				Grain yield/ plant			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	0.23	1.69	-0.82	-0.02	29.04**	53.23**	25.37**	43.26**
2	IR 69432 X Nerica 7	3.46**	2.41*	-0.22	-1.92	34.55**	93.96**	10.49**	64.19**
3	IR 69432 X Giza 178	-3.39**	-14.57**	-5.14**	-16.73**	27.98**	77.68**	22.30**	70.82**
4	IR 6500-127 X GZ 1368	-0.51**	11.12**	-1.45	4.76**	42.11**	72.55**	28.02**	64.71**
5	IR 6500-127 X Nerica 7	2.50*	2.90**	-1.25	-0.46	64.65**	108.78**	52.26**	95.88**
6	IR 6500-127 X Giza 178	-0.39	-11.84**	-2.29	-16.19**	45.53**	94.54**	22.89**	68.24**
7	IR 12 G 3222 X GZ 1368	-7.26**	-45.20**	-7.40**	-46.89**	16.84**	54.53**	10.34**	23.87**
8	IR 12 G 3222 X Nerica 7	1.27	-2.16*	-3.45**	-7.59**	60.67**	-12.85*	28.97**	-35.48**
9	IR 12 G 3222 X Giza 178	2.78*	-1.34	-0.25	-5.19**	30.40**	45.86**	28.22**	27.74**
10	IR 12 G 3213 X GZ 1368	0.29	1.31	-0.71	-1.72	14.23**	75.00**	5.97*	43.34**
11	IR 12 G 3213 X Nerica 7	-0.11	-7.53**	-3.71**	-12.58**	58.81**	-1.81	25.66**	-25.94**
12	IR 12 G 3213 X Giza 178	3.49	-4.87**	-0.11	-8.49**	54.42**	93.52**	26.99**	36.52**
13	11 L 236 X GZ 1368	5.74**	8.29**	3.89**	1.63	30.43**	94.32**	24.41**	64.21**
14	11 L 236 X Nerica 7	7.42**	9.50**	4.32**	5.42**	72.44**	54.76**	39.51**	19.93**
15	11 L 236 X Giza 178	5.27**	7.31**	4.10**	1.54	30.75**	46.83**	27.26**	36.53**
L.S.D	0.05	2.06	1.62	2.37	1.87	2.32	2.48	2.67	2.87
	0.01	2.75	2.17	3.17	2.50	3.09	3.32	3.57	3.83

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

Nerica 7, 11 L 236 x GZ 1368 and 11 L 236 x Nerica 7 under normal and water deficit conditions recorded highly significant mid and better parent heterosis in a desirable direction for root volume trait. Approximately, high estimated values of mid and better parent heterosis were reported in IR 69432 x GZ 1368 exhibited significant and highly significant and positive estimates of heterosis for root/shoot ratio under both conditions.

On the other hand, among 15 crosses, two crosses recorded significant positive mid and better parent heterosis for flag leaf area under both conditions. Moreover, significant and highly significant and positive estimates of mid and better parent heterosis were observed for chlorophyll content in the crosses IR 12 G 3222 x GZ 1368, 11 L 236 x GZ 1368 and 11 L 236 x Nerica 7 under both conditions. The cross IR 12 G 3222 x GZ 1368 under both conditions exhibited significant and highly significant positive heterosis of flag leaf area and chlorophyll content measured as a deviation from mid-parent and better parent. These results were in harmony with that observed by Abd El-Lattef and Mady (2009), El-Naem (2010), El-Gamal (2013), El-Naem (2014), Ghazy (2017) and Daher (2018). On the other hand, the cross IR 12 G 3222 x GZ 1368 exhibited significant and highly significant heterosis in a desirable direction for relative water content, number of panicles/plant and grain yield/plant measured as a deviation from mid-parent and better parent under both conditions.

On the other hand, among 15 crosses, only one cross recorded significant positive mid and better parent heterosis for number of filled grains/plant and only one cross recorded significant positive mid and better parent heterosis for fertility % under both conditions. Very few crosses recorded significant positive either mid or better heterosis for 1000-grain weight, while, the most of other remaining crosses recorded highly significant magnitude of mid and better heterosis in negative direction for such trait. Similar results were reported by several scientists like, El Abd et al., (2003), EL-Keredy et al., (2003), Chitra et al., (2006), Saravanan et al., (2006), El Abd et al., (2007), Ganapathy and Ganesh (2008) and Amudha, et al., (2010).

Conclusively, from these results it could be concluded that IR 12 G 3222, GZ 1368, 11 L 236 and Giza 178 were the best general combiners and the crosses IR 69432 × GZ 1368 and IR12G3222 x GZ1368 were the best crosses for estimates of SCA and heterosis effects relative to the mid- and better- parents for most of the studied traits under water deficit and normal conditions.

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دراسات على القدرة على الإئتلاف وقوة الهجين لبعض صفات الجذر والمحصول لبعض التراكيب الوراثية فى الأرز تحت الظروف الطبيعية وظروف نقص المياه

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قسم بحوث الارز– معهد بحوث المحاصيل الحقلية– مركز البحوث الزراعية– مصـــر

تم التهجين بين ثمانية تراكيب وراثية بنظام السلالة x الكشاف وذلك فى تجربة اقيمت فى المزرعة البحثية لمحطة بحوث سخا – كفر الشيخ – مصر وذلك خلال مواسم زراعة الأرز ٢٠٢١ – ٢٠٢٢ وذلك بهدف دراسة القدرة على التآلف للتراكيب الوراثية المستخدمة فى الدراسة. تمت الدراسة على بعض صفات الجذر وصفات المحصول ومكوناته تحت الظروف الطبيعية و ظروف نقص المياه .

أوضحت النتائج أن تباينات القدرة العامة والقدرة الخاصة على التآلف كانت معنوية وعالية المعنوية لجميع الصفات المدروسة. أوضحت تأثيرات القدرة العامة على الإئتلاف أن الاب اى ار ١٢ جى ٣٢٢٢ كان أفضل الأباء لصفات طول الجذر، عدد الجذور لكل نبات ومساحة ورقة العلم تحت الظروف الطبيعية و ظروف نقص المياه، فضلا عن ذلك كان الأب جى زد ١٣٦٨ أفضل الأباء لصفة حجم الجذر تحت كلا البيئتين، فى حين كانت السلالة آى ار ٦٩٤٣٢ افضل الأباء قدرة عامة لصفة النسبة المئوية للوزن الجاف للمجموع الجذرى إلى المجموع الخضرى تحت كلا الظرفين. بينما كانت السلالة ١١إل ٢٣٦ أفضل الأباء قدرة عامة على التآلف لصفات محتوى الكلوروفيل، عدد الحبوب الممتلئة على النورة، النسبة المئوية للخصوبة ومحصول النبات الفردى تحت كلا البيئتين.

فضلا" عن ذلك كان الهجين أى أر ٦٩٤٣٢ x جى زد ١٣٦٨ افضل التراكيب الوراثية قدرة خاصة على التالف لصفة طول الجذر، عدد الجذور لكل نبات، حجم الجذر و نسبه الوزن الجاف للمجموع الجذرى الى الخضرى تحت كلا البيئتين. اظهرت النتائج ان الهجين أى أر ١٢ جى ٣٢١٣ x جيزة ١٧٨ كان افضل التراكيب الوراثيه قدره خاصه على التالف لصفات المحتوى المائى للاوراق، مساحة الورقه العلم، محتوى الكلوروفيل، وزن الاف حبة و صفة النسبة المئوية للخصوبة تحت كلا البيئتين، فضلا

عن ذلك اوضحت النتائج ان التراكيب الوراثـة أى أر ٦٩٤٣٢ x جـى زد ١٣٦٨ تحت الظروف الطبيعية و أى أر ٦٩٤٣٢ x نيريكا ٧ تحت ظروف ندرة المياه كانت أفضل التراكيب الوراثيه قدره خاصه على التالف لصفة محصول النبات الفردى .

أظهرت النتائج ايضا أن الهجن أى أر ٦٩٤٣٢ x جى زد ١٣٦٨، أى أر ٦٥٠٠-١٢٧x نيريكـا ٧، أى أر ١٢ جـى ٣٢٢٢ x جـى زد ١٣٦٨، ١١إل ٢٣٦ x جـى زد ١٣٦٨و ١١ إل ٢٣٦ x نيريكـا ٧ اظهـرت معنويـه عاليـة وفـى الاتجـاه المرغـوب لقـوة الهجين وذلك عند قياسها كـإنحراف عن قيم متوسط الابـوين وافضـل الابـوين لكثير من الصفات المدروسة تحت الظروف الطبيعية وظروف نقص المياة.

التوصية: مما سبق نستنتج أن الأباء آى ار ١٢ جى ٣٢٢٢، جى زد ١٣٦٨ و١١ إل ٢٣٦ و جيزة ١٧٨ أفضل الأباء قدرة عامة علي التآلف لغالبية الصفات المدرسة تحت كلا البيئتين. وأن الهجن أى أر ٦٩٤٣٢ x جى زد ١٣٦٨ و أى أر ١٢ جى ٣٢٢٢ x جى زد ١٣٦٨ أفضل التراكيب الوراثية لتقديرات القدرة الخاصة علي التآلف وقوة الهجين عند قياسها كانحراف عن متوسط الأبوين والأب الأفضل لبعض الصفات المدروسة تحت كلا البيئتين .