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STUDIES ON COMBINING ABILITY AND HETEROSIS FOR YIELD, ITS COMPONENTS AND SOME GRAIN QUALITY TRAITS IN RICE USING LINE X TESTER UNDER NORMAL AND WATER DEFICIT

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ABSTRACT: Combining ability and heterosis were studied on 15 F1 hybrids and their parents to understand the inheritance of yield, its components and some grain quality traits for selecting superior genotypes. A line x tester mating design was conducted during 2021and 2022rice seasons at the Experimental Farm, of Sakha Research Station Kafr El-Sheikh, Egypt. The results revealed that GCA and SCA were highly significant for all studied traits except grain shape under both conditions. 11 L236 genotype was the best general combiner for number of days to 50% heading, number of filled grains/panicle, sterility% and grain yield/plant under normal and water deficit conditions. Also Giza 178 was the best general combiner for number of panicles/plant, grain yield/plant and hulling % under both conditions while, IR6500-127, Giza 178 and GZ1368-S-5-4 for head rice % and for amylose content Lines 11 L236 and tester Nerica7 under both conditions were good combiners for this trait. Crosses IR 69432 x Nerica7, IR 69432 x GZ1368-S-5-4, IR 12G3213 x Giza178, IR 12G3222 x Giza178 and IR 12G3222 x Nerica7 had high and significant SCA in desirable direction for most studied traits under both condition. Crosses IR6500-127 x Nerica7, 11 L236 x GZ1368-S-5-4, IR69432 x Nerica7, IR 12G3213 x Nerica7, IR 12G3222 x GZ1368-S-5-4 and IR 12G3222 x Nerica7 exhibited highly significant and desirable estimates of heterosis as a deviation from mid and better parent for most studied traits under both conditions.

Key words: *Rice, combining ability, heterosis, water deficit, yield and line x tester design.*

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 Sedeek *et al.*, (2022) 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 El-Agoury *et al.*, (2023). As water resources for agronomic uses become more limiting, the development of drought-tolerant lines becomes increasingly more important Daher (2018), Sedeek *et al.*, (2022) 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).

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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). The aim of this investigation is to Identify the pattern of yield inheritance, its components, and some grain quality characteristics to select superior genotypes for use in hybridization programs to produce hybrids tolerant to water shortages.

MATERIALS AND METHODS

The experiments was carried out using line x tester mating design, during 2021 and 2022 rice growing seasons at the experimental farm of Sakha Research Station, 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 among 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 seeds 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). 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. At maturity stage days to 50% heading (days), plant height (cm), number of panicles / plant, number of filled grains/ panicle, 1000-grain weight (g), sterility percentage (%), grain yield/ plant (g), grain shape, hulling (%), milling (%), head rice (%) and amylose content (%) were recorded for randomly chosen guarded 25 plants from the middle row/replicate using the standard evaluation system for rice, IRRI (1996).

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 yield and its components and some grain quality traits, i.e.

number of days to 50 % heading (days), plant height (cm), number of panicles/plant, 1000-grain weight (g), number of filled grains/panicle, sterility percentage (%), grain yield/ plant (g), grain shape (mm), hulling (%), milling (%), head rice (%) and amylose content (%) under normal and water deficit conditions are presented in Table 1. Highly significant mean square estimates were recorded for genotypes, parents, crosses and the interaction among them for all yield and its components and some grain quality traits under both water deficit and normal conditions, except grain shape traits under both conditions for all sources of variance, 1000-grain weight (g) and sterility % under normal, hulling % and milling % under water stress for parents vs. crosses which were insignificant. These results agree with those obtained by Saleem *et al., (*2010), Negm (2011) and El-Hity *et al.,* (2015). Estimates of both general (GCA) and specific combining ability (SCA) variances were found to be highly significant for all yield and its components and some grain quality traits under both water deficit and normal conditions, except grain shape traits under both conditions which were insignificant, indicating the importance of additive and non-additive genetic variances in determining the inheritance of these studied traits. The obtained results are in harmony with those previously observed by El-Naem (2010) and Daher *et al.,* (2023).

Table (1): Analysis of variance of the line x tester analysis for grain yield, yield components and some grain quality traits under normal and water deficit conditions.

S.O.V	d.f	Days to 50%heading, (day)		Plant height, (cm)		No. of panicles/plant	
		N	D	N	D	N	D
Replications	2	1.09	0.28	0.10	0.17	1.09	0.39
Genotypes	22	80.26**	123.78**	584.20**	306.77**	162.75**	19.54**
Parents	7	54.38**	106.93**	654.45**	481.71**	51.38**	11.79**
Crosses	14	94.80**	98.45**	524.23**	240.71**	127.91**	21.77**
Parents vs. Crosses	1	58.00**	596.29**	932.04**	6.96**	1430.01**	42.61**
Lines (gca)	4	78.30**	42.19**	589.80**	215.00**	35.70**	16.20**
Testers(gca)	2	216.60**	26.02**	86.40**	134.60**	704.60**	34.20**
Lines x Testers (sca)	8	72.60**	144.69**	600.90**	280.10**	29.85**	21.45**
Error	45	3.11	1.60	1.43	2.04	0.97	2.16

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

Table (1): Continued

S.O.V	d.f	1000-grain weight		No. of filled grains/panicle		Sterility (%)		Grain yield / plant	
		N	D	N	D	N	D	N	D
Replications	2	0.16	0.68	0.54	0.70	0.47	0.81	1.20	0.97
Genotypes	22	20.75**	19.39**	3961.30**	4254.78**	27.47**	288.41**	225.07**	231.84**
Parents	7	22.96**	18.53**	3712.23**	7769.95**	37.66**	151.12**	144.00**	104.04**
Crosses	14	21.01**	17.75**	4359.99**	2792.09**	24.30**	362.18**	62.77**	147.44**
Parents vs. Crosses	1	1.53	48.40**	122.96**	126.39**	0.43	216.70**	3064.78**	2308.08**
Lines (gca)	4	30.04**	12.03**	2142.92**	2105.80**	36.81**	245.51**	58.16**	33.85**
Testers (gca)	2	37.83**	21.78**	12020.62**	2568.20**	10.48**	51.18**	162.76**	478.03**
Lines x Testers (sca)	8	12.30**	19.61**	3553.37**	3191.20**	21.51**	498.26**	40.07**	121.59**
Error	45	0.37	1.94	7.01	6.10	1.04	2.56	2.63	3.03

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

Table (1): Continued

S.O.V	d.f	Grain shape		Hulling (%)		Milling (%)		Head rice (%)		Amylose content(%)	
		N	D	N	D	N	D	N	D	N	D
Replications	2	0.00	0.16	0.02	0.07	0.08	1.05	0.26	0.09	0.02	0.17
Genotypes	22	0.37	0.34	14.86**	22.79**	10.06**	13.19**	26.85**	91.10**	14.45**	20.07**
Parents	7	0.64	0.29	13.35**	33.17**	12.97**	11.04**	12.03**	74.53**	12.93**	22.69**
Crosses	14	0.22	0.35	16.13**	18.96**	8.22**	15.03**	29.61**	95.82**	15.55**	19.65**
Parents vs. Crosses	1	0.51	0.69	7.74**	3.77	15.55**	2.49	91.85**	141.03**	9.60**	7.61**
Lines (gca)	4	0.06	0.44	10.20**	6.90**	6.07**	17.44**	16.37**	16.69**	4.40**	33.22**
Testers(gca)	2	0.74	0.44	62.26**	32.17**	16.00**	17.59**	93.64**	9.42**	41.10**	17.59**
Lines x Testers (sca)	8	0.17	0.28	7.55**	21.68**	7.34**	13.18**	20.23**	156.98**	14.73**	13.38**
Error	45	0.05	0.06	0.06	0.11	0.12	0.51	0.17	0.10	0.20	0.02

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

Mean performance of parents and their F_1 generation.

Conspicuously, Table (2) shows that Nerica 7 rice variety was the earlier rice cultivar comparing with other rice cultivars under both conditions, the shortest plants which favorite for rice breeders under water deficit conditions were observed in GZ 1368-S-5-4, while, the shortest ones were exhibited in IR 6500-127 under normal,. In addition, high number of panicles/plant was detected for Giza 178 under both conditions. IR 6500-127 was found to be the rice cultivar with heavy grains. The highest mean values for number of filled grains/panicle were recorded by IR 12 G 3213 under normal conditions and IR 12 G 3222 under water deficit. Low sterility % was observed for IR 12 G 3222 rice genotypes comparing with the other cultivated parents. IR 12 G 3213 , IR 12 G 3222 were found the highest mean values for grain yield/plant under normal and water deficit conditions respectively. The most desirable short to bold grain genotypes was IR 69432 for grain shape under both conditions, indicating that these genotypes could be used as a good grain shape donors under both conditions. The highest estimated values of hulling % and milling % were detected for IR 12 G 3222 under both conditions. In addition, Regarding to head rice %, the highest values were recorded for variety Giza 178 under normal and water deficit conditions. For amylose content %, the parental varieties IR 69432 and 11 L 236 were the lowest amylose content % its estimated value was (17.2 %) under normal. While the variety 11 L 236 was the lowest amylose content its estimated value was (16 %) under water deficit condition.

In addition, the F_1 mean values of, IR 12 G 3213 x Giza 178 and 11 L 236 x GZ 1368-S-5-4 rice crosses were the highest desirable values of number of days to 50 % heading under normal and water deficit conditions, respectively. IR 69432 x Giza 178 was the most desirable short plant under both conditions, which agrees with the target of rice breeders for selected ideal plant height under water deficit condition for resistance to lodging and suitable for mechanical harvesting. On the other hand, for number of panicles/ plant, the crosses, IR 12 G 3222 x Giza 178 under normal conditions and IR 12 G 3213 x GZ 1368-S-5-4 under water deficit exhibited the highest mean values. The cross, IR 6500-127 x Nerica 7 exhibited the highest mean values for 1000-grain weight (29.1 g, and 27.2 g) under normal and water deficit conditions, respectively. For number of filled grains/panicle the crosses IR 12 G 3213 x Nerica 7 under normal and IR 12 G 3222 x Nerica 7 under water deficit conditions exhibited the highest mean values. While, the crosses 11 L 236 x GZ 1368-S-5-4 under normal conditions and IR 6500-127 x GZ 1368-S-5-4 under water deficit gave the lowest mean values of sterility %. Grain yield/plant was found to be higher than the highest parent for seventeen rice crosses, indicating that over-dominance played a remarkable role in the inheritance of these traits in these mentioned crosses. The cross 11 L 236 x Giza 178 exhibited the lowest mean values of grain shape under water deficit and normal conditions, comparing with the other crosses under the same conditions. The crosses IR 6500-127 x Giza 178 and IR 12 G 3222 x Giza 178 exhibited the highest mean values of hulling % (84.4 and 81.3 %), under normal and water deficit conditions, respectively. While, the crosses IR 6500-127 x Giza 178 and IR 69432 x Giza 178 exhibited the highest mean values of milling % (73.7 and 70.7 %) under normal and water deficit conditions respectively. Moreover, the crosses IR 6500-127 x Giza 178 under normal and IR 6500-127 x Nerica 7 under water deficit conditions exhibited the highest mean values of head rice %. While, the lowest mean values of amylose content % were recorded by crosses 11 L 236 x Nerica 7 under normal and IR 12 G 3213 x GZ 1368-S-5-4 under water deficit conditions. Comparing the general average of parents and hybrids, we find that it is greater for hybrids than parents for all traits except amylose content % under normal conditions.

Table (2): Mean performance of the line x tester analysis for grain yield, yield components and some grain quality traits under normal and water deficit conditions.

Genotypes	Days to 50% heading (day)		Plant height (cm)		No. of panicles /plant		1000-grain weight (g)	
	N	D	N	D	N	D	N	D
IR 69432 X GZ 1368	110	107	131	90	27	11	25.0	19.7
IR 69432 X Nerica 7	104	102	110	97	19	17	22.0	20.0
IR 69432 X Giza 178	113	109	101	84	29	17	28.0	19.1
IR 6500-127 X GZ 1368	118	113	135	90	23	11	28.0	19.8
IR 6500-127 X Nerica 7	104	101	132	89	26	12	29.1	27.2
IR 6500-127 X Giza 178	114	105	104	100	30	14	28.4	20.8
IR 12 G 3222 X GZ 1368	104	100	135	115	28	16	23.0	19.2
IR 12 G 3222 X Nerica 7	106	104	128	98	20	11	25.0	20.2
IR 12 G 3222 X Giza 178	105	97	141	85	33	16	28.9	24.8
IR 12 G 3213 X GZ 1368	119	116	132	102	23	19	23.0	20.2
IR 12 G 3213 X Nerica 7	103	97	125	95	22	12	22.0	18.2
IR 12 G 3213 X Giza 178	100	90	139	98	31	17	26.0	22.2
11 L 236 X GZ 1368	103	95	108	103	24	16	22.0	19.2
11 L 236 X Nerica 7	105	98	134	92	29	12	27.0	23.2
11 L 236 X Giza 178	105	97	132	112	28	15	25.0	21.2
Mean for crosses	**107**	**102**	**125.8**	**96.7**	**26.1**	**14.4**	**25.5**	**21.0**
IR 69432	109	107	103	89	17	11	26.0	19.0
IR 6500-127	108	103	101	92	11	10	28.5	22.5
IR 12 G 3222	106	104	137	121	16	14	27.0	22.0
IR 12 G 3213	104	101	135	96	21	14	24.0	20.8
11 L 236	107	103	128	107	17	14	23.0	21.8
GZ 1368-S-5-4	103	103	122	83	21	13	22.0	19.8
Nerica 7	98	99	118	96	13	11	26.0	20.2
Giza 178	112	102	102	84	23	16	23.0	20.8
Mean for varieties	**105**	**102**	**118.3**	**96.0**	**17.4**	**12.9**	**24.4**	**20.9**
LS D at 0.05	2.91	2.09	1.97	2.01	2.01	2.42	1.00	2.26
at 0.01	3.89	2.79	2.64	2.68	2.68	3.24	1.34	3.02

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

Table (2): Continued

Genotypes	No. of filled grains/panicle		Sterility (%)		Grain yield / plant (g)		Grain shape(mm)	
	N	D	N	D	N	D	N	D
IR 69432 X GZ 1368	184	139	7.3	10.9	51.4	30.8	2.6	2.42
IR 69432 X Nerica 7	180	133	8.7	12.6	45.3	35.3	1.85	1.50
IR 69432 X Giza 178	177	128	13.2	25.8	55.0	44.8	2.18	1.91
IR 6500-127 X GZ 1368	185	139	7.5	9.2	49.5	30.8	1.88	1.75
IR 6500-127 X Nerica 7	208	125	10.0	19.2	47.2	33.3	2.34	2.25
IR 6500-127 X Giza 178	200	182	10.4	29.1	55.3	46.2	1.83	1.53
IR 12 G 3222 X GZ 1368	171	120	13.2	32.4	48.0	38.4	2.41	2.21
IR 12 G 3222 X Nerica 7	245	210	9.5	15.2	56.1	35.0	2.2	2
IR 12 G 3222 X Giza 178	174	130	6.5	13.0	57.7	45.6	1.98	1.66
IR 12 G 3213 X GZ 1368	171	164	7.2	10.0	47.9	42.0	2.40	2.2
IR 12 G 3213 X Nerica 7	274	190	11.8	19.8	56.8	21.7	2.36	2.1
IR 12 G 3213 X Giza 178	170	150	8.5	16.2	57.4	40.0	1.9	1.8
11 L 236 X GZ 1368	245	188	2.9	12.5	53.0	44.5	2.5	2.19
11 L 236 X Nerica 7	223	170	5.9	14.0	59.4	32.5	2.22	1.97
11 L 236 X Giza 178	168	131	6.1	14.1	57.3	37.0	1.7	1.4
Mean for crosses	**198.3**	**154.5**	**8.6**	**16.9**	**53.2**	**37.2**	**2.2**	**1.9**
IR 69432	207	138	8.5	10.3	41.0	21.5	1.48	1.21
IR 6500-127	198	122	8.3	23.4	31.0	17.0	2.22	2.1
IR 12 G 3222	212	200	3.9	4.7	48.5	31.0	2.13	1.82
IR 12 G 3213	235	195	5.1	7.1	45.2	29.3	2.15	2.0
11 L 236	225	188	9.8	24.5	42.6	27.1	2.2	1.89
GZ 1368-S-5-4	174	113	5.3	13.9	38.7	18.7	2.28	1.95
Nerica 7	135	88	12.0	17.1	26.3	14.9	2.8	2.15
Giza 178	185	105	11.8	15.4	45.0	23.3	1.86	1.58
Mean for varieties	**196.4**	**143.6**	**8.1**	**14.6**	**39.2**	**22.9**	**2.1**	**1.8**
LS D at 0.05	4.37	4.07	1.68	2.64	2.67	2.87	0.20	0.41
at 0.01	5.84	5.45	2.25	3.52	3.57	3.83	0.26	0.55

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

Table (2): Continued

Genotypes	Hulling (%)		Milling (%)		Head rice (%)		Amylose content(%)	
	N	D	N	D	N	D	N	D
IR 69432 X GZ 1368	83.0	80.3	73.6	70.3	64.0	53.3	19.1	23.5
IR 69432 X Nerica 7	80.0	76.7	73.3	67.0	56.3	53.7	17.1	20.7
IR 69432 X Giza 178	83.0	80.3	73.4	70.7	66.0	60.0	19.9	20.7
IR 6500-127 X GZ 1368	83.3	80.0	73.3	70.3	63.3	60.0	22.5	18.4
IR 6500-127 X Nerica 7	76.7	76.7	70.0	67.0	64.7	63.5	17.3	18.0
IR 6500-127 X Giza 178	84.4	80.0	73.7	65.7	66.8	50.0	15.2	20.9
IR 12 G 3222 X GZ 1368	80.7	76.0	70.0	67.0	60.0	46.7	18.1	23.0
IR 12 G 3222 X Nerica 7	76.7	76.7	70.0	67.0	64.8	63.3	17.3	17.6
IR 12 G 3222 X Giza 178	83.5	81.3	73.5	67.0	66.0	53.3	19.2	24.7
IR 12 G 3213 X GZ 1368	83.0	80.3	71.0	70.0	63.7	63.3	19.0	16.0
IR 12 G 3213 X Nerica 7	80.0	80.0	73.3	70.3	62.7	46.3	17.7	17.3
IR 12 G 3213 X Giza 178	80.0	76.7	73.3	68.0	66.0	56.7	18.0	18.3
11 L 236 X GZ 1368	83.3	76.7	73.3	66.7	60.3	56.7	19.5	17.1
11 L 236 X Nerica 7	80.7	76.0	70.0	63.3	58.0	53.3	12.3	20.5
11 L 236 X Giza 178	83.3	80.0	72.9	70.0	66.0	53.3	18.8	20.2
Mean for crosses	**81.4**	**78.5**	**72.3**	**68.0**	**63.2**	**55.6**	**18.1**	**19.8**
IR 69432	80.0	78.0	73.0	67.8	61.0	53.7	17.2	18.4
IR 6500-127	76.7	71.3	68.0	63.3	57.7	48.0	18.4	17.0
IR 12 G 3222	83.5	81.3	73.3	69.3	58.7	55.7	22.1	24.0
IR 12 G 3213	80.0	78.0	73.0	68.3	59.7	51.3	17.6	17.8
11 L 236	80.0	74.8	69.7	68.8	63.3	58.3	17.2	16.0
GZ 1368-S-5-4	80.3	78.0	69.0	69.0	63.6	58.7	22.1	22.5
Nerica 7	83.3	81.0	71.7	68.0	62.7	57.0	18.7	19.4
Giza 178	80.0	76.0	72.0	67.0	63.7	59.3	17.5	17.3
Mean for varieties	**80.5**	**77.3**	**71.2**	**67.7**	**61.3**	**55.3**	**18.9**	**19.1**
LS D at 0.05	0.41	0.54	0.56	0.85	0.67	0.52	0.42	0.22
at 0.01	0.54	0.72	0.75	1.14	0.90	0.69	0.56	0.29

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

1. Estimates of general and specific combining ability effects

1.1. General combining ability effects

The estimates of general combining ability effects consider an important indicator of the potential lines for generating superior breeding populations. A negligible or negative combining ability effect indicates a poor ability to transfer its genetic superiority to hybrids. On the other hand, the largest significant negative values have the smallest effects, except in case of, duration (days), plant height and sterility % traits. Obviously, under normal and water deficit conditions data in Table 3 indicated that the line 11 L 236 and the tester Nerica 7 were the best general combiners for earliness. Also, the tester Nerica 7 was the best general combiner for plant height while, the line IR 69432 was the best general combiner for this trait, and for number of panicle/plant the line IR 12 G 3213 and the tester Giza 178 were the best general combiner for this trait. In addition, 11 L 236 rice line was a good general combiner for increasing number of filled grains/panicle and sterility%. While, the results revealed that among the studied parents, Giza 178 followed by 11 L 236 were the best general combiners for grain yield /plant. However, some parents with high mean values exhibited low GCA effects. Hence, both performances *per se* and GCA effects should be taken into account for parental selection. For grain shape line IR 6500-127 and tester Giza 178 were the best general combiner for this trait under both conditions. Lines 11 L 236, IR 12 G 3213 and tester Giza 178 were found to be good combiners for hulling % under normal and water deficit conditions. Moreover, line IR 69432 and tester Giza 178 under normal conditions also, line IR 12 G 3213 and tester GZ 1368 under water deficit conditions for milling %. As for head rice % line IR 6500-127 was the best general combiner under both conditions while testers Giza 178 and GZ 1368 were the best under normal and water deficit conditions respectively. Lines 11 L 236 under both conditions, IR 12 G 3213 under water deficit conditions and tester Nerica 7 under both conditions were found to be good combiners for Amylose content %. Generally, 11 L 236 was the best one, since it possessed significant and desirable GCA effects for most of the studied traits under normal and water deficit conditions followed by Nerica 7 and Giza 178 under both conditions. Therefore, it may be concluded that crosses involving these parents would result in the identification of superior segregants with favorable genes for grain yield and its related traits in this investigation. High GCA effects are related to additive and additive x additive components for genetic variation, the parents with higher positive significant GCA effects are considered as good combiners, while those with negative GCA effects are poor general combiners except in case of earliness, plant height, sterility %, grain shape and amylose content %. Similar results were obviously recorded by El-Naem (2010), El-Hity *et al.,* (2015) and Daher *et al.,* (2023). According to the results most of the studied genotypes were good combiners for water deficit conditions, consequently successful breeding program could be conducted for drought tolerance depending on pyramiding of gene specific to the studied traits and selection must be done in a later generation for most studied traits and under controlled conditions in order to minimize environmental effects.

1.2. Specific combining ability effects

The estimates of specific combining ability of fifteen crosses for twelve grain yield, its related traits and some grain quality traits are presented in Table (4). Highly significant negative estimates of SCA for number of days to 50% heading (earliness) were recorded for IR 12 G 3213 x Giza 178, IR 12 G 3222 x Nerica 7 cross combinations under normal and water deficit conditions, respectively. Moreover, IR 12 G 3222 x Giza 178 cross combination under normal and water deficit conditions exhibited negative and highly significant SCA effects for plant height. Significant and highly significant positive estimates of specific combining ability effects were recorded in 3 crosses under normal conditions and 2 crosses under water deficit for number of panicles/plant the highest positive values were estimated for the cross IR 69432 x Nerica 7 followed by IR 12 G 3213 x GZ 1368 under both conditions.

Table (3): Estimates of general combining ability (GCA) effects for grain yield, its related traits and some grain quality traits under normal and water deficit conditions.

Genotypes	Days to 50% heading (day)		Plant height (cm)		No. of panicles /plant		1000-grain weight (g)	
	N	D	N	D	N	D	N	D
L1- IR 69432	1.20*	-0.98*	-6.33**	-6.33**	0.80	0.60	-0.49*	-1.41**
L2- IR 6500-127	4.20**	1.24**	-3.67**	-3.67**	-1.87**	-2.07**	3.01**	1.59**
L3- IR 12 G 3222	-2.80**	0.24	2.67**	2.67**	0.13	-0.07	0.14	0.40
L4- IR 12 G 3213	0.20	2.58**	1.67**	1.67**	1.80**	1.60**	-1.83**	-0.79
L5- 11 L 236	-2.80**	-3.09**	5.67**	5.67**	-0.87	-0.07	-0.83**	0.21
S.E (g_i)	0.59	0.42	0.48	0.48	0.44	0.49	0.20	0.46
S.E (g_l-g_j)	0.83	0.60	0.67	0.67	0.63	0.69	0.29	0.66
L.S.D at 0.05	1.19	0.84	0.96	0.96	0.88	0.98	0.44	0.92
at 0.01	1.59	1.13	1.29	1.29	1.18	1.32	0.54	1.24
T1- GZ 1368-S-5-4	3.80**	0.24	3.33**	3.33**	-0.20	0.20	-1.29**	-1.39**
T2- Nerica 7	-3.80**	-1.42**	-2.47**	-2.47**	-1.40**	-1.60**	-0.48**	0.77*
T3- Giza 178	0.00	1.18	-0.87**	-0.87**	1.60**	1.40**	1.77**	0.62
S.E (g_i)	0.46	0.33	0.37	0.37	0.34	0.38	0.16	0.36
S.E (gt-g_j)	0.64	0.46	0.52	0.52	0.49	0.54	0.22	0.51
LS D at 0.05	0.93	0.67	0.75	0.75	0.69	0.77	0.32	0.72
at 0.01	1.24	0.89	1.00	1.00	0.92	1.03	0.43	0.97

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

Table (3): Continued

Genotypes	No. of filled grains / panicle		Sterility (%)		Grain yield/ plant		Grain shape	
	N	D	N	D	N	D	N	D
L1- IR 69432	-25.18**	-21.13**	1.19**	-1.84**	-2.58**	0.31	0.02	0.38**
L2- IR 6500-127	4.49**	-5.80**	0.59	0.90	-2.49**	-0.56	-0.14**	-0.17*
L3- IR 12 G 3222	-3.29**	-1.13	1.19**	8.60**	0.78	-2.33**	0.04	-0.11
L4- IR 12 G 3213	11.82**	19.53**	0.62	-2.92**	0.88	-0.43	0.06	-0.03
L5- 11 L 236	12.16**	8.53**	-3.58**	-4.73**	3.41**	3.01**	0.02	-0.07
S.E (g_i)	0.88	0.82	0.34	0.53	0.54	0.58	0.04	0.08
S.E (g_l-g_j)	1.25	1.16	0.48	0.75	0.76	0.82	0.06	0.12
L.S.D at 0.05	1.78	1.66	0.69	1.07	1.09	1.17	0.08	0.16
at 0.01	2.38	2.21	0.92	1.43	1.46	1.57	0.11	0.22
T1- GZ 1368-S-5-4	-1.78**	-4.47**	-0.96**	0.73	-3.20**	2.31**	0.20**	0.14*
T2- Nerica 7	29.16**	14.73**	0.57*	-2.10**	-0.19	-6.43**	0.04	0.05
T3- Giza 178	-27.38**	-10.27**	0.39	1.37**	3.38**	4.13**	-0.24**	-0.19**
S.E (g_i)	0.68	0.64	0.26	0.41	0.42	0.45	0.03	0.06
S.E (gt-g_j)	0.97	0.90	0.37	0.58	0.59	0.64	0.04	0.09
LS D at 0.05	1.37	1.29	0.53	0.83	0.85	0.91	0.06	0.12
at 0.01	1.84	1.73	0.70	1.11	1.13	1.22	0.08	0.16

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

Table (3): Continued

Genotypes	Hulling (%)		Milling (%)		Head rice (%)		Amylose content (%)	
	N	D	N	D	N	D	N	D
L1- IR 69432	0.85**	0.25*	1.22**	1.25**	-1.06**	0.09	0.63**	1.84**
L2- IR 6500-127	-0.05	0.05	0.09	-0.42*	1.51**	2.19**	0.27*	-0.69**
L3- IR 12 G 3222	-0.92**	-0.18	-1.08**	-1.09**	0.44**	-1.14**	0.13	1.97**
L4- IR 12 G 3213	-1.15**	1.15**	-0.05	1.68**	0.84**	-0.01	0.17	-2.59**
L5- 11 L 236	1.28**	-1.28**	-0.18	-1.42**	-1.73**	-1.14**	-1.20**	-0.53**
S.E (g_i)	0.08	0.11	0.11	0.17	0.14	0.10	0.09	0.04
S.E (g_l-g_j)	0.12	0.15	0.16	0.24	0.19	0.15	0.12	0.06
L.S.D at 0.05	0.16	0.22	0.22	0.34	0.28	0.20	0.18	0.08
at 0.01	0.22	0.30	0.30	0.46	0.38	0.27	0.24	0.11
T1- GZ 1368-S-5-4	0.91**	0.41**	-0.19*	0.97**	-0.98**	0.51**	1.57**	-0.19**
T2- Nerica 7	-2.33**	-1.63**	-0.93**	-1.17**	-1.86**	0.41**	-1.73**	-0.97**
T3- Giza 178	1.43**	1.21**	1.11**	0.19	2.84**	-0.91**	0.15*	1.17**
S.E (g_i)	0.06	0.08	0.09	0.13	0.11	0.08	0.07	0.03
S.E (gt-g_j)	0.09	0.12	0.12	0.19	0.15	0.11	0.09	0.05
LS D at 0.05	0.12	0.16	0.18	0.26	0.22	0.16	0.14	0.06
at 0.01	0.16	0.22	0.24	0.35	0.30	0.22	0.19	0.08

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

With regard to1000 grain weight, highly significant positive estimates of specific combining ability effects were recorded, the highest positive values were estimated for the cross 11 L 236 x Nerica 7 under normal conditions and IR 6500-127 x Nerica 7 under water deficit conditions. Significant and highly significant and positive estimates of specific combining ability effects were detected for 6 crosses under normal and 6 crosses under water deficit conditions for number of filled grains/panicle 11 L 236 x GZ 1368-S-5-4 and IR 6500-127 x Giza 178 were the best cross combinations for number of filled grains/panicle.

Moreover, IR 69432 x GZ 1368-S-5-4 under normal condition and IR 69432 x Nerica 7 under water deficit condition were the best cross combination for grain yield/plant. The cross combinations IR 12 G 3213 x Nerica 7 was the best specific combining ability for hulling % and milling % under normal conditions while, IR 12 G 3222 x Giza 178 and 11 L 236 x Giza 178 were the best specific combining ability for hulling % and milling % respectively under water deficit conditions. Cross combinations IR 12 G 3222 x Nerica 7 exhibited highly significant and positive SCA effects for head rice % under normal and water deficit conditions respectively. With regard to amylose content % the cross combinations IR 6500-127 x Giza 178 and IR 12 G 3222 x Nerica 7 were the best specific combining ability under normal and water deficit condition.

The superiority of these crosses may be due to complementary and duplicate type of gene interactions. Hence, these hybrids are expected to produce desirable segregates and could be exploited successfully in breeding programs.

Moreover, these cross combinations also included the parents which recorded either good or poor GCA for these traits. In table (4) results revealed that there is a preponderance of non-additive gene action for grain yield and most of its related traits in the hybrids resulted in high amount of vigor in F1. So, selection can be postponed to later generation. These findings were in agreement with those of EL-Naem (2010), El-Hity *et al.*, (2015), Abo-Zeid (2016), Daher *et al.*, (2023) and El-Agoury *et al.*, (2023).

Table (4): Estimates of specific combining ability (SCA) effects for grain yield and some grain quality traits under normal and water deficit conditions.

Crosses	Days to 50% heading (day)		Plant height (cm)		No. of panicles /plant		1000-grain weight (g)	
	N	**D**	**N**	**D**	**N**	**D**	**N**	**D**
IR 69432 X GZ 1368	-2.80**	3.64**	-3.7**	-3.7**	-3.80**	-4.20**	1.29**	1.46
IR 69432 X Nerica 7	-1.20	-0.02	9.1**	9.1**	3.40**	3.60**	-2.52**	-0.37
IR 69432 X Giza 178	4.00**	-3.62**	-5.5**	-5.5**	0.40	0.60	1.23**	-1.08
IR 6500-127 X GZ 1368	2.20	8.09**	-6.3**	-6.3**	-1.13	-1.53	0.79*	-1.43
IR 6500-127 X Nerica 7	-4.20**	-5.24**	-1.5	-1.5	1.07	1.27	1.06**	3.87**
IR 6500-127 X Giza 178	2.00	-2.84**	7.9**	7.9**	0.07	0.27	-1.85**	-2.44**
IR 12 G 3222 X GZ 1368	-4.80**	1.09	12.3**	12.3**	1.87**	1.47	-1.34**	-0.80
IR 12 G 3222 X Nerica 7	4.80**	-7.24**	1.1	1.1	-1.93*	-1.73*	-0.16	-1.96*
IR 12 G 3222 X Giza 178	0.00	6.16**	-13.5**	-13.5**	0.07	0.27	1.50**	2.76**
IR 12 G 3213 X GZ 1368	7.20**	-6.24**	0.3	0.3	3.20**	2.80**	0.63	1.39
IR 12 G 3213 X Nerica 7	-1.20	7.42**	-0.9	-0.9	-2.60**	-2.40**	-1.19**	-2.77**
IR 12 G 3213 X Giza 178	-6.00**	-1.18	0.5	0.5	-0.60	-0.40	0.56	1.38
11 L 236 X GZ 1368	-1.80	-6.58**	-2.7**	-2.7**	-0.13	1.47	-1.37**	-0.61
11 L 236 X Nerica 7	1.80	5.09**	-7.9**	-7.9**	0.07	-0.73	2.81**	1.23
11 L 236 X Giza 178	0.00	1.49*	10.5**	10.5**	0.07	-0.73	-1.44**	-0.62
S.E (S_{ij})	1.02	0.73	0.82	0.82	0.77	0.85	0.35	0.80
S.E (S_{ij} - S_{kl})	1.44	1.03	1.17	1.17	1.09	1.20	0.50	1.14
LS D at 0.05	2.06	1.47	1.66	1.66	1.56	1.72	0.70	1.62
at 0.01	2.75	1.97	2.21	2.21	2.08	2.30	0.94	2.16

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

Table (4): Continued

Crosses	No. of filled grains/ panicle		Sterility (%)		Grain yield/ plant		Grain shape	
	N	**D**	**N**	**D**	**N**	**D**	**N**	**D**
IR 69432 X GZ 1368	17.78**	10.13**	-1.47*	-6.28**	4.02**	-6.81**	0.22	-0.14
IR 69432 X Nerica 7	-34.16**	-15.07**	-1.60**	-1.72	-5.09**	6.43**	-0.36**	0.04
IR 69432 X Giza 178	16.38**	4.93**	3.07**	8.00**	1.07	0.37	0.14	0.09
IR 6500-127 X GZ 1368	-10.89**	-5.20**	-0.84	-10.69**	2.03*	-5.94**	-0.34*	-0.24
IR 6500-127 X Nerica 7	-18.82**	-38.40**	-0.03	2.13*	-3.28**	5.30**	0.28*	0.50**
IR 6500-127 X Giza 178	29.71**	43.60**	0.87	8.56**	1.25	0.64	0.05	-0.26
IR 12 G 3222 X GZ 1368	-16.11**	-28.87**	4.43**	24.81**	-2.74**	3.43**	0.01	-0.07
IR 12 G 3222 X Nerica 7	24.62**	41.93**	-0.80	-9.57**	2.36*	-6.23**	-0.03	-0.17
IR 12 G 3222 X Giza 178	-8.51**	-13.07**	-3.63**	-15.24**	0.38	2.81**	0.02	0.23
IR 12 G 3213 X GZ 1368	-32.22**	-5.53**	-1.01	-6.07**	-2.94**	5.13**	-0.02	0.35*
IR 12 G 3213 X Nerica 7	39.84**	19.27**	2.07**	6.59**	2.96**	-6.43**	0.10	-0.35*
IR 12 G 3213 X Giza 178	-7.62**	-13.73**	-1.06	-0.52	-0.02	1.31	-0.08	0.00
11 L 236 X GZ 1368	41.44**	29.47**	-1.11	-1.76	-0.37	4.19**	0.12	0.10
11 L 236 X Nerica 7	-11.49**	-7.73**	0.37	2.57**	3.06**	0.93	0.01	-0.03
11 L 236 X Giza 178	-29.96**	-21.73**	0.74	-0.81	-2.68**	-5.13**	-0.13	-0.06
S.E (S_{ij})	1.53	1.43	0.59	0.92	0.94	1.00	0.07	0.14
S.E (S_{ij} - S_{kl})	2.16	2.02	0.83	1.31	1.32	1.42	0.10	0.20
LS D at 0.05	3.09	2.89	1.19	1.86	1.90	2.02	0.26	0.28
at 0.01	4.13	3.86	1.59	2.48	2.54	2.70	0.35	0.38

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

Table (4): Continued.

Crosses	Hulling (%)		Milling (%)		Head rice (%)		Amylose content (%)	
	N	D	N	D	N	D	N	D
IR 69432 X GZ 1368	0.09	0.79**	0.42*	-0.01	2.88**	-2.87**	-1.17**	2.06**
IR 69432 X Nerica 7	0.33*	-0.77**	0.76**	-1.17**	-3.94**	-2.37**	0.13	0.04
IR 69432 X Giza 178	-0.43**	-0.01	-1.18**	1.17**	1.06**	5.25**	1.05**	-2.10**
IR 6500-127 X GZ 1368	1.29**	0.69**	1.15**	1.66**	-0.39	1.73**	2.59**	-0.51**
IR 6500-127 X Nerica 7	-2.07**	-0.57**	-1.41**	0.50	1.89**	5.13**	0.69*	-0.13
IR 6500-127 X Giza 178	0.77**	-0.11	0.25	-2.16**	-1.51**	-6.85**	-3.29**	0.63**
IR 12 G 3222 X GZ 1368	-0.44**	-3.08**	-0.98**	-0.97*	-2.62**	-8.24**	-1.67**	1.43**
IR 12 G 3222 X Nerica 7	-1.20**	-0.34	-0.24	1.17**	3.06**	8.46**	0.83**	-3.19**
IR 12 G 3222 X Giza 178	1.64**	3.42**	1.22**	-0.19	-0.44	-0.22	0.85**	1.77**
IR 12 G 3213 X GZ 1368	-0.91**	2.89**	-2.01**	0.26	0.28	7.63**	-0.81**	-1.01**
IR 12 G 3213 X Nerica 7	2.33**	1.63**	2.03**	1.70**	0.56*	-9.67**	1.19**	1.07**
IR 12 G 3213 X Giza 178	-1.43**	-4.51**	-0.01	-1.96**	-0.84**	2.05**	-0.39	-0.07
11 L 236 X GZ 1368	-0.04	-1.28**	1.42**	-0.94*	-0.15	1.76**	1.06**	-1.97**
11 L 236 X Nerica 7	0.60**	0.06	-1.14**	-2.20**	-1.57**	-1.54**	-2.84**	2.21**
11 L 236 X Giza 178	-0.56**	1.22**	-0.28	3.14**	1.73**	-0.22	1.78**	-0.23**
S.E (S_{ij})	0.14	0.19	0.20	0.41	0.24	0.18	0.26	0.08
S.E (S_{ij} - S_{kl})	0.20	0.27	0.28	0.58	0.33	0.26	0.36	0.11
LS D at 0.05	0.28	0.38	0.40	0.82	0.48	0.36	0.53	0.16
at 0.01	0.38	0.51	0.54	1.10	0.65	0.49	0.70	0.22

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

Estimates of mid and better parent 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 most of cross combinations under both conditions for grain yield /plant the best one was IR 6500-127 x Nerica 7.

The availability of sufficient hybrid vigor in several crosses in respect of grain yield suggests that a hybrid breeding program could profitably be undertaken in rice under water deficit condition. The crosses IR 12 G 3213 x Giza 178 under normal, 11 L 236 x GZ 1368-S-5-4 under water deficit conditions exhibited highest negative heterosis for days to 50% heading when it measured as a deviation from mid-parent. Appearance of significant and negative heterosis for number of days to 50% heading indicated the possibility of exploiting heterosis for earliness.

For plant height the cross11 L 236 x GZ 1368-S-5-4 under normal and IR 12 G 3222 x Giza 178 under water deficit conditions recorded highly significant mid parent heterosis and for better parent heterosis the cross11 L 236 x GZ 1368-S-5-4 under normal and the cross11 L 236 x Nerica 7 under water deficit conditions recorded highly significant values. Approximately, high estimated values of mid parent heterosis were reported in IR 12 G 3213 x Giza 178 under normal and IR 69432 x Nerica 7 under water deficit conditions exhibited significant and highly significant positive estimates of heterosis for number of panicles/plant. While, the cross IR 6500-127 x Nerica 7 under normal and the cross IR 69432 x Nerica 7 under water deficit conditions recorded highly significant values for better parent heterosis. Very few crosses recorded significant positive either mid or better parent 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. The best cross combinations for mid parent heterosis was 11 L 236 x Nerica 7 under normal conditions whilst, the cross combination IR 6500-127 x Nerica 7 recorded highly significant values for mid-parent and better parent heterosis under water deficit conditions.

Table (5): Estimates of heterosis as a deviation from mid-parent (MP) and better-parent (BP) for grain yield and some grain quality traits under normal and water deficit conditions.

No	Genotypes	Number of days to 50% heading (day)				Plant height (cm)			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	3.77**	7.79**	6.80**	11.97**	17.14**	4.65**	27.18**	8.43**
2	IR 69432 X Nerica 7	0.48	4.76**	6.12**	11.11**	-0.45	4.86**	6.80**	8.99**
3	IR 69432 X Giza 178	2.26	-3.11**	3.67**	-1.80	-1.46	-2.89**	-0.98	0.00
4	IR 6500-127 X GZ 1368	11.85**	19.61**	14.56**	20.79**	21.80**	2.86**	33.66**	8.43**
5	IR 6500-127 X Nerica 7	0.97	7.00**	6.12**	8.08**	20.55**	-5.32**	30.69**	-3.26**
6	IR 6500-127 X Giza 178	3.64**	4.19**	5.56**	10.89**	2.46**	13.64**	2.97**	19.05**
7	IR 12 G 3222 X GZ 1368	-0.48	8.06**	0.97	10.68**	4.79**	12.75**	11.88**	38.55**
8	IR 12 G 3222 X Nerica 7	3.92**	0.48	8.16**	5.05**	0.39	-9.68**	8.47**	2.08
9	IR 12 G 3222 X Giza 178	-3.67**	8.11**	-0.94	11.11**	17.99**	-17.07**	38.24**	1.19
10	IR 12 G 3213 X GZ 1368	14.98**	6.86**	15.53**	7.92**	3.26**	13.97**	9.39**	22.89**
11	IR 12 G 3213 X Nerica 7	1.98	21.00**	5.10**	22.22**	-1.19	-1.04	5.93**	-1.04
12	IR 12 G 3213 X Giza 178	-11.54**	14.85**	-1.92	13.86**	30.37**	16.67**	36.27**	16.67**
13	11 L 236 X GZ 1368	1.90	-4.63**	3.88**	0.00	-13.14**	8.42**	-10.50**	24.10**
14	11 L 236 X Nerica 7	0.49	6.60**	5.10**	14.14**	8.94**	-9.36**	13.56**	-4.17**
15	11 L 236 X Giza 178	-4.11**	-1.32	-1.87	-0.88	14.78**	17.28**	29.41**	33.33**
L.S.D 0.05			1.81	2.91	2.09	1.71	1.74	1.97	2.01
0.01		3.37	2.42	3.89	2.79	2.29	2.32	2.64	2.68

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

Table (5): Continued

No	Genotypes	No. of panicles / plant				1000 grain weight (g)			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	57.89**	-8.33	42.86**	-15.38	4.17*	1.43	-3.85	3.51
2	IR 69432 X Nerica 7	26.67**	54.55**	11.76	54.55**	-15.38**	-6.50	-15.38**	-15.90**
3	IR 69432 X Giza 178	65.00**	25.93**	43.48**	6.25	3.70*	-10.55*	0.00	-19.54**
4	IR 6500-127 X GZ 1368	43.75**	-4.35**	9.52	-15.38	6.75**	-14.05*	-8.07**	-24.64**
5	IR 6500-127 X Nerica 7	116.67**	14.29	100.00**	9.09	3.05	27.38**	-4.49**	12.68**
6	IR 6500-127 X Giza 178	111.76**	7.69	56.52**	-12.50	-2.75	-16.92**	-6.68**	-20.83**
7	IR 12 G 3222 X GZ 1368	51.35**	23.08**	33.33**	23.08*	-6.12**	-14.16**	-14.81**	-23.12**
8	IR 12 G 3222 X Nerica 7	37.93**	-8.33	25.00**	-15.38	-5.66**	-17.10**	-7.41**	-19.12**
9	IR 12 G 3222 X Giza 178	94.87**	10.34	65.22**	0.00	5.13**	1.60	3.25	-0.88
10	IR 12 G 3213 X GZ 1368	15.00**	40.74**	9.52	35.71**	0.00	-4.98	-4.17	-11.24*
11	IR 12 G 3213 X Nerica 7	37.50**	-4.00	15.79**	-14.29	-12.00**	-21.74**	-15.38**	-23.38**
12	IR 12 G 3213 X Giza 178	147.37**	28.57	52.17**	6.25	0.00	-9.31	-7.14**	-6.56
13	11 L 236 X GZ 1368	10.53*	18.52*	0.00	14.29	-2.22	-7.51	-4.35	-11.75*
14	11 L 236 X Nerica 7	33.33**	-4.00	17.65**	-14.29	10.20**	1.93	3.85	-2.35
15	11 L 236 X Giza 178	55.00**	0.00	34.78**	-6.25	-1.96	-6.85	-10.71**	-10.77*
L.S.D 0.05			2.10	2.01	2.42	1.95	1.99	1.00	2.26
0.01		2.32	2.81	2.68	3.24	2.61	2.66	1.34	3.02

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

Table (5): Continued

No	Genotypes	No. of filled grains/ panicle				Sterility (%)			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	1.66	-1.07	-11.11**	-17.26**	5.80	-10.32	37.74*	5.16
2	IR 69432 X Nerica 7	-4.68**	3.91**	-21.26**	-20.83**	-25.96**	-8.25	2.35	21.94
3	IR 69432 X Giza 178	-15.59**	-6.23**	-24.15**	-23.81**	30.05**	100.52**	55.29**	149.68**
4	IR 6500-127 X GZ 1368	7.25**	18.30**	-2.63*	13.93**	7.84	-50.49**	38.36*	-33.81**
5	IR 6500-127 X Nerica 7	28.00**	19.05**	9.47**	2.46	-17.02*	-4.95	16.47	12.06
6	IR 6500-127 X Giza 178	12.68**	60.35**	5.26**	49.18**	3.48	50.52**	25.30*	88.96**
7	IR 12 G 3222 X GZ 1368	-7.53**	-27.71**	-20.74**	-45.21**	186.96**	463.44**	238.46**	1014.89**
8	IR 12 G 3222 X Nerica 7	38.45**	36.81**	12.29**	-4.11*	0.53	39.24**	143.59**	223.40**
9	IR 12 G 3222 X Giza 178	-19.37**	-19.75**	-29.03**	-40.64**	-17.20	29.35*	66.67**	176.60**
10	IR 12 G 3213 X GZ 1368	-11.40**	1.55	-25.97**	-21.90**	16.13	-4.91	35.85*	40.19*
11	IR 12 G 3213 X Nerica 7	49.73**	39.60**	18.61**	-0.95	6.79	63.46**	66.20**	178.04**
12	IR 12 G 3213 X Giza 178	-24.24**	-7.14**	-26.41**	-28.57**	-26.76	138.32**	19.72	127.10**
13	11 L 236 X GZ 1368	29.63**	24.92**	9.87**	0.00	-61.59**	-34.90**	-45.28**	-10.07
14	11 L 236 X Nerica 7	24.58**	23.19**	0.00	-9.57**	-52.42**	-32.75**	-39.80**	-18.29*
15	11 L 236 X Giza 178	-23.71**	-10.58**	-33.63**	-30.32**	-43.52**	-29.32**	-37.76**	-8.44
L.S.D 0.05			3.53	4.37	4.07	1.46	2.28	1.68	2.64
0.01		5.06	4.72	5.84	5.45	1.95	3.05	2.25	3.52

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

Table (5): Continued

No.	Genotypes	Grain yield/ plant				Grain shape			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	29.04**	53.23**	25.37**	43.26**	31.37**	19.01*	75.90**	40.94**
2	IR 69432 X Nerica 7	34.55**	93.96**	10.49**	64.19**	-18.68**	11.36	25.00**	46.20**
3	IR 69432 X Giza 178	27.98**	77.68**	22.30**	70.82**	20.70**	25.20*	40.54**	35.09**
4	IR 6500-127 X GZ 1368	42.11**	72.55**	28.02**	64.71**	-24.85**	-22.74**	-24.30**	-20.09*
5	IR 6500-127 X Nerica 7	64.65**	108.78**	52.26**	95.88**	-16.40**	-3.42	-7.28	9.59
6	IR 6500-127 X Giza 178	45.53**	94.54**	22.89**	68.24**	-18.42**	-32.85**	-6.95	-29.29**
7	IR 12 G 3222 X GZ 1368	16.84**	54.53**	10.34**	23.87**	0.14	-14.41	3.43	-13.85
8	IR 12 G 3222 X Nerica 7	60.67**	-12.85*	28.97**	-35.48**	-18.52**	-29.27**	-5.58	-22.08*
9	IR 12 G 3222 X Giza 178	30.40**	45.86**	28.22**	27.74**	-7.84	-8.62	0.68	-1.01
10	IR 12 G 3213 X GZ 1368	14.23**	75.00**	5.97*	43.34**	-2.70	8.77	-2.04	11.71
11	IR 12 G 3213 X Nerica 7	58.81**	-1.81	25.66**	-25.94**	-14.49**	-32.40**	-3.67	-23.87*
12	IR 12 G 3213 X Giza 178	54.42**	93.52**	26.99**	36.52**	-25.17**	-27.03	-3.39	-9.09
13	11 L 236 X GZ 1368	30.43**	94.32**	24.41**	64.21**	2.39	-6.41	4.17	-6.41
14	11 L 236 X Nerica 7	72.44**	54.76**	39.51**	19.93**	-18.83**	-23.05**	-7.50	-15.81
15	11 L 236 X Giza 178	30.75**	46.83**	27.26**	36.53**	-17.56**	-21.30*	-8.47	-14.14
L.S.D 0.05			2.48	2.67	2.87	0.17	0.35	0.20	0.41
0.01		3.09	3.32	3.57	3.83	0.23	0.47	0.26	0.55

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

Table (5): Continued

No.	Genotypes	Hulling (%)				Milling (%)			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	3.56**	0.37	3.36**	0.37	3.58**	5.47**	0.55	4.71**
2	IR 69432 X Nerica 7	-2.02**	-6.06**	-3.96**	-7.92**	1.10**	0.00	0.00	0.00
3	IR 69432 X Giza 178	3.75**	1.65**	3.75**	0.37**	1.03**	5.29**	0.14	5.29**
4	IR 6500-127 X GZ 1368	6.11**	4.37**	3.74**	0.00	7.01**	10.81**	6.23**	6.23**
5	IR 6500-127 X Nerica 7	-4.13**	-2.04**	-7.92**	-7.92	0.21	5.03**	-2.37**	0.00
6	IR 6500-127 X Giza 178	6.32**	5.75**	4.13**	2.56**	5.29**	0.08	2.36**	-4.71**
7	IR 12 G 3222 X GZ 1368	-1.34**	-6.92**	-3.12**	-8.76**	-1.62**	-0.21	-4.50**	-1.82**
8	IR 12 G 3222 X Nerica 7	-7.92**	-7.92**	-7.92**	-7.92**	-3.45**	-0.92	-4.50**	-1.82**
9	IR 12 G 3222 X Giza 178	2.02**	3.29**	0.00	0.00	1.17**	-0.92	0.27	-1.82**
10	IR 12 G 3213 X GZ 1368	-0.19	4.13**	-0.37	4.13**	-1.41**	10.92**	-4.11**	10.68**
11	IR 12 G 3213 X Nerica 7	-2.02**	-2.02**	-3.96**	-3.96**	1.31**	5.24**	0.41	4.71**
12	IR 12 G 3213 X Giza 178	0.00	-5.75**	0.00	-4.13**	2.19**	1.01	0.41	0.00
13	11 L 236 X GZ 1368	3.93**	-2.17**	3.74**	-4.13**	5.70**	-3.19**	5.16**	-3.33**
14	11 L 236 X Nerica 7	-1.16**	-5.06**	-3.12**	-8.76**	-0.99**	-8.79**	-2.37**	-9.57**
15	11 L 236 X Giza 178	4.13**	3.36**	4.13**	2.56**	2.89**	2.31**	1.25**	1.43*
L.S.D 0.05			0.47	0.41	0.54	0.48	0.74	0.56	0.85
0.01		0.47	0.62	0.54	0.72	0.65	0.98	0.75	1.14

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

Table (5): Continued

No	Genotypes	Head rice (%)				Amylose content (%)			
		M.P		B.P		M.P		B.P	
		N	D	N	D	N	D	N	D
1	IR 69432 X GZ 1368	4.32**	-11.17**	3.73**	-15.80**	-2.80**	14.91**	11.05**	27.72**
2	IR 69432 X Nerica 7	-8.97**	-7.97**	-10.21**	-10.50**	-4.74**	9.52**	-0.58	12.50**
3	IR 69432 X Giza 178	5.85**	0.00	3.61**	-5.21**	14.70**	15.97**	15.70**	19.65**
4	IR 6500-127 X GZ 1368	6.03**	5.91**	2.59**	-5.21**	11.11**	-6.84**	22.28**	8.24**
5	IR 6500-127 X Nerica 7	7.48**	15.09**	3.19**	5.50**	-6.74**	-1.10*	-5.98**	5.88**
6	IR 6500-127 X Giza 178	8.73**	-11.74**	3.61**	-21.01**	-15.32**	21.87**	-13.14**	22.94**
7	IR 12 G 3222 X GZ 1368	-0.33**	-23.44**	-2.76**	-26.22**	-18.10**	-1.08*	-18.10**	2.22**
8	IR 12 G 3222 X Nerica 7	6.75**	6.66**	3.35**	5.50**	-15.20**	-18.89**	-7.49**	-9.28**
9	IR 12 G 3222 X Giza 178	7.84**	-12.62**	3.61**	-15.80**	-3.03**	19.61**	9.71**	42.77**
10	IR 12 G 3213 X GZ 1368	4.28**	9.26**	2.59**	0.63	-4.28**	-20.60**	7.95**	-10.11**
11	IR 12 G 3213 X Nerica 7	2.45**	-18.27**	0.00	-22.83**	-2.48*	-6.99**	0.57	-2.81**
12	IR 12 G 3213 X Giza 178	14.41**	-6.00**	3.61**	-10.43**	5.11*	8.43**	2.86*	5.78**
13	11 L 236 X GZ 1368	-1.47**	-10.43**	-2.27**	-10.43**	-1.88	-12.01**	10.50**	4.46**
14	11 L 236 X Nerica 7	-6.00**	-13.54**	-7.50**	-15.80**	-32.32**	14.62**	-24.19**	25.23**
15	11 L 236 X Giza 178	6.11**	-15.80**	3.61**	-15.80**	6.98**	19.99**	7.43**	23.40**
L.S.D 0.05			0.45	0.67	0.52	0.37	0.19	0.42	0.22
0.01		0.78	0.60	0.90	0.69	0.49	0.25	0.56	0.29

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

On the other hand among 15 crosses around half cross combinations recorded significant positive mid and better parent heterosis for number of filled grain / plant, and it was the best of them for mid and better parent heterosis the cross IR 12 G 3213 x Nerica 7 under normal conditions and the cross IR 6500-127 x Giza 178 under water deficit conditions. Cross 11 L 236 x GZ 1368-S-5-4 recorded significant negative mid and better parent heterosis for sterility % under normal conditions while, cross IR 6500-127 x GZ 1368-S-5-4 was the best under water deficit conditions. 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), Amudha *et al.*, (2010), Daher *et al.*, (2023) and El-Agoury *et al.*, (2023).

Moreover, significant and highly significant and negative estimates of mid and better parent heterosis were observed for grain shape in the cross IR 6500-127 x GZ 1368-S-5-4 under both conditions however, IR 6500-127 x Giza 178 was the best cross combinations under water deficit conditions. The cross IR 6500-127 x Giza 178 under both conditions exhibited significant and highly significant positive heterosis of hulling %, and for milling % the cross IR 6500-127 x GZ 1368-S-5-4 under both conditions gave highly significant values of mid-parent and better parent. On the other hand, the crosses IR 12 G 3213 x Giza 178, IR 6500-127 x Nerica 7 recorded highly significant heterosis in a desirable direction for head rice % measured as a deviation from mid-parent and better parent under both conditions. As for amylose content % the crosses11 L 236 x Nerica 7 and IR 12 G 3213 x GZ 1368-S-5-4 were the best combinations under both conditions. Similar results were reported by El-Naem (2010), El-Naem (2014), Abo-Zeid (2016), Devi *et al.*, (2018) and Sakran *et al.*, (2022).

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دراسات على القدرة على التآلف للمحصول ومكوناته وبعض صفات الجودة فى الأرز باستخدام نظام السلالة × الكشاف تحت الظروف الطبيعية وندرة المياه

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قسم بحوث الارز – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية – الجيزة – مصر

الملخص العربى

تمت دراسة القدرة العامة والخاصة على التآلف وتقدير قوة الهجين باستخدام خمسة عشر هجينا وأبائهم لدراسة السلوك الوراثي لصفات المحصول ومكوناته وبعض صفات الجودة وذلك بهدف انتخاب أفضل التراكيب الوراثية تحت الظروف العادية وظروف نقص المياه وذلك باستخدام تصميم اختبار السلالة × الكشاف خلال موسمي الزراعة ٢٠٢١ و٢٠٢٢ بالمزرعة البحثية محطة البحوث الزراعية – سخا – كفرالشيخ – مصـــر. أظهرت النتائج أن القدرة العامة والقدرة الخاصة على التآلف كانت عالية المعنوية لجميع الصفات المدروسة باستثناء صفة شكل الحبة حيث كانت غير معنوية تحت كلا البيئتين. كما أوضحت تأثيرات القدرة العامة على الإئتلاف أن الاب ١١ إل ٢٣٦ كان أفضل الآباء لصفات عدد الأيام حتى ٥٠% طرد، عدد الحبوب الممتلئة / الدالية، النسبة المئوية للعقم ومحصول النبات الفردي تحت كلا البيئتين. سجل الاب جيزة ١٧٨ أعلى قدرة عامة على الإئتلاف لصفات عدد الداليات / نبات، محصول النبات الفردي والنسبة المئوية للتقشير تحت كلا البيئتين والآباء آى أر ٦٥٠٠-١٢٧، جيزة ١٧٨ و جي زد ١٣٦٨ لصفة النسبة المئوية للحبوب السليمة والأب ١١ إل ٢٣٦ لصفة للنسبة المئوية لمحتوى الأميلوز تحت كلا البيئتين. هذا وقد وجد أن الهجن أى أر ٦٩٤٣٢ x نيريكا ٧، أي أر ٦٩٤٣٢ × جي زد ١٣٦٨، أى أر ١٢ جى ٣٢١٣ × جيزة ١٧٨ ، أى أر ١٢ جى ٣٢٢٢ × جيزة ١٧٨ و أى أر ١٢ جى ٣٢٢٢ × نيريكا ٧ كانت أفضل التراكيب الوراثية لمعظم الصفات المدروسة حيث كانت قدرتها الخاصة على التآلف عالية المعنوية في الإتجاه المرغوب تحت كلا البيئتين. أظهرت النتائج أن الهجن أى أر ٦٥٠٠-١٢٧ x نيريكا ٧، ١١ إل ٢٣٦ x جى زد ١٣٦٨، أى أر ٦٩٤٣٢ × نيريكا ٧، أى أر ١٢ جى ٣٢١٣ × نيريكا ٧، أى أر ١٢ جى ٣٢٢٢ × جى زد ١٣٦٨ و أى أر ١٢ جى ٣٢٢٢ × نيريكا ٧ اظهرت معنوية عالية وفى الاتجاه المرغوب لقوة الهجين وذلك عند قياسها كإنحراف عن قيم متوسط الأبوين وأفضل الأبوين لكثير من الصفات المدروسة تحت الظروف الطبيعية وظروف نقص المياة.