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Research Article

Combining Ability and Heterosis Studying for Yield and its Attributes of Hybrid Rice Under Normal and Salinity Conditions Using Line × tester Scheme

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Abstract:

The present investigation was conducted under normal and salinity conditions during the two rice successive seasons of 2020 and 2021. Three CMS lines of rice, IR69625A, G46A and GAB-A were used as female parents. In addition, four Egyptian tester lines viz., Giza179, PR5, PR6 and GZ9399 were used as testers beside their twelve F1 crosses. A randomized complete block design with three replications was used and the data were analyzed according to line × tester design. The results indicated highly significant differences among genotypes, parents, crosses and parents vs. crosses under the two environments (normal and salinity conditions).The results showed that dominance genetic variance (σ^2D) was greater than additive genetic variance for Plant height, Number of panicles/plant, Spikelet fertility %, 1000-grain weight, Grain yield/plant, sodium content and potassium content under normal and salinity conditions, Panicle weight under salinity condition, indicating that non-additive gene action played an important role in the inheritance of this trait. For heterosis over the mid-parents (H.M.P.%): The most desirable hybrids; For grain yield plant-1, the highly values and highly significant heterosis based on mid-parents for grain yield plant-1 were observed for the crosses GAB-A/PR5, GAB-A/PR6, GAB-A/GZ9399, G46A/GZ9399, G46A/PR6 and G46A/PR6 under both conditions. The following genotypes could use in breeding program and expected improvement in such traits under normal and saline condition, G46A, PR6, GZ9399, Giza179 and GAB-A as a good donor. G46A/PR6, G46A/PR5, GAB-A/ PR6 and IR69625A/Giza179 could use as good crosses.

1. Introduction

Rice (*Oryza sativa*, L.) is one of the strategic crops in Egypt and the improvement of its productivity is an essential requirement to ensure food security. Salinity is one of the major environmental stresses that limit the productivity of rice crops (Ramadan et al., 2020). Rice is the most important crop, being the dominant food in most of the countries around the world. In Egypt, rice is considered one of the most adapted summer crops to the salt-affected coastal areas. Rice can withstand water-logging and standing water helps diluting and leach salts from surface soil (Ismail et al., 2008).

Rice is a very important crop in Egypt and the production of rice yield is facing several challenges such as saline soil and drought. Furthermore, about 30% of lands in northern part of delta are salt affected soil (Negm et al., 2019). Accordingly, salinity considered one of the major abiotic stresses affecting rice sustain-ability and yield. Rice scientists in Egypt at Rice Re-search and Training Center (RRTC) have long worked on developing new cultivars and promising lines to overcome adverse environments for rice cultivation, among these cultivars Sakha104, Giza178 and Gi-za179 (Zayed et al., 2017).

Salinity as an abiotic stress widely limits the crop production severely. Salt stress reduced rice growth rate, promoted metabolic alterations, and decreased ability to uptake water and nutrients. Moreover, poor development of rice spikelets, especially inferior spikelets caused by salt stress significantly reduced rice grain yield (Sajid et al., 2017).

Understanding the genetic behavior of salinity tolerance is a major concern to produce new genotypes suitable for the salt affected areas in Egypt. In breeding program, the knowledge of genetic variability for evolving high grain quality is important. Genetic advance is more helpful in predicting the gain under selection than heritability estimates alone (Anis and Gharib, 2016).

El-Mowafi et al., (2019 and 2022) revealed significantly general and positive specific combining ability (SCA) effects for the yield and yield component under both normal, water stress and saline stress conditions. The inconsistent correlation between the general combining ability (GCA) and (SCA) manifested complex interactions among the positive and negative alleles of the genes controlling the yield traits. Generally, the findings of this investigation demonstrated the importance of the GCA and SCA for understanding the genetic components and gene actions of the yield characteristics in new aromatic hybrid rice parental lines. There-fore, we recommend considering these findings in the selection of elite parents for developing superior aromatic hybrid rice varieties under water-stress conditions.

Mazal et al., (2021) revealed that the dominance genetic variance (σ2D) was greater than the additive genetic variance (σ2A) in controlled the inheritance of all the studied traits, They indicated that the heritability values are high for plant height (97.10%) and sterility % (97.73%), indicating slight effects of environment on the traits. On the other hand, heritability estimates in the narrow sense are low to moderate, these results also illustrated that major part of the total genotypic variance was non-additive in nature for these traits. The contributions of the lines were higher than the contribution of the testers for number of panicles/plant (32.30%), number of filled grains/panicle (24.18%), sterility % (32.10%) and grain yield/plant (27.30%). The contribution of line × tester interaction was important for number of filled grains/panicle (69.26%), grain yield/plant (66.18%), sterility % (65.88%), number of panicles/plant (55.81%) and plant height (52.47%).

Accordingly, the aim of this study, the potentiality of heterosis over mid parents in rice for some agronomic, sodium and potassium content and yield com-ponents traits. Furthermore estimate the combining ability to detect the best general combiner and the best combination for studied traits. Assessment the genetic parameters and heritability estimates in both broad and narrow sense for the studied traits under normal saline condition. Selected the best genotypes can used in breeding program under normal and salinity conditions.

2. Materials and Methods

The present investigation was conducted at the Experimental Farm of Rice Research and Training Center (RRTC), Sakha, Kafer El-Sheikh and El-Sirw Station, Egypt, Egypt, during the 2021 season.

The genetic materials used in this investigation involved three CMS lines of rice obtained from different sterile sources of Wild Abortive (WA) and Gambiaca (three lines system). These lines were; IR69625A, G46A and GAB-A which used as female parent. In addition four Egyptian tester lines viz., Giza179, PR5, PR6 and GZ9399 were used as tester beside their twelve F1 crosses (Table 1).

Table 1: Cytoplasmic male sterile lines and tester lines used for this study.

Genotypes	Cytoplasmic source pedigree	Grain type	Origin
PTGMS lines (female) CMS lines			
IR69625A	Wild abortive (WA) CMS line	Indica long grain	IRRI
G46A	Gambiaca	Indica long grain	China
GAB-A	Gambiaca	Indica long grain	IRRI
Tester lines (male) Restorer line			
Giza179	GZ1368-5-S-5/GZ6296-12-1-2-1-1	Indica short grain	Egypt
PR5	Giza 178/GZ6296-12-1-2-1-1	Indica long grain	Egypt
PR6	Giza 178/GZ6296-12-1-2-1-1	Indica long grain	Egypt
GZ9399	Giza 178/IR65844-29-1-3-1-2	Indica short grain	Egypt

The representative soil samples were taken form experimental site in the two station and the main soil physical and chemical properties were listed in Table2.

Table 2: Some chemical and physical analysis of experimental sites during 2021 season.

Soil	E.C.	pH	meqL^{-1}			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}
Normal	2.07	7.59	2.98	1.12	14.96	0.47
Salinity	8.13	8.46	12.9	6.1	65.23	0.35

Soil	meqL^{-1}			
	$Co_3^{=}$	Hco_3^{-}	Cl^{-}	$So_4^{=}$
Normal	2.17	1.34	13.35	5.36
Salinity	6.82	7.36	61.29	12.33

The experiments were performed in randomized complete block design in the two sites as apart. The sowing date in the two sites was May1st . The seedlings aged 30 days of tested material were transplanted as one seedling hill-1 with spaces of 20x20 for row and hill. Each lines, tester and cross has only on row with length of 5m. All recommendations package were applied as it developed by National rice program, ministry of agriculture.

At harvest, the parents and F1 were evaluated under the two environments; i.e., normal and salinity conditions. Ten traits; i.e., plant height, panicle length, days to heading, sodium and potassium content, panicles plant-1, spikelets fertility percentage, 1000-Grain weight, panicle weight and grain yield plant-1 for yield traits. Randomized complete block design with three replications was used and the data were analyzed according to line × tester design.

2.1 Statistical analyses

2.1.1 Estimates of combining ability

The data were analyzed by using the ordinary analysis of variance to test the significance of differences among the 19 genotypes (three CMS lines, four restorers as testers and their 12 F1 hybrids). If the genotypes mean squares were found to be significant, there was a need to proceed for further analysis, i.e., line x tester analysis.

2.1.2 Estimates of combining ability effects

General combining (GCA) and specific combining (SCA) effects of each lines and crosses were calculated according to Griffing (1956).

2.1.3 Heterosis versus the mid-parents (MP)%

The amount of heterosis as proposed by Mather (1949) and Mather and Jinkes (1982).

2.1.4 Estimates of variance components and heritability

2.1.4.1 Genetic parameters

The following variance components were estimated based on the expectations of mean squares according to Kempthone (1957) and Virmaniet al., (1997).

2.1.4.2Heritability.

The formula of Burton (1952) was used to estimate heritability in the broad and narrow senses.

3. Results and Discussions

The obtained results can be summarized as follow:

The analysis of variance in Table3 indicated highly significant differences among genotypes, parents, crosses, parents vs. crosses under the two environments normal and salinity conditions with respect all studied characters. Negm (2012) and El-Mowafiet al., (2019 and 2022) reported similar results.

Table 3: Analysis of variance of all the studied traits.

SOV	df	Days to heading (day)		Plant height (cm)		Number of panicles/plant		Panicle length (cm)		Panicle weight (g)	
		N	S	N	S	N	S	N	S	N	S
Replications	2	2.74	1.63	3.00	6.79*	0.07	1.00	0.05	2.55	0.04	0.021
Treatments	18	65.66**	53.63**	74.02**	215.45**	13.06**	78.27**	8.18**	11.91**	4.03**	0.958**
Parents	6	89.00**	79.60**	83.21**	183.82**	12.60**	72.87**	2.70*	10.15**	0.52*	1.040**
Pa vs Cros	1	18.92**	23.86**	478.11**	1444.63**	89.88**	62.04**	113.97**	36.95**	51.42**	0.993**
Crosses	11	57.18**	42.17**	32.27**	120.96**	6.32**	82.69**	1.55*	10.59**	1.64**	0.089
Lines	2	298.78**	180.36**	51.36**	147.19**	9.36**	38.03**	6.11**	20.29**	6.64**	1.430**
Testers	3	1.66**	20.63**	36.92**	71.74**	8.96**	146.55**	1.20*	21.11**	1.38**	1.837**
L x T	6	4.41**	6.88**	23.58**	136.82**	3.99**	65.66**	0.20*	2.10**	0.11*	0.425**
Error	36	1.63	1.58	1.06	3.16	0.57	2.85	0.10	1.70	0.01	0.061

SOV	df	Spikelet fertility %		1000-grain weight (g)		Grain yield/plant (g)		Na^+		K^+	
		N	S	N	S	N	S	N	S	N	S
Replications	2	0.23	21.01*	0.03	0.21	0.09	4.24	0.01	0.01	0.51**	0.06*
Treatments	18	28.25**	1221.32**	1.69**	7.45**	463.19**	190.36**	0.04*	0.04*	0.02	0.02
Parents	6	9.05**	1874.85**	2.80**	6.57**	241.35**	232.46**	0.02	0.02	0.01	0.01
Pa vs Cros	1	66.86**	567.03**	0.28*	49.53**	5131.24**	551.44**	0.02	0.02	0.07*	0.07*
Crosses	11	35.22**	4497.45**	1.22**	4.10**	159.82**	134.57**	0.05*	0.05*	0.01	0.01
Lines	2	1.85**	467.49**	4.92**	0.29*	134.71**	93.46**	0.11**	0.11**	0.01	0.01
Testers	3	32.55**	954.76**	0.41**	10.76**	332.57**	152.08**	0.09*	0.09*	0.01	0.01
L x T	6	47.68**	406.33**	0.39**	2.04**	81.81**	139.52**	0.01	0.01	0.02	0.02
Error	36	1.07	6.441	0.02	0.16	1.32	2.92	0.02	0.08	0.10	0.05

3.1 The most desirable mean values for mean performance:

The data in Table 4 indicated that the mean performance for the studied traits high significantly varied from combination to another under both environments: salinity and normal ones. Furthermore, all measured traits of all line, tester and crosses were decreased under salt stress comparing to normal condition.

The best genotypes were; for days to heading, GAB-A, G46A/PR6 under both conditions. For plant height, GAB-A under normal condition and IR69625A under saline soil condition followed by G46A/PR5. For panicles plant-1, GAB-A under normal condition, while the best parent under salinity condition was GZ9399 followed by Giza179. Furthermore, the best crosses IR69625A/Giza179 and IR69625A/PR6 under normal condition; GAB-A/PR6 and IR69625A/GZ9399 under salinity condition. For panicle length, PR6 and the best crosses G46A/PR6 followed by G46A/GZ9399 under normal, GAB-A/Giza179 under salinity condition. Regarding panicle weight, the parents PR6 under normal condition and GZ9399 under salinity condition they were the best. G46A/PR5 andG46A/PR6 under normal condition, in addition, IR69625A/GZ9399 and GAB-A/GZ9399 under salinity they were the best.

For spikelet's fertility percentage, Giza179 under both conditions, among hybrids, G46A/PR5 under normal condition furthermore, G46A/GZ9399 and GAB-A/GZ9399 were the highest under salinity condition. For 1000-grain weight, among parents, under normal condition the highest mean values were scored by PR6 and GZ9399 under salinity condition. Among hybrids the highest mean values were scored by the hybrids IR69625A/PR6, IR69625A/Giza179 and IR69625A/PR5 under normal, while GAB-A/GZ9399 was the best cross under salinity. For grain yield plant-1, among parents the highest mean values were obtained by GZ9399 under normal while Giza179 and GZ9399 were gave the highest grains weight under salinity conditions, among hybrids the highest mean values under normal condition were scored by the hybrids G46A/PR6 and the cross GAB-A/PR6 under salinity conditions. Regarding sodium content, G46A and IR69625A/Giza179 were the best under normal and salinity conditions.

Table 4: The mean performance for the parental lines and their F1 crosses under two different conditions for studied characters:

Genotypes	Days to heading (day)		Plant height (cm)		Number of panicles/plant		Panicle length (cm)		Panicle weight (g)	
	N	S	N	S	N	S	N	S	N	S
IR69625A	107.33	105.00	106.33	61.00	22.33	13.00	23.90	15.67	4.33	3.13
G46A	93.67	92.67	97.00	68.33	20.33	7.67	23.40	21.00	4.47	2.43
GAB-A	90.33	88.67	94.00	70.33	24.67	10.00	22.03	20.40	3.80	2.30
Giza179	94.33	92.67	97.67	71.00	24.33	19.00	24.47	18.60	4.50	3.47
PR5	96.33	92.00	106.00	83.00	19.33	11.00	24.20	17.00	4.80	2.30
PR6	94.33	92.67	107.00	81.00	21.33	12.33	25.03	18.67	5.03	2.30
GZ9399	93.33	94.67	102.67	66.67	23.67	21.33	23.83	18.97	4.90	3.60
IR69625A/Giza179	103.33	99.67	108.00	82.33	26.33	19.00	25.90	23.00	5.80	3.50
IR69625A/PR5	103.67	101.00	109.33	89.67	25.00	12.00	26.93	18.67	5.93	2.90
IR69625A/PR6	102.00	99.67	111.00	87.67	26.33	12.67	27.17	18.33	6.53	2.37
IR69625A/GZ9399	101.33	98.67	111.00	83.67	25.67	23.00	26.43	21.00	5.67	3.63
G46A/Giza179	94.33	91.33	105.33	76.67	23.33	11.00	27.30	20.33	7.03	2.57
G46A/PR5	94.00	95.33	108.33	66.33	24.33	12.67	27.50	17.67	7.43	1.80
G46A/PR6	92.00	91.00	110.33	89.67	25.33	10.67	27.83	17.50	7.73	2.33
G46A/GZ9399	93.33	91.67	103.67	83.00	26.00	20.00	27.57	20.50	7.27	3.20
GAB-A/Giza179	93.00	91.00	100.67	84.67	24.67	11.67	25.90	23.00	5.80	2.67
GAB-A/PR5	94.67	96.00	105.33	80.67	21.33	10.33	26.53	21.33	5.90	2.67
GAB-A/PR6	95.33	93.00	106.67	79.67	24.33	24.33	26.47	20.67	7.00	3.20
GAB-A/GZ9399	95.33	96.33	110.67	80.67	26.00	20.33	25.70	21.40	6.10	3.63
LSD 0.05%	1.75	1.73	1.41	2.44	1.04	2.32	0.43	1.79	0.14	0.34
0.01%	2.52	2.48	2.03	3.52	1.49	3.34	0.61	2.58	0.20	0.49

Genotypes	Spikelet fertility %		1000-grain weight (g)		Grain yield/plant (g)		Na^+		K^+	
	N	S	N	S	N	S	N	S	N	S
IR69625A	92.03	61.66	27.30	18.87	38.28	16.50	0.58	1.38	1.66	1.26
G46A	88.63	33.09	27.80	20.40	41.84	12.20	0.35	1.15	1.70	1.30
GAB-A	91.20	33.05	25.13	20.70	33.90	13.17	0.44	1.24	1.72	1.32
Giza179	93.67	89.19	27.40	22.33	46.50	34.10	0.46	1.26	1.78	1.38
PR5	92.67	31.69	27.60	20.13	52.45	14.47	0.58	1.38	1.86	1.46
PR6	93.43	43.32	28.00	21.43	54.30	20.00	0.46	1.26	1.74	1.34
GZ9399	90.93	85.06	26.83	23.33	58.27	30.77	0.46	1.26	1.74	1.34
IR69625A/Giza179	88.67	82.33	27.97	22.53	57.17	33.77	0.32	1.12	1.78	1.38
IR69625A/PR5	89.47	47.87	27.90	23.13	65.31	17.47	0.39	1.19	1.78	1.38
IR69625A/PR6	93.43	48.39	28.23	22.60	64.43	21.57	0.54	1.34	1.84	1.44
IR69625A/GZ9399	88.40	81.84	27.33	24.03	71.01	26.43	0.49	1.29	1.79	1.39
G46A/Giza179	82.63	72.77	27.87	21.40	58.10	23.33	0.44	1.24	1.84	1.44
G46A/PR5	94.63	70.44	27.33	22.33	64.06	24.53	0.44	1.24	1.82	1.42
G46A/PR6	86.63	69.67	27.30	22.87	79.61	20.70	0.54	1.34	1.82	1.42
G46A/GZ9399	93.77	88.15	27.23	24.53	78.38	32.30	0.54	1.34	1.88	1.48
GAB-A/Giza179	88.83	65.93	26.13	22.47	57.83	22.67	0.51	1.31	1.94	1.54
GAB-A/PR5	86.73	67.53	26.60	21.00	68.48	22.60	0.51	1.31	1.78	1.38
GAB-A/PR6	91.37	84.58	27.13	23.83	65.31	38.00	0.84	1.64	1.66	1.26
GAB-A/GZ9399	90.03	87.88	26.53	24.80	64.43	36.07	0.60	1.40	1.78	1.38
LSD 0.05%	1.42	3.490	0.21	0.55	1.58	2.35	0.21	0.39	0.44	0.32
0.01%	2.04	5.022	0.31	0.79	2.27	3.38	0.30	0.57	0.63	0.45

Concerning potassium content, the best genotype was the cross GAB-A/Giza179 under normal, salinity conditions. Some authors like, Zayed et al., (2010,2014 and 2017); Negm (2012 and 2016); El-Mowafi et al., (2019 and 2022) and Mazal et al., (2021) mentioned similar findings.

3.2General combining ability:

Data listed in Table 5 clarified that the General combing values of both lines and testers for all studied characters, except sodium and potassium leaf content were positively or negatively highly significantly. Interestingly, the good combiners were; for days to heading, G46A and GAB-A, For plant height, G46A. In the case of panicles plant-1, IR69625A and PR6 under both conditions were the best. For panicle length, the rice genotypes PR5 and PR6 were the best combiners under normal condition while GAB-A and Giza179 were the good combiner under salinity condition. Regarding panicle weight, G46A and PR6 under normal condition, while, IR69625A, GAB-A and GZ9399 were the best under salinity stress condition. For spikelet's fertility percentage, G46A, GAB-A and GZ9399 were the best under salinity condition. For 1000-grain weight, IR69625A, G46A and PR6 under normal, while only genotype GZ9399 under salinity stress conditions.

In the case of the grain yield plant-1, the most desirable and highly significant positive GCA effects were observed for the genotypes of G46A, PR6 and GZ9399 under normal condition, in addition to, GZ9399 under salinity and normal condition while, GAB-A was highly significant GCA effects under salin-ity condition only. The genotype GZ9399 could be strongly recommended as good general combiners for this trait especially breeding programs for normal and salinity condition. The genotype, IR69625A showed desirable general combining ability effects for the sodium content under normal condition proving to be good combiner for this trait. At the same time the genotypes were not significant for this trait under salinity condition. Zewdu (2020) found that analysis of variance indicated that genotypes, general combining and specific combining abilities mean square values were highly significant ($p \leqslant 0.001$) for all measured traits which indicated the genetic diversity of the parents and the importance of both additive and non-additive gene effects in the inheritance of the measured traits respectively.

Table 5: General combining ability effects of parents all studied traits.

Genotypes		Days to heading		Plant height (cm)		No. Panicles plant^{-1}		Panicle length (cm)		Panicle weight (g)	
		N	S	N	S	N	S	N	S	N	S
Lines	IR69625A	5.72**	4.36**	2.31**	3.78**	0.94**	1.03*	-0.16*	-0.04	-0.53**	0.228**
	G46A	-3.44**	-3.05**	-0.61*	-3.14**	-0.14	-2.06**	0.78**	-1.28**	0.85**	-0.397**
	GAB-A	-2.28**	-1.31**	-1.69**	-0.64	-0.81**	1.03*	-0.62**	1.32**	-0.32**	0.169*
L.S.D. 0.05% 0.01%		**0.62 0.89**	**0.61 0.88**	**0.50 0.72**	**0.86 1.24**	**0.37 0.53**	**0.82 1.18**	**0.15 0.22**	**0.63 0.91**	**0.05 0.07**	**0.120 0.173**
Testers	Giza179	0.03	-1.39**	-2.86**	-0.83	-0.11	-1.75**	-0.40**	1.83**	-0.31**	0.039
	PR5	0.58	2.06**	0.14	-3.17**	-1.33**	-3.97**	0.22*	-1.06*	-0.09*	-0.417**
	PR6	-0.42	-0.83	1.81**	3.61**	0.44	0.25	0.39**	-1.45**	0.57**	-0.239*
	GZ9399	-0.19	0.17	0.92*	0.39	1.00**	5.47**	-0.20	0.68	-0.17**	0.817**
L.S.D. 0.05% 0.01%		**0.88 1.26**	**0.86 1.24**	**0.71 1.02**	**1.22 1.76**	**0.52 0.75**	**1.16 1.67**	**0.21 0.31**	**0.90 1.29**	**0.07 0.10**	**0.170 0.245**

Genotypes		Spikelet fertility %		1000-grain weight (g)		Grain yield/plant (g)		Na^+		K^+	
		N	S	N	S	N	S	N	S	N	S
Lines	IR69625A	0.44	-7.17**	0.56**	0.11	-1.70**	-1.81**	-0.08*	-0.08	-0.01	-0.01
	G46A	-0.13	2.98**	0.14**	-0.18	3.86**	-1.40**	-0.03	-0.03	0.03	0.03
	GAB-A	-0.31	4.20**	-0.70**	0.06	-2.16**	3.21**	0.10*	0.10	-0.02	-0.02
L.S.D. 0.05% 0.01%		**1.68 2.42**	**1.23 1.78**	**0.08 0.11**	**019 0.28**	**0.56 0.80**	**0.83 1.19**	**0.07 0.11**	**0.14 0.20**	**0.15 0.22**	**0.11 0.16**
Testers	Giza179	-2.84**	1.40	0.02	-0.83**	-8.48**	-0.03	-0.09	-0.09	0.04	0.04
	PR5	0.73	-10.34**	-0.02	-0.81**	-0.22	-5.09**	-0.07	-0.07	-0.01	-0.01
	PR6	0.93	-4.74**	0.26**	0.14	3.61**	0.14	0.12*	0.12	-0.04	-0.04
	GZ9399	1.18	13.68**	-0.26**	1.49**	5.09**	4.98**	0.03	0.03	0.01	0.01
L.S.D. 0.05% 0.01%		**1.68 2.42**	**1.75 2.51**	**0.11 0.15**	**0.27 0.39**	**0.79 1.14**	**1.17 1.69**	**0.10 0.15**	**0.20 0.28**	**0.22 0.31**	**0.16 0.23**

*and**, significant and highly significant, respectively.

The estimate of variance due to GCA was higher than that due to SCA for these traits suggesting greater importance of additive genetic variance which is in agreement with the results of Lathaet al., (2013), Ramesh et al., (2018), El Mowafi and AbouShousha (2003), Negm, (2012 and 2016) and El Mowafi et al., (2019 and 2022).

3.3 Specific combining ability:

Going back to Table 6 it was observed that the mean values of SCA of all crosses of studied traits un-der both conditions; salinity and normal ones except for heading date, sodium leaf content and potassium leaf content. As for, days to heading, desirable and significant negative SCA effects were exhibited for GAB-A/Giza179 under both conditions which was only had negatively significant values the rest of crosses did not have significant values except three crosses under saline condition.

. The best crosses were; for plant height, G46A/GZ939 and GAB-A/Giza179 under normal condition. Five crosses, IR69625A/Giza179 IR69625A/PR6, IR69625A/GZ9399, G46A/PR5 and GAB-A/PR6 exhibited desirable and highly significant negative SCA effects under salinity tolerance. For panicles plant-1, two hybrids i.e. G46A/PR5 and GAB-A/GZ9399 were the desirable and highly significant positive SCA effects under normal condition; the crosses, IR69625A/Giza179, G46A/PR5 and GAB-A/PR6 were the best crosses under salinity condition. Concerning panicle length, all twelve studied crosses were not significant desirable SCA effects. In the case of panicle weight, IR69625A/Giza179, G46A/PR5 and GAB-A/PR6; under normal condition and two crosses IR69625A/Giza179 and GAB-A/PR6 were the best crosses under salinity condition. For spikelet's fertility percentage, IR69625A/Giza179,G46A/PR5 and GAB-A/PR6 were the best under both conditions. Regarding 1000-grain weight, G46A/Giza179, GAB-A/PR6 and GAB-A/GZ9399 under normal condition while, IR69625A/PR5 and GAB-A/PR6 were the best crosses under salinity condition. For grain yield plant-1, IR69625A/Giza179, IR69625A/GZ9399, G46A/PR6, G46A/GZ9399, GAB-A/Giza179 and GAB-A/PR5 under normal and four crosses, IR69625A/Giza179, G46A/PR5, G46A/GZ9399 and GAB-A/PR6 under salinity conditions.

Table 6: Estimates of specific combining ability (SCA) effects for studied traits.

Hybrid combinations	Days to heading (day)		Plant height (cm)		Number of panicles/plant		Panicle length (cm)		Panicle weight (g)	
	N	S	N	S	N	S	N	S	N	S
IR69625A/Giza179	0.72	1.31*	1.03*	-2.67**	0.61	4.08**	-0.31*	0.92	0.12*	0.361**
IR69625A/PR5	0.50	-0.81	-0.64	7.00**	0.50	-0.69	0.11	-0.52	0.04	0.217
IR69625A/PR6	-0.17	0.75	-0.64	-1.78*	0.06	-4.25**	0.17	-0.47	-0.02	-0.494**
IR69625A/GZ9399	-1.06	-1.25*	0.25	-2.56**	-1.17**	0.86	0.03	0.07	-0.14**	-0.083
G46A/Giza179	0.89	0.39	1.28*	-1.42	-1.31**	-0.83	0.15	-0.49	-0.03	0.053
G46A/PR5	0.00	0.94	1.28*	-9.42**	0.92*	3.06**	-0.27	-0.27	0.16**	-0.258*
G46A/PR6	-1.00	-0.50	1.61**	7.14**	0.14	-3.17**	-0.10	-0.05	-0.21**	0.097
G46A/GZ9399	0.11	-0.83	-4.17**	3.69**	0.25	0.94	0.22	0.82	0.07	0.108
GAB-A/Giza179	-1.61*	-1.69*	-2.31**	4.08**	0.69	-3.25**	0.15	-0.43	-0.09	-0.414**
GAB-A/PR5	-0.50	-0.14	-0.64	2.42*	-1.42**	-2.36**	0.16	0.79	-0.21**	0.042
GAB-A/PR6	1.17	-0.25	-0.97	-5.36**	-0.19	7.42**	-0.07	0.52	0.23**	0.397**
GAB-A/GZ9399	0.94	2.08**	3.92**	-1.14	0.92*	-1.81*	-0.25	-0.88	0.07	-0.025
L.S.D. 0.05%	***1.24***	***1.22***	***1.00***	***1.73***	***0.73***	***1.64***	***0.30***	***1.27***	***0.10***	***0.241***
0.01%	***1.78***	***1.76***	***1.44***	***2.49***	***1.06***	***2.36***	***0.43***	***1.82***	***0.14***	***0.346***

Hybrid combinations	Spikelet fertility %		1000-grain weight (g)		Grain yield/plant (g)		Na+		K+	
	N	S	N	S	N	S	N	S	N	S
IR69625A/Giza179	1.51**	15.83**	0.08	0.29	1.16*	8.99**	-0.02	-0.02	-0.06	-0.06
IR69625A/PR5	-1.25*	-6.91**	0.06	0.86**	1.06	-2.26*	0.02	0.02	0.00	0.00
IR69625A/PR6	2.51**	-11.99**	0.12	-0.61**	-3.66**	-3.38**	-0.02	-0.02	0.08	0.08
IR69625A/GZ9399	-2.78**	3.06*	-0.26**	-0.54*	1.44*	-3.36**	0.02	0.02	-0.02	-0.02
G46A/Giza179	-3.94**	-3.89**	0.41**	-0.56**	-3.46**	-1.85*	0.04	0.04	-0.04	-0.04
G46A/PR5	4.49**	5.52**	-0.08	0.36	-5.75**	4.40**	0.02	0.02	-0.01	-0.01
G46A/PR6	-3.71**	-0.85	-0.39**	-0.06	5.97**	-4.65**	-0.08	-0.08	0.02	0.02
G46A/GZ9399	3.17**	-0.78	0.06	0.26	3.25**	2.10*	0.02	0.02	0.03	0.03
GAB-A/Giza179	2.43**	-11.94**	-0.49**	0.27	2.30**	-7.14**	-0.02	-0.02	0.10	0.10
GAB-A/PR5	-3.24**	1.39	0.02	-1.22**	4.69**	-2.15*	-0.04	-0.04	0.01	0.01
GAB-A/PR6	1.20*	12.83**	0.27**	0.67**	-2.31**	8.03**	0.10	0.10	-0.10	-0.10
GAB-A/GZ9399	-0.39	-2.28	0.20*	0.28	-4.68**	1.25	-0.04	-0.04	-0.01	-0.01
L.S.D. 0.05%	***1.01***	***2.46***	***0.15***	***0.39***	***1.12***	***1.66***	***0.15***	***0.28***	***0.31***	***0.22***
0.01%	***1.45***	***3.55***	***0.22***	***0.56***	***1.61***	***2.39***	***0.21***	***0.40***	***0.44***	***0.32***

Regarding to sodium and potassium content the hybrids combinations have positive and negative values for SCA effects without any significant under normal and salinity conditions. The current finding are in agreement with those reported by Latha et al. (2013), Ramesh et al. (2018), El Mowafi and AbouShousha (2003), Negm (2012 and 2016) and El Mowafiet al., (2019 and 2022) who found that GCA and SCA effects were highly significant for spikelets panicle-1 and 100-grain weight, indicating the relevance of both additive and non-additive effects in the inheritance of these traits as well as the greater importance of non-additive gene action.

3.4 Genetic variance components, contribution of line and testers:

The results' in Table7 showed that dominance genetic variance (σ^2D) was more than additive genetic variance for pant height, number of panicles/plant, spikelet fertility%, 1000-grain weight, Grain yield/plant, sodium and potassium content under normal and salinity condition besides, Panicle weight under salinity condition, indicating that non-additive gene action was played an important role in the inheritance of this trait. Meanwhile, Days to heading and Panicle length under both condition besides, panicle weight under normal condition showed that dominance genetic variance (σ^2D) less than additive genetic variance for these traits, indicating that the additive gene action played an important role in the inheritance of this traits.

Heritability estimates in broad sense (h2b) were high for days to heading, plant height, and number of panicles plant-1, spikelets fertility, 1000- grain weight and grain yield under normal and salinity condition, besides panicle weight under normal condition, indicating the most of variability in these traits was due to ge-netic variation. Also, it could notice that the heritability estimates in narrow sense were relatively high for panicle weight under normal condition, due to additive genetic variance. The proportional contribution of lines, testers and their interaction for seen characters studied are presented in Table7.

It could be noted that the contribution of lines was more than testers in days to heading under both conditions and three traits under normal condition i.e. panicle length, panicle weight and 1000-grain weight, indicating that the lines played a great role in developing and improving these characters through lines × testers' method in developing cross containing plants tolerant to normal condition. On the other hand, for number of panicles/plant and sodium content under both conditions, besides, Spikelet fertility%, Panicle length, Panicle weight and 1000-grain weight under salinity condition and Grain yield/plant under normal condition. It revealed preponderance influence for these traits the contribution of tester was more than So, the tester played a great role in developing and improving these traits through lines × testers' method to obtain high tolerant cross to salinity conditions. The interaction line x tester; were found important for the characters potassium content and plant height under two studied condition moreover, spikelet fertility% under normal condition and grain yield per plant under salinity condition were high for the interaction between lines and tester contribute in these traits. Heritability was classified as low (below30%), medium (30-60%) and high (above 60%) (Babuet al., 2012).

Heritability estimates in narrow sense (h2n) were relatively low for most studied traits and these results suggested that a major part of phenotypic variance for these traits was due to dominance genetic variance and environmental effects. Moreover, heritability was relatively moderate for panicle length under normal condition and days to heading under both studied condition, indicating the importance of both additive and dominance genetic variance (El-Mowafi et al.,2019 and 2022). As shown in Table7 heritability estimates in broad sense (h2b) were high for days to heading, plant height, number of panicles plant-1, spikelets fertility, 1000- grain weight and grain yield under normal and salinity condition, besides panicle weight under normal condition, indicating the most of variability in these traits was due to genetic variation.

Also, it could notice that the heritability estimates in narrow sense were relatively high for panicle weight under normal condition, due to additive genetic variance. On contrary, Hammoud (2004) found that narrow sense heritability estimates were lower than of broad sense for most traits studied indicating the im-portance of non-additive genetic variance in the inheritance of vegetative traits, subsequently selection procedures are preferred in the late generation.

Table 7: Estimates of genetic parameters for studied traits.

Genetic Parameter	Days to heading (day)		Plant height (cm		Number of panicles/plant		Panicle length (cm)		Panicle weight (g)	
	N	S	N	S	N	S	N	S	N	S
Additive variance (σ^2 A)	3.20	2.10	0.27	2.51	0.10	0.31	0.08	0.50	0.09	0.030
Dominant variance (σ^2 D)	0.93	1.77	7.51	44.55	1.14	20.94	0.04	0.13	0.03	0.121
Broad sense heritability (h^2b) %	71.75	71.03	88.05	93.01	68.49	88.17	54.89	27.16	92.28	71.22
Narrow sense heritability (h^2n) %	55.63	38.54	3.07	5.55	5.47	1.30	38.05	21.44	68.01	14.19
Contribution of lines	95.01	77.76	28.94	22.13	26.92	8.36	71.72	34.84	73.47	26.18
Contribution of testers	0.79	13.34	31.20	16.17	38.66	48.33	21.14	54.36	22.86	50.45
Contribution of line x tester	4.20	8.90	39.86	61.70	34.42	43.31	7.14	10.80	3.67	23.37

Genetic Parameter	Spikelet fertility % %		1000-grain weight (g)		Grain yield/plant (g)		Na^+		K^+	
	N	S	N	S	N	S	N	S	N	S
Additive variance (σ^2 A)	1.30	5.35	0.05	0.10	3.89	1.87	0.01	0.01	0.01	0.01
Dominant variance (σ^2 D)	15.54	133.30	0.12	0.63	26.83	45.53	0.01	0.02	0.03	0.01
Broad sense heritability (h^2b) %	93.02	95.56	87.41	82.29	95.88	93.74	7.60	34.99	39.06	30.32
Narrow sense heritability (h^2n) %	8.50	3.69	24.22	11.70	12.14	4.01	10.10	3.57	0.53	0.96
Contribution of lines	0.95	14.99	73.33	1.29	15.32	12.63	39.48	37.48	11.87	12.80
Contribution of testers	25.21	45.92	9.22	71.56	56.75	30.82	47.50	49.52	21.04	22.08
Contribution of line x tester	73.84	39.09	17.45	27.15	27.93	56.55	13.02	13.00	67.09	65.13

3.5 For heterosis over the mid-parents (HM.P.%):

Data arranged in Table 8 showed that the values of heterosis of all studied traits were positively or negatively highly significant. For days to heading the most desirable hybrid combinations were G46A/PR6 under normal and salinity conditions; G46A/GZ9399 under salinity condition. In case of plant height, the best cross was G46A/PR5. Regarding for panicles plant-1, G46A/PR5, G46A/PR6, IR69625A/PR6 and IR69625A/PR5 under normal condition; and GAB-A/PR6, G46A/GZ9399, G46A/PR5 and IR69625A/GZ9399 under salinity condition were the best crosses. Concerning panicle length and panicle weight most crosses were exhibited the favorable positive and highly significant heterotic effects under normal and salinity conditions. With regard to spikelets fertility percentage, G46A/GZ9399 and G46A/PR5 un-der normal condition; most hybrids have a positive and highly significant desirable heterosis under salinity condition except one cross. In the case of 100-grain weight, IR69625A/Giza179, GAB-A/PR6, GAB-A/GZ9399 and IR69625A/PR6 under normal condition were the best-crosses. Furthermore, all crosses were have the positive value of heterosis and all of them were highly significant heterosis except the cross G46A/Giza179, indicating the highly improvement and introduce the 1000-grain weight in the crosses under salinity condition. For grain yield plant-1, the highly values and highly significant heterosis based on mid-parents for grain yield plant-1 were observed for the crosses GAB-A/PR5, GAB-A/PR6, GAB-A/GZ9399, G46A/GZ9399, G46A/PR6 and G46A/PR6 under both conditions. Concerning sodium content, the most desirable hybrid combinations were IR69625A/Giza179, IR69625A/PR5, IR69625A/GZ9399 and G46A/PR5 under normal condition and salinity condition. In the case of potassium content, the most desirable highly significant positive hybrid combinations were IR69625A/PR6, IR69625A/GZ9399, G46A/Giza179, G46A/PR6, G46A/GZ9399 and GAB-A/Giza179 under normal and salinity conditions.

Table 8: Heterosis over mid parent estimates (%) in rice crosses.

Crosses	Days to heading (day)		Plant height		No. panicles/plant		Panicle length (cm)		Panicle weight (g)	
IR69625A/Giza179	2.48	0.84	5.88**	24.74**	12.86**	18.75**	7.09**	34.23**	31.37**	6.06**
IR69625A/PR5	1.81	2.54**	2.98**	24.54**	20.02**	0.00	11.98**	14.29**	29.90**	6.81**
IR69625A/PR6	1.16	0.84	4.06**	23.48**	20.61**	0.04	11.06**	6.76**	39.53**	-12.70**
IR69625A/GZ9399	1.00	-1.20	6.22**	31.07**	11.61**	33.99**	10.75**	21.25**	22.86**	7.88**
G46A/Giza179	0.35	-1.40	8.21**	10.06**	4.48**	-17.50**	14.06**	2.677**	56.74**	-12.90**
G46A/PR5	-1.05	3.24**	6.73**	-12.30**	22.69**	35.73**	15.55**	-7.00**	60.30**	-23.90**
G46A/PR6	-2.13*	-1.80*	8.17**	20.10**	21.60**	6.70**	14.93**	-11.77**	62.74**	-1.48**
G46A/GZ9399	-0.18	-2.10*	3.84**	22.96**	18.18**	37.93**	16.75**	2.58**	55.18**	6.14**
GAB-A/Giza179	0.73	0.36	5.05**	19.82**	0.69	-19.50**	11.40**	17.95**	39.76**	-7.45**
GAB-A/PR5	1.44	6.27**	5.33**	5.22**	-3.05**	-1.62	14.77**	14.06**	37.21**	16.09**
GAB-A/PR6	3.25**	2.57**	6.14**	5.29**	5.78**	117.9**	12.49**	5.81**	58.55**	39.13**
GAB-A/GZ9399	3.81**	5.08**	12.5**	17.77**	7.57**	29.78**	12.08**	8.71**	40.23**	23.05**
LSD 0.05%	1.83	1.80	1.48	2.55	1.08	2.42	0.45	1.87	0.14	0.35
0.01%	2.46	2.42	1.98	3.42	1.45	3.25	0.61	2.51	0.192	0.48

Crosses	Spikelet fertility %		1000-grain weight (g)		Grain yield/plant (g)		Na+		K+	
IR69625A/Giza179	-4.50**	9.15**	2.27**	9.37**	34.87**	33.48**	-38.50**	-15.15**	3.49**	4.55
IR69625A/PR5	-3.12**	2.56	1.64**	18.62**	43.97**	12.82**	-32.80**	-13.77**	1.14**	1.47**
IR69625A/PR6	0.75	-7.80**	2.10**	12.16**	39.19**	18.19**	3.85**	1.52**	8.24**	10.77**
IR69625A/GZ9399	-3.37**	11.60**	0.98**	13.89**	47.09**	11.83**	-5.77**	-2.27**	5.29**	6.92**
G46A/Giza179	-9.35**	19.00**	0.98**	0.16	31.54**	0.78	8.64**	2.91**	5.75**	7.46**
G46A/PR5	4.39**	117.0**	-1.34**	10.19**	35.88**	83.95**	-5.38**	-1.98**	2.25**	2.90**
G46A/PR6	-4.83**	82.40**	-2.15**	9.35**	65.61**	28.57**	33.33**	11.20**	5.81**	7.58**
G46A/GZ9399	4.44**	49.20**	-0.31**	12.19**	56.59**	50.34**	33.33**	11.20**	9.30**	12.12**
GAB-A/Giza179	-3.90**	7.87**	-0.51**	4.44**	43.86**	-4.08**	13.33**	4.80**	10.86**	14.07**
GAB-A/PR5	-5.66**	109.0**	0.89**	2.87**	58.61**	63.53**	0.00	0.00	-0.56*	-0.72**
GAB-A/PR6	-1.02	122.0**	2.13**	13.13**	48.10**	129.1**	86.67**	31.20**	-4.05**	-5.26**
GAB-A/GZ9399	-1.14	48.80**	2.12**	12.65**	39.81**	64.18**	33.33**	12.00**	2.89**	3.76**
LSD 0.05%	1.48	3.64	0.20	0.57	1.65	2.45	0.20	0.41	0.45	0.32
0.01%	1.99	4.88	0.27	0.77	2.21	3.29	0.27	0.54	0.61	0.43

5. Conclusions

Finally based on this investigation the following genotypes could use in breeding program and expected improvement in such traits under normal and saline condition, G46A, PR6, GZ9399, Giza179 and GAB-A as a good donor. G46A/PR6, G46A/PR5, GAB-A/ PR6 and IR69625A/Giza179 could use as a good cross.

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