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Combining Ability and Heterosis in Rice Genotypes under Salinity Stress via Half-Diallel Design

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Abstract

Salinity stress is one of the major environmental constraints limiting rice production worldwide, particularly in arid and semi-arid regions where water quality and soil salinization continue to worsen. Developing rice genotypes with improved salinity tolerance is essential for sustaining productivity in affected areas. In this study, seven rice parental genotypes and their 21 F_1 crosses, developed through a half-diallel mating design, were evaluated under normal irrigation and salinity stress to investigate heterosis, general combining ability (GCA), and specific combining ability (SCA) for key agronomic traits. The traits studied included days to 50% heading, number of panicles per plant, panicle length, panicle weight, 100-grain weight, and grain yield per plant. The analysis of variance revealed highly significant differences among genotypes, parents, crosses, and parents versus crosses for most traits under both conditions, reflecting substantial genetic variability. GCA and SCA mean squares were found to be significant for all studied traits. Several parents, particularly P3, P4, P5, and P6, were identified as good general combiners for earliness, yield, and their components. In addition, crosses such as P3 × P6, P1 × P6, P5 × P6, and P2 × P5 showed desirable heterotic effects under salinity stress, highlighting their potential for developing high-yielding, salt-tolerant rice hybrids. The results emphasize the effectiveness of half-diallel analysis in identifying superior parents and cross combinations for breeding programs aimed at improving salinity tolerance and yield stability in rice.

Keywords: Rice; salinity stress; half-diallel; combining ability; heterosis; grain yield.

Introduction

Salinity stress is one of the greatest challenges to rice production worldwide. It represents one of the most severe abiotic constraints limiting rice growth, productivity, and geographical distribution. Egypt is one of the countries suffering from soil salinity problems. Rice production in Egypt has also been affected by government restrictions on cultivated area due to water limitations. As a result, developing new rice genotypes tolerant to salinity stress is becoming an urgent necessity, since severe salinity can reduce rice yield by 12.9–40.9% depending on the cultivar and the level of stress **(Sen *et al.*, 2017; Wei et al., 2023).**

Salinity stress reduces rice productivity by affecting almost every growth stage. At the seedling stage, it causes poor germination, stunted growth, and leaf chlorosis. During the vegetative stage, salinity decreases tiller number and plant height, while at the reproductive stage, it increases spikelet sterility, reduces grain filling, and decreases grain yield per plant **(Zheng et al., 2023; Xu et al., 2024**; **Anwar et al., 2025).** Grain yield reductions under salt stress have been reported to be more severe during the reproductive phase, when yield components such as panicle number, panicle weight, and 1000-grain weight are highly sensitive **(Zhu et al., 2020; Wei et al., 2023; Zheng *et al*., 2023).** Such negative effects emphasize the importance of breeding for salinity tolerance in rice.

Genetic improvement for salinity tolerance depends on the availability of genetic variability among parental lines. Rice breeders rely on systematic mating designs to partition this variability and to identify the nature of gene action controlling yield and related traits under normal and stress conditions. Among these designs, the half-diallel method is considered one of the most effective approaches, as it allows the estimation of both general combining ability (GCA) and specific combining ability (SCA) for a set of parents and their crosses. GCA reflects the average performance of a parent across all its crosses and is mainly associated with additive gene action. In contrast, SCA reflects the deviation of a particular cross from its expected performance and is associated with non-additive gene action, such as dominance and epistasis **(Fasahat et al., 2017; Singh *et al*., 2025).**

The relative importance of GCA and SCA provides useful information for breeders to decide the best breeding strategy. If additive effects predominate, selection in early generations may be effective, while if non-additive effects are more important, hybrid development may be more promising. Several studies in rice under salinity stress have shown that both additive and non-additive gene effects are involved in the inheritance of grain yield and yield-related traits, though their relative contribution varies with the genetic material and the trait studied **(El-Badawy *et al*., 2022; Negm *et al.,* 2023; Zayed *et al.,* 2023).**

Heterosis is another important concept in rice breeding, particularly under stress conditions. It refers to the superiority of F1 hybrids over their parents for desirable traits. Exploiting heterosis has been a successful strategy to increase rice yield potential. Under salinity stress, hybrids that combine tolerance with high yield are particularly valuable because they can sustain productivity in unfavorable environments.

This study aimed to evaluate the performance of rice parental lines and their crosses under normal and saline conditions, estimate combining ability and heterosis for major agronomic traits, and identify promising parents and hybrids useful for developing salinity-tolerant rice varieties.

Material and method:

1. Plant Materials

Seven rice (*Oryza sativa L.*) parental genotypes were used in this study: Sakha 108, GZ 179, GZ 177, Sakha 101, GZ 9794-15-1-1-1, GZ 10487-2-2-7-4, and GZ 11042-5-8-2-2. Seeds were obtained from the genetic stock maintained at the Rice Research and Training Center (RRTC), Egypt. Their pedigree, type, and origin are listed in Table 1.

Table 1. Name, pedigree, type, and origin of the rice parental genotypes.

NO.	Entry name	Pedigree	Type	Origin
1	Sakha 108	Sakha-101 / HR 1315824	Japonica	Egypt
2	GZ 179	(GZ 6296-12/GZ1368-5- S-4)	Indica/ Japonica	Egypt
3	GZ 177	[Giza 171] Ymji No.1 // PiNo.4	Japonica	Egypt
4	Sakha 101	Giza 176 / Milyang79	Japonica	Egypt
5	GZ 9794-15-1-1-1	gz6522-15-1-1-3/ir69923-3-3-2-3	Indica/ Japonica	Egypt
6	GZ 10487-2-2-7-4	IRAT-112 / Giza177	Indica/ Japonica	Egypt
7	GZ 11042-5-8-2-2	Sakha-101 / IR60080-46 A	Indica/ Japonica	Egypt

2. Field Experiment

During the 2022 growing season, grains of the seven parental genotypes were sown in the nursery. After 30 days, seedlings were transplanted into the permanent field in two rows per genotype, each 5 m long, with a spacing of 20 × 20 cm. At flowering, bulk emasculation was performed using the hot water treatment method (42–44 °C for 10 min) as described by **Butany (1961**), and crosses were made in a half-diallel design (Method II, Model I), resulting in 21 F_1 hybrids in addition to the parental genotypes.

In the 2023 summer season, parents and their F_1 crosses were sown on 30th April, the Seedlings (30 days old) were transplanted into two adjacent experimental fields in a randomized complete block design (RCBD) with three replications. The first: Normal (control) well-watered with irrigation water EC = 0.77 dS m^{-1}. The second: Saline lysimeter experiment with irrigation water EC = 6.00 dS m^{-1}. Each genotype was planted in three rows per replicate (row length = 5.0 m, spacing = 20 × 20 cm). Standard agronomic practices for rice were followed.

3. Data Analysis

The analyses of variance (ANOVA) for all studied traits were performed under normal irrigation, salinity stress, and combined data across environments following the procedures described by **Steel and Torrie (1980**). General combining ability (GCA) and specific combining ability (SCA) were estimated using the half-diallel method as outlined by (**Griffing 1956; Method II, Model I**), assuming fixed effects. Heterosis relative to the better parent and the standard check variety (Sakha 108) was calculated.

Results and Discussion:

1. Analysis of variance and mean performance

The analysis of variance for days to 50% heading, number of panicles per plant, panicle length, panicle weight, 100-grain weight, and grain yield per plant under normal irrigation, salinity stress, and combined analysis is presented in Tables 2 and 3.

Table 2. Mean squares for days to 50% heading, no. panicles per plant, and panicle length (cm), under normal irrigation (N) and salt stress (S), as well as the combined over them (C).

S. O. V.	D. F.		Days to 50% heading			No. panicles per plant			Panicle length (cm)		
	s	c	N	S	C	N	S	C	N	S	C
Environment		1			5104.35**			612.69**			443.62**
Rep. /E.	2	4	0.58	0.08	0.33	1.05	0.55	0.80	1.19	0.50	0.85
Genotypes	27	27	49.83**	66.97**	109.17**	26.02**	15.09**	35.52**	18.45**	33.44**	48.66**
parent	6	6	129.94**	139.80**	263.19**	20.94**	14.66**	30.21**	11.11**	19.35**	27.69**
Cross	20	20	26.57**	48.12**	66.62**	27.69**	13.11**	35.06**	17.56**	17.56**	35.12**
Par.vs.cr.	1	1	34.16**	6.98	36.02**	23.04**	57.38**	76.57**	80.41**	435.69**	445.22**
G. x E.		27			7.63**			5.59**			3.24*
par. X E.		6			6.55**			5.39**			2.77*
Cr. X E.		20			8.07**			5.74**			0.01
Par. vs. cr. x E.		1			5.13**			3.85*			70.88**
Error	54	108	1.55	2.76	2.16	0.98	0.40	0.69	0.45	0.61	0.53
GCA	6	6	64.92**	73.14**	134.52**	6.60**	4.46**	10.31**	3.82**	4.93**	8.34**
SCA	21	21	2.80**	7.81**	8.35**	9.27**	5.19**	12.28**	6.82**	12.92**	18.47**
GCA x E.		6			7.63**			5.59**			3.24**
SCA x E.		21			3.54**			0.76**			0.41*
Error	54	108	0.52	0.92	0.72	0.33	0.13	0.23	0.15	0.20	0.18
GCA/SCA			23.15	9.37	16.11	0.71	0.86	0.84	0.56	0.38	0.45
GCA x E. /GCA					0.05			0.54			0.38
SCA x E. /SCA					0.42			0.06			0.02

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

Table 3. Mean squares for panicle weight (g), weight of 100 grains, and grain yield per plant, under normal irrigation (N) and salt stress (S), as well as the combined over them (C).

S. O. V.	D. F.		Panicle weight (g)			Weight of 100 grains (g)			Grain yield per plant (g)		
	s	c	N	S	C	N	S	C	N	S	C
Environment		1			98.00**			5.68**			13858.62**
Rep. /E.	2	4	0.19	0.41	0.30	0.072	0.01	0.01	43.90**	4.73	24.31*
Genotypes	27	27	2.62**	1.41**	3.37**	0.18**	0.24**	0.37**	83.87**	43.76**	79.96**
parent	6	6	1.62**	0.90*	1.67**	0.14**	0.12**	0.20**	24.30**	30.93**	37.80**
Cross	20	20	2.77**	1.62**	3.85**	0.17**	0.17**	0.29**	81.33**	42.35**	67.05**
Par.vs.cr.	1	1	5.39**	0.28	4.07**	0.81**	2.26**	2.89**	492.16**	148.90**	591.24**
G. x E.		27			0.65*			0.05*			47.67**
par. X E.		6			0.85*			0.06**			17.43*
Cr. X E.		20			0.54**			0.04*			56.63**
Par. vs. cr. x E.		1			1.61**			0.18**			49.82**
Error	54	108	0.23	0.19	0.21	0.89	0.65	0.01	2.06	5.27	3.67
GCA	6	6	0.43**	0.75**	0.88**	0.08**	0.08**	0.15**	52.97**	45.66**	53.97**
SCA	21	21	1.00**	0.39**	1.20**	0.06**	0.08**	0.12**	20.81**	5.71**	18.85**
GCA x E.		6			0.65**			0.05**			47.67**
SCA x E.		21			0.30**			0.01**			44.66**
Error	54	108	0.08	0.06	0.07	0. 30	0. 22	0. 26	0.69	1.76	1.22
GCA/SCA			0.43	1.94	0.73	1.35	1.04	1.28	2.55	8.00	2.86
GCA x E. /GCA					0.74			0.35			0.88
SCA x E. /SCA					0.25			0.08			2.36

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

Highly significant differences were detected among genotypes, parents, crosses, and parents versus crosses for all traits under normal, salinity, and across the two environments, except for days to 50% heading and panicle weight for parents vs. crosses under salt stress. confirming the presence of substantial genetic variability. Moreover, significant genotype × environment interactions indicated that the genotypes responded differently under normal irrigation compared to salinity stress. This variation reflects the presence of diverse genetic backgrounds and differential adaptive mechanisms among the studied rice genotypes, suggesting that salinity tolerance is controlled by multiple physiological and genetic factors.

Genotypes mean performance for all studied traits under normal, salt stress, and combined data are presented in Tables 4-5. For days to 50% heading, the earliest parent was P3, which recorded the lowest mean values under normal irrigation (92.33 days), salinity stress (82.33 days), and cross-irrigation (87.33 days). Among the crosses, P2 × P5 was the earliest under normal irrigation (95.70 days), while P3 × P5 showed the lowest values under salinity stress (82.33 days) and combined data (89.50 days). Earliness is considered advantageous under salinity as it allows plants to escape prolonged stress.

Regarding the number of panicles per plant, parent P4 (Sakha 101) recorded the highest mean under normal irrigation and combined analysis, while P6 (GZ 10487-2-2-7-4) ranked first under salinity stress. Among the hybrids, P3 × P5 produced the maximum number of panicles under normal irrigation and combined data, whereas P2 × P4 performed best under salinity stress.

Table 4. Mean performance for days to 50% heading, no. panicles per plant, and panicle length (cm), under normal irrigation (N) and salt stress (S), as well as the combined over them (C).

Genotypes	Days to 50% heading (Days)			No. of panicles per plant			Panicle length (cm)		
	N	S	C	N	S	C	N	S	C
P1	104.30	95.44	99.87	16.60	11.80	14.20	21.20	15.70	18.45
P2	93.33	84.66	89.00	13.87	11.30	12.58	22.10	17.30	19.70
P3	92.33	82.33	87.33	14.60	9.66	12.13	23.50	15.60	19.55
P4	110.33	100.33	105.33	21.00	14.33	17.67	24.20	18.10	21.15
P5	95.00	83.00	89.00	15.27	8.70	11.98	19.90	14.40	17.15
P6	96.00	87.00	91.50	17.40	14.66	16.03	22.00	16.70	19.35
P7	100.4	86.00	93.20	13.26	11.13	12.20	25.60	22.20	23.90
P1 X P2	102.67	93.67	98.17	15.67	11.66	13.67	25.67	23.17	24.42
P1 X P3	101.33	92.33	96.83	15.33	10.76	13.05	25.22	22.72	23.97
P1 X P4	103.67	90.67	97.17	19.33	12.62	15.98	26.10	23.60	24.85
P1 X P5	101.67	88.00	94.83	16.67	14.67	15.67	27.30	24.80	26.05
P1 X P6	102.67	89.00	95.83	14.33	12.50	13.42	29.50	27.00	28.25
P1 X P7	102.00	91.00	96.50	12.66	11.33	12.00	28.10	25.60	26.85
P2 X P3	95.33	84.67	90.00	18.34	14.43	16.38	25.10	22.60	23.85
P2 X P4	100.67	91.33	96.00	19.50	16.70	18.10	19.00	16.50	17.75
P2 X P5	95.70	86.67	91.19	12.66	9.66	11.16	25.66	23.16	24.41
P2 X P6	97.33	88.33	92.83	21.67	12.77	17.22	26.00	23.50	24.75
P2 X P7	97.66	87.00	92.33	22.00	15.33	18.67	23.50	21.00	22.25
P3 X P4	101.33	85.33	93.33	16.43	14.66	15.55	25.40	22.90	24.15
P3 X P5	96.66	82.33	89.50	22.66	16.78	19.72	24.00	21.50	22.75
P3 X P6	97.33	83.6	90.47	19.34	15.67	17.50	24.50	22.00	23.25
P3 X P7	98.66	86.33	92.50	16.67	14.22	15.44	24.50	22.00	23.25
P4 X P5	104.33	96.67	100.50	14.63	12.44	13.54	27.00	24.50	25.75
P4 X P6	103.36	95.67	99.52	16.63	14.33	15.48	21.60	19.10	20.35
P4 X P7	105.33	94.00	99.67	19.00	15.00	17.00	27.20	24.70	25.95
P5 X P6	99.66	89.00	94.33	19.67	16.33	18.00	22.10	19.60	20.85
P5 X P7	97.33	84.33	90.83	15.50	12.33	13.91	23.00	20.50	21.75
P6 X P7	101.33	90.33	95.83	12.67	10.63	11.65	22.50	20.00	21.25
LSD 5%	2.04	2.71	1.68	1.62	1.03	0.95	1.09	1.28	0.83
LSD 1%	2.71	3.61	2.23	2.15	1.37	1.26	1.46	1.70	1.10

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

For panicle length, parent P7 (GZ 11042-5-8-2-2) consistently exhibited the longest panicles across normal, saline, and combined conditions. Among the hybrids, P1 × P6 produced the greatest mean values under both environments and the combined analysis. Concerning panicle weight, parent P2 was superior under normal irrigation, while P5 had the highest values under salinity stress and in the combined analysis. The cross P2 × P5 consistently recorded the heaviest panicles across both environments and the combined data. For 100-grain weight, parents P5 and P6 recorded the highest means under normal conditions, with P6 maintaining superiority under salinity stress and in the combined analysis. Among the crosses, P4 × P5 and P5 × P7 showed the best performance under normal irrigation, whereas P3 × P5 and P4 × P5 were superior under salinity stress. In the combined analysis, P4 × P5 maintained the highest mean value.

With respect to grain yield per plant, parents P6, P4, and P1 recorded the highest yields under normal irrigation, with P6 remaining superior under salinity stress and in the combined analysis. Among the crosses, P3 × P6 achieved the highest yield under normal irrigation and combined data, while P1 × P6 and P5 × P6 were the best under salinity stress. These results confirm that specific cross combinations can outperform their parents under stress through complementary trait expression.

In conclusion, the results demonstrate wide genetic variation for the studied traits under both normal and saline conditions. Parents P3, P4, P5, P6, and P7 were identified as promising sources of favorable alleles, while crosses such as P3 × P5, P2 × P5, P5 × P6, P1 × P6, and P3 × P6 emerged as superior combinations for earliness, panicle traits, grain weight, and yield potential under salinity stress.

Table 5. Mean performance for panicle weight (g), and weight of 100 grains and grain yield per plant, under normal irrigation (N) and salt stress (S), as well as the combined over them (C).

Genotypes	Panicle weight (g)			weight of 100 grains			Grain yield per plant (g)		
	N	S	C	N	S	C	N	S	C
P1	3.30	2.45	2.88	2.83	2.24	2.54	44.71	24.53	34.62
P2	5.20	2.50	3.85	2.45	2.10	2.28	43.00	27.45	35.23
P3	4.54	2.90	3.72	2.70	1.98	2.34	40.92	23.30	32.11
P4	3.12	2.09	2.61	2.81	2.30	2.56	45.20	24.86	35.03
P5	4.34	3.80	4.07	2.92	2.23	2.58	44.40	29.80	37.10
P6	3.89	3.00	3.45	2.86	2.61	2.74	47.30	32.34	39.82
P7	3.65	2.98	3.32	2.36	2.10	2.23	38.80	28.10	33.45
P1 X P2	5.23	3.30	4.27	2.89	2.54	2.72	53.30	29.70	41.50
P1 X P3	4.80	2.97	3.89	2.78	2.23	2.51	48.20	22.00	35.10
P1 X P4	4.73	3.10	3.92	3.10	2.58	2.84	55.50	26.78	41.14
P1 X P5	5.10	3.00	4.05	2.94	2.59	2.77	50.60	31.32	40.96
P1 X P6	5.50	3.50	4.50	2.87	2.65	2.76	53.10	36.70	44.90
P1 X P7	4.98	3.60	4.29	3.21	2.72	2.97	39.78	28.10	33.94
P2 X P3	4.60	2.67	3.64	2.66	2.27	2.47	52.27	26.80	39.54
P2 X P4	3.50	1.16	2.33	2.99	2.53	2.76	45.00	27.40	36.20
P2 X P5	6.70	3.91	5.31	3.20	2.90	3.05	53.90	30.10	42.00
P2 X P6	3.51	2.83	3.17	3.02	2.58	2.80	54.00	34.50	44.25
P2 X P7	2.60	1.50	2.05	2.56	2.20	2.38	42.00	32.20	37.10
P3 X P4	4.90	3.20	4.05	2.73	2.79	2.76	54.00	24.89	39.45
P3 X P5	3.70	2.74	3.22	2.91	3.02	2.97	50.10	31.30	40.65
P3 X P6	4.62	3.21	3.92	2.73	2.41	2.57	58.00	33.59	45.80
P3 X P7	4.50	3.00	3.75	3.12	2.66	2.89	45.00	28.80	36.90
P4 X P5	6.28	3.76	5.02	3.38	2.97	3.18	51.10	30.30	40.70
P4 X P6	4.40	3.10	3.75	2.96	2.78	2.87	47.60	32.30	39.95
P4 X P7	3.80	1.50	2.65	2.44	2.20	2.32	44.00	27.70	35.85
P5 X P6	3.62	2.90	3.26	2.94	2.67	2.81	48.00	36.70	42.35
P5 X P7	4.10	3.40	3.75	3.26	2.76	3.01	40.03	30.13	35.08
P6 X P7	5.24	3.61	4.43	2.87	2.59	2.73	45.00	34.40	39.70
LSD 5%	0.78	0.71	0.52	0.16	0.14	0.10	2.34	3.75	2.19
LSD 1%	1.04	0.94	0.69	0.21	0.18	0.14	3.12	4.99	2.90

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

2. Combining Ability Analysis

Significant differences were observed for both GCA and SCA of all studied traits, Tables 2 and 3, indicating the role of both additive and non-additive gene actions in their inheritance; such variance was reported by **(Sakran *et al*., 2022; El-Aghoury *et al*., 2023)**. The GCA/SCA ratios were higher than unity for all studied traits except number of panicles per plant and panicle length in both environments and combined analysis. confirming the importance of both additive and non-additive gene effects in the inheritance of these traits in rice. A ratio greater than unity indicates the predominance of additive and additive × additive gene effects controlling these traits. For the exceptional case, a ratio less than unity reflects a greater contribution of non-additive gene action. The ratio between SCA × E/SCA was much higher than GCA× E/GCA for days to 50% heading and grain yield per plant, indicating that non-additive gene effects were more strongly influenced by environmental conditions than additive effects. Conversely, the ratio between GCA× E/GCA was much higher than that of SCA × E/SCA for the number of panicles per plant, panicle length, panicle weight, and weight of 100 grains, suggesting that additive gene effects were more influenced by environmental variation than non-additive effects for these traits.

2.1. General Combining Ability (GCA) Effects

Data of (GCA) effects for all studied traits under normal irrigation, salinity stress, and combined data are shown in Tables 6 and 7. Positive GCA effects are desirable for the number of panicles per plant, panicle length, panicle weight, 100-grain weight, and grain yield per plant, while negative GCA effects are preferable for days to 50% heading.

Results exhibited that the parent P3 recorded the most desirable significant and negative GCA effects for days to 50% heading under normal, saline, and combined data. Also, P2, P5, and P6 showed significant negative values in the combined data. These results indicated that these parents could be regarded as good combiners for earliness in rice.

Regarding the number of panicles per plant, parent P4 expressed the highest positive GCA effect under the two environments and combined analysis. while P6 showed superiority under salinity stress and combined analysis. P3 and P6 also recorded significant values in the combined data for this trait.

For panicle length, parents P1 and P7 exhibited highly significant and positive GCA effects under normal, saline, and combined conditions. In terms of panicle weight, parent P5 was superior across all environments, recording the highest positive and significant GCA effects under normal irrigation, salinity stress, and combined analysis. Also, P1 recorded significant and positive GCA effects under combined conditions.

For 100-grain weight, parents P5 and P6 were the best general combiners. P5 recorded consistently positive GCA effects under all conditions, whereas P6 performed particularly well under salinity stress. P4 also recorded a significant positive GCA in the combined data.

Concerning grain yield per plant, parent P6 exhibited the highest and most desirable positive GCA effects under all environments, followed by P1 under normal irrigation and P5 under saline conditions. This suggests that P6 is a stable and reliable donor of yield-contributing genes under both stress and non-stress conditions.

In conclusion, the results revealed that P3 is a good combiner for earliness, P4 and P6 for number of panicles per plant, P1 and P7 for panicle length, P5 for panicle weight and 100-grain weight, and P6 for grain yield per plant. These parents could therefore be effectively utilized in hybridization programs aimed at improving rice performance under both normal and saline conditions.

Table 6. General combining ability effects for days to 50% heading, no. panicles per plant, and panicle length (cm), under normal irrigation (N) and salt stress (S), as well as the combined over them (C).

parent	Days to 50% heading (Days)			No. panicles per plant			Panicle length (cm)		
	N	S	C	N	S	C	N	S	C
P1	2.58**	2.71**	2.65**	-0.89**	-0.84**	-0.87**	1.07**	1.07**	1.07**
P2	-2.59**	-1.13**	-1.86**	0.26	-0.17	0.04	-0.62**	-0.46**	-0.54**
P3	-2.67**	-3.54**	-3.11**	0.30	0.13	0.21**	0.11	-0.42**	-0.15**
P4	4.45**	4.80**	4.62**	1.36**	1.08**	1.22**	0.00	-0.13	-0.07
P5	-1.56**	-2.02**	-1.79**	-0.32	-0.56**	-0.44**	-0.65**	-0.65**	-0.65**
P6	-0.63**	-0.14	-0.38**	0.43*	0.76**	0.60**	-0.50**	-0.46**	-0.48**
P7	0.42	-0.68*	-0.13	-1.14**	-0.40**	-0.77**	0.59**	1.06**	0.82**
L.S.D gi 0.05	0.44	0.59	0.22	0.35	0.23	0.13	0.24	0.28	0.11
L.S.D gi 0.01	0.59	0.79	0.30	0.47	0.30	0.17	0.32	0.37	0.15
L.S.D gi-gj 0.05	0.68	0.90	0.39	0.54	0.34	0.22	0.36	0.43	0.19
L.S.D gi-gj 0.01	0.90	1.20	0.53	0.72	0.46	0.30	0.49	0.57	0.26

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

Table 7. General combining ability effects for panicle weight (g), weight of 100 grains, and grain yield per plant, under normal irrigation (N) and salt stress (S), as well as the combined over them (C).

parent	Panicle weight (g)			Weight of 100 grains (g)			Grain yield per plant (g)		
	N	S	C	N	S	C	N	S	C
P1	0.15	0.11	0.13**	0.05**	-0.03*	0.01	0.95**	-1.37**	-0.21
P2	0.11	-0.33**	-0.11**	-0.09**	-0.09**	-0.09**	0.57*	-0.05	0.26
P3	0.07	0.03	0.05	-0.07**	-0.08**	-0.08**	0.88**	-2.45**	-0.78**
P4	-0.19*	-0.37**	-0.28**	0.02	0.04**	0.03**	0.69**	-1.88**	-0.59**
P5	0.29**	0.44**	0.37**	0.16**	0.15**	0.15**	0.12	1.49**	0.81**
P6	-0.10	0.20*	0.05	0.01	0.09**	0.05**	2.11**	4.09**	3.10**
P7	-0.34**	-0.09	-0.21**	-0.09**	-0.08**	-0.09**	-5.33**	0.17	-2.58**
L.S.D gi 0.05	0.17	0.15	0.07	0.03	0.03	0.01	0.51	0.82	0.29
L.S.D gi 0.01	0.23	0.21	0.09	0.05	0.04	0.02	0.68	1.09	0.39
L.S.D gi-gj 0.05	0.26	0.24	0.12	0.05	0.05	0.02	0.78	1.25	0.51
L.S.D gi-gj 0.01	0.35	0.31	0.17	0.07	0.06	0.03	1.04	1.66	0.69

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

2.2. Specific Combining Ability (SCA) Effects

Estimates of SCA effects of the rice hybrids for all the studied traits under normal irrigation, salinity stress, and combined analyses are shown in Tables 8 and 9.

For days to 50% heading, the cross P1 × P4 recorded the most desirable and significant negative SCA effect across environments, suggesting their potential for developing early flowering hybrids under normal and saline conditions. Also, the cross recorded P3 × P4 recorded significant negative SCA effects in the combined analysis.

Table 8. Specific combining ability effects for days to 50% heading, no. panicles per plant, and panicle length (cm), under normal irrigation (N) and salt stress (S), as well as the combined over them (C).

	Days to 50% heading (Days)			No. panicles per plant			Panicle length (cm)		
cross	N	S	C	N	S	C	N	S	C
P1 X P2	2.76**	3.19**	2.98**	-0.60	-0.42	-0.51	0.89*	1.48**	1.18*
P1 X P3	1.50*	4.27**	2.89**	-0.98	-1.62**	-1.30*	-0.30	0.99*	0.35
P1 X P4	-3.28**	-5.73**	-4.51**	1.95**	-0.71*	0.62	0.70*	1.58**	1.14*
P1 X P5	0.72	-1.59	-0.43	0.98	2.99**	1.98**	2.55**	3.30**	2.92**
P1 X P6	0.79	-2.47**	-0.84	-2.11**	-0.51	-1.31*	4.60**	5.30**	4.95**
P1 X P7	-0.92	0.08	-0.42	-2.21**	-0.52	-1.37*	2.11**	2.39**	2.25**
P2 X P3	0.68	0.45	0.56	0.87	1.39**	1.13*	1.27**	2.40**	1.83**
P2 X P4	-1.10	-1.23	-1.17	0.97	2.70**	1.84**	-4.72**	-3.99**	-4.35**
P2 X P5	-0.07	0.92	0.43	-4.18**	-2.69**	-3.43**	2.59**	3.18**	2.89**
P2 X P6	0.63	0.70	0.67	4.08**	-0.91**	1.59**	2.78**	3.33**	3.06**
P2 X P7	-0.08	-0.08	-0.08	5.97**	2.82**	4.39**	-0.81*	-0.68	-0.74
P3 X P4	-0.36	-4.82**	-2.59**	-2.14**	0.37	-0.89	0.95**	2.37**	1.66**
P3 X P5	0.97	-1.00	-0.02	5.78**	4.13**	4.96**	0.20	1.48**	0.84
P3 X P6	0.71	-1.61	-0.45	1.70**	1.69**	1.70**	0.55	1.79**	1.17*
P3 X P7	0.99	1.67	1.33	0.60	1.40**	1.00	-0.54	0.28	-0.13
P4 X P5	1.52*	5.00**	3.26**	-3.31**	-1.16**	-2.24**	3.31**	4.19**	3.75**
P4 X P6	-0.37	2.11*	0.87	-2.07**	-0.60	-1.33*	-2.24**	-1.40**	-1.82**
P4 X P7	0.55	0.99	0.77	1.87**	1.23**	1.55**	2.27**	2.69**	2.48**
P5 X P6	1.93**	2.26*	2.09*	2.66**	3.04**	2.85**	-1.09**	-0.38	-0.74
P5 X P7	-1.45*	-1.86*	-1.66	0.05	0.20	0.13	-1.28**	-0.99*	-1.14*
P6 X P7	1.62*	2.26*	1.94*	-3.53**	-2.82**	-3.17**	-1.93**	-1.69**	-1.81**
LSD sij 0.05	1.29	1.72	1.83	1.03	0.66	1.03	0.69	0.81	0.91
LSD sij 0.01	1.72	2.29	2.48	1.36	0.87	1.40	0.92	1.08	1.23
LSD sij-sik 0.05	1.92	2.56	1.57	1.52	0.97	0.89	1.03	1.20	0.78
LSD sij-sik 0.01	2.55	3.40	2.13	2.03	1.30	1.20	1.37	1.60	1.05
LSD sij-ski 0.05	1.79	2.39	0.55	1.42	0.91	0.31	0.97	1.13	0.27
LSD sij-ski 0.01	2.39	3.18	0.75	1.89	1.21	0.42	1.28	1.50	0.37

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

Table 9. Specific combining ability effects for panicle weight (g), weight of 100 grains, and grain yield per plant, under normal irrigation (N) and salt stress (S), as well as the combined over them (C).

	Panicle weight (g)			Weight of 100 grains (g)			Grain Yield per plant (g)		
cross	N	S	C	N	S	C	N	S	C
P1 X P2	0.52*	0.60*	0.56	0.05	0.16**	0.10	4.11**	1.62	2.86*
P1 X P3	0.13	-0.09	0.02	-0.07	-0.17**	-0.12*	-1.30	-3.68**	-2.49*
P1 X P4	0.32	0.44	0.38	0.15**	0.06	0.10	6.19**	0.53	3.36**
P1 X P5	0.21	-0.47*	-0.13	-0.15**	-0.03	-0.09	1.86*	1.70	1.78
P1 X P6	1.00**	0.27	0.63*	-0.07	0.08	0.01	2.38**	4.48**	3.43**
P1 X P7	0.72**	0.65**	0.69*	0.38**	0.32**	0.35**	-3.51**	-0.20	-1.85
P2 X P3	-0.03	0.05	0.01	-0.05	-0.06	-0.06	3.15**	-0.21	1.47
P2 X P4	-0.86**	-1.06**	-0.96**	0.18**	0.07	0.12*	-3.93**	-0.17	-2.05
P2 X P5	1.85**	0.88**	1.37**	0.25**	0.34**	0.29**	5.54**	-0.85	2.35
P2 X P6	-0.95**	0.04	-0.45	0.22**	0.07	0.15*	3.66**	0.95	2.30
P2 X P7	-1.62**	-1.00**	-1.31**	-0.14**	-0.13**	-0.14*	-0.91	2.58*	0.83
P3 X P4	0.57*	0.63**	0.60*	-0.10	0.32**	0.11*	4.75**	-0.28	2.23
P3 X P5	-1.11**	-0.65**	-0.88**	-0.05	0.45**	0.20**	1.33	2.75*	2.04
P3 X P6	0.20	0.06	0.13	-0.08	-0.11*	-0.10	7.34**	2.44*	4.89**
P3 X P7	0.32	0.14	0.23	0.41**	0.31**	0.36**	1.77*	1.58	1.68
P4 X P5	1.73**	0.77**	1.25**	0.32**	0.27**	0.30**	2.62**	1.19	1.90
P4 X P6	0.24	0.35	0.30	0.05	0.14**	0.09	-2.87**	0.58	-1.14
P4 X P7	-0.12	-0.96**	-0.54	-0.37**	-0.27**	-0.32**	0.96	-0.09	0.44
P5 X P6	-1.02**	-0.66**	-0.84**	-0.11*	-0.08	-0.09	-1.89*	1.61	-0.14
P5 X P7	-0.30	0.13	-0.09	0.31**	0.19**	0.25**	-2.43**	-1.03	-1.73
P6 X P7	1.23**	0.58*	0.90**	0.07	0.07	0.07	0.55	0.64	0.59
LSD sij 0.05	0.50	0.45	0.57	0.10	0.09	0.11	1.49	2.38	2.38
LSD sij 0.01	0.66	0.60	0.77	0.13	0.11	0.15	1.98	3.17	3.23
LSD sij-sik 0.05	0.74	0.67	0.49	0.15	0.13	0.10	2.21	3.54	2.04
LSD sij-sik 0.01	0.98	0.89	0.66	0.20	0.17	0.13	2.94	4.70	2.77
LSD sij-skl 0.05	0.69	0.62	0.17	0.14	0.12	0.03	2.07	3.31	0.72
LSD sij-skl 0.01	0.92	0.83	0.23	0.18	0.16	0.04	2.75	4.40	0.98

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

For 100-grain weight, the cross P3 × P7 was the best under normal and combined data, while P3 × P5 expressed the most desirable SCA effects under salinity stress. P1 x P7 and P4 x P5 ranked second and third in the combined analysis.

With respect to grain yield per plant, the cross P3 × P6 recorded the highest positive and significant SCA effects under normal irrigation, whereas P1 × P6 and P3 × P5 performed best under salinity stress. Such results confirm the importance of non-additive gene action in controlling yield under salinity. P3 × P6 was the best under combined analysis, followed by P1 x P6 and P1 x P4.

Generally, the predominance of additive gene effects for days to 50% heading, panicle weight, 100-grain weight, and grain yield per plant suggests that conventional breeding approaches such as pedigree selection could be effective for these traits. On the other hand, the number of panicles per plant and panicle length were predominantly governed by non-additive effects, indicating that heterosis breeding would be more efficient for improving rice productivity under saline conditions. Consequently, Breeding programs should focus on utilizing both the best general combiners (P3, P4, P5, and P6) and superior hybrid combinations (P2 × P5, P1 × P6, and P3 × P6) for developing rice genotypes that combine high yield potential with salinity tolerance.

About the number of panicles per plant, the cross P2 × P7 was identified as the best under normal conditions, while P3 × P5 was superior under salinity stress and combined conditions. In addition, the cross P5 × P6, P1 × P5, P2 × P4, P3 × P6, and P2 × P6 recorded a significant positive SCA effect in the combined analysis.

Regarding panicle length, the cross P1 × P6 expressed the highest positive and significant SCA effects under all environments. Moreover, the crosses P1 × P5, P2 × P5, P2 × P6, and P4 x P5 showed highly significant positive SCA effect in the combined data.

Regarding panicle weight, the cross P2 × P5 consistently recorded the highest positive and significant SCA effects under normal, saline, and combined analyses. P4 x P5 and P6 x P7 ranked second and third in combined data.

3. Heterosis

Heterosis relative to the better parent and check variety (Sakha 108) for all the studied traits under normal irrigation, salt stress, and across them is presented in Tables 10-12.

Days to 50% heading, desirable heterosis was detected only in crosses that expressed negative values. The most promising was the cross P1 × P4, which showed significant reductions under salinity (−10.13**) relative to the better-parent. When compared with the check variety (Sakha 108), P2 × P3 recorded the greatest earliness with significant negative values under normal (−8.60**), salinity (−11.28**), and combined (−9.88**) conditions.

For the number of panicles per plant, the cross P5 × P7 exhibited the highest positive and significant heterotic effects relative to the better parent under normal conditions, P5 × P6 under salinity stress, and in the combined analysis. Furthermore, the same cross P3 × P6 showed the highest positive and significant heterotic effects compared with the check variety (Sakha 108) under normal conditions, while the cross P5 × P6 surpassed the check under salinity stress and in the combined analysis.

With respect to panicle length, the cross P1 × P6 demonstrated the highest positive and significant heterotic effects when evaluated relative to the better-parent, and the check variety (Sakha 108) across normal irrigation, salinity stress, and the combined analysis.

For panicle weight, the cross P4 × P5 exhibited the highest positive and significant heterotic effects relative to the better parent under normal irrigation. Under salinity stress, the crosses P1 × P4 and P1 × P2 recorded the highest significant heterotic effects relative to the mid-parent and better-parent, respectively. Regarding heterosis in comparison with the check variety (Sakha 108), the cross P2 × P5 was superior under normal irrigation, salinity stress, and in the combined analysis.

In terms of grain yield per plant, the highest positive and significant heterosis over the check variety (Sakha 108) was observed in the cross P3 × P6 under normal irrigation and in the combined analysis, while P1 × P6 showed the greatest heterotic advantage under salinity stress. Regarding better-parent heterosis, the most desirable effects were obtained in the crosses P1 × P4 under normal irrigation, P1 × P6 under salinity stress, and P1 × P2 in the combined analysis.

Table 10. Heterosis relative to BP parents and relative to the check variety (Sakha108) for days to 50% heading and no. panicles per plant under normal irrigation (N) and salt stress (S), as well as the combined over them (C).

Genotypes	Days to 50% heading (Days)						No. panicles per plant					
	relative to bp parents			relative to check Varity (sakha108)			relative to bp parents			relative to check Varity (sakha108)		
	N	S	C	N	S	C	N	S	C	N	S	C
P1 X P2	10.00**	10.64**	10.31**	-1.57	-1.85	-1.70	7.95**	4.27	6.54	28.81**	15.76**	23.57**
P1 X P3	9.75**	12.15**	10.88**	-2.84**	-3.26*	-3.04	6.33**	-10.23	-0.03**	26.88**	-0.34	15.95**
P1 X P4	12.28	10.13**	11.27	-0.61	-5.00**	-2.71	15.86**	-7.26	6.48	38.24**	12.63*	27.96**
P1 X P5	10.11**	6.89**	8.59**	-2.52*	-7.80**	-5.04**	7.95**	2.37**	5.69**	28.81**	24.32**	27.01**
P1 X P6	11.20**	8.10	9.74**	-1.57	-6.75**	-4.04**	14.29**	5.73	11.8**	36.36**	31.36**	34.35**
P1 X P7	10.47	10.53**	10.50 *	-2.21*	-4.65**	-3.37 *	11.10**	4.57**	9.43**	32.56**	29.92**	31.50**
P2 X P3	3.25**	2.84	3.06	-8.6**	-11.28**	-9.88**	3.19	10.15*	5.87	23.13**	22.29**	22.79**
P2 X P4	9.03**	10.93**	9.93**	-3.48**	-4.31**	-3.88**	11.90**	16.54**	13.78**	33.52**	41.53**	36.73**
P2 X P5	3.65*	5.27**	4.41	-8.25**	-9.19**	-8.70**	-17.48**	2.30*	-9.45	-1.53	24.24**	8.81
P2 X P6	5.42**	7.29**	6.30**	-6.68**	-7.45**	-7.05**	3.19	-21.96**	-6.28	23.13**	-3.05	12.62**
P2 X P7	5.77**	5.67	5.73 *	-6.37**	-8.84**	-7.55**	4.76	-4.50	1.90	25.00**	18.64**	22.45**
P3 X P4	9.75**	3.64*	6.87**	-2.85**	-10.59**	-6.55**	0.48	6.98	3.11	19.89**	29.92**	23.91**
P3 X P5	4.69**	0.00	2.48	-7.33**	-13.74**	-10.39**	20.62**	17.10**	19.19**	43.92**	42.20**	43.23**
P3 X P6	5.42**	1.54	3.59	-6.68**	-12.41**	-9.42**	22.24**	6.89	17.01**	45.85**	32.80**	40.61**
P3 X P7	6.86**	4.86**	5.92**	-5.41**	-9.54**	-7.38**	-4.76	-3.00**	-3.14**	13.64**	20.51**	16.39**
P4 X P5	9.82**	16.47**	12.92**	0.03	1.29	0.63	6.19*	5.44	5.89	26.70**	28.05**	27.24**
P4 X P6	8.80**	15.27**	11.81**	-0.90	0.24	-0.36	6.19*	-2.25	3.68	26.70**	21.44**	24.59**
P4 X P7	10.87**	13.25**	11.98**	0.99	-1.51	-0.21	-9.52**	2.32	-3.76	7.95*	27.12**	15.65**
P5 X P6	4.91**	7.23**	5.99**	-4.45**	-6.75**	-5.55**	41.78**	27.29**	35.15**	40.17**	58.14**	47.38**
P5 X P7	2.45*	1.60	2.06	-6.68**	-11.64**	-9.05**	46.55**	13.64**	31.5**	44.89**	41.19**	43.4**
P6 X P7	5.55**	5.03**	4.73**	-2.85**	-5.35**	-4.05**	-13.79**	-22.92**	-17.97**	-14.77**	-4.24	-10.54 *

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

Table 11. Heterosis relative to BP parents and relative to the check variety (sakha108) for panicle length (cm) and panicle weight (cm) under normal irrigation (N) and salt stress (S), as well as the combined over them (C).

Genotypes	Panicle length (cm)						Panicle weight (cm)					
	relative to bp parents			relative to check Varity (sakha108)			relative to bp parents			relative to check Varity (sakha108)		
	N	S	C	N	S	C	N	S	C	N	S	C
P1 X P2	16.15**	33.93**	23.96**	21.08**	47.58**	32.36**	0.58	32.00*	10.78	58.48**	34.69*	48.35**
P1 X P3	7.32**	31.33**	21.68**	18.96**	44.71**	29.92**	-7.69	2.41	0.91	45.45**	21.22	35.13**
P1 X P4	7.85**	30.39**	17.49**	23.11**	50.32**	34.69**	-9.04**	6.90	1.69**	43.33**	26.53	36.17**
P1 X P5	12.81**	37.02**	23.17**	28.77**	57.96**	41.19**	-1.92	-21.05*	-0.49	54.55**	22.45	40.87**
P1 X P6	21.90**	49.17**	33.57**	39.15**	71.97**	53.12**	5.77**	-7.89	10.57**	66.67**	42.86**	56.52**
P1 X P7	9.77**	15.32**	12.34**	32.55**	63.06**	45.53**	-4.23**	-5.26	5.41**	50.91**	46.94**	49.22**
P2 X P3	6.81**	30.64**	21.07**	18.40**	43.95**	29.27**	-11.54	-7.93	-5.58	39.39**	8.98	26.43
P2 X P4	-21.49**	-8.84*	-16.08**	-10.38**	5.10	-3.79	-32.69**	-60.00**	-39.48**	6.06	-52.65**	-18.96
P2 X P5	6.03**	27.96**	15.41**	21.04**	47.52**	32.30**	28.85**	2.89	30.34**	103.03**	59.59**	84.52**
P2 X P6	7.44**	29.83**	17.02**	22.64**	49.68**	34.15**	-32.50**	-25.53	-22.11	6.36	15.51	10.26
P2 X P7	-8.20**	-5.41	-6.90**	10.85**	33.76**	20.60**	-50.00**	-60.53**	-49.63**	-21.21	-38.78**	-28.70
P3 X P4	4.96*	26.52**	14.18**	19.81**	45.86**	30.89**	7.93	10.34	8.87	48.48**	30.61*	40.87**
P3 X P5	-0.83	18.78**	7.57**	13.21**	36.94**	23.31**	-18.50*	-27.89**	-20.88 *	12.12	11.84	12.00
P3 X P6	1.24	21.55**	9.93**	15.57**	40.13**	26.02**	1.76	-15.53	-3.81	40.00**	31.02*	36.17**
P3 X P7	-4.30*	-0.90	-2.72	15.57**	40.13**	26.02**	-0.88	-21.05	-7.86	36.36**	22.45	30.43 *
P4 X P5	11.57**	35.36**	21.75**	27.36**	56.05**	39.57**	44.70**	-1.05	23.34**	90.30**	53.47**	74.61**
P4 X P6	-10.74**	5.52	-3.78	1.89	21.66**	10.30**	1.38	-18.42	-7.86	33.33**	26.53	30.43 *
P4 X P7	6.25**	11.26**	8.58**	28.30**	57.32**	40.65**	-12.44	-60.53**	-34.89	15.15	-38.78**	-7.83
P5 X P6	0.45	17.37**	7.75 *	4.25	24.84**	13.01**	-16.59	-23.68*	-19.90	9.70	18.37	13.39
P5 X P7	-10.16**	-7.66**	-9.00**	8.49**	30.57**	17.89**	-5.53	-10.53	-7.86	24.24*	38.78**	30.43 *
P6 X P7	-12.11**	-9.91**	-11.09**	6.13*	27.39**	15.18**	34.70**	20.33	28.45**	58.79**	47.35**	53.91**

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

Table 12. Heterosis relative to BP parents and relative to the check variety (sakha108) for weight of 100 grains (g) and grain yield per plant (g) under normal irrigation (N) and salt stress (S), as well as the combined over them (C).

Genotypes	Weight of 100 grains (g)						Grain yield per plant (g)					
	relative to bp parents			relative to check Varity (sakha108)			relative to bp parents			relative to check Varity (sakha108)		
	N	S	C	N	S	C	N	S	C	N	S	C
P1 X P2	2.12	13.39**	7.10**	2.12	13.39**	7.10**	19.21**	8.20	17.81**	19.21**	21.08**	19.87**
P1 X P3	-1.77	-0.45	-1.18	-1.77	-0.45	-1.18	7.81**	-19.85	-0.35	7.81**	-10.31	1.39
P1 X P4	9.54**	12.17**	11.15**	9.54**	15.18**	12.03**	22.79**	-2.44	16.79**	24.13**	9.17	18.83**
P1 X P5	0.68	12.61**	7.38**	3.89	15.63**	9.07**	11.95**	5.10	10.40	13.17**	27.68**	18.31**
P1 X P6	-1.71	1.53	0.91	1.41	18.30**	8.88**	12.26**	13.48*	12.76**	18.77**	49.61**	29.69**
P1 X P7	9.93**	4.21**	8.41**	13.43**	21.43**	16.96**	-15.9**	-13.11	-14.77	-11.03**	14.55	-1.96
P2 X P3	-1.48	8.10*	5.34	-6.01*	1.34	-2.76	21.56**	-2.37	12.24	16.91**	9.25	14.20**
P2 X P4	6.41*	10.00**	8.02**	5.65*	12.95**	8.88**	-0.44	-0.18	2.77	0.65	11.70	4.56
P2 X P5	9.59**	26.09**	18.45**	13.07**	29.46**	20.32**	19.25**	1.01	13.21**	20.55**	22.71**	21.32**
P2 X P6	3.42*	-1.15	2.38	6.71*	15.18**	10.45**	14.16**	6.68	11.13 *	20.78**	40.64**	27.82**
P2 X P7	-12.33	-15.71	-12.98	-9.54**	-1.79	-6.11	-11.21	-0.43*	-6.83	-6.06*	31.27**	7.16
P3 X P4	-2.85	21.30**	8.02**	-3.53	24.55**	8.88**	19.47**	0.12	12.60 *	20.78**	1.47	13.94**
P3 X P5	-0.34	31.30**	15.15**	2.83	34.82**	16.96**	10.62**	5.03	9.57	11.83**	27.60**	17.42**
P3 X P6	-6.51	-7.66**	-6.03 *	-3.53	7.59*	1.38	22.62**	3.87	15.01**	29.72**	36.93**	32.28**
P3 X P7	6.85**	1.92**	5.67**	10.25**	18.75**	14.00**	-4.86**	-10.95	-7.33	0.65	17.41*	6.59
P4 X P5	15.75**	29.13**	23.3**	19.43**	32.59**	25.25**	13.05**	1.68	9.70	14.29**	23.52**	17.56**
P4 X P6	1.37	6.51*	4.94	4.59	24.11**	13.21**	0.63	-0.12	0.33	6.46*	31.68**	15.4**
P4 X P7	-16.44**	-15.71	-15.17**	-13.78**	-1.79	-8.48**	-6.98	-14.35	-9.97	-1.59	12.92	3.55
P5 X P6	0.68	2.30	2.56	3.89	19.20**	10.65**	1.48	13.48*	6.35	7.36**	49.61**	22.33**
P5 X P7	11.64**	5.75**	10.05**	15.19**	23.21**	18.74**	-15.37**	-6.83	-11.90	-10.47**	22.83**	1.33
P6 X P7	0.35	-0.77	-0.18	1.41	15.63**	7.69**	-4.86	6.37	-0.30	0.65	40.24**	14.67**

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

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