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Genetic Behavior of Yield and its Components of some Rice (*Oryza sativa* L.) Genotypes under Two Water Irrigation System

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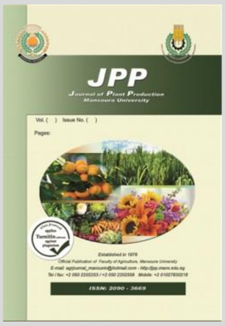

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ABSTRACT

This study aimed to estimate the combining ability and heterosis of yield and its components of some rice genotypes (*Oryza sativa* L.) under two different irrigation systems. Eight genetic diverse parents and 28 hybrids derived from them through the half-diallel mating design. The experiments were conducted at experimental farm of the Rice Research and Training Center, Kafr El Sheikh, Egypt, during 2023 and 2024 rice seasons. The studied traits were; number of panicles per plant, main panicle length, number of grains per panicle, spikelet fertility (%), main panicle weight, 1000-grain weight, number of filled grains per panicle, grain yield per plant and harvest index %. The results showed that the mean squares values for irrigation, genotypes, parents and F_1 hybrids were highly significant for all the studied traits in both irrigation treatments and their combined. Crosses mean squares for parents vs crosses as indication to the average heterosis overall crosses were significant for all studied traits under both irrigation treatments and their combined. The best crosses were $P_1{\times}P_6$, $P_2{\times}P_6$, $P_2{\times}P_8$, $P_3{\times}P_4$, $P_3{\times}P_6$, $P_3{\times}P_8$, $P_5{\times}P_7$ and $P_6{\times}P_8$ for yield and most of its components under both irrigation treatments and the combined data. The parents (Sakha108, PL77-8-7 and Sakha super 302) were the best general combiners for yield and most of its components. The crosses $P_1{\times}P_6$, $P_1{\times}P_8$, $P_2{\times}P_6$, $P_2{\times}P_8$, $P_3{\times}P_6$, $P_3{\times}P_8$, $P_4{\times}P_5$, $P_5{\times}P_6$ and $P_6{\times}P_8$ had high values of mean performance and gave the highest desirable SCA effects in both irrigation treatments and the combined data for grain yield per plant.

Keywords: Rice, water stress, diallel, heterosis and combining ability.

INTRODUCTION

Rice cultivation in Egypt is currently facing growing challenges due to climate change and severe water scarcity. These challenges demand the development of strategic varieties that are efficient in water use and ability of drought tolerance stress (El-basiouny and El-Behiry 2020). Rice (*Oryza sativa* L.), is a staple food crop in Egypt. It is known to be one of the most water demanding cereals high lighting the urgent need to develop drought -tolerant genotypes without compromising productivity and grain quality (Samal *et al.*, 2018). In Egypt, the rice cultivated area is about 0.492 million hectares, about, 0.123 million hectares as direct seeded rice and the annual production of this area more than 4.227 million tons of paddy rice (EAS 2024). The rice production need to increase up to 40% for all rice ecosystems even under deferent stress area to achieve the food security by 2050 (Shi *et al* 2023).

A biotic stress is considered as one of the major constraint for maximizing grain yield in more than 30% of rice fields in Egypt, therefore the development of the Egyptian rice varieties tolerance to drought stress is very great important. Dramatic reduction of grain yield occurs when stress coincides with the irreversible reproductive processes making the genetic analysis of drought tolerance and climate change (Dar *et al.,* 2021). Genetic diversity helps rice breeders to detecting the desirable genotypes, as well as, expecting possible genetic potentials (Debsharma *et al.,* 2022). Genetic diversity studies based on the quantitative characters has some disadvantages in terms of time, space and labor cost, in addition this method cannot determine the exact level of genetic diversity among the genotypes because of the effect of additive gene action on the controlling of these characters (Gaballah *et al*., 2022).

The diallel analysis provides information on the nature and amount of genetic parameters and general and specific combining abilities of parents and their crosses. Combining ability analysis is a useful method to assess the potential ability of varieties. This will be helpful in choosing parents in hybridization programs to get desirable segregates (Gaballah *et al.,* 2021). The information about gene effects including additive and dominance gene effects, non-allelic gene interaction i.e. additive × additive, additive × dominance and dominance × dominance is very important and essential to rice breeders for improving new rice varieties under both normal, as well as, adverse conditions (Hassan *et al.,* 2023).

The objectives of the present study were to: 1) assess the mean performance of some rice varieties and their cross combinations, under water deficit by detecting variations in yield, and its components responses between drought-sensitive and tolerant genotypes, 2) estimate the magnitude of heterosis to improve rice productivity under normal drought condition and their combined and 3) evaluate combining ability for yield, its related traits of the tested rice genotypes under both irrigation treatments and the combined analysis.

MATERIALS AND METHODS

The present study was conducted at the Experimental Farm of Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt during 2023 and 2024 rice growing seasons. Eight parental materials were as shown in Table 1 were planted during 2023 season in three successive dates of planting with ten days intervals to overcome the differences in days to heading among these parental genotypes to get good

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synchronization to make the crosses among the parental lines to obtain the hybrid seed. Thirty days old seedlings of each parent was individually transplanted in the permanent field in ten rows. Each row was 5 m long and contained 25 hills. Bulk emasculation was conducted using the hot-water technique of (Jodon 1938) as modified by (Butany 1961) by using hot water (42-44 °C for 10 min). The eight parental genotypes were crossed in 8 x 8 half-diallel set analysis without reciprocals to produce 28 F_1 hybrids during 2023 season.

Table 1. Pedigree, grain type and origin of the eight genotypes used as parents under this study.

No.	Genotypes name	Pedigree	grain type	Origin
P1	Giza177	(GZ5581/GZ4316)	Japonica	Egyptian
P2	Sakha104	GZ4096/ GZ4100	Japonica	Egyptian
P3	Sakha108	(Sakha101/HR5824-B-3-2-3/Sakha101)	Japonica	Egyptian
P4	GZ 11332	GZ8455/SKC/HUA565	Japonica	Egyptian
P5	GZ10487-2-2-7-4-1	G177 X IRAT112	Japonica	Egyptian
P6	Sakha super 302	Unknown	Japonica	Egyptian
P7	PL77-8-6	Sakha103/SZ97	Japonica	Egyptian
P8	PL77-8-7	Sakha103/SZ97	Japonica	Egyptian

In 2024 season: The parents and their F_1 crosses, were sown at 30th April, as direct seeded method then after one month the seedlings were transplanted into two adjacent experimental fields. The first one was normally irrigated every 4 days (continuous flooding) and the second one was irrigated 10 days (water deficit), in a randomized complete block design (RCBD) with three replications. Each genotype (parents and F_1 crosses) was transplanted in three rows per replicate. Each row was 5.0 m long with the spacing of 20 × 20 cm among rows and hills.

In the two seasons, recommended package of practices and plant protection measures such as field preparation, transplanting, fertilizers, weed controls… etc., were followed as recommended by RRTC (2023).

The data were recorded according to (IRRI 2018). For yield and its components: number of panicles per plant, main panicle length (cm), number of grains per main panicle, spikelet fertility (%), main panicle weight (g), number of filled grains per panicle, 1000-grain weight (g), grain yield per plant (g) and harvest index %.

Chemical and mechanical soil analyses and organic matter were performed according to (Page *et al.,* 1982) at the Agricultural Research Center, Ministry of Agricultural, Egypt. Some chemical and physical properties of the soil present in the experimental site at a depth of 0-30 cm are presented in Table 2.

Table 2. Chemical, mechanical and soil texture properties of the experimental field used for the study during the 2024 rice season

Characters	2024
Particle size distribution	
Sand %	12.32
Clay %	54.14
Silt %	32.17
texture	Clay
Organic matter %	1.41
Chemical analysis	
pH (1:2.5)	8.35
EC (ds.m^{-1})	0.68
Available N (ppm)	17.70
Available P (ppm)	14.0
Available K (ppm)	236.31
Anions (Cmolc/ kg soil)	
CO_3^{--}	--
HCO_3^-	5.65
Cl^-	9.54
SO_4^{--}	18.04
Cations (Cmolc/ kg soil)	
Ca	11.65
Mg	4.95
Na	1.90
K	15.87
Available Micronutrients (ppm)	
Fe	5.14
Mn	3.25
Zn	0.70

Climate data, including minimum and maximum air temperatures, as well as, relative humidity, were obtained from the Sakha Agro-meteorological Station, Central Laboratory for Agricultural Climate, during 2023 and 2024 rice seasons, at Sakha Research Station, Kafr El-Sheikh Governorate and shown in Table 3.

Table 3. The monthly minimum and maximum air temperature (°C) and relative humidity (%) at Sakha Agricultural Research Station during the 2024 rice growing season

Month	Day	2024				
		Air Temp.		RH %		Rain (mm/day)
		Min.	Max.	Min.	Max.	
May	1-10	17.9	27.7	51.4	88.6	0
	11-20	19.1	28.6	53.1	89.9	0
	21-31	22.1	30.5	50.8	85.7	0
June	1-10	23.9	31.5	52.1	81.6	0
	11-20	23.0	30.6	56.6	89.6	0
	21-30	24.5	32.9	49.6	89.9	0
July	1-10	24.9	33.0	58	90.9	0
	11-20	25.8	35	54	93.9	0
	21-31	26.1	35.9	54.2	94.3	0
August	1-10	25.3	34.7	58.3	92.2	0
	11-20	26.0	32.2	62.2	86.5	0
	21-31	25.1	33.9	59.3	94.9	0
September	1-10	26.0	32.1	57.4	89	0
	11-20	23.9	32.5	60.8	92.2	0
	21-30	23.4	34.7	52.4	95	0
October	1-10	22.3	30.4	58.1	88.4	0
	11-20	19.9	29.3	61.4	92	0
	21-31	21.9	30.8	61.1	94.4	0

Statistical analyses:

Data was analyzed according to Snedecor and Cochran (1989) to test the significant of 36 genotypes (eight parents and 28 F_1). The analysis of variance was calculated for each character. General and specific combining ability estimates (GCA and SCA) were obtained by employing Griffing's diallel cross analysis designated as method 2 model I. A partitioning of genotypes sum of squares for each experiment (Griffing 1956). Heterosis percentage relative to mid-parent and better parent for all studied traits were estimated according to (Paschal and Wilcox 1975)

RESULTS AND DISCUSSION

A. Analysis of variance:

As shown in Table 4 The mean square values were highly significant to different source of variance for all traits studied of the rice genotypes under different irrigation system. Suggests that, wide genetic diversity was found and water deficit had negative impact on yield formation due to limited water availability during critical growth stages.

Similar results were reported by (El-Mouhamady *et al.,* 2022), who found that drought stress significantly reduced yield and its components in Rice.

Table 4. Mean squares for yield and yield components of some rice genotypes under Normal irrigation (N) and water deficit irrigation (D), as well as their combined analysis (Comb.) during 2024 season.

S.O.V.	d.f.		Number of panicles per plant			Main panicle length (cm)			Number of grains per panicle		
	S.	Comb.	N	D	Comb.	N	D	Comb.	N	D	Comb.
Irri.		1			375.81**			119.12**			21128.64**
Rep/I	2	4	0.34	0.16	0.25	0.01	0.78	0.39	2.21	0.49	1.35
Genotypes	35	35	16.08**	12.84**	27.08**	14.09**	9.25**	22.44**	1676.90**	1438.22**	3066.06**
parent	7	7	18.68**	10.26**	26.83**	14.51**	12.65**	26.93**	1443.88**	879.37**	2243.3**
Cross	27	27	12.15**	9.56**	19.89**	7.72**	5.51**	12.45**	1414.27**	1236.06**	2607.54**
P. vs C.	1	1	103.93**	119.39**	223.05**	183.15**	86.64**	260.86**	10398.98**	10808.42**	21205.42**
G. × I		35			1.83**			0.90			49.06**
P. × I		7			2.11**			0.24			79.95**
C. × I		27			1.82**			0.78			42.79**
P. vs C. vs I		1			0.27			8.93**			1.98
Error	70	140	0.61	0.57	0.59	0.67	0.71	0.69	5.34	4.96	5.15
GCA	7	7	16.31**	10.84**	26.11**	10.49**	7.88**	18.20**	1573.47**	1234.69**	2760.51**
SCA	28	28	2.62**	2.64**	4.76**	3.25**	1.89*	4.80**	305.34**	290.58**	587.4**
GCA × I		7			1.04**			0.17			47.64**
SCA × I		28			0.51**			0.34			8.53**
Error	70	140	0.20	0.19	0.20	0.22	0.24	0.23	1.78	1.65	1.72
GCA/SCA			6.22	4.11	5.49	3.23	4.18	3.79	5.15	4.25	4.7
GCA × I/GCA					0.04			0.01			0.02
SCA × I/SCA					0.11			0.07			0.01

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

Table 4. Cont.

S.O.V.	d.f.		Spikelet fertility (%)			Main panicle weight (g)			Number of filled grains per panicle		
	S.	Comb.	N	D	Comb.	N	D	Comb.	N	D	Comb.
Irri.		1			2288.87**			27.34**			41584.74**
Rep/I	2	4	0.05	5.18	2.62	0.004	0.09*	0.05	2.63	8.68	5.66
Genotypes	35	35	13.78**	33.05**	30.49**	1.28**	1.08**	2.29**	1635.51**	1391.06**	2934.15**
parent	7	7	2.11	20.65**	11.48**	0.83**	0.81**	1.56**	1262.09**	686.23**	1800.96**
Cross	27	27	6.71**	30.93**	19.63**	1.16**	0.85**	1.95**	1257.01**	1195.45**	2373.78**
P. vs C.	1	1	286.33**	177.11**	456.92**	7.82**	9.03**	16.83**	14469.01**	11606.34**	25996.55**
G. × I		35			16.34**			0.07**			92.43**
P. × I		7			11.28**			0.09**			147.37**
C. × I		27			18.01**			0.06**			78.69**
P. vs C. vs I		1			6.53			0.02			78.81**
Error	70	140	1.36	2.32	1.84	0.02	0.02	0.02	6.13	5.43	5.78
GCA	7	7	2.54*	25.44**	11.26**	1.4	1.06	2.40**	1446.48**	1248.81**	2594.61**
SCA	28	28	5.11**	7.41**	9.89**	0.19	0.18	0.36**	319.84**	267.41**	573.91**
GCA × I		7			16.71**			0.06**			100.69**
SCA × I		28			2.63**			0.01**			13.34**
Error	70	140	0.45	0.77	0.61	0.01	0.01	0.01	2.04	1.81	1.93
GCA/SCA			0.50	3.43	1.14	7.56	5.80	6.74	4.52	4.67	4.52
GCA × I/GCA					1.48			0.03			0.04
SCA × I/SCA					0.27			0.04			0.02

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

Table 4. Cont.

S.O.V.	d.f.		1000-grain weight (g)			Grain yield per plant (g)			Harvest index (%)		
	S.	Comb.	N	D	Comb.	N	D	Comb.	N	D	Comb.
Irri.		1			161.48**			3220.33**			563.17**
Rep/I	2	4	0.25	0.63	0.44	2.73	0.29	1.51	16.07**	11.28*	13.67**
Genotypes	35	35	7.46**	6.38**	13.05**	86.96**	48.43**	126.18**	20.16**	15.91**	30.59**
parent	7	7	3.23**	4.12**	6.48**	27.99**	20.01**	45.15**	10.24**	5.59	8.91*
Cross	27	27	5.46**	4.97**	9.70**	72.97**	30.39**	92.27**	15.53**	15.35**	25.94**
P. vs C.	1	1	90.94**	60.31**	149.69**	877.46**	734.59**	1608.88**	214.75**	103.25**	307.91**
G. × I		35			0.79*			9.21**			5.48*
P. × I		7			0.87			2.85*			6.92*
C. × I		27			0.74			11.09**			4.94
P. vs C. vs I		1			1.57			3.17			10.09
Error	70	140	0.51	0.53	0.52	1.28	1.26	1.27	3.05	3.51	3.28
GCA	7	7	5.07**	5.08**	9.38**	72.26**	34.04**	98.21**	10.71**	6.79**	14.52**
SCA	28	28	1.84*	1.39	3.09**	18.17**	11.67**	28.02**	5.72**	4.93**	9.12**
GCA × I		7			0.77**			8.09**			2.99*
SCA × I		28			0.14			1.82**			1.54
Error	70	140	0.17	0.18	0.17	0.43	0.42	0.42	1.02	1.17	1.09
GCA/SCA			2.75	3.65	3.03	3.98	2.92	3.50	1.87	1.38	1.59
GCA × I/GCA					0.08			0.08			0.21
SCA × I/SCA					0.04			0.06			0.17

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

Mean squares for genotypes, parents and F_1 hybrids were highly significant for all the traits studied under both irrigation treatments, as well as, the combined analysis except spikelet fertility (%) for parents under normal irrigation and harvest index (%) under drought stress, indicating diversity between the parental used in the present study for these traits studied. Genotypes x irrigation, parental x irrigation and F_1 x irrigation interaction were significant for all traits studied except main panicle length, 1000-grain weight, and harvest index of parents x irrigation and crosses x irrigation and parents vs crosses vs irrigation no. of panicles per plant, no. of grains per panicle, spikelet's fertility(%), main panicle weight and grain yield per plant in combined analysis, such results, indicated that the tested genotypes varied from each other, ranked differently from stress and rank to normal irrigation. These results are in general agreement with those obtained by Anyanwu and Obi (2015), Abd El-Aty *et al.,* (2016), Madhuri *et al.,* (2017), Saravanan *et al.,* (2018), Dubey *et al.,* (2020), El-Mowafi *et al.,* (2021) and El-Shamey *et al.,* (2022).

B. Mean Performance:

The mean performances of the parents and F_1 hybrids for yield and yield components under normal irrigation (N) and water deficit irrigation (D), as well as combined analysis (Comb.) are shown in Table 5.

For number of panicles per hill, the parental Sakha108 gave the highest mean values (20.37, 17.00 and 18.68) under both irrigation treatments, as well as, the combined analysis. Thirteen, thirteen and thirteen crosses had high values under normal and water deficit irrigation treatments and the combined analysis, respectively. The best crosses were $P_2 \times P_4$, $P_2 \times P_5$, $P_2 \times P_6$, $P_2 \times P_7$, $P_2 \times P_8$, $P_3 \times P_4$, $P_3 \times P_5$, $P_3 \times P_6$, $P_3 \times P_7$ and $P_3 \times P_8$ under both irrigation treatments and the combined analysis.

Regarding panicle length, the parents Sakha108 and Sakha super 302 were the highest values among all parents under both irrigation treatments and their combined, the best crosses were $P_2 \times P_3$, $P_2 \times P_6$, $P_3 \times P_5$, $P_3 \times P_6$, $P_3 \times P_8$ and $P_6 \times P_8$ under normal and water deficit irrigation treatments and their combined.

For number of grains per panicle, the parental Sakha super 302 was the highest value (182.59, 152.08 and 167.33) under both irrigation treatments, as well as, the combined analysis, respectively. The best hybrids seven, seven and seven had highest values under normal and water deficit irrigation treatments and the combined analysis, $P_2 \times P_6$, $P_2 \times P_8$, $P_3 \times P_6$, $P_3 \times P_8$, $P_5 \times P_6$, $P_6 \times P_7$ and $P_6 x P_8$ under both irrigation treatments and the combined analysis.

The parents PL77-8-7 and Sakha super 302 gave the highest mean values for spikelet fertility under both irrigation treatments and their combined, respectively. The best crosses were $P_1 x P_6$, $P_3 \times P_6$, $P_4 \times P_6$, $P_4 \times P_8$, $P_5 \times P_7$, $P_5 \times P_8$ and $P_6 \times P_8$ under normal and water deficit irrigation treatments and their combined.

Regarding to panicle weight, the parents Sakha108, Sakha super 302 and PL77-8-7 gave highest values under both irrigation treatments and the combined analysis. Fifteen, ten and ten crosses had highest values under normal and water deficit irrigation treatments and their combined, respectively. The best crosses were $P_1 \times P_6$, $P_1 \times P_8$, $P_2 \times P_6$, $P_2 \times P_8$, $P_3 \times P_5$, $P_3 \times P_6$, $P_3 \times P_8$, 5×6, $P_5 \times P_8$ and $P_6 \times P_8$ under both irrigation treatments and the combined analysis.

Table 5. Mean performance of some rice genotypes for yield and yield components under normal irrigation (N) and water deficit irrigation (D), as well as their combined analysis (Comb.).

Genotypes	Number of panicles per plant			Main panicle length (cm)			Number of grains per panicle		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
Giza177	16.05	12.67	14.36	20.37	19.76	20.06	134.22	114.17	124.19
Sakha104	19.67	15.87	17.77	21.80	20.60	21.20	142.77	118.33	130.55
Sakha108	20.37	17.00	18.68	22.50	21.90	22.20	153.60	126.44	140.02
GZ 11332	16.92	12.62	14.77	19.85	19.66	19.75	136.11	116.62	126.37
GZ10487-2-2-7-4-1	17.13	14.42	15.78	21.09	19.80	20.45	129.28	110.61	119.95
Sakha super 302	14.14	11.78	12.96	21.58	21.10	21.34	182.59	152.08	167.33
PL77-8-6	15.2	13.92	14.56	15.46	15.06	15.26	105.34	93.34	99.34
PL77-8-7	13.24	12.29	12.77	21.42	20.40	20.91	140.42	131.64	136.03
$P_1 \times P_2$	20.47	16.19	18.33	24.67	22.44	23.55	137.39	117.91	127.65
$P_1 \times P_3$	20.24	16.08	18.16	23.79	22.05	22.92	141.93	116.35	129.14
$P_1 \times P_4$	17.62	14.50	16.06	21.37	20.25	20.81	146.90	125.74	136.32
$P_1 \times P_5$	17.19	15.64	16.42	23.90	21.76	22.83	161.32	142.50	151.91
$P_1 \times P_6$	17.53	15.81	16.67	22.60	21.16	21.88	173.45	149.49	161.47
$P_1 \times P_7$	16.53	15.35	15.94	21.22	20.81	21.01	127.57	114.69	121.13
$P_1 \times P_8$	18.00	14.90	16.45	25.20	22.36	23.78	165.50	144.83	155.17
$P_2 \times P_3$	19.94	16.80	18.37	24.92	23.18	24.05	146.33	126.49	136.41
$P_2 \times P_4$	21.45	17.18	19.32	22.79	21.01	21.90	145.35	124.19	134.77
$P_2 \times P_5$	20.17	19.22	19.69	22.37	21.72	22.05	157.00	142.66	149.83
$P_2 \times P_6$	21.68	18.71	20.20	25.26	23.59	24.42	201.37	175.13	188.25
$P_2 \times P_7$	20.83	19.85	20.34	22.06	20.83	21.45	148.12	130.41	139.27
$P_2 \times P_8$	20.91	18.59	19.75	24.46	22.13	23.29	190.84	170.34	180.59
$P_3 \times P_4$	21.82	17.23	19.52	23.45	21.35	22.40	159.67	138.02	148.84
$P_3 \times P_5$	20.75	18.46	19.61	25.52	23.20	24.36	170.50	150.52	160.51
$P_3 \times P_6$	20.45	17.75	19.10	25.62	23.26	24.44	204.08	176.10	190.09
$P_3 \times P_7$	21.41	19.24	20.33	22.93	21.39	22.16	165.82	145.24	155.53
$P_3 \times P_8$	20.50	18.09	19.29	27.97	26.20	27.09	193.44	169.91	181.67
$P_4 \times P_5$	18.51	15.75	17.13	23.90	21.33	22.62	176.50	154.96	165.73
$P_4 \times P_6$	16.17	14.01	15.09	23.75	20.70	22.22	159.54	134.81	147.18
$P_4 \times P_7$	16.48	15.01	15.75	22.47	20.72	21.59	140.21	127.13	133.67
$P_4 \times P_8$	17.43	15.63	16.53	22.61	20.72	21.66	140.28	132.71	136.49
$P_5 \times P_6$	17.42	15.21	16.32	24.80	22.27	23.53	192.67	173.36	183.01
$P_5 \times P_7$	19.17	15.30	17.23	21.53	20.30	20.91	142.31	113.44	127.88
$P_5 \times P_8$	19.71	15.04	17.37	22.13	21.95	22.04	160.59	152.03	156.31
$P_6 \times P_7$	15.99	14.36	15.17	22.35	21.66	22.01	189.09	171.18	180.13
$P_6 \times P_8$	17.07	14.32	15.70	25.67	24.68	25.17	195.00	173.24	184.12
$P_7 \times P_8$	15.16	13.58	14.37	22.65	21.25	21.95	163.28	151.66	157.47
Means of parents	16.59	13.82	15.21	20.51	19.78	20.15	140.54	120.40	130.47
Means of crosses	18.95	16.35	17.65	23.64	21.94	22.79	164.14	144.47	154.31
Means of genotypes	18.43	15.79	17.11	22.94	21.46	22.20	158.90	139.12	149.01
L.S.D 0.05	1.27	1.23	1.23	1.33	1.37	1.33	3.75	3.62	3.63
L.S.D 0.01	1.68	1.63	1.61	1.76	1.81	1.74	4.98	4.80	4.76

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

Table 5. Cont.

Genotypes	Spikelets fertility (%)			Main panicle weight (g)			Number of filled grains per main panicle		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
Giza177	90.40	85.17	87.78	4.13	3.30	3.72	121.32	97.23	109.28
Sakha104	91.13	81.06	86.10	4.62	3.96	4.29	130.11	95.88	112.99
Sakha108	92.41	83.78	88.09	5.04	4.14	4.59	141.93	105.93	123.93
GZ 11332	90.31	85.95	88.13	4.04	3.18	3.61	122.92	100.23	111.58
GZ10487-2-2-7-4-1	91.50	84.15	87.83	4.37	3.54	3.96	118.29	93.08	105.69
Sakha super 302	91.26	85.12	88.19	5.11	4.02	4.57	166.62	129.42	148.02
PL77-8-6	90.20	87.24	88.72	3.81	3.43	3.62	95.00	81.42	88.21
PL77-8-7	92.16	90.03	91.10	5.16	4.73	4.95	129.41	118.48	123.95
$P_1\times P_2$	96.36	83.27	89.82	4.86	4.05	4.46	132.39	98.19	115.29
$P_1\times P_3$	93.97	88.61	91.29	4.98	3.95	4.46	133.38	103.10	118.24
$P_1\times P_4$	94.83	81.29	88.06	4.32	3.69	4.00	139.30	102.22	120.76
$P_1\times P_5$	92.81	87.84	90.33	4.88	4.18	4.53	149.67	125.11	137.39
$P_1\times P_6$	95.01	91.23	93.12	5.93	4.87	5.40	164.80	136.38	150.59
$P_1\times P_7$	93.26	88.53	90.89	4.30	3.87	4.08	119.00	101.56	110.28
$P_1\times P_8$	95.16	91.13	93.15	5.55	4.83	5.19	157.50	132.01	144.76
$P_2\times P_3$	97.04	81.60	89.32	5.14	4.13	4.64	142.00	103.21	122.60
$P_2\times P_4$	94.61	83.42	89.02	4.47	3.94	4.20	137.52	103.60	120.56
$P_2\times P_5$	96.97	86.35	91.66	4.81	4.43	4.62	152.24	123.20	137.72
$P_2\times P_6$	95.86	88.34	92.10	5.65	4.95	5.30	193.03	154.71	173.87
$P_2\times P_7$	98.45	89.19	93.82	4.83	4.51	4.67	145.83	109.76	127.80
$P_2\times P_8$	94.69	87.11	90.90	6.03	5.24	5.64	180.70	148.38	164.54
$P_3\times P_4$	94.79	88.11	91.45	4.67	4.12	4.40	151.33	121.60	136.47
$P_3\times P_5$	95.99	87.72	91.86	5.65	4.80	5.23	163.67	132.03	147.85
$P_3\times P_6$	95.29	92.15	93.72	6.04	5.20	5.62	194.47	162.27	178.37
$P_3\times P_7$	96.51	87.90	92.21	5.30	4.50	4.90	160.03	127.66	143.85
$P_3\times P_8$	93.98	85.97	89.97	6.15	5.53	5.84	181.78	146.06	163.92
$P_4\times P_5$	93.77	88.07	90.92	4.98	4.14	4.56	165.50	136.48	150.99
$P_4\times P_6$	94.03	90.52	92.27	4.87	4.19	4.53	150.00	122.01	136.00
$P_4\times P_7$	92.75	87.50	90.12	4.11	3.74	3.92	130.03	111.24	120.64
$P_4\times P_8$	97.67	93.10	95.38	4.89	4.49	4.69	137.00	123.55	130.27
$P_5\times P_6$	94.64	90.61	92.63	5.91	5.07	5.49	182.33	157.09	169.71
$P_5\times P_7$	96.02	92.47	94.25	5.11	4.37	4.74	136.65	104.90	120.77
$P_5\times P_8$	95.60	92.91	94.26	5.90	5.11	5.51	153.51	141.26	147.38
$P_6\times P_7$	92.70	87.76	90.23	4.80	3.94	4.37	175.27	150.18	162.72
$P_6\times P_8$	96.05	92.29	94.17	6.30	5.43	5.86	187.33	159.88	173.61
$P_7\times P_8$	93.65	89.98	91.81	4.70	4.23	4.47	152.90	136.46	144.68
Means of parents	91.17	85.31	88.24	4.54	3.79	4.16	128.20	102.71	115.46
Means of crosses	95.09	88.39	91.74	5.18	4.48	4.83	156.04	127.65	141.84
Means of Genotypes	94.22	87.71	90.96	5.04	4.33	4.68	149.85	122.10	135.98
L.S.D 0.05	1.90	2.47	2.17	0.21	0.24	0.22	4.02	3.79	3.85
L.S.D 0.01	2.52	3.28	2.85	0.28	0.31	0.29	5.33	5.02	5.05

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

Table 5. Cont.

Genotypes	1000-grain weight (g)			Grain yield per plant (g)			Harvest index (%)		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
Giza177	28.87	26.91	27.89	37.87	29.54	33.70	44.47	45.59	45.03
Sakha104	28.01	25.81	26.91	39.40	32.26	35.83	48.22	45.72	46.97
Sakha108	30.38	28.62	29.50	42.45	33.77	38.11	48.81	43.51	46.16
GZ 11332	27.77	26.30	27.04	36.70	28.83	32.77	48.69	43.23	45.96
GZ10487-2-2-7-4-1	28.29	27.54	27.92	39.51	32.41	35.96	45.31	42.77	44.04
Sakha super 302	29.95	27.68	28.82	44.10	35.56	39.83	47.65	46.20	46.92
PL77-8-6	27.97	27.52	27.74	34.46	29.10	31.78	45.59	43.97	44.78
PL77-8-7	29.86	29.42	29.64	39.61	34.47	37.04	44.67	43.05	43.86
$P_1\times P_2$	31.54	29.02	30.28	45.15	36.08	40.61	49.57	44.78	47.18
$P_1\times P_3$	31.61	28.99	30.30	48.85	37.77	43.31	49.77	44.61	47.19
$P_1\times P_4$	29.34	27.61	28.47	40.82	31.87	36.35	46.87	40.74	43.80
$P_1\times P_5$	30.15	28.56	29.35	46.97	38.36	42.66	50.91	45.39	48.15
$P_1\times P_6$	33.99	31.56	32.78	53.07	41.99	47.53	50.48	46.36	48.42
$P_1\times P_7$	29.88	27.42	28.65	39.40	34.24	36.82	48.30	46.21	47.25
$P_1\times P_8$	32.37	30.05	31.21	44.49	37.29	40.89	45.81	42.16	43.99
$P_2\times P_3$	30.36	27.79	29.08	46.45	38.43	42.44	48.46	47.65	48.05
$P_2\times P_4$	30.46	27.70	29.08	45.57	36.12	40.84	49.23	47.05	48.14
$P_2\times P_5$	31.49	28.72	30.11	42.94	36.43	39.68	50.52	48.52	49.52
$P_2\times P_6$	30.20	28.14	29.17	51.56	41.54	46.55	52.55	50.02	51.28
$P_2\times P_7$	30.42	28.34	29.38	41.16	34.80	37.98	47.37	45.15	46.26
$P_2\times P_8$	33.05	31.01	32.03	50.39	37.83	44.11	50.18	45.55	47.86
$P_3\times P_4$	31.06	29.06	30.06	48.27	39.80	44.03	52.49	45.64	49.06
$P_3\times P_5$	31.65	30.98	31.31	49.44	39.39	44.41	53.94	47.34	50.64
$P_3\times P_6$	33.11	31.27	32.19	56.44	42.53	49.49	53.92	47.41	50.67
$P_3\times P_7$	31.34	30.59	30.97	44.38	39.16	41.77	50.63	49.48	50.05
$P_3\times P_8$	32.53	30.98	31.76	54.89	42.85	48.87	50.78	46.57	48.67
$P_4\times P_5$	30.30	29.08	29.69	46.80	39.10	42.95	54.22	49.83	52.02
$P_4\times P_6$	29.49	27.76	28.62	42.50	36.16	39.33	47.81	45.51	46.66
$P_4\times P_7$	28.32	27.75	28.04	36.39	32.93	34.66	47.54	44.70	46.12
$P_4\times P_8$	30.86	28.93	29.89	42.38	37.08	39.73	50.24	47.49	48.86
$P_5\times P_6$	32.73	29.71	31.22	47.83	41.13	44.48	52.29	50.60	51.44
$P_5\times P_7$	29.13	28.50	28.82	42.42	37.31	39.87	51.73	47.99	49.86
$P_5\times P_8$	31.60	30.39	30.99	46.48	41.68	44.08	50.32	49.33	49.83
$P_6\times P_7$	30.16	28.83	29.50	41.30	36.08	38.69	46.92	45.00	45.96
$P_6\times P_8$	32.47	31.00	31.74	53.50	46.06	49.78	51.35	47.56	49.45
$P_7\times P_8$	31.01	29.90	30.45	41.45	37.45	39.45	47.7	46.37	47.03
Means of parents	28.89	27.48	28.18	39.26	31.99	35.63	46.68	44.26	45.47
means of crosses	31.09	29.27	30.18	46.12	38.27	42.19	50.07	46.61	48.34
Means of Genotypes	30.60	28.87	29.74	44.59	36.87	40.73	49.31	46.08	47.70
L.S.D 0.05	1.16	1.19	1.15	1.84	1.82	1.80	2.84	3.04	2.90
L.S.D 0.01	1.53	1.57	1.51	2.44	2.42	2.37	3.76	4.04	3.80

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

For number of filled grains per panicle, the parental Sakha super 302 was the heist value (166.62, 129.42 and 148.02) under both irrigation treatments, as well as, the combined analysis, respectively. The best crosses were $P_2 \times P_6$, $P_3 \times P_6$, $P_3 \times P_8$, $P_5 \times P_8$, $P_6 \times P_7$ and $P_6 \times P_8$ under normal and water deficit irrigation treatments and the combined analysis.

Regarding to 1000-grain weight, the parents Sakha108 and PL77-8-7 gave high values under both irrigation treatments and their combined, respectively. The best crosses were $P_1 \times P_6$, $P_1 \times P_8$, $P_2 \times P_8$, $P_3 \times P_5$, $P_3 \times P_6$, $P_3 \times P_8$, $P_5 \times P_6$, $P_5 \times P_8$ and $P_6 \times P_8$ under normal and water deficit irrigation treatments and the combined analysis.

For grain yield per plant, the parents Sakha108 and Sakha super 302 were the highest values under both irrigation treatments and their combined. Eighteen, twenty-four and twenty-one hybrids had high values under normal and water deficit irrigation treatments, as well as, the combined analysis, respectively. $P_1 \times P_6$, $P_1 \times P_8$, $P_2 \times P_6$, $P_2 \times P_8$, $P_3 \times P_6$, $P_3 \times P_8$, $P_4 \times P_5$, $P_5 \times P_6$ and $P_6 \times P_8$ were the best crosses for this trait in both irrigation treatments and the combined analysis.

The parents Sakha104, Sakha108, GZ 11332 and Sakha super 302 gave the highest mean values for harvest index under both irrigation treatments and their combined, respectively. The best crosses were $P_2 \times P_5$, $P_2 \times P_6$, $P_3 \times P_5$, $P_3 \times P_6$, $P_3 \times P_7$, $P_3 \times P_8$, $P_4 \times P_5$, $P_5 \times P_6$, $P_5 \times P_7$, $P_5 \times P_8$ and $P_6 \times P_8$ under both irrigation treatments and the combined analysis.

Many recent studies have highlighted the critical importance of yield-related traits in assessing the genetic performance of rice genotypes under both normal and water deficit conditions, traits such as number of panicles per plant, weight of main panicles, main panicle length, Number of filled grains per main panicle, spikelet fertility (%), 1000-grains weight, grain yield per hill and harvest index%, play a crucial role in determining the overall productivity of rice, especially under water deficit, these studies have shown that water deficit negatively effects for most of these traits, emphasizing the need to select genotypes that under such conditions (Gaballah *et al.,* 2022).

Moreover, harvest index has been identified as a key indicator of the plant's efficiency in converting biomass into grain yield, making it a valuable trait for selecting drought tolerant lines (Abd El-Aty *et al.,* 2022b). The number of filled grains and spikelet fertility are also strongly correlated with final grain yield (Du *et al.,* 2024). Therefore, improving these traits through breeding and selection programs essential for enhancing rice productivity under limited water availability.

All the previous results are in good agreement with those reported by Li *et al.,* (2015), Abade *et al.,* (2016), Abd El-Aty *et al.,* (2016), Ghazy (2017), Dien *et al.,* (2019), Al Azzawi *et al.,* (2020), El-Mowafi *et al.,* (2021), Osman (2021), El-Shamey *et al.,* (2022), Abd El-Aty *et al.,* (2022a) and Abd El-Aty *et al.,* (2022b).

C. Heterosis:

Heterosis expressed as the parentage deviation of F_1 mean performance from the mid parent average values for all the traits studied at both irrigation treatments and an average of them are presented in Table 6.

Crosses mean squares for P. Vs C. as medication to average heterosis over all crosses were significant for all traits studied under both irrigation treatments, as well as, the combined analysis.

For the number of panicles per plant twenty-one, twenty-five and twenty-six parental combinations exhibited significant positive heterotic effects relative to mid-parent under normal and water deficit irrigation treatments and their combined, respectively. The best crosses were $P_1 \times P_6$, $P_1 \times P_8$, $P_2 \times P_6$, $P_2 \times P_7$, $P_2 \times P_8$, $P_3 \times P_6$, $P_3 \times P_7$, P3×P8, P4×P_8, $P_5 \times P_8$ and $P_6 \times P_8$ under both irrigation treatments, as well as, the combined analysis.

Regarding to the main panicle length hybrids twenty-five, twenty-one and twenty-seven gave significant positive heterotic effects relative to mid-parent under both irrigation regimes and their combined, respectively. The best crosses were $P_1 \times P_7$, $P_2 \times P_7$, $P_3 \times P_7$, $P_3 \times P_8$, $P_4 \times P_7$, $P_5 \times P_7$, $P_6 \times P_7$, $P_6 \times P_8$ and $P_7 \times P_8$ under normal and water deficit irrigation treatments and combined data.

$P_1 \times P_5$, $P_2 \times P_6$, $P_2 \times P_8$, $P_3 \times P_5$, $P_3 \times P_6$, $P_3 \times P_7$, $P_3 \times P_8$, $P_4 \times P_5$, $P_5 \times P_6$, $P_5 \times P_8$, $P_6 \times P_7$ and $P_7 \times P_8$ hybrids exhibited the highest heterotic values for grain number per panicle under both irrigation regimes and the combined data.

Recent studied have shown that heterosis was significant and positive for number of panicles per plant in rice under normal irrigation and water deficit conditions, indicating the efficiency of certain hybrids in Improving these important traits (Kushal et al., 2023) and (Rahman et al., 2023).

The results of the present study are agreement with these findings, supporting the potential use of such hybrids in breeding programs to enhance productivity related traits under varying water regimes.

Similar findings were reported by Kushal *et al.,* (2023), who found significant by in heterosis in panicle traits under water deficit, and by Rahman *et al.,* (2023) who emphasized the role of hybrids vigor in enhancing grain yield component under both normal and water deficit conditions.

For spikelet fertility (%), the twenty-six, eighteen and twenty-four hybrids exhibited significant positive heterotic effects relative to mid-parent in the normal and water deficit irrigation treatments, as well as, combined analysis, the best crosses $P_1 \times P_6$, $P_2 \times P_6$, $P_3 \times P_6$, $P_4 \times P_8$, $P_5 \times P_6$, $P_5 \times P_7$ and $P_6 \times P_8$ under both irrigation treatments, as well as, the combined data.

The twenty-five, twenty-four and twenty-seven hybrids for main panicle weight, twenty-seven, twenty-four, twenty-seven hybrids regarding number of filled grains per panicle and twenty-four, twenty-one and twenty-three crosses for 1000-grain weight expressed significantly positive heterotic effects relative to mid-parent value in the normal and water deficit irrigation treatments, as well as, the combined analysis, respectively. The best crosses $P_1 \times P_5$, $P_1 \times P_8$, $P_2 \times P_6$, $P_2 \times P_8$, $P_3 \times P_5$, $P_3 \times P_6$, $P_3 \times P_7$, $P_3 \times P_8$, $P_4 \times P_5$, $P_5 \times P_6$, $P_5 \times P_7$, $P_5 \times P_8$, $P_6 \times P_7$ and $P_6 \times P_8$ for main panicle weight and number of filled grains per panicle. Also, the best crosses, $P_1 \times P_6$, $P_1 \times P_8$, $P_2 \times P_8$, $P_3 \times P_5$, $P_3 \times P_6$, $P_3 \times P_7$, $P_3 \times P_8$, $P_4 \times P_5$, $P_5 \times P_6$, $P_5 \times P_8$ and $P_6 \times P_8$ for grains weight under in both irrigation treatments and the combined analysis.

Several recent studied have reported significant heterosis effects for key yield-related traits in rice under both normal and water deficit conditions.

Specifically, significant positive heterosis was observed for traits such as spikelet's fertility percentage, main panicle weight, number of filled grains per panicle and 1000-grain weight. These findings reflect the genetic potential of specific hybrid, combinations to enhance yield components and overall productivity, especially under stress conditions (Abd El-Aty *et al.,* 2022b), (Kushal *et al.,* 2023), and (Rahman *et al.,* 2023). Such results highlight the importance of exploiting heterosis in rice breeding programs aimed at improving drought tolerance and yield stability.

Regarding to the grain yield per plant, twenty-seven, twenty-eight and twenty-eight parental combinations expressed significantly positive heterotic effects relative to mid-parent in normal, water deficit irrigation treatments and the combined analysis the best crosses $P_1 \times P_6$, $P_2 \times P_6$, $P_2 \times P_8$, $P_3 \times P_4$, $P_3 \times P_6$, $P_3 \times P_8$, $P_5 \times P_7$ and $P_6 \times P_8$ under both irrigation treatments and the combined analysis.

Nineteen, elven, and fifteen hybrids for harvest index expressed significantly positive heterotic relative to mid-parent in normal and water deficit irrigation, as well as, the combined analysis, respectively. The best crosses $P_2 \times P_5$, $P_2 \times P_6$, $P_3 \times P_5$, $P_3 \times P_7$, $P_3 \times P_8$, $P_4 \times P_5$, $P_4 \times P_8$, $P_5 \times P_6$, $P_5 \times P_7$ and $P_5 \times P_8$ under both irrigation treatments and their combined.

Table 6. Percentage of heterosis relative to mid parents (M.P) for yield and yield components under normal irrigation (N) and water deficit irrigation (D) as well as their combined analysis (Comb.)

Crosses	Number of panicles per plant			Main panicle length (cm)			Number of grains per panicle		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
$P_1 \times P_2$	14.59**	13.46**	14.09**	17.00**	11.20**	14.16**	-0.80	1.43	0.22
$P_1 \times P_3$	11.17**	8.38*	9.92**	11.02**	5.90	8.49**	-1.37	-3.29*	-2.24
$P_1 \times P_4$	6.87	14.67**	10.25**	6.27	2.75	4.53	8.68**	8.97**	8.81**
$P_1 \times P_5$	3.62	15.49**	8.95*	15.30**	10.00**	12.71**	22.44**	26.79**	24.44**
$P_1 \times P_6$	16.1**	29.28**	21.99**	7.76*	3.58	5.70*	9.50**	12.29**	10.78**
$P_1 \times P_7$	5.80	15.46**	10.24**	18.43**	19.53**	18.97**	6.50**	10.54**	8.38**
$P_1 \times P_8$	22.91**	19.32**	21.26**	20.62**	11.37**	16.09**	20.52**	17.84**	19.26**
$P_2 \times P_3$	-0.37	2.24	0.81	12.49**	9.08**	10.82**	-1.25	3.35*	0.83
$P_2 \times P_4$	17.27**	20.62**	18.74**	9.43**	4.40	6.96*	4.24**	5.71**	4.91**
$P_2 \times P_5$	9.64**	26.89**	17.43**	4.30	7.54*	5.87*	15.42**	24.62**	19.63**
$P_2 \times P_6$	28.25**	35.34**	31.44**	16.45**	13.14**	14.83**	23.78**	29.53**	26.39**
$P_2 \times P_7$	19.46**	33.32**	25.84**	18.42**	16.8**	17.63**	19.40**	23.22**	21.16**
$P_2 \times P_8$	27.08**	32.00**	29.35**	13.19**	7.94*	10.63**	34.79**	36.29**	35.49**
$P_3 \times P_4$	17.02**	16.33**	16.71**	10.77**	2.78	6.81*	10.22**	13.57**	11.75**
$P_3 \times P_5$	10.68**	17.53**	13.81**	17.07**	11.28**	14.24**	20.54**	26.99**	23.48**
$P_3 \times P_6$	18.52**	23.35**	20.72**	16.23**	8.19*	12.26**	21.41**	26.46**	23.70**
$P_3 \times P_7$	20.41**	24.49**	22.31**	20.80**	15.75**	18.31**	28.07**	32.17**	29.95**
$P_3 \times P_8$	22.01**	23.49**	22.70**	27.36**	23.92**	25.67**	31.58**	31.67**	31.62**
$P_4 \times P_5$	8.72*	16.50**	12.16**	16.75**	8.14*	12.52**	33.01**	36.39**	34.57**
$P_4 \times P_6$	4.11	14.81**	8.82*	14.67**	1.58	8.18**	0.12	0.35	0.22
$P_4 \times P_7$	2.60	13.14**	7.37*	27.26**	19.34**	23.33**	16.13**	21.11**	18.45**
$P_4 \times P_8$	15.57**	25.50**	20.06**	9.57**	3.45	6.56*	1.45	6.91**	4.04**
$P_5 \times P_6$	11.42**	16.14**	13.57**	16.25**	8.89**	12.65**	23.55**	31.99**	27.41**
$P_5 \times P_7$	18.56**	7.99	13.62**	17.78**	16.44**	17.13**	21.31**	11.24**	16.63**
$P_5 \times P_8$	29.78**	12.59**	21.74**	4.12	9.20**	6.59*	19.09**	25.52**	22.13**
$P_6 \times P_7$	8.97*	11.74*	10.27**	20.68**	19.81**	20.25**	31.34**	39.51**	35.1**
$P_6 \times P_8$	24.67**	19.01**	22.02**	19.40**	18.95**	19.18**	20.74**	22.13**	21.39**
$P_7 \times P_8$	6.59	3.63	5.17	22.83**	19.85**	21.37**	32.88**	34.82**	33.81**

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

Table 6. Cont.

Crosses	Spikelet fertility (%)			Main panicle weight (g)			No. of filled grains per panicle		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
$P_1 \times P_2$	6.17**	0.19	3.31**	11.16**	11.65**	11.38**	5.31**	1.69	3.74*
$P_1 \times P_3$	2.81**	4.89**	3.81**	8.69**	6.13	7.54**	1.33	1.50	1.40
$P_1 \times P_4$	4.95**	-4.99**	0.12	5.63*	13.86**	9.27**	14.07**	3.53	9.36**
$P_1 \times P_5$	2.05	3.76*	2.87**	14.76**	22.07**	18.02**	24.92**	31.47**	27.82**
$P_1 \times P_6$	4.61**	7.15**	5.84**	28.33**	33.09**	30.43**	14.47**	20.34**	17.05**
$P_1 \times P_7$	3.28**	2.70	3.00**	8.22**	14.94**	11.30**	10.02**	13.70**	11.68**
$P_1 \times P_8$	4.25**	4.04**	4.15**	19.40**	20.37**	19.85**	25.63**	22.40**	24.14**
$P_2 \times P_3$	5.75**	-1.00	2.55*	6.51**	2.04	4.47*	4.40**	2.28	3.50*
$P_2 \times P_4$	4.29**	-0.10	2.19*	3.20	10.35**	6.43**	8.70**	5.66**	7.37**
$P_2 \times P_5$	6.19**	4.54**	5.40**	6.97**	18.10**	12.04**	22.58**	30.39**	25.95**
$P_2 \times P_6$	5.11**	6.32**	5.69**	16.02**	23.97**	19.60**	30.11**	37.34**	33.23**
$P_2 \times P_7$	8.59**	5.99**	7.34**	14.51**	21.95**	17.99**	29.57**	23.81**	27.03**
$P_2 \times P_8$	3.31**	1.83	2.60*	23.38**	20.64**	22.09**	39.26**	38.44**	38.89**
$P_3 \times P_4$	3.75**	3.82*	3.79**	3.00	12.70**	7.33**	14.28**	17.97**	15.89**
$P_3 \times P_5$	4.39**	4.48**	4.43**	20.13**	25.10**	22.36**	25.79**	32.69**	28.78**
$P_3 \times P_6$	3.76**	9.11**	6.33**	18.95**	27.63**	22.81**	26.05**	37.89**	31.18**
$P_3 \times P_7$	5.71**	2.80	4.30**	19.77**	18.90**	19.37**	35.09**	36.28**	35.61**
$P_3 \times P_8$	1.83	-1.08	0.42	20.67**	24.66**	22.53**	33.99**	30.17**	32.26**
$P_4 \times P_5$	3.15**	3.55*	3.34**	18.43**	23.23**	20.56**	37.22**	41.19**	38.99**
$P_4 \times P_6$	3.58**	5.82**	4.67**	6.32**	16.48**	10.79**	3.62*	6.25**	4.78**
$P_4 \times P_7$	2.76*	1.05	1.92	4.58	13.32**	8.57**	19.34**	22.47**	20.76**
$P_4 \times P_8$	7.05**	5.81**	6.44**	6.34**	13.60**	9.70**	8.59**	12.98**	10.63**
$P_5 \times P_6$	3.56**	7.07**	5.25**	24.69**	34.10**	28.87**	27.99**	41.20**	33.78**
$P_5 \times P_7$	5.70**	7.91**	6.77**	24.81**	25.48**	25.12**	28.13**	20.22**	24.57**
$P_5 \times P_8$	4.10**	6.69**	5.36**	23.85**	23.63**	23.75**	23.95**	33.54**	28.36**
$P_6 \times P_7$	2.17*	1.83	2.01	7.53**	5.72	6.71**	33.99**	42.45**	37.77**
$P_6 \times P_8$	4.73**	5.39**	5.05**	22.59**	24.09**	23.28**	26.57**	28.98**	27.67**
$P_7 \times P_8$	2.71*	1.52	2.12*	4.74*	3.73	4.26	36.27**	36.52**	36.39**

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

Table 6: Cont.

Crosses	1000-grain weight (g)			Grain yield per plant (g)			Harvest index (%)		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
$P_1 \times P_2$	10.90**	10.12**	10.53**	16.86**	16.76**	16.81**	6.97*	-1.91	2.56
$P_1 \times P_3$	6.71**	4.41*	5.60**	21.65**	19.33**	20.63**	6.72*	0.12	3.50
$P_1 \times P_4$	3.61	3.77	3.69*	9.50**	9.2**	9.37**	0.63	-8.28*	-3.72
$P_1 \times P_5$	5.48**	4.90*	5.19**	21.41**	23.85**	22.49**	13.42**	2.74	8.12**
$P_1 \times P_6$	15.58**	15.64**	15.61**	29.49**	29**	29.28**	9.59**	1.02	5.31
$P_1 \times P_7$	5.15*	0.76	3.00	8.95**	16.8**	12.46**	7.26*	3.19	5.23
$P_1 \times P_8$	10.24**	6.72**	8.52**	14.86**	16.53**	15.62**	2.78	-4.87	-1.03
$P_2 \times P_3$	4.00*	2.12	3.09	13.50**	16.41**	14.8**	-0.11	6.80	3.20
$P_2 \times P_4$	9.24**	6.32**	7.83**	19.75**	18.24**	19.08**	1.60	5.79	3.60
$P_2 \times P_5$	11.87**	7.67**	9.83**	8.84**	12.67**	10.56**	8.02*	9.66**	8.82**
$P_2 \times P_6$	4.20*	5.19*	4.68*	23.50**	22.51**	23.05**	9.63**	8.83**	9.24**
$P_2 \times P_7$	8.71**	6.30**	7.53**	11.45**	13.41**	12.34**	1.00	0.70	0.85
$P_2 \times P_8$	14.23**	12.28**	13.28**	27.56**	13.39**	21.07**	8.03*	2.63	5.39
$P_3 \times P_4$	6.83**	5.80**	6.33**	21.96**	27.13**	24.24**	7.67*	5.22	6.52*
$P_3 \times P_5$	7.88**	10.31**	9.07**	20.64**	19.04**	19.92**	14.62**	9.74**	12.28**
$P_3 \times P_6$	9.78**	11.06**	10.40**	30.42**	22.69**	26.98**	11.81**	5.70	8.87**
$P_3 \times P_7$	7.45**	8.97**	8.20**	15.40**	24.57**	19.52**	7.27*	13.11**	10.08**
$P_3 \times P_8$	8.00**	6.76**	7.39**	33.77**	25.59**	30.06**	8.64**	7.59*	8.14**
$P_4 \times P_5$	8.09**	8.01**	8.05**	22.83**	27.69**	24.99**	15.37**	15.87**	15.61**
$P_4 \times P_6$	2.18	2.82	2.49	5.20*	12.3**	8.35**	-0.74	1.78	0.47
$P_4 \times P_7$	1.63	3.13	2.36	2.27	13.67**	7.39**	0.85	2.51	1.65
$P_4 \times P_8$	7.08**	3.85	5.49**	11.08**	17.13**	13.83**	7.61*	10.08**	8.8**
$P_5 \times P_6$	12.38**	7.58**	10.05**	14.43**	21.03**	17.39**	12.49**	13.75**	13.1**
$P_5 \times P_7$	3.56	3.54	3.55	14.70**	21.33**	17.71**	13.81**	10.67**	12.28**
$P_5 \times P_8$	8.66**	6.72**	7.70**	17.51**	24.63**	20.77**	11.85**	14.97**	13.37**
$P_6 \times P_7$	4.15*	4.47*	4.31*	5.14*	11.6**	8.06**	0.65	-0.19	0.24
$P_6 \times P_8$	8.58**	8.57**	8.58**	27.83**	31.52**	29.51**	11.23**	6.58	8.95**
$P_7 \times P_8$	7.25**	5.02*	6.14**	11.92**	17.82**	14.64**	5.69	6.57	6.13*

*** and ** indicates significant at 0;.05 and 0.01 levels of probability.**

Results of the current study revealed that heterosis was significant and influenced for most of the evaluated traits under both normal and water deficit conditions.

These traits include number of panicles per plant, main panicle length, number of filled grains per panicles, spikelet fertility percentage, main panicle weight, 1000-grain weight, grain yield per plants and harvest index.

These findings are in line with recent studies that have emphasized the role yield-related of heterosis in enhancing yield-related traits in rice under varying environments conditions including water-limited environments, Indicating the efficiency of selecting promising hybrids in breeding programs (Xu et al., 2021; Rasheed et al., 2021; Kushal et al., 2023 and Rahman et al., 2023).

D. Combining ability:

Tables 4, 7 and 8 present the mean squares of combining ability GCA, SCA and GCA/SCA ratio for the traits studied under both irrigation treatments normal and water deficit irrigation, as well as their combined data.

The mean squares associated with general and specific combining ability were highly significant for traits studied under normal and water deficit, as well as, the combined analysis except 1000-grain weight for SCA under water deficit irrigation conditions.

High GCA/SCA ratio largely exceed the unity were detected for all traits studied except spikelet fertility in normal irrigation, indicating that the total genetic variability associated with these traits were result of additive and additive × additives types of gene action for the exceptional cases, however, non-additive type of gene action seems to be more prevalent.

The mean squares of interaction between irrigation treatments and both types combining ability were highly significant for traits studied except 1000-grain weight.

Panicle length, 1000-grain weight and harvest index in SCA × I. indicating that magnitude of all types of gene action varied from irrigation treatment to another.

It is fairly evident that ratios for SCA × irrigation/SCA was higher than of GCA × irrigation treatments /GCA for number of panicles per plant, panicle length, panicle weight and biology yield per plant, while GCA × irrigation/GCA much higher than SCA × Irrigation/SCA for number of grains per panicles, spikelet fertility, number filled grains per panicle, 1000-grain weight, grains yield per plant and harvest index. Such results indicated that non additive, additive and additive × additive genetic variance were much more influenced by the irrigation treatments than the additive genetic ones. Combining ability was stated by several investigators to be more sensitive to environmental changes than GCA (Gilbert 1958), such effects are being used to compare the average performance of each variety with other verities or lines and facilitate - selection of varieties for further improvement to traits studied.

All the previous results are in close agreement with the findings of Anyanwu and Obi (2015), Waza *et al.,* (2015), Abd El-Aty *et al.,* (2016), Gahtyari *et al.,* (2017), Ambikabathy *et al.,* (2019), AnandaLekshmi *et al.,* (2020), Singh *et al.,* (2020), Casco *et al.,* (2021), Abd El-Aty *et al.,* (2022a) and Al-Daej (2022).

1. General combining ability effect (GCA)

General combining ability effects were found to be differed significantly from zero in traits studied. Highly positive values would be of interest under traits studied as shown in Table 7.

The parental (Sakha104) expressed significantly positive ($\hat{g}i$) effects for number of panicles per plant and panicle length in both irrigation treatments, as well as the combined over them and spikelet fertility at normal irrigation treatments.

The Parental (Sakha108) and parental (PL77-8-7) exhibited significant and positive GCA effects ($\hat{g}_i$) for several important yield related traits under both normal and water deficit irrigation treatments, as well as the combined analysis.

Both parents were among the best general combiners for number of grains per panicle, panicle weight, number of filled grains per panicle, 1000-grain weight and grain yield per plant, indicating their high genetic potential for improving these traits.

Moreover, parents showed additional significantly positive GCA effects ($\hat{g}_i$) for number of panicles per plant under both irrigation treatments, along with a positive effect on spikelet fertility percentage under water deficit irrigation conditions and the combined analysis.

These findings highlight the superior genetic contribution of parent Sakha108 in particular and its potential as a promising donor in rice breeding programs aiming to improve growth and yield traits. especially under water limited environments

The parental GZ10487-2-2-7-4-1 gave desirable ($\hat{g}_i$) effects for harvest index under both irrigation treatments and the combined analysis and grain yield per plant under water deficit irrigation and the combined analysis.

The parental Super 302 expressed significant positive and the best general combiner for panicle length, number of grains per panicle, grain yield per plant and harvest index in both irrigation treatments and the combined analysis, spikelet fertility in water deficit treatment and the combined analysis, and panicle weight under normal irrigation and the combined analysis.

These results are agreement with the findings reported by Anyanwu and Obi (2015), Abd El-Aty *et al.,* (2016), Madhuri *et al.,* (2017), Deepika *et al.,* (2019), El-Mowafi *et al.,* (2021), Azad *et al.,* (2022) and Sakran *et al.,* (2022).

Table 7. Estimates of general combining ability effects (ĝi) for yield and yield components under normal irrigation (N) and water deficit irrigation (D), as well as their combined analysis (Comb.)

Parent	Number of panicles per plant			Main panicle length (cm)			Number of grains per panicle		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
P_1 (Giza177)	-0.61**	-0.83**	-0.72**	-0.30*	-0.28	-0.29**	-10.76**	-11.22**	-10.99**
P_2 (Sakha104)	1.90**	1.62**	1.76**	0.36*	0.30*	0.33**	-1.82**	-2.83**	-2.32**
P_3 (Sakha108)	2.00**	1.56**	1.78**	1.27**	1.13**	1.20**	5.89**	2.34**	4.12**
P_4 (GZ 11332)	-0.25	-0.76**	-0.50**	-0.65**	-0.77**	-0.71**	-8.94**	-8.13**	-8.54**
P_5 (GZ10487-2-2-7-4-1)	0.14	0.14	0.14**	-0.02	-0.10	-0.06	-1.06**	-0.14	-0.60**
P6 (Sakha super 302)	-1.12**	-0.84**	-0.98**	0.67**	0.64**	0.65**	25.03**	20.54**	22.78**
P_7 (PL77-8-6)	-0.99**	-0.16	-0.57**	-2.04**	-1.60**	-1.82**	-14.30**	-11.16**	-12.73**
P_8 (PL77-8-7)	-1.06**	-0.74**	-0.90**	0.70**	0.69**	0.70**	5.97**	10.59**	8.28**
L.S.D(0.05) gi	0.26	0.26	0.10	0.28	0.29	0.11	0.79	0.76	0.30
L.S.D(0.01) gi	0.35	0.34	0.13	0.37	0.38	0.15	1.04	1.00	0.40
L.S.D(0.05) gi-gj	0.40	0.39	0.19	0.42	0.43	0.21	1.19	1.14	0.57
L.S.D(0.01) gi-gj	0.53	0.52	0.26	0.56	0.57	0.28	1.57	1.52	0.75

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

Table 7. Cont.

Parent	Spikelet fertility (%)			Main panicle weight (g)			Number of filled grains per panicle		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
P_1 (Giza177)	-0.58**	-0.71**	-0.64**	-0.23**	-0.29**	-0.26**	-11.00**	-10.59**	-10.80**
P_2 (Sakha104)	0.83**	-2.80**	-0.98**	-0.03	0.02	-0.01	-0.48	-6.61**	-3.55**
P_3 (Sakha108)	0.44*	-0.98**	-0.27**	0.27**	0.15**	0.21**	6.18**	0.88*	3.53**
P_4 (GZ 11332)	-0.49*	-0.55*	-0.52**	-0.50**	-0.43**	-0.46**	-9.22**	-7.78**	-8.50**
P_5 (GZ10487-2-2-7-4-1)	0.09	0.49	0.29**	0.06**	0.03	0.04**	-0.85*	0.73	-0.06
P6 (Sakha super 302)	-0.18	1.38**	0.60**	0.44**	0.27**	0.36**	23.18**	20.24**	21.71**
P_7 (PL77-8-6)	-0.42*	0.84**	0.21*	-0.46**	-0.29**	-0.38**	-13.90**	-9.43**	-11.67**
P_8 (PL77-8-7)	0.32	2.32**	1.32**	0.45**	0.54**	0.49**	6.09**	12.56**	9.32**
L.S.D(0.05) gi	0.40	0.52	0.18	0.04	0.05	0.02	0.84	0.79	0.32
L.S.D(0.01) gi	0.53	0.69	0.24	0.06	0.07	0.02	1.12	1.05	0.42
L.S.D(0.05) gi-gj	0.60	0.78	0.34	0.07	0.07	0.03	1.27	1.20	0.61
L.S.D(0.01) gi-gj	0.80	1.04	0.45	0.09	0.10	0.05	1.69	1.59	0.8

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

Table 7. Cont.

Parent	1000-grain weight (g)			Grain yield per plant (g)			Harvest index (%)		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
P_1 (Giza177)	0.12	-0.28*	-0.08	-0.69**	-1.52**	-1.10**	-1.32**	-1.33**	-1.32**
P_2 (Sakha104)	-0.19	-0.75**	-0.47**	0.07	-0.61**	-0.27**	0.05	0.54	0.29*
P_3 (Sakha108)	0.70**	0.70**	0.70**	3.23**	1.56**	2.40**	1.38**	0.10	0.74**
P_4 (GZ 11332)	-1.01**	-0.94**	-0.97**	-2.52**	-2.11**	-2.32**	0.20	-0.73*	-0.27*
P_5 (GZ10487-2-2-7-4-1)	-0.18	0.11	-0.03	0.05	0.63**	0.34**	1.07**	0.98**	1.02**
P6 (Sakha super 302)	0.66**	0.38**	0.52**	3.3**	2.48**	2.89**	0.68*	1.01**	0.84**
P_7 (PL77-8-6)	-0.92**	-0.35**	-0.64**	-4.59**	-2.17**	-3.38**	-1.25**	-0.19	-0.72**
P_8 (PL77-8-7)	0.82**	1.12**	0.97**	1.15**	1.73**	1.44**	-0.81**	-0.36	-0.59**
L.S.D(0.05) gi	0.24	0.25	0.10	0.38	0.38	0.15	0.59	0.64	0.24
L.S.D(0.01) gi	0.32	0.33	0.13	0.51	0.51	0.20	0.79	0.85	0.32
L.S.D(0.05) gi-gj	0.37	0.38	0.18	0.58	0.58	0.29	0.90	0.96	0.46
L.S.D(0.01) gi-gj	0.49	0.50	0.24	0.77	0.76	0.37	1.19	1.28	0.60

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

2. Specific combing ability effect (SCA):

For number of panicles per plant, thirteen, ten and fifteen hybrid exhibited significant positive ($\hat{s}_{ij}$) effects at normal and water deficit irrigation, as well as, the combined analysis, respectively. The crosses $P_2 \times P_6$, $P_2 \times P_7$, $P_2 \times P_8$, $P_3 \times P_6$, $P_3 \times P_7$ and $P_3 \times P_8$ gave the highest desirable ($\hat{s}_{ij}$) effects under both irrigation treatments and their combined as shown in Table 8.

Regarding main panicle length, ten, seven, and fourteen parental combinations had significantly positive ($\hat{s}_{ij}$) effects under both irrigation treatments and their combined, respectively. The Crosses $P_1 \times P_2$, $P_2 \times P_6$, $P_3 \times P_8$, $P_4 \times P_7$ and

$P_6 \times P_8$ gave the highest desirable ($\hat{s}_{ij}$) effects at normal and water deficit irrigation, as well as the combined analysis.

The seventeen, eighteen and nineteen crosses for number grains per panicle gave significantly positive ($\hat{s}_{ij}$) effects in both irrigation regimes and their combined, respectively. The crosses $P_1 \times P_5$, $P_2 \times P_6$, $P_2 \times P_8$, $P_3 \times P_6$, $P_3 \times P_7$, $P_3 \times P_8$, $P_4 \times P_5$, $P_5 \times P_6$, $P_6 \times P_7$ and $P_7 \times P_8$ gave the best crosses per ($\hat{s}_{ij}$) effects under both irrigation treatments and their combined.

Table 8. Estimates of specific combining ability effects ($\hat{s}_{ij}$) for yield and yield components under normal irrigation (N) and water deficit irrigation (D), as well as their combined analysis (Comb.)

Crosses	Number of panicles per plant			Panicle length (cm)			Number of grains per panicle		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
$P_1\times P_2$	0.76	-0.39	0.19	1.66**	0.96*	1.31**	-8.94**	-7.16**	-8.05**
$P_1\times P_3$	0.43	-0.44	-0.004	-0.12	-0.26	-0.19	-12.10**	-13.89**	-12.99**
$P_1\times P_4$	0.06	0.30	0.18	-0.63	-0.16	-0.39	7.7**	5.97**	6.84**
$P_1\times P_5$	-0.75	0.55	-0.10	1.28**	0.68	0.98**	14.24**	14.74**	14.49**
$P_1\times P_6$	0.84*	1.68**	1.26**	-0.71	-0.66	-0.69*	0.29	1.05	0.67
$P_1\times P_7$	-0.29	0.55	0.13	0.61	1.24**	0.92**	-6.27**	-2.05	-4.16**
$P_1\times P_8$	1.25**	0.67	0.96**	1.86**	0.49	1.17**	11.39**	6.34**	8.87**
$P_2\times P_3$	-2.38**	-2.16**	-2.27**	0.34	0.29	0.32	-16.64**	-12.14**	-14.39**
$P_2\times P_4$	1.38**	0.53	0.96**	0.13	0.03	0.08	-2.79*	-3.98**	-3.39**
$P_2\times P_5$	-0.28	1.67**	0.69*	-0.92*	0.07	-0.43	0.98	6.51**	3.74**
$P_2\times P_6$	2.48**	2.14**	2.31**	1.28**	1.20**	1.24**	19.25**	18.29**	18.77**
$P_2\times P_7$	1.49**	2.60**	2.05**	0.79	0.68	0.74*	5.34**	5.28**	5.31**
$P_2\times P_8$	1.65**	1.92**	1.78**	0.45	-0.32	0.06	27.79**	23.46**	25.63**
$P_3\times P_4$	1.64**	0.64	1.14**	-0.11	-0.46	-0.29	3.82**	4.68**	4.25**
$P_3\times P_5$	0.19	0.98*	0.59*	1.32**	0.71	1.02**	6.78**	9.19**	7.98**
$P_3\times P_6$	1.15**	1.24**	1.19**	0.73	0.03	0.38	14.27**	14.10**	14.18**
$P_3\times P_7$	1.97**	2.06**	2.01**	0.75	0.41	0.58	15.33**	14.94**	15.14**
$P_3\times P_8$	1.13**	1.48**	1.31**	3.05**	2.92**	2.99**	22.68**	17.85**	20.27**
$P_4\times P_5$	0.20	0.58	0.39	1.62**	0.75	1.18**	27.61**	24.11**	25.86**
$P_4\times P_6$	-0.88*	-0.19	-0.54	0.78	-0.62	0.08	-15.44**	-16.72**	-16.08**
$P_4\times P_7$	-0.71	0.13	-0.29	2.21**	1.64**	1.92**	4.55**	7.31**	5.93**
$P_4\times P_8$	0.31	1.34**	0.82**	-0.39	-0.66	-0.53	-15.65**	-8.88**	-12.26**
$P_5\times P_6$	-0.02	0.13	0.06	1.20**	0.27	0.74*	9.80**	13.84**	11.82**
$P_5\times P_7$	1.59**	-0.47	0.56*	0.64	0.54	0.59	-1.22	-14.38**	-7.80**
$P_5\times P_8$	2.20**	-0.15	1.03**	-1.5**	-0.11	-0.80**	-3.21**	2.46*	-0.38
$P_6\times P_7$	-0.33	-0.44	-0.38	0.77	1.17**	0.97**	19.46**	22.69**	21.07**
$P_6\times P_8$	0.82*	0.11	0.47	1.35**	1.89**	1.62**	5.10**	2.99*	4.05**
$P_7\times P_8$	-1.22**	-1.32**	-1.27**	1.04*	0.70	0.87**	12.72**	13.11**	12.91**
LSD 0.05 ($\hat{s}_{ij}$)	0.81	0.79	0.56	0.85	0.88	0.60	2.41	2.32	1.65
LSD 0.01 ($\hat{s}_{ij}$)	1.08	1.05	0.73	1.13	1.16	0.79	3.19	3.08	2.16
LSD 0.05 (s_{ij}-s_{ik})	1.20	1.17	0.83	1.26	1.30	0.89	3.56	3.43	2.44
LSD 0.01 (s_{ij}-s_{ik})	1.59	1.55	1.08	1.67	1.72	1.17	4.72	4.56	3.19
LSD 0.05 (s_{ij}-s_{kl})	1.13	1.10	0.28	1.19	1.22	0.30	3.36	3.24	0.81
LSD 0.01 (s_{ij}-s_{kl})	1.50	1.46	0.36	1.57	1.62	0.39	4.45	4.29	1.06

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

Table 8. Cont.

Crosses	Spikelet fertility (%)			Panicle weight (g)			Number of filled grains panicle		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
$P_1\times P_2$	1.89**	-0.93	0.48	0.08	-0.005	0.04	-5.99**	-6.71**	-6.35**
$P_1\times P_3$	-0.11	2.59**	1.24*	-0.10	-0.25**	-0.17**	-11.66**	-9.30**	-10.48**
$P_1\times P_4$	1.68**	-5.16**	-1.74**	0.0005	0.08	0.04	9.66**	-1.51	4.08**
$P_1\times P_5$	-0.92	0.36	-0.28	0.004	0.12	0.06	11.67**	12.87**	12.27**
$P_1\times P_6$	1.56*	2.86**	2.21**	0.68**	0.56**	0.62**	2.77*	4.62**	3.70**
$P_1\times P_7$	0.04	0.69	0.36	-0.05	0.12	0.03	-5.96**	-0.52	-3.24**
$P_1\times P_8$	1.20	1.82*	1.51**	0.29**	0.26**	0.27**	12.56**	7.94**	10.25**
$P_2\times P_3$	1.55*	-2.34**	-0.39	-0.13	-0.37**	-0.25**	-13.56**	-13.17**	-13.36**
$P_2\times P_4$	0.06	-0.94	-0.44	-0.04	0.02	-0.01	-2.64*	-4.11**	-3.38**
$P_2\times P_5$	1.84**	0.95	1.39**	-0.26**	0.06	-0.10*	3.72**	6.98**	5.35**
$P_2\times P_6$	1.00	2.05*	1.52**	0.20**	0.32**	0.26**	20.47**	18.98**	19.73**
$P_2\times P_7$	3.83**	3.43**	3.63**	0.28**	0.45**	0.36**	10.35**	3.70**	7.03**
$P_2\times P_8$	-0.68	-0.12	-0.40	0.58**	0.35**	0.47**	25.24**	20.33**	22.78**
$P_3\times P_4$	0.62	1.92*	1.27*	-0.13*	0.07	-0.03	4.51**	6.39**	5.45**
$P_3\times P_5$	1.25*	0.50	0.87	0.28**	0.30**	0.29**	8.48**	8.32**	8.40**
$P_3\times P_6$	0.82	4.04**	2.43**	0.30**	0.45**	0.37**	15.25**	19.04**	17.14**
$P_3\times P_7$	2.27**	0.33	1.30**	0.45**	0.31**	0.38**	17.89**	14.10**	16.00**
$P_3\times P_8$	-1.00	-3.08**	-2.04**	0.40**	0.51**	0.45**	19.66**	10.51**	15.09**
$P_4\times P_5$	-0.05	0.42	0.19	0.38**	0.22**	0.30**	25.72**	21.42**	23.57**
$P_4\times P_6$	0.49	1.98*	1.23*	-0.11	0.02	-0.05	-13.81**	-12.56**	-13.19**
$P_4\times P_7$	-0.56	-0.51	-0.53	0.02	0.14	0.08	3.29*	6.35**	4.82**
$P_4\times P_8$	3.62**	3.62**	3.62**	-0.10	0.05	-0.02	-9.72**	-3.34**	-6.53**
$P_5\times P_6$	0.52	1.04	0.78	0.37**	0.44**	0.41**	10.16**	14.01**	12.08**
$P_5\times P_7$	2.14**	3.43**	2.79**	0.46**	0.32**	0.39**	1.54	-8.50**	-3.48**
$P_5\times P_8$	0.98	2.40**	1.69**	0.35**	0.22**	0.29**	-1.58	5.86**	2.14*
$P_6\times P_7$	-0.91	-2.17**	-1.54**	-0.22**	-0.37**	-0.29**	16.13**	17.27**	16.70**
$P_6\times P_8$	1.70**	0.89	1.30**	0.37**	0.29**	0.33**	8.22**	4.97**	6.59**
$P_7\times P_8$	-0.46	-0.89	-0.68	-0.33**	-0.34**	-0.34**	10.86**	11.23**	11.04**
LSD 0.05 ($\hat{s}_{ij}$)	1.22	1.59	0.98	0.13	0.15	0.10	2.58	2.43	1.74
LSD 0.01 ($\hat{s}_{ij}$)	1.61	2.10	1.29	0.18	0.20	0.13	3.42	3.22	2.29
LSD 0.05 (s_{ij}-s_{ik})	1.80	2.35	1.46	0.20	0.22	0.15	3.82	3.59	2.58
LSD 0.01 (s_{ij}-s_{ik})	2.39	3.11	1.91	0.26	0.30	0.19	5.06	4.77	3.39
LSD 0.05 (s_{ij}-s_{kl})	1.70	2.21	0.49	0.19	0.21	0.05	3.60	3.39	0.86
LSD 0.01 (s_{ij}-s_{kl})	2.25	2.94	0.64	0.25	0.28	0.06	4.78	4.49	1.13

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

Table 8. Cont.

Crosses	1000-grain weight (g)			Grain yield /plant (g)			Harvest index (%)		
	N	D	Comb.	N	D	Comb.	N	D	Comb.
$P_1\times P_2$	1.01**	1.19**	1.10**	1.17	1.33*	1.25**	1.53	-0.51	0.51
$P_1\times P_3$	0.19	-0.30	-0.06	1.72**	0.86	1.29**	0.40	-0.24	0.08
$P_1\times P_4$	-0.37	-0.04	-0.21	-0.56	-1.37*	-0.97*	-1.32	-3.28**	-2.30**
$P_1\times P_5$	-0.40	-0.15	-0.27	3.01**	2.37**	2.69**	1.84*	-0.34	0.75
$P_1\times P_6$	2.61**	2.60**	2.60**	5.86**	4.16**	5.01**	1.80	0.60	1.20
$P_1\times P_7$	0.08	-0.82*	-0.37	0.08	1.06	0.57	1.55	1.65	1.60*
$P_1\times P_8$	0.83*	0.34	0.59*	-0.56	0.21	-0.18	-1.38	-2.23*	-1.80**
$P_2\times P_3$	-0.75*	-1.03**	-0.89**	-1.44*	0.61	-0.41	-2.28*	0.93	-0.68
$P_2\times P_4$	1.06**	0.52	0.79**	3.43**	1.97**	2.70**	-0.33	1.16	0.42
$P_2\times P_5$	1.26**	0.48	0.87**	-1.78**	-0.47	-1.12**	0.08	0.92	0.50
$P_2\times P_6$	-0.88*	-0.36	-0.62*	3.59**	2.8**	3.20**	2.51**	2.38*	2.45**
$P_2\times P_7$	0.93*	0.57	0.75**	1.09	0.70	0.90*	-0.75	-1.28	-1.01
$P_2\times P_8$	1.82**	1.76**	1.79**	4.58**	-0.16	2.21**	1.62	-0.71	0.46
$P_3\times P_4$	0.76*	0.41	0.59*	2.97**	3.47**	3.22**	1.60	0.19	0.90
$P_3\times P_5$	0.53	1.28**	0.90**	1.56*	0.32	0.94*	2.17*	0.18	1.18
$P_3\times P_6$	1.15**	1.31**	1.23**	5.31**	1.62**	3.47**	2.55**	0.22	1.39*
$P_3\times P_7$	0.97*	1.36**	1.16**	1.15	2.89**	2.02**	1.18	3.49**	2.34**
$P_3\times P_8$	0.41	0.28	0.34	5.92**	2.68**	4.30**	0.90	0.75	0.82
$P_4\times P_5$	0.88*	1.03**	0.95**	4.67**	3.70**	4.19**	3.64**	3.50**	3.57**
$P_4\times P_6$	-0.77*	-0.56	-0.66*	-2.88**	-1.08	-1.98**	-2.38*	-0.85	-1.61*
$P_4\times P_7$	-0.35	0.16	-0.09	-1.09	0.34	-0.38	-0.72	-0.46	-0.59
$P_4\times P_8$	0.44	-0.13	0.16	-0.84	0.58	-0.13	1.54	2.50*	2.02**
$P_5\times P_6$	1.64**	0.34	0.99**	-0.12	1.15	0.51	1.22	2.53*	1.87**
$P_5\times P_7$	-0.37	-0.14	-0.25	2.36**	1.97**	2.17**	2.59**	1.13	1.86**
$P_5\times P_8$	0.35	0.28	0.32	0.69	2.44**	1.56**	0.75	2.63**	1.69*
$P_6\times P_7$	-0.18	-0.07	-0.12	-2.01**	-1.10	-1.55**	-1.83*	-1.90	-1.86**
$P_6\times P_8$	0.39	0.62	0.51	4.45**	4.97**	4.71**	2.16*	0.83	1.50*
$P_7\times P_8$	0.51	0.25	0.38	0.30	1.01	0.66	0.44	0.84	0.64
LSD 0.05 ($\hat{s}_{ij}$)	0.74	0.76	0.52	1.18	1.17	0.82	1.82	1.95	1.31
LSD 0.01 ($\hat{s}_{ij}$)	0.98	1.01	0.69	1.57	1.55	1.07	2.42	2.59	1.72
LSD 0.05 (s_{ij}-s_{ik})	1.10	1.13	0.77	1.75	1.73	1.21	2.69	2.89	1.95
LSD 0.01 (s_{ij}-s_{ik})	1.46	1.49	1.02	2.32	2.29	1.59	3.57	3.83	2.55
LSD 0.05 (s_{ij}-s_{kl})	1.03	1.06	0.26	1.65	1.63	0.40	2.54	2.72	0.65
LSD 0.01 (s_{ij}-s_{kl})	1.37	1.41	0.34	2.18	2.16	0.53	3.37	3.61	0.85

*** and ** indicates significant at 0.05 and 0.01 levels of probability.**

While elven, elven and fourteen hybrids for spikelet fertility in had significantly positive ($\hat{s}_{ij}$) effects in normal and water deficit irrigation treatments as well combined data, respectively. The crosses $P_1\times P_6$, $P_2\times P_7$, $P_4\times P_8$ and $P_5\times P_7$ gave the highest desirable ($\hat{s}_{ij}$) effects for this trait under both irrigation treatments and the combined analysis.

Regarding to the fourteen, fourteen and fourteen crosses for panicle weight, eighteen, nineteen, and twenty combinations for number of filled grains per panicle had significantly positive ($\hat{s}_{ij}$) effects in normal and stress water deficit irrigation treatments, as well as, the combined analysis, respectively. The highest significantly desirable ($\hat{s}_{ij}$) effects crosses $P_1\times P_6$, $P_1\times P_8$, $P_2\times P_6$, $P_2\times P_8$, $P_3\times P_6$, $P_3\times P_8$, $P_4\times P_5$, $P_5\times P_6$ and $P_6\times P_8$ for these traits under both irrigation treatments and the combined analysis.

Considering 1000-grain weight, twelve, seven and thirteen crosses expressed significantly positive ($\hat{s}_{ij}$) effects at normal and water deficit irrigation treatments, as well as their combined, respectively. The crosses $P_1\times P_6$, $P_2\times P_8$, $P_3\times P_6$, $P_3\times P_7$and $P_4\times P_5$ gave the highest desirable ($\hat{s}_{ij}$) effects under both irrigation regimes and the combined analysis.

Regarding grains yield per plant, thirteen, thirteen and seventeen cross combinations had significantly positive ($\hat{s}_{ij}$) effects in normal and water deficit irrigation treatments and their combined, respectively. The crosses $P_1\times P_6$, $P_2\times P_6$, $P_3\times P_4$, $P_3\times P_6$, $P_3\times P_8$, $P_4\times P_5$, $P_5\times P_7$ and $P_6\times P_8$ gave the highest desirable ($\hat{s}_{ij}$) effects under both irrigation treatments and the combined analysis.

For harvest index (%), seven, six and ten crosses had significant and positive ($\hat{s}_{ij}$) effects in normal and water deficit irrigation treatments, as well as, the combined analysis, respectively. The best crosses $P_2\times P_6$ and $P_4\times P_5$ under both irrigation and combined data.

These results are in general agreement with those obtained by Labroo *et al.,* (2021), El-Shamey *et al.,* (2022), Abd El-Aty *et al.,* (2022b) and Du *et al.,* (2024).

CONCLUSION

The hybrids $P_1\times P_6$, $P_1\times P_8$, $P_2\times P_6$, $P_2\times P_8$, $P_3\times P_6$, $P_3\times P_8$, $P_4\times P_5$, $P_5\times P_6$ and $P_6\times P_8$ exhibited the best values for grain yield per plant and most yield-contributing traits under both normal irrigation and water deficit conditions, as well as, the combined analysis. The results also, revealed that these hybrids expressed significant specific combining ability (SCA) effects for grain yield per plant under both environments, which is associated with the involvement of one or more parents possessing good general combining ability (GCA). Moreover, these hybrids showed superiority in most yield-related traits, indicating their potential as promising genetic materials that could be exploited in breeding programs aimed to develop high-yielding genotypes with relative tolerance to environmental stresses, particularly water deficit.

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السلوك الوراثي للمحصول ومكوناته لبعض التراكيب الوراثية للأرز بإستخدام نظاميين من الري

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الملخص

أجريت هذه الدراسة بغرض التعرف علي قوة الهجين والقدرة على التآلف للمحصول ومكوناته على ثمانية تراكيب وراثية من محصول الأرز من خلال تحليل الهجن التبادلية (٨×٨) بدون التهجين العكسي (جريفينج الطريقة الثانية الموديل الأول ١٩٥٦) لانتاج ٢٨ هجيناً خلال الموسم الصيفي ٢٠٢٣، في الموسم الصيفي ٢٠٢٤ تم زراعة الأباء والهجن الناتجة (٣٦ تركيب وراثى) زراعة بذرة جافة في أرض جافة في تجربتين منفصلتين بإستخدام تصميم قطاعات كاملة العشوائية في ثلاث مكررات تحت نظامين من الري (٤ أيام و ١٠ أيام). وكانت أهم الصفات المدروسة عدد الداليات للنبات ، طول الدالية الرئيسية، عدد الحبوب في السنبلة الرئيسية، نسبة الخصوبة، وزن الدالية الرئيسية، عدد الحبوب الممتلئة في الدالية الرئيسية، وزن الألف حبة، محصول الحبوب للنبات و دليل الحصاد. وكانت أهم النتائج :- كان التباين الراجع لكل من الري، التراكيب الوراثية، الآباء والهجن عالي المعنوية لكل الصفات المدروسة في التجربيتين والتحليل المشترك لهم. كان التباين الراجع للآباء × الهجن كمؤشر لقوة الهجين معنوياً لكل الصفات المدروسة في التجربتين والتحليل المشترك بينهما. كان التباين الراجع للقدرة العامة والخاصة على الائتلاف معنوياً لكل الصفات المدروسة في التجربتين والتحليل المشترك بينهما وكانت أفضل الهجن في صفة محصول النبات ومعظم مكوناته $P_2\times P_6$, $P_1\times P_6$, $P_2\times P_8$, $P_3\times P_4$, $P_3\times P_6$, $P_3\times P_8$, $P_5\times P_7$ و$P_6\times P_8$. كانت الآباء سخا ١٠٨، سخا سوبر ٣٠٢ والسلالة ٧٧-٨-٧ أفضل الآباء في القدرة العامة على الائتلاف لصفة محصول الحبوب للنبات ومعظم مكونات المحصول. سجلت الهجن $P_1\times P_6$, $P_1\times P_8$, $P_2\times P_6$, $P_2\times P_8$, $P_3\times P_6$, $P_3\times P_8$, $P_4\times P_5$, $P_5\times P_6$ و $P_6\times P_8$ أفضل الهجن في قيم صفة محصول الحبوب للنبات والقدرة الخاصة علي الائتلاف في معاملة الرى العادى ونقص الماء وكذلك التحليل المشترك بينهما.