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Genetic Behavior of Grain Yield and Quality Traits under Water Deficit and Normal Conditions of some Rice Genotypes

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Cross Mark

ABSTRACT

The main objective of this study was to assess the combining ability and heterosis for rice grain yield and quality traits to recognize the most desirable genotypes for rice breeding programs. Six lines were crossed to three testers in this study and the resultant eighteen hybrids. Parents and their 18 F_1 crosses were evaluated under two separate irrigation experiments; the first and second experiments were irrigated every four days (normal condition) and the second experiment was irrigated every twelve days (a stress condition), respectively. Results indicated that water deficit treatment was significantly reduced all the studied traits except for amylose content (%).Two crosses, Sakha107 x M 206 and Sakha107 X Sakha Super 300 had the highest desirable mean values for hulling (%), milling (%), head rice, grain thickness (mm), and grain shape. Three crosses namely, Sakha107 x M206, Sakha107 X Sakha Super 300 and Sakha108 x Sakha Super 300 had the highest mean values of no. of panicles/ plant, panicle length (cm), panicle weight (g), 1000- grain weight (g), grain yield / plant (g) and fertility (%). The varieties, Sakha 107 and Sakha108 as line, M206 and Sakha super 300 as a tester were the best general combiners and could be used in rice breeding programs for improving all the studied traits under both conditions. The most desirable mid-parent and better-parent heterosis for grain yield and quality traits were detected for the crosses, Sakha107 X M206, Sakha108 X M206 and Sakha107 X Sakha Super 300 under both and across environments, respectively.

***Keywords*:** Rice, Line x Tester, combining ability, yield and grain quality traits.

INTRODUCTION

Water scarcity is one of the greatest challenges in the whole world. Drought is the several widespread and damaging of all environmental stresses. Egypt was suffering from severe water scarcity in recent years, which has been exacerbated by the new conflict over water with the Nile River countries. In Egypt, rice ranks the second cereal crop after wheat with a cultivated area of 1.074 million fed, and produced about 4.5 million tons in 2020 season (FAOSTAT, 2020), as a result of its high water needs relative to other crops. Therefore, many efforts are being made to develop new rice genotypes tolerant to drought stress since severe drought can cause up to 40% loss in rice yield (Fukagawa and Ziska, 2019). A significant reduction in all physiological traits under drought stress relative to normal conditions Lafitte *et al.*, (2004). Drought has a strong effect on yield and physiological traits. Rice responses to drought are assumed to be complex that concern various physiological, biochemical and molecular changes (Zhang *et al.*, 2018). Grain yield/plant has reduced under water stress during vegetative, panicle initiation, flowering by 28%, 34%, and 40%, respectively (Nakashima and Suenaga, 2017). Drought affected almost every growth stage causing a decrease to yield and yield components (Wassmann *et al.*, 2009). Drought led to reducing in plant height, due to reduce the rate of growth of stems (Rajiv *et al.*, 2010).

The line x tester mating design provides reliable information about the nature and magnitude of gene action and combining ability effects present in the genetic materials (Dhillon 1975). The line x tester analysis design is one of the efficient methods of breeding both self and cross-pollinated plants and to estimate promising parents and crosses, and their general and specific combining abilities (Kempthorne, 1957).

Combining ability is a powerful instrument in determining the best combiners that may be utilized in the hybrid program or accumulate fixable genes and obtain desirable segregates. Combining ability enables the breeder to define the pattern of gene effects in the expression of quantitative traits by determining potentially superior parents and hybrids (Zhang *et al.*, 2015). Combining ability delivers information on the two components of variance: additive and non-additive variances which are important to determine upon the parents and crosses to select desirable hybrids. The GCA is a function of additive genetic effects while SCA measures non-additive gene effects including dominance and epistasis (Upadhyay and Jaiswal, 2015). The Line X Tester analysis enables breeders to estimate different types of gene actions, also provides information about the general combining ability (GCA) of parents and specific combining ability (SCA) effects of crosses (Zhang *et al.*, 2002).

Heterosis estimates were attributed to both additive and high degree of dominance or epistatic interactions and both for one or more yield, its component and grain quality characters. Vanaja and Babu (2004) pointed out that yield increase in rice was due to favorable heterosis in number of

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grains per panicle. In this paper an attempt has been made to assess the combining ability and to determine the nature and magnitude of gene action for yield and its related and grain quality characters to explore the best combination of hybrids for the exploitation of maximum heterosis or hybrid vigor in F_1 hybrids for yield and its component (number of panicles/plant, panicle length, panicle weight, 1000-grain weight, grain yield plant^{-1} and fertility (%) traits), and grain quality characters (Grain shape, grain thickness (mm), hulling (%), milling (%), head rice (%) and amylose content (%).

Grain quality depends not just on the variety of rice, but quality also depends on the crop production environment, harvesting, processing, and milling systems. The appearance of milled rice is essential to the consumer, making it also crucial to producers and millers. Thus, it is a significant breeding consideration. The main objective of this study was to assess the combining ability for rice grain quality to recognize the most desirable genotypes for rice breeding programs. Recently the trend has changed to incorporate preferred quality characteristics that increase the total economic value of rice; it has been reported that herbal extracts may enhance the quality traits of crops (Saad *et al.,* 2021). Grain quality depends not just on the variety of rice, but quality also depends on the crop production environment, harvesting, processing, and milling systems. Therefore, the objectives of this work are to estimate heterosis, general and specific combining ability for some yield and quality traits under normal conditions and water deficit.

MATERIALS AND METHODS

1. Plant materials:

A set of nine parents consisting of six varieties used as lines *viz.,* Giza 177, Sakha 105, Sakha 106, Sakha 107, Sakha 108, GZ 10101-5 and three genotypes used as testers *viz.,* Hispagran, Sakha super 300 and M 206 of rice (*Oryza sativa*, L.) were selected for this study. Seeds of the parental lines were obtained from the genetic stock of the Rice Research and Training Center (RRTC), Egypt. The names, pedigree and type of included varieties are shown in **Table (1).**

Table 1. Names, pedigree, type of included varieties.

NO	Entry name	Pedigree	Type
1	G177	[Giza 171] Ymji No.1 // PiNo.4	Japonica
2	Sakha 105	GZ5581-46-3/GZ4316-7-1-1	Japonica
3	Sakha 106	Giza 177/ Hexi 30	Japonica
4	Sakha 107	(Giza 177/BL1)	Japonica
5	Sakha 108	(Sakha101/ HR5824-B-3-2-3// Sakha 101)	Japonica
6	GZ 10101	Sakha 103 x IR385	Japonica
7	Hispagran	Unknown	Japonica
8	Sakha super 300	----	Japonica
9	M206	M-202/M204	Japonica

2. Field experiment:

In 2020 growing season, the nine parent's grains were sown. After thirty days old seedlings each parent was individually transplanted in the permanent field in two rows, 5 meters long and 20 x 20 cm apart between plants and rows. At flowering stage during this season, the six lines were crossed with the three testers to produce 18 F_1 crosses using bulk emasculation method according to Butany (1961) by using hot water (42-44 °C for 10 min).

In 2021 summer season, the parents and their F_1 crosses were sown 30th April, and then seedlings were transplanted into two adjacent experimental fields. The first one was normally irrigated every 4 days (continuous flooding) and the second one (drought stress) was irrigated every 12 days. After 30 days from the sowing, seedlings of each genotype were individually transplanted into their permanent field (s) in a randomized complete block design (RCBD) with three replications. Each genotype (parents and F_1 crosses) was planted in three rows per replicate. Each row was 5.0 m long with the spacing of 20 × 20 cm among rows and hills. Water stress was applied after 12 days from transplanting. Remain recommended agricultural rice practices were applied at the proper time. Data were recorded on twenty randomly selected plants from parents and F_1 plant samples. Data were recorded for number of panicles/plant, panicle length, panicle weight, 1000-grain weight, grain yield plant^{-1} and fertility %.

Data for quality characters were collected from eight grains include: grain shape, grain thickness (mm), hulling %, milling %, head rice % and amylose content %. The last three traits were evaluated by Little *et al.,* (1958), Williams *et al.,* (1958) and Cagampang *et al.,* (1973), respectively.

3. Statistical analysis

Combining ability analysis was done using line x tester method (Kempthorne, 1957). Analysis of variance was carried out for all traits in each experiment (normal irrigation and water stress condition) and combined analysis over the two environments was performed if the homogeneity test was not significant, according to Steel and Torrei (1980). Heterosis percentage relative to mid- parent and better parent for all studied traits were estimated according to Mather (1949) and Mather and Jinkes (1982).

RESULTS AND DISCUSSION

1. Yield and its attributed traits:

Analysis of variance and mean performance

The analysis of variance for no. of panicles/ plant, panicle length (cm), panicle weight (g) 1000- grain weight (g), grain yield / plant (g) and fertility (%) under normal irrigation, drought stress and combined analyses are presented in Tables (2 and 3). Highly significant mean squares due to irrigation treatment were detected for all studied traits with mean values of normal irrigation higher than those of drought stress condition Tables (4 and 5). Such results are expected since drought stress caused a severe reduction in the growth of the plants and yield productivity.

Moonmoon *et al.,* (2017), found that drought affected almost every growth stage causing a decrease to yield and yield components, 1000-grain weight, tillers number hill^{-1}, filled grains hill^{-1}, number of spikelets panicle^{-1}, and grain yield. Highly significant differences were detected among genotypes, parents, crosses, parents vs. crosses, lines, testers and line x tester for all studied traits under both and across environment except, Parents x E for no. of panicles/ plant, panicle weight (g) and fertility (%) under combined data. Which reveals a wide diversity between the genetic materials involved in this study. Such results indicated great variability among studied rice entry under normal and drought stress conditions. Similar results were reported by Anis *et al.,* (2016), Mazal *et al.,* (2021) and Ghidan and Khedr (2021). Also, significant mean squares due to entry and their partitions with environments were detected for most studied traits revealing that the studied entry responded differently from normal irrigation treatment to drought stress conditions.

Table 2. Mean squares for no. of panicles/ plant, panicle length (cm) and panicle weight (g) under normal irrigation (N) and drought stress (D) as well as their combined analyses.

S.O.V.	DF		No. of panicles/ plant			Panicle length (cm)			Panicle weight (g)		
	Single	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Env. (E)		1			1474.4**			1980.15**			826.21**
Rep/ E	2	4	3.7	0.19	1.95	0.55	1.87	1.21	0.2	0.08	0.06
Genotypes	26	26	36.34**	55.01**	82.70**	21.66**	14.67**	34.92**	4.29**	4.25**	8.52**
Parents (P)	8	8	15.98**	12.34**	27.90**	4.58**	7.48**	10.93**	3.16**	3.12**	6.28**
Crosses (C)	17	17	41.38**	54.75**	85.68**	10.92**	9.65**	19.96**	0.78**	1.11**	1.86**
P *vs* C	1	1	113.5**	400.82**	470.65**	340.88**	157.76**	481.22**	73.16**	66.64**	139.73**
Lines	5	5	17.9**	42.57**	53.33**	6.31**	4.55**	10.63**	0.66**	0.92**	1.54**
Testers	2	2	258.1**	342.17**	560.58**	75.32**	67.2**	141.42**	4.66**	6.91**	11.45**
Line x Tester	10	10	9.8**	3.37**	6.88**	0.35**	0.69**	0.34**	0.064**	0.058**	0.10**
Genotype x E		26			8.64**			1.41**			0.024**
Crosses x E		17			10.45**			0.60**			0.032**
Lines x E		5			7.13**			0.21**			0.032**
Tester x E		2			39.58**			1.093**			0.113**
Line x Tester x E		10			6.28**			0.69**			0.016**
Parents x E		8			0.41			1.12**			0.002
P *vs* C x E		1			43.86**			17.42**			0.075**
Error	52	104	4.11	0.08	2.1	0.24	0.28	0.26	0.02	0.03	0.03
δ2GCA			1.54	1.42	1.48	0.32	0.27	0.29	1.14	0.78	0.96
δ2 SCA			1.09	1.05	1.07	0.11	0.23	0.17	0.77	0.64	0.70
δ2 GCA x E					0.33			1.11			0.09
δ2 SCA x E					0.54			1.30			0.14

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

Table 3. Mean squares for 1000- grain weight (g), grain yield / plant (g) and fertility (%) under normal irrigation (N) and drought stress (D) as well as their combined analyses.

S.O.V.	DF		1000- grain weight (g)			Grain yield / plant (g)			Fertility (%)		
	Single	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Env. (E)		1			2614.22**			5530.04**			9421.62**
Rep/ E	2	4	1.02	1.08	1.05	0.09	0.74	0.42	0.1	0.06	0.08
Genotypes	26	26	5.74**	7.82**	12.92**	59.14**	43.55**	100.54**	7.14**	115.06**	65.48**
Parents (P)	8	8	1.28**	1.56**	2.72**	28.64**	22.32**	49.87**	7.34**	1.81	7.80**
Crosses (C)	17	17	7.97**	10.7**	17.92**	28.23**	20.5**	46.46**	2.59**	174.61**	92.18**
P *vs* C	1	1	2.22**	8.78**	9.90**	828.77**	605.32**	1425.34**	82.88**	8.93**	73.15**
Lines	5	5	9.46**	12.7**	21.95**	61.04**	35.31**	91.08**	3.26**	182.33**	106.59**
Testers	2	2	36.60**	52.28**	86.38**	73.62**	80.37**	153.59**	11.68**	171.95**	96.46**
Line x Tester	10	10	1.49**	1.39**	2.16**	2.75**	1.12**	2.73**	0.44**	171.01**	84.12**
Genotype x E		26			0.63**			2.14**			56.71**
Crosses x E		17			0.77**			2.26**			85.01**
Lines x E		5			0.21**			5.25**			79.5**
Tester x E		2			2.49**			0.39**			87.16**
Line x Tester x E		10			0.71**			1.14**			87.3**
Parents x E		8			0.29**			1.08**			1.34
P *vs* C x E		1			1.08**			8.75**			18.70**
Error	52	104	0.14	0.13	0.13	0.75	1.22	0.99	0.95	1.08	1.02
δ2GCA			1.17	1.52	1.93	0.76	0.36	0.56	7.78	5.16	6.47
δ2 SCA			4.06	5.44	4.75	0.92	0.58	0.75	14.22	8.77	11.49
δ2 GCA x E					0.25			0.12			0.07
δ2 SCA x E					0.80			0.37			0.26

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

Genotypes mean performance for all studied traits under normal, drought and combined data are presented in Tables (4 and 5). Results revealed that the line Sakha 107 and tester M206 as the parental genotypes as well as the cross combinations Sakha 107 x M206 and Sakha108 x M206 had the desirable values for no. of panicles/ plant under normal, drought and across them.

Regarding panicle length, the parents Sakha 108 and M206 recorded the highest positive value, while the cross Sakha107 X M206 had the highest value under normal, drought and combined data.

For panicle weight, the parents Sakha 108 and Sakha Super 300 recorded the highest mean value under normal, drought and combined data. Among the F_1 hybrids, the cross Sakha108 X M206 gave higher mean values under all environments.

Concerning 1000-grain weight, the parents Sakha 107 and Sakha 108 gave the highest mean values under normal, drought and combined data, while the tester M206 and Sakha Super 300 had the better values under all environments. However, the most desirable mean values for 1000-grain weight were detected for the cross Sakha107 X M206 under normal irrigation (33.35g), drought stress (31.59 g) and combined data (32.47 g) Table (5).

For grain yield plant^{-1}, the highest mean value was detected for the parental genotypes Sakha 108 and tester M206 under normal, drought and combined analyses; meanwhile, the hybrids Sakha107 X M206 and Sakha107 X Sakha Super 300 exhibited the desirable mean values under normal, drought and combined analyses.

As for fertility (%), the line Sakha107 and tester M206 recorded the best mean values under normal, drought and combined data, while the cross, Sakha107 X Sakha Super 300 had the best mean values for this trait under all environments.

In conclusion, the three studied crosses Sakha107 X M206, Sakha108 X M206 and Sakha107 X Sakha Super 300 are of prime importance and could be used in future rice breeding programs.

Table 4. Mean performances of all genotypes for no. of panicles/ plant, panicle length (cm) and panicle weight (g) under normal irrigation (N) and drought stress (D) as well as the combined data over them.

Genotypes	No. of panicles/ plant			Panicle length (cm)			Panicle weight (g)		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177	17.60	14.00	15.80	20.58	18.13	19.36	3.68	2.79	3.24
Sakha 105	17.80	14.00	15.90	20.71	18.08	19.40	3.77	2.88	3.33
Sakha106	19.30	16.03	17.67	22.28	20.84	21.56	4.21	3.32	3.77
Sakha107	23.00	19.00	21.00	23.02	21.07	22.24	4.46	3.57	4.02
Sakha108	21.30	18.00	19.65	23.50	21.26	22.69	4.65	3.76	4.21
GZ10101-5	20.30	17.00	18.65	23.02	20.26	21.64	4.46	3.57	4.02
Hispagran	16.70	13.00	14.85	19.58	16.71	18.15	5.05	4.16	4.61
Sakha Super 300	21.50	17.00	19.25	21.27	20.08	20.68	6.79	5.90	6.35
M206	22.60	18.00	20.30	21.55	21.25	21.40	5.63	4.74	5.19
Giza177 x Hispagran	18.00	15.00	16.50	22.92	19.81	21.37	6.02	4.65	5.34
Sakha 105 X Hispagran	19.00	15.00	17.00	23.62	19.12	21.37	6.00	4.66	5.33
Sakha106 X Hispagran	20.00	16.00	18.00	23.41	20.22	21.82	6.10	5.21	5.66
Sakha107 X Hispagran	21.00	18.00	19.50	25.08	21.34	23.21	6.40	5.40	5.90
Sakha108 X Hispagran	20.00	17.00	18.50	23.98	21.10	22.54	6.30	5.23	5.77
GZ10101-5 X Hispagran	19.00	15.00	17.00	23.06	20.27	21.67	6.10	5.15	5.63
Giza177 x Sakha Super 300	21.00	18.00	19.50	25.21	22.09	23.65	6.50	5.46	5.98
Sakha 105 X Sakha Super 300	21.00	19.00	20.00	25.27	23.67	24.47	6.60	5.65	6.13
Sakha106 X Sakha Super 300	15.00	21.00	18.00	25.93	22.72	24.33	6.60	5.70	6.15
Sakha107 X Sakha Super 300	23.00	27.00	25.00	28.29	24.42	26.36	7.40	6.46	6.93
Sakha108 X Sakha Super 300	22.00	22.00	22.00	26.75	23.81	25.28	6.70	5.76	6.23
GZ10101-5 X Sakha Super 300	21.00	20.00	20.50	25.87	22.36	24.12	6.60	5.69	6.15
Giza177 x M206	24.00	22.00	23.00	27.12	23.69	25.41	6.70	5.78	6.24
Sakha 105 X M206	25.00	23.00	24.00	27.21	23.35	25.28	6.90	6.04	6.47
Sakha106 X M206	27.00	25.00	26.00	27.73	23.72	25.73	7.20	6.33	6.77
Sakha107 X M206	29.00	28.00	28.50	28.82	25.17	27.00	7.40	6.53	6.98
Sakha108 X M206	28.00	26.00	27.00	27.93	24.38	26.16	7.70	6.78	7.24
GZ10101-5 X M206	26.00	24.00	25.00	27.54	23.61	25.58	7.10	6.23	6.67
L.S.D 0.05	1.26	1.14	1.20	0.81	0.87	0.75	0.23	0.29	0.19
L.S.D 0.01	1.68	1.53	1.61	1.09	1.17	1.01	0.31	0.39	0.26

Table 5. Mean performances of all genotypes for 1000- grain weight (g), grain yield / plant (g) and fertility (%) under normal irrigation (N) and drought stress (D) as well as the combined data over them.

Genotypes	1000- grain weight (g)			Grain yield / plant (g)			Fertility (%)		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177	28.10	26.40	27.25	41.89	35.58	38.74	92.10	92.63	92.37
Sakha 105	28.23	27.41	27.82	42.24	35.53	38.89	93.78	93.42	93.60
Sakha106	29.13	28.07	28.60	43.39	37.00	40.20	94.53	93.75	94.14
Sakha107	29.46	28.64	29.05	44.56	39.35	41.96	95.74	94.72	95.23
Sakha108	29.42	28.21	28.82	47.96	41.54	44.75	95.29	93.79	94.54
GZ10101-5	28.68	28.02	28.35	44.56	39.35	41.96	95.29	93.79	94.54
Hispagran	27.70	27.22	27.46	37.99	32.98	35.49	92.08	92.03	92.06
Sakha Super300	29.28	27.51	28.40	45.06	39.54	42.30	94.08	93.52	93.80
M206	29.63	28.60	29.12	47.64	39.84	43.74	96.82	94.02	95.42
Giza177 x Hispagran	26.62	23.00	24.81	45.97	39.11	42.54	94.97	94.46	94.72
Sakha 105 X Hispagran	26.63	24.55	25.59	46.90	40.34	43.62	95.39	94.94	95.17
Sakha106 X Hispagran	27.24	25.60	26.42	49.74	40.50	45.12	95.43	95.13	95.28
Sakha107 X Hispagran	27.82	26.66	27.24	50.45	44.59	47.52	96.10	95.59	95.85
Sakha108 X Hispagran	27.32	26.24	26.78	49.89	41.41	45.65	96.02	95.51	95.77
GZ10101-5 X Hispagran	27.16	25.22	26.19	47.11	40.11	43.61	95.44	94.88	95.16
Giza177 x Sakha Super 300	27.84	26.93	27.39	47.52	41.83	44.68	96.28	95.72	96.00
Sakha 105 X Sakha Super 300	27.93	27.01	27.47	47.86	42.09	44.98	96.23	95.76	96.00
Sakha106 X Sakha Super 300	28.10	27.18	27.64	50.53	42.70	46.62	96.39	95.88	96.14
Sakha107 X Sakha Super 300	30.25	29.69	29.97	55.21	46.91	51.06	98.87	96.01	96.87
Sakha108 X Sakha Super 300	28.20	27.19	27.70	53.31	46.12	49.72	96.52	95.84	96.18
GZ10101-5 X Sakha Super 300	27.97	27.08	27.53	49.41	42.64	46.03	96.35	96.11	96.23
Giza177 x M206	28.36	27.67	28.02	49.16	42.55	45.86	96.91	96.40	96.66
Sakha 105 X M206	28.84	27.76	28.30	49.75	43.89	46.82	96.02	96.51	96.27
Sakha106 X M206	29.72	28.10	28.91	54.64	45.18	49.91	97.02	97.22	97.12
Sakha107 X M206	33.35	31.59	32.47	55.63	48.06	51.85	97.73	98.36	98.62
Sakha108 X M206	29.92	28.33	29.13	55.07	46.84	50.96	97.14	96.63	96.89
GZ10101-5 X M206	29.67	27.79	28.73	50.10	44.52	47.31	96.92	96.41	96.67
L.S.D 0.05	0.61	0.78	0.61	1.42	1.82	1.57	0.12	0.14	0.13
L.S.D 0.01	0.81	1.04	0.81	1.90	2.43	2.10	0.16	0.15	0.14

Combining ability analysis

Variance for general (GCA) and specific (SCA) combining abilities for no. of panicles/plant, panicle length, panicle weight, 1000-grain weight, grain yield plant^{-1} and fertility % under normal irrigation, drought and their combined analyses are presented in Tables (2 and 3). δ^2 GCA were higher than those of δ^2 SCA for no. of panicles/plant, panicle length and panicle weight under normal, drought and their combined data, which indicating that the predominance of additive genetic variance in controlling of these traits. These findings were previously reported by Gowayed, *et al.*, (2020) and El-Badawy, *et al.*, (2022). On the other hand, mean squares due to SCA were much higher than those of GCA for 1000-grain weight, grain yield plant^{-1} and fertility % under normal, drought and their combined analyses, revealing the importance of non-additive gene action in governing these traits. The importance of non-additive genetic variance in controlling these traits were previously reported by Dharwal *et al.*, (2017).

Meanwhile, the interaction between SCA X irrigation treatments was higher than of GCA X environment for all studied traits, revealing that non-additive gene action was more influenced by drought more than additive genetic variance. This result was in accordance with El-Badawy, *et al.*, (2022).

General combining ability effects

Results of GCA effects for all studied traits under normal irrigation, drought stress and combined data are shown in Tables (6 and 7).

Results exhibited that the line, GZ10101-5 had desirable significant and positive GCA effects for no. of panicles/plant under normal and combined analyses, while the parent, Sakha107 exhibited desirable GCA effects under drought condition. Besides, the line, Sakha108 revealed highly significant and positive GCA effects for panicle length and panicle weight under both and across environments.

The highest desirable significant and positive GCA effects were obtained by the parent, Sakha 107 for 1000-grain weight, grain yield plant^{-1} and fertility percentage under normal, drought and combined data. Similar results were obtained by Gaballah *et al.*, (2021) and Mohamed *et al.*, (2021). The tester, M206 expressed the highest significant and positive values for no. of panicles/plant, panicle length and 1000-grain weight under normal, drought and combined data. The tester, Sakha Super 300 seemed to be the best general combiner for panicle weight, grain yield/plant and fertility % under normal, drought stress and their combined analyses.

Table 6. Estimates of GCA effects (gi) of parent lines and testers for no. of panicles/ plant, panicle length and panicle weight under normal irrigation (N) and drought stress (D) as well as their combined data.

Genotypes	No. of panicles/plant			Panicle length			Panicle weight		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Lines									
Giza177	-2.83**	-2.28**	-2.55**	-0.79**	-0.63**	-0.71**	-0.28**	-0.41**	-0.16**
Sakha 105	-2.83**	-1.61**	-2.22**	-0.51**	-0.45**	-0.48**	-0.18**	-0.26**	-0.15**
Sakha106	4.16**	0.05	1.49**	-0.18**	-0.27**	-0.22**	-0.05**	0.04	-0.21**
Sakha107	-2.5**	3.72**	1.22**	0.35**	0.6**	0.47**	0.12*	0.14**	0.13**
Sakha108	-0.5	1.06**	0.28	1.51**	1.16**	1.33**	0.47**	0.51**	0.49**
GZ10101-5	4.5**	-0.94**	1.78**	-0.38**	-0.41**	-0.39**	-0.08**	-0.02	-0.1
LSD 5%	1.36	1.02	1.20	0.33	0.36	0.30	0.09	0.12	0.08
LSD 1%	1.81	1.27	1.54	0.44	0.48	0.41	0.12	0.16	0.11
Testers									
Hispagran	-2.67**	-4.61**	-3.64	-2.2**	-2.18**	-2.19**	-0.53**	-0.66**	-0.59**
Sakha Super300	-1.66**	0.56	-0.55	0.35**	0.69**	0.52**	0.48**	0.58**	0.53**
M206	4.33**	4.05**	4.19**	1.85**	1.49**	1.67**	0.05**	0.08**	0.06**
L.S.D 5%	0.96	0.88	0.92	0.26	0.28	0.24	0.05	0.08	0.06
L.S.D 1%	1.28	1.19	1.20	0.34	0.37	0.32	0.10	0.12	0.08

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

Table 7. Estimates of GCA effects (gi) of parent lines and testers for 1000-grain weight, grain yield/plant and fertility % under normal irrigation (N) and drought stress (D) as well as their combined data.

Genotypes	1000- grain weight			Grain yield / plant			Fertility %		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Lines									
Giza177	-0.89**	-1.22**	-1.06**	-2.9**	-2.14**	-2.52**	-0.38**	1.24**	0.43
Sakha 105	-0.7**	-0.64**	-0.67**	-2.28**	-1.19**	-1.73**	-0.55**	-9.13**	-4.83**
Sakha106	-0.14**	-0.12**	-0.14**	1.18**	-0.51**	0.33	-0.15**	1.65**	0.75**
Sakha107	1.98**	2.22**	2.10**	3.31**	3.22**	3.26**	1.16**	2.87**	2.01**
Sakha108	-0.02**	0.16**	0.07**	2.3**	1.49**	1.89**	0.11	1.86**	0.98**
GZ10101-5	-0.23**	-0.39**	-0.31**	-1.61**	-0.87**	-1.23**	-0.19**	1.51**	0.66
LSD 5%	0.25	0.32	0.25	0.58	0.74	0.63	0.83	0.90	0.70
LSD 1%	0.33	0.43	0.33	0.78	0.99	0.85	1.11	1.20	1.02
Testers									
Hispagran	-1.37**	-1.87**	-1.62**	-2.11**	-2.29**	-2.2**	-0.87**	0.89**	-0.51**
Sakha Super300	-0.12**	0.42**	0.15**	1.92**	1.87**	1.90**	0.72**	2.55**	1.63**
M206	1.48**	1.45**	1.47**	0.19	0.42**	0.30	0.15	-3.44**	-1.12**
L.S.D 5%	0.19	0.25	0.19	0.45	0.42	0.50	0.65	0.70	0.59
L.S.D 1%	0.26	0.33	0.26	0.60	0.77	0.66	0.86	0.93	0.79

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

Specific combining ability effect (SCA)

Estimates of SCA effects of the 18 F_1 crosses for all the studied characters under normal irrigation, drought stress and combined analyses are shown in Tables (8 and 9).

Results exhibited that seven, three and six crosses had positive and significant SCA effects for no. of panicles/plant under normal, stress condition as well as combined data, respectively. However, the most desirable SCA effects were detected for the crosses Sakha107 X Hispagran under normal irrigation and Sakha108 X Sakha Super 300 under stress condition and combined data.

For panicle length, six, nine and five crosses had desirable SCA effects under normal irrigation, drought stress and combined analyses, respectively. The cross Sakha108 X Sakha Super 300 was the best among all crosses under normal irrigation and Sakha108 X Hispagran under stress condition and combined data, since it had the most desirable effects for this trait.

Regarding panicle weight, seven crosses under normal, seven crosses under drought, and seven crosses in the combined data expressed significant and positive SCA effects. However, the cross Sakha108 X Sakha Super 300 was the best since it had the highest significant and positive effects in all environments.

For 1000-grain weight, eight, seven and seven crosses exhibited significant and positive SCA effects under normal, stress conditions and combined analyses, respectively. However, the most desirable SCA effects were detected for the crosses GZ10101-5 X Sakha Super 300 under normal irrigation, Sakha108 X Hispagran under stress condition and Sakha107 X M206 in the combined data.

Regarding grain yield plant^{-1}, nine, eight and seven crosses gave significant and positive SCA effects under normal, stress conditions and their combined data, respectively. Moreover, the cross Sakha108 X Sakha Super 300 showed the most desirable SCA for grain yield plant^{-1}under normal irrigation and Sakha107 X Hispagran under stress condition and combined analyses.

As for fertility %, five, seven and seven hybrids had desirable SCA effects under normal, stress and combined data, respectively. However, the cross Sakha107 X Hispagran was the best since it had the highest significant and positive effects in all environments. Similar results were obtained by Gaballah *et al.,* (2021) and Mohamed *et al.,* (2021).

In general, the two crosses, Sakha107 X Hispagran and Sakha108 X Sakha Super 300 are of prime importance regarding yield and its attributed traits in rice breeding programs.

Table 8. Estimates of SCA effects (Sij) of cross combinations for no. of panicles/ plant, panicle length and panicle weight under normal irrigation (N) and drought stress (D) as well as the combined over them.

Cross combinations	No. of panicles/ plant			Panicle length			Panicle weight		
	Normal	**Drought**	**Comb.**	**Normal**	**Drought**	**Comb.**	**Normal**	**Drought**	**Comb.**
Giza177 x Hispagran	-0.50	1.28**	0.39**	0.03	0.13**	0.08**	0.14**	0.01	0.07**
Sakha 105 X Hispagran	0.33*	-0.89**	-0.28**	-0.22**	-0.46**	-0.34	0.05**	0.08**	0.06**
Sakha106 X Hispagran	0.17	-0.39*	-0.11**	0.19**	0.33**	0.25**	-0.19**	-0.09**	-0.11
Sakha107 X Hispagran	2.50**	0.61**	1.55**	0.45**	-0.74**	-0.14	0.03	-0.13**	-0.05
Sakha108 X Hispagran	-4.67**	-0.56**	-2.6**	-0.44**	0.92**	0.27**	0.05**	0.12**	0.08**
GZ10101-5 X Hispagran	2.17**	-0.06	1.05**	-0.01	-0.19**	-0.1	-0.08**	0.01	-0.03
Giza177 x Sakha Super 300	-1.50**	-0.06	-0.78**	-0.08	0.18**	0.05	0.02	0.12**	0.07**
Sakha 105 X Sakha Super 300	0.33	-0.22	0.05	-0.11	-0.19**	-0.15	-0.08**	-0.13**	-0.1
Sakha106 X Sakha Super 300	1.15**	0.28	0.71**	0.19**	0.01	0.1	0.08**	0.01	0.04
Sakha107 X Sakha Super 300	0.15	-1.72**	-0.78**	-0.12	-0.12	-0.12	-0.24**	-0.16**	-0.2
Sakha108 X Sakha Super 300	1.02**	2.11**	1.56**	0.55**	0.09**	0.25**	0.15**	0.17**	0.16**
GZ10101-5 X Sakha Super 300	-1.17**	-0.39*	-0.78**	-0.35**	0.03*	-0.2	0.05**	-0.01	0.02
Giza177 x M206	0.15	-0.06	-0.22	-0.04	0.19**	0.07	0.03	0.04**	0.03
Sakha 105 X M206	1.02**	-0.22	0.4	0.18**	0.03	0.10	-0.15**	-0.15**	-0.15
Sakha106 X M206	-1.17**	0.28	-0.33	-0.14*	-0.21**	-0.17	0.12**	0.12**	0.12**
Sakha107 X M206	-0.83*	-0.06	-0.32	-0.23**	0.37**	0.07	0.03	0.12**	0.07**
Sakha108 X M206	2.02**	-0.15	0.9**	0.03	-0.41**	-0.19	-0.05**	-0.09**	-0.07
GZ10101-5 X M206	-1.17**	0.28	-0.41	0.20**	0.04*	0.12**	0.02	-0.04*	-0.01
LSD S_{ij} 0.05	0.89	0.91	0.77	0.58	0.62	0.53	0.16	0.20	0.14
LSD S_{ij} 0.01	1.19	1.21	1.03	0.77	0.82	0.71	0.22	0.27	0.18
LSD sij-skl 0.05	1.22	1.47	1.02	1.46	1.69	1.19	0.25	0.41	0.29
LSD sij-skl 0.01	1.63	1.96	1.35	1.95	2.26	1.58	0.33	0.55	0.38

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

Table 9. Estimates of SCA effects (Sij) of cross combinations for 1000-grain weight, grain yield /plant and fertility % under normal irrigation (N) and drought stress (D) as well as the combined over them.

Cross combinations	1000-grain weight			Grain yield / plant			Fertility %		
	Normal	**Drought**	**Comb.**	**Normal**	**Drought**	**Comb.**	**Normal**	**Drought**	**Comb.**
Giza177 X Hispagran	0.38**	-0.99**	-0.30**	0.53**	-1.42**	-0.44	-0.21**	-1.96**	-1.08**
Sakha 105 X Hispagran	0.35**	-0.01**	0.09**	-0.22**	0.25**	0.03	0.07	3.82**	1.94**
Sakha106 X Hispagran	-0.73**	0.51**	0.38**	-0.31**	1.21**	0.45**	0.14**	-1.86**	-0.86**
Sakha107 X Hispagran	0.20**	-0.77**	-1.03**	0.84**	2.01**	1.42**	0.59**	8.95**	4.65**
Sakha108 X Hispagran	0.25**	0.86**	0.53**	-0.50**	-0.78**	-0.64**	0.20**	-17.63**	-8.71**
GZ10101-5 X Hispagran	-0.44**	0.40**	0.32**	-0.34**	-1.24**	-0.79**	-0.58**	8.68**	4.05**
Giza177 x Sakha Super 300	0.25**	0.63**	0.49**	0.21**	-0.92**	-0.35**	0.02	-1.84**	-0.91**
Sakha 105 X Sakha Super 300	-0.14**	0.14**	0.19**	-1.30**	-0.27**	-0.78**	-0.04	3.43**	1.69**
Sakha106 X Sakha Super 300	-0.11**	-0.20**	-0.17**	1.08**	1.18**	1.13**	0.02	-1.59**	-0.78**
Sakha107 X Sakha Super 300	-1.29**	-0.04**	-0.07**	-1.21**	1.14**	-0.03	-0.60**	-1.96**	-1.28**
Sakha108 X Sakha Super 300	-0.11**	-0.48**	-0.32**	1.26**	0.71**	0.98**	0.01	2.98**	1.49**
GZ10101-5 X Sakha Super 300	1.40**	-0.04**	-0.11**	-0.06	-1.89**	-0.97**	0.36**	-1.02**	-0.21
Giza177 x M206	0.21**	0.35**	-0.18**	-0.76**	-1.87**	-1.31**	0.33**	-1.38**	-0.52**
Sakha 105 X M206	-0.16**	-0.13**	-0.28**	0.37**	-0.13**	0.12	-0.19**	3.47**	1.64**
Sakha106 X M206	-0.04**	-0.31**	-0.21**	0.39**	2.00**	1.18**	-0.14**	-2.09**	-1.11**
Sakha107 X M206	0.26**	0.82**	1.11**	0.38**	1.04**	0.71**	0.07	-1.81**	-0.87**
Sakha108 X M206	-0.18**	-0.37**	-0.20**	0.38**	0.22**	0.3**	-0.04	3.93**	1.94**
GZ10101-5 X M206	-0.08**	-0.35**	-0.21**	-0.74**	-1.24**	-1.01**	-0.03	-2.12**	-1.07**
LSD S_{ij} 0.05	0.43	0.55	0.43	1.01	1.27	1.10	1.44	1.56	1.33
LSD S_{ij} 0.01	0.57	0.74	0.58	1.34	1.69	1.47	1.93	2.08	1.77
LSD sij-skl 0.05	0.61	0.78	0.61	0.72	0.74	0.65	1.42	1.79	1.55
LSD sij-skl 0.01	0.81	1.04	0.81	0.96	0.99	0.86	1.90	2.39	2.05

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

Heterosis

Heterosis relative to mid-parent and better-parent for no. of panicles per plant, panicle length, panicle weight, 1000-grain weight, grain yield plant-1 and fertility (%) under normal irrigation, drought stress and the combined data are presented in Tables (10, 11, 12 and 13).

Regarding no. of panicles /plant, the cross Sakha106 X Hispagran exhibited the highest positive and significant heterotic effects relative to mid-parent under normal irrigation and combined data and the cross, Sakha 105 X M206 under drought conditions. However, the cross GZ10101-5 X Sakha Super 300 showed the highest positive and significant heterotic effects relative to better-parent under normal, stress conditions and combined analyses.

Concerning panicle length, the cross Sakha106 X Sakha Super 300 expressed the most desirable mid-parent heterosis under normal irrigation and the cross, GZ10101-5 X Hispagran under drought stress and combined analyses recording 26.53**, 18.74** and 23.76**, respectively. This particular cross exhibited the most desirable better-parent heterosis under normal irrigation (26.26**), drought stress (17.52**) and combined data (18.77**). Similar results were with Thorat *et al.,* (2017), Ghidan and Khedr (2021) and Hussein (2021).

The cross Sakha108 X M206 exhibited the highest positive and significant mid-parent heterosis under all environments. However, the cross, Sakha 105 X M206 gave the highest positive and significant better-parent heterosis under normal, drought and combined analyses.

Concerning 1000-grain weight, the cross Sakha107 X M206 exhibited the highest positive and significant heterotic effects relative to mid-parent under normal, stress conditions and combined data. However, the cross Sakha108 X M206 showed the highest positive and significant heterotic effects relative to better-parent under normal condition, while the cross Sakha107 X Sakha Super 300 had the highest positive and significant heterotic values under drought condition and combined data. These results are in harmony with those obtained by Latha *et al.,* (2013), Anis *et al.,* (2016), Naik, (2018) and Ghidan and Khedr (2021).

For grain yield plant^{-1}, eleven, twelve and fourteen crosses expressed positive and significant mid-parent heterosis under normal, stress condition and combined data, respectively. The respective better parent heterosis values were detected for twelve, twelve and twelve crosses under all environments. However, the best mid-parent heterosis values were detected for the crosses Sakha 105 X M206 (normal), Sakha106 X Sakha Super 300 under stress condition and combined data. While the most desirable better parent heterosis were obtained for the cross, Sakha108 X M206 under normal, drought and combined data.

As for fertility %, the hybrid, Sakha 105 X Hispagran had the highest positive and significant heterotic effects relative to mid-parent under normal conditions. While the cross, GZ10101-5 X Sakha Super 300 showed positive and significant heterotic effects relative to mid-parent under drought and combined data. However, the cross, Sakha108 X M206 expressed the most desirable better parent heterosis under all environments. Previously obtained by Kondhia *et al.,* (2015), Thorat *et al.,* (2017) and Huang *et al.,* (2020).

Table 10. Heterosis relative to mid parents for no. of panicles/ plant, panicle length and panicle weight under normal irrigation (N) and drought stress (D) as well as the combined over them.

Cross combinations	No. of panicles/ plant			Panicle length			Panicle weight		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177 x Hispagran	4.96**	11.11**	8.03**	14.13**	13.73**	13.93**	-37.4**	33.81**	35.63**
Sakha 105 X Hispagran	7.42**	16.13**	11.77**	20.47**	15.62**	18.05**	-39.6**	45.02**	-42.3**
Sakha106 X Hispagran	19.40**	-37.50**	28.45**	-28.73**	-20.31**	-24.52**	27.94**	33.00**	30.47**
Sakha107 X Hispagran	10.14**	11.11**	10.63**	17.23**	9.93**	13.58**	-36.0**	32.39**	34.22**
Sakha108 X Hispagran	6.87**	-22.58**	14.73**	20.40**	-24.06**	22.23**	-40.4**	-48.2**	-44.3**
GZ10101-5 X Hispagran	-23.76**	-43.75**	-33.76**	-28.77**	18.74**	23.76**	30.64**	37.64**	34.14**
Giza177 x Super 300	11.11**	10.23**	10.67**	11.85**	7.71**	9.78**	31.75**	39.30**	35.53**
Sakha 105 X Super 300	-26.47**	-27.16**	0.34	19.09**	11.05**	15.07**	-34.1**	41.44**	37.79**
Sakha106 X Super 300	-28.88**	46.93**	-37.90**	26.53**	12.71**	19.62**	30.87**	37.36**	34.11**
Sakha107 X Super 300	5.79**	12.50**	9.15**	16.43**	12.97**	14.70**	31.9**	36.36**	34.16**
Sakha108 X Super 300	3.37*	-50.00**	26.69**	26.38**	-18.68**	-22.53**	-43.9**	-52.0**	-47.9**
GZ10101-5 X Super 300	-27.19**	-51.35**	-39.27**	-27.95**	-18.94**	-23.44**	34.5**	-40.4**	37.50**
Giza177 x M206	8.11**	13.33**	10.72**	12.58**	14.16**	13.37**	32.4**	35.32**	33.90**
Sakha 105 X M206	5.26**	29.41**	17.34**	20.80**	-18.05**	19.42**	32.8**	38.63**	35.72**
Sakha106 X M206	-30.54**	-48.57**	-39.55**	25.33**	17.47**	21.40**	-31.5**	38.03**	34.77**
Sakha107 X M206	9.20**	7.14**	8.17**	13.07**	12.40**	12.73**	-38.3**	-45.4**	-41.9**
Sakha108 X M206	6.06**	25.00**	15.53**	21.80**	13.39**	17.60**	40.43**	48.5**	47.4**
GZ10101-5 X M206	-27.76**	-45.45**	-36.61**	-28.81**	16.28**	22.54**	34.43**	41.32**	37.88**

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

Table 11. Heterosis relative to mid parents for 1000- grain weight, grain yield/plant and fertility (%) under normal irrigation (N) and drought stress (D) as well as the combined over them.

Cross combinations	1000- grain weight			Grain yield / plant			Fertility %		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177 x Hispagran	-4.59**	-14.21**	-9.40**	15.10**	14.08**	14.59**	-3.13**	2.31**	2.72**
Sakha 105 X Hispagran	-7.18**	-8.92**	-8.05**	9.30**	11.37**	10.34**	3.42**	-2.84**	-3.13**
Sakha106 X Hispagran	-5.63**	-6.91**	-6.27**	9.82**	12.82**	11.32**	2.59**	2.98**	2.79**
Sakha107 X Hispagran	-0.52**	-2.40**	-1.46**	-16.91**	-17.76**	17.33**	2.65**	2.39**	2.52**
Sakha108 X Hispagran	-4.99**	-4.44**	-4.72**	9.64**	12.13**	10.89**	2.45**	2.46**	2.46**
GZ10101-5 X Hispagran	-6.12**	-9.94**	-8.03**	10.71**	16.45**	13.58**	-0.76**	-2.86**	-1.81**
Giza177 x Super 300	-2.02**	-2.59**	-2.30**	-22.24**	-15.74**	-18.99**	2.28**	2.41**	2.34**
Sakha 105 X Super 300	-4.37**	-2.81**	-3.59**	14.25**	11.57**	12.91**	2.21**	2.40**	2.30**
Sakha106 X Super 300	-4.36**	-4.08**	-4.22**	-20.05**	17.59**	18.82**	1.41**	2.80**	2.10**
Sakha107 X Super 300	5.84**	6.30**	6.07**	-17.39**	-19.67**	-18.53**	2.33**	2.37**	2.35**
Sakha108 X Super 300	-3.98**	-3.15**	-3.57**	18.71**	15.71**	17.21**	-2.97**	-3.29**	-3.13**
GZ10101-5 X Super 300	-5.33**	-5.38**	-5.36**	-16.39**	-18.11**	-17.25**	2.69**	4.23**	3.46**
Giza177 x M206	-0.70**	-0.16**	-0.43**	-20.87**	14.50**	17.68**	2.49**	2.80**	2.64**
Sakha 105 X M206	-1.74**	-0.36**	-1.05**	18.97**	16.92**	17.94**	1.93**	2.51**	2.22**
Sakha106 X M206	0.66**	-1.07**	-0.21**	-19.46**	-18.29**	-18.87**	1.13**	2.90**	2.01**
Sakha107 X M206	7.30**	4.37**	5.34**	17.39**	16.07**	16.73**	2.51**	2.28**	2.39**
Sakha108 X M206	3.24**	2.03**	2.64**	13.14**	12.70**	12.92**	2.38**	2.49**	2.44**
GZ10101-5 X M206	1.77**	-1.84**	-0.04**	11.21**	-17.20**	14.21**	1.51**	2.83**	2.17**

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

Table 12. Heterosis relative to better parents for no. of panicles/ plant, panicle length and panicle weight under normal irrigation (N) and drought stress (D) as well as the combined over them.

Cross combinations	No. of panicles/ plant			Panicle length			Panicle weight		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177 X Hispagran	2.27	7.14**	4.71**	11.35**	9.27**	10.31**	18.8**	11.78**	15.30**
Sakha 105 X Hispagran	-2.33	5.88**	1.78**	18.53**	10.01**	14.27**	15.45**	15.19**	15.32**
Sakha106 X Hispagran	6.19**	22.22**	14.21**	-25.84**	11.48**	-18.66**	-1.37**	-2.04**	-1.70**
Sakha107 X Hispagran	6.74**	7.14**	6.94**	14.04**	5.75**	9.89**	18.8**	12.02**	15.42**
Sakha108 X Hispagran	-2.33	11.76**	4.72**	-18.82**	-17.88**	-18.35**	17.23**	19.20**	18.21**
GZ10101-5 X Hispagran	10.62**	27.78**	19.20**	26.26**	17.52**	18.77**	1.57**	2.43**	2.00**
Giza177 x Super 300	3.63*	-0.19	1.72**	5.07**	-2.98**	1.05**	-20.7**	-25.2**	-23. 2**
Sakha 105 X Super 300	-30.23**	23.53**	-3.35**	16.38**	9.02**	12.70**	17.23**	20.25**	18.74**
Sakha106 X Super 300	19.47**	38.89**	29.18**	-24.46**	11.62**	-18.04**	5.99**	7.35**	6.67**
Sakha107 X Super 300	-8.70**	-5.26**	-6.98**	6.72**	1.26**	3.99**	-26.7**	-29.8**	-28.2**
Sakha108 X Super 300	0.08	42.11**	21.05**	20.38**	15.88**	18.13**	-31.4**	-36.2**	-33.8**
GZ10101-5 X Super 300	26.09**	47.37**	36.73**	-22.64**	-18.45**	-20.54**	13.35**	14.98**	14.16**
Giza177 x M206	-1.48	0.55	-0.74**	4.17**	4.15**	4.16**	-24.7**	-25.7**	-25.2**
Sakha 105 X M206	2.33	29.41**	15.87**	16.20**	17.01**	16.86**	19.01**	21.52**	20.26**
Sakha106 X M206	23.89**	44.44**	34.17**	-21.33**	14.73**	18.03**	8.93**	10.80**	9.86**
Sakha107 X M206	4.97**	0.45	2.49**	8.72**	4.70**	6.71**	-20.7**	-23.8**	-22.3**
Sakha108 X M206	-2.33	17.65**	7.66**	21.64**	11.35**	16.50**	17.23**	-20. 4**	18.6**
GZ10101-5 X M206	15.04**	33.33**	24.19**	-27.79**	11.11**	-19.45**	4.51**	5.65**	5.08**

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

Table 13. Heterosis relative to better parents for 1000- grain weight (g), grain yield / plant (g) and fertility (%) under normal irrigation (N) and drought stress (D) as well as the combined over them.

Cross combinations	1000- grain weight (g)			Grain yield / plant (g)			Fertility (%)		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177 X Hispagran	-5.27**	-15.50**	-10.39**	9.74**	9.91**	9.83**	-3.11**	-1.98**	-2.54**
Sakha 105 X Hispagran	-9.05**	-10.76**	-9.91**	5.46**	5.79**	5.63**	2.33**	2.35**	2.34**
Sakha106 X Hispagran	-8.07**	-10.49**	-9.28**	3.19**	6.79**	4.99**	0.09	2.22**	1.16**
Sakha107 X Hispagran	-1.45**	-2.74**	-2.09**	-11.03**	-13.52**	-12.28**	1.72**	1.63**	1.67**
Sakha108 X Hispagran	-6.69**	-4.62**	-5.66**	6.21**	6.45**	6.33**	2.28**	2.41**	2.34**
GZ10101-5 X Hispagran	-8.34**	-11.82**	-10.08**	4.43**	10.16**	7.29**	-0.83**	2.53**	0.85**
Giza177 x Super 300	-4.43**	-4.06**	-4.24**	-14.64**	-9.46**	-12.05**	0.95**	1.47**	1.21**
Sakha 105 X Super 300	-4.61**	-3.78**	-4.19**	12.14**	7.99**	10.06**	1.97**	2.27**	2.12**
Sakha106 X Super 300	-5.16**	-4.97**	-5.06**	14.70**	13.39**	14.05**	0.21**	2.65**	1.43**
Sakha107 X Super 300	2.68**	3.67**	3.17**	5.19**	7.35**	6.27**	0.38**	0.92**	0.65**
Sakha108 X Super 300	-4.28**	-5.06**	-4.67**	-15.12**	12.93**	14.03**	-2.08**	-2.64**	-2.36**
GZ10101-5 X Super 300	-5.60**	-5.45**	-5.52**	-16.00**	-15.70**	-15.85**	-2.12**	-3.84**	-2.98**
Giza177 x M206	-3.60**	-1.91**	-2.76**	11.96**	5.22**	8.59**	0.76**	1.83**	1.30**
Sakha 105 X M206	-1.97**	-1.60**	-1.78**	-18.31**	-16.64**	-17.47**	1.29**	2.37**	1.83**
Sakha106 X M206	0.30**	-1.75**	-0.72**	-15.60**	-17.56**	-16.58**	0.33**	2.78**	1.55**
Sakha107 X M206	16.28**	12.74**	14.51**	11.43**	11.02**	11.22**	1.39**	1.48**	1.43**
Sakha108 X M206	20.89**	24.44**	25.17**	21.33**	14.73**	18.03**	8.93**	10.80**	9.86**
GZ10101-5 X M206	15.04**	20.33**	18.19**	-27.79**	11.11**	-19.45**	4.51**	5.65**	5.08**

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

2. Grain quality traits:

Analysis of variance and mean performance

The analysis of variance for hulling (%), milling (%), amylose content (%), head rice (%), grain thickness (mm) and grain shape under normal irrigation, drought stress and the combined data are presented in Tables (14 and 15) . Highly significant mean squares due to environments were detected for all studied traits with mean values of normal irrigation higher than those of drought stress condition. Such results are expected since drought stress caused a severe reduction in the growth of the plants. Highly significant differences were detected among genotypes, parents, crosses, parents vs. crosses, lines, testers and line x tester for all studied traits under normal, drought and combined data, except Line x Tester for head rice % under normal irrigation. Which reveals a wide diversity between the genetic materials involved in this study. These results were in harmony with Mady (1994), Badawi (2002), Dipti *et al*., (2002), Shaalan (2003) and Rebeira *et al*., (2014).

Genotypes mean performance for all studied traits under normal, drought and combined analyses are presented in Tables (16 and 17). Results exhibited that the parents, Sakha107 and M206 as the parental genotypes as well as the cross combinations, Sakha107 X M206 and Sakha108 X M206 expressed the highly positive values under normal, drought and across of them for hulling (%).

Regarding milling (%), the parent Sakha107 recorded the highest mean value under normal and combined data, while Sakha 108 had the highest mean value under drought conditions. However, the highest mean value for milling (%) was exhibited by the cross, Sakha107 X M206 under normal, drought and their combined data. Similar results with Abd-El Salam *et al.*, (2016).

For amylose content (%) the parent, Sakha107 and tester M206 recorded the lowest mean value under normal, drought and combined data. While the crosses, Sakha107 X Sakha Super 300 under normal, Sakha106 X M206 under drought and combined data exhibited desirable values for this trait.

As for head rice (%), grain thickness and grain shape, the parent Sakha107 and tester M206 recorded the highest mean values under normal, drought and combined data. While the hybrid, Sakha107 X Sakha Super 300 exhibited the highest mean value under normal, drought and their combined data for these traits. Similar results with Abd-El Salam *et al.*, (2016).

Table 14. Mean squares for hulling (%), milling (%) and amylose content (%) under normal irrigation (N) and drought stress (D) as well as their combined analyses.

S.O.V.	DF		Hulling (%)			Milling (%)			Amylose content (%)		
	Single	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Env. (E)		1			21162.1**			1569.38**			144.55**
Rep/ E	2	4	1.08	2.08	1.58	1.07	1.02	1.05	1.08	1.01	1.04
Genotypes	26	26	4.39**	2.77**	6.25**	36.98**	49.97**	81.99**	3.49**	1.45**	4.05**
Parents (P)	8	8	1.24**	3.84**	4.54**	20.85**	21.95**	35.04**	1.38**	0.85**	1.91**
Crosses (C)	17	17	5.03**	2.41**	6.99**	44.33**	65.84**	106.76**	4.37**	1.25**	4.92**
P *vs* C	1	1	18.73**	0.29**	7.19**	41.1**	4.5**	36.39**	5.29**	1.67**	6.44**
Lines	5	5	4.31**	1.64**	5.61**	33.41**	34.52**	66.98**	2.10**	1.11**	3.01**
Testers	2	2	22.5**	13.73**	35.54**	189.5**	398.72**	568.4**	30.86**	6.98**	33.41**
Line x Tester	10	10	1.9**	0.53**	1.98**	20.75**	14.91**	34.33**	0.21**	0.24**	0.19**
Genotype x E		26			0.90**			4.96**			0.58**
Crosses x E		17			0.43**			3.39**			0.70**
Lines x E		5			0.33**			0.95**			0.10**
Tester x E		2			0.67**			19.8**			4.43**
Line x Tester x E		10			0.44**			1.33**			0.25**
Parents x E		8			0.53**			7.76**			0.33**
P *vs* C x E		1			11.82**			9.20**			0.50**
Error	52	104	1.08	0.93	1.1	0.95	1.08	1.02	0.59	0.48	0.53
δ2GCA			0.75	0.31	0.53	6.89	8.12	7.55	0.45	0.16	0.32
δ2 SCA			2.60	1.23	1.92	23.09	25.71	24.4	1.21	0.63	0.97
δ2 GCA x E					0.32			2.36			0.08
δ2 SCA x E					0.43			3.46			0.15

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

Table 15. Mean squares for head rice %, grain thickness (mm) and grain shape under normal irrigation (N) and drought stress (D) as well as their combined analyses.

S.O.V.	DF		Head rice (%)			Grain thickness (mm)			Grain shape		
	Single	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Env. (E)		1			1538.33**			91.94**			145.5**
Rep/ E	2	4	1.03	1.08	1.06	1.05	1.02	1.04	1.08	1.05	1.06
Genotypes	26	26	30.20**	107.87**	113.03**	0.27**	0.2**	0.38**	0.22**	0.35**	0.54**
Parents (P)	8	8	45.16**	8.44**	38.87**	0.19**	0.21**	0.18**	0.11**	0.16**	0.25**
Crosses (C)	17	17	24.10**	152.16**	147.01**	0.32**	0.21**	0.49**	0.29**	0.42**	0.68**
P *vs* C	1	1	14.35**	150.41**	128.83**	0.04**	0.01**	0.01**	0.03**	0.79**	0.57**
Lines	5	5	17.72**	89.57**	91.13**	0.39**	0.14**	0.49**	0.22**	0.35**	0.52**
Testers	2	2	151.19**	996.63**	961.13**	1.42**	1.37**	2.76**	1.63**	2.53**	4.12**
Line x Tester	10	10	1.87	14.55**	11.98**	0.05**	0.02**	0.04**	0.06**	0.03**	0.08**
Genotype x E		26			25.03**			0.09**			0.029**
Crosses x E		17			29.25**			0.03**			0.021**
Lines x E		5			16.16**			0.04**			0.023**
Tester x E		2			185.9**			0.03**			0.05**
Line x Tester x E		10			4.44**			0.02**			0.01**
Parents x E		8			14.73**			0.23**			0.018**
P *vs* C x E		1			35.92**			0.028**			0.24**
Error	52	104	0.21	0.13	0.17	0.03	0.05	0.04	0.05	0.03	0.04
δ2GCA			2.85	3.77	3.31	0.04	0.02	0.03	0.03	0.05	0.04
δ2 SCA			12.21	10.33	11.27	0.16	0.11	0.13	0.14	0.21	0.17
δ2 GCA x E					1.31			0.02			0.01
δ2 SCA x E					3.06			0.03			0.03

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

Combining ability analysis

Variance due to GCA and SCA combining abilities for hulling (%), milling (%), amylose content (%), head rice (%), grain thickness (mm) and grain shape under normal irrigation, drought and combined analyses are presented in Tables (14 and 15). δ^2 due to SCA were higher than those of δ^2 GCA for hulling (%), milling (%), amylose content (%), head rice (%), grain thickness (mm) and grain shape under normal irrigation, drought and combined analyses, which revealing the importance of non-additive gene action in governing these traits. The importance of non-additive genetic variance in controlling these traits were previously reported Patel *et al.,* (2019). Meanwhile, the interaction between SCA and environment was higher than of GCA x environment for all studied traits revealing that non additive gene action was more influenced by drought more than additive genetic variance.

General combining ability effects

Results of GCA effects for all studied traits under normal irrigation, drought stress and combined data are shown in Tables (18 and 19). Positive GCA effects are desirable for hulling (%), milling (%), head rice (%), grain thickness and grain shape under normal irrigation, drought and combined analyses. Unlike amylose content (%) which negative GCA effects are preferable.

Results exhibited that the line, Sakha107 had desirable significant and positive GCA effects for hulling % under normal, drought and combined data. Concerning milling %, the most desirable positive GCA effects for this trait were exhibited by the parent Sakha108 under normal, drought and combined data, respectively. Similar results with Patel *et al.,* (2019)

For amylose content (%), the parents Sakha107 exhibited desirable significant and negative GCA effects under normal, drought and their combined data. Regarding studied testers, Super300 seemed to be the best general combiner for hulling (%) under normal and drought condition but the tester M206 under combined data. The tester, Super 300 seemed to be the best general combiner for milling (%) under normal, drought and their combined data. The tester M206 expressed the highest negative and significant GCA values for amylose content (%) under both and across environments.

Regarding head rice (%), the line Sakha106 seemed to be the best general combiner for this trait under normal, drought and their combined data while the tester M206 seemed to be the best general combiner for head rice %. For grain thickness, the line Sakha107 seemed to be the best general combiner for this trait under normal, drought and their combined data, while the tester Super300 seemed to be the best general combiner for grain thickness.

Table 16. Mean performances of all genotypes for hulling (%), milling (%) and amylose content (%) under normal irrigation (N) and drought stress (D) as well as the combined over them.

Genotypes	Hulling (%)			Milling (%)			Amylose content (%)		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177	81.13	77.09	79.11	64.80	63.37	64.08	17.31	17.36	17.34
Sakha 105	81.15	78.04	79.60	70.90	63.90	67.40	16.69	17.24	16.96
Sakha106	82.10	79.69	80.90	71.95	65.80	68.88	16.19	17.05	16.62
Sakha107	82.98	79.90	81.44	73.00	68.30	70.65	15.45	16.12	15.78
Sakha108	82.67	80.50	81.59	72.30	68.80	70.55	16.24	16.18	16.21
GZ10101-5	81.13	77.09	79.11	64.80	63.37	64.08	17.31	17.36	17.34
Hispagran	82.10	79.45	80.78	71.00	63.90	67.45	17.53	17.73	17.63
Sakha Super300	82.41	80.04	81.23	72.90	64.75	68.83	17.00	17.11	17.06
M206	82.59	80.41	81.50	73.80	71.30	72.55	15.96	17.30	16.63
Giza177 x Hispagran	77.30	77.02	77.16	56.30	52.07	54.18	18.31	17.64	17.97
Sakha 105 X Hispagran	79.71	77.87	78.79	67.00	59.20	63.10	18.06	17.42	17.74
Sakha106 X Hispagran	81.12	79.00	80.06	68.30	61.90	65.10	17.07	17.24	17.15
Sakha107 X Hispagran	80.71	79.29	80.00	69.30	64.85	67.08	16.63	17.30	16.97
Sakha108 X Hispagran	80.48	79.00	79.74	68.40	63.20	65.80	16.88	17.30	17.09
GZ10101-5 X Hispagran	80.05	79.00	79.53	67.60	63.20	65.40	17.67	17.30	17.49
Giza177 x Super 300	80.95	79.46	80.20	70.00	66.64	68.32	15.93	16.86	16.40
Sakha 105 X Super 300	80.01	79.52	79.77	70.10	67.20	68.65	15.83	16.86	16.34
Sakha106 X Super 300	81.46	79.76	80.61	71.00	67.50	69.25	15.69	16.74	16.21
Sakha107 X Super 300	82.53	80.32	81.43	72.30	69.50	70.90	14.51	15.69	15.10
Sakha108 X Super 300	81.71	79.98	80.85	72.00	67.90	69.95	15.43	16.74	16.08
GZ10101-5 X Super 300	81.16	79.98	80.57	70.50	67.90	69.20	15.73	16.74	16.23
Giza177 x M206	81.74	80.00	80.87	72.00	68.20	70.10	15.19	16.68	15.94
Sakha 105 X M206	82.35	80.09	81.31	72.30	69.30	70.80	14.95	15.69	15.32
Sakha106 X M206	81.74	80.21	81.03	72.30	69.30	70.80	15.07	15.69	15.38
Sakha107 X M206	82.58	80.43	77.16	73.00	70.00	71.50	18.31	17.64	17.97
Sakha108 X M206	82.38	80.23	78.79	72.30	69.30	70.80	18.06	17.42	17.74
GZ10101-5 X M206	81.83	80.23	80.06	72.30	69.30	70.60	17.07	17.24	17.15
L.S.D 0.05	1.04	1.24	0.91	2.04	2.20	1.88	1.42	1.82	1.57
L.S.D 0.01	1.40	1.66	1.22	2.73	2.94	2.51	1.90	2.43	2.10

Table 17. Mean performances of all genotypes for head rice (%), grain thickness (mm) and grain shape under normal irrigation (N) and drought stress (D) as well as the combined over them.

Genotypes	Head rice (%)			Grain thickness (mm)			Grain shape		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177	62.92	62.92	62.92	1.50	1.93	1.72	1.81	1.84	1.83
Sakha 105	63.38	63.38	63.38	1.51	2.12	1.82	2.16	1.89	2.03
Sakha106	64.53	64.53	64.53	1.56	2.24	1.90	2.29	2.33	2.31
Sakha107	65.89	65.89	65.89	1.98	2.43	2.21	2.44	2.55	2.50
Sakha108	64.97	64.97	64.97	1.90	2.29	2.10	2.29	2.34	2.32
GZ10101-5	62.92	62.92	62.92	1.50	1.93	1.72	1.81	1.84	1.83
Maso	62.44	62.44	62.44	1.60	1.68	1.64	2.02	1.96	1.99
Super300	65.22	65.22	65.22	2.50	1.85	1.98	2.26	2.17	2.22
M206	67.97	67.97	67.97	2.11	1.79	1.95	2.28	2.25	2.27
Giza177 X Hispagran	46.00	46.00	46.00	1.30	1.52	1.41	1.35	1.05	1.20
Sakha 105 X Hispagran	48.19	48.19	48.19	1.38	1.66	1.52	1.57	1.49	1.53
Sakha106 X Hispagran	56.62	56.62	56.62	1.48	1.80	1.64	1.83	1.64	1.74
Sakha107 X Hispagran	57.79	57.79	57.79	1.52	1.92	1.72	2.09	1.82	1.96
Sakha108 X Hispagran	57.15	57.15	57.15	1.50	1.85	1.68	2.07	1.74	1.91
GZ10101-5 X Hispagran	55.00	57.15	56.08	1.40	1.85	1.63	2.02	1.74	1.88
Giza177 x Super 300	59.20	59.20	59.20	1.52	1.97	1.75	2.17	1.90	2.04
Sakha 105 X Super 300	60.70	60.70	60.70	1.55	2.03	1.79	2.17	1.97	2.07
Sakha106 X Super 300	65.17	65.17	65.17	1.56	2.10	1.83	2.22	2.08	2.15
Sakha107 X Super 300	68.53	68.53	68.53	2.30	2.42	2.36	2.44	2.45	2.45
Sakha108 X Super 300	66.37	66.37	66.37	1.70	2.11	1.91	2.25	2.08	2.17
GZ10101-5 X Super 300	63.89	66.37	65.13	1.56	2.11	1.84	2.20	2.08	2.14
Giza177 x M206	66.80	66.80	66.80	1.70	2.19	1.95	2.30	2.09	2.20
Sakha 105 X M206	67.87	67.87	67.87	2.00	2.31	2.16	2.43	2.39	2.41
Sakha106 X M206	67.12	67.87	67.50	1.90	2.31	2.11	2.38	2.39	2.39
Sakha107 X M206	46.00	46.00	46.00	1.30	1.52	1.41	1.35	1.05	1.20
Sakha108 X M206	48.19	48.19	48.19	1.38	1.66	1.52	1.57	1.49	1.53
GZ10101-5 X M206	56.62	56.62	56.62	1.48	1.80	1.64	1.83	1.64	1.74
L.S.D 0.05	0.73	0.77	0.68	0.18	0.19	0.17	0.31	0.26	0.28
L.S.D 0.01	0.98	1.03	0.91	0.17	0.18	0.19	0.22	0.25	0.27

As for grain shape, the line GZ10101-5 seemed to be the best general combiner for this trait under normal, drought stress and combined data, while the tester Sakha Super 300 seemed to be the best general combiner for grain shape. Similar results with Patel *et al.,* (2019).

Specific combining ability effect (SCA)

Estimates of SCA effects of the 18 F_1 cross combinations for all the studied characters under normal irrigation, drought stress and combined analyses are shown in Tables (20 and 21). Results illustrated that eight, nine and eight crosses had positive and significant SCA effects for hulling % under normal, stress condition as well as combined data, respectively. However, the most desirable SCA effects were detected for the cross Sakha 105 X Hispagran under normal irrigation and Sakha106 X Hispagran under stress condition and combined data.

Table 18. Estimates of GCA effects (gi) of parent lines and testers for hulling (%), milling (%) and amylose content under normal irrigation (N) and drought stress (D) as well as their combined data.

Genotypes	Hulling (%)			Milling (%)			Amylose content (%)		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Lines :									
Giza177	-1.1**	-0.66**	-0.88**	-3.70**	-3.38**	-3.54**	0.51**	0.35**	0.43**
Sakha 105	-0.41**	-0.31**	-0.35**	-0.11**	-0.61**	-0.36**	0.36**	0.23**	0.29
Sakha106	0.34**	0.17**	0.25**	0.71**	0.45**	0.58**	-0.04**	0.01	-0.02
Sakha107	0.84**	0.53**	0.68**	1.08**	1.12**	1.11**	-0.82**	-0.59**	-0.70**
Sakha108	0.42**	0.25**	0.33**	1.71**	2.44**	2.07**	-0.20**	-0.13**	-0.16**
GZ10101-5	-0.09**	0.02**	-0.03**	0.31**	-0.02	0.14**	0.19**	0.13**	0.16**
LSD 5%	0.02	0.04	0.03	0.02	0.03	0.03	0.06	0.08	0.07
LSD 1%	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.08	0.06
Testers :									
Hispagran	-1.21**	-0.98**	-1.09**	-3.66**	-5.38**	-4.52**	1.47**	0.67**	1.07**
Super300	0.21**	0.28**	0.24**	2.5**	3.35**	2.93**	-0.44**	-0.1**	-0.28**
M206	1.0**	0.7**	0.85**	1.16**	2.03**	1.59**	-1.03**	-0.57**	-0.79**
L.S.D 5%	0.02	0.03	0.03	0.02	0.02	0.04	0.09	0.1	0.09
L.S.D 1%	0.04	0.06	0.05	0.04	0.03	0.04	0.15	0.2	0.17

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

Table 19. Estimates of GCA effects (gi) of parent lines and testers for head rice (%), grain thickness and grain shape under normal irrigation (N) and drought stress (D) as well as combined data (C).

Genotypes	Head rice (%)			Grain thickness (mm)			Grain shape		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Lines :									
Giza177	-1.67**	-4.42**	-3.04**	-0.2**	-0.15**	-0.17**	-0.21**	-0.29**	-0.25**
Sakha 105	-1.08**	-3.09**	-2.08**	-0.1**	-0.07**	-0.08**	-0.12**	-0.07**	-0.09**
Sakha106	2.33**	3.78**	3.02**	-0.04**	0.01**	-0.02**	-0.01**	0.06**	0.02
Sakha107	0.03**	1.44**	0.55**	0.4**	0.21**	0.30**	0.04**	-0.06**	-0.01
Sakha108	0.65**	2.04**	1.33**	0.03**	0.03**	0.03**	0.09**	0.1**	0.09**
GZ10101-5	-0.26**	0.25**	0.22**	-0.09**	-0.03**	-0.06**	0.21**	0.26**	0.24**
LSD 5%	0.02	0.03	0.03	0.01	0.02	0.04	0.06	0.03	0.05
LSD 1%	0.04	0.06	0.05	0.04	0.03	0.04	0.05	0.04	0.04
Testers :									
Hispagran	-3.26**	-8.3**	-5.78**	-0.28**	-0.30**	-0.29**	-0.33**	-0.42**	-0.37**
Super300	0.98**	2.22**	1.6**	0.29**	0.24**	0.27**	0.25**	0.3**	0.27**
M206	2.28**	6.08**	4.18**	-0.01**	0.06**	0.02	0.08**	0.12**	0.1**
L.S.D 5%	0.09	0.1	0.09	0.01	0.02	0.04	0.07	0.1	0.09
L.S.D 1%	0.15	0.2	0.17	0.04	0.03	0.04	0.15	0.2	0.17

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

Table 20. Estimates of SCA effects (Sij) of cross combinations for hulling (%), milling (%) and amylose content (%) under normal irrigation (N) and drought stress (D) as well as the combined over them.

Cross combinations	Hulling (%)			Milling (%)			Amylose content (%)		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177 x Hispagran	-1.49**	-0.83**	-1.16**	-6.13**	-4.86**	-5.5**	0.35**	-0.09**	0.18**
Sakha 105 X Hispagran	0.75**	0.35**	0.55**	0.96**	2.31**	1.63**	0.25**	-0.10**	0.07**
Sakha106 X Hispagran	0.74**	0.48**	0.61**	1.43**	2.54**	1.98**	-0.32**	0.19**	-0.06**
Sakha107 X Hispagran	0.23**	-0.31**	-0.04**	1.40**	-0.49**	0.47**	0.02**	-0.19**	-0.08**
Sakha108 X Hispagran	-0.88**	0.08**	-0.4**	1.16**	0.11**	0.64**	-0.34**	0.01**	-0.1**
GZ10101-5 X Hispagran	0.65**	0.23**	0.40**	1.13**	0.38**	0.75**	0.04**	0.18**	0.11**
Giza177 x Super 300	0.89**	0.32**	0.60**	2.73**	1.15**	1.94**	-0.09**	-0.15**	-0.1**
Sakha 105 X Super 300	-0.18**	-0.18**	-0.18**	-0.76**	-0.66**	-0.71**	-0.05**	0.12**	0.04**
Sakha106 X Super 300	-0.70**	-0.14**	-0.42**	-0.70**	-0.49**	-0.59**	0.20**	0.03**	0.15**
Sakha107 X Super 300	-0.02**	0.26**	0.12**	-0.40**	2.11**	0.86**	-0.18**	0.51**	0.22**
Sakha108 X Super 300	0.39**	0.02**	0.25**	-0.06**	-0.64**	-0.35**	0.11**	-0.34**	-0.11**
GZ10101-5 X Super 300	-0.36**	-0.28**	-0.32**	-0.80**	-1.47**	-1.13**	0.01**	-0.17**	-0.08**
Giza177 x M206	0.16**	0.24**	0.22**	3.40**	1.78**	2.59**	-0.25**	0.06**	-0.09**
Sakha 105 X M206	-0.02**	-0.04**	-0.03**	-0.20**	-0.93**	-0.57**	-0.19**	0.26**	0.04**
Sakha106 X M206	-0.15**	-0.20**	-0.17**	-0.73**	-0.85**	-0.79**	0.12**	-0.32**	-0.2**
Sakha107 X M206	0.24**	0.32**	0.26**	-1.03**	0.30**	-0.37**	0.16**	-0.15**	-0.15**
Sakha108 X M206	-0.06**	-0.24**	-0.15**	-1.10**	-0.18**	-0.63**	0.21**	0.05**	0.14**
GZ10101-5 X M206	-0.19**	-0.08**	-0.14**	-0.33**	-0.11**	-0.22**	-0.05**	0.10**	0.02**
LSD S_{ij} 0.05	0.04	0.05	0.04	0.33	0.10	0.22	0.03	0.03	0.06
LSD S_{ij} 0.01	0.06	0.08	0.07	0.35	0.15	0.25	0.04	0.05	0.05
LSD sij-skl 0.05	0.25	0.41	0.29	0.72	0.74	0.65	0.22	0.27	0.32
LSD sij-skl 0.01	0.33	0.55	0.38	0.96	0.99	0.86	0.25	0.30	0.37

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

For milling %, seven, eight and six crosses had positive and significant SCA effects under normal, stress condition as well as combined data, respectively. However, the most desirable SCA effects were detected for the cross Sakha106 X Hispagran under normal, stress condition and combined data. Similar results with Patel *et al.*, (2019) Concerning amylose content (%), eight, eight and nine crosses had negative and significant SCA effects under normal, stress condition as well as combined data, respectively. The cross, Sakha108 X Hispagran revealed the highest significant and negative SCA effects for this trait under normal, the cross, Sakha108 X Sakha Super 300 under drought and the cross Sakha107 X M206 under combined analyses.

Regarding head rice (%), eight, eight and nine crosses had positive and significant SCA effects under normal, stress condition as well as combined data, respectively. However, the most desirable SCA effects were detected for the cross Giza177 x M206 under normal, the cross Sakha106 X Hispagran under stress condition and combined analyses.

As for grain thickness, ten, eight and seven crosses had positive and significant SCA effects under normal, stress condition as well as combined data, respectively. However, the most desirable SCA effects were detected for the cross Sakha107 X Super 300 under normal and combined data, and the cross Sakha107 X Super 300 under stress condition.

For grain shape, nine, twelve and twelve crosses had positive and significant SCA effects under normal, stress condition as well as combined data, respectively. However, the most desirable SCA effects were detected for the cross GZ10101-5 X Hispagran under normal, the cross Sakha106 X Hispagran under stress condition and the cross Giza177 x M206 under combined data.

Table 21. Estimates of SCA effects (Sij) of cross combinations for head rice (%), grain thickness (mm) and grain shape under normal irrigation (N) and drought stress (D) as well as the combined over them.

Cross combinations	Head rice (%)			Grain thickness (mm)			Grain shape		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177 X Hispagran	-1.49**	-3.04**	-2.17**	0.07**	-0.07**	-0.07**	-0.25**	-0.21**	-0.23**
Sakha 105 X Hispagran	0.74**	-0.35**	0.19**	0.02**	-0.01**	-0.01**	-0.12**	0.10**	-0.16**
Sakha106 X Hispagran	0.75**	3.39**	3.07**	-0.09**	0.03**	-0.03**	0.01**	0.11**	0.06**
Sakha107 X Hispagran	-0.44**	-2.18**	-1.31**	0.05**	-0.04**	-0.01**	0.05**	0.01**	0.03**
Sakha108 X Hispagran	0.24**	-0.18**	0.03**	-0.05**	0.06**	0.01**	0.15**	-0.05**	0.05**
GZ10101-5 X Hispagran	0.21**	2.36**	1.28**	0.01**	0.03**	0.02**	0.15**	0.03**	0.09**
Giza177 x Super 300	0.70**	1.72**	1.21**	0.09**	0.01**	0.05**	0.14**	0.03**	0.08**
Sakha 105 X Super 300	-0.15**	-0.25**	-0.2**	-0.09**	-0.01**	-0.05**	0.05**	-0.07**	-0.01**
Sakha106 X Super 300	-0.54**	-1.46**	-1.1**	0.01**	-0.03**	-0.01**	-0.01**	0.03**	0.01**
Sakha107 X Super 300	-0.02**	0.55**	0.26**	-0.31**	0.09**	-0.08**	-0.01**	0.02**	0.01**
Sakha108 X Super 300	-0.32**	0.77**	0.22**	0.20**	-0.04**	0.14**	-0.08**	0.09**	0.01**
GZ10101-5 X Super 300	0.34**	-1.32**	-0.49**	0.11**	-0.01**	0.05**	-0.08**	-0.09**	0.01**
Giza177 x M206	0.98**	1.65**	1.31**	0.04**	0.05**	0.04**	0.11**	0.09**	0.1**
Sakha 105 X M206	-0.49**	0.35**	-0.07**	-0.03**	0.02**	-0.01**	0.07**	-0.11**	-0.02**
Sakha106 X M206	-0.49**	-2.01**	-1.25**	-0.02**	0.01**	-0.01**	0.01**	0.02**	0.01**
Sakha107 X M206	0.28**	1.30**	0.79**	0.06**	-0.05**	0.01**	-0.04**	0.07**	0.01**
Sakha108 X M206	-0.01**	-0.33**	-0.17**	-0.05**	-0.01**	-0.03**	-0.07**	0.04**	-0.01**
GZ10101-5 X M206	-0.26**	-0.96**	-1.60**	-0.01**	-0.01**	-0.01**	-0.07**	-0.11**	-0.04**
LSD S_{ij} 0.05	0.02	0.03	0.03	0.01	0.02	0.04	0.05	0.03	0.05
LSD S_{ij} 0.01	0.04	0.06	0.05	0.04	0.03	0.04	0.04	0.03	0.04
LSD sij-skl 0.05	0.20	0.22	0.20	0.15	0.14	0.14	0.12	0.14	0.13
LSD sij-skl 0.01	0.19	0.18	0.21	0.20	0.15	0.17	0.14	0.16	0.15

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

Heterosis

Heterosis relative to mid and better parents for hulling (%), milling (%), amylose content (%), head rice (%), grain thickness (mm) and grain shape under normal irrigation, drought stress and their combined analyses are presented in Tables (22, 23, 24 and 25).

The most desirable heterotic effects relative to mid-parent for hulling (%) were detected for the crosses GZ10101-5 X Hispagran under normal conditions as well as combined data, and the cross Sakha106 X Hispagran under drought condition. Moreover, the best better-parent heterosis for this trait was detected by the cross (Sakha108 X Hispagran) under normal condition, (Sakha108 X Sakha Super 300) under stress conditions and the cross, (Sakha107 X Hispagran) under combined analyses, recording 2.91%, 2.35% and 2.45%, respectively. Shaalan (2003) and Rebeira *et al.* (2014) gave similar results.

The cross Sakha106 X Hispagran expressed the most desirable mid-parent heterosis for milling (%) under normal conditions and combined data as well as the cross Sakha108 X Sakha Super 300 gave the best mid-parent heterosis for this trait under drought conditions. While the cross, Sakha107 X Hispagran had the highest positive and significant heterotic values relative to better-parent under normal condition and combined data, and the cross Sakha108 X Sakha Super 300 under drought conditions.

As for amylose content (%), the cross GZ10101-5 X Sakha Super 300 expressed the highest negative and significant heterotic effects relative to mid-parent under normal irrigation, drought stress and combined analyses, while the cross, Sakha108 X Sakha Super 300 had the most desirable heterotic values relative to better-parent under all environments.

Concerning head rice (%), the respective crosses for mid-parent heterosis were four, seven and seven as well as two, three and two crosses relative to better parent heterosis. However, the cross, Sakha106 X Hispagran recoded the highest positive and significant heterotic effects relative to mid-parent under normal conditions and combined data, while the cross, GZ10101-5 X Sakha Super 300 showed the highest positive and significant heterotic effects under drought stress condition. Moreover, the cross, GZ10101-5 X Sakha Super 300 gave the best heterotic effects relative to better-parent under all environments.

Regarding grain thickness (mm), five, twelve and seven crosses expressed desirable positive heterosis relative to mid-parent under normal, stress conditions and combined data as well as two, six and two crosses for better parent heterosis in normal, stress and combined analyses. However, the cross GZ10101-5 X Sakha Super 300 exhibited positive and significant mid-parent heterosis under normal and combined data as well as the cross, Sakha106 X Hispagran under drought conditions. Meantime, the hybrid GZ10101-5 X Sakha Super 300 exhibited the most desirable better-parent heterosis under normal, drought conditions and combined data being 18.48%, 13.47% and 12.65%, respectively.

For grain shape, eight, six and seven crosses expressed positive and significant mid-parent heterosis under normal, stress condition and combined data, respectively. The respective better parent heterosis values were detected for six, two and four crosses. However, the best mid-parent heterosis values were detected for the cross, Sakha106 X Hispagran under normal and combined data and GZ10101-5 X Hispagran under drought stress conditions. While the most desirable better parent heterosis were obtained for the cross, Sakha106 X M206 under normal irrigation, drought stress and combined data. Similar results with Patel *et al.*, (2019) and Hussein (2021).

Table 22. Heterosis relative to mid parents for hulling (%), milling (%) and amylose content (%) under normal irrigation (N) and drought stress (D) as well as the combined over them.

Cross combinations	Hulling (%)			Milling (%)			Amylose content (%)		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177 x Hispagran	-5.29**	-1.60**	-3.44**	-17.08**	-18.30**	-17.69**	5.07**	0.54**	2.81**
Sakha 105 X Hispagran	-1.01**	1.14**	0.07**	1.67**	4.00**	2.58**	-7.13**	-2.18**	-4.65**
Sakha106 X Hispagran	-0.15**	1.59**	0.72**	3.90**	1.26**	2.84**	-8.69**	-3.75**	-6.22**
Sakha107 X Hispagran	-2.35**	-1.11**	-1.73**	-5.57**	-7.36**	-6.46**	5.55**	-0.37**	2.59**
Sakha108 X Hispagran	-2.16**	0.61**	-0.78**	-2.50**	4.47**	0.98**	-6.04**	-1.83**	-3.94**
GZ10101-5 X Hispagran	0.59**	1.09**	0.84**	-0.48**	1.78**	0.65**	-7.44**	-4.17**	-5.81**
Giza177 x Super 300	-1.19**	-0.72**	-0.96**	-4.44**	-4.55**	-4.50**	1.21**	-0.86**	0.17**
Sakha 105 X Super 300	-0.97**	-0.13**	-0.55**	-1.97**	3.41**	0.72**	-5.48**	-1.99**	-3.74**
Sakha106 X Super 300	-0.73**	0.20**	-0.27**	-0.79**	0.66**	-0.07**	-6.60**	-5.79**	-6.20**
Sakha107 X Super 300	-2.22**	-0.48**	-1.35**	-3.75**	-1.89**	-2.82**	0.87**	2.22**	1.54**
Sakha108 X Super 300	-0.20**	0.44**	0.12**	-0.89**	4.57**	1.79**	-9.14**	-5.57**	-8.07**
GZ10101-5 X Super 300	-0.25**	0.34**	0.05**	-0.54**	0.29**	-0.13**	-10.58**	-7.96**	-8.55**
Giza177 x M206	-2.31**	-1.22**	-1.77**	-4.54**	-4.75**	-4.64**	-0.04	2.03**	1.00**
Sakha 105 X M206	-1.01**	-0.36**	-0.68**	-0.83**	1.68**	0.43**	-7.18**	0.57**	-3.30**
Sakha106 X M206	-0.30**	-0.28**	-0.29**	-1.03**	-1.07**	-1.05**	-7.11**	-6.27**	-6.69**
Sakha107 X M206	-2.41**	-0.54**	-1.48**	-4.99**	-6.37**	-5.68**	4.87**	-0.17**	2.35**
Sakha108 X M206	-1.24**	-0.02	-0.63**	-2.22**	3.65**	0.71**	-5.18**	-1.64**	-3.41**
GZ10101-5 X M206	-0.53**	0.46**	-0.04**	-0.34**	0.73**	0.19**	-6.17**	-4.69**	-5.43**

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

Table 23. Heterosis relative to mid -parents for head rice (%), grain thickness (mm) and grain hape under normal irrigation (N) and drought stress (D) as well as the combined over them (C).

Cross combinations	Head rice (%)			Grain thickness (mm)			Grain shape		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177 X Hispagran	-3.07**	-26.61**	-14.84**	-16.13**	-15.79**	-15.96**	-29.50**	-44.74**	-37.12**
Sakha 105 X Hispagran	5.56**	-7.60**	-1.02**	-15.79**	7.07**	-4.36**	6.63**	-5.24**	0.70**
Sakha106 X Hispagran	5.88**	2.07**	3.97**	-5.82**	17.74**	5.96**	12.47**	2.20**	7.33**
Sakha107 X Hispagran	-7.50**	-23.40**	-15.45**	-11.25**	-12.63**	-11.94**	-24.88**	-22.60**	-23.74**
Sakha108 X Hispagran	-1.61**	-5.60**	-3.60**	-14.36**	4.91**	-4.73**	-1.81**	-2.96**	-2.38**
GZ10101-5 X Hispagran	-1.26**	2.17**	0.45**	4.97**	14.58**	9.78**	6.31**	7.73**	7.02**
Giza177 x Super 300	-5.40**	-10.81**	-8.10**	-6.33**	-8.16**	-7.25**	-15.08**	-23.54**	-19.31**
Sakha 105 X Super 300	-1.74**	0.46**	-0.64**	-14.99**	5.26**	-4.86**	-2.42**	-7.56**	-4.99**
Sakha106 X Super 300	-1.90**	2.37**	0.24**	6.27**	14.64**	10.45**	5.03**	3.06**	4.04**
Sakha107 X Super 300	-3.54**	-9.94**	-6.74**	-15.08**	-6.57**	-10.83**	-6.28**	-19.29**	-12.78**
Sakha108 X Super 300	0.83**	4.54**	2.69**	12.47**	15.79**	14.13**	3.83**	3.81**	3.82**
GZ10101-5 X Super 300	2.10**	5.04**	3.57**	22.25**	16.11**	19.18**	8.90**	2.08**	5.49**
Giza177 x M206	-4.36**	-10.29**	-7.32**	-14.29**	-6.80**	-10.54**	-3.94**	-19.07**	-11.51**
Sakha 105 X M206	-1.61**	1.96**	0.18**	-15.21**	4.46**	-5.38**	-1.10**	-7.76**	-4.43**
Sakha106 X M206	-1.21**	2.11**	0.45**	-0.25**	13.24**	6.49**	6.35**	4.28**	5.32**
Sakha107 X M206	-6.36**	-13.35**	-9.85**	-9.97**	-8.85**	-9.41**	-5.31**	-26.59**	-15.95**
Sakha108 X M206	-1.91**	-1.50**	-1.70**	-13.81**	5.71**	-4.05**	-2.37**	-7.17**	-4.77**
GZ10101-5 X M206	-1.87**	1.33**	-0.27**	4.97**	13.92**	9.45**	5.15**	-7.49**	-1.17**

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

Table 24. Heterosis relative to better -parents for hulling (%), milling (%) and amylose content (%) under normal irrigation (N) and drought stress (D) as well as the combined over them (C).

Cross combinations	Hulling (%)			Milling (%)			Amylose content (%)		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177 x Hispagran	-5.85**	-3.06**	-4.45**	-20.70**	-18.62**	-19.66**	4.41**	-0.51**	1.95**
Sakha 105 X Hispagran	-1.78**	-0.72**	-1.25**	-3.98**	2.92**	-0.53**	-7.97**	-2.88**	-5.43**
Sakha106 X Hispagran	-1.03**	-0.51**	-0.77**	-2.44**	-4.35**	-3.39**	-12.26**	-3.92**	-8.09**
Sakha107 X Hispagran	-2.91**	-1.99**	2.45**	5.63**	-2.36**	3.49**	3.00**	1.75**	0.63**
Sakha108 X Hispagran	2.91**	-0.65**	-1.78**	-3.84**	3.78**	-0.03**	-6.90**	-2.20**	-4.55**
GZ10101-5 X Hispagran	-0.29**	-0.40**	-0.34**	-2.44**	-3.51**	-2.97**	-9.47**	-4.34**	-6.90**
Giza177 x Super 300	-1.19**	-0.87**	-1.03**	-5.07**	-5.93**	-5.50**	-2.66**	-2.76**	-2.71**
Sakha 105 X Super 300	-1.15**	-0.35**	-0.75**	-2.61**	2.58**	-0.01**	-7.73**	-2.16**	-4.94**
Sakha106 X Super 300	-1.03**	-0.25**	-0.64**	-2.03**	-3.23**	-2.63**	-7.29**	-6.47**	-6.88**
Sakha107 X Super 300	2.74**	-0.76**	-1.75**	-5.07**	-5.05**	-5.06**	-5.13**	-2.43**	-3.78**
Sakha108 X Super 300	-0.54**	2.35**	-0.10**	-0.96**	1.76**	0.40**	-14.67**	-11.10**	-11.48**
GZ10101-5 X Super 300	-0.48**	0.02	-0.23**	-1.08**	-1.82**	-1.45**	-10.59**	-8.30**	-10.84**
Giza177 x M206	-2.65**	-1.86**	-2.26**	-5.39**	-8.14**	-6.77**	-3.73**	-2.43**	-3.08**
Sakha 105 X M206	-1.17**	-0.65**	-0.91**	-1.23**	-1.31**	-1.27**	-9.25**	-2.16**	-5.71**
Sakha106 X M206	-0.35**	-0.34**	-0.35**	-2.03**	-2.81**	-2.42**	-7.92**	-9.31**	-8.61**
Sakha107 X M206	-2.50**	-0.77**	-1.63**	-5.19**	-7.51**	-6.35**	0.80**	-2.09**	-0.64**
Sakha108 X M206	-1.52**	-0.61**	1.06**	-3.29**	3.05**	-0.12**	-7.49**	-1.81**	-4.65**
GZ10101-5 X M206	-0.92**	-0.36**	-0.64**	-2.03**	-3.37**	-2.70**	-6.80**	-5.38**	-6.09**

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

Table 25. Heterosis relative to better -parents for head rice (%), grain thickness (mm) and grain shape under normal irrigation (N) and drought stress (D) as well as the combined over them (C).

Cross combinations	Head rice (%)			Grain thickness (mm)			Grain shape		
	Normal	Drought	Comb.	Normal	Drought	Comb.	Normal	Drought	Comb.
Giza177 x Hispagran	-9.46**	-26.89**	-18.17**	-18.75**	-21.24**	-20.00**	-33.17**	-46.43**	-39.80**
Sakha 105 X Hispagran	-2.48**	-9.23**	-5.85**	-27.96**	2.07**	-12.94**	-3.98**	-12.44**	-8.21**
Sakha106 X Hispagran	-3.45**	-1.72**	-2.58**	-19.43**	0.82**	-2.98**	0.88**	-7.11**	-3.12**
Sakha107 X Hispagran	-7.90**	-23.97**	-15.93**	-13.75**	-21.70**	-17.72**	-27.31**	-23.98**	-25.65**
Sakha108 X Hispagran	-2.35**	-6.93**	-4.64**	-26.54**	-4.25**	-15.39**	-3.98**	-9.22**	-6.60**
GZ10101-5 X Hispagran	-3.38**	-1.28**	-2.33**	-9.95**	5.66**	-2.15**	3.51**	-0.89**	1.31**
Giza177 x Super 300	-6.89**	-12.26**	-9.58**	-7.50**	-19.64**	-13.57**	-20.09**	-29.61**	-24.85**
Sakha 105 X Super 300	-2.15**	-0.07	-1.11**	-26.07**	-6.25**	-16.16**	-3.06**	-10.73**	-6.89**
Sakha106 X Super 300	-2.89**	-0.22**	-1.55**	-7.58**	3.13**	-2.23**	4.80**	1.29**	3.05**
Sakha107 X Super 300	-5.43**	-12.29**	-8.86**	-23.23**	-20.99**	-22.11**	-14.34**	-28.63**	-21.49**
Sakha108 X Super 300	0.03	3.43**	2.02**	9.00**	-0.41**	4.30**	0.05	-3.92**	-1.96**
GZ10101-5 X Super 300	1.46**	4.01**	2.45**	18.48**	13.47**	12.65**	5.33**	-3.92**	0.70**
Giza177 x M206	-6.10**	-12.04**	-9.07**	-21.05**	-19.21**	-20.13**	-9.61**	-25.64**	-17.62**
Sakha 105 X M206	-2.25**	1.77**	-0.24**	-19.43**	-7.86**	-13.65**	-1.75**	-11.11**	-6.43**
Sakha106 X M206	-1.97**	-0.15**	-1.06**	-5.21**	0.87**	-2.17**	6.11**	2.28**	4.20**
Sakha107 X M206	-7.80**	-14.74**	-11.27**	-12.50**	-18.98**	-15.74**	-10.09**	-31.88**	-20.98**
Sakha108 X M206	-1.03**	-0.25**	-0.64**	-2.03**	-3.23**	-2.63**	-7.29**	-6.47**	-6.88**
GZ10101-5 X M206	-2.50**	-0.77**	-1.63**	-5.19**	-7.51**	-6.35**	0.80**	-2.09**	-0.64**

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

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السلوك الوراثي لمحصول الحبوب وصفات الجودة لبعض التراكيب الوراثية للأرز تحت ظروف الري العادي والإجهاد المائي

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تهدف الدراسة الي تقدير القدرة على الائتلاف لصفات المحصول وجودة حبوب الأرز للتعرف على أفضل التراكيب الوراثية لاستخدامها في برنامج التربية. واستخدم تصميم السلالة x الكشاف لتحليل 18 تركيب وراثي مع الآباء. تم زراعة الآباء والهجن في تجربتين منفصلتين الأولى تروى كل 4 أيام (الري العادي) والثانية تروى كل 12 يوم (ظروف الجفاف). أوضحت النتائج أن معاملة الري كل 12 يوم أدت إلى نقص كل الصفات المدروسة ما عدا صفة محتوى الأميلوز الذي زاد تحت ظروف الجفاف. وكان تباين القدرة الخاصة على الائتلاف أعلى من تباين القدرة العامة لكل الصفات المدروسة ما عدا صفة عدد السنابل / نبات، طول السنبلة ووزن السنبلة. وسجل الهجينين سخا 107 M206 X Sakha 107 ، M206 Super 300 Xسجلا أفضل القيم المرغوبة لصفات التقشير والتبيض ونسبة الأرز السليم وسمك الحبة وشكلها . وكذلك سجلت الثلاثة هجن وهى (M206 x Sakha 107 ، M206 Super 300 x ، Sakha 108 x Sakha Super 300) سجلوا أفضل القيم المرغوبة لصفات عدد السنابل / نبات، طول السنبلة ، وزن الألف حبه ، محصول الحبوب / نبات ، ونسبة الخصوبة ، كما سجلت هذه الهجن أفضل قدرة خاصة على الائتلاف. وسجلت الأصناف سخا 107، سخا 108 والسلالة M206 والصنف سخا سوبر 300 أفضل قدرة عامة على الائتلاف لاستخدامها في برنامج التربية لتحسين تلك الصفات تحت ظروف الري العادي والإجهاد المائي . وأعطت الهجن سخا M206 x 107 و الهجين سخا M206 x 108 والهجين سخا 107 x سخا سوبر 300 أفضل القيم المرغوبة والمعنوية لقوة الهجين منسوبة الي متوسط الابوين او الاب الافضل وذلك تحت ظروف كل بيئة علي حدة والتحليل التجميعي.