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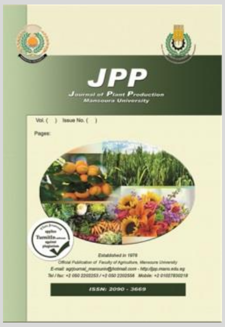
Genetic Behavior of Some Rice Root Characteristics, Yield and Yield Components as Affected by Water Deficit

Daher, E. M. A.; S. A. El-Naem; A. G. Hefeina* and H. A. N. Taha

Rice Research Section, Field Crops Research Institute, Agriculture Research Center, Giza, Egypt.



ABSTRACT

Eight local and exotic cultivars of rice were crossed to obtain 28 F_1 crosses, through half diallel mating design. The eight parents and their 28 F_1s (excluding reciprocals) were grown in a randomized block design with three replications at the farm of Sakha Research Station, Sakha, Kafr El-Sheikh, Egypt in 2020 and 2021 rice seasons. GCA and SCA were significant for most of studied traits. GCA/SCA ratios were found to be less than unity for all studied traits, indicating that the non-additive type of gene action was great importance in the inheritance of these traits. Estimates of GCA effects indicated that, the parent IET1444 was a good general combiner for most of studied characters. The hybrid combinations IR 65600-77×Nerica 9 were the best SCA for most of studied characters. IR 65600-77×Nerica 9 rice hybrid exhibited significant and highly significant positive estimates of heterosis as a deviation from mid and better parent for root length, number of roots/plant, root volume, root/shoot ratio, relative water content, flag leaf area, number of panicles/plant, 1000-grain weight and grain yield/plant under water deficit conditions, except root length for better parent was insignificant.

Keywords: Rice – root traits – combining ability and heterosis.

INTRODUCTION

Drought, like many other environmental stresses, has adverse effects on crop yield. Low water availability is one of the major causes for crop yield reductions affecting the majority of the farmed regions around the world. Drought tolerance is a complex trait, expression of which depends on action and interaction of different morphological, physiological and biochemical traits. Rice breeders have the common goal of identifying traits that confer an advantage under drought. They also have worked to identify lines with superior performance in the target environments, in order to gradually accumulate favorable alleles in improved cultivars and used the current knowledge about how plants grow to hypothesize which traits might be advantageous, and have then looked for genetic variation in those traits that can be correlated with yield in the target environments.

Combining ability is defined as the ability of a parent line in hybrid combinations (Kambal and Webster, 1965). It plays an important role in selecting superior parents for hybrid combinations and in studying the nature of genetic variation (Duvick, 1999). The mating designs provide reliable information about general combining ability (GCA) and specific combining ability (SCA) of the parents and crosses. The differences in GCA are mainly due to additive gene action while the differences in SCA are attributed to non-additive gene effects (Fasahat *et al*., 2016). Estimation of GCA helps the breeder to identify parents with superior combining ability which may be hybridized to exploit heterosis, and also for development of breeding populations from which agronomically superior lines can be selected (Fasahat *et al*., 2016). Therefore, the knowledge of combining ability provides information the nature and magnitude of gene effects that regulate grain yield and yield characters hence enabling the breeder to design an effective breeding method for genetic enhancement of grain yield and yield components (Dar *et al*. 2014). The need of further studies on combining ability, type of gene action and heterosis for studied traits under water deficit conditions as one of the important objectives of research for the development of acceptable varieties. Therefore, the present study was suggested to study, combining ability effects, the nature of gene action heterosis for some root and vegetative characters on a half diallel crosses of eight rice genotypes under water deficit conditions.

MATERIALS AND METHODS

A half diallel set was made in 2020 summer season using eight local and exotic rice genotypes viz., Sakha 108, Sakha 104, IR 69116, Sakha 109, IR 65600-77, Nerica.9, Sakha Super 300, and IET 1444, excluding reciprocals at the Experimental Farm of Sakha Research Station, Sakha, Kafr El-Sheikh, Egypt. The parents and F_1s were evaluated in a randomized complete blocks design (RCBD) with three replications during summer 2021. Each genotype was planted in four rows per replicate. Row was five meters in length with the spacing of 20 × 20 cm among rows and plants, individual seedling at 30 days old were transplanted per hill. However, the outer two rows were used as borders, while, the inner two rows were used for root and vegetative characters evaluation. Normal irrigation was done every 4 days for the normal condition. Flush irrigation was used every 12 days for the water deficit conditions. Recommended agricultural practices were followed for the two conditions. For root measurements, 20 rice plants from each genotype were grown in plastic bag, one plant per bag. The bag was 20 cm in diameter and 0.5 m

* **Corresponding author.**
E-mail address: ahmad.gamal95@yahoo.com
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in height with holes on the top and down two sides. Bags were placed with water deficit treated basin. The studied traits, root length (cm), number of roots/plant, root volume (cm^3) and root/soot ratio, chlorophyll content, number of panicles/plant, fertility percentage (%), 1000-grain weight (g) and grain yield/plant (g) were scored according to IRRI (1996).

Relative water content % (R.W.C): It was determined by the method of Barrs and Weatherly (1962).

Flag leaf area (cm^2): It was measured at the flowering stage following the manual method proposed by Yoshida *et al.* (1962).

Leaf rolling: It was measured as an indicator of degree of drought tolerance on the scale of 1-9 from plant leaf. It was recorded by visual estimation based on method by De Datta *et al.* (1988).

Combining ability was analyzed according to Griffing (1956). Tests of significance for general and specific combining ability were M.S. (g)/ M.S. (e) and M.S. (s) / M.S. (e), respectively, referred to Griffing (1956) as his method 2, model I. The heterosis were estimated as the deviation of the F1 mean value from the mid- and better-parent mean values as suggested by Matzinger *et al.* (1962) and Fonsecca and Patterson (1968), respectively. The following formulae were used for the estimation of mid-parent (MP) and better-parent (BP) heterosis for all the traits:

Heterosis over the mid-parent = [(F1 – MP) / MP × 100],

S.E. (F1 – MP) = $(3Me / 2r)^{1/2}$,

Heterosis over the better-parent = [(F1 – BP) / BP × 100], and

S.E. (F1 – BP) = $(2Me / r)^{1/2}$.

Where, **Me = error mean squares for parents and F1s from an individual environment; MP = mean mid-parent value = (P1 + P2) / 2; P1 = mean performance of parent one; P2 = mean performance of parent two; BP = mean of better-parent value; r = number of replications. The phenotypic correlation coefficients were calculated as per the method of Dewey and Lu (1959).**

RESULTS AND DISCUSSION

Analysis of variance

The ANOVA for 12 traits in 8 × 8 half diallel set (Table 1) showed highly significant mean square estimates were recorded for genotypes, parents, crosses and the interaction among them for all root characteristics, yield and yield components under water deficit and normal conditions, except root/shoot ratio and 1000-grain weight under both conditions and leaf rolling under normal conditions which were insignificant. These results agree with those obtained by Saleem *et al.* (2010), El-Hity *et al.*, (2016), Daher (2018) and Sakran *et al.* (2022). Results also revealed that variances due to the general combining ability (GCA) and the specific combining ability (SCA) were significant for all the studied traits, indicating the important of both additive and non-additive gene action in the inheritance of all traits except root /shoot ratio and 1000-grain weight under both conditions and leaf rolling for (SCA) and (GCA) under both conditions and normal conditions, respectively.

Table 1. Mean square estimates of ordinary and combining ability analysis for root characteristics, yield and yield components under water deficit and normal conditions.

Source	d.f	Root length		Number of roots/plant		Root volume		Root /shoot ratio		Relative water content		Flag leaf area	
		N	D	N	D	N	D	N	D	N	D	N	D
Replication	2	2.79	5.44	25.00	25.00	22.75	4.00	0.003	0.002	4.91	5.94	1.74	3.31
Genotype	35	88.02**	73.16**	6367.63**	3310.39**	956.65**	173.55**	0.21	0.28	529.99**	785.80**	645.48**	126.56**
Parent	7	54.00**	70.07**	3257.79**	1662.38**	304.23**	56.36**	0.21	0.04	556.39**	777.56**	369.01**	138.72**
Crosses	27	92.25**	75.11**	6763.57**	3797.63**	993.98**	196.36**	0.22	0.34	483.87**	626.59**	707.73**	122.64**
Parents *vs.* Crosses	1	211.88**	42.00**	17446.10**	1691.01**	4515.72**	378.00**	0.03	0.25	1590.19**	5142.02**	900.09**	147.17**
Error	70	0.95	0.87	25.00	25.00	8.61	4.00	0.41	0.004	4.45	4.02	0.99	1.13
GCA	7	71.39**	50.98**	4337.76**	1390.31**	411.31**	68.79**	0.08	0.07	269.77**	501.28**	439.62**	25.82**
SCA	28	18.83**	17.74**	1568.74**	1031.75**	295.78**	55.11**	0.07	0.10	153.38**	202.10**	159.05**	46.28**
Error	70	0.32	0.29	8.33	8.33	2.87	1.33	0.14	0.003	1.48	1.34	0.33	0.38
GCA/SCA		0.38	0.29	0.27	0.13	0.13	0.12	0.087	0.074	0.18	0. 25	0.27	0.05

Table 1. Continued

Source	d.f	Leaf rolling		Chlorophyll content		No. of panicles /plant		Fertility %		1000-grain weight, g		Grain yield / plant, g	
		N	D	N	D	N	D	N	D	N	D	N	D
Replication	2	1.23	0.06	10.37	9.02	1.78	0.70	8.25	6.59	0.2	0.1	4.23	4.61
Genotype	35	0.22	4.19**	39.28**	74.07**	37.30**	29.77**	25.02**	489.42**	3.9	4.0	273.53**	199.96**
Parent	7	0.33	5.52**	39.83**	110.70**	44.57**	16.29**	67.55**	625.12**	5.4	3.3	218.95**	138.00**
Crosses	27	0.18	3.93**	39.81**	61.00**	24.94**	33.54**	12.84**	472.00**	3.7	4.2	211.33**	190.00**
Parents *vs.* Crosses	1	0.56	1.65*	21.12**	170.63**	320.38**	22.39**	56.16**	9.75**	1.5	3.3	2335.23**	902.70**
Error	70	0.89	0.18	4.23	4.51	0.98	0.99	4.03	4.03	0.1	0.1	4.02	4.03
GCA	7	0.02	2.95**	21.39**	32.19**	9.51**	19.05**	21.85**	275.96**	3.4	2.7	85.39**	112.52**
SCA	28	0.09	1.01	11.02**	22.82**	13.17**	7.64**	4.96**	134.93**	0.8	1.0	92.63**	55.17**
Error	70	0.30	0.06	1.41	1.50	0.33	0.33	1.34	1.34	0.09	0.08	1.34	1.34
GCA/SCA		0.13	0.30	0.20	0.14	0.072	0.26	0.57	0.21	4.40	2.80	0.092	0.21

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

Moreover, the GCA variance was greater than the SCA variance for all the studied traits, indicating the preponderance of additive gene action for these traits, except root/shoot ratio, relative water content and flag leaf area under water deficit and number of panicles/plant, fertility% and grain yield/plant under normal conditions. The GCA/SCA ratio was lower than unity for all the studied traits under water deficit and normal conditions, exhibited that predominance of non-additive gene action was played remarkable role in the inheritance of these traits. Similar results were obtained previously by Rahimi *et al.* (2010), El-Hity *et al.*, (2016), Daher (2018) and Sakran *et al.* (2022).

Mean performance of parents and their F_1 generation.

The data in Table 2 shows that the highest mean values of root length were recorded by parent IET 1444 (31.0 cm and 33.0 cm) under water deficit and normal conditions, respectively. Moreover, Sakha 109 gave the lowest mean values (15.50 cm) under water deficit conditions. The parent namely, Nerica 9 under normal conditions exhibited the lowest mean values of root length (20.00 cm). On the other hand, the highest mean values of root length were recorded by cross, Sakha 108 × IET 1444 (31.00, 36.00 cm) under water deficit and normal conditions, respectively. While, the cross Sakha 104 × Nerica 9 under water deficit and normal conditions showed the lowest mean values of root length (13.00 cm and 16.00 cm), respectively. For number of roots/plant, the parental genotype, IET 1444 under water deficit and normal conditions recorded the highest mean values (130.0 and 180.00 roots/plant), respectively, while, Nerica 9 under water deficit and normal conditions recorded the lowest mean values of number of roots/plant. On the other hand, the results showed that the cross namely, IR 65600-77 × Nerica 9 (200.0 and 240 roots) under water deficit and normal conditions, respectively recorded the highest mean values of number of roots/plant. While, the cross, Sakha 104 × Sakha 109 (50.00 and 85 roots/plant) under water deficit and normal conditions, respectively showed the lowest mean values of number of roots/plant. For root volume, the three parents, Sakha 104, IET 1444, Sakha Super 300 and the crosses, Sakha 109 × Sakha Super 300 and Sakha 104 × IET 1444 gave the highest mean values under water deficit conditions. While, the genotypes, Sakha 104, Sakha Super 300 and the cross Nerica 9 × Sakha Super 300 gave the highest mean values under normal conditions.

On the other side, the parents, Nerica 9 and IR 65600-77 under conditions as well as the crosses, Sakha 108 × Sakha 104, Sakha 108 × Sakha 109 under water deficit conditions and Sakha 108 × IR 69116, Sakha 109×IR 65600-77 under normal conditions exhibited the lowest mean values. Concerning to root/shoot ratio, the highest mean values were detected by the genotypes Sakha Super 300 (0.52) under water deficit conditions and Sakha 104 under normal conditions with values of 1.16. While the variety IET 1444 gave the lowest mean values of 0.16 and 0.28 under water deficit and normal conditions, respectively. The results also revealed that the F1 hybrid, Sakha 104 × Sakha 109 and IR 69116 × IR 65600-77 exhibited the highest mean values (1.37 and 1.40) for root/shoot ratio under water deficit and normal conditions, respectively. On the other hands, the lowest mean values were recorded by crosses, IR 69116×IR 65600-77 and IR 65600-77× Sakha Super 300 under water deficit and normal conditions, respectively.

For relative water content, the varieties, IR 69116 and IR 65600-77 recorded the highest mean values (61.01 and 92.09) under water deficit and normal conditions, respectively. While, the varieties Sakha 109 and Sakha 108 gave the lowest mean values of relative water content (18.22 and 52.07) under water deficit and normal conditions, respectively. On the other hand, the highest mean values were recorded by cross, Nerica 9×IET 1444 under water deficit and normal conditions. While the lowest mean values were recorded by crosses, Sakha 104×Sakha 109 (32.13) under water deficit and Sakha 104×IET 1444 (50.20) under normal conditions. In the case of flag leaf area, data in Table 2 exhibited that among parents Sakha 104 and IR 65600-77 scored the highest mean values under water deficit and normal conditions (34.35 and 49.10 cm^2, respectively. On the other hand, the lowest mean values were obtained by Sakha 109 (14.02 and 15.71 cm^2) under water deficit and normal conditions, respectively. Among hybrids IR 65600-77×Nerica 9 under water deficit and normal conditions scored the highest mean values (35.90 and 87.93 cm^2), respectively. The hybrid Sakha 104 × IR 65600-77 exhibited the lowest mean values under water deficit conditions (15.60 cm^2) but the lowest mean values under normal conditions was observed for the hybrid Sakha 104×Nerica 9 with value 22.10 cm^2. For leaf rolling, the variety, Nerica 9 recorded the lowest mean value (2.00) under water deficit conditions. While, the variety Sakha 109 gave the highest mean value of leaf rolling (6.00) under water deficit conditions. On the other hand, the lowest mean values were recorded by cross, Sakha Super 300×IET 1444 under water deficit conditions. For chlorophyll content, among parents the highest mean values under water deficit and normal conditions were obtained by IET 1444 and IR69116 (42.10 and 51.00 SPAD), respectively, while, the lowest mean values were recorded for the genotype Sakha 109 (23.53 and 40.23SPAD) under water deficit and normal conditions, respectively. On the other side, among hybrids Sakha 108 × IET 1444 recorded the highest mean values under water deficit conditions as well as the cross IR 69116 × Sakha 109 under normal conditions with values (46.22 and 51.13 SPAD), respectively. Meanwhile, the lowest mean values were recorded for the hybrid Sakha 104 × IET 1444 under water deficit conditions (34.43 SPAD) and the hybrid IR 65600-77X IET 1444 under normal conditions (32.01 SPAD). High number of panicles/plant was detected for IET 1444 (17.0) under deficit and Sakha 104 (24.0) under normal conditions,

The cross IR 65600-77 × Sakha Super 300 gave the highest mean value of 19.00 and 28.00 panicle/plant, under water deficit and normal conditions, respectively. Moreover, High fertility % was observed for IET 1444 (97.0 and 98.22%) under water deficit and normal conditions, respectively. While, the cross, Nerica 9 × Sakha Super 300 (94.10%) under water deficit and Sakha super 300 × IET 1444 (98.25%) under normal conditions exhibited the highest mean values for fertility %. Nerica.9 was found the highest mean values (30.0 g/1000 grains) under water deficit, while, IR 65600-77 was the highest mean values (36.0 g/1000 grains) under normal conditions.

Table 2. Mean performance of the eight parents and their F_1 generation of 8 × 8 diallel cross for root characteristics, yield and yield components under water deficit and normal conditions.

Genotype	Root Length, (cm)		Number of roots/plant		Root volume, (cm^3)		Root /shoot ratio		Relative water content		Flag leaf area, (cm^2)	
	N	D	N	D	N	D	N	D	N	D	N	D
1-Sakha 108	22.0	19.5	105.0	95.0	30.0	15.0	0.55	0.25	52.07	42.10	20.53	16.81
2-Sakha 104	22.0	21.0	144.0	100.0	40.0	25.0	1.16	0.21	61.17	19.08	40.22	34.35
3-IR 69116	21.0	17.0	104.0	94.0	30.0	17.0	0.52	0.21	74.14	61.01	33.21	17.10
4-Sakha 109	21.0	15.5	150.0	110.0	18.0	15.0	0.78	0.24	76.09	18.22	15.71	14.02
5-IR 65600-77	26.0	21.0	100.0	82.0	16.0	12.0	0.57	0.36	92.09	49.22	49.10	26.02
6-Nerica 9	20.0	17.0	80.0	48.0	15.0	12.0	0.43	0.38	70.24	57.09	34.52	26.11
7-Sakha Super 300	23.0	22.0	135.0	100.0	40.0	18.0	0.53	0.52	54.06	41.08	23.40	20.31
8-IET 1444	33.0	31.0	180.0	130.0	30.0	20.0	0.28	0.16	80.13	51.09	36.81	17.22
9- Sakha 108 × Sakha 104	16.0	15.0	85.0	62.0	25.0	8.0	0.83	0.30	89.15	44.24	40.50	22.89
10- Sakha 108 × IR 69116	20.0	16.0	120.0	65.0	15.0	9.0	0.64	0.28	87.31	50.06	25.01	21.61
11- Sakha 108 × Sakha 109	26.0	18.0	98.0	60.0	30.0	8.0	0.38	0.22	75.11	60.13	29.30	27.69
12- Sakha 108 × IR 65600-77	28.0	22.0	185.0	115.0	43.0	28.0	0.56	0.24	66.07	50.08	45.20	30.47
13- Sakha 108 × Nerica 9	21.0	13.0	170.0	112.0	40.0	25.0	0.50	0.26	64.05	51.19	31.32	19.95
14- Sakha 108 × Sakha Super 300	23.0	18.0	128.0	88.0	24.0	20.0	0.56	0.22	87.02	49.16	34.43	32.88
15- Sakha 108 × IET 1444	36.0	31.0	192.0	148.0	51.0	32.0	0.68	0.41	77.15	54.07	37.20	25.61
16- Sakha 108 × IR 69116	26.0	13.5	91.0	76.0	30.0	23.0	0.37	1.16	75.08	60.15	26.02	20.68
17- Sakha 104 × Sakha 109	23.0	11.0	85.0	50.0	25.0	10.0	0.56	1.37	61.22	32.13	29.53	17.74
18- Sakha 104 × IR 65600-77	18.0	15.0	120.0	92.0	40.0	17.0	0.87	1.20	90.32	68.03	62.52	15.60
19- Sakha 104 × Nerica 9	16.0	13.0	140.0	60.0	35.0	15.0	0.84	0.27	59.17	57.27	22.10	20.11
20- Sakha 104 × Sakha Super 300	26.0	19.0	156.0	126.0	60.0	28.0	0.96	0.25	91.02	59.02	29.22	18.61
21- Sakha 104 × IET 1444	27.0	22.5	165.0	89.0	50.0	33.0	1.03	0.21	50.20	41.10	23.02	21.22
22- IR 69116 × Sakha 109	27.2	18.0	90.0	70.0	25.0	13.0	0.29	0.25	71.30	53.07	24.92	18.41
23- IR 69116 × IR 65600-77	35.0	14.0	180.0	120.0	40.0	22.0	1.40	0.11	89.25	39.17	53.80	34.33
24- IR 69116 × Nerica 9	28.0	23.5	89.0	65.0	30.0	14.0	0.92	0.23	81.06	77.07	35.71	26.20
25- IR 69116 × Sakha Super 300	25.0	30.0	195.0	120.0	40.0	21.0	0.61	0.20	91.74	80.13	41.42	35.30
26- IR 69116 × IET 1444	26.0	21.0	150.0	76.0	40.0	19.0	0.46	0.22	88.08	61.27	39.40	20.41
27- Sakha 109 × IR 65600-77	28.0	17.0	120.0	100.0	20.0	14.0	0.49	0.25	80.22	73.13	25.90	22.61
28- Sakha 109 × Nerica 9	31.0	21.0	180.0	150.0	80.0	26.0	0.36	0.22	68.15	57.11	28.60	16.30
29- Sakha 109 × Sakha Super 300	29.2	21.0	150.0	125.0	53.0	35.0	0.63	0.40	69.07	48.15	38.21	29.30
30- Sakha 109 × IET 1444	29.0	18.0	170.0	145.0	50.0	27.0	0.61	0.34	69.08	52.30	34.20	33.32
31- IR 65600-77 × Nerica 9	35.0	21.5	240.0	200.0	31.0	25.0	0.24	0.90	95.07	81.00	87.93	35.90
32- IR 65600-77 × Sakha Super 300	26.0	18.0	170.0	118.0	50.0	12.0	0.18	0.24	94.07	61.23	46.26	32.32
33- IR 65600-77X IET 1444	35.0	21.0	210.0	111.0	75.0	27.0	0.53	0.21	94.25	76.00	37.41	21.72
34- Nerica 9 × Sakha Super 300	26.0	19.0	225.0	150.0	90.0	32.0	0.68	0.46	84.00	52.22	74.72	18.22
35- Nerica 9 × IET 1444	35.0	14.0	235.0	120.0	60.0	27.0	0.91	0.29	98.07	98.07	43.86	25.02
36- Sakha Super 300 × IET 1444	31.0	28.0	210.0	110.0	50.0	25.0	0.87	0.73	72.13	64.27	33.96	16.02
L.S.D :0.05	1.59	1.53	8.16	8.16	4.79	3.27	1.04	0.05	3.45	3.27	1.62	1.74
:0.01	2.12	2.03	10.8	10.8	6.37	4.34	1.39	0.07	4.58	4.36	2.16	2.31

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

Table 2. Continued

Genotype	Leaf rolling		Chlorophyll content (SPAD)		No. of panicles /plant		Fertility (%)		1000-grain weight, (g)		Grain yield /plant, (g)	
	N	D	N	D	N	D	N	D	N	D	N	D
1-Sakha 108	2	5.00	44.13	34.15	17.0	14.0	88.20	73.04	28.0	22.0	45.00	23.00
2-Sakha 104	1.33	3.66	41.30	28.63	24.0	13.0	93.33	64.00	27.0	22.0	49.00	24.16
3-IR 69116	2	4.00	51.00	38.21	12.0	10.0	98.13	93.01	28.0	25.0	30.00	26.00
4-Sakha 109	1.33	6.00	40.23	23.53	20.0	10.0	89.26	59.21	27.0	22.0	48.00	26.14
5-IR 65600-77	1.66	3.00	43.23	35.13	18.0	12.0	94.25	90.31	36.0	25.0	50.00	17.25
6-Nerica 9	1.33	2.00	48.73	40.10	15.0	13.0	95.22	85.17	31.0	30.0	31.00	24.08
7-Sakha Super 300	2	5.33	45.13	34.11	14.0	11.0	97.07	94.23	27.0	22.0	46.00	20.00
8-IET 1444	2	3.00	43.00	42.10	20.0	17.0	98.22	97.00	21.0	19.0	52.00	40.16
9- Sakha 108 × Sakha 104	2	4.00	44.03	39.67	23.0	10.0	96.18	75.29	28.0	22.0	54.00	26.00
10- Sakha 108 × IR 69116	1.33	5.33	44.48	41.61	19.0	9.0	94.26	56.02	25.0	19.0	44.00	18.00
11- Sakha 108 × Sakha 109	2	4.33	42.08	32.06	21.0	9.0	93.12	63.07	29.0	21.0	56.00	24.16
12- Sakha 108 × IR 65600-77	2	3.66	45.11	36.03	20.0	14.0	93.01	78.29	30.0	25.0	59.00	26.06
13- Sakha 108 × Nerica 9	2	3.00	46.55	35.6	23.0	13.0	91.29	69.14	29.0	23.0	69.00	33.16
14- Sakha 108 × Sakha Super 300	1.33	3.66	47.45	45.05	25.0	19.0	95.09	93.19	21.0	16.0	51.08	44.00
15- Sakha 108 × IET 1444	2	3.33	46.42	46.22	22.0	17.0	97.10	89.11	25.0	22.0	65.00	30.07
16- Sakha 108 × IR 69116	2	3.00	47.63	42.16	23.0	9.0	95.16	83.20	27.0	14.0	45.00	18.06
17- Sakha 104 × Sakha 109	2	5.00	41.05	37.16	21.0	9.0	95.23	72.32	27.0	21.0	62.22	25.30
18- Sakha 104 × IR 65600-77	2	4.00	44.21	40.00	18.0	13.0	96.07	74.27	27.0	22.0	59.00	23.21
19- Sakha 104 × Nerica 9	2	5.00	43.03	40.40	17.0	11.6	96.06	83.01	27.0	22.0	55.11	23.16
20- Sakha 104 × Sakha Super 300	2	4.33	45.25	34.06	23.0	14.0	96.26	81.31	27.0	23.0	59.16	31.16
21- Sakha 104 × IET 1444	1.33	3.33	43.25	27.05	21.0	18.0	95.22	86.16	24.0	23.0	64.11	38.25
22- IR 69116 × Sakha 109	2	5.33	51.13	36.07	16.0	12.0	94.10	87.31	28.0	26.0	47.00	27.10
23- IR 69116 × IR 65600-77	2	5.00	42.16	33.33	26.0	9.0	93.03	90.10	32.0	23.0	46.08	22.16
24- IR 69116 × Nerica 9	2	3.66	48.65	37.11	20.0	12.0	97.32	92.03	22.0	20.0	61.00	34.10
25- IR 69116 × Sakha Super 300	2	3.33	40.10	36.07	22.0	16.0	94.22	86.12	27.0	25.0	63.11	42.00
26- IR 69116 × IET 1444	2	2.66	45.00	44.36	17.0	11.0	97.13	47.20	28.0	14.0	46.00	27.16
27- Sakha 109 × IR 65600-77	2	4.66	45.01	38.07	25.0	18.0	93.02	83.25	27.0	24.0	49.00	39.00
28- Sakha 109 × Nerica 9	2	2.33	40.26	36.63	24.0	17.0	96.25	55.07	29.0	26.0	43.00	38.00
29- Sakha 109 × Sakha Super 300	2	5.66	42.07	37.07	23.0	12.0	95.25	83.13	28.0	24.0	60.00	35.00
30- Sakha 109 × IET 1444	2	2.00	43.06	40.06	18.0	13.0	97.30	91.10	28.0	20.0	50.00	31.22
31- IR 65600-77 × Nerica 9	2	2.00	45.21	35.61	20.0	16.0	86.24	74.16	38.0	32.0	57.06	45.00
32- IR 65600-77 × Sakha Super 300	2	2.66	36.32	33.58	28.0	19.0	94.32	91.33	28.0	25.0	67.00	40.00
33- IR 65600-77 × IET 1444	1.33	2.00	34.43	31.13	24.0	17.0	88.31	83.07	31.0	22.0	40.05	35.00
34- Nerica 9 × Sakha Super 300	2	4.66	37.57	32.58	21.0	11.0	95.31	94.10	27.0	24.0	69.20	36.16
35- Nerica 9 × IET 1444	1.66	4.00	45.21	44.01	23.0	17.0	96.26	92.10	20.0	17.0	52.25	45.00
36- Sakha Super 300 × IET 1444	1.66	1.66	42.10	38.20	23.0	15.0	98.25	89.03	23.0	21.0	48.16	37.16
L.S.D : 0.05	1.54	0.69	3.36	3.47	1.61	1.62	3.28	3.28	1.6	1. 6	3.27	3.28
: 0.01	2.05	0.92	4.47	4.61	2.15	2.16	4.36	4.36	2.1	2.2	4.35	4.36

***and ** significant at 0.05 and 0.01 probability levels, respectively. D = water deficit, N = normal irrigation.**

The cross, IR 65600-77 × Nerica 9 exhibited the highest mean values for 1000-grain weight (32.0 g, and 38.0 g) under water stress and normal conditions, respectively. While the crosses Sakha 104 × IR 69116 and IR 69116×IET 1444 under water stress and Nerica 9×IET 1444 under normal conditions gave the lowest mean values. Regarding to grain yield/plant, the variety, IET 1444 recorded the highest mean values (40.16 and 52.00 g) under water deficit and normal conditions, respectively. While, the varieties IR 65600-77 and IR 69116 gave the lowest mean values of grain yield (17.25 and 30.00 g) under water deficit and normal conditions, respectively. On the other hand, the highest mean values were recorded by cross, IR 65600-77 × Nerica 9 under water deficit conditions and Nerica 9 × Sakha Super 300 under normal conditions. While the lowest mean values were recorded by crosses, Sakha 108 × IR 69116 and IR 65600-77× IET 1444 under water deficit and normal conditions mean values of 18.00 and 40.05 (g), respectively.

General and specific combining ability effects:

Data in Table 3 show that the estimates of GCA effects indicated that the parent IET 1444 was a good combiner for root length and number of roots/plant under both conditions and root volume, leaf rolling, chlorophyll content, number of panicles/plant and grain yield/plant under water deficit conditions and fertility % under normal conditions. The parent Sakha Super 300 was a good combiner for fertility % under water deficit conditions and root volume, number of panicles/plant and grain yield/plant under normal conditions. Moreover, the parent, IR 65600-77 was good combiner for flag leaf area under both conditions and relative water content under normal conditions. Sakha 104 was a good combiner for root/shoot ratio under water deficit conditions.

The parent IR 69116 was a good general combiner for chlorophyll content under normal conditions. Nerica 9 was a good combiner for 1000-grain weight under both conditions and relative water content under water deficit conditions. In addition, the results also revealed that among the studied parents, highly significant and positive estimates of GCA of root length were recorded for IET 1444 under both conditions, Sakha Super 300 under water deficit conditions and IR 65600-77 under normal conditions, indicating that these three parents were the greatest combiners for improving this trait under water deficit and normal conditions. IET 1444, Sakha Super 300, IR 65600-77 and Nerica 9 were found to be good combiners for number of roots/plant under water deficit and normal conditions. Highly significant and positive estimates of GCA of root volume were recorded for IET 1444, Sakha Super 300 under both conditions and Nerica.9 under normal conditions. Sakha 104, IR 65600-77 and Sakha 109 were found to be good combiners for root/shoot ratio under water deficit conditions.

Table 3. Estimates of general combining ability (GCA) effects for root characteristics, yield and yield components under water deficit and normal conditions.

Parent	Root Length		Number of roots/plant		Root volume		Root /shoot ratio		Relative water content		Flag leaf area, cm^2	
	N	D	N	D	N	D	N	D	N	D	N	D
1-Sakha 108	-2.11**	-0.20	-14.88**	-8.05**	-6.73**	-2.23**	-0.04	-0.10**	-4.46**	-5.43**	-4.98**	0.16
2-Sakha 104	-3.91**	-2.30**	-20.68**	-16.55**	-1.03*	0.18	0.21	0.17**	-5.61**	-9.73**	-2.04**	-0.76**
3-IR 69116	-0.59**	-0.40*	-21.38**	-14.05**	-7.53**	-2.73**	0.00	-0.06**	3.75**	4.55**	-2.11**	-0.19
4-Sakha 109	0.03	-1.90**	-14.38**	-0.05	-3.63**	-1.93**	-0.08	0.01**	-4.83**	-8.50**	-9.17**	-1.97**
5-IR 65600-77	2.19**	-0.35*	8.83**	9.95**	-2.43**	-1.33**	-0.03	0.04**	9.88**	4.97**	12.34**	3.19**
6-Nerica 9	-0.31	-1.50**	10.23**	3.25**	4.08**	0.58	-0.04	-0.01**	-0.46	9.07**	5.95**	0.08
7-Sakha Super 300	-0.29	2.30**	16.73**	11.65**	9.18**	2.68**	-0.01	0.01**	0.26	-0.11	1.12**	1.02**
8-IET 1444	4.99**	4.35**	35.53**	13.85**	8.08**	4.78**	0.01	-0.07**	1.46**	5.18**	-1.11**	-1.53**
L.S.D :0.05	0.33	0.32	1.71	1.71	1.00	0.68	0.22	0.01	0.72	0.68	0.34	0.36
:0.01	0.44	0.42	2.27	2.27	1.33	0.91	0.29	0.01	0.96	0.91	0.45	0.48

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

Table 3. Continued

Parent	Leaf rolling		Chlorophyll content		No. of panicles /plant		Fertility (%)		1000-grain weight		Grain yield / plant	
	N	D	N	D	N	D	N	D	N	D	N	D
1-Sakha 108	0.01	0.34**	1.05**	1.25**	0.05	-0.12	-1.46**	-5.47**	-4.0**	-0.9**	1.51**	-2.64**
2-Sakha 104	-0.06	0.21**	-0.28	-1.43**	0.75**	-0.95**	0.58	-4.13**	-6.0**	-1.0**	2.33**	-4.04**
3-IR 69116	0.08	0.24**	2.73**	1.55**	-1.95**	-2.22**	1.05**	0.32	-2.0	-1.0**	-6.10**	-3.33**
4-Sakha 109	0.01	0.74**	-0.88*	-2.74**	0.15	-1.02**	-0.82*	-7.12**	3.0*	0.5**	-0.99**	-0.18
5-IR 65600-77	0.01	-0.39**	-1.50**	-1.36**	1.05**	0.98**	-2.65**	1.41**	3.80**	2.2**	0.42	-0.89*
6-Nerica 9	-0.03	-0.53**	1.01**	1.05**	-0.85**	0.35*	0.62	2.13**	7.0**	2.4**	-0.45	2.89**
7-Sakha Super 300	0.04	0.28**	-1.28**	-0.68	0.65**	0.78**	1.18**	8.18**	-1.20**	0.1	3.66**	3.16**
8-IET 1444	-0.06	-0.89**	-0.84*	2.36**	0.15	2.18**	1.50**	4.69**	-2.60**	-2.3**	-0.37	5.03**
L.S.D :0.05	0.32	0.14	0.70	0.73	0.34	0.34	0.69	0.69	0.3	0.3	0.68	0.69
:0.01	0.43	0.19	0.93	0.96	0.45	0.45	0.91	0.91	0.4	0.5	0.91	0.71

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

Highly significant and positive estimates of GCA of relative water content and 1000-grain weight were recorded for IR 65600-77 under both conditions and Nerica 9 under water deficit conditions. IR 65600-77 and Sakha Super 300 under both conditions and Nerica 9 under normal conditions were found to be good combiners for flag leaf area. Highly significant and negative estimates of GCA of leaf rolling were recorded for IET 1444, Nerica 9 and IR 65600-77 under water deficit conditions, indicating that these parents were the greatest combiners for improving this trait. IR 69116, Sakha 108 and Nerica 9 under both conditions and IET 1444 under water deficit conditions were found to be good combiners for chlorophyll content. Moreover, Sakha Super 300 under both conditions and IET 1444, Nerica 9 under water deficit and Sakha 104 and Sakha 108 under normal conditions were the best general combiners for grain yield/plant under water deficit and normal conditions. Generally, IET 1444 was the best one, since it possessed significant and desirable GCA effects for most of the studied traits followed by Sakha Super 300, Nerica 9 and IR 65600-77 under water deficit conditions, while Sakha Super 300 and IR 65600-77 under normal conditions were the greatest combiners for improving most of the studied traits.

The estimates of SCA of twenty-eight crosses for twelve of root characteristics, yield and yield components are presented in (Table 4). Significant and highly significant positive estimates of SCA effects were recorded in eleven crosses under water deficit and twelve crosses under normal conditions for root length, the highest positive values were estimated for the crosses, Sakha 108 × IET 1444 under both conditions, IR 69116 × Sakha Super 300 and IR 69116 × Nerica 9 under water deficit conditions, IR 69116 × IR 65600-77 and IR 65600-77 × Nerica 9 under normal conditions. significant and highly significant and positive estimates of SCA effects were detected for twelve crosses under water deficit and fourteen crosses under normal conditions for number of roots/plant, The highest positive values were estimated for the crosses, IR 65600-77 × Nerica 9 under both conditions, Sakha 109 × Nerica 9 and Sakha 108 × IET 1444 under water deficit, IR 69116 × Sakha Super 300 and Nerica 9 × Sakha Super 300 under normal conditions. Significant and highly significant positive estimates of SCA effects were detected for eleven crosses under water deficit and fifteen crosses under normal conditions for root volume, the highest positive value was estimated for the crosses Sakha 109 × Sakha Super 300 and Sakha 108 × IR 65600-77 under water deficit and Sakha 109 × Nerica 9 and Nerica 9 × Sakha Super 300 under normal conditions.

Significant and highly significant positive estimates of SCA effects were detected for seven crosses under water deficit and one cross under normal conditions for root/shoot ratio. The highest positive value was estimated for the cross Sakha 104 × Sakha 109 and Sakha 104 × IR 65600-77 under water deficit and IR 69116 × IR 65600-77 under normal conditions. Highly significant positive estimates of SCA were inventoried for twelve crosses under water deficit and fourteen crosses under normal conditions for relative water content, the best hybrid combinations were Nerica 9 × IET 1444 under both conditions and Sakha 109 × IR 65600-77 under water deficit and Sakha 108 × Sakha 104 under normal conditions.

Significant and highly significant positive estimates of SCA effects were detected for thirteen and fifteen crosses for flag leave area under water deficit and normal conditions, respectively, the best crosses combinations were Sakha 109 × IET 1444 and Sakha 104 × IR 69116 under water deficit, IR 65600-77 × Nerica 9 and Nerica 9 × Sakha Super 300 under normal conditions. The estimates of SCA effects showed that highly significant negative (SCA) values were recorded in twelve, six crosses under water deficit and normal conditions for leaf rolling, respectively, the best crosses were Sakha 109 × Nerica 9 and Sakha 109 × IET 1444 under water deficit conditions, Sakha 108 × Sakha Super 300 and Sakha 108 × Sakha 109 under normal conditions.

Table 4. Estimates of specific combining ability (SCA) effects for the studied traits under water deficit and normal conditions.

Genotypes	Root length		Number of roots/plant		Root volume		Root / Shoot ratio		Relative water content		Flag leaf area, cm^2	
	N	D	N	D	N	D	N	D	N	D	N	D
Sakha 108 × Sakha 104	-4.10**	-1.83**	-27.98**	-15.68**	-6.72**	-10.20**	0.03	-0.16**	22.04**	4.13**	10.44**	-0.20
× IR 69116	-3.42**	-2.73**	7.72**	-15.18**	-10.22**	-6.30**	0.05	0.06**	10.84**	-4.33**	-4.99**	-2.03**
× Sakha 109	1.96**	0.77	-21.28**	-34.18**	0.88	-8.10**	-0.13	-0.07**	7.22**	18.78**	6.36**	5.82**
× IR 65600-77	1.80**	3.22**	42.52**	10.82**	12.68**	11.30**	0.00	-0.09**	-16.53**	-4.72**	0.75	3.44**
× Nerica 9	-2.70**	-4.63**	26.12**	14.52**	3.18*	6.40**	-0.05	-0.02	-8.21**	-7.71**	-6.74**	-3.97**
× Sakha Super 300	-0.72	-3.43**	-22.38**	-17.88**	-17.92**	-0.70	-0.01	-0.07**	14.05**	-0.57	1.19*	8.02**
× IET 1444	7.00**	7.52**	22.82**	39.92**	10.18**	9.20**	0.10	0.20**	2.97**	-0.95	6.20**	3.30**
Sakha 104 × IR 69116	0.38	4.37**	37.52**	28.32**	9.08**	7.30**	0.31	-0.29**	-14.14**	-31.01**	7.28**	11.62**
× Sakha 109	0.76	-4.13**	-28.48**	-35.68**	-9.82**	-8.50**	-0.20	0.81**	-5.52**	-4.91**	3.66**	-3.21**
× IR 65600-77	-6.40**	-1.68**	-16.68**	-3.68	3.98**	-2.10*	0.06	0.60**	8.87**	17.52**	15.13**	-10.51**
× Nerica 9	-5.90**	-2.53**	1.92	-28.98**	-7.52**	-6.00**	0.04	-0.28**	-11.95**	2.66**	-18.89**	-2.89**
× Sakha Super 300	4.08**	-0.33	11.42**	28.62**	12.38**	4.90**	0.13	-0.32**	19.20**	13.59**	-6.95**	-5.33**
× IET 1444	-0.20	1.12*	1.62	-10.58**	3.48*	7.80**	0.20	-0.28**	-22.83**	-9.62**	-10.91**	-0.17
IR 69116 × Sakha 109	1.61**	0.97*	-22.78**	-18.18**	-3.32*	-2.60**	-0.26	-0.08**	-4.80**	1.74	-0.89	-3.10**
× IR 65600-77	7.28**	-4.58**	44.02**	21.82**	10.48**	5.80**	0.79**	-0.26**	-1.56	-25.62**	6.48**	7.65**
× Nerica 9	2.78**	6.07**	-48.38**	-26.48**	-6.02**	-4.10**	0.32	-0.09**	0.59	8.18**	-5.21**	2.64**
× Sakha Super 300	-0.24	8.77**	51.12**	20.12**	-1.12	0.80	-0.01	-0.14**	10.55**	20.42**	5.32**	10.80**
× IET 1444	-4.52**	-2.28**	-12.68**	-26.08**	-0.02	-3.30**	-0.17	-0.03*	5.69**	-3.73**	5.53**	-1.54**
Sakha 109 × IR 65600-77	-0.34	-0.08	-22.98**	-12.18**	-13.42**	-3.00**	-0.03	-0.18**	-2.01*	21.39**	-14.36**	-2.29**
× Nerica 9	5.16**	5.07**	35.62**	44.52**	40.08**	7.10**	-0.15	-0.16**	-3.75**	1.27	-5.26**	-5.49**
× Sakha Super 300	3.31**	1.27**	-0.88	11.12**	7.98**	14.00**	0.09	0.00	-3.54**	1.48	9.17**	6.57**
× IET 1444	-2.14**	-3.78**	0.32	28.92**	6.08**	3.90**	0.06	0.02	-4.73**	0.35	7.40**	13.14**
IR 65600-77X Nerica 9	7.00**	4.02**	72.42**	84.52**	-10.12**	5.50**	-0.33	0.48**	8.46**	11.70**	32.55**	8.95**
× Sakha Super 300	-2.02**	-3.28**	-4.08	-5.88*	3.78**	-9.60**	-0.41	-0.19**	6.75**	1.10	-4.29**	4.43**
× IET 1444	1.70**	-2.33**	17.12**	-15.08**	29.88**	3.30**	-0.07	-0.14**	5.73**	10.58**	-10.91**	-3.61**
Nerica 9X Sakha Super 300	0.48	-1.13**	49.52**	32.82**	37.28**	8.50**	0.10	0.07**	7.02**	-12.01**	30.56**	-6.55**
× IET 1444	4.20**	-8.18**	40.72**	0.62	8.38**	1.40	0.32	-0.02	19.89**	28.55**	1.93**	2.80**
Sakha Super 300 × IET 1444	0.18	2.02**	9.22**	-17.78**	-6.72**	-2.70**	0.26	0.41**	-6.77**	3.93**	-3.14**	-7.14**
L.S.D :0.05	0.89	0.85	4.55	4.55	2.67	1.82	00.58	0.03	1.92	1.83	0.91	0.97
:0.01	1.18	1.13	6.06	6.06	3.55	2.42	0.77	0.04	2.56	2.43	1.20	1.29

***and ** significant at 0.05 and 0.01 probability levels, respectively**. **D = water deficit, N = normal irrigation**

Table 4. Continued

Genotypes	Leaf rolling		Chlorophyll content		No. of panicles /plant		Fertility (%)		1000-grain weight, g		Grain yield/plant	
	N	D	N	D	N	D	N	D	N	D	N	D
Sakha 108 × Sakha 104	0.21	-0.20	-0.19	-0.32	1.48**	-2.29**	2.50**	4.34**	1.5**	1.6**	-2.42*	2.25*
× IR 69116	-0.59	-2.03**	-0.69**	0.98**	0.18	-2.02**	0.11	-19.37**	-1.9**	-1.4**	-3.98**	-6.46**
× Sakha 109	0.14	5.82**	-1.15**	-0.52**	0.08	-3.22**	0.84	-4.89**	1.6**	-1.0*	2.91**	-3.44**
× IR 65600-77	0.14	3.44**	-0.32	-0.05	-1.82**	-0.22	2.56**	1.81	-0.9*	1.4**	4.66**	-0.83
× Nerica 9	0.17	-3.97**	0.21	-0.59**	3.08**	-0.59	-2.43**	-8.06**	1.2**	-0.8	15.37**	2.49**
× Sakha Super 300	-0.56	8.02**	-1.19**	-0.72**	3.58**	4.98**	0.81	9.93**	-4.9**	-5.5**	-6.65**	13.05**
× IET 1444	0.21	3.30**	0.08	0.11	1.08*	1.58**	2.50**	9.35**	0.5	2.9**	11.29**	-2.75**
Sakha 104 × IR 69116	-0.53	11.62**	0.51*	-0.55**	4.48**	2.81**	-2.86**	-12.73**	0.3	1.7**	0.19	1.10
× Sakha 109	0.21	-3.21**	-0.62**	0.28	-0.62	-2.39**	0.91	3.03**	-0.2	-0.9*	8.31	-0.91
× IR 65600-77	0.21	-10.51**	-0.12	0.41*	-4.52**	-0.39	3.58**	-3.55**	-3.7**	-1.5**	3.67**	-2.29*
× Nerica 9	0.24	-2.89**	0.41	1.55**	-3.62**	-1.09*	0.31	4.47**	-0.6	-1.7**	0.66	-6.11**
× Sakha Super 300	0.17	-5.33**	-0.65**	0.08	0.88	0.81	-0.06	-3.28**	1.3**	1.6**	0.60	1.61
× IET 1444	-0.39	-0.17	-0.05	0.25	-0.62	3.41**	-1.42	5.06**	-0.3	4.0**	9.46**	6.83**
IR 69116 × Sakha 109	0.07	-3.10**	-0.12	0.58**	-2.92**	1.88**	-0.68	13.58**	0.4	4.1**	1.52	0.18
× IR 65600-77	0.07	7.65**	-0.29	1.38**	6.18**	-3.12**	0.08	7.83**	0.9*	-0.5	-0.81	-4.04**
× Nerica 9	0.11	2.64**	0.25	0.18	2.08**	0.51	1.10	9.05**	-6.0**	-3.7**	14.98**	4.11**
× Sakha Super 300	0.04	10.80**	-0.15	-0.95**	2.58**	4.08**	-2.57**	-2.91**	0.9*	3.6**	12.98**	11.74**
× IET 1444	0.14	-1.54**	-0.22	-0.45*	-1.92**	-2.32**	0.02	-38.35**	3.3**	-5.0**	-0.11	-4.97**
Sakha 109 × IR 65600-77	0.14	-2.29**	0.25	0.55**	3.08**	4.68**	1.94*	8.42**	-4.6**	-1.1*	-3.00**	9.64**
× Nerica 9	0.17	-5.49**	0.45*	-1.65**	3.98**	4.31**	1.90*	-20.47**	0.5	0.8	-8.13**	4.86**
× Sakha Super 300	0.11	6.57**	-0.29	0.88**	1.48**	-1.12*	0.34	1.53	1.4**	1.0*	4.76**	1.59
× IET 1444	0.21	13.14**	-0.69**	-1.62**	-3.02**	-1.52**	2.07*	12.99**	2.8**	-0.2	-1.21	-4.06**
IR 65600-77 × Nerica 9	0.17	8.95**	0.61**	-0.85**	-0.92*	1.31**	1.73	6.24**	6.0**	5.1**	4.53**	12.57**
× Sakha Super 300	0.11	4.43**	0.55**	-0.99**	5.58**	3.88**	1.23	1.20	-2.1**	0.4	10.35**	7.30**
× IET 1444	-0.46	-3.61**	-0.19	-0.49*	2.08**	0.48	-5.10**	-3.57**	2.3**	-0.2	-12.57**	0.43
Nerica 9 × Sakha Super 300	0.14	-6.55**	-0.25	1.15**	0.48	-3.49**	-1.05	3.25**	0.0	-0.8	13.42**	-0.32
× IET 1444	-0.09	2.80**	0.01	1.65**	2.98**	1.11*	-0.41	4.74**	-5.6**	-4.7**	0.50	6.65**
Sakha Super 300 × IET 1444	-0.16	-7.14**	-0.05	-1.49**	1.48**	-1.32**	1.01	-4.38**	-0.7	0.9*	-7.69**	-1.46
L.S.D :0.05	0.91	0.97	0.42	0.39	0.90	0.91	1.83	1.83	0.9	0.9	1.83	1.83
:0.01	1.20	1.29	0.55	0.51	1.20	1.20	2.43	2.43	1.2	1.2	2.43	2.43

***and ** significant at 0.05 and 0.01 probability levels, respectively. D = water deficit, N = normal irrigation**

The estimates of SCA showed that significant and highly significant positive (SCA) values were recorded in twelve crosses, under water deficit conditions, their estimates were maximized in case of the crosses, Sakha 108 × Sakha Super 300 and Sakha 104 × IR 65600-77, which appeared to be the best specific cross combinations for chlorophyll content. While, under normal conditions, seven crosses showed highly significant positive estimates of (SCA) effects, the best crosses were IR 69116 × Sakha 109 and Sakha 108 × Sakha Super 300. Significant and highly significant positive estimates of SCA effects were recorded in eleven crosses under water deficit and fifteen crosses under normal conditions for number of panicles/plant,

The highest positive values were estimated for the crosses, Sakha 108 × Sakha Super 300 and Sakha 109 × IR 65600-77 under water deficit, IR 69116 × IR 65600-77 and IR 65600-77 × Sakha Super 300 under normal conditions. Highly significant positive estimates of SCA were recorded in fourteen crosses under water deficit and seven crosses under normal conditions for fertility %. The highest positive values were estimated for the crosses IR 69116 × Sakha 109 and Sakha 109 × IET 1444 under water deficit and Sakha 104 × IR 65600-77 and Sakha 108 × IR 65600-77 under normal conditions. Significant and highly significant positive estimates of SCA effects were detected for eleven crosses under water deficit and normal conditions for 1000-grain weight, The highest positive value was estimated for the cross IR 65600-77 × Nerica 9 under water deficit and normal conditions, the highest (SCA) values for 1000-grain weight could be used in breeding program for increasing this trait.

Significant and highly significant positive estimates of SCA effects were recorded in eleven, twelve crosses for grain yield/plant under water deficit and normal conditions, respectively, the highest positive values were estimated for the crosses, Sakha 108 × Sakha Super 300 and IR 65600-77 × Nerica 9 under water deficit conditions, Sakha 108 × Nerica 9 and IR 69116 × Nerica 9 under normal conditions. The results revealed that there is a preponderance of non-additive gene action for root and some vegetative characters in the hybrids resulted in high amount of vigor in F_1, selection can be postponed to later generation. These findings were in agreement with those of Gaballah (2009), El-Naem (2010), El-Hity *et al.*, (2015), Abo-Zeid (2016), Ghazy (2017), Daher (2018) and Sakran *et al. (*2022).

Estimates of heterosis

The superiority of hybrids, particularly over the better-parents, is useful in assessing the feasibility of commercial exploitation of heterosis s and identifying the parental combinations capable of producing the highest level of transgressive segregants. In this study, because the parents are highly adapted varieties, heterosis over the mid-parent and over the better-parent has high practical significance. Investigations about the degree of heterosis are important for deciding the directions of future breeding programs. In the present investigation, both mid and better parent heterosis was determined.

The range of heterosis and number of crosses showing significant desirable heterosis over mid-parent and better-parent for all the twelve characters are presented in Table 5. The highest estimated values of heterosis over mid and better-parent were observed for root length (53.85% and 38.24%), (52.17% and 47.62%) under water deficit and normal conditions, respectively. Maximum heterosis over the mid and better-parent for number of roots/plant was 207.69% and 143.90%, respectively under water deficit conditions, 166.67% and 140.00% under normal conditions. The highest estimated values of heterosis over mid and better-parent were observed for root volume (113.33% and 108.33%), (384.85% and 344.44%) under water deficit and normal conditions, respectively.

Furthermore, the highest estimated values of heterosis over mid and better-parent were observed for root/shoot ratio (508.89% and 470.83%), (156.88% and 145.61%) under water deficit and normal conditions, respectively. The highest estimated values of heterosis over mid and better-parent were observed for relative water content (35.61% and 22.39%), (228.17% and 220.80%) under water deficit and normal conditions, respectively. Maximum heterosis over the mid and better-parent for flag leaf area was 113.25% and 93.42%, respectively under water deficit conditions, 157.98% and 116.44% under normal conditions.

The highest estimated values of heterosis over mid and better-parent were observed for leaf rolling (-60.00% and -44.44%), (-33.33% and -33.33%) under water deficit and normal conditions, respectively. Maximum heterosis over the mid and better-parent for chlorophyll content was 42.49% and 31.92%, respectively under water deficit conditions, 12.09% and 5.19% under normal conditions. The highest estimated values of heterosis over mid and better-parent were observed for grain yield/plant (351.55% and 300.00%), (197.56% and 190.48%) under water deficit and normal conditions, respectively. Maximum heterosis over the mid and better-parent for number of panicles/plant was 58.33% and 46.15%, respectively under water deficit conditions and 100.00% under normal conditions.

The highest estimated values of heterosis over mid and better-parent were observed for fertility% (17.39% and 12.99%), (5.97% and 4.32%) under water deficit and normal conditions, respectively. Maximum heterosis over the mid and better-parent for 1000-grain weight was 122.00% and 90.90%, respectively under water deficit conditions, 166.70% and 55.60% under normal conditions. The highest estimated values of heterosis over mid and better-parent were observed for grain yield/plant (351.55% and 300.00%), (197.56% and 190.48%) under water deficit and normal conditions, respectively. Results further indicated that 3, 12, 13, 7, 6, 12, 7, 7, 1, 2 and 22 crosses had significant positive better-parent heterosis for root length, number of roots/plant, root volume, root/shoot ratio, relative water content, flag leave area, chlorophyll content, number of panicles/plant, fertility%, 1000-grain weight and grain yield/plant under water deficit conditions while, 16, 14, 16, 4, 20, 10, 0, 17, 0, 0 and 25 crosses under normal conditions, respectively. 4 and 3 crosses had significant negative better-parent heterosis for leaf rolling under water deficit and normal conditions, respectively.

Table 5. Estimates of heterosis as a deviation from mid and better parent of the twenty eight rice crosses for root characteristics, yield and yield components under deficit and normal conditions.

Genotypes	Root length				Number of roots/plant				Root volume				Root / Shoot ratio			
	MP		BP		MP		BP		MP		BP		MP		BP	
	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D
Sakha 108×Sakha 104	-27.27**	-25.93**	-27.27**	-28.57**	-31.73**	-36.41**	-40.97**	-38.00**	-28.57**	-60.00**	-37.50**	-68.00**	-2.92	30.43**	-28.45	20.00*
×IR 69116	-6.98*	-12.33**	-9.09*	-17.95**	14.83**	-31.22**	14.29**	-31.58**	-50.00**	-43.75**	-50.00**	-47.06**	19.63	21.74*	16.36	12.00
×Sakha 109	20.93**	2.86	18.18**	-7.69	-23.14**	-41.46**	-34.67**	-45.45**	25.00**	-46.67**	0.00	-46.67**	-42.86**	-8.84	-51.28**	-10.67
×IR 65600-77	16.67**	8.64*	7.69*	4.76	80.49**	29.94**	76.19**	21.05**	86.96**	107.41**	43.33**	86.67**	0.00	-21.31**	-1.75	-33.33**
×Nerica 9	0.00	-28.77**	-4.55	-33.33**	83.78**	56.64**	61.90**	17.89**	77.78**	85.19**	33.33**	66.67**	2.04	-17.46**	-9.09	-31.58**
×Sakha Super 300	2.22	-13.25**	0.00	-18.18**	6.67*	-9.74**	-5.19	-12.00**	-31.43**	21.21*	-40.00**	11.11	3.70	-41.99**	1.82	-57.05**
×IET 1444	30.91**	22.77**	9.09**	0.00	34.74**	31.56**	6.67**	13.85**	70.00**	82.86**	70.00**	60.00**	63.86**	100.00**	23.64	64.00**
Sakha 104×IR 69116	20.93**	-28.95**	18.18**	-35.71**	-26.61**	-21.65**	-36.81**	-24.00**	-14.29	9.52	-25.00**	-8.00	-55.95**	452.38**	-68.10**	452.38**
×Sakha 109	6.98*	-39.73**	4.55	-47.62**	-42.18**	-52.38**	-43.33**	-54.55**	-13.79	-50.00**	-37.50**	-60.00**	-42.27**	508.89**	-51.72**	470.83**
×IR 65600-77	-25.00**	-28.57**	-30.77**	-28.57**	-1.64	1.10	-16.67**	-8.00	42.86**	-8.11	0.00	-32.00**	0.58	321.05**	-25.00	233.33**
×Nerica 9	-23.81**	-31.58**	-27.27**	-38.10**	25.00**	-18.92**	-2.78	-40.00**	27.27**	-18.92*	-12.50*	-40.00**	5.66	-8.47	-27.59	-28.95**
×Sakha Super 300	15.56**	-11.63**	13.04**	-13.64**	11.83**	26.00**	8.33**	26.00**	50.00**	30.23**	50.00**	12.00	13.61	-31.51**	-17.24	-51.92**
×IET 1444	-1.82	-13.46**	-18.18**	-27.42**	1.85	-22.61**	-8.33**	-31.54**	42.86**	46.67**	25.00**	32.00**	43.98**	13.51	-10.63	0.00
IR 69116×Sakha 109	29.37**	10.77*	29.37**	5.88	-29.13**	-31.37**	-40.00**	-36.36**	4.17	-18.75*	-16.67*	-23.53*	-55.38**	11.11	-62.82**	4.17
×IR 65600-77	48.94**	-26.32**	34.62**	-33.33**	76.47**	36.36**	73.08**	27.66**	73.91**	51.72**	33.33**	29.41**	156.88**	-61.40**	145.61**	-69.44**
×Nerica 9	36.59**	38.24**	33.33**	38.24**	-3.26	-8.45	-14.42**	-30.85**	33.33**	-3.45	0.00	-17.65	93.68**	-22.03**	76.92**	-39.47**
×Sakha Super 300	13.64**	53.85**	8.70*	36.36**	63.18**	23.71**	44.44**	20.00**	14.29	20.00*	0.00	16.67	16.83	-45.21**	15.72	-61.54**
×IET 1444	-3.70	-12.50**	-21.21**	-32.26**	5.63*	-32.14**	-16.67**	-41.54**	33.33**	2.70	33.33**	-5.00	15.00	20.72*	-11.54	6.35
Sakha 109×IR 65600-77	19.15**	-6.85	7.69*	-19.05**	-4.00	4.17	-20.00**	-9.09	17.65	3.70	11.11	-6.67	-27.41	-16.67*	-37.18*	-30.56**
×Nerica 9	51.22**	29.23**	47.62**	23.53**	56.52**	89.87**	20.00**	36.36**	384.85**	92.59**	344.44**	73.33**	-40.50**	-27.96**	-53.85**	-41.23**
×Sakha Super 300	32.58**	12.00**	26.81**	-4.55	5.26*	19.05**	0.00	13.64**	82.76**	112.12**	32.50**	94.44**	-3.82	5.26	-19.23	-23.08**
×IET 1444	7.41**	-22.58**	-12.12**	-41.94**	3.03	20.83**	-5.56*	11.54**	108.33**	54.29**	66.67**	35.00**	15.09	70.00**	-21.79	41.67**
IR 65600-77X Nerica 9	52.17**	13.16**	34.62**	2.38	166.67**	207.69**	140.00**	143.90**	100.00**	108.33**	93.75**	108.33**	-52.00**	143.24**	-57.89**	136.84**
×Sakha Super 300	6.12*	-16.28**	0.00	-18.18**	44.68**	29.67**	25.93**	18.00**	78.57**	-20.00*	25.00**	-33.33**	-67.27**	-44.70**	-68.42**	-53.21**
×IET 1444	18.64**	-19.23**	6.06*	-32.26**	50.00**	4.72	16.67**	-14.62**	226.09**	68.75**	150.00**	35.00**	24.71	-52.59**	-7.02	-58.97**
Nerica 9×Sakha Super 300	20.93**	-2.56	13.04**	-13.64**	109.30**	102.70**	66.67**	50.00**	227.27**	113.33**	125.00**	77.78**	41.67**	35.29**	28.30	-11.54
×IET 1444	32.08**	-41.67**	6.06*	-54.84**	80.77**	34.83**	30.56**	-7.69	166.67**	68.75**	100.00**	35.00**	156.34**	-14.71	111.63**	-44.23**
Sakha Super 300×IET 1444	10.71**	5.66	-6.06*	-9.68**	33.33**	-4.35	16.67**	-15.38**	42.86**	31.58**	25.00**	25.00**	114.81**	-98.73**	64.15**	-98.83**
LSD 0.05	1.38	1.32	1.59	1.53	7.07	7.07	8.16	8.16	4.15	2.83	4.79	3.27	0.90	0.04	1.04	0.05
0.01	1.84	1.76	2.12	2.03	9.40	9.40	10.86	10.86	5.52	3.76	6.37	4.34	1.20	0.06	1.39	0.07

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

Table 5. Continued

Genotypes	Relative water content				Flag leaf area, cm^2				Leaf rolling				Chlorophyll content			
	MP		BP		MP		BP		MP		BP		MP		BP	
	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D
Sakha 108×Sakha 104	191.42**	-21.87**	111.76**	-27.68**	33.36**	-10.53**	0.71	-33.36**	20.00*	-7.69	50.00**	9.09	3.08	24.93**	-0.23	14.84**
×IR 69116	69.35**	-20.66**	43.10**	-32.47**	-6.90*	27.42**	-24.67**	26.34**	-33.33**	18.52	-33.33**	33.33**	-6.48	15.02**	-12.78**	8.90
×Sakha 109	149.01**	-5.43**	78.41**	-19.93**	61.72**	79.59**	42.75**	64.68**	20.00*	-21.21**	50.00**	-13.33	-0.24	11.18*	-4.65	-6.10
×IR 65600-77	-1.53	-1.11	-28.25**	-3.82*	29.84**	42.25**	-7.94**	17.09**	9.09	-8.33	20.00	22.22	3.27	4.03	2.21	2.57
×Nerica 9	30.46**	-16.29**	14.18**	-27.11**	13.79**	-7.04*	-9.27**	-23.58**	20.00*	-14.29	50.00**	50.00**	0.25	-4.11	-4.48	-11.22*
×Sakha Super 300	109.24**	-7.36**	106.71**	-9.07**	56.73**	77.11**	47.09**	61.86**	-33.33**	-29.03**	-33.33**	-31.25**	6.31	31.98**	5.13	31.92**
×IET 1444	65.58**	-18.20**	51.01**	-32.52**	29.76**	50.47**	1.06	48.68**	0.00	-16.67*	0.00	11.11	6.56	21.25**	5.19	9.80*
Sakha 104×IR 69116	87.48**	-11.09**	23.06**	-18.86**	-29.11**	-19.62**	-35.29**	-39.80**	20.00*	-21.74**	50.00**	-18.18	3.21	26.15**	-6.60*	10.34*
×Sakha 109	228.17**	-52.84**	220.80**	-57.21**	5.59*	-26.63**	-26.58**	-48.34**	50.00**	3.45	50.00**	36.36**	0.70	42.49**	-0.61	29.80**
×IR 65600-77	62.49**	23.24**	-1.92	11.20**	39.99**	-48.31**	27.33**	-54.58**	33.33**	20.00*	50.00**	33.33**	4.61	25.46**	2.27	13.85**
×Nerica 9	57.42**	-12.84**	5.48**	-18.47**	-40.86**	-33.47**	-45.05**	-41.45**	50.00**	76.47**	50.00**	150.00**	-4.41	17.56**	-11.70**	0.75
×Sakha Super 300	202.60**	2.43	121.58**	-3.52*	-8.14**	-31.90**	-27.34**	-45.81**	20.00*	-3.70	50.00**	18.18	4.70	8.58	0.26	-0.15
×IET 1444	43.08**	-41.83**	-1.74	-48.71**	-40.23**	-17.71**	-42.76**	-38.22**	-20.00*	0.00	0.00	11.11	2.61	-23.52**	0.58	-35.75**
IR 69116×Sakha 109	79.98**	-28.87**	16.87**	-29.33**	1.87	18.32**	-24.96**	7.66	20.00*	6.67	50.00**	33.33**	12.09**	16.84**	0.26	-5.61
×IR 65600-77	16.59**	-36.49**	-3.08	-47.16**	30.74**	59.18**	9.58**	31.90**	9.09	42.86**	20.00	66.67**	-10.51**	-9.11	-17.32**	-12.78**
×Nerica 9	38.45**	6.76**	32.87**	3.95*	5.46*	21.26**	3.46**	0.36	20.00*	22.22*	50.00**	83.33**	-2.44	-5.23	-4.61	-7.46
×Sakha Super 300	79.72**	25.01**	50.37**	8.08**	69.34**	88.69**	24.73**	73.79**	0.00	-28.57**	0.00	-16.67	-16.57**	-0.26	-21.37**	-5.61
×IET 1444	57.15**	-20.57**	44.37**	-23.54**	12.54**	18.93**	7.03**	18.52**	0.00	-23.81**	0.00	-11.11	-4.26	10.48**	-11.76**	5.38
Sakha 109×IR 65600-77	45.44**	17.65**	-12.89**	-2.61	-20.08**	12.93**	-47.25**	-13.11**	33.33**	3.70	50.00**	55.56**	7.87*	29.80**	4.12	8.37
×Nerica 9	83.40**	-21.40**	21.49**	-23.94**	13.87**	-18.77**	-17.15**	-37.57**	50.00**	-41.67**	50.00**	16.67	-9.48**	15.14**	-17.37**	-8.65*
×Sakha Super 300	132.94**	-25.44**	68.14**	-35.88**	95.35**	70.68**	63.24**	44.26**	20.00*	0.00	50.00**	6.25	-1.44	28.60**	-6.79	8.66*
×IET 1444	99.33**	-32.61**	35.22**	-34.73**	30.24**	113.25**	-7.09**	93.42**	20.00*	-55.56**	50.00**	-33.33**	3.48	22.09**	0.16	-4.83
IR 65600-77×Nerica 9	28.32**	35.61**	3.24	15.32**	110.29**	37.73**	79.07**	37.51**	33.33**	-20.00	50.00**	0.00	-1.67	-5.32	-7.22*	-11.18*
×Sakha Super 300	41.28**	18.56**	2.15	13.26**	27.61**	39.49**	-5.78**	24.18**	9.09	-36.00**	20.00*	-11.11	-17.80**	-3.01	-19.53**	-4.41
×IET 1444	31.66**	17.51**	2.35	-5.15**	-12.92**	0.45	-23.81**	-16.53**	-27.27**	-33.33**	-20.00*	-33.33**	-20.14**	-19.38**	-20.35**	-26.05**
Nerica 9×Sakha Super 300	72.90**	-15.98**	49.76**	-25.65**	157.98**	-21.48**	116.44**	-30.19**	20.00*	27.27**	50.00**	133.33**	-19.94**	-12.19**	-22.89**	-18.74**
×IET 1444	83.00**	30.44**	74.84**	22.39**	22.96**	15.50**	19.13**	-4.15	0.00	60.00**	25.00	100.00**	2.61	7.10	0.18	4.55
Sakha Super 300×IET 1444	56.53**	-4.21**	41.20**	-19.79**	12.79**	-14.62**	-7.75**	-21.10**	-16.67*	-60.00**	-16.67	-44.44**	-4.46	0.24	-6.72	-9.26*
L.S.D :0.05	2.98	2.84	3.45	3.27	1.41	1.50	1.62	1.74	1.33	0.60	1.33	0.69	2.91	3.00	3.36	3.47
:0.01	3.97	3.77	4.58	4.36	1.87	2.00	2.16	2.31	1.77	0.80	1.77	0.92	3.87	3.99	4.47	4.61

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

Table 5. Continued

Genotypes	No. of panicles /plant				Fertility (%)				1000-grain weight				Grain yield/plant			
	MP		BP		MP		BP		MP		BP		MP		BP	
	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D
Sakha 108×Sakha 104	12.20**	-25.93**	-4.17	-28.57**	5.97	3.07	3.06	3.07	1.82	0.00	0.00	0.00	45.95**	89.90**	38.46**	79.31**
× IR 69116	31.03**	-25.00**	11.76*	-35.71**	1.18	-28.64**	-3.94	-39.77**	-10.71**	-19.15**	-10.71**	-24.00**	60.00**	24.14**	25.71**	12.50*
× Sakha 109	13.51**	-25.00**	5.00	-35.71**	4.95	-13.66*	4.32	-13.66*	5.45*	-4.55	3.57	-4.55	53.42**	65.11**	47.37**	48.50**
× IR 65600-77	29.03**	3.70	17.00**	0.00	1.96	4.73	-1.32	-13.31*	-6.25**	6.38*	-16.67**	0.00	57.78**	151.65**	47.92**	100.51**
× Nerica 9	43.75**	-3.70	35.29**	-7.14	-0.46	-12.60*	-4.12	-18.82*	-1.69	-11.54**	-6.45*	-23.33**	146.43**	144.32**	97.14**	134.39**
×Sakha Super 300	61.29**	52.00**	47.06**	35.71**	2.65	11.42*	-2.04	-1.11	-23.64**	-27.27**	-25.00**	-27.27**	43.90**	282.61**	41.90**	238.46**
× IET 1444	18.92**	9.68*	10.00*	0.00	4.17	4.81	-1.15	-8.13	2.04	7.32*	-10.71**	0.00	64.56**	21.92**	47.73**	-17.23*
Sakha 104× IR 69116	27.78**	-21.74**	-4.17	-30.77**	-0.60	5.98	-3.03	-10.55*	-1.82	-40.43**	-3.57	-44.00**	52.54**	18.43*	15.38*	12.88*
× Sakha 109	-4.55	-21.74**	-12.50**	-30.77**	4.31	17.39*	2.04	12.99*	0.00	-4.55	0.00	-4.55	61.61**	64.43**	59.54**	55.47**
×IR65600-77	-5.26	0.00	-25.00**	0.00	2.43	-3.74	1.92	-17.76*	-14.29**	-6.38*	-25.00**	-12.00**	49.37**	108.94**	47.50**	60.07**
× Nerica 9	-12.82**	-10.26*	-29.17**	-10.26	1.90	11.29*	0.89	-2.54	-6.90**	-15.38**	-12.90**	-26.67**	83.70**	61.72**	41.31**	63.72**
×Sakha Super 300	21.05**	16.67**	-4.17	7.69	1.12	2.77	-0.83	-13.71*	0.00	4.55	0.00	4.55	57.78**	154.42**	51.71**	114.94**
× IET 1444	-4.55	20.00**	-12.50**	5.88	-0.58	7.03	-3.06	-11.17	0.00	12.20**	-11.11**	4.55	54.22**	50.49**	45.45**	5.28
	0.00	20.00**	-20.00**	20.00**	0.43	14.71*	-4.11	-6.13	1.82	10.64**	0.00	4.00	62.07**	67.94**	23.68**	66.53**
× IR 65600-77	100.00**	-21.74**	85.71**	-30.77**	-3.28	-1.71	-5.19	-3.14	0.00	-8.00**	-11.11**	-8.00*	53.61**	86.93**	15.21*	38.54**
× Nerica 9	48.15**	4.35	33.33**	-7.69	0.67	3.30	-0.83	-1.05	-25.42**	-27.27**	-29.03**	-33.33**	197.56**	126.20**	190.48**	113.13**
×Sakha Super 300	69.23**	52.38**	57.14**	45.45**	-3.46	-8.01	-3.98	-8.60	-1.82	6.38*	-3.57	0.00	125.39**	223.08**	75.31**	162.50**
× IET 1444	6.25	-18.52**	-15.00**	-35.59**	-1.07	-50.32**	-1.12	-51.34**	14.29**	-36.36**	0.00	-44.00**	43.75**	3.82	4.55	-25.23**
Sakha 109×IR65600-77	47.06**	56.52**	25.00**	38.46**	1.38	11.35*	-1.30	-7.82	-14.29**	2.13	-25.00**	-4.00	25.64**	225.14**	22.50**	139.66**
× Nerica 9	37.14**	47.83**	20.00**	30.77**	4.35	-23.71**	1.08	-35.34**	0.00	0.00	-6.45*	-13.33**	45.76**	149.81**	13.16*	133.51**
×Sakha Super 300	35.29**	14.29*	15.00**	9.09	2.25	8.36	-1.87	-11.78*	3.70	9.09**	3.70	9.09*	62.16**	166.43**	57.89**	115.08**
× IET 1444	-10.00**	3.70-	-10.00*	-23.53**	3.80	16.63*	-0.94	-6.09	16.67**	-8.10	3.70	-7.58*	21.95**	18.69*	13.64*	-14.07*
IR65600-77×Nerica 9	37.93**	23.08**	33.00**	23.08**	-0.51	2.93	-1.01	0.00	13.43**	16.36**	5.56	6.67*	87.10**	311.59**	42.67**	218.02**
×Sakha Super 300	100.00**	58.33**	100.00**	46.15**	-1.40	-1.02	-2.83	-3.08	-11.11**	6.38*	-22.22**	0.00	76.32**	351.55**	67.50**	300.00**
× IET 1444	41.18**	13.33*	20.00**	0.00	-8.24	-11.31*	-10.09	-14.37*	8.77**	0.00	-13.89**	-12.00**	-4.63	58.91**	-8.97	-3.67
Nerica 9×Sakha Super 300	44.83**	-8.33	40.00**	-15.38*	-1.81	4.90	-1.81	-0.14	-6.90**	-7.69**	-12.90**	-20.00**	142.81**	199.52**	92.22**	155.59**
× IET 1444	31.43**	13.33*	15.00**	0.00	-2.00	1.11	-2.00	-5.06	-23.08**	-27.89**	-35.48**	-41.11**	60.77**	94.24**	18.75*	23.85**
Sakha Super 300×IET 1444	35.29**	7.14	15.00**	-11.76*	0.03	-6.89	0.03	-8.22	-41.7	24.4	-14.81**	-45.5	20.42**	60.43**	9.47	2.29
L.S.D :0.05	1.40	1.41	1.61	1.62	3.28	2.84	3.28	3.28	1.4	1.4	1.6	1.6	2.83	2.84	3.27	3.28
:0.01	1.86	1.87	2.15	2.16	4.36	3.78	4.36	4.36	1.9	1.9	2.1	2.2	3.77	3.77	4.35	3.77

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

It is clear from Table 5 that most of the studied hybrids were superior for root length; their estimated values of heterosis were highly significant with positive direction for this trait, out of them, IR 69116 × Sakha Super 300 and IR 69116 × Nerica 9 under water deficit, IR 65600-77 × Nerica.9 and Sakha 109 × Nerica 9 under normal conditions. Moreover, highly significant positive estimates of heterosis for mid and better-parent were recorded in IR 65600-77 × Nerica 9 and Nerica 9 × Sakha Super 300, rice genotypes for number of roots/plant under both conditions.

On the other hand, Nerica.9 × Sakha Super 300 under both conditions, Sakha 109 × Sakha Super 300 under water deficit, Sakha 109 × Nerica 9 under normal conditions rice hybrid exhibited either highly significant positive estimates of heterosis for root volume. Highly significant positive estimates of heterosis for mid and better-parent were recorded in Sakha 104 × Sakha 109 and Sakha 104 × IR 69116 under water deficit, IR 69116 × IR 65600-77 and Nerica 9 × IET 1444 under normal conditions, rice genotypes for root/shoot ratio under both conditions. On the other hand, Nerica 9 × IET 1444 and IR 65600-77 × Nerica 9 under water deficit, Sakha 104 × Sakha 109 and Sakha 104 × Sakha Super 300 under normal conditions rice hybrid exhibited either highly significant positive estimates of heterosis for relative water content.

Highly significant positive estimates of heterosis for mid and better-parent were recorded in Sakha 109 × IET 1444 and IR 69116 × Sakha Super 300 under water deficit Nerica.9 × Sakha Super 300 and IR 65600-77 × Nerica 9, rice genotypes for flag leaf área under normal conditions. Moreover, Sakha Super 300 × IET 1444 and Sakha 109 × IET 1444 under water deficit, Sakha 108 × IR 69116 and Sakha 108 × Sakha Super 300 under normal conditions rice hybrid exhibited either highly significant negative estimates of heterosis for leaf rolling.

Highly significant positive estimates of heterosis for better-parent were recorded in Sakha 104 × Sakha 109 and Sakha 108 × Sakha Super 300, rice genotypes for chlorophyll content under water deficit conditions. High estimated values of mid and better parent heterosis were recorded in IR 656-77 × Sakha Super 300 under water deficit and normal conditions, IR 69116 × Sakha Super 300 under deficit and IR 69116 × IR 65600-77 under normal conditions exhibited highly significant and positive estimates of heterosis for number of panicles/plant.

On the other hand, among 28 crosses, only two, crosses namely, IR 65600-77 × Nerica 9 and Sakha 109 × Sakha Super 300 recorded significant positive mid and better parent heterosis for 1000-grain weight under water deficit conditions.

The cross Sakha 104 × Sakha 109 exhibited highest positive heterosis for fertility % measured as a deviation from mid-parent and better parent under water deficit conditions. On the other hand, IR 65600-77 × Sakha Super 300 and Sakha 108 × Sakha Super 300 under water deficit, IR 69116 × Nerica 9 and Sakha 108 × Nerica 9 under normal conditions rice hybrid exhibited either highly significant positive estimates of heterosis for grain yield/plant. These results were in harmony with that observed by Abd El-Lattef and Mady (2009), El-Naem (2010), El-Gamal (2013), El-Naem (2014), Ghazy (2017), Daher (2018) and Sakran *et al. (*2022).

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السلوك الوراثي لبعض صفات جذور الأرز والمحصول ومكوناته تحت ظروف نقص المياه

الحسينى محمد عبد الخالق ضاهر ، صبرى على الناعم ، أحمد جمال حفينه و حنان عبد العاطى نبيه طه

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

الملخص

تم التهجين بين ثمانية تراكيب وراثية بنظام التهجين التبادلى (دايلل) فى إتجاة واحد اقيمت تجربة حقلية فى المزرعة البحثية لمحطة بحوث سخا – كفر الشيخ – مصر وذلك خلال موسمي زراعة الأرز 2020 – و2021 وذلك بهدف دراسة طبيعة الفعل الجينى المتحكم فى وراثة لبعض صفات الجذوروالمحصول ومكوناته المدروسة تحت ظروف الري العادي والجفاف لإكتشاف سلوك القدرة على التالف للتراكيب الوراثية المستخدمة فى الدراسة. تمت الدراسة على بعض صفات الجذر والمحصول ومكوناته تحت ظروف ندره المياه والظروف الطبيعيه. أوضحت النتائج أن النسبة بين كل من تباين القدرة العامة على التآلف و تباين القدرة الخاصة على التآلف أقل من الواحد الصحيح مشيرة إلى أهمية الفعل الجينى السيادى والتفوقى فى التحكم فى السلوك الوراثى لجميع الصفات المدروسه. كما أوضحت تأثيرات القدرة العامة على الإئتلاف أن الاب أى إى تى 1444 كان أفضل الأباء فى معظم الصفات المدروسه. بينما كان الهجين أى أر 77- 65600 × نيركا9. افضل التراكيب الوراثية للقدرة الخاصة على التالف لمعظم الصفات المدروسه. كما أظهرت النتائج أن هذا الهجين اظهر معنويه عاليه وموجبه لقوة الهجين وذلك عند قياسها كإنحراف عن قيم متوسط الابوين وافضل الابوين لصفات طول الجذر وعدد الجذور لكل نبات وحجم الجذر والنسبة المئوية للوزن الجاف للمجموع الجذرى إلى المجموع الخضرى والمحتوى المائى للاوراق ومساحه الورقه العلم ووزن الالف حبه ومحصول النبات الفردى تحت ظروف ندره المياه ما عدا طول الجذر للاب الافضل كان غير معنوى.