J. of Plant Production, Mansoura Univ.,Vol 12 (1):73 - 86, 2021

Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Assessment of Some Agro-Physiological Traits and Genetic Markers in Rice (*Oryza sativa* L.) Under Normal and Water Stress Conditions

Ghidan, W. F. [1*] and Rania A. Khedr[2]

[1]Rice Research Department, Field Crops Research Institute, Agricultural Research Center, Egypt
[2]Crop Physiology Research Department, Field Crops Research Institute, Agricultural Research Center, Egypt

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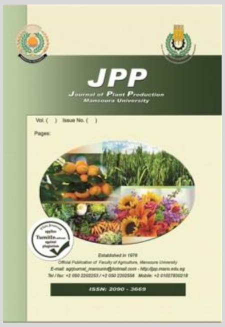

ABSTRACT

Water stress is a serious abiotic stress that causes extreme loss of rice yield. Keeping these in view, fifteen hybrids along with their eight parents were evaluated at the experimental farm of Rice Research Department, Sakha, Kafr El-Sheikh, Egypt, during the two rice-growing seasons of 2019 and 2020. The analysis of variance revealed significant differences among the genotypes, crosses, lines, and lines x testers interaction for all the studied traits. Sakha 107 was identified as the potential genotype for improving grain yield under water stress based on mean value and GCA effect. While, Sakha 108 was identified as a good general combiner for improving grain yield and its related traits under irrigated condition. The significant yield reduction was observed under water stress in the majority of the rice genotypes studied. The cross combinations Sakha 107/ APO, Sakha 107/ WAB 96-1-1, Sakha 104/ WAB 96-1-1 and Sakha 101/ APO exhibited significantly low drought susceptibility index (DSI) and high yield stability index (YSI) values based on preliminary screening, and good specific combinations for certain physiological and biochemical traits, were established as genotypes tolerant to water stress. RM260, RM279 and RM514 showed the highest degree of polymorphism in the selected rice genotypes for SSR-based genotyping. Among the studied genotypes tested, the parental lines Sakha 107, IRRI 148, WAB 96-1-1 and APO were found to be more diverse based on their genetic distance. It could be considered and used for marker-assisted breeding programs as a possible water stress tolerant donor.

Keywords: Rice, water stress, combining ability, heterosis, physiological traits, genetic parameters and SSR markers.

INTRODUCTION

Rice (*Oryza sativa* L.) is a major and staple food crop in many parts of the world, feeding more than three billion people and providing 50-80 % of their daily calories intake (Muthayya *et al.,* 2014). Shortage of water for irrigation is one of the most crucial factors limiting growth and production of almost all the crops, including rice worldwide (Hossain *et al.,* 2020). Drought stress severely impairs its production, when exposed to water stress at critical growth stages, particularly at the reproductive stage; it is a drought-susceptible crop with serious deleterious effects (Suriyan *et al.,* 2010). Global climate change and arithmetically multiplying world populace augmented with drought stress are making the situation more serious and to cope with the ever-growing food, feed and shelter needs of human beings is becoming more difficult day-by-day (Honogbo *et al.,* 2005). The yield of crops depends on specific climate conditions and strongly influenced by climate change. The overall rice yield variability due to climate variability over the last three decades. In addition, it was concluded that approximately 53% of rice harvesting regions experiencing the influence of climate variability on yield at the rate of about 0.1 t/hm^2 per year and approximately 32% of rice yield variability is explained by year-to-year global climate variability (Ray *et al.,* 2015).

Water stress decreases the leaf and tiller formation that ultimately reduce yield by affecting panicle development (Singh *et al.,* 2017). Because of water stress, plants respond with morpho- physiological and biochemical adjustments aimed to resisting the loss of water as a try to preserve their hydric status (Kapoor *et al.,* 2020). Decreased synthesis of photosynthetic pigments (Chlorophyll a and b) is a common phenomenon during drought stress, which is closely related to the reduction of plant biomass and yield (Nasrin *et al.,* 2020). Relative water content (RWC) had a powerful and positive yield correlation, RWC measurements display the magnitude of stress and use as a screening method for the status of plant water, which decreased with drought stress. The leaf temperature increased with increasing water stress (Hossain *et al.,* 2020). Reactive oxygen species (ROS) are important secondary signaling molecules that regulate normal plant growth, and responses to stress. As reactive molecules, ROS oxidize and modify some cellular components and prevent them from performing their original functions (Mittler *et al.,* 2004). During water stress, ROS can damage many cell components, including proteins, lipids and DNA by increase the contents of malondialdehyde (MDA), which is considered as a suitable marker for membrane lipid peroxidation (Huang *et al.,* 2019). Under water stress, the membrane system seriously damages and leaf MDA content significantly increases (Na Wu *et al.,* 2011). The reduction in lipid peroxidation was one of the characteristics of rice that can tolerate drought stress.

In rice varieties, molecular marker technology has

* **Corresponding author.**
E-mail address: w_ghidan@hotmail.com
DOI: 10.21608/jpp.2021.57396.1013

become an important method for evaluating genetic variation. Molecular markers could reveal significant differences among genotypes at the level of DNA in contrast to morphological characteristics, providing a more effective, accurate and efficient instrument for the characterization, conservation and management of germplasm and untouched by environmental influence (Singh and Sengar, 2015). SSR markers can detect a high degree of allelic diversity, and it have been widely used to identify genetic variation among rice subspecies (Chukwu *et al.*, 2020). Simple sequence repeat (SSR) markers are successful in detecting genetic polymorphisms and distinguishing between genotypes from different sources of germplasm, they can also detect the finer level of variation within the same variety among closely related breeding materials (Lapitan *et al.*, 2007). The present study was conducted to evaluate the combining ability effects, heterosis, gene action and genetic differentiation by determining the specific markers of DNA associated with drought tolerance using SSR markers of rice for the morphological and physiological characteristics of non-stress and stress of water conditions.

MATERIALS AND METHODS

Plant materials and growth conditions

The present investigation was carried out during the two rice-growing seasons of 2019 and 2020 at the experimental research farm of the Rice Research Department, Sakha, Kafr El-Sheikh, Egypt. The parental material for the present investigation comprised 15 hybrids, five Egyptian cultivars *viz.*, Giza 177, Sakha 101, Sakha 104, Sakha 107 and Sakha 108 and three-drought genotypes tolerant advance breeding *viz.* IRRI 148, WAB 96-1-1 and APO. The crosses were made following line x tester mating design (Kempthrone, 1957) by crossing five Egyptian inbred lines with three testers to generate 15 crosses during the 2019 rice-growing season. During the 2020 rice-growing season, all F_1s and their parents were grown in two different conditions in a Randomized Complete Block Design with three replications. Two rows of 2 m length per hybrid and two rows of parents were planted, 25 days old, seedlings of hybrids and parents were transplanted in the field with standard spacing of 20x20 cm with continuous flooding (non-stress condition). For water stress condition, the experimental material was exposed to limited moisture condition withholding irrigation at every 12 days of direct seeded.

In order to raise a healthy crop, all recommended agronomic practices were followed. Ten plants were randomly selected, and the observed results related to 14 different yields, certain physiological and biochemical traits were recorded. Plant height (cm), number of panicles plant^{-1}, panicle length (cm), panicle weight (g), 1000-grain weight (g), spikelets fertility percentage (%), grain yield plant^{-1} (g), Days to 50% flowering (day), chlorophyll a, chlorophyll b, total chlorophyll (µg/ml), relative water content RWC (%), leaf temperature (ºc) and lipid peroxidation content MDA (µmols MDA g^{-1}FW). The water stress tolerance indices used for the evaluation of rice genotypes, were calculated according to El-Hashash and EL-Agoury, 2019.

Physiological traits and water stress tolerance indices

Flag leaves of ten plants were randomly taken from each plot to estimate photosynthetic pigments; chlorophyll a (Chlla), chlorophyll b (Chllb) and total chlorophyll (Tchll) using the Spectro-photometric method according to Moran, 1982. Relative water content (RWC) was measured according to Ritchie and Nguyen, 1990. Leaf temperature was measured using porometer (L1-COR Model L1 1600). Lipid peroxidation was measured in term of malondialdehyde (MDA) content using an extinction coefficient of 155 mM cm^{-1}. MDA was estimated according to Heath and Packer, 1968.

Screening rice genotypes using SSR markers

Genomic DNA was isolated from fresh three-week old rice leaf samples grown in the greenhouse using a DNA extraction method described by Murray and Thompson, 1980. Three SSR primers; RM260 (McCouch et al., 2002), RM279 (Ordonez *et al.*, 2010) and RM514 (Temnykh *et al.*, 2001), were reported to have associated with drought tolerance traits in rice. Sequence information of the selected SSR loci was retrieved from the Gramene database (http://www.gramene.org/). PCR amplification was performed in 20µl of reaction mixture following the earlier reported work of Bashier *et al.*, 2018. Annealing temperature was changed according to the melting temperature (Tm) value of different primer pairs and the amplified products were resolved through 1.5% agarose gel. The molecular weight of the amplified products for the different studied SSR markers was determined using gel analysis software (AlphaEaseFC 4.0, USA). Individual alleles (variation in molecular weight of amplified product for individual primer pairs) for the SSR markers were scored to prepare a 1/0 matrix based on the presence (1) and absence (0). The genetic clusters for the eight genotypes were identified and plotted using XTSYS-pc 2.01p. Similarity computed using SimQual and SAHN for clustering (Rohlf 1989).

Statistical analysis

The data thus collected were subjected to statistical analysis of variance using the method described by Steel and Torrie, 1980 to estimate significant differences among hybrids and parents. Combining ability estimation was computed according to Kempthorne, 1957. While, the average degree of dominance was done according to Kempthorne and Curnow, 1961. The characters showing significant differences were subjected to heterosis calculation. Deviation of F_1 from it either of the parental values was interpreted by Mather and Jink, 1977 depicting types of gene action operating for controlling the trait. The t test was applied to determine significant differences of F_1 hybrid means from respective mid parent and better parent values using formulae as reported by Wyanne *et al.*, 1970.

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance revealed significant differences among the genotypes, crosses, lines, and lines x testers interaction for all the studied traits, under both non-stress and water stress conditions. (Tables 1a and 1b). Except in the presence of the certain panicle weight trait, non-significant was exhibited under non-stress condition of parents and parents *vs* crosses. Whereas for parents *vs* crosses, chlorophyll b and lipid peroxidation content

(MDA), were found to be non-significant under water stress and non-stress conditions, respectively. While, the analysis of variance revealed non-significant values among testers for chlorophyll b under both conditions, relative water content (RWC) under non-stress condition and MDA under non-stress condition. This result indicated that the genotypes had wide genetic diversity among themselves. Significant variances due to lines x testers interaction for all the traits studied in both conditions, suggested the presence of significant variances for SCA among hybrids. In addition, in all the traits studied, the significant mean square values of parents *vs* crosses showed a good range of heterosis performance. These results coincide with the findings of Abo-Yousef *et al.,* 2020, they also found significant difference among parents *vs.* crosses for some agro-morphological traits.

The significant differences between lines x testers interaction for these traits suggested that specific combining ability is widely attributed to the expression of these traits and gives significance of dominance or non-additive genetic variances for all these traits. Several researchers have reported the predominance of dominant gene action for a majority of the yield traits in rice (Abo-Yousef *et al.,* 2020). The significant mean squares of the lines and testers also revealed the prevalence of additive genetic variances for these traits. Earlier studies have reported the occurrence of both additive and non-additive gene effects on yield and relevant yield component traits in rice (Rahimi *et al.,* 2010). These findings illustrated the importance of combining ability studies and showed good prospects for the selection of suitable parents and crosses for the development of suitable hybrids and varieties. The Major role of non-additive gene effects in the manifestation of all the traits were observed by the higher value of specific combining ability variance σ^2SCA than the general combining ability variance σ^2GCA. It suggested that non-additive gene action was more significant in their expression and indicated very good prospects for the exploitation of non-additive genetic variation through hybrid breeding for grain yield and its component characters. Non-additive genes have also been reported for the expression of yield and their components (Selvaraj *et al.,* 2011 and Ghidan *et al.,* 2019).

Table 1a. Analysis of variance for lines, testers involving parents of physiological and biochemical studied traits.

Source of variance	df	Days to 50% flowering (day)		Chlla (µg/ml)		Chllb (µg/ml)		Tchll (µg/ml)		RWC (%)		Leaf temperature(ºc)		MDA (µmols MDA g-1FW)	
		Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Replications	2	1.406	2.797*	0.230	0.512**	0.050	0.036	0.332	0.316	1.110*	2.150	0.023**	0.011	461.602**	2774.150**
Genotypes	22	81.134**	419.949**	3.731**	3.937**	0.508**	0.312**	6.465**	5.572**	11.729**	29.715**	1.564**	1.931**	992.428**	8593.468**
Parents	7	123.119**	267.518**	1.867**	2.358**	0.361**	0.336**	3.730**	3.545**	18.956**	8.757**	0.839**	1.105**	437.427**	2524.223**
Crosses	14	64.705**	415.041**	4.711**	4.943**	0.604**	0.322**	7.949**	6.917**	5.751**	25.842**	1.567**	2.169**	1340.036**	11247.575**
Parents *vs* Crosses	1	17.257**	1555.667**	3.054**	0.896**	0.202**	0.001	4.829**	0.942**	44.834**	230.640**	6.597**	4.378**	10.920	13920.689**
Lines	4	135.578**	1069.922**	10.403**	11.688**	1.075**	0.735**	17.422**	17.325**	9.509**	34.468**	2.196**	3.703**	2281.721**	24358.661**
Testers	2	113.867**	358.822**	1.093**	6.153**	0.028	0.043	1.468**	5.403**	0.800	36.457**	1.803**	0.328*	255.159	1523.679*
Lines x Testers	8	16.978**	101.656**	2.769**	1.269**	0.512**	0.186**	4.833**	2.091**	5.110**	18.875**	1.193**	1.863*	1140.413**	7123.005**
Error	44	1.057	0.721	0.141	0.093	0.023	0.033	0.146	0.110	0.351	0.734	0.133	0.113	136.273	541.994
δ^2 GCA		1.687	11.079	0.069	0.130	0.003	0.005	0.110	0.171	0.023	0.246	0.013	0.011	7.057	145.818
δ^2 SCA		5.307	33.645	0.876	0.392	0.163	0.051	1.562	0.660	1.586	6.047	0.354	0.583	334.714	2193.670

***, ** Significant at 0.05 and 0.01 probability levels, respectively; Chlla: Chlorophyll a; Chllb: Chlorophyll b; Tchll: Total Chlorophyll; RWC: Relative water content and MDA: Malondialdehyde content**

Table 1b. Analysis of variance for lines, testers involving parents of yield and its related studied traits.

Source of variance	df	Plant height (cm)		No of panicles plant-1		Panicle length(cm)		Panicle weight(g)		1000-grain weight(g)		Spikelets fertility (%)		Grain yield plant-1(g)	
		Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Replications	2	0.934	3.580	1.101	0.101	0.073	0.008	0.108	0.017	0.507	0.230	0.166	0.459	0.594	2.455
Genotypes	22	988.887**	929.422**	85.988**	4.171**	21.679**	30.014**	2.538**	1.347**	19.518**	14.492**	54.727**	102.921**	62.215**	85.997**
Parents	7	953.253**	753.232**	5.565**	4.280**	11.025**	21.961**	0.220	0.456**	14.866**	7.989**	13.259**	81.799**	65.138**	37.646**
Crosses	14	747.771**	605.746**	93.533**	3.470**	10.790**	14.033**	3.851**	1.234**	19.725**	18.220**	73.429**	120.252**	54.590**	106.613**
Parents vs Crosses	1	4613.952**	6694.206**	543.314**	13.232**	248.699**	310.122**	0.384	9.170**	49.178**	7.827**	83.188**	8.128**	148.493**	135.813**
Lines	4	717.756**	1022.389**	43.644**	2.978**	6.273**	10.007**	6.123**	0.484**	19.741**	21.827**	88.082**	37.013**	43.456**	152.783**
Testers	2	1661.600**	545.089**	370.067**	6.289**	34.897**	33.360**	4.699**	5.725**	34.395**	23.560**	177.502**	647.189**	186.864**	374.217**
Lines x Testers	8	534.322**	412.589**	49.344**	3.011**	7.022**	11.215**	2.504**	0.487**	16.050**	15.082**	40.084**	30.138**	27.089**	16.628**
Error	44	3.943	1.489	1.208	0.404	0.855	0.032	0.164	0.016	0.613	0.124	0.541	0.568	0.802	1.877
δ^2 GCA		7.546	6.829	1.562	0.016	0.133	0.100	0.048	0.026	0.130	0.111	1.179	3.186	0.972	3.181
δ^2 SCA		176.793	137.033	16.046	0.869	2.056	3.728	0.780	0.157	5.146	4.986	13.181	9.857	8.762	4.917

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

Mean Performance

The mean performance was found to be significantly for all yield and its contributing and physiological traits under both non-stress and stress water traits in different parents as well as their combinations (Tables 2a and 2b). The lowest mean values are desirable for days to 50% flowering and plant height traits. Two genotypes, Giza 177 and Sakha 107 recorded the desirable mean values of 88.33 and 89.67 days for 50% flowering among lines and testers. While, the crosses with lowest mean values were obtained from three combinations Giza 177/ WAB 96-1-1, Sakha 107/ WAB 96-1-1 and Sakha 107/ APO of 97.33 days under drought condition. With regard to physiological and biochemical traits, the data showed that photosynthetic pigments; Chlla, Chllb and Tchll reduced to water stress condition compared to non-stress condition for all studied genotypes. The reduction in the synthesis of photosynthetic pigments Chlla and b are a common phenomenon that is closely linked to the reduction of plant biomass and yield output (Nasrin *et al.,* 2020). Among lines and testers, the three varieties; Sakha 108, Sakha 104 and WAB 96-1-1 exhibited the highest photosynthetic pigments under non-stress condition, while the parental variety Sakha107 gave the highest mean values under water stress condition.

Table 2a. Mean values of lines, testers and crosses with respect to yield and physiological and biochemical studied traits.

Genotypes	Days to 50% flowering(day)		Chlla (µg/ml)		Chllb ((µg/ml)		Tchll (µg/ml)		RWC (%)		Leaf temperature(°c)		MDA (µmolsMDAg^{1}FW)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Lines														
Giza 177	95.00	88.33	11.45	8.14	2.92	2.35	14.37	10.49	77.29	75.35	29.40	30.60	177.48	278.23
Sakha 101	109.67	106.67	12.44	9.95	3.26	2.93	15.70	12.87	78.01	76.47	29.17	30.47	171.79	285.98
Sakha 104	104.33	98.33	13.18	8.83	3.26	2.30	16.44	11.13	79.65	77.25	28.33	30.17	154.23	241.03
Sakha 107	94.00	89.67	12.64	9.88	3.26	2.36	15.90	12.24	83.60	79.15	27.80	29.57	151.13	232.50
Sakha 108	103.00	101.33	13.79	9.07	3.85	2.72	17.64	11.79	79.02	78.26	28.93	29.43	153.97	251.36
Testers														
IRRI 148	108.00	110.33	12.75	9.39	3.17	2.72	15.93	12.12	82.42	80.53	28.80	29.00	165.33	210.80
WAB 96-1-1	109.00	111.67	13.93	8.35	3.92	3.00	17.85	11.35	83.27	77.68	28.20	29.83	142.08	217.78
APO	109.67	111.33	12.73	10.79	3.20	3.19	15.93	13.98	82.57	79.63	28.63	29.07	149.83	211.83
Crosses														
Giza 177 / IRRI 148	102.33	100.33	11.09	7.55	2.65	1.81	13.74	9.36	79.08	73.20	31.23	31.70	175.67	378.46
Giza 177 / WAB 96-1-1	100.33	97.33	11.29	7.69	3.12	2.35	14.41	10.03	80.29	72.45	29.37	31.17	157.58	385.18
Giza 177 / APO	101.33	98.33	10.91	7.60	2.68	2.46	13.60	10.06	79.96	75.10	29.47	30.03	152.42	293.21
Sakha 101/ IRRI 148	114.67	122.33	12.58	9.92	3.59	2.90	16.17	12.82	79.65	74.97	29.23	29.90	131.75	265.83
Sakha 101/ WAB 96-1-1	102.33	111.67	12.70	8.45	3.90	2.89	16.60	11.33	79.51	74.58	29.25	29.90	144.67	326.53
Sakha 101/ APO	108.33	120.67	11.73	8.26	2.97	2.69	14.70	10.95	78.81	72.31	30.07	30.63	167.92	251.10
Sakha 104/ IRRI 148	105.33	118.67	11.97	9.80	2.69	2.54	14.66	12.34	79.90	78.48	28.70	29.30	162.23	231.47
Sakha 104/ WAB 96-1-1	98.00	118.33	11.99	7.97	2.94	2.61	14.93	10.58	75.17	74.11	28.47	30.03	191.17	230.43
Sakha 104/ APO	100.33	123.33	11.37	8.07	3.13	2.81	14.50	10.88	76.93	69.02	29.27	31.23	196.33	229.40
Sakha 107/ IRRI 148	105.33	111.67	15.54	11.00	4.12	3.02	19.66	14.02	79.14	76.60	29.63	29.90	163.01	271.51
Sakha 107/ WAB 96-1-1	104.67	97.33	12.44	10.23	2.97	2.54	15.41	12.77	80.82	78.10	28.67	29.00	147.25	173.60
Sakha 107/ APO	105.33	97.33	13.58	10.82	3.62	3.08	17.20	13.91	79.60	77.64	28.37	29.17	121.42	218.81
Sakha 108/ IRRI 148	112.67	125.67	12.00	10.66	3.34	2.98	15.34	13.64	78.73	75.54	29.70	30.00	134.85	265.83
Sakha 108/ WAB 96-1-1	107.67	108.33	14.15	9.80	3.32	2.96	17.47	12.76	78.97	71.78	29.47	31.27	144.15	213.90
Sakha 108/ APO	108.33	131.33	13.00	8.11	3.57	2.71	16.57	10.82	79.01	69.13	28.73	31.20	170.50	329.89
$LSD_{0.05}$	1.69	1.39	0.62	0.50	0.25	0.30	0.63	0.54	0.97	1.41	0.60	0.55	19.16	38.21
$LSD_{0.01}$	2.26	1.87	0.82	0.67	0.33	0.40	0.84	0.73	1.30	1.88	0.80	0.74	25.64	51.13

Chlla: Cchlorophyll a; Chllb: Chlorophyll b; Tchll: Total Chlorophyll; RWC: Relative water content and MDA: Malondialdehyde content.

Table 2b. Mean values of lines, testers and crosses with respect to yield and its related studied traits.

Genotypes	Plant height (cm)		No of panicles plant^{-1}		Panicle length (cm)		Panicle weight(g)		1000-grain weight(g)		Spikelets fertility(%)		Grain yield plant^{-1}(g)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Lines														
Giza 177	99.45	74.00	19.00	8.33	21.17	13.73	3.50	2.21	27.70	23.13	95.67	77.81	40.80	24.33
Sakha 101	90.33	66.00	19.67	11.00	22.57	17.40	3.80	2.39	27.83	23.30	95.17	82.80	44.83	29.06
Sakha 104	104.67	76.67	17.00	10.33	23.60	15.73	3.52	2.46	26.44	23.83	94.33	73.14	43.33	30.67
Sakha 107	105.33	80.00	17.00	11.67	20.00	17.83	3.50	3.13	26.10	24.95	95.33	84.25	44.33	36.92
Sakha 108	94.67	76.67	19.00	10.67	21.33	16.00	3.60	2.07	28.30	24.88	94.57	82.40	45.71	31.66
Testers														
IRRI 148	141.00	110.33	16.33	12.00	26.17	21.17	2.95	2.16	23.17	20.83	91.50	81.11	33.67	28.09
WAB 96-1-1	128.00	101.33	16.00	11.00	22.00	21.67	3.83	2.98	30.56	24.83	91.00	89.40	37.07	30.06
APO	122.67	99.33	17.67	12.00	21.10	18.67	3.60	2.29	25.17	21.13	90.67	87.86	35.50	29.67
Crosses														
Giza 177 / IRRI 148	109.67	78.67	23.67	9.67	24.50	19.43	2.10	1.03	21.96	19.70	84.12	77.63	37.57	20.36
Giza 177 / WAB 96-1-1	99.00	83.67	16.33	8.33	23.48	20.37	4.87	2.45	28.41	24.58	95.59	90.37	45.55	37.55
Giza 177 / APO	139.33	100.67	30.33	9.67	28.77	21.89	3.20	0.82	25.07	23.03	92.55	89.40	41.67	25.33
Sakha 101/ IRRI 148	137.33	100.33	31.00	11.00	26.60	22.18	3.32	1.61	24.23	21.55	93.40	75.63	45.28	28.25
Sakha 101/ WAB 96-1-1	129.33	114.33	17.67	8.67	24.07	21.23	2.90	1.88	25.19	22.50	94.97	89.96	47.81	37.58
Sakha 101/ APO	140.33	109.33	18.33	9.33	27.17	23.10	1.96	1.00	26.52	20.57	87.78	78.40	37.66	31.68
Sakha 104/ IRRI 148	148.33	114.67	26.33	10.00	27.33	25.13	1.53	1.48	21.03	19.54	86.00	77.44	37.70	31.00
Sakha 104/ WAB 96-1-1	111.00	94.33	17.33	9.00	24.50	19.83	3.53	2.30	26.64	23.77	94.60	90.18	44.56	39.58
Sakha 104/ APO	106.67	119.00	20.67	11.33	24.50	22.40	2.47	1.41	23.63	21.83	80.90	74.86	42.49	34.45
Sakha 107/ IRRI 148	140.00	124.67	24.33	10.33	28.77	24.57	5.10	1.32	27.79	25.55	95.06	78.88	45.42	34.05
Sakha 107/ WAB 96-1-1	125.33	103.67	17.67	10.67	25.00	23.00	4.80	2.95	29.13	27.27	97.71	90.37	49.42	42.42
Sakha 107/ APO	145.33	106.67	28.67	9.00	26.50	22.87	3.83	1.22	25.52	23.27	94.65	82.63	42.08	39.58
Sakha 108/ IRRI 148	137.67	131.33	30.67	12.33	27.50	23.33	2.59	1.30	22.12	20.00	86.38	76.33	47.27	28.34
Sakha 108/ WAB 96-1-1	114.33	100.33	20.67	10.33	25.33	18.13	3.93	2.47	22.18	20.40	93.06	89.89	51.07	34.43
Sakha 108/ APO	135.33	111.67	30.33	9.67	29.40	25.93	4.58	2.22	27.61	26.27	91.59	84.03	40.49	30.44
$LSD_{0.05}$	3.26	2.00	1.80	1.04	1.52	0.29	0.66	0.20	1.29	0.58	1.21	1.24	1.47	2.25
$LSD_{0.01}$	4.36	2.68	2.41	1.40	2.03	0.39	0.89	0.27	1.72	0.77	1.62	1.65	1.97	3.01

The differences among the crosses were highly significant, under non-stress condition the four crosses, Sakha 107/ IRRI 148, Sakha 108/ WAB 96-1-1, Sakha 107/ APO and Sakha 108/ APO revealed the highest concentration of photosynthetic pigments. While, under stress condition the four crosses, Sakha 107/ IRRI 148, Sakha 107/ APO, Sakha 108/ IRRI 148 and Sakha 107/ WAB 96-1-1 gave the highest concentrations.

Relative water content (RWC) also decreased for all studied genotypes under water stress compared to non-stress conditions (Hossain *et al.,* 2020). RWC is a very significant tool for plant water status screening, also had a powerful constructive correlation with yield (Hassanzadeh *et al.,* 2009). The two genotypes, Sakha107 and Sakha108 recorded the highest percentage of RWC among lines and testers under both conditions. The cross combinations Sakha 104 / IRRI 148, Sakha 107 / WAB 96-1-1, Sakha 107 / APO and Sakha 107 / IRRI 148 reported the highest percentage of RWC under water stress condition. On the contrary, under water stress condition, leaf temperature and lipid peroxidation content (MDA) were increased (Barnaby *et al.,* 2019). The reduction in lipid peroxidation content was one of the characteristics of rice that can tolerate drought stress (Zain, 2014). The lowest leaf temperature was obtained from the two parental varieties Sakha 107 and Sakha 108 under both conditions. Regarding the cross combinations, under water stress condition, the four crosses Sakha 104/ IRRI 148, Sakha 107/ WAB 96-1-1, Sakha 107/ APO and Sakha 107/ IRRI 148 showed the lowest leaf temperature. In terms of MDA, the three testers recorded the lowest mean values followed by the two lines Sakha 107 and Sakha 108. The lowest and desirable MDA mean values were provided by the six cross combinations Sakha 107/ WAB 96-1-1, Sakha 107/ APO, Sakha 108/ WAB 96-1-1, Sakha 104/ APO, Sakha 104/ WAB 96-1-1 and Sakha 104/ IRRI 148.

Regarding the plant height, the variety Sakha 101 recorded the lowest and desirable mean values under both conditions with mean values of 90.33 and 66.00 cm, respectively. In both conditions, the cross combination Giza 177/ WAB 96-1-1 exhibited the lowest and desirable mean values of 99.00 and 83.67 cm, respectively, knowing that the cross Giza 177/ IRRI 148 exhibited less tall with mean value of 78.67 cm in water-stress condition. Concerning the number of panicles plant^{-1}, the two parental genotypes IRRI 148 and APO exhibited the highest mean values of 12.00 panicles plant^{-1} under water deficit stress. The two crosses Sakha 108/ IRRI 148 and Sakha 104/ APO were identified as good performing combinations, recorded the highest mean values of 12.33 and 11.33 panicles plant^{-1}, respectively under the same condition. For panicle length under water-stress condition, the two parental lines, Sakha 107 and Sakha 101 exhibited the highest mean values of 17.83 and 17.40 cm. Among crosses combinations, the highest mean values were observed in the two hybrids Sakha 108/ APO (25.93 cm) and Sakha 104/ IRRI 148 (25.13 cm). Regarding the panicle weight, the parental genotype Sakha 107 among lines and testers recorded the highest mean value of 3.13 g. In the meantime, the hybrid combination Sakha 107/ WAB 96-1-1 exhibited the highest mean value of 2.95 g under drought condition.

As regards the 1000-grain weight under water stress condition, the three parental lines Sakha 107, Sakha 108 and WAB 96-1-1 showed the maximum mean performance values of 24.95, 24.88 and 24.83 g, respectively. While, the two crosses Sakha 107/ WAB 96-1-1 and Sakha 108/ APO recorded the highest mean values of 27.27 and 26.27 for the same trait, respectively. Additionally, in terms of the spikelets fertility percent under water stress condition, the two parental varieties, WAB 96-1-1 and APO recorded the highest mean values of 89.40 and 87.86%, respectively. In this concern, the two crosses Giza 177/ WAB 96-1-1 and Sakha 107/ WAB 96-1-1 recorded the highest mean values of 90.37%, while the minimum value (74.86%) was obtained from the cross combination of Sakha 104 / APO. For grain yield plant^{-1}, among lines and testers, the genotype Sakha 107 recorded the highest mean value of 36.92 g. While, the highest mean values were observed in the two cross combinations Sakha 107/ WAB 96-1-1 and Sakha 104/ WAB 96-1-1 of 42.42 and 39.58 g, respectively under water stress condition. Genotype x environment interaction arises when different genotypes react differently to the different environments and are paramount in the identification and development of genotypes that perform well over a wide range of growing conditions (Dou *et al.,* 2016). The adjusted mean of genotypes over the environments based on the combined analysis of variance is used to select genotypes that are superior across the test environments and are good performers in comparison with the checks that have a general good adaptability (Peng *et al.,* 2006).

Estimates of combining ability variances

General combining ability effects

For the illustrating genetic worth of parents for hybridization program, the general combing ability effects of eight parents for 14 traits are consolidated in Tables 3a and 3b. The negative estimates of GCA effects are desirable for earliness, medium dwarf plant height, leaf temperature and MDA. Among the studied lines and testers under water stress condition, the parental line Giza 177 was observed to have good GCA effects and desirable direction for days to 50% flowering and plant height traits, followed by the parental line Sakha 107 for days to 50% flowering and the genotype WAB 96-1-1 for plant height trait, which recorded significant and negative GCA effects. In the current study, parents with high mean and positive GCA are preferred for positive grain yield characteristics, whereas parents with low mean and negative GCA are preferred for negative grain yield characteristics, such as flowering days to 50 percent, plant height and drought recovery rate. The positive estimates of GCA effects are desirable for photosynthetic pigments and RWC, on the contrary, the negative effects are desirable for leaf temperature and MDA. Among the studied lines and testers, Sakha 107 and Sakha 108 followed by the genotype IRRI 148 recorded significant positive GCA effects in all photosynthetic pigments (Chlla, Chllb and Tchll) under both studied conditions. The two parents Sakha 107 and Sakha 104 were the best general combiners for MDA and the only variety Sakha 107 exhibited a desirable effect for leaf temperature under water stress condition and insignificant differences among the three testers under both conditions

The two genotypes Sakha 108 and IRRI 148 were identified as good general combiners for number of panicles plant^{-1} under both conditions. For panicle length, the variety Sakha 107 exhibited a good general combiner under water deficit condition among the lines. While, among testers in both conditions the genotype APO showed a high positive desirable effect. The parental variety Sakha 107 had the highly significant GCA effects for panicle weight, 1000-grain weight, spikelets fertility percentage and grain yield plant^{-1} under stress condition of water. In the same direction, WAB 96-1-1 was identified as a good general combiner among testers for the same traits. While, the variety Sakha

108 a potential parent also had the highly significant GCA effect of panicle weight. Ghidan *et al.,* 2019 suggested that parents with high GCA would produce transgressive segregants later generations and may be utilized in hybridization programs. Selecting parents are a crucial step in breeding programs to enhance drought tolerance. Parents with higher average performance and general combining ability potential for drought tolerance and yield contributing characters are ideal for obtaining desirable segregants.

Table 3a. Estimates of general combining ability effects for physiological and biochemical studied traits.

Genotypes	Days to 50% flowering (day)		Chlla (µg/ml)		Chllb ((µg/ml)		Tchll ((µg/ml)		RWC (%)		Leaf temperature(°c)		MDA (µmolsMDAg^{1}FW)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Lines														
Giza 177	-3.80**	-13.51**	-1.33**	-1.45**	-0.42**	-0.48**	-1.75**	-1.93**	0.74**	-0.62*	0.71**	0.67**	4.49	81.27**
Sakha 101	3.31**	6.04**	-0.09	-0.19	0.25**	0.14*	0.16	-0.05	0.29	-0.25	0.21	-0.15	-9.28*	10.14
Sakha 104	-3.91**	7.93**	-0.64**	-0.45**	-0.32**	-0.04	-0.97**	-0.49**	-1.71**	-0.33	-0.50**	-0.11	25.85**	-40.58**
Sakha 107	-0.02	-10.07**	1.43**	1.62**	0.33**	0.19**	1.76**	1.81**	0.81**	3.25**	-0.42**	-0.94**	-13.50**	-49.70**
Sakha 108	4.42**	9.60**	0.63**	0.46**	0.17**	0.19**	0.80**	0.66**	-0.14	-2.05**	-0.01	0.53**	-7.56	-1.14
LSD 0.05	0.69	0.57	0.25	0.20	0.10	0.12	0.26	0.22	0.40	0.57	0.24	0.23	7.82	15.60
LSD 0.01	0.92	0.76	0.34	0.27	0.14	0.16	0.34	0.30	0.53	0.77	0.33	0.30	10.47	20.88
Testers														
IRRI 148	2.93**	3.56**	0.21*	0.72**	0.04	-0.04	0.25*	0.69**	0.26	1.56**	0.39**	-0.14	-3.89	11.61
WAB 96-1-1	-2.53**	-5.58**	0.09	-0.23**	0.01	-0.02	0.10	-0.26**	-0.09	0.01	-0.26**	-0.02	-0.43	-5.08
APO	-0.40	2.02**	-0.30**	-0.49**	-0.05	0.06	-0.35**	-0.43**	-0.17	-1.56**	-0.13	0.16	4.32	-6.53
LSD 0.05	0.53	0.44	0.19	0.16	0.08	0.09	0.20	0.17	0.31	0.44	0.19	0.17	6.06	12.08
LSD 0.01	0.71	0.59	0.26	0.21	0.11	0.13	0.27	0.23	0.41	0.59	0.25	0.23	8.11	16.17

***, ** Significant at 0.05 and 0.01 probability levels, respectively; Chlla: Cchlorophyll a; Chllb: Chlorophyll b; Tchll: Total Chlorophyll; RWC: Relative water content and MDA: Malondialdehyde content.**

Table 3b. Estimates of general combining ability effects for yield and its related traits.

Genotypes	Plant height(cm)		No of panicles plant^{-1}		Panicle length(cm)		Panicle weight(g)		1000-grain weight(g)		Spikelets fertility(%)		Grain yield plant^{-1}(g)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Lines														
Giza 177	-11.93**	-18.56**	-0.16	-0.73**	-0.64*	-1.66**	0.01	-0.26**	0.01	-0.22	-0.47	2.74**	-2.14**	-5.26**
Sakha 101	7.73**	1.78**	-1.27**	-0.29	-0.28	-0.06	-0.66**	-0.20**	0.18	-1.12**	0.83**	-1.74**	-0.15	-0.50
Sakha 104	-5.93**	3.11**	-2.16**	0.16	-0.78*	0.23**	-0.87**	0.03	-1.37**	-0.94**	-4.06**	-2.24**	-2.16**	2.01**
Sakha 107	8.96**	5.44**	-0.04	0.04	0.53	1.25**	1.20**	0.13**	2.35**	2.71**	4.58**	0.89**	1.90**	5.68**
Sakha 108	1.18	8.22**	3.62**	0.82**	1.18**	0.24**	0.32*	0.30**	-1.17**	-0.43**	-0.88**	0.35	2.54**	-1.93**
LSD 0.05	1.33	0.82	0.74	0.43	0.62	0.12	0.27	0.08	0.52	0.24	0.49	0.50	0.60	0.92
LSD 0.01	1.78	1.09	0.99	0.57	0.83	0.16	0.36	0.11	0.70	0.32	0.66	0.68	0.80	1.23
Testers														
IRRI 148	6.67**	3.71**	3.60**	0.71**	0.71**	0.70**	-0.45**	-0.35**	-1.71**	-1.39**	-2.23**	-5.88**	-1.09**	-4.60**
WAB 96-1-1	-12.13**	-6.96**	-5.67**	-0.56**	-1.75**	-1.71**	0.63**	0.71**	1.17**	1.05**	3.96**	7.09**	3.95**	5.31**
APO	5.47**	3.24**	2.07**	-0.16	1.04**	1.01**	-0.17	-0.36**	0.53*	0.34**	-1.73**	-1.20**	-2.86**	-0.71*
LSD 0.05	1.03	0.63	0.57	0.33	0.48	0.09	0.21	0.06	0.41	0.18	0.38	0.39	0.46	0.71
LSD 0.01	1.38	0.85	0.76	0.44	0.64	0.12	0.28	0.09	0.54	0.24	0.51	0.52	0.62	0.95

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

Specific combining ability effects

Estimates of SCA effects of the F_1 crosses for studied traits are presented in Tables 4a and 4b. Under water stress condition, five cross combinations exhibited negative and high significant desirable SCA effects to 50% flowering. The cross combination Sakha 107/ APO is a good specific combiner for some physiological and biochemical traits as Chlla and Tchll under water stress condition followed by the cross combination Sakha 108/ WAB 96-1-1 under both conditions. While, Sakha 108/ IRRI 148 was a good specific combiner for Chlla, Tchll, RWC and leaf temperature under water stress condition. In the present study, under both non-stress and water stress conditions, none of the cross combinations exhibited high specific combining ability effects for all 14 studied traits. Vanave *et al.,* 2018 and Abo-Yousef *et al.,* 2020 also reported that no specific cross combination was desirable for all the studied traits in their study. About 15% of hybrids showed a significant desirable effect for grain yield plant^{-1} under water stress condition (Table 4b). Based on the above, Giza 177/ WAB 96-1-1, Sakha 107/ APO and Sakha 108/ IRRI 148 cross-combinations showed a highly significant and desirable SCA effect for grain yield^{-1} under stress conditions, respectively.

In addition, seven crosses were found to be negative and highly significant desirable SCA effects on plant height. Where it was observed that, three cross combinations Giza 177/ IRRI 148, Sakha 107/ APO and Sakha 108/ WAB 96-1-1 exhibited desirable SCA effects in both conditions for days to 50% flowering and plant height. No more crosses showed significant desirable SCA effects for number of panicles plant^{-1} under stress condition except for three hybrids namely Sakha 104/ APO, Sakha 107/ WAB 96-1-1 and Sakha 108/ IRRI 148 with mean values of 1.38%, 1.22% and 0.84%, respectively. The hybrid combination, Sakha 108/ APO recorded the highest significant SCA effect for panicle length under stress condition also showed desirable and highly significant SCA effects for panicle weight, 1000-grain weight and spikelets fertility percentage under both non-stress and stress conditions. While, the cross combination Giza 177/ WAB 96-1-1 exhibited the significant SCA effects for panicle length, panicle weight and 1000-grain weight under stress condition for panicle length trait and highly significant SCA effects of panicle weight and 1000-grain weight under both conditions.

For panicle weight, three hybrid combinations showed positive significant and highly significant SCA effects under stress condition. While, for 1000-grain weight trait exhibited positive and highly significant SCA effects by six-hybrid combinations under the same condition. Four crosses were found to be positive and significant SCA effects for spikelets fertility percentage under both conditions. For most of the traits, the perusal of SCA effects along with per se performance revealed that some of the crosses showing favorable SCA effects also had superior per se performance, suggesting that the selection of these crosses would be successful on the basis of per se performance. Such outcomes are in line with those of Selvaraj *et al.,* 2011. Those reported several promising unique combiners for grain yield per plant based on high per se performance and SCA effects. In addition, the majority of cross-combinations involved high/low or average/low gene interactions that substantiate the non-additive gene action activity for the expression of these traits. The findings of Bagheri and Jelodar, 2010 and Ghidan *et al.,* 2019, support these results.

Table 4a. Estimates of specific combining ability effects for physiological and biochemical studied traits.

Crosses	Days to 50% flowering(day)		Chlla (µg/ml)		Chllb (µg/ml)		Tchll (µg/ml)		RWC (%)		Leaf temperature(°c)		MDA (µmolsMDAg^{1}FW)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Giza 177 / IRRI 148	-1.93**	-1.89**	-0.22	-0.79**	-0.21*	-0.35**	-0.43	-1.14**	-0.96**	-1.94**	0.819**	0.87**	17.67*	14.57
Giza 177 / WAB 96-1-1	1.53*	4.24**	0.10	0.31	0.29**	0.16	0.39	0.47*	0.60	-1.14*	-0.391	0.22	-3.87	37.98**
Giza 177 / APO	0.40	-2.36**	0.12	0.48**	-0.09	0.19	0.03	0.67**	0.36	3.08*8	-0.428*	-1.09**	-13.80*	-52.55**
Sakha 101/ IRRI 148	3.29**	0.56	0.03	0.32	0.07	0.11	0.09	0.43*	0.06	-0.54	-0.675**	-0.11	-12.47	-26.94
Sakha 101/WAB 96-1-1	-3.58**	-0.98	0.28	-0.19	0.40**	0.08	0.68**	-0.11	0.27	0.62	-0.004	-0.22	-3.01	50.46**
Sakha 101/ APO	0.29	0.42	-0.30	-0.13	-0.47**	-0.20	-0.77	-0.32	-0.34	-0.08	0.679**	0.33	15.48*	-23.53*
Sakha 104/ IRRI 148	1.18	-5.00**	-0.02	0.46*	-0.26**	-0.07	-0.29	0.39*	2.30**	3.05**	-0.504*	-0.75**	-17.12*	-10.57
Sakha 104/WAB 96-1-1	-0.69	3.80**	0.12	-0.41*	0.01	-0.02	0.13	-0.43*	-2.08**	0.24	-0.080	-0.13	8.35	5.08
Sakha 104/ APO	-0.49	1.20*	-0.10	-0.05	0.25**	0.09	0.15	0.04	-0.23	-3.29**	0.583**	0.89**	8.77	5.49
Sakha 107/ IRRI 148	-2.71**	6.00**	1.48**	-0.41*	0.51**	0.18	1.99**	-0.23	-0.98**	-2.40**	0.352	0.68**	23.01**	38.60**
Sakha 107/WAB 96-1-1	2.09	0.80	-1.50**	-0.22	-0.61**	-0.32**	-2.12	-0.54**	1.05**	0.65	0.043	-0.33	3.79	-42.63**
Sakha 107/ APO	0.62	-6.80**	0.03	0.63**	0.10	0.14	0.13	0.77**	-0.07	1.75**	-0.395	-0.35	-26.80**	4.03
Sakha 108/ IRRI 148	0.18	0.33	-1.26**	0.41*	-0.11	0.14	-1.37**	0.55**	-0.44	1.83**	0.008	-0.69**	-11.09	-15.66
Sakha 108/WAB 96-1-1	0.64	-7.87**	1.01**	0.51**	-0.10	0.10	0.91**	0.61**	0.15	-0.37	0.432*	0.47*	-5.25	-50.89**
Sakha 108/ APO	-0.82	7.53**	0.25	-0.93**	0.20*	-0.23*	0.46*	-1.16**	0.28	-1.46**	-0.439*	0.22	16.34*	66.55**
LSD $_{0.05}$	1.19	0.99	0.44	0.35	0.18	0.21	0.44	0.39	0.69	0.99	0.423	0.39	13.55	27.02
LSD $_{0.01}$	1.60	1.32	0.58	0.47	0.24	0.28	0.59	0.52	0.92	1.33	0.566	0.52	18.13	36.16

***, ** Significant at 0.05 and 0.01 probability levels, respectively; Chlla: Cchlorophyll a; Chllb: Chlorophyll b; Tchll: Total Chlorophyll; RWC: Relative water content and MDA: Malondialdehyde content.**

Table 4b. Estimates of specific combining ability effects of yield and its related traits.

Crosses	Plant height (cm)		No of panicles plant^{-1}		Panicle length(cm)		Panicle weight(g)		1000-grain weight(g)		Spikelets fertility(%)		Grain yield plant^{-1}(g)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Giza 177 / IRRI 148	-13.00**	-12.71**	-3.38**	-0.27	-1.80**	-1.83**	-0.84**	-0.05	-1.48**	-1.35**	-4.40**	-2.29**	-2.94**	-2.78**
Giza 177 / WAB 96-1-1	-4.87**	2.96**	-1.44*	-0.33	-0.35	1.52**	0.85**	0.30**	2.09**	1.10**	0.87*	-2.52**	0.01	4.49**
Giza 177 / APO	17.87**	9.76**	4.82**	0.60	2.14**	0.31**	-0.02	-0.25**	-0.61	0.26	3.53**	4.80**	2.93**	-1.71*
Sakha 101/ IRRI 148	-5.00**	-11.38**	5.07**	0.62	-0.06	-0.69**	1.05**	0.46**	0.63	1.40**	3.58**	0.19	2.78**	0.35
Sakha 101/WAB 96-1-1	5.80**	13.29**	1.00	-0.44	-0.13	0.78**	-0.45	-0.33**	-1.30**	-0.09	-1.04*	1.54**	0.28	-0.23
Sakha 101/ APO	-0.80	-1.91**	-6.07**	-0.18	0.18	-0.08	-0.60*	-0.13	0.67	-1.31**	-2.54**	-1.73**	-3.06**	-0.11
Sakha 104/ IRRI 148	19.67**	1.62*	1.29*	-0.82*	1.18*	1.97**	-0.52*	0.10	-1.02*	-0.79**	1.06*	2.50**	-2.79**	0.59
Sakha 104/WAB 96-1-1	1.13	-8.04**	1.56*	-0.56	0.81	-0.91**	0.40	-0.14*	1.70**	1.00**	3.47**	2.27**	-0.97	-0.74
Sakha 104/ APO	-20.80**	6.42**	-2.84**	1.38**	-1.98**	-1.07**	0.13	0.04	-0.67	-0.22	-4.54**	-4.76**	3.76**	0.15
Sakha 107/ IRRI 148	-3.56**	9.29**	-2.82**	-0.38	1.30*	0.39**	0.98**	-0.16*	2.02**	1.57**	1.48**	0.81	0.87	-0.03
Sakha 107/WAB 96-1-1	0.58	-1.04	-0.22	1.22**	0.01	1.24**	-0.40	0.41**	0.48	0.85**	-2.06**	-0.67	-0.17	-1.57*
Sakha 107/ APO	2.98*	-8.24**	3.04**	-0.84*	-1.29*	-1.62**	-0.57*	-0.25**	-2.50**	-2.43**	0.57	-0.13	-0.70	1.60*
Sakha 108/ IRRI 148	1.89	13.18**	-0.16	0.84*	-0.62	0.17	-0.66**	-0.35**	-0.14	-0.84**	-1.73**	-1.20**	2.08**	1.87*
Sakha 108/WAB 96-1-1	-2.64*	-7.16**	-0.89	0.11	-0.33	-2.62**	-0.39	-0.24**	-2.96**	-2.87**	-1.25**	-0.61	0.85	-1.95*
Sakha 108/ APO	0.76	-6.02**	1.04	-0.96*	0.95	2.45**	1.06**	0.59**	3.10**	3.70**	2.97**	1.82**	-2.93**	0.07
LSD $_{0.05}$	2.30	1.42	1.28	0.74	1.07	0.21	0.47	0.14	0.91	0.41	0.85	0.87	1.04	1.59
LSD $_{0.01}$	3.08	1.90	1.71	0.99	1.44	0.28	0.63	0.19	1.22	0.55	1.14	1.17	1.39	2.13

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

Evaluation of heterosis

The heterotic responses of hybrids over heterobeltiosis for the 14 studied traits under non-stress and stress of water are presented in Tables 5a and 5b. Negative heterosis was desirable for days to 50% flowering, plant height, leaf temperature and MDA but positive heterosis was desirable for the remaining traits studied. Major positive and negative heterosis in the traits studied were observed. In this investigation, none of the hybrids exhibited the most serious heterobeltiosis for all the traits. The negative and highly significant heterobeltiosis for the days of 50% flowering were found in the three cross combinations Sakha 101/ WAB 96-1-1, Sakha 104/ WAB 96-1-1 and Sakha 104/ APO (-6.12, -6.07 and -3.83%, respectively) under non-stress condition. While, under stress of water condition, none of the cross combinations exhibited heterobeltiosis. For physiological and biochemical traits, the highly significant and desirable positive SCA effect heterobeltiosis was recorded for the cross combination Sakha 107/ IRRI 148 for photosynthetic pigments (Chlla, Chllb and Tchll) under both non-stress and stress conditions. In addition, six hybrid combinations gave negative significant heterosis effects desirable that varied from -1.35 to -2.79% over the respectively heterobeltiosis for the leaf temperature trait under water stress condition. While, for MDA content the cross Sakha 101/ IRRI 148 exhibited the negative significant heterobeltiosis effects and desirable (-20.31%) under normal condition (Nasrin *et al.,* 2020). It was observed that parents of all the hybrids were of one good and one poor combiner indicated the presence of dominance gene action. Therefore, these hybrids are recommended for heterosis breeding, because the usefulness of a particular cross in the exploitation of heterosis is judged by specific combining ability effect.

Table 5a. Estimates of better parent (HBP %) heterosis of the F1s generation of physiological and biochemical studied traits.

Crosses	Days to 50% flowering (day)		Chlla (µg/ml)		Chllb (µg/ml)		Tchll (µg/ml)		RWC (%)		Leaf temperature(°c)		MDA (µmolsMDAg1FW)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Giza 177 / IRRI 148	7.72**	13.58**	-13.07**	-19.66**	-16.49**	-33.41**	-13.75**	-22.75**	-4.05**	-9.10**	8.45**	3.59**	6.25	79.53**
Giza 177 / WAB 96-1-1	5.61**	10.19**	-18.98**	-7.98**	-20.34**	-21.69**	-19.28**	-11.60**	-3.57**	-6.73**	4.14**	1.85**	10.91	76.87**
Giza 177 / APO	6.67**	11.32**	-14.25**	-29.60**	-16.15**	-22.96**	-14.63**	-28.08**	-3.16**	-5.69**	2.91**	-1.85**	1.72	38.41*
Sakha 101/ IRRI 148	6.17**	14.69**	-1.39**	-0.27	10.24**	-0.91**	1.51**	-0.41**	-3.36**	-6.90**	1.50**	-1.86**	-20.31*	26.10
Sakha 101/WAB 96-1-1	-6.12**	4.69**	-8.81**	-15.08**	-0.43**	-3.67**	-6.97**	-11.96**	-4.51**	-3.99**	3.71**	-1.86**	1.82	49.94*
Sakha 101/ APO	-1.22	13.13**	-7.83**	-23.48**	-8.80**	-15.76**	-7.70**	-21.72**	-4.55**	-9.19**	5.01**	0.55*	12.07	18.54
Sakha 104/ IRRI 148	0.96	20.68**	-9.23**	4.29**	-17.30**	-6.61**	-10.83**	1.84**	-3.06**	-2.55**	1.29**	-2.87**	5.19	9.80
Sakha 104/WAB 96-1-1	-6.07**	20.34**	-13.90**	-9.70**	-24.94**	-13.01**	-16.32**	-6.78**	-9.73**	-4.59**	0.95**	-0.44	34.55**	5.81
Sakha 104/ APO	-3.83**	25.42**	-13.73**	-25.21**	-3.99**	-12.11**	-11.80**	-22.22**	-6.83**	-13.33**	3.29**	3.54**	31.03**	8.29
Sakha 107/ IRRI 148	12.06**	24.54**	21.88**	11.33**	26.28**	10.77**	23.44**	14.54**	-5.34**	-4.88**	6.59**	1.13**	7.86	28.80
Sakha 107/WAB 96-1-1	11.35**	8.55**	-10.70**	3.51**	-24.26**	-15.35**	-13.67**	4.30**	-3.33**	-1.32	3.12**	-2.79**	3.64	-20.28
Sakha 107/ APO	12.06**	8.55**	6.68**	0.31	11.04**	-3.44**	7.97**	-0.55*	-4.78**	-2.49**	2.04**	-1.35**	-18.97	3.29
Sakha 108/ IRRI 148	9.39**	24.01**	-12.98**	13.52**	-13.32**	9.42**	-13.05**	12.60**	-4.48**	-6.20**	3.13**	1.93**	-12.42	26.10
Sakha 108/WAB 96-1-1	4.53**	6.91**	1.56**	8.09**	-15.15**	-1.33**	-2.11**	8.26**	-5.16**	-8.28**	4.49**	4.80**	1.45	-1.78
Sakha 108/ APO	5.18**	29.61**	-5.73**	-24.87**	-7.44**	-15.03**	-6.10**	-22.62**	-4.32**	-13.19**	0.35	6.00**	13.79	55.73**
LSD 0.05	1.69	1.39	0.62	0.50	0.25	0.30	0.63	0.54	0.97	1.41	0.60	0.55	19.16	38.21
LSD 0.01	2.26	1.87	0.82	0.67	0.33	0.40	0.84	0.73	1.30	1.88	0.80	0.74	25.64	51.13

***, ** Significant at 0.05 and 0.01 probability levels, respectively; Chlla: Cchlorophyll a; Chllb: Chlorophyll b; Tchll: Total Chlorophyll; RWC: Relative water content and MDA: Malondialdehyde content.**

Table 5b. Estimates of better parent (HBP %) heterosis of the F1s generation of yield and its related studied traits.

Crosses	Plant height (cm)		No of panicles plant^{-1}		Panicle length (cm)		Panicle weight (g)		1000-grain weight(g)		Spikelets fertility(%)		Grain yield plant^{-1}(g)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Giza177/IRRI148	10.28**	6.31**	24.56**	-19.44**	-6.37**	-8.19**	-40.00**	-53.24**	-20.73**	-14.86**	-12.07**	-4.28**	-7.91**	-27.52**
Giza177/WAB96-1-1	-0.45	13.06**	-14.04**	-24.24**	6.74**	-6.00**	26.96**	-17.79**	-7.05**	-1.01**	-0.08	1.09	11.64**	24.93**
Giza177/APO	40.11**	36.04**	59.65**	-19.44**	35.91**	17.25**	-11.11**	-64.05**	-9.48**	-0.43	-3.26**	1.75**	2.13**	-14.63**
Sakha101/IRRI148	52.03**	52.02**	57.63**	-8.33**	1.66*	4.79**	-12.63**	-32.87**	-12.93**	-7.51**	-1.86**	-8.66**	0.99	-2.79*
Sakha101/WAB96-1-1	43.17**	73.23**	-10.17**	-21.21**	6.65**	-2.00**	-24.35**	-36.80**	-17.59**	-9.40**	-0.21	0.63	6.64**	25.04**
Sakha101/APO	55.35**	65.66**	-6.78**	-22.22**	20.38**	23.75**	-48.51**	-58.22**	-4.71**	-11.73**	-7.76**	-10.77**	-15.99**	6.80**
Sakha104/IRRI148	41.72**	49.57**	54.90**	-16.67**	4.46**	18.74**	-56.40**	-39.92**	-20.44**	-18.01**	-8.83**	-4.52**	-13.01**	1.09
Sakha104/WAB96-1-1	6.05**	23.04**	1.96*	-18.18**	3.81**	-8.46**	-7.83**	-22.82**	-12.85**	-4.30**	0.29	0.87	2.82**	29.08**
Sakha104/APO	1.91	55.22**	16.98**	-5.56**	3.81**	20.00**	-31.48**	-42.90**	-10.62**	-8.39**	-14.24**	-14.80**	-1.95*	12.34**
Sakha107/IRRI148	32.91**	55.83**	43.14**	-13.89**	9.94**	16.06**	45.71**	-57.98**	6.49**	2.40**	-0.29	-6.37**	2.44**	-7.77**
Sakha107/WAB96-1-1	18.99**	29.58**	3.92**	-8.57**	13.64**	6.15**	25.22**	-5.85**	-4.68**	9.29**	2.50**	1.09	11.47**	14.89**
Sakha107/APO	37.97**	33.33**	62.26**	-25.00**	25.59**	22.50**	6.48**	-61.17**	-2.22**	-6.72**	-0.72	-5.96**	-5.08**	7.19**
Sakha108/IRRI148	45.42**	71.30**	61.40**	2.78**	5.10**	10.24**	-28.15**	-39.81**	-21.85**	-19.62**	-8.65**	-7.37**	3.42**	-10.50**
Sakha108/WAB96-1-1	20.77**	30.87**	8.77**	-6.06**	15.15**	-16.31**	2.61**	-17.23**	-27.42**	-18.00**	-1.60*	0.54	11.73**	8.75**
Sakha108/APO	42.96**	45.65**	59.65**	-19.44**	37.81**	38.89**	27.31**	-3.20**	-2.45**	5.56**	-3.15**	-4.36**	-11.42**	-3.87**
LSD 0.05	3.26	2.00	1.80	1.04	1.52	0.29	0.66	0.20	1.29	0.58	1.21	1.24	1.47	2.25
LSD 0.01	4.36	2.68	2.41	1.40	2.03	0.39	0.89	0.27	1.72	0.77	1.62	1.65	1.97	3.01

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

With regard to plant height trait, recorded none of the cross combinations exhibited desirable combination effect for heterobeltiosis under both conditions. These results are in agreement with earlier findings of Jelodar, 2010. For the number of panicles plant^{-1}, high significant and positive heterobeltiosis were exhibited in the hybrid combination Sakha 108/ IRRI 148 under both conditions. In addition, regards panicle length, out of 15 cross combinations, ten combinations recorded positive, highly significant heterotic effects that varied from 4.79 to 38.89% over the respectively heterobeltiosis under stress condition. Where, the hybrid Sakha 108/ APO recorded the highest significant heterotic effects under both conditions. With regard of panicle weight, the results revealed that none of the cross combinations showed significant heterobeltiosis effects under stress condition. The maximum highly significant and positive heterobeltiosis for the 1000-grain weight were found in hybrid Sakha 108/ APO under stress of water condition. However, the cross Sakha 107/ IRRI 148 showed a high positive heterobeltiosis under both conditions. Positive significant and highly significant heterosis over heterobeltiosis effect was observed by the hybrid Giza 177/ APO under stress condition. Heterosis is a very important consideration in breeding programs for the yield and yield components of the crop. Yield is part of plant breeding creation and its ultimate goal. In most crosses, highly significant and maximum positive heterosis was observed in grain yield plant^{-1} as a deviation from the heterobeltiosis under both non-stress and stress conditions. The three cross combinations Giza 177/ WAB 96-1-1, Sakha 101/ WAB 96-1-1 and Sakha 104/ WAB 96-1-1 recorded the highest heterosis values over heterobeltiosis (24.93, 25.04 and 29.08%, respectively). These results are in corroborating with the findings of Bhati *et al.,* 2015.

Generally, plants exposed to water stress have lower evapotranspiration, which further leads to the development of certain water stress symptoms such as reduced leaf area and changes in physiological and biochemical processes such as stomatal leaf water status, photosynthesis, leaf temperature, hormonal balance, osmotic adjustments. Therefore, water stress quantification from plant-based approaches involve direct measurement of several aspects of plant water status and indirect measurements of plant processes which are highly sensitive to water deficit (Wang *et al.*, 2015).

Genetic parameters of variance

Genetic parameters for studying the traits under non-stress and stress of water conditions in rice genotypes are presented in Tables 6a and 6b. In the present investigation, all the studied traits showed high heritability in a broad sense under both conditions. Hence, direct selection can be done through these traits for future improvement of genotypes under respective environment for the improvement of water stress tolerance and higher grain yield. Earlier worker of Manickavelu *et al.,* 2006 also reported similar results.

Table 6a. Estimates of genetic components of variance for studied physiological and biochemical traits.

Components of variance	Days to 50% flowering (day)		Chlla (µg/ml)		Chllb (µg/ml)		Tchll (µg/ml)		RWC (%)		Leaf temperature(°c)		MDA (µmolsMDAg^{1}FW)	
	Normal	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**
Additive variance (δ^2 A)	3.37	22.16	0.14	0.26	0.01	0.01	0.22	0.34	0.05	0.49	0.03	0.02	14.11	291.64
Dominance variance (δ^2 D)	5.31	33.64	0.88	0.39	0.16	0.05	1.56	0.66	1.59	6.05	0.35	0.58	334.71	2193.67
Phenotypic Variance (δ^2P)	9.74	56.52	1.15	0.74	0.19	0.09	1.93	1.11	1.98	7.27	0.51	0.72	485.10	3027.30
Genotypic Variance (δ^2e)	8.68	55.80	1.01	0.65	0.17	0.06	1.78	1.00	1.63	6.54	0.38	0.60	348.83	2485.31
Broadsense (h^2b%)	89.14	98.72	87.80	87.51	87.99	64.80	92.44	90.09	82.30	89.91	74.09	84.23	71.91	82.10
Narrowsense (h^2n%)	34.65	39.20	11.89	34.88	3.38	10.28	11.43	30.70	2.29	6.77	5.15	3.01	2.91	9.63
GCA %	38.87	39.71	13.55	39.86	3.84	15.87	12.36	34.07	2.78	7.53	6.95	3.58	4.05	11.73
SCA %	61.13	60.29	86.45	60.14	96.16	84.13	87.64	65.93	97.22	92.47	93.05	96.42	95.95	88.27

Chlla: Cchlorophyll a; Chllb: Chlorophyll b; Tchll: Total Chlorophyll; RWC: Relative water content and MDA: Malondialdehyde content.

Table 6b. Estimates of genetic components of variance for studied yield and its related traits.

Components of variance	Plant height (cm)		No of panicles plant^{-1}		Panicle length (cm)		Panicle weight (g)		1000-grain weight(g)		Spikelets fertility(%)		Grain yield plant^{-1}(g)	
	Normal	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**	**Normal**	**Stress**
Additive variance (δ^2 A)	15.09	13.66	3.12	0.03	0.27	0.20	0.10	0.05	0.26	0.22	2.36	6.37	1.94	6.36
Dominance variance (δ^2 D)	176.79	137.03	16.05	0.87	2.06	3.73	0.78	0.16	5.15	4.99	13.18	9.86	8.76	4.92
Phenotypic Variance (δ^2P)	195.83	152.18	20.38	1.31	3.18	3.96	1.04	0.23	6.02	5.33	16.08	16.80	11.51	13.16
Genotypic Variance (δ^2e)	191.89	150.69	19.17	0.90	2.32	3.93	0.88	0.21	5.41	5.21	15.54	16.23	10.71	11.28
Broadsense (h^2b%)	97.99	99.02	94.07	69.02	73.09	99.20	84.23	93.10	89.81	97.68	96.63	96.62	93.03	85.74
Narrowsense (h^2n%)	7.71	8.97	15.33	2.48	8.39	5.03	9.17	23.45	4.32	4.16	14.66	37.94	16.90	48.36
GCA %	7.87	9.06	16.30	3.60	11.47	5.07	10.89	25.18	4.81	4.26	15.17	39.26	18.16	56.41
SCA %	92.13	90.94	83.70	96.40	88.53	94.93	89.11	74.82	95.19	95.74	84.83	60.74	81.84	43.59

Low narrow-sense heritability has been obtained in all the studied traits under both conditions, indicating that non-additive gene effects play an important role in controlling the traits studied. Ahmadikhah, 2008, reported low specific heritability for characteristics associated with yield. Gholizadeh *et al.*, 2014 also found that low additive gene effects and high dominant gene action caused the lower narrow-sense heritability. It shows that a commonly adopted genotype can be produced if these traits are subject to some selection scheme to manipulate fixable genetic variance. The characteristics of high heritability along with moderate or low genetic development can be enhanced by combining superior segregating population genotypes developed from combination breeding (Garg *et al.,* 2017). Therefore, it appears that hybridization must be an option for the population's use of specific hybrids. The estimated genetic advance for traits also demonstrated the potential to enhance most traits in order to achieve sufficient high yield lines. The findings indicate that improvement in these traits can be achieved in later generations through single plant selection followed by hybridization or intermating of selected segregants by recurrent selection. Similar findings have been observed previously by Sarma, *et al.,* 2007 and Abo-Yousef *et al.,* 2020.

The phenotypic variances for all the studied traits under both conditions were higher than the genotypic variances with the exception of the lipid peroxidation content (MDA), was the least. This may be due to the non-genetic factor that played an important role in the manifestation of these traits except MDA trait. Wide ranges of phenotypic and genotypic variance were observed in the experimental material for all the studied traits under investigation in both conditions. The maximum phenotypic (485.10 and 3027.30) and genotypic (348.83 and 2485.31) variance were exhibited by the MDA trait under non-stress and stress conditions. Exhibited high genotypic and phenotypic variances in stress condition indicating the importance of these characters in water stress condition for further improvement. Lonbani and Arzani 2011 and Ghidan *et al.,* 2018, obtained similar results. With respect to additive and non-additive variances, the data revealed that the values of non-additive variance were higher than the values of additive variance in all traits under studying for non-stress and stress conditions, indicating the effects of environmental variability on these traits, with the exception of the grain yield under stress of water condition. The grain yield plant^{-1}, exhibited high value of dominance variance than the value of additive under drought condition.

The GCA effects of all the studied traits evaluated under both conditions except for grain yield plant^{-1} under water stress condition, which were lower than SCA effects terms. As compared to SCA effects were usually lower than GCA effects (Titan *et al.*, 2012). In addition, Sharma *et al.,* 2006 reported that for some traits, GCA variance was significant and greater than SCA. The difference in the results reported by researchers may be attributed to differences of parental materials used hybridization and to genotype × environments. The results showed that, non-additive gene effects were dominant in genetic control of the above traits. Lipid peroxidation is considered as an indicator of oxidative stress and MDA is considered as a lipid peroxidation biomarker (Panda, 2007). In the present study, when the rice genotypes are subjected to water stress condition, MDA levels prominently increased. The increased MDA content suggests that drought stress damaged the cell membrane, which disturbs metabolic processes and finally inhibits the growth and physiological processes as reported in different rice seedlings (Zhang *et al.,* 2010). This effect was also evidenced in the present findings by the decrease in photosynthetic pigments under water stress condition. The low level of oxidative damage in some rice genotypes under different stress treatment suggests the potentiality of rice lines for oxidative protection under water stress (Singh *et al.*, 2013).

Estimation of water stress tolerance Index

According to grain yield plant^{-1} in non-stress and water stress conditions, yield reduction percent (YR), yield stability index (YSI), stress tolerance index (STI) and drought susceptibility index (DSI) indices were calculated and data were presented in Table 7. The drought susceptibility index was used to characterize the relative drought resistance of the genotypes studied which may be defined as a percentage of reduction in yield between non-stress and stress conditions (Mederski and Jeffers, 1973). It should be emphasized that DSI provides a measure of drought resistance based on minimization of yield loss under dry compared to moist conditions rather than on the yield level under dry conditions. The cross combinations, showed different degree of susceptibility or tolerance of the genotypes to drought. A ranking of the best tolerant genotypes were Sakha 107/ APO, Sakha 104/ WAB 96-1-1 and Sakha 101/ APO, which revealed lowest values of DSI.

The parameters of stress tolerance index (STI) and yield stability index (YSI) also were calculated, the genotypes with high values of these parameters could be selected as tolerant genotypes to water stress. The values of STI indices suggest that, the highest tolerance and yield potential were for the cross combinations Giza 177/ WAB 96-1-1, Sakha 101/ WAB 96-1-1, Sakha 104/ WAB 96-1-1, Sakha 107/ WAB 96-1-1 and Sakha 108/ WAB 96-1-1. While, the values of the YSI indices indicate that, the cross combinations Sakha 101/ APO, Sakha 104/ WAB 96-1-1, Sakha 107/ WAB 96-1-1 and Sakha 107/ APO exhibited the highest tolerance and yield potential. In addition, these combinations showed the lowest percentage of the yield reduction ratio (YR). Therefore, they can be grouped as tolerant genotypes to water stress condition as compared with the other genotypes.

Table 7. Estimates of different water stress tolerance indices for grain yield plant-^{1}

Genotypes	Grain yield plant^{-1}			
	YR	YSI	STI	DSI
Lines				
Giza 177	40.37	0.60	0.56	1.63
Sakha 101	35.18	0.65	0.74	1.42
Sakha 104	29.22	0.71	0.75	1.18
Sakha 107	16.72	0.83	0.93	0.68
Sakha 108	30.74	0.69	0.82	1.24
Testers				
IRRI 148	16.57	0.83	0.54	0.67
WAB 96-1-1	18.91	0.81	0.63	0.76
APO	16.42	0.84	0.60	0.66
Crosses				
Giza 177 / IRRI 148	45.81	0.54	0.43	1.85
Giza 177 / WAB 96-1-1	17.56	0.82	0.97	0.71
Giza 177 / APO	39.21	0.61	0.60	1.58
Sakha 101/ IRRI 148	37.61	0.62	0.73	1.52
Sakha 101/ WAB 96-1-1	21.40	0.79	1.02	0.86
Sakha 101/ APO	15.88	0.84	0.68	0.64
Sakha 104/ IRRI 148	17.77	0.82	0.66	0.72
Sakha 104/ WAB 96-1-1	11.18	0.89	1.00	0.45
Sakha 104/ APO	18.92	0.81	0.83	0.76
Sakha 107/ IRRI 148	25.03	0.75	0.88	1.01
Sakha 107/ WAB 96-1-1	14.16	0.86	1.19	0.57
Sakha 107/ APO	5.94	0.94	0.94	0.24
Sakha 108/ IRRI 148	40.05	0.60	0.76	1.62
Sakha 108/ WAB 96-1-1	32.58	0.67	1.00	1.32
Sakha 108/ APO	24.82	0.75	0.70	1.00

Yield reduction percent (YR); Yield stability index (YSI); Stress tolerance index (STI) and Drought susceptibility index (DSI).

SSR markers association analysis

The eight parental genotypes used in the current research have been subjected to profiling and evaluation for DNA polymorphism using SSR markers (Figure 1). In SSR amplified fragments, the presence, absence matrix for the studied genotypes are found in the Table 8. The three SSR markers spread on three chromosomes 2, 3 and 12 generated polymorphic alleles. Data showed that, a total number of 11 alleles were detected at the loci of the three markers across the eight rice genotypes. The number of alleles per locus generated by each marker with an average of 3.67 alleles per locus. Data showed that, across the eight rice genotypes, 11 alleles were detected at the loci of the three markers. An average of 3.67 alleles per locus is the number of alleles per locus produced by each marker. A high level of DNA polymorphism was detected using three SSR markers; RM260, RM279 and RM 514. SSR marker, RM260 showed five alleles ranged from 735bp to 290bp. The allele with molecular size 735bp was presented in all genotypes except the variety Sakha 101, also the allele with molecular size 330bp was presented in all genotypes except the variety Giza 177. While, the allele with molecular size 710bp was absent in three genotypes (Giza 177, Sakha 101 and Sakha 107). Freeg *et al.,* 2016 recorded same molecular size for RM260 (710bp) which indicating that RM260 is a positive marker for water stress. Moreover, Afiukwa *et al.,* 2016 found that RM260 one of the markers, which could be used for detecting drought tolerance.

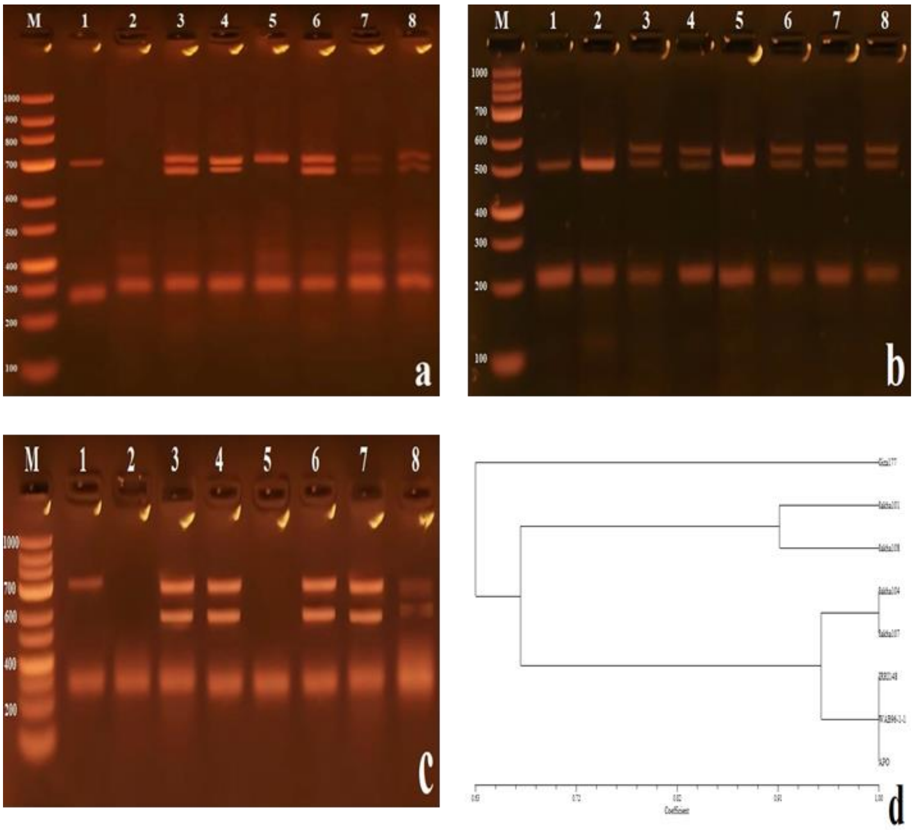

Figure 1: a) DNA profile of the eight genotypes with SSR marker RM260; b) DNA profile of the eight genotypes with SSR marker RM279; c) DNA profile of the eight genotypes with SSR marker RM514; d) Clustering dendrogram showing the genetic relationships among eight genotypes on the alleles detected by three SSR markers. M: Marker 100bp; 1: Giza 177; 2: Sakha 101; 3: Sakha 104; 4: Sakha 107; 5: Sakha 108; 6: IRRI 148; 7: WAB 96-1-1 and 8: APO

Table 8. The presence (1) and absence (0) matrix for SSR amplified fragments for the studied parental genotypes.

Markers	No. of Alleles	MW (bp)	1	2	3	4	5	6	7	8
RM260	1	735	1	0	1	1	1	1	1	1
	2	710	0	0	1	1	0	1	1	1
	3	403	0	1	0	0	1	1	1	1
	4	330	0	1	1	1	1	1	1	1
	5	290	1	0	0	0	0	0	0	0
RM279	1	579	0	0	1	1	0	1	1	1
	2	530	1	1	1	1	1	1	1	1
	3	234	1	1	1	1	1	1	1	1
RM514	1	751	1	0	1	1	0	1	1	1
	2	607	0	0	1	1	0	1	1	1
	3	321	1	1	1	1	1	1	1	1
Total bands			6	5	9	9	6	10	10	10

1: Giza 177; 2: Sakha 101; 3: Sakha 104; 4: Sakha 107; 5: Sakha 108; 6: IRRI 148; 7: WAB 96-1-1 and 8: APO

RM279 marker obtained three alleles ranged from molecular size 579bp to 234bp. The alleles with molecular size 530bp and 234bp were found in all genotypes, while the alleles with molecular size 579bp were presented in all genotypes except the varieties Giza 177, Sakha 101 and Sakha 108. The result obtained from RM279 indicates that the genotypes Sakha 104, Sakha 107, IRRI 148, WAB 98-1-1 and APO considered high tolerate to water stress. Shamsudin *et al.,* 2016 found that RM279 is flanking SSR markers for drought-QTL region. Furthermore, RM279 was found as one of the markers that demonstrated a significant association with the plant paddy weight under water stress condition (Tabkhkar *et al.,* 2018). In addition, it was detected that RM279 has digenic epistasis under water stress condition for grain yield (Zou *et al.,* 2005). Analysis of RM514 showed three alleles ranged from 751bp to 321bp with total 19 bands. All genotypes obtained the allele with molecular size 321bp, while the other two alleles (751bp and 607bp) were presented in the genotypes Sakha 104, Sakha

107, IRRI 148, WAB 98-1-1 and APO. The allele with molecular size 751bp was also presented in the variety Giza 177. In 2005, Zou *et al.,* found that the SSR marker RM514 has digenic epistasis under water stress condition for both grain yield and total grain weight. The cluster analysis based on similarity coefficients was done to determine the phylogenetic relationships among the eight genotypes (Figure 1d). All genotypes clearly grouped into two major clusters in the dendrogram at 63% similarity based on similarity coefficients. The first cluster represents the genotype Giza 177. While, the second cluster represents two sup clusters, the first sub cluster includes the genotypes Sakha 101 and Sakha 108 at 91%. While, the second sub cluster included the genotypes Sakha 104, Sakha 107, IRRI 184, WAB 96-1-1 and APO at 95%. The clustering system generated three genetic clusters with similarity coefficient 91%. The results showed that, Cluster 3 (contained 3 and 2 genotypes) is closer to cluster 2 than cluster 1.

CONCLUSIONS

This study briefly illustrated the relative efficacy of non-stress and water stress conditions based on various rice genotypes to detect their compatibility with yield and related components along with some physiological traits. The high magnitude of heterosis observed for grain yield plant^{-1} under water stress condition is worth exploitable for development of superior lines or hybrids for water-limited regions. In most crosses, highly significant and maximum positive heterosis was observed in grain yield plant^{-1} as a deviation from the heterobeltiosis under both conditions. Thus, superior cross combinations can also be utilized in hybrid breeding program to generate variability by utilizing transgressive segregants. Physiological profiling for water stress tolerance indicated that, the varieties Sakha 107, Sakha 108 and IRRI 148 exhibited significant positive in GCA effects in all the photosynthetic pigments under both non-stress and stress conditions. However, the hybrid combination Sakha 108/ IRRI 148 is a good specific combiner for photosynthetic pigments, relative water content and leaf temperature under water stress condition, RWC may be a good criterion to identify water stress tolerant genotypes with higher yield. The genotypes Sakha 107, IRRI 148, WAB 96-1-1 and APO were found to be more diverse based on molecular analysis among all genotypes according to their highest genetic distance. These varieties, could be considered as the potential donor for water stress tolerant, and used for marker-assisted breeding programs. The critical information gained from this investigation should be further applied for the screening of rice genetic resources for water stress tolerance.

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تقييم بعض الصفات المحصولية والفسيولوجية والمعلمات الجزيئية في الأرز تحت ظروف الري العادي والحرمان المائي

وليد فؤاد غيضان[1] و رانيا انور خضر[2]
[1]قسم بحوث الأرز ، معهد بحوث المحاصيل الحقلية، مركز البحوث الزراعية، مصر.
[2]قسم بحوث فسيولوجيا المحاصيل، معهد بحوث المحاصيل الحقلية، مركز البحوث الزراعية، مصر.

يعتبر الحرمان المائي من أهم الإجهادات الغير حيوية التي تؤثر سلبا على محصول الأرز، لذا فقد تم اجراء هذه الدراسة لتقييم مدي التباين الوراثى للمحصول والمكونات ذات الصلة وبعض الصفات الفسيولوجية بغرض تقدير القدرة علي الائتلاف وقوة الهجين والمعلمات الجزيئية SSR في ظل ظروف الحرمان المائي والري العادى. تم تقييم 15هجين بالاضافة الي الأباء في المزرعة البحثية بقسم بحوث الأرز، سخا ، كفرالشيخ خلال موسمي زراعة الأرز عام 2019 و 2020. أظهر تحليل التباين وجود إختلاف بين التراكيب الوراثية والهجن والسلالات والتفاعل فيما بين السلالات والكشافات لجميع الصفات تحت الدراسة. أظهر الصنف سخا 107 قدرته العالية علي تحسين محصول الحبوب تحت ظروف الإجهاد المائي ، كما أظهر الصنف سخا 108 ايضا قدرة عالية لتحسين محصول الحبوب تحت ظروف الري الطبيعية. أما بالنسبة الي الحرمان المائي ومدى تأثر المحصول فقد لوحظ ان التراكيب الوراثية سخا 107/ أبو و سخا 107/ واب96-1-1 و سخا 104/ واب96-1-1 و سخا 101/ أبو - قد أظهرت إنخفاض في قيم دليل حساسية الإجهاد المائي بالاضافة الي قيم عالية في دليل تأثر محصول الحبوب مما يعطي دليل علي القدرة العالية الخاصة للائتلاف للمحصول وبعض الصفات الفسيولوجية والبيوكميائية تحت ظروف الحرمان المائي. وبالنظر الي المعلمات الجزيئية فقد اظهرت النتائج ان التراكيب الوراثية سخا 107 ، أي أر أي 148 ، واب96-1-1 و أبو - لهم القدرة علي تحمل الحرمان المائي ويمكن إستخدامهم في برامج التربية.