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Genetic Analysis of Yield Attributes in Rice for Water Deficit Under Egyptian Conditions

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ABSTRACT

Rice parental genotypes with good combining abilities provide an efficient tool to enhance rice yield under water deficit conditions. Using 15 F_1 hybrids derived from a half diallel mating involving six parental genotypes, two experiments were carried out during 2019 and 2020 growing seasons to investigate the genetic analysis and combining ability for yield and its components under irrigated (E I) and water stress (E II) environments. Eight agronomic traits were studied over a period of two seasons, and cluster analysis based on 16 SSR primers found that the genotypes under study differed greatly in terms of variation. Overall, all yield attributes have been significantly affected by water deficit and was governed by both additive and non-additive gene actions. Based on the mean values and GCA effects, Gaori and IET1444 are suitable for incorporation of earliness and drought tolerance traits. Obviously that Gaori, IET1444, IRAT 170 and WAB 450 would serve as good general combiners for grain yield attributes under (E II) conditions. Due importance should be given for six combinations viz, Giza 177 x IRAT 170, Giza 177x Gaori, Sakha 101x IRAT 170, Sakha 101x IET 1444, Gaori x WAB 450 and IET 1444x WAB 450 to identify as new genotypes with high grain yield under water deficit condition. There might be a great possibility to get the best new combinations through crossing genotypes with highest genetic distance. Therefore, these findings should be considered when selecting elite genotypes for developing superior new rice crosses under water-stress conditions.

Keywords: Rice, genotypes, water deficit, diallel analysis, GCA and SCA effects.

INTRODUCTION

Rice is a key worldwide crop that feeds the majority of the world's population and will continue to play an important role in global food and livelihood security. Rice is widely grown in many regions of the world, including Egypt. According to researchers, the global population will continue to rise from 7.7 billion to 9 billion in 2035 (Leonilo *et al.,* 2020). As a result, an increase in world rice demand from 763 to 850 million tones will be required.

Drought is a significant limiting factor that has a negative impact on rice production. Due to limited water supplies and a variety of biotic and abiotic difficulties, there is a high demand for sustainable rice production systems. During the summer season, rice occupies around 22% of Egypt's entire growing area and consumes roughly 20% of the country's total water resources. Because Egypt's water resources are restricted, in addition to the country's growing population, the overall water requirements for the rice crop are a severe challenge due to the river Nile's limited irrigation water supply. Some rice-growing areas, particularly those near the terminal irrigation canals in the northern part of the Nile Delta, have irrigation water shortages at various phases of growth, which is considered one of Egypt's most significant constraints to rice production (Abd Allah *et al.,* 2009). Therefore, the development of water stress tolerance genotypes with a high yield potential is one of the main objectives of rice breeding for boosting rice production in Egypt.

Rice, despite its drought sensitivity, offers a significant opportunity to breed for drought tolerance because of its inherent capacity and availability of vast genetic variability for larger adaptations in varied ecosystems. Despite the realization about the importance of water use efficiency in crop improvement, the available genetic variability for drought tolerance has not been progressively exploited in drought improvement breeding endeavors (Venuprasad *et al.,* 2008). Drought tolerance breeding necessitates knowledge of gene action and combining ability of yield attributes in both stress and non-stress conditions. (Ashfaq *et al.,* 2012). It is crucial to identify possible rice parents and their hybrids that combine properly for each high yielding and water stress tolerance in order to build an effective program for synthesis of genotypes with water stress tolerance and high yielding potential. The choice of an effective breeding program necessitates an intensive knowledge of the type gene action concerned in character expression. The general combining ability (GCA) is a useful tool for determining which parents to choose depending on the performance of their progenies, and it indicates additive gene action (Sprague and Tatum 1942). The specific combining ability (SCA) indicates non-additive gene action related with dominance, over-dominance, and epistatic effects, and it gauges the performance of hybrid combinations which reported by Latha *et al.,* (2013) and Su *et al.,* (2017). The most generally employed mating design for hybrids improvement is diallel fashion analysis, that's appeared as an effective biometric

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approach for assessing each GCA and SCA, in addition to providing information about the nature of gene actions (Kempthorne 1957). In hybrid combinations, genetic diversity among parental genotypes plays a significant influence. The incidence of genotype by-environment interaction within the target genotype – environment system of a breeding program necessitates the use of multi environmental trials. Consequently, six parental genotypes with different responses to drought stress had been crossed in a half diallel fashion in the current investigation to determine the nature of gene action, and to identify the best combining parents, and hybrid combinations for improving high yielding drought tolerant rice genotypes.

MATERIALS AND METHODS

Plant Materials and Experimental Design

Six parental genotypes of rice viz., Giza 177, Sakha 101, IRAT 170, Gaori, IET 1444 and WAB 450-I-B-p-38-HB were selected for present study. Giza 177 temperate japonica Egyptian variety has good yield and quality traits but unfurtionately sensitive to water deficit condition, Sakha 101 temperate japonica Egyptian variety is the most distributed and high yielding variety across Egypt but it is clearly affected by the water stress in its yield and performance as well. IRAT 170, Gaori and WAB 450-I-B-p-38-HB are exotic rice genotypes and suited to water stress conditions. The remaining genotype IET 1444 is high yielding variety adapted to drought condition. Crossing was carried out among these genotypes in half diallel fashion design to produce 15 hybrids during 2019 growing season.

During the 2020 growing season, the parental genotypes and hybrid combinations were examined at the Sakha Agricultural Research Station Experimental Farm in Kafr EL-Sheikh, Egypt (30˚ 57′ 12″ north latitude, 31˚ 07′ 19″ east longitude). Clay (64.3%), sand (7.6%), and silt (28.1%) made up the mechanical properties of the soil, which had a pH range of 7.8 to 8.5. The relative humidity was 62.74 per cent and the mean maximum and minimum temperature of 32.97ºC and 23.75ºC was recorded. Two experiments were used to grow the F_1 hybrid combinations as well as their parental genotypes. The first experiment (E I) was transplanted into normal irrigation conditions (N). The second experiment (E II) was transplanted under a water stress condition (S) with flash irrigation every 10 days without any water standing and when required according to permanent wilting point (Table 1). After two weeks of transplanting until the maturity stage, the stress condition was revealed.

Soil moisture content was measured gravimetrically in soil samples obtained at intervals of 15 cm down to 45 cm. Soil samples were taken just before each irrigation and 48 hours later. In the field, the field capacity was determined. The permanent wilting point and bulk density were measured to a depth of 45 cm using Klute's method (1986).

Table 1. Some soil constants measured before each irrigation

Soil depth(cm)	F.C.%	W.P.%	Bulk density g/cm3
0-15 cm	45.68	24.7	1.12
15-30 cm	41.3	22.4	1.18
30-45 cm	38.75	20.28	1.23
Mean	41.91	22.46	1.177

Where, F.C.% = field capacity, W.P.% = permanent wilting

Periodic soil sampling at 15 and 30 cm soil depth after suspension water was used to assess the soil moisture content status during the reproductive stage (stress period). During the stress stage, the water table was also measured. With three replications, all of the experiments were designed using the Randomized Complete Block Design (RCBD). Thirty-day-old seedlings were transplanted one per hill, with a 20-cm row spacing and a 20-cm plant spacing. The Egyptian rice research program recommended that all cultural practices be followed. Phenotypic data for eight yield component traits was collected from 10 individual plants from each genotype in each replication at maturity stage. These yield characteristics included the days to heading (day; DH), plant height (cm; PH), panicle length (cm; PL), No. productive tillers / plant (PT), spikelet sterility (%; SS), 100-grain weight (g; GW), grain yield plant (GY) and harvest index (HI) according to (IRRI, 2013).

Microsatellite marker analysis:

Leaf samples were taken from single plants of 21-day-old seedlings for six parental genotypes and their fifteen combinations, and genomic DNA was extracted using Murray and Thompson's CTAB (Cetyl Tri Methyl Ammonium Bromide) method (1980). On the basis of a previously published rice microsatellite framework map, sixteen primer pairs distributed among three chromosomes (chr4, 5, and 6) were selected for phylogenetic analysis (Table 2). The rice genome database (http://www.gramene.org) can be used to find the original source, repeat motifs, primer sequences, and chromosomal positions for these markers.

Table 2. SSR markers used in the current study and some of their basic features.

No.	Marker Name	Chr.	Exp. Pro. size	Repeat Motif	Ann. Temp.	F primer seq.	R primer seq.
1	RM131	4	210	(CT)9	64.5	TCCTCCCTCCCTTCGCCCACTG	CGATGTTCGCCATGGCTGCTCC
2	RM252	4	190	(CT)19	62.5	TTCGCTGACGTGATAGGTTG	ATGACTTGATCCCGAGAACG
3	RM255	4	140	(AGG)5(AG)2-(GA)16	62.2	TGTTGCGTGTGGAGATGTG	CGAAACCGCTCAGTTCAAC
4	RM335	4	110	(CTT)25	63.0	GTACACACCCACATCGAGAAG	GCTCTATGCGAGTATCCATGG
5	RM451	4	200	(GAT)8	62.5	GATCCCCTCCGTCAAACAC	CCCTTCTCCTTTCCTCAACC
6	RM518	4	170	(TC)15	63.0	CTCTTCACTCACTCACCATGG	ATCCATCTGGAGCAAGCAAC
7	RM159	5	225	(GA)19	68.0	GGGGCACTGGCAAGGGTGAAGG	GCTTGTGCTTCTCTCTCTCTCTCTCTCTC
8	RM161	5	160	(AG)20	68.5	TGCAGATGAGAAGCGGCGCCTC	TGTGTCATCAGACGGCGCTCCG
9	RM169	5	155	(GA)12	68.5	TGGCTGGCTCCGTGGGTAGCTG	TCCCGTTGCCGTTCATCCCTCC
10	RM249	5	120	(AG)5A2(AG)14	62.5	GGCGTAAAGGTTTTGCATGT	ATGATGCCATGAAGGTCAGC
11	RM274	5	145	(GA)15-7-(CGG)5	62.5	CCTCGCTTATGAGAGCTTCG	CTTCTCCATCACTCCCATGG
12	RM440	5	170	(CTT)22	62.0	CATGCAACAACGTCACCTTC	ATGGTTGGTAGGCACCAAAG
13	RM480	5	215	(AC)30	62.5	GCTCAAGCATTCTGCAGTTG	GCGCTTCTGCTTATTGGAAG
14	RM412	6	190	(GA)22	59.5	CACTTGAGAAAGTTAGTGCAGC	CCCAAACACACCCAAATAC
15	RM527	6	220	(GA)17	60.5	GGCTCGATCTAGAAAATCCG	TTGCACAGGTTGCGATAGAG
16	RM528	6	225	(AGAT)9	61.5	GGCATCCAATTTTACCCCTC	AAATGGAGCATGGAGGTCAC

Reaction conditions have been done in a 25 µL total volume made up of 0.1 µM each primer, 1 unit Taq DNA polymerase, 0.2 µM each dNTP, 10 mM Tris-HCl pH 7.2, 50 mM KCl, 1.5 mM MgCl2, DMSO (50%), and 120 µg DNA. The reaction was amplified in DNA Engine Dyad™ thermal cycler (Bio-Rad Laboratories, Hercules, California, USA) programmed for one cycle at 95 °C for 5 min followed by 35 cycles of 95 °C for 1 min, 55- 65 °C (in accordance with the primer) for 2 min, and an extension period at 72 °C for 7 min. A 1.5 µL aliquot of PCR products was loaded onto 3% denaturing polyacrylamide gels and run in 0.5× TBE buffer at 1800 V for about 2 h. To visualize DNA fragments, gels were stained with silver nitrate according to Promega's technique (Madison, Wisconsin, USA). Perfect DNA 50 bp (EMD Chemicals, Madison, Wisconsin, USA) and PCR marker 50-500bp (EMD Chemicals) ladders were used to determine allele sizes.

Data Analysis

Dendrogram analysis: The presence and absence of each marker allele-genotype combination were scored qualitatively in amplified products from SSR analysis. A unit character was assigned to each SSR band amplified by a specific primer. Data was entered as discrete variables into a binary matrix, with 1 indicating the presence of the character and 0 indicating its absence. To develop a dendogram, the UPGMA (average linkage) approach was used to create a cluster diagram based on these distances. Numerical Taxonomy and Multivariate Analyses system, Version 2.1, (NTSYSpc; Rolhf, 2000) was used to compute the similarity matrix, genetic distances, and dendogram analysis. Correlation of traits: Pearson correlation coefficients were used to calculate correlation between the values of the estimated traits, which were then plotted using the packages corrplot and Performance Analytics (Wei *et al.,* 2018). Analysis of variance: Data were analyzed separately for individual environments and also combined analysis over environments (Singh, 1973) using DIALLEL-INDOSTAT software. Estimates of general combining ability (GCA), specific combining ability (SCA) effects and heterosis were obtained according to Griffing's method 2, model 1 (Griffing B. (1956).

RESULTS AND DISCUSSION

Clustering of the genotypes based on SSR primers variations:

Cluster Analysis was used to categorize a set of variables. The aim was to establish a set of clusters in which examples within a cluster were more comparable to each other than cases within other clusters, resulting in a high degree of linkage between members of the same cluster and a low degree of association between members of different clusters. As a result, each data cluster was able to identify the class to which its members belonged. Anderberg, (1973) reported that, the description could be abstracted by applying the specific to the general class or type. The dendrogram analysis of six parental lines and their F_1 crosses in this study was based on data from 16 SSR primers, and the results revealed two main clusters with internal sub-clusters exhibiting varied degrees of diversity (Figure 1). The dendrogram separated all genotypes (parent and their F_1 crosses) into two clusters. The first cluster was separated into two sub-clusters, the first of which only included one genotype, Giza 177 (Egyptian japonica sensitive variety for water stress condition). The second sub cluster included three parental genotypes and four crosses and further divided into two groups. The two japonicas parental genotypes (Sakha101 and Gaori) came close each other in Group I because of their level of tolerance for water stress deficit (moderate tolerance). The exotic indica genotype (IET1444) came in Group II separately from the other genotypes maybe because it is geographically diverse and level of tolerance (high moderate). The second cluster was further divided into two sub-clusters. The first sub cluster included four F_1 hybrid combinations and an exotic indica parental genotype (IRAT170). The second sub-cluster included seven F_1 hybrid combinations and another exotic indica parental genotype (WAB450 -I-B-p-38-HB), the F_1 hybrid combinations included at least one of the exotic parental genotype or both of them in their genetic background. This meant that, depending on their phylogeny, more genetically similar genotypes were placed together in the same cluster. The evaluation of genetic variance among parental genotypes is critical for the effective utilization of the rice breeding program. The UPGMA cluster analysis revealed a substantial diversity difference across parental genotypes in this study (Figure 1), suggesting that combining the genotypes with the highest genetic distance could produce the best new combinations (El-Refaee *et al.,* 2016).

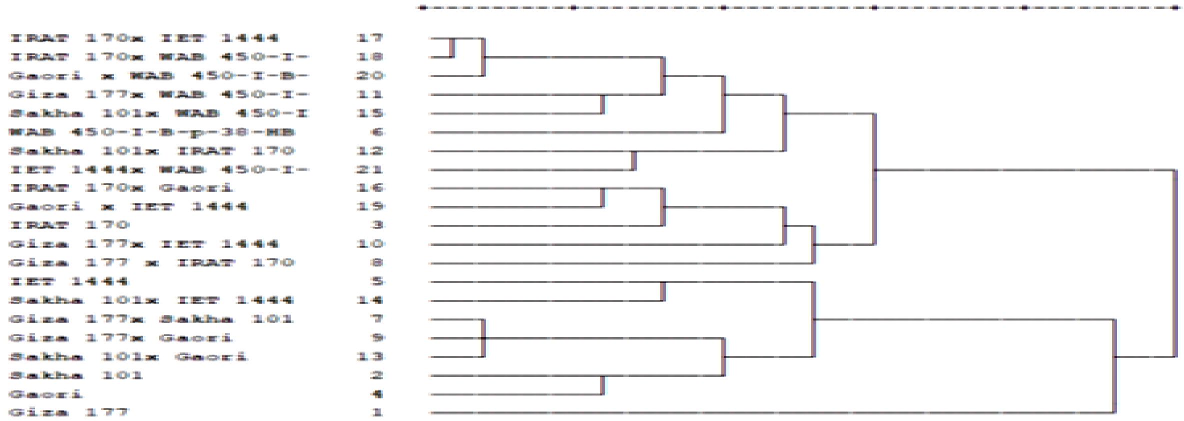

Figure 1. Dendrogram of studied rice genotypes using UPGMA method based on Dice's coefficient for 16 SSR primers data.

Mean performance of the studied genotypes for the eight traits

Table 2 shows the mean performance of the parental genotypes and their hybrid combinations under normal and water-stress conditions. Water-stress conditions had a substantial impact on all attributes in this investigation when compared to normal irrigation conditions. Plant height (PH), productive tillers plant^{-1} (PT), spikelet sterility (SS), harvest index (HI), and grain yield plant $^{-1}$ (GY) were the traits that were most influenced by water stress. In comparison to water-stressed conditions, the parental lines and their hybrid combinations performed better in all traits. Furthermore, the hybrids were shown to have high productive tillers plant^{-1} (PT), panicle length (PL), spikelet sterility (SS), harvest index (HI), and grain yield plant $^{-1}$ (GY) when compared to the parental lines, particularly the 100-grain weight (GW) trait. When compared to normal irrigation conditions, all 21 genotypes showed significantly different depression when exposed to water stress. For days to heading, it is clear that the earlier plants were observed from Giza 177 x Gaori followed by IRAT 170 x Gaori they had 96.44 and 96.57 days respectively under non stress condition. Meanwhile, under stress condition the cross IRAT 170x Gaori followed by Giza 177x Sakha 101 gave the lowest values (82.59 and 82.68 days) respectively. The parental genotype Giza 177 was the most earlier genotypes under both of two conditions with values 92.61 and 62.60 respectively. Obviously, water stress conditions caused earliness in heading which increased in the most of all genotypes. While, it was interesting to note that the tested genotypes were affected differently by water deficit conditions. The results showed that the most affected genotypes were Giza 177 that recording about 30-day earliness under water stress conditions. Meanwhile, six days or less differences were observed for crosses; IET 1444 x WAB 450, IRAT 170x IET 1444 and Gaori x WAB 450 under water deficit conditions. The genotypes displaying the lowest reduction in the heading date indicate that they are tolerant of water stress conditions.

Concerning plant height, the cross Sakha 101x IRAT 170 showed highest value under non stress (131.17 cm), followed by Giza 177 x IRAT 170 (130.93cm). However, the hybrid combinations; Gaori x WAB450, IRAT 170 x IET1444, Gaori x IET1444 and Sakha 101x IET1444 showed the lowest reduction in plant height, thus confirms that it is tolerant to stress of salinity. Giza 177 (1) was (75.58 cm) the shortest genotype under water deficit conditions, reduced plant height stature was also reported by Lee *et al.*, (2003). Water stress may have inhibited cell expansion in the leaf growth zone, resulting in a reduction in plant height in sensitive genotype (Fraga *et al.,* 2010). The results in Table 2, revealed that the highest number of productive tillers/plant under normal irrigated condition were recorded for the two combinations; Sakha 101 x IET1444 (21.37) and Giza 177 x IET1444 (20.79), meanwhile, under water stress conditions the hybrid combinations Giza177 x IET1444 and IET1444 x WAB450 which their estimated values were 17.60 and 16.27 panicles. For panicle length trait, the longest panicles detected in the two combinations; Sakha 101 x WAB450 (25.72 cm) and IRAT170 x IET1444 (25.50 cm) under normal condition, meanwhile, under water stress conditions the hybrid combinations IRAT170 x WAB450 and IET1444 x WAB450 which their estimated values were 23.16 and 23.07 cm. With respect to 100-grain weight, the heaviest grains detected in the hybrid combinations; IRAT170 x Gaori followed by IRAT170 x WAB450 which their estimated values were 3.26 g and 3.15 g at non-stress and 3.02 g and 3.0 g at saline conditions, respectively.

Table 2. Mean performance of the studied rice genotypes under normal irrigation and water stress conditions

Genotypes	Days to heading (days)		Plant height (cm)		No. productive tillers plant^{-1}		Panicle length (cm)		100-gain weight (g)		Spikelet Sterility (%)		Harvest index (%)		Grain yield plant^{-1} (g)	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
Giza 177	92.61	62.61	108.86	75.58	17.21	9.51	22.70	15.48	2.86	2.04	7.60	36.51	38.02	19.23	34.60	16.41
Sakha 101	106.36	81.87	99.83	75.91	20.45	15.21	21.62	17.72	2.71	2.14	8.91	15.64	42.10	29.88	40.93	29.39
IRAT 170	105.16	94.19	124.14	112.13	15.36	13.89	24.30	22.75	3.20	2.92	11.83	14.66	30.46	26.39	29.33	24.79
Gaori	98.87	82.67	92.59	82.65	18.61	15.17	20.95	18.23	2.73	2.31	11.19	16.07	33.40	26.09	33.31	25.35
IET 1444	106.83	94.71	107.66	96.43	20.23	17.15	23.87	22.82	2.59	2.36	9.46	11.80	32.38	27.29	36.47	31.27
WAB450-I-B-p-38-HB	114.12	103.37	117.86	105.60	15.22	13.60	25.27	23.84	3.05	2.74	10.46	12.43	27.40	23.41	33.64	30.12
Giza 177x Sakha 101	103.49	82.68	104.57	89.40	21.26	14.36	22.17	19.25	2.73	2.21	9.77	25.57	38.31	23.40	37.23	22.22
Giza 177 x IRAT 170	99.47	90.67	130.93	111.54	19.38	14.63	22.89	21.08	2.99	2.50	22.66	27.30	38.78	26.63	38.25	28.80
Giza 177x Gaori	96.44	84.23	104.14	90.80	16.75	13.71	22.90	19.62	2.67	2.32	7.39	19.16	37.03	27.39	35.93	24.58
Giza 177x IET 1444	99.54	92.39	112.74	102.16	20.79	17.62	24.13	20.69	2.73	2.55	17.55	20.52	28.84	21.48	29.97	23.43
Giza 177x WAB 450	108.81	100.70	117.01	108.61	15.86	13.56	24.97	20.41	2.86	2.51	20.01	22.19	35.44	28.87	35.20	27.83
Sakha 101x IRAT 170	109.12	97.23	131.17	110.31	17.93	16.07	22.52	21.05	2.94	2.70	16.60	18.98	41.25	33.53	41.33	33.80
Sakha 101x Gaori	99.88	89.99	105.99	94.90	20.60	15.55	22.25	18.73	2.76	2.61	8.16	17.26	34.54	26.85	36.01	26.78
Sakha 101x IET 1444	107.20	93.50	104.34	96.73	21.37	16.25	24.77	21.70	2.65	2.40	14.38	18.42	43.68	31.60	43.13	33.84
Sakha 101x WAB 450	118.32	105.46	122.27	109.46	16.62	14.67	25.73	22.28	3.07	2.77	15.80	19.66	39.93	30.59	38.36	30.66
IRAT 170x Gaori	96.57	82.60	123.21	110.68	17.15	15.27	22.24	18.71	3.26	3.03	12.83	14.09	33.77	29.26	34.62	30.10
IRAT 170x IET 1444	104.64	99.81	115.57	109.22	17.53	15.27	25.50	22.89	2.75	2.58	9.25	11.35	36.43	33.41	35.61	31.24
IRAT 170x WAB 450	107.19	101.46	120.11	112.01	17.42	16.01	24.78	23.16	3.15	3.01	8.84	10.59	38.29	34.10	32.48	29.39
Gaori x IET 1444	99.07	91.73	115.01	106.76	15.60	13.53	22.61	21.42	2.56	2.40	13.28	18.02	36.31	24.83	36.54	27.19
Gaori x WAB 450	106.33	101.15	116.81	110.80	16.93	15.15	24.90	20.76	2.90	2.60	14.91	15.53	38.32	32.24	37.55	30.22
IET 1444x WAB 450	103.51	99.42	130.44	120.90	18.56	16.28	24.74	23.07	2.82	2.57	8.43	10.13	36.39	33.33	38.63	33.02
LSD at 0.05%	2.13	1.53	1.66	1.74	0.93	0.85	0.63	0.73	0.11	0.10	1.92	2.22	1.63	1.60	1.53	1.62
LSD at 0.01%	2.83	2.03	2.20	2.30	1.24	1.13	0.84	0.97	0.14	0.13	2.54	2.94	2.16	2.12	2.03	2.15

For spikelet sterility percentage which presented in Table 2, showed that, the most desirable mean values were recorded from the hybrid combinations; Giza 177 x Gaori and Sakha 101x Gaori under normal conditions, on the other hand, under water deficit condition the combinations IET 1444x WAB 450 and IRAT 170x WAB 450 showed the lowest sterility percentage. Concerning harvest index, the most desirable mean values were recorded from Sakha 101x IET 1444 (43.68%) and Sakha 101x IRAT 170 (41.25%) under normal condition, meanwhile, under water stress conditions the hybrid combinations; IRAT 170x WAB 450 (34.10%) and Sakha 101x IRAT 170 (33.53%). For grain yield plant^{-1}, the highest yield detected in the hybrid combinations; Sakha 101x IET 1444 followed by Sakha 101x IRAT 170, IET 1444x WAB 450 and IRAT 170x IET 1444 which their estimated values were 43.13 g, 41.33 g, 38.63 g and 35.61 g under normal irrigated and 33.84 g, 33.80 g, 33.02 g and 31.24 g at water stress conditions, respectively. Under water stress, the reproductive stage is one of the most sensitive growth stages. This is the most crucial stage in terms of grain yield, because good fertilization at this stage is eventually transformed into grain yield. As a result, water SCArcity during the flowering and grain filling stages diminishes yield significantly because it impacts numerous physiological mechanisms such as floral fertility in rice, which is very sensitive to water stress (Kumar *et al.,* 2014). This led to inadequate fertilization and poor seed setting as a consequence. Almost all genotypes reduced their percentage of spikelet fertility under stress, but those that dramatically decreased the percentage of fertility in conjunction with a very high reduction in grain yield were regarded as the sensitive genotypes for the reproductive stage (Hossain *et al.,* 2015).

In general, genotypes that showed the least decline when water was SCArce were more drought tolerant than others. Previous research has found similar findings (Herwibawa *et al.,* 2019). According to the results for yield trait which showed high reduction in its value under drought stress comparing with normal condition, this indicate that yield affected by terminal drought, this occurs near the end of the growing season, but can also start before flowering. Also, reduction in yield characters may be resulted in vegetative stage drought reported previously by Ouk *et al.,* (2007). However, Kamoshita *et al.,* (2008) found that because of recovery growth in the later growing season, this reduction may be less than terminal water deficit. Overall, the new cross combinations outperformed the parental lines for yield-related traits, demonstrating the apparent hybrid vigour.

Correlation analysis for the studied genotypes:

Figure 2 shows the correlation analysis of the eight traits for all genotypes under both normal and water-stress conditions. The data revealed that 6 correlation coefficients showed significantly ($p < 0.05$) 5 of these were positive and only one was negative correlation among the traits under normal growth conditions (Figure 2, upper triangle). Among these, three had highly positive correlations. The three highly positive correlations were between GY with HI, GW with PH and PL with DH, respectively.

A total of 26 correlation coefficients were determined to be significant (p 0.05) under water-stress conditions, 19 of which were positive and the other 7 were negative correlations (Figure 3 lower triangle). There were six absolute positive correlations in the positive correlations: GY with DH and HI, GW with PH, PH with DH, and PL with DH and PH. Similarly, the negative correlation there was one correlation, which was between the GY with SS (Figure 2 lower triangle). There were varied degrees of association among most of the other traits in the same text (Figure 3 lower triangle). Except for the DH and PH under water-stress conditions, the data showed a positive association among the yield attributes. Under normal irrigation conditions, the GY was positively linked with the HD, PH, PT, PL, and HI. The grain yield showed a significant correlation with yield-related components under normal irrigated conditions, which was consistent with earlier findings (Leonilo *et al.,* 2020).

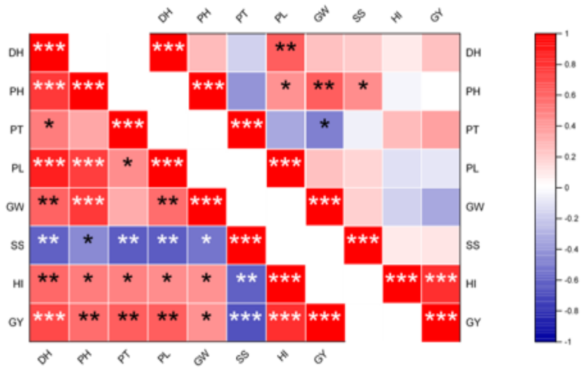

Figure 2. Corrplot depicting Pearson's correlation between 8 yield attributes by 21 genotypes under normal (upper triangle) and water-stress (lower triangle) conditions.

Red squares indicate a positive correlation; blue squares indicate a negative correlation; and white squares indicate no correlation. The asterisks indicate significant correlations using a two-tailed t-test (* and ** p < 0.05; and *** p < 0.01). DH: Days to heading, PH: Plant height, PT: No. productive tillers plant^{-1}, PL: Panicle length, GW:100-gain weight, SS: Spikelet Sterility, HI: Harvest index and GY: Grain yield plant^{-1}.

Combined analysis of variance for the eight traits of the studied genotypes:

The analysis of variance of different genotypes in diverse conditions (irrigated and water stress conditions) revealed significant variances for all characters assessed, showing that the germplasm employed in the study has a significant level of genetic variability (Table 3). As a result, the genotypes studied can be used to improve grain yield and other agronomic traits in water-stressed conditions. Previous studies have stressed the importance of genetic variability in the development of new better genotypes (Malemba *et al.,* 2017). Combined analysis of variance revealed that the environmental differences were statistically significant for all the traits under this study. The differences due to combined analysis among the entries were significant for all studied traits in this study: days to heading, plant height, no of productive tillers plant^{-1}, panicle length, 100-gain weight, spikelet sterility (%), Harvest index (%) and grain yield plant^{-1}. The mean squares due to entries x environment interactions were significant for all the traits. The significance of mean squares due to genotype, environment, genotype x environment for days to heading, plant height, no of productive tillers plant^{-1}, panicle length, 100-gain weight, spikelet sterility (%), Harvest index (%) and grain yield plant^{-1} suggested the importance of both genotype and environment components for these traits. Therefore, it is concluded from the present study and also the previous work by Abd Allah *et al.,* (2009) and Suresh *et al.,* (2013) that the drought tolerant, high yielding genotype of rice cannot simply be developed by crossing the drought tolerant and high yielding parents without referring to the environmental influence.

Table 3. Combined analysis of variance of the studied genotypes for eight yield characteristics under normal and water stress conditions

Source	d.f	DH	PH	PT	PL	GW	SS	HI	GY
location	1	4503.06*	5311.16*	269.99*	258.43*	3.22*	970.74*	2091.25*	2029.78*
Rep.xloca	2	1.95	29.74*	8.18*	2.78*	0.07*	4.33	9.90	16.24*
Entries	20	349.63**	752.3**	21.88*	16.73*	0.29*	109.47**	85.99*	68.23*
Parents	5	677.69**	997.76**	27.3*	35.42*	0.44*	103.71**	72.99**	87.71*
Crosses	14	230.81*	481.8**	21.29*	10.16*	0.25*	113.78**	80.93**	56.13*
PxF1	1	372.71**	3311.93**	2.91*	15.23*	0.17*	77.92**	221.9**	140.23**
Entr.xloca	20	324.75**	324.97**	264.06*	263.39*	260.26*	324.18**	286.16**	281.39*
Paren.xloc	5	97.22*	133.01**	8.43*	8.11*	0.08*	163.08**	51.84**	46.45*
Cros.xloc	14	30.61**	29.71**	1.85*	1.62*	0.02*	27.97**	18.37*	13.46*
P1vsF1xL	1	375.98**	214.06**	8.67*	0.17	0.17*	72.21**	2.33	2.69
Error	80	1.74	1.46	0.4	0.24	0.01	2.17	1.32	1.25

*** and ** Significant differences at the 0.05 and 0.01 levels of probability, respectively. DH: Days to heading, PH: Plant height, PT: No. productive tillers plant^{-1}, PL: Panicle length, GW:100-gain weight, SS: Spikelet Sterility, HI: Harvest index and GY: Grain yield plant^{-1}.**

Combining ability analysis under both two environments:

GCA and SCA variances were significant in both the environments for all the traits in this study (Table 4). In addition, the GCA variance was greater in magnitude than SCA variance in individual environments and also in combined analysis for all the traits except for spikelet sterility (%) in EI, wherein SCA variance was greater than GCA variance. The significance of both GCA and SCA variances observed for all the studied in both the environments indicated the importance of both additive and non-additive gene action for the expression of these traits (Iflekharudduala *et al.,* 2008). Also the magnitude of GCA variances was higher than SCA variances indicating the predominant role of additive effects in determining the expression of these traits. Breeders use the criteria such as (i) comparison of GCA: SCA variance ratio and (ii) least deviation of the ratios in order to rank the characters possessing relatively more fixable additive variation, which will largely help to exercise selection in the succeeding generations based on one or more traits. Hence, GCA/SCA ratio was used as a measure to understand the nature of genetic variance involved. In the present study, days to heading, plant height, no of productive tillers plant^{-1}, panicle length, 100-gain weight, Harvest index (%) and grain yield plant^{-1} had high GCA variance (fixable genetic portion) than SCA variance (non-fixable genetic portion) and thus simple selection would confer rapid improvement of these traits. Because these attributes exhibited higher magnitude of SCA variance than GCA variance in the relative environments, selection for spikelet fertility in the irrigated environment could be postponed to later generations until the non-additive component had mitigated to additive (Venkatesan *et al.,* 2007).

Table 4. Analysis of variance for combining ability for yield and component traits under irrigated (E I) and water stress (EII) environments

Sources of variation	Mean sum of squares					
	GCA		SCA		GCA/SCA	
	EI	EII	EI	EII	EI	EII
Days to heading (days)	355.27**	854.76**	31.30**	117.56**	11.35:1	7.27:1
Plant height (cm)	770.60**	1225.81**	192.20**	231.73**	4.01:1	5.29:1
Productive tillers plant^{-1}	45.06**	25.81**	5.76**	4.90**	7.82:1	5.27:1
Panicle length (cm)	17.11**	45.98**	2.30**	3.20**	7.44:1	14.37:1
100-gain weight (g)	0.39**	0.63**	0.03**	0.07**	12.26:1	8.71:1
Spikelet Sterility (%)	14.40**	393.49**	68.76**	26.51**	0.21:1	14.84:1
Harvest index (%)	88.98**	122.79**	42.98**	35.67**	2.07:1	3.44:1
Grain yield plant^{-1} (g)	65.81**	148.38**	25.22**	22.59**	2.61:1	6.57:1

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

The interaction between genetics and environment is a primary cause of deception in general and specific combining ability testing. In this study, the genotype x environment interaction was significant for all the traits under this study and it was partitioned into GCA x E and SCA x E (Table 5). The GCA x E and SCA x E were found to be significant for all the studied traits suggesting the need for selecting different parental lines to develop populations specific to irrigated and water stress environments (Kuchanur *et al.,* 2013).

Table 5. Combined analysis of variance for combining ability for yield and component traits over environments in rice

Sources of variation	GCA	SCA	Environment	GCA X environment	SCA X environment	GCA:SCA
Days to heading (days)	1525.10**	133.52**	387.18**	250.67**	87.96**	11.42:1
Plant height (cm)	1740.77**	271.82**	388.51**	631.14**	179.15**	6.40:1
Productive tillers plant^{1}	631.10**	61.28**	23.02**	87.23**	43.99**	10.30:1
Panicle length (cm)	396.36**	57.07**	19.02**	238.54**	43.35**	6.95:1
100-gain weight (g)	335.27**	57.73**	0.25**	237.89**	39.32**	5.81:1
Sterility (%)	162.07**	97.37**	383.75**	624.59**	76.34**	1.66:1
Harvest index (%)	667.42**	87.30**	155.61**	156.95**	71.97**	7.65:1
Grain yield plant^{1} (g)	721.52**	86.53**	127.04**	122.50**	51.92**	8.34:1

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

Breeding value of parents

The estimates of GCA effects and parent mean performance would aid the breeder in comprehending the genetic architecture and potentiality of the selected parents in F_1 and subsequent generations (Kuchanur *et al.,* 2013). El-Refaee (2002) established a strong relationship between overall performance and GCA effects. This information will be helpful in choosing the appropriate parents for the exploitation of variation and extracting superior genotypes through recombination breeding. The objective appears to be realizable only when these parents were evaluated for their combining ability attributes over environments. Breeding for drought tolerance in rice is always centered on the choice of parents of early to medium duration coupled with high yield. The parents exhibiting positive GCA effects towards long duration may not be a good choice under such circumstances. Therefore, in the present study the parents exerting significant GCA effects towards the desirable directions were identified. The GCA effects of the parental genotypes for all the yield traits under stress and non-stress environments are given in Tables 6 and 7. Estimation of GCA effects and per se performance revealed that Giza 177 showed significant negative GCA effects for days to heading and plant height (desirable traits) but unfortunately, showed significant negative GCA effects for the other yield components particularly under water stress condition in cause of its sensitivity to drought. This finding are in a harmony with those that reported by Abd El-Hadi *et al.,* (2020). The parental genotype, Gaori showed significant negative GCA effects for days to heading and plant height under both normal and water stress conditions. Moreover, it showed significant positive GCA effects for grain yield attributes particularly in the interaction between the two environments. The parent IET1444 showed negative GCA effects and higher mean values for days to heading, plant height and spikelet sterility, in addition it showed significant positive GCA effects for no. of productive tillers plant^{-1}, panicle length and grain yield plant^{-1} under water stress condition. Based on the mean values and GCA effects Gaori and IET1444 are suitable for incorporation of earliness and drought tolerance traits. These results support the previous findings indicating higher drought tolerance of these two parental genotypes (Sultan *et al.,* 2010).

It is an interesting noticed that, the two parental genotypes, IRAT 170 and WAB 450 showed significant positive GCA effects for panicle length, 100-grain weight, harvest index and grain yield plant^{-1} under water stress condition (EII). It is obviously that as shown in Tables 6 and 7, Gaori, IET1444, IRAT 170 and WAB 450 would serve as good general combiners for grain yield attributes under water stress condition. The diallel analysis across environments identified good trait-specific combiners viz., Giza177 and Gaori for earliness and short plant stature, IET1444 for productive tillers plant^{-1} and panicle length, WAB450 for panicle length and 100-grain weight, IRAT170 for 100-grain weight and Sakha 101 for harvest index based on GCA effects.

In general, it was noticed that none of these parents were beneficial for all of the traits in both conditions. As a result, numerous crossings involving these parents would be desired, with selection in the segregating generations to isolate superior genotypes. These findings are consistent with those previously published by Hassan *et al.,* (2011).

Table 6. General and specific combining ability effects for yield and component traits under irrigated (E I), water stress (E II) conditions and interaction in rice

Genotypes	DH			PH			PT			PL		
	EI	**EII**	**Interaction**	**EI**	**EII**	**Interaction**	**EI**	**EII**	**Interaction**	**EI**	**EII**	**Interaction**
						GCA effects						
Giza 177	-4.36**	-8.53**	-10.12**	-1.83**	-7.15**	-8.16**	0.07	-1.15**	-4.21**	-0.35	-1.65**	-4.68**
Sakha 101	2.86**	-1.44*	1.37**	-4.22**	-7.28**	-5.09**	0.88*	0.28	1.24**	-0.57*	-0.85**	-0.05
IRAT 170	-0.07	2.00**	-0.71**	8.44**	8.40**	6.74**	-1.03**	-0.21	-2.29**	0.16	0.90**	-1.15**
Gaori	-3.98**	-3.64**	-0.75**	-6.43**	-3.95**	-2.13**	0.60	0.43	3.57**	-1.06**	-1.19**	1.93**
IET 1444	-0.03	2.76**	4.26**	-1.04	2.22**	3.48**	1.61**	1.66**	4.52**	0.53*	1.27**	3.79**
WAB 450	5.57**	8.85**	5.95**	5.08**	7.76**	5.16**	-2.14**	-1.00**	-2.83**	1.30**	1.52**	0.15**
						SCA effects						
Giza 177x Sakha 101	1.01	0.63	1.59**	-3.91**	2.28**	-0.05	1.82**	1.33**	2.34**	-0.52*	1.00**	1.01**
Giza 177 x IRAT 170	-0.08	5.18**	2.49**	9.79**	8.74**	9.20**	-1.36**	0.51	-0.49**	-0.52*	1.09**	0.22
Giza 177x Gaori	0.80	4.38**	3.96**	-2.14**	0.35	0.48	0.26	1.15**	2.08**	0.70**	1.72**	2.58**
Giza 177x IET 1444	-0.05	6.14**	0.25	1.08	5.54**	0.51	0.87*	1.89**	-1.41**	0.34	0.32	-2.46**
Giza 177x WAB 450	3.62**	8.36**	2.51**	-0.78	6.44**	-0.65	-0.38	1.00**	-3.17**	0.41	-0.21	-3.38**
Sakha 101x IRAT 170	2.35**	4.65**	4.10**	12.41**	7.64**	10.63**	-2.17**	-0.92**	-0.94**	-0.67**	0.25	0.39**
Sakha 101x Gaori	-2.98**	3.05**	0.40	2.09**	4.58**	3.71**	-0.54	-0.28	-0.04	0.27	0.02	0.52**
Sakha 101x IET 1444	0.39	0.16	1.65**	-4.93**	0.24	-0.98**	0.06	0.46	1.64**	1.21**	0.53*	2.24**
Sakha 101x WAB 450	5.92**	6.03**	5.32**	6.87**	7.42**	6.50**	-1.19**	-0.42	-1.45**	1.39**	0.87**	0.48**
IRAT 170x Gaori	-3.37**	-7.79**	-6.70**	6.66**	4.68**	4.54**	1.36**	0.22	-0.34	-0.47*	-1.74	-2.23**
IRAT 170x IET 1444	0.76	3.02**	-0.24	-6.36**	-2.95**	-6.79**	1.97**	0.96**	-0.66**	1.21**	-0.02	-1.54**
IRAT 170x WAB 450	-2.29**	-1.41*	-3.33**	-7.94**	-5.70**	-8.30**	0.72*	0.07	-1.09**	-0.29	0.00	-1.63**
Gaori x IET 1444	-0.90	0.58	-5.18**	7.94**	6.94**	2.41**	0.35	0.32	-4.69**	-0.47*	0.59*	-4.96**
Gaori x WAB 450	0.76	3.92**	-0.20	3.63**	5.43**	1.99**	-0.91**	-0.57	-3.28**	1.05**	-0.31	-2.17**
IET 1444x WAB 450	-6.01**	-4.21**	-7.16**	11.87**	9.36**	8.57**	-1.92**	-1.80**	-3.91**	-0.70**	-0.46	-2.62**

Table 7. General and specific combining ability effects for yield and component traits under irrigated (E I), water stress (E II) conditions and interaction in rice

Genotypes	GW			SS%			HI%			GY		
	EI	EII	Interaction	EI	EII	Interaction	EI	EII	Interaction	EI	EII	Interaction
						GCA effects						
Giza 177	-0.04	-0.20**	-3.79**	0.77	7.81**	0.62**	-0.60	-4.45**	-6.20**	-0.91	-4.65**	-6.45**
Sakha 101	-0.05	-0.10*	0.58**	-0.49	0.73	0.78**	3.88**	1.46*	3.33**	3.11**	1.17	2.80**
IRAT 170	0.19**	0.24**	-1.46**	0.93	-1.71	-2.06**	-0.81	1.46**	-1.35**	-1.51*	0.77	-2.04**
Gaori	-0.05	-0.02	3.02**	-0.94	-1.14	2.02**	-0.52	-0.14	2.73**	-0.72	-0.91	2.24**
IET 1444	-0.16**	-0.07	2.77**	-0.58	-2.91**	1.15**	-0.56	0.67	2.94**	0.47	1.80**	4.03**
WAB 450	0.11*	0.15**	-1.13**	0.31	-2.79**	-2.50**	-1.39**	1.01	-1.44**	-0.44	1.81**	-0.57**
						SCA effects						
Giza 177x Sakha 101	-0.04	-0.03	0.73**	-2.86**	-0.88	-1.10*	-0.81	-1.30*	-0.29	-1.12*	-2.42**	-1.00**
Giza 177 x IRAT 170	-0.02	-0.08*	-0.11**	8.62**	3.30**	5.89**	-0.66	-2.06**	-1.43**	4.52**	4.55**	4.47**
Giza 177x Gaori	-0.10**	0.01	1.33**	-4.79**	-5.41**	-3.73**	2.30**	4.29**	4.67**	1.41*	2.01**	3.08**
Giza 177x IET 1444	0.07	0.28**	-2.62**	5.01**	-2.28*	-1.43**	-5.84**	-2.43**	-6.93**	-5.74**	-1.84**	-6.59**
Giza 177x WAB 450	-0.07	0.02	-3.51**	6.59**	-0.72	-0.55	-1.76**	0.62	-4.05**	0.40	2.54**	-2.01**
Sakha 101x IRAT 170	-0.05	0.03	0.59**	3.81**	2.06*	3.54**	2.34**	2.72**	3.13**	3.59**	3.84**	4.31**
Sakha 101x Gaori	0.00	0.19**	0.47**	-2.76**	-0.24	-1.13**	-4.66**	-2.17**	-3.04**	-2.53**	-1.60**	-1.69**
Sakha 101x IET 1444	0.01	0.03	1.39**	3.10**	2.69**	4.27**	4.52**	1.78**	4.52**	3.40**	2.75**	4.45**
Sakha 101x WAB 450	0.16**	0.18**	-0.48**	3.63**	3.81**	3.07**	1.60**	0.43	0.36	-0.45	-0.44	-1.10**
IRAT 170x Gaori	0.27**	0.28**	-0.86**	0.49	-0.96	-1.37**	-0.75	0.24	-1.38**	0.71	2.12**	0.28
IRAT 170x IET 1444	-0.13**	-0.13**	-2.26**	-3.44**	-1.93*	-4.82**	1.96**	3.59**	0.65	0.50	0.55	-1.60**
IRAT 170x WAB 450	-0.01	0.08*	-1.44**	-4.74**	-2.81**	-5.26**	4.64**	3.94**	2.81**	-1.71**	-1.31*	-3.00**
Gaori x IET 1444	-0.08*	-0.04	-5.09**	2.45**	4.16**	-1.72**	1.55*	-3.40**	-5.95**	0.64	-1.83**	-5.62**
Gaori x WAB 450	-0.02	-0.06	-2.58**	3.19**	1.56	-0.17	4.38**	3.68**	1.48**	2.57**	1.20*	-0.66*
IET 1444x WAB 450	0.02	-0.05	-2.06**	-3.65**	-2.07**	-4.91**	2.49**	3.95**	1.18**	2.45**	1.29*	-0.18

Breeding value of crosses combinations

The potential for hybrids to be exploited for further breeding cycles in any crop is essentially determined by (i) high mean performance of the hybrids across a range of environments, (ii) the specific combining ability effects of the parents and (iii) the magnitude of heterosis in the desired direction. When good performing parents are crossed with each other in plant breeding, it is usually anticipated that better hybrids would result. However, this assumption may not be true all the time (Jatoi *et al.*, 2012). The hybrids identified based on mean performance, SCA effects and heterosis could be exploited in heterosis breeding or to advance them to further breeding cycles to identify useful transgressive segregants. The heterosis and SCA effects are estimated values. Whereas per se performance is the realized value, therefore weight age should be given to per se performance while making selection among cross combinations (El-Mowafi *et al.*, 2018).

Under normal irrigated and water-stress conditions, the SCA estimations of 15 cross combinations for the studied traits are summarized in (Tables 6 and 7). The findings revealed that four (EI) and three (EII) of the 15 hybrid rice combinations had significantly negative SCA effects over the days to heading. In addition, for the plant height trait, five (EI) and two (EII) hybrids revealed a negative SCA effect. Under both normal and water-stress conditions, five hybrids demonstrated considerably positive SCA effects of productive tillers plant^{-1}. There were five and six hybrids that demonstrated superior SCA effects under normal and water-stress conditions, respectively, in terms of panicle length. For the GW, two hybrids (EI) and five hybrids (EII) demonstrated significantly positive SCA effects. The results showed that, six (EI) and five (EII) illustrated significantly negative SCA effects for spikelet sterility. Regarding harvest index, nine (EI) and seven (EII) hybrids showed significantly positive SCA effects.

Six (EI) and eight (EII) hybrids showed the highest SCA effects for the GY. It is important to note that six combinations viz, Giza 177 x IRAT 170, Giza 177x Gaori, Sakha 101x IRAT 170, Sakha 101x IET 1444, Gaori x WAB 450 and IET 1444x WAB 450 possessed significantly positive SCA effects for grain yield over environments.

These crosses also had better mean grain yield performance and significant SCA effects for one or more yield attributes. At least one of the parents in these crosses was a good general combiner for grain yield under stress, implying that these crossings will eventually produce desirable transgressive segregants. These crosses should be prioritized for identifying new genotypes with high grain yield under stress in order to improve grain production under water stress. It is observed that the crosses showing consistently positive SCA effects over environments also exhibited high per se performance. Therefore, per se performance and SCA effects were considered as a criterion to identify the best crosses for further advancement. All the high performing crosses involving parents with high x high, high x low and low x high general combiners, indicated that non-additive gene actions, which are unfixable in nature were involved in the selected cross combinations. These crosses of high x low or low x high GCA with the expression of high positive SCA effects might be due to the dominant x additive, dominant x dominant and recessive x dominant epistasis (Muthuram *et al.*, 2010) and these hybrids are expected to produce desirable transgressive segregation in later generations.

CONCLUSION

The results show that improving yield in rice for water-stressed conditions can be accomplished by selecting acceptable parents based on per se performance and combining ability, as well as selecting proper breeding programs based on the nature of gene action and combining ability. It is obviously that Gaori, IET1444, IRAT 170 and WAB 450 would serve as good general combiners for grain yield attributes under water stress condition (E II). Due importance should be given to six combinations viz, Giza 177 x IRAT 170, Giza 177x Gaori, Sakha 101x IRAT 170, Sakha 101x IET 1444, Gaori x WAB 450 and IET 1444x WAB 450 in order to identify new genotypes with high grain yield under water deficit condition. The present study identified the importance of both additive and non-additive components of genetic variances in governing the inheritance of yield and other traits.

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التحليل الوراثى لصفات المحصول فى الارز للاجهاد المائى تحت الظروف المصرية

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يعتبرتوفر التراكيب الوراثية الابوية المناسبة مع القدرة العالية على الائتلاف اداة فعالة لتحسين صفات المحصول فى الارز فى ظل ظروف نقص مياة الرى. تم اجراء تجربتين خلال الموسمين الزراعيين 2019 و 2020 وذلك لدراسة التحليل الوراثى والقدرة على الائتلاف فى صفات المحصول ومكوناتة تحت ظرفيين بيئيين من الرى العادى (EI) والاجهاد المائى (EII) باستخدام هجن الجيل الاول المتحصل عليها من نظام تهجين نصف دائرى المشتمل على ستة تراكيب وراثية ابوية. تمت دراسة ثمانية صفات محصولية على مدار موسميين وكذلك التحليل العنقودى باستخدام 16 معلم جزيئى SSR للتفرقة بين التراكيب الوراثية المستخدمة فى الدراسة والذى اظهر وجود تباينات كبيرة فيما بينها. بشكل عام تاثرت جميع صفات المحصول ومكوناتة بشكل كبير بنقص المياة واظهر كلا من الفعل الجينى المضيف وغير المضيف التحكم فى وراثة هذة الصفات. بناءا على قيم كلا من متوسطات الاداء والقدرة العامة على الائتلاف اظهر كلا من التركيبيين الوراثيين Gaori و IET1444 انهما مناسبين لادخال صفات التبكير وتحمل الجفاف فى الهجن. ولقد اوضح كلا من التراكيب الوراثية الابوية Gaori , IET1444 , IRAT 170 و WAB 450 افضل قدرة عامة على التالف لصفات المحصول ومكوناتة تحت ظروف الجفاف. اظهرت النتائج انة يجب اعطاء الاهمية لستة توليفات وراثية جديدة وهى Giza 177 x IRAT 170 , Giza 177x Gaori , Sakha 101x IRAT 170 , Sakha 101x IET 1444 , Gaori x WAB 450 و IET 1444x WAB 450 فى تحديد الانماط الجديدة من التوليفات الوراثية للهجن ذات صفات المحصول العالية تحت ظروف الجفاف. اوضح النتائج انة قد تكون هناك امكانية كبيرة للحصول على افضل هجن جديدة عن طريق تهجين التراكيب الوراثية ذات المسافات الوراثية المتباعدة. لذلك مع الاخذ فى الاعتبار هذة النتائج فى اختيار التراكيب الوراثية الابوية للحصول على مجموعات هجن جديدة متفوقة فى ظل ظروف الاجهاد المائي فى الارز تحت الظروف المصرية.