

IDENTIFICATION OF DROUGHT TOLERANT MOLECULAR MARKERS IN RICE (*Oryza sativa* L.)

I- ASSESSMENT OF F1 GENOTYPES UNDER NORMAL AND DROUGHT CONDITION

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ABSTRACT

The present study was carried out at the Experimental Farm of the Rice Research and Training Center (RRTC), Sakha, Kafer EL-Shiekh, Egypt, during three successive rice growing seasons 2010, 2011 and 2012 aiming to establish combiners that may have drought tolerance characters by hybridization between local sensitive and imported tolerant rice cultivars which will be subjected to aggressive Simple Sequence Repeat (SSR) molecular technique. So, eight genotypes namely; Moroberekan, IET1444, Azucena, IRAT170, GZ530-20-10, Giza177, Giza 178 and Sakha101 were chosen for line by tester cross. The hybrid grains were grown in 2011 as F1 and transplanted in a randomized complete block design (RCBD), with three replications, (each F1 cross transplanted between its parents). All the genotypes (eight parents and 15 F1 crosses) were planted under both normal and imposed drought conditions.

The obtained results exhibited that, the parents Moroberekan, IET 1444, Giza 178 and Sakha 101 and the F1 crosses involved these parents, in particular the crosses Moroberekan x Giza177 and IET 1444 x Sakha 101 showed the most favorable mean performances values for root, yield and physiological characters, under stress conditions. Moreover, under drought stress, the following F1 crosses; IET 1444 x Giza177, IRAT 17 x Sakha101 show remarkable increase in the mean performance of average panicle length, average number of panicles per plant, average grain yield per plant as well as harvest index. However, insignificant heterotic effects were recorded for average root volume (RV) with the F1 combiner; GZ350-20-10 x Giza178. Nevertheless, root to shoot ratio (R:S) did not show insignificant heterosis effects under drought condition.

The most desirable crosses under normal and drought stress were; Moroberekan x Giza177, Moroberekan x Sakha101, IET 1444 x Giza178, IET 1444 x Sakha101. Since these crosses maintained the most favorable shoot, root, yield and physiological characters under both normal and drought stress conditions. The vigorous growth of F1 rice hybrids may partially attributed to the development and function of the root system. Also, it was found that F1 hybrid surpassed parents in the total root length, number. of root per plant. As a result, the root system of F1 hybrids was not only greater in volume, but also longer in length. Additionally, root to shoot ratio showed higher values than that of parents.

Significant GCV estimates were recorded for all the studied traits except the parents IET 1444 for average root volume per plant and the parent Giza 178 for root to shoot ratio under normal condition and Giza 177 for average number of roots per plant for number of roots per plant. Also, significant GCV estimates were recorded for all the studied traits except the parents IRAT 170, Giza 177 and Giza 178 for average relative water content.

The studied root, yield and physiological characters showed significant positive estimates of SCA estimates for F1 combiners; Moroberekan x Giza177, Moroberekan x Giza178, IET 1444 x Giza178 and IET 1444 x Sakha101 under normal and drought conditions. The most common crosses for the studied characters were IET 1444 x Sakha 101, IRAT 170 x Giza178, Moroberekan x Sakha 101 and IET 144 x Giza 177.

Keywords: *Oryza sativa* L, drought stress, root, yield, physiology, heterosis, general and specific combining ability.

INTRODUCTION

Drought is a major abiotic stress that causes severe yield loss in rice as a staple food crop. Improvement of drought resistant rice varieties has become an urgent task under the background of global crisis of water resource. Genetic resources played very important roles in crop genetic improvement, especially intargeting the resistance to biotic or abiotic stresses. Wild rice accessions has great contribution in rice breeding by providing resistance genes (e.g. *Xa21*, *BPH14*, *BPH15*) (Ronald *et al.*,1992; Song *et al.*,1995; Yang *et al.*, 2004; Du *et al.*, 2009; Hu *et al.*, 2012). It was also reported that wild rice can carry positive alleles of QTLs influencing grain yield or quality (Xiao *et al.*, 1998; Fu *et al.*,2010; Mallikarjuna Swamy *et al.*,2011). There are tremendous differences in growth habits between rice genotypes, or among wild rice species (Oka,1974; Vaughan, 1994; Cai and Morishima, 2006; Tan *et al.*, 2008). Replicated individuals with consistent genotypes and approximate growth situation could be developed via 1-2 rounds of tiller trans planting. As the identification of resistant genotype to drought or other abiotic stresses heavily depends on population size and growth stage of plant (Boonjung and Fukai, 1996) very few reports have been published on screening of drought resistance in rice species. Thanh *et al.* (2006) obtained 39 drought resistant BC1F2 lines by backcrossing. Zhang *et al.* (2006) developed a population of 159 introgression lines using an elite indica variety Guichao No2 as the receptor and Dongxiang wild rice (*O. rufipogon*) as the donor. The breeding line, IL23, contained two QTLs of drought resistance from the wild rice accession. This study aimed to establish new rice combiners that may have drought tolerance characters by hybridization between local sensitive and imported tolerant rice cultivars which will be subjected to aggressive SSR molecular technique.

MATERIALS AND METHODS

The present study was carried out at the Experimental Farm of the Rice Research and Training Center (RRTC), Sakha, Kafer EL-Shiekh, Egypt, during three successive rice growing seasons 2010, 2011 and 2012 .

I- Plant Material

Eight genotypes namely; Moroberekan, IET1444, Azucena, IRAT170, GZ530-20-10, Giza177, Giza 178 and Sakha101 were chosen based on the previous studies that describes these genotypes with wide range of variation towards drought stress due to their different genetic background. The

introduced varieties Moroberekan, IET1444 and Azusena were used as drought resistant while, IRAT170, GZ530-20-10 and Giza178 were used as moderate resistant and Giza177 and Sakha101 were used as drought susceptible.

II- Field work procedures

The above mentioned eight rice genotypes utilized in this study were grown in three sowing dates during 2010 season, parents growing with 10 days intervals to overcome the difference of heading date among them. Thirty days after sowing, seedlings of each genotype were individually transplanted in the permanent field. A line by tester cross was carried out among the eight parents at flowering to produce F1 hybrid grains. Bulk emasculation method was practiced by using hot water technique according to Jodan (1938) and modified by Butany (1961). The hybrid grains were grown in 2011 rice growing season as F1 plants on the first week of May and plants were transplanted individually after 30 days from sowing in a randomized complete block design (RCBD), with three replications, each replicate consisted of three rows for each F1 cross and its parents (each F1 cross planted between its parents). All the genotypes (eight parents and 15 F1 crosses) were planted under both normal and drought conditions (drought stress was imposed by using flush irrigation every 12 days without standing water after irrigation). All other agricultural practices were used.

III. The studied traits

1. **Root characters** under study were, maximum root length (cm), root volume (cm³), Number of roots plant⁻¹ and root: shoot ratio
2. **Yield and yield component** characters are; number of panicles/plant, sterility percentage (sterile spikelet were indented by pressing the spikelets with the fingers and counting the empty ones and sterility percentage was calculated), 1000- grain weight, grain yield/plant (g), dry matter (g), harvest index estimated by the formula suggested by Yoshida (1981), drought susceptibility index determined according to the formula given by Ali Dib *et al*, 1990.
3. **Physiological and chemical** characters are; leaf rolling on methods proposed by De Data *et al*, (1988), leaf angle, according to Yoshida, (1976), flag Leaf area (cm²) according to following formula: leaf area = K x leaf length x leaf width where K = 0.75, chlorophyll content, nitrogen content (N) according to Barrs and Weatherly (1962), potassium content (K), according to Cottenie *et al*, (1982), relative water content was determined by the method of Barrs and Weatherly (1962), water use efficiency.

Line x tester statistical analysis:

The obtained data were subjected to the convenient statistical analysis by using the analysis of variances for randomized complete blocks design as suggested by Panse and Sukhatme (1954) to test the significance of differences among the genotypes (lines, testers and their F1 hybrids).

RESULTS AND DISCUSSION

1. Mean performance of the studied F1 genotypes

1.1. Mean performance of root characters

The studied root characters; number of roots per plant (NRP), maximum root length (MRL), root volume (ROV) and root to shoot ratio (RSR) are presented in Table (1). The mean performance of the studied root characters under drought stress as compared with normal condition showed significant decrease with very few exceptions especially with root shoot ratio trait.

It is evident that number of roots per plant (NRP), illustrate that, under normal condition, the parents Morobroken, Asucena and Sakha 101 scored the highest number of roots per plant values of 298.63, 278.98 and 278.94 for the three studied parents, respectively. On the other hand the parents Morobroken, Asucena and IRAT170, under drought stress displayed the highest mean values of 249.10, 245.88 and 303.80 respectively. While, other parents GZ350-20-10 and Giza 177 scored the lowest mean value of 225.05 and 225.05 respectively under normal condition. The corresponded mean values under drought stress were 201.21 and 211.42 respectively. The F1 crosses, under normal condition, Morobroken x Giza 178, Morobroken x Giza 177 and IRAT170 x Giza 178 scored the highest mean values. On the other hand, the crosses GZ350-20-10 x Giza 177, and GZ350-20-10 x Sakha 101 showed the lowest mean values for all irrigation conditions (236.94, 241.36, 225.40, and 229.60, respectively).

Data of maximum root length (MRL) illustrate that, under normal conditions, drought stress and their combined, of the parents Moroberekan, Azucena and IET 444 scored, the deepest root length (38.02, 35.40 and 34.09 cm), (30.89, 28.07 and 26.11 cm) and (34.45, 31.73 and 30.10 cm), respectively. While Giza 177, Sakha101, and Giza 178 scored the shortest root length. The measured root lengths were (21.96, 25.00 and 23.92 cm), (18.20, 20.17 and 21.09 cm) and (20.08, 22.58 and 22.50 cm). It is evident that, under normal conditions, drought stress and their combined of the crosses, IRAT 170 x Giza177, Moroberekan x Giza177 and Moroberekan x Giza178 scored the deepest root lengths of (50.91, 48.21 and 47.01 cm), (34.09, 39.58 and 38.67 cm) and (42.50, 43.89 and 42.84 cm). Reversely, the crosses GZ350-20-10 x Sakha 101 and GZ350-20-10 x Giza 177 showed the lowest mean values of (27.89 and 31.76 cm), (22.94 and 29.14 cm) and (25.41 and 30.45 cm) arranged in the same order.

Root volume (ROV), data in Table (1) state that the parent Moroberekan exhibited the highest root volume values of 67.91, 58.70 and 63.30 cm³ under normal, drought stress and their combined conditions. While the parent Giza 178 showed the highest mean value 63.72 cm³ under normal condition but, under drought stress, the highest value (52.11 cm³) was scored with the parent IRAT 170. Conversely, the parent GZ350-20-10 recorded the lowest mean value of 47.31 cm³ under normal condition. The parent Giza 177 showed the lowest root volume value 33.98 cm³ under drought condition. The crosses, Moroberekan x Giza177 (75.93, 65.63 and 70.78 cm³), Moroberekan x Giza178 (71.3, 62.00 and 66.86 cm³), and IET 1444 x

Sakha101 (70.21, 60.69 and 65.45 cm³) recorded the highest mean values at normal conditions, drought stress and their combined conditions. In contrast the crosses, GZ350-20-10 x Giza 177 (50.37, 43.54 and 46.95 cm³), and GZ350-20-10 x Sakha 101(51.12, 44.19 and 47.65 cm³) showed the lowest root volume values under normal condition.

Data of root to shoot ratio (RSR) being presented in Table (1) prove that the parent Giza 178 recorded the highest root to shoot ratio 0.75 under normal condition. As well, Moroberekan showed the highest mean value 0.66 under drought condition. Nevertheless, the parent GZ350-20-10 offers the lowest ratio 0.66 under normal condition. However, Giza 177 scored the lowest root to shoot ratio 0.073 under drought conditions. Another trend was observed among crosses, Moroberekan x Giza177 (0.72, 0.63 and 0.67), IET 1444 x Sakha101 (0.69, 0.63 and 0.66) and IRAT 170 x Giza178 (0.69, 0.63 and 0.65) showed the higher mean ratios under normal, drought stress and their combined. On the other hand, the crosses, GZ350-20-10 x Giza 177(50.37, 43.54 and 46.95), and GZ350-20-10 x Sakha 101(51.12, 44.19 and 47.65) showed the lowest ratios for normal, drought stress and combined conditions, respectively.

Table (1): Mean performances of root characters for the studied eight parents and the fifteen F1 crosses as affected by normal and drought stress and their combined data

Character	Root volume			Root :shoot ratio			Maximum root length			Number of roots		
	N	S	C	N	S	C	N	S	C	N	S	C
Genotypes												
P1	67.91	58.70	63.305	0.73	0.66	0.69	38.02	30.89	34.455	298.63	249.10	273.87
P2	56.03	51.76	53.895	0.71	0.61	0.66	35.40	28.07	31.735	278.98	245.88	262.43
P3	53.75	46.07	49.91	0.72	0.59	0.64	34.09	26.11	30.1	250.02	222.89	236.46
P4	59.96	52.11	56.035	0.69	0.60	0.64	32.12	25.05	28.585	277.32	303.80	290.56
P5	47.31	40.89	44.1	0.66	0.57	0.62	27.52	21.33	24.425	225.05	201.21	213.13
P6	54.99	33.98	44.485	0.69	0.55	0.66	21.96	18.20	20.08	244.06	211.42	231.24
P7	63.72	50.92	59.965	0.75	0.60	0.67	23.92	21.09	22.505	250.64	232.19	238.92
P8	62.83	42.21	52.52	0.73	0.62	0.67	25.00	20.17	22.585	278.94	223.96	251.45
P1XP6	75.93	65.63	70.78	0.72	0.63	0.67	48.21	39.58	43.895	322.14	306.45	314.30
P1XP7	71.73	62.00	66.865	0.68	0.61	0.64	47.01	38.67	42.84	325.13	309.30	317.22
P1XP8	69.44	60.02	64.73	0.67	0.55	0.61	40.29	36.70	38.495	305.63	290.75	298.19
P2XP6	65.63	56.73	61.18	0.68	0.52	0.60	41.24	36.71	38.975	294.95	280.59	287.77
P2XP7	67.92	58.71	63.315	0.66	0.59	0.62	45.82	37.69	41.755	307.76	292.77	300.27
P2XP8	64.87	56.07	60.47	0.64	0.49	0.56	41.05	33.76	37.405	291.72	277.51	284.62
P3XP6	63.72	55.07	59.395	0.68	0.58	0.63	35.06	28.83	31.945	290.03	275.91	282.97
P3XP7	67.93	58.71	63.32	0.63	0.56	0.59	39.15	24.25	31.7	295.45	281.06	288.26
P3XP8	70.21	60.69	65.45	0.69	0.63	0.66	44.61	28.18	36.395	300.43	285.79	293.11
P4XP6	66.78	57.72	62.25	0.67	0.59	0.63	50.91	34.09	42.5	299.67	285.07	292.37
P4XP7	69.07	59.70	64.385	0.69	0.62	0.65	45.96	36.70	41.33	305.90	291.01	298.46
P4XP8	63.73	55.08	59.405	0.63	0.50	0.56	42.37	33.75	38.06	286.86	272.89	279.88
P5XP6	50.37	43.54	46.955	0.46	0.41	0.43	31.76	29.14	30.45	236.94	225.40	231.17
P5XP7	53.42	46.18	49.8	0.48	0.42	0.45	35.06	28.84	31.95	256.91	244.40	250.66
P5XP8	51.12	44.19	47.655	0.44	0.39	0.41	27.89	22.94	25.415	241.36	229.60	235.48
L.S.D 5%	2.39	2.42	1.72	0.016	0.01	0.01	1.34	0.79	0.82	11.95	12.3	8.77

The observed inhibition in root growth resulted from drought stress is commonly reported by many authors; Levitt (1972), O'Toole and Chang (1979), Blum (1982), O'Toole and De Datta (1986), Passioura (1982), Yoshida and Hasegawa (1982) and O'Toole and De Datta (1986). Generally, the parents Moroberekan, IRAT 170, IET 1444 and Sakha 101 and the F1 crosses involved these parents, in particular the crosses Moroberekan x Giza177 and Moroberekan x Giza178 showed the most favorable mean performances values for shoot characters, under stress conditions. The enhancement of the above mentioned parents for the studied root characters under drought condition was early reported by many investigators among them; Blum (1982), Passioura (1982), Yoshida and Hasegawa (1982), O'Toole and De Datta (1986), Sharma and Koranne (1995), Yogameenashi *et al.* (2003), Fahmi *et al.* (2004), Sedeek (2006). Moreover, drought avoidance may be performed by maintenance of turgor through increased root depth, efficient root system and by reduction of water lost (O'Tool and Moya 1978, Begg 1980). According to the results, the reduction of root characters of rice plants under drought stress may be relatively mild, so plants may possess the ability to avoid drought.

1.2. Mean performance of yield and its component

The mean performances of yield and its component characters for parents and F1 crosses grown under normal and drought stress as well as their combined conditions are listed in Table (2). Statistically data showed significant differences among all studied genotypes for all yield and its component studied characters as shown in Table ().

Data of average plant grain yield, (PGY) demonstrate that, under normal condition, the parents Sakha 101, Giza 178 and Giza 177 yielded the highest mean value (41.96, 39.74 and 36.00 g/plant) respectively, while under drought stress the parents Giza 178 IET 444 and Azucena produced the highest grain yield values (27.58, 23.38 and 22.67 g/plant), respectively. On the other hand, under normal condition, Moroberekan and IRAT 170 parents showed the lowest mean values (25.81 and 26.67 g/plant). Nevertheless, under drought stress, the parents Giza 177 and Sakha 101 yielded the lowest grain yield per plant 17.86 and 20.16 g. The studied F1 crosses; IET 1444 x Sakha101, Moroberekan x Giza178 and Azucena x Giza178, under normal condition, produced the highest mean grain yield 43.71, 42.36 and 42.09 g/plant, respectively. Conversely, the crosses GZ350-20-10 x Giza177, GZ350-20-10 x Sakha101 and GZ350-20-10 x Giza178 yielded the lowest mean grain yield per plant under normal, drought stress and combined, respectively. The corresponded mean grain yield per plant values were; (34.04, 23.20 and 28.62 g/plant), (35.05, 20.65 and 27.85 g/plant) and (36.66, 22.03 and 29.35 g/plant), for the mentioned crosses arranged in the same order.

Concerning average panicle length (PAL) data prove that the studied parents Moroberekan, IRAT 170 and Azucena showed the longest panicles as their panicle lengths were, (28.63, 27.39 and 25.98 cm), (25.81, 23.30 and 24.39 cm) and (27.2, 24.64 and 25.89 cm), for normal, drought stress and their combined, respectively.

Whilst, the parents IET 444 and Sakha101 showed the lowest mean value (25.81 and 26.67 cm) under normal condition. The other parents Giza 177 and Sakha 101 showed the shortest mean panicle length values (23.18 and 24.34 cm) under normal condition. On the contrary, under drought stress the parents Sakha 101 and Giza 177 showed the lowest mean panicle length values 20.67 and 21.15cm, respectively.

The studied F1 crosses; Moroberekan x Sakha101, IET 1444 x Sakha 101, Moroberekan x Giza 178 and IRAT 170 x Giza177, under normal, drought stress and their combined respectively, produced the longest mean panicle length. The recorded panicle lengths were (28.91, 27.51 and 28.21cm), (28.02, 26.01 and 27.02), (27.53, 25.88 and 26.71), (27.50, 25.10 and 26.30 cm) and (27.18, 25.42 and 26.30 cm), for the above mentioned crosses arranged in the same order. On the other hand, the crosses GZ350-20-10 x Giza178, GZ350-20-10 x Giza 177 and IRAT 170 x Sakha 101 produced the shortest mean panicle length under normal, drought stress and combined, respectively. The corresponded mean panicle length values were; (22.66, 22.91 and 22.79cm), (24.26, 22.78 and 23.52 cm) and (24.16, 22.60 and 23.38 cm), for the mentioned crosses arranged in the same order.

As for number of panicles per plant (NPP), data indicate that the parents Giza 178, Sakha 101 and Giza 177 produced the highest number of panicles per plant values under normal, drought stress and their combined respectively. The corresponded recorded number of panicles values were; (23.46, 17.12 and 20.29 panicle/plant), (18.14, 13.95 and 16.05 panicle/plant), (22.91, 16.33 and 19.62 panicle/plant) arranged in the same order. On the other hand GZ350-20-10 and IET444 showed the lowest mean value (13.13, 9.88 and 11.51 per plant) and (13.78, 10.75 and 12.27 per plant) under normal, drought stress and their combined respectively. It is realized also that the crosses, Moroberekan x Giza 178 produced (23.03, 14.75 and 18.89) followed by Moroberekan x Sakha 101 which averaged (21.09, 12.36 and 16.73) and Moroberekan x Giza 177 that gave (20.10, 13.98 and 17.04) under normal, drought stress and their combined respectively. The lowest scored mean number of panicles per plant were achieved by the crosses, GZ350-20-10 x Sakha101 (12.82, 8.74 and 10.78) and GZ350-20-10 x Giza177 (13.66, 9.75 and 11.71), under normal, drought stress and their combined respectively.

Harvest index per plant (HIP) of the studied genotypes showed that the parents; Sakha 101, Giza 178 and Giza 177 attained high harvest index mean values (0.42, 0.33 and 0.38), (0.39, 0.32 and 0.36) and (0.39, 0.29 and 0.34) under normal, drought stress and their combined conditions respectively. On the other hand the parents Moroberekan and IRAT 170 showed low mean harvest index values (0.26, 0.26 and 0.26) and (0.27, 0.25 and 0.26), under normal, drought stress and their combined conditions respectively. The F1 crosses, Moroberekan x Sakha101 (0.37, 0.32 and 0.34), IET 1444 x Sakha101 (0.37, 0.30 and 0.34) and Azucena x Sakha101 (0.37, 0.29 and 0.33) attained high mean harvest index values under normal, drought stress and their combined conditions, respectively. It is also recognized that, the low harvest index mean values were recorded with the

following F1 crosses; GZ350-20-10 x Sakha101 (0.32, 0.23 and 0.27), GZ350-20-10 x Giza177 (0.32, 0.28 and 0.30) and GZ350-20-10 x Giza178 (0.32, 0.28 and 0.30) under normal, drought stress and their combined conditions, respectively.

Sterility percent (S)% was used as a criteria for measuring the direct effect of drought on the average seed set per plant for the studied genotypes, Table (2). The recorded data show that, under normal condition, the parents Giza 178, Sakha 101 and Giza 177 scored the lowest mean value (4.67, 5.39 and 5.63%), respectively. The lowest mean value, under drought stress (8.47 and 8.59%) among parents were scored with IRAT170 and Giza 178, respectively. Reversely, under the same condition, Azucena and GZ350-20-10 showed relatively highest mean values (8.37 and 8.65%), respectively. However, Giza 177 and Moroberekan scored the highest sterility mean values (12.56% and 12.93) under drought condition. Regarding the crosses performance it is apparent that the crosses; IET 1444 x Giza178, Moroberekan x Giza177, Moroberekan x Giza178, Azucena x Giza178, and IET 1444 x Giza177 scored relatively low mean sterility values. The corresponded scored values were; (5.51, 6.74 and 6.13%), (6.41, 9.28 and 7.85 %), (7.23, 8.98 and 8.11%), (7.24, 8.99 and 8.12%) and (7.92, 9.51 and 8.72%) under normal, drought stress and their combined conditions respectively. On the other hand, the cross GZ350-20-10 x Giza177 showed the highest values of (11.83, 13.44 and 12.64%) under normal, drought and the combined conditions, respectively.

The mean performance of the studied genotypes in F1 with regard to **thousand grains weight (TGW)**, show that the parents Moroberekan and Azucena produced the relatively high mean values for such trait (3.78, 3.56 and 3.67 g) and (3.63, 3.46 and 3.55 g) under normal, drought and the combined conditions, respectively. However, the Parents Giza 178 and IET 444 showed the lowest TGW mean values, (2.34, 2.13 and 2.24 g) and (2.42, 2.20 and 2.31 g) under normal, stress and combined conditions, respectively. As for the crosses, data proved that the crosses Moroberekan x Giza177, Moroberekan x Giza178, Moroberekan x Sakha101 and Azucena x Giza177 showed comparable high mean value (3.61, 3.53 and 3.57 g), (3.57, 3.51 and 3.54 g), (3.57, 3.27 and 3.42 g) and (3.52, 3.48 and 3.50 g) as compared with the rest of the studied crosses. However, the cross Giza IET 1444 x Giza178 produced the lowest mean value (2.68, 2.21 and 2.45 g) under normal, drought stress and combined conditions, respectively.

Generally, the parents Moroberekan, Azucena, IRAT 170, IET 1444 and Sakha 101 and the F1 crosses involved these parents, in particular the crosses Moroberekan x Giza177 and Moroberekan x Giza178 showed the most favorable mean performances values for yield and yield components characters, under stress conditions. Moreover, under drought stress, the following F1 crosses; GZ350-20-10 x Giza177, GZ350-20-10 x Giza178, GZ350-20-10 x Sakha101 showed remarkable increase in the mean performance of average panicle length per plant, average grain yield per plant as well as harvest index. These results are in accordance with those reported by Young and Virmani (1990), Reddy *et al.* (1991), Ramalingam *et*

al. (1994), El-Mowafi (2001), El-Mowafi and Abou Shousha (2003), Hammoud (2004), El-Mowafi and Abd El-Hadi (2005).

1.3. Mean performance of the physiological characters

The mean performances of the studied physiological characters are listed in Table (3). Statistically data proved significant differences among all studied genotypes for all the studied characters as shown in Table (3).

Regarding Leaf rolling score (LRS), it is clear that, all studied genotypes, grown under drought conditions showed variable symptoms of rolled leaf. Since, minimal leaf rolling score was associated with the following parents; IET 1444, Moroberekan, BG 35-1 and Giza 178. It is also evident that the F1 crosses; IET 1444 X Moroberekan, IET 1444 x BG 35-1 and BG 35-1 x Giza 178 showed relatively low rolling score (1-3). This result indicate the drought tolerance of these genotypes as compared with the other studied genotypes. At heading stage the sensitive parents; (Sakha 101) and Giza 177 and the crosses GZ350-20-10x Sakha101, GZ350-20-10x Giza178, GZ350-20-10x Giza177, and IRAT 170 x Sakha101 showed sever drought symptoms that scored high rolled leaf level score 7-9. The studied fifteen crossed genotypes showed six genotypes namely; (GZ350-20-10 x Sakha101, GZ350-20-10 x Giza178, GZ350-20-10 x Giza177, and IRAT 170 x Sakha101) which appeared the worst; three genotypes (Azucena x Sakha101, IET 1444 x Giza178 and IRAT 170 x Giza177) showed average score (5) and two genotypes (Azucena x Giza177 and Azucena x Giza178) had mild symptom (grade 2-3). It is worthy to mention that, from the comparison between the hybrid genotypes, the variation in drought resistance among the sensitive parents is parallel to that among their hybrid genotypes. Drought sensitive parent Sakha 101 is the most sensitive genotype to water deficit as it had severe leaf desiccation and growth inhabitation in comparison with the plants under normal condition. As the hybrids of this parent, (Moroberekan x Sakha101, IET 1444 x Sakha101 and GZ350-20-10x Sakha101) had relatively high to mild levels of leaf rolling but less desiccation, similar to most of hybrid combination.

Data presented in Table (4) concerned the flag leaf area (FLA). It realized that the parents Moroberekan, Azucena maintained the highest mean flag leaf area. Where, the recorded values of the parents were (41.83 and, 35.31cm²), (39.55 and 37.31 cm²) for normal and drought stress, respectively. However, the crosses (IRAT 170 x Giza177), (Azucena x Giza177) and (Moroberekan x Giza177) average the following mean values (41.35 and 38.68 cm²), (41.91 and 39.21cm²) and (40.85 and 38.21cm²) under normal and drought stress conditions, respectively. Reversely, the lowest flag leaf area mean values were recorded with Sakha 101, Giza 178, (GZ350-20-10 x Giza178) and (GZ350-20-10 x Sakha101). These genotypes had (26.90 and 25.30 cm²), (28.06 and 26.24 cm²), (32.92 and 30.79 cm²) and (33.92 and 31.46 cm²) under normal and drought stress conditions, respectively.

Leaf chlorophyll contents (mg/g), (CH) of all studied genotypes showed considerable variation. The lowest chlorophyll content value was associated with the parents Sakha 101 (44.90 and 34.99 mg/g) followed by Giza 177

(42.92 and 38.62 mg/g) while, the parent GZ350-20-10 scored the lowest mean value (35.80, 33.13 and 34.47 mg/g) under normal and stress conditions, respectively. Considerable high chlorophyll content mean values were scored in the following F₁ crosses; IRAT 170 x Giza178 (42.06 and 38.93 mg/g), Moroberekan x Giza177 (41.85 and 38.73 mg/g), Moroberekan x Giza178 (41.76 and 38.65 mg/g), and IRAT 170 x Sakha101 (41.74 and 38.63 mg/g) under normal and drought stress. On the other hand the F₁ crosses; GZ350-20-10 x Sakha101, GZ350-20-10 x Giza178, and GZ350-20-10 x Giza177 genotypes had the lowest mean values (35.80 and 33.13 mg/g), (31.92 and 29.54 mg/g), (32.63 and 30.21 mg/g), and (34.71 and 32.13 mg/g) under normal and drought stress conditions, respectively.

Relatively high nitrogen content (mg/g) (N), mean values were established in the following parents genotypes; Giza 178 (0.49 and 0.43 mg/g), Giza 177 (0.45 and 0.36 mg/g), Moroberekan (0.43 and 0.39 mg/g). In addition the F₁ crosses; Moroberekan x Giza178 (0.51 and 0.53 mg/g) and IET 1444 x Giza178 (0.50 and 0.49 mg/g) produced considerably high mean values for such trait, under both normal and drought conditions, respectively. While the parents genotypes IET 444 (0.30 and 0.29 mg/g), GZ350-20-10 (0.31 and 0.28 mg/g) and the crosses GZ350-20-10 x Giza177 (0.27 and 0.23 mg/g) and GZ350-20-10 x Sakha101 (0.32 and 0.29 mg/g) produced relatively low mean values under normal and drought stress conditions, respectively.

Relatively high potassium content (K) (mg/g), mean values were scored in the studied parents; (Moroberekan) (0.76 and 0.68 mg/g), Azucena (0.71 and 0.65 mg/g). Moreover, the crosses; IET 1444 x Sakha101 (0.91 and 0.81 mg/g), IET 1444 x Giza178 (0.89 and 0.80 mg/g) and Moroberekan x Giza178 (0.86 and 0.79 mg/g) produced relatively high potassium content under both normal and drought conditions, respectively. While the parents genotypes Giza 177 (0.56 and 0.50 mg/g), GZ350-20-10 (0.64 and 0.56 mg/g) and the crosses GZ350-20-10 x Giza177 (0.47 and 0.40 mg/g), GZ350-20-10 x Sakha101 (0.56 and 0.49 mg/g) and GZ350-20-10 x Giza177 (0.61 and 0.55 mg/g) gave relatively low mean potassium content values under normal and drought stress conditions, respectively.

Concerning relative water content (RWC), data reveal that, the highest mean values of the genotypes, IRAT 170 (81.32 and 94.64), Giza 178 (80.20 and 93.67), IET 1444, (79.40 and) Moroberekan x Giza 177 (81.06 and 94.67), Moroberekan x Sakha101 (81.04 and 94.64) and IET 1444 x Sakha101 (80.49 and 94.01) under normal and stress conditions, respectively. On the other hand, the lowest values of relative water content scored with the genotypes Sakha 101 (63.00 and 73.58), GZ350-20-10 (69.03 and 80.62), GZ350-20-10x Giza177 (60.95 and 71.18) and Azucena x Sakha101 (63.28 and 73.91) for the two studied normal and drought stress conditions.

Moreover, the excessive mean water use efficiency, (WUE) values were obtained with the parents; Sakha 101 (0.73 and 0.60), Giza 178 (0.70 and 0.83) and IET 444 (0.50 and 0.70). However, the crosses; IET 1444 x Sakha101 (0.76 and 0.9), Moroberekan x Giza 178 (0.74 and 1.00), Azucena

x Giza178 (0.74 and 0.91) and ILET 1444 x Giza178 (0.72 and 0.93) showed the same relatively high water use efficiency mean values under normal and drought stress conditions, respectively. While the parent Moroberekan (0.45 and 0.66) and the crosses GZ350-20-10 x Giza177 (0.60 and 0.70), GZ350-20-10 x Sakha101 (0.61 and 0.62) showed lowest mean values under normal and drought stress conditions, respectively.

Table (3): Mean performances of physiological characters for the studied eight parents and fifteen F1 crosses as affected by normal and drought stress conditions

Characters	Leaf rolling		Flag leaf area		Chlorophyll content		Nitrogen content		Potassium content		Relative water content		Water use efficiency	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S
Genotypes														
P1	2	3	41.83	35.31	37.96	34.73	0.43	0.39	0.76	0.68	76.33	89.14	0.45	0.66
P2	2	3	39.55	37.31	41.88	38.77	0.40	0.34	0.71	0.65	77.07	90.01	0.47	0.68
P3	1	3	35.96	33.64	37.30	34.53	0.30	0.29	0.69	0.62	79.40	92.73	0.50	0.70
P4	1	5	36.11	33.58	39.78	36.82	0.33	0.30	0.70	0.64	81.32	94.98	0.47	0.64
P5	2	5	34.13	31.59	35.80	33.13	0.31	0.28	0.64	0.56	69.03	80.62	0.58	0.68
P6	1	7	29.25	27.36	42.92	38.62	0.45	0.36	0.56	0.50	71.08	83.01	0.63	0.54
P7	1	5	28.06	26.24	41.39	39.01	0.49	0.43	0.70	0.63	80.20	93.67	0.70	0.83
P8	1	9	26.90	25.30	44.90	34.99	0.42	0.30	0.66	0.58	63.00	73.58	0.73	0.60
P1XP6	3	3	40.85	38.21	41.85	38.73	0.45	0.39	0.71	0.68	81.06	94.67	0.67	0.80
P1XP7	3	3	38.09	35.63	41.76	38.65	0.51	0.53	0.86	0.79	71.17	83.13	0.74	1.00
P1XP8	7	7	36.78	34.41	37.78	34.97	0.43	0.37	0.71	0.67	81.04	94.64	0.75	0.88
P2XP6	3	3	41.91	39.21	41.35	38.27	0.44	0.38	0.68	0.59	71.64	83.67	0.65	0.77
P2XP7	2	2	39.35	36.81	39.35	36.42	0.46	0.39	0.71	0.68	77.25	90.22	0.74	0.91
P2XP8	5	5	37.79	35.35	39.46	36.52	0.38	0.38	0.60	0.53	63.28	73.91	0.70	0.75
P3XP6	7	7	35.72	33.41	35.72	33.06	0.49	0.42	0.77	0.69	78.10	91.21	0.63	0.78
P3XP7	5	5	36.07	33.74	38.00	35.17	0.50	0.49	0.89	0.80	79.85	93.26	0.72	0.93
P3XP8	7	7	34.75	32.51	38.75	35.87	0.42	0.46	0.91	0.81	80.49	94.01	0.76	0.96
P4XP6	5	5	41.35	38.68	40.35	37.35	0.41	0.35	0.72	0.67	74.88	87.45	0.65	0.93
P4XP7	3	3	39.06	36.53	42.06	38.93	0.42	0.36	0.77	0.70	71.64	83.67	0.69	0.76
P4XP8	7	7	38.84	36.33	41.74	38.63	0.41	0.35	0.70	0.62	75.07	87.68	0.63	0.81
P5XP6	7	7	35.71	33.41	34.71	32.13	0.27	0.23	0.47	0.40	60.95	71.18	0.60	0.70
P5XP7	7	7	33.63	31.46	32.63	30.21	0.33	0.30	0.61	0.55	68.04	79.47	0.64	0.66
P5XP8	9	9	32.92	30.79	31.92	29.54	0.32	0.29	0.56	0.49	69.31	80.95	0.61	0.62
LSD 5%	1.97	1.44	0.6	0.54	1.36	1.11	0.006	0.006	0.01	0.01	1.46	1.56	1.16	1.05

The obtained results proved that, generally, the parents Moroberekan, GZ350-20-10, Giza 178 and Sakha 101 as well as the F1 crosses involved these parents, in particular the crosses Moroberekan x Giza177 and Moroberekanx Giza178 showed the most favorable mean performances values for the studied physiological characters, under stress conditions. Moreover, under drought stress, the following F1 crosses; GZ350-20-10 x Giza177, IRAT 17 x Sakha101 showed remarkable increase in the mean performance of average flag leaf are, average grain yield per plant as well as harvest index. These results are in accordance with those reported by Young and Virmani (1990), Reddy *et al.* (1991), Ramalingam *et al.* (1994), El-Mowafi (2001), El-Mowafi and Abou Shousha (2003), Hammoud (2004), El-Mowafi and Abd El-Hadi (2005).

2. Heterosis percentages over mid parents for F1 crosses

2.1. Heterosis percentages of root characters

Data in Table (4) show that, under drought stress, significant positive heterosis effect was realized for average root volume (RV), in the crosses, Moroberekan x Giza177, Moroberekan x Giza178, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza177, IET 1444 x Giza178, IET 1444 x Sakha101, IRAT 170 x Giza177 and IRAT 170 x Giza178. The other studied character, root to shoot ratio (R:S) showed significant estimates with All crosses except Moroberekan x Giza177 and IRAT 170 x Giza177. As well, for maximum root length (MRL) positive significant heterosis effects, under drought condition, were scored with the crosses; Moroberekan x Giza177, Moroberekan x Giza178, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza177, IET 1444 x Sakha101, IRAT 170 x Giza177, IRAT 170 x Giza178, IRAT 170 x Sakha101, GZ350-20-10 x Giza177, GZ350-20-10 x Giza178 and GZ350-20-10 x Sakha101. Typically similar significant estimates were found for average root number per plant (RNP) in the crosses; Moroberekan x Giza177, Moroberekan x Giza178, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza177, IET 1444 x Giza178, IET 1444 x Sakha101, IRAT 170 x Giza177, IRAT 170 x Giza178 and GZ350-20-10 x Giza178.

It is evident that, under drought condition, insignificant heterotic effects were recorded for average root volume (RV) with the F1 combiner; GZ350-20-10 x Giza178. Nevertheless, root to shoot ratio (R:S) did not show insignificant heterosis effects under drought condition. In addition, for maximum root length (MRL) insignificant heterosis effects were scored with the F1 cross; IET 1444 x Giza178. Relatively similar insignificant estimates were found for average root number per plant (RNP) in the crosses; IRAT 170 x Sakha101.

2.2. Heterosis percentages for yield and yield components characters

Data in Table (5) show the heterosis percentages over mid parents (MP) of yield and its component characters. It is evident that, under drought stress, significant Positive heterosis effects for yield and its component characters were scored for average panicle length (PL) with the crosses; Moroberekan x Giza177, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Sakha101, IET 1444 x Giza177, IET 1444 x Sakha101 and IRAT 170 x Giza177. The other studied yield character, average number of panicles per plant (NPP) exhibited significant estimates with, Moroberekan x Giza177, Azucena x Giza177, IET 1444 x Giza177, IET 1444 x Giza178 and IET 1444 x Sakha101. As well, for average thousand grains weight (1000 G W) significant heterosis effects were scored with the crosses; Moroberekan x Giza177, Moroberekan x Giza178, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IRAT 170 x Giza177, IRAT 170 x Giza178, IRAT 170 x Sakha101 and GZ350-20-10 x Giza178. Typically similar significant estimates were found for average sterility percentage (S%) in the crosses; Moroberekan x Giza178, Azucena x Giza177, Azucena x Giza178, IET 1444 x Giza178, IET 1444 x Sakha101, IRAT 170 x Giza177, IRAT 170 x Giza178, IRAT 170 x Sakha101, GZ350-20-10 x Giza178 and GZ350-20-10 x Sakha101.

Comparatively similar insignificant estimates were found for drought susceptibility index (DSI) in the crosses GZ350-20-10x Giza178. Finally insignificant heterotic effects were detected for the average grain yield per plant (GY) with the crosses; Moroberekan x Giza177, Moroberekan x Giza178, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza177, IET 1444 x Giza178, IET 1444 x Sakha101, IRAT 170 x Giza177 and IRAT 170 x Giza178. It is worthy to mention that, under drought stress, all the studied F1 crosses showed negative heterosis percentages for harvest index (HI).

Table (5): General combining ability estimates of root characters (5 lines and 3 tester) parents genotypes grown under normal and drought stress and their combined data

Character	Root volume			Root : shoot ratio			Maximum root length			Number of roots		
Genotype	N	S	C	N	S	C	N	S	C	N	S	C
P1	7.61*	6.55*	7.08*	0.06*	0.06*	0.06*	4.06*	5.83*	4.95*	26.91*	25.60*	26.26*
P2	1.38*	1.17*	1.28*	0.03*	-0.01*	0.01*	1.59*	3.56*	2.58*	7.42*	7.06*	7.24*
P3	2.53	2.15*	2.34*	0.04*	0.05*	0.04*	-1.50*	-5.40*	-3.45*	4.58*	4.35*	4.46*
P4	1.77*	1.50*	1.63*	0.04*	0.03*	0.04*	5.39*	2.36*	3.87*	6.75*	6.42*	6.59*
P5	-13.29*	-11.37*	-12.33*	-0.17*	-0.13*	-0.15*	-9.54*	-6.35*	-7.94*	-45.6*	-43.4*	-44.5*
L.S.D 5%	0.56	0.57	0.41	0.004	0.003	0.002	0.32	0.19	0.19	2.82*	2.90	2.07
P6	-0.27*	-0.26*	-0.27*	0.01*	0.01*	0.01*	0.38*	0.68*	0.53*	-1.98*	-1.88*	-1.93*
P7	1.26*	1.06*	1.16*	0.001*	0.02*	0.01*	1.49*	0.74*	1.11*	7.51*	7.14*	7.32*
P8	-0.98*	-0.79*	-0.89*	-0.01*	-0.03*	-0.02*	-1.87*	-1.42*	-1.64*	-5.53*	-5.26*	-5.39*
L.S.D 5%	0.44	0.44	0.31	0.003	0.003	0.002	0.25	0.14	0.15	2.19*	2.25	1.60

The significance of heterotic effect showed considerable fluctuation since, insignificant heterosis percentages were recorded for yield and its component characters in some tested F1 combiners under drought condition. Insignificant heterotic effects were recorded for average panicle length (PL) with the crosses; Moroberekan x Giza178, Azucena x Giza178, IET 1444 x Giza178, IRAT 170 x Giza178, GZ350-20-10 x Giza177 and GZ350-20-10 x Sakha101. While, number of panicles per plant (NPP) showed insignificant estimates with, Moroberekan x Giza178, IRAT 170 x Giza178 and IRAT 170 x Sakha101. As well, for average thousand grains weight (1000GW) insignificant heterosis effects were scored with the crosses; IET 1444 x Giza177, IET 1444 x Giza178, IET 1444 x Sakha101 and GZ350-20-10 x Sakha101. Relatively similar insignificant estimates were found for sterility percentage (S%) in the crosses; Moroberekanx Giza178, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, and GZ350-20-10 x Sakha101. Comparatively similar insignificant estimates were found for drought susceptibility index (DSI) in the crosses Azucena x Giza178, IET 1444 x Giza178 and IRAT 170 x Giza178. Similar insignificant estimates were obtained for harvest index (HI) in the following F1 crosses; Moroberekan x Sakha101, Azucena x Giza177, IET 1444 x Giza177, IRAT 170 x Giza177 and GZ350-20-10x Giza177. Finally insignificant heterotic effects were detected for the average grain yield per plant (GY) with the crosses, IRAT 170 x Giza178 and GZ350-20-10x Sakha101.

2.3. Heterosis percentages over Mid parents for physiological characters

It is obvious that, under drought stress Table (6), significant positive heterosis effect was realized for average flag leaf area, cm² (FL), in the crosses, Moroberekan x Giza177, Moroberekan x Giza178, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza177, IET 1444 x Giza178, IET 1444 x Sakha101, IRAT 170 x Giza177, IRAT 170 x Giza178, IRAT 170 x Sakha101, GZ350-20-10 x Giza177, GZ350-20-10 x Giza178 and GZ350-20-10 x Sakha101. The other studied character, average chlorophyll content, mg/g (CHC) showed significant estimates with All crosses except Moroberekan x Sakha101, Azucena x Giza177, Azucena x Sakha101, IET 1444 x Sakha101, IRAT 170 x Giza177 and IRAT 170 x Giza178. As well, for average nitrogen content mg/g (N) significant heterosis effects were scored with the crosses; Moroberekan x Giza177, Moroberekan x Giza178, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Sakha101, IET 1444 x Giza177, IET 1444 x Giza178, IET 1444 x Sakha101, IRAT 170 x Giza177 and IRAT 170 x Sakha101. Typically similar significant estimates were found for potassium content mg/g (K) in the crosses; Moroberekan x Giza177, Moroberekan x Giza178, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Giza178, IET 1444 x Giza177, IET 1444 x Giza178, IET 1444 x Sakha101, IRAT 170 x Giza177 and IRAT 170 x Giza178. Comparatively similar insignificant estimates were found for relative water content (RWC) in the crosses; Moroberekan x Giza177, Moroberekan x Sakha101, IET 1444 x Giza177, IET 1444 x Sakha101, IRAT 170 x Sakha101 and GZ350-20-10 x Sakha101.

No significant heterosis percentages, under drought condition, were recorded for average flag leaf area (FL), with the tester combiners; Moroberekan x Giza178, Azucena x Giza178, IET 1444 x Giza178, IRAT 170 x Giza178, GZ350-20-10 x Giza177 and GZ350-20-10 x Sakha101. Nevertheless, average chlorophyll content (CHC), showed insignificant estimates with, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Sakha101, IET 1444 x Sakha101, IRAT 170 x Giza177 and IRAT 170 x Giza178,. As well, for average nitrogen content mg/g (N) insignificant heterosis effects were scored with the crosses; Azucena x Giza178, IRAT 170 x Giza178 and GZ350-20-10 x Sakha101. Relatively similar insignificant estimates were found for average potassium content mg/g (K) in the crosses; Moroberekan x Sakha101 and Azucena x Giza178. Comparatively similar insignificant estimates were found relative water content (RWC) in the crosses Azucena x Giza178, IET 1444 x Giza178 and IRAT 170 x Giza177.

The obtained results insured that, the most desirable crosses under normal and drought stress were; Moroberekan x Giza177, Moroberekan x Sakha101, IET 1444 x Giza178, IET 1444 x Sakha101. Since these crosses maintained the most favorable shoot, root, yield and physiological characters under both normal and drought stress conditions. it is noticed that the parent Giza 177 showed negative heterosis percentages for number of days to heading in all crosses.

These results emphasized that vigorous growth of F1 rice hybrids may partially attributed to the development and function of the root system. Total root length and total roots number were also greater than those of the parents. Also, it was found that F1 hybrid surpassed parents in the total root length, number. of root per plant. As a result, the root system of F1 hybrids was not only greater in volume, but also longer in length. Additionally, root to shoot ratio showed higher values than that of parents. These results are in line with those mentioned by Gomez and Rangasamy (2003) reported that the parents PMK 1, Karumkuruvai and Chandaikar and the hybrids PMK 1 x IR 64, Poongar x MDU 5, Karumkuruvai x ADT 43 were the most promising for studied root traits. The hybrids PMK 1 x IR 64, Poongar x MDU 5, Karumkuruvai x ADT 43 had high per se performance, significant standard heterosis were detected studied traits. Moreover, Abd-Allah (2004) reported that, the most desirable heterosis as deviation from better-parent were obtained from the crosses Giza 177 x Moroberekan and IET 1444 x Moroberekan for root length, root volume, root: shoot ratio, no. of root xylem vessels number. The scored useful heterosis over mid and better parent for some root characters i.e., root length, root number, root volume, root fresh weight, root dry weight and root/shoot ratio using four rice genotypes in six-population design, Abd El-Lateef *et al.* (2006).

3. General combining ability of the F1 parents

Theoretically, an estimate of GCA effect of a parent depends upon the group of other parents of which it was crossed with, (Abdalla, 2000)

3.1. General combining ability of root characters

Estimates of general combining ability (GCA) effects of root characters for parental genotypes are presented in table (7). Data of (GCA) estimates for the studied line parents for root characters prove that, under normal and stress conditions, significant GCV estimates were recorded for all the studied traits except the parents Giza 177 for average root volume per plant and the parent Giza 178 for root to shoot ratio under normal condition and Giza 177 for average number of roots per plant for number of roots per plant. Moreover, under drought stress, the following parental genotypes showed negative significant GCA estimates, GZ350-20-10 and Sakha 101 for average roots volume, Azucena, GZ350-20-10 and Sakha 101 for root to shoot ratio, IET 1444, GZ350-20-10 and Sakha 101 for maximum root length and GZ350-20-10 and Sakha 101 for average root number.

3.2. General combining ability of yield characters

Generally, data of general combining ability of the studied parents for yield and yield components characters Table (8) demonstrate that under normal and stress conditions, significant GCV estimates were recorded for all the studied traits except the parents Azucena and IET 1444 for average panicle length and the parent IET 1444 and Sakha 101 for average number of panicles per plant, under normal condition and Sakha 101 and Giza 178 for thousand grain weight, Azucena for average grain yield per plant, under drought stress condition only.

In addition, under drought stress, the following parental genotypes showed negative significant GCA estimates for yield characters, IRAT 170, GZ350-20-10 and Giza 178 for average panicle length, IRAT 170, GZ350-20-10 Giza 177 and Sakha 101 for average root number per plant, IET 1444, GZ350-20-10 and Sakha 101 for thousand grain weight, for average sterility percentage, GZ350-20-10, Giza 177 and Sakha 101 for average grain yield per plant and GZ350-20-10 for grain index.

3.3. General combining ability of physiological characters

As seen in Table (9) data of (GCA) exhibit that, under normal and stress conditions, significant GCV estimates were recorded for all the studied traits except the parents IRAT 170, Giza 177, Giza 178 and Sakha 101 for average relative water content. The following parents, under drought stress condition showed positive significant general combining ability Moroberekan, Azucena, IRAT 170, Giza 177 for average flag leaf area, Moroberekan, Azucena, IRAT 170, Giza 177, Giza 178 for average chlorophyll content, Moroberekan, Azucena, IET 1444 and Giza 178 for average nitrogen content, Moroberekan, IET 1444, IRAT 170 and Giza 178 for average potassium content and the parents Moroberekan and IET 1444 for relative water content. Reversely, under drought stress, the following parental genotypes showed negative significant GCA estimates for physiological characters, IET 1444, GZ350-20-10, Giza 178 and Sakha 101 for average flag leaf area, IET 1444, GZ350-20-10 and Sakha 101 for average chlorophyll content, IRAT 170, GZ350-20-10, Giza 177 and Sakha 101 for average nitrogen content, Azucena, GZ350-20-10, Giza 177 and Sakha 101 for average potassium content and Azucena, GZ350-20-10 and Giza 177 for relative water content.

4. Specific combining ability of F1 crosses

4.1. Specific combining ability of root characters

Data of specific combining ability (SCA) of the fifteen F1 crosses (Table.10) demonstrate that, under normal and stress conditions, significant SCV estimates were recorded for all the studied traits except the crosses Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza178, IRAT 170 x Giza177, GZ350-20-10x Giza177, GZ350-20-10x Giza178 and GZ350-20-10x Sakha101 for average root volume, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza177 and GZ350-20-10x Sakha101 for root to shoot ratio, Moroberekanx Giza178, Azucena x Sakha101 and GZ350-20-10 x Giza177 for maximum root length, Moroberekan x Sakha101, Azucena x Giza177 and GZ350-20-10 x Giza177 under drought stress condition and finally for average number of tillers per plant with the crosses Moroberekan x Giza178, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza177, IRAT 170 x Giza177, IRAT 170 x Giza178, IRAT 170 x Sakha101, GZ350-20-10 x Giza178 and GZ350-20-10 x Sakha101.

Negative SCA estimates were detected with all the studied genotypes. These negative estimates for average root volume were with the F1combiners; Moroberekan x Giza178, Moroberekan x Sakha101 and IRAT 170 x Sakha101. For average root to shoot ratio; Moroberekan x Giza178, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Sakha101, IET 1444 x Giza177, IET 1444 x Giza178, IRAT 170 x Sakha101, GZ350-20-10 x Giza177 and GZ350-20-10 x Giza178 for maximum root length; Moroberekan x Sakha101, Azucena x Giza177, IET 1444 x Giza177, IET 1444 x Giza178, IRAT 170 x Giza178, IRAT 170 x Sakha101 and GZ350-20-10 x Sakha101. Finally, for average root number; Moroberekan x Sakha101, IET 1444 x Giza178 and GZ350-20-10 x Giza177.

4.2. Specific combining ability of yield and yield component

Estimates of specific combining ability (SCA) estimates (Table,11) of the studied genotypes for yield and yield components characters proved that, under normal condition significant (SCV) estimates were recorded for all the studied traits except the crosses Moroberekan x Giza177, Moroberekan x Giza178, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101 and GZ350-20-10 x Giza177 for average panicle length; Moroberekan x Giza177, Moroberekan x Giza178, Azucena x Giza178, IET 1444 x Giza178, IRAT 170 x Giza178 and GZ350-20-10 x Giza178 for average number of panicles per plant and Moroberekan x Giza177, Moroberekan x Giza178, Moroberekan x Sakha101, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza177, IET 1444 x Giza178, IRAT 170 x Giza178, GZ350-20-10 x Giza177, GZ350-20-10 x Giza178 and GZ350-20-10 x Sakha101 for thousand grain weight; Moroberekan x Giza177, Moroberekan x Giza178, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza178, IRAT 170 x Giza178, GZ350-20-10 x Giza178 and GZ350-20-10 x Sakha101 for average grain yield per plant, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IRAT 170 x Giza178, IRAT 170 x Sakha101 and GZ350-20-10 x Giza178 and GZ350-20-10 x Sakha101 for average harvest index. However, under drought stress, the following genotypes showed insignificant (SCA) estimates for yield characters, Moroberekan x Giza178 and GZ350-20-10 x Giza177 for average panicle length and for average number of panicles per plant, Moroberekan x Giza177, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza177, IET 1444 x Sakha101, IRAT 170 x Giza177, IRAT 170 x Sakha101 and GZ350-20-10 x Sakha101 for thousand grain weight; Azucena x Giza178, IRAT 170 x Giza177, IRAT 170 x Giza178, IRAT 170 x Sakha101 and GZ350-20-10 x Giza178 for average sterility percentage, Moroberekan x Sakha101, Azucena x Giza177, IET 1444 x Giza178 and IRAT 170 x Sakha101 for average grain yield per plant and Moroberekan x Giza178, Azucena x Giza177, Azucena x Giza178, Azucena x Sakha101, IET 1444 x Giza177, IET 1444 x Giza178, IET 1444 x Sakha101 and IRAT 170 x Giza177 for average grain index.

4.3. Specific combining ability of physiological characters

Generally, data of specific combining ability (SCA) prove that, under normal and stress conditions, significant SCV estimates were recorded for all the studied traits except the Crosses IRAT 170, Giza 177, Giza 178 and Sakha 101 for average relative water content. The following crosses, under drought stress condition showed positive significant general combining ability Moroberekan, Azucena, IRAT 170, Giza 177 for average flag leaf area; Moroberekan, Azucena, IRAT 170, Giza 177, Giza 178 for average chlorophyll content; Moroberekan, Azucena, IET 1444 and Giza 178 for average nitrogen content; Moroberekan, IET 1444, IRAT 170 and Giza 178 for average potassium content and the crosses; Moroberekan and IET 1444 for relative water content. Reversely, under drought stress, the following genotypes showed negative significant sCA estimates for physiological characters, IET 1444, GZ350-20-10, Giza 178 and Sakha 101 for average flag leaf area; IET 1444, GZ350-20-10 and Sakha 101 for average chlorophyll content; IRAT 170, GZ350-20-10, Giza 177 and Sakha 101 for average nitrogen content; Azucena, GZ350-20-10, Giza 177 and Sakha 101 for average potassium content and Azucena, GZ350-20-10 and Giza 177 for relative water content.

The above mention results indicated the importance of SCA for choosing the most favorable combiners under drought stress. The most common crosses for the studied characters were IET 1444 x Sakha 101, IRAT 170 x Giza 177 and IRAT 170 x Sakha 101. These results are in harmony with those reported by Sheng *et al.* (2005) they reported that drought at tillering stage enhanced the water use efficiency (WUE) of rice plant significantly in the course of and after treatment. The differences in yield and rice quality between rice cultivars in various water saving treatments were significant or highly significant. Moreover, Aidy *et al.* (2006) reported that Sakha 101 and the line GZ 6296-21-1-2-1-1 were the best general combiners for the physiological traits. Additive gene action played the major role in the inheritance of most of the studied traits. While, Manickavelu *et al.* (2006) reported that relative water content, leaf rolling, and leaf drying were governed by additive gene action; and mass selection, progeny selection and pedigree breeding can be used to improve these traits. Non-additive gene action was observed for the drought recovery rate. Moreover, Sedeek (2006) mentioned that both general and specific combining ability variances were highly significant for all characters. The additive and additive x additive types of gene action were of great importance in the inheritance of studied characters. As well, Sibounheunga *et al.* (2006) stated that the reduced in RWC could influence by severe stress condition and caused in maintenance of plant water relations under water deficit.

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تمييز الدلائل الجزيئية لتحمل الجفاف في الأرز

١- تقدير الطراز الجيني للهجين الأول تحت الظروف الطبيعية و الجفاف
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**مركز البحوث والتدريب في الارز معهد المحاصيل الحقلية مركز البحوث الزراعيه
*** معهد الهندسة الوراثية الزراعيه مركز البحوث الزراعيه

تم اجراء هذه التجربة بمحطة التجارب بمركز التدريب وبحوث الارز - سخا - كفر الشيخ خلال
الثلاث مواسم المتتالية ٢٠١٠ الى ٢٠١٣ بغرض تأسيس عشائر هجينية تحمل صفات التحمل للجفاف لنبات
الارز باستخدام التهجين ومتابعة هذه الصفات على المستوى الجزيئي باستخدام تكنيك Simple Sequence
Repeat (SSR). حيث تم اجراء التهجينات بين عدد ثمانية ابناء محلية و مستوردة للحصول على ١٥
عشيرة هجينية وذلك بنظام (سلالة X مختبر). وكانت الالباء المستخدمة Moroberekan, IET1444,
Azucena, IRAT170, GZ530-20-10, Giza177, Giza 178 and Sakha101. خلال
موسم ٢٠١١ تمت زراعة الالباء و الهجن المتحصل عليها تحت كل من مستوى الجفاف المستحدث و الظروف
الطبيعية في تجربة قطاعات كاملة العشوائية من ٣ مكررات لدراسة كل من صفات المجموع الجذري و
المحصول بالاضافة الى بعض التقديرات الفسيولوجية.
أوضحت النتائج ان المتوسط المظهرى العام للصفات تحت الدراسة المجموع الجذري, المحصول
ومكونات و الصفات الفسيولوجية للهجين الناتجة عن الالباء Moroberekan, IET 1444, Giza 178
and Sakha 101 و الهجن الداخلة فيهم وخاصة الهجن Moroberekan x Giza177 and IET 1444 x Sakha 101
تحت كل من الظروف الطبيعية و الجفاف. كانت الهجن الاتية متميزة معنويا
بدرجات متفاوتة لصفات المحصول و مكونات Moroberekan, IET 1444 x Giza177, IET 1444 x Sakha101
بالاضافة الى صفات المجموع الجذري .
كانت افضل الهجن تحت الظروف الطبيعية و الجفاف بالنسبة لتأثيرات التباين الهجينى لصفات
المجموع الجذري ومكونات المحصول والصفات الفسيولوجية Moroberekan x Giza177, Moroberekan x Sakha101, IET 1444 x Giza178, IET 1444 x Sakha101
وأثبتت النتائج ان قوة الهجين لهجن الجيل الاول تحت ظروف الجفاف ترجع الى زيادة متوسطات صفات المجموع
الجذري. كما أنه على مستوى المتوسط العام كان متوسط صفات طول وعدد وحجم المجموع الجذري متميزا
في اغلب الهجن مقارنة بالالباء. أثبتت القدرة العامة على التألف للأباء تحت الدراسة تقديرات موجبة و معنوية
للأباء Moroberekan, Giza 178 and Sakha 101 للصفات تحت الدراسة خاصة
صفات المجموع الجذري و المحصول بينما كانت القدرة الخاصة على التألف موجبة و معنوية تحت ظروف
الجفاف للهجين Moroberekan x Giza177 and IRAT 170 x Giza177 and Moroberekan x Sakha 101, IET 1444 x Sakha 101,
لجميع الصفات تحت الدراسة.

قام بتحكيم هذا البحث

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Table (2): Mean performances of yield and yield components characters for the studied eight parents and fifteen F1 crosses as affected by normal and drought stress and their combined data

Characters	Panicle length			Number of tillers/plant			1000- grain weight			Sterility %			Grain yield/plant			Harvest index			DS%
Genotypes	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	
P1	28.63	25.81	27.22	14.43	11.18	12.81	3.78	3.56	3.67	7.70	12.56	10.13	25.81	21.87	23.84	0.26	0.26	0.26	0.15
P2	25.98	23.30	24.64	15.47	12.05	13.76	3.63	3.46	3.55	8.37	10.31	9.34	27.07	22.67	24.87	0.28	0.27	0.28	0.16
P3	23.18	21.68	22.43	13.78	10.75	12.27	2.42	2.20	2.31	7.70	11.36	9.53	28.74	23.38	26.06	0.29	0.27	0.28	0.18
P4	27.39	24.39	25.89	15.73	11.92	13.83	3.48	3.41	3.45	6.55	8.47	7.51	26.67	21.39	24.03	0.27	0.25	0.26	0.20
P5	24.05	22.50	23.28	13.13	9.88	11.51	2.59	2.42	2.51	8.65	11.16	9.91	33.17	22.56	27.87	0.31	0.27	0.29	0.32
P6	24.43	21.15	22.79	18.14	13.95	16.05	2.84	2.49	2.67	5.63	12.23	8.93	36.00	17.86	26.93	0.39	0.29	0.34	0.50
P7	25.25	22.96	24.11	23.46	17.12	20.29	2.34	2.13	2.24	4.67	8.59	6.63	39.74	27.58	33.66	0.39	0.32	0.36	0.31
P8	24.34	20.67	22.51	22.91	16.33	19.62	2.77	2.37	2.57	5.39	12.07	8.73	41.96	20.16	31.06	0.42	0.33	0.38	0.52
P1XP6	27.50	25.10	26.30	20.10	13.98	17.04	3.61	3.53	3.57	6.41	9.28	7.85	38.36	26.64	32.50	0.34	0.27	0.31	0.30
P1XP7	27.53	25.88	26.71	23.03	14.75	18.89	3.57	3.51	3.54	7.23	8.98	8.11	42.36	33.29	37.83	0.33	0.29	0.31	0.21
P1XP8	28.91	27.51	28.21	21.09	12.36	16.73	3.57	3.27	3.42	9.40	11.08	10.24	42.94	29.18	36.06	0.37	0.32	0.34	0.32
P2XP6	26.02	26.07	26.05	16.85	14.05	15.45	3.52	3.48	3.50	8.38	10.16	9.27	37.41	25.71	31.56	0.33	0.28	0.31	0.31
P2XP7	24.93	23.69	24.31	18.71	12.80	15.76	3.39	3.36	3.38	7.24	8.99	8.12	42.09	30.19	36.14	0.35	0.29	0.32	0.28
P2XP8	26.41	24.58	25.50	17.25	10.74	14.00	3.38	3.36	3.37	8.62	10.70	9.66	39.83	25.05	32.44	0.37	0.29	0.33	0.37
P3XP6	25.51	24.35	24.93	14.39	13.14	13.77	2.80	2.35	2.58	7.92	9.51	8.72	36.03	25.90	30.97	0.35	0.30	0.33	0.28
P3XP7	24.46	22.88	23.47	18.19	14.86	16.53	2.68	2.21	2.45	5.51	6.74	6.13	41.13	31.00	36.07	0.34	0.29	0.32	0.24
P3XP8	28.02	26.01	27.02	18.94	15.69	17.32	2.88	2.29	2.59	8.16	7.87	8.02	43.71	31.90	37.81	0.37	0.30	0.34	0.27
P4XP6	27.18	25.42	26.30	14.28	11.36	12.82	3.74	3.54	3.64	9.92	11.98	10.95	36.89	31.12	34.01	0.33	0.29	0.31	0.15
P4XP7	25.43	23.79	24.61	18.10	14.97	16.54	3.42	3.36	3.39	8.10	10.06	9.08	39.42	25.18	32.30	0.34	0.28	0.31	0.36
P4XP8	24.16	22.60	23.38	17.08	14.24	15.66	3.43	3.46	3.45	9.62	11.94	10.78	36.06	27.07	31.57	0.35	0.30	0.33	0.25
P5XP6	24.26	22.78	23.52	13.66	9.75	11.71	2.87	2.28	2.58	11.83	13.44	12.64	34.04	23.20	28.62	0.32	0.28	0.30	0.32
P5XP7	22.66	22.91	22.79	14.85	11.17	13.01	2.90	2.43	2.67	9.64	11.14	10.39	36.66	22.03	29.35	0.32	0.28	0.30	0.40
P5XP8	25.11	23.75	24.43	12.82	8.74	10.78	2.89	2.38	2.64	9.78	11.73	10.76	35.05	20.65	27.85	0.32	0.22	0.27	0.41
L.S.D5%	0.85	0.93	0.67	0.95	0.7	0.62	1.97	1.44	1.37	0.63	0.59	0.41	2.29	1.44	1.34	0.023	0.021	0.31	0.015

Table (4): The estimated heterosis percentages over mid parent (MP) and their significance for yield characters of the studied fifteen F1 crosses grown under normal, drought stress and their combined data

Genotypes	Sterility %			Grain yield /plant, g			Harvest index			Panicle length			Number of panicles/plant			1000-grain weight			DS%
	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	
P1XP6	13.76*	-24.11*	-12.15*	24.12*	34.13*	28.04*	-14.45*	-8.68*	-12.01*	7.42*	4.53*	6.04*	23.45*	11.27*	18.14*	5.94ns	16.65*	10.97*	-39.80*
P1XP7	54.79*	4.60ns	22.36*	29.24*	34.66*	31.58*	-14.19*	-10.53*	-12.53*	2.19ns	1.92ns	2.06ns	21.58*	4.25ns	14.17*	13.06*	23.52*	18.02*	-30.89*
P1XP8	74.43*	-8.20*	17.33*	26.73*	38.85*	31.38*	-13.88*	-4.97ns	-9.93*	9.15*	10.58*	9.84*	12.98*	-10.15*	3.19ns	5.82ns	10.20*	7.87*	-38.46*
P2XP6	48.78*	-1.50ns	3.78ns	18.63*	26.88*	21.85*	-14.72*	-2.57ns	-9.57*	3.22ns	13.46*	8.12*	0.27ns	8.07*	3.67ns	8.89*	16.97*	12.76*	-38.31*
P2XP7	54.95*	4.72ns	22.47*	26.74*	20.15*	23.91*	-9.62*	-8.98*	-9.34*	-2.68ns	-0.79ns	-1.76ns	-3.89ns	-12.23*	-7.44*	13.66*	20.23*	16.84*	-7.32ns
P2XP8	59.95*	3.76ns	10.65*	15.41*	16.96*	16.01*	-11.75*	-10.81*	-11.34*	4.96*	5.23*	5.10*	-10.10*	-24.29*	-16.10*	5.74ns	15.40*	10.35*	-28.85*
P3XP6	40.66*	-16.29*	-2.41ns	11.31*	25.63*	16.88*	-12.17*	1.82ns	-6.24*	7.74*	9.83*	8.75*	-9.82*	6.41*	-2.73ns	6.46n	0.16ns	3.49ns	-44.28*
P3XP7	17.92*	-21.54*	-7.58*	20.13*	21.68*	20.79*	-12.27*	-8.87*	-10.72*	-0.12ns	-0.83ns	-0.47ns	-2.29ns	6.65*	1.55ns	12.83*	2.02ns	7.68*	-21.14ns
P3XP8	51.51*	-30.68*	-8.13*	23.65*	46.54*	32.38*	-10.45*	-9.23*	-9.91*	18.56*	15.34*	17.00*	3.23ns	15.85*	8.59*	11.04*	0.22ns	5.97*	-48.56*
P4XP6	76.08*	41.43*	45.74*	17.73*	57.59*	33.14*	-15.02*	-1.03ns	-9.10*	4.89*	8.07*	6.40*	-15.68*	-12.17*	-14.17*	18.26*	19.81*	19.01*	-69.15*
P4XP7	73.35*	18.71*	36.95*	18.72*	2.33ns	11.75*	-12.42*	-12.18*	-12.32*	-3.37*	-2.60ns	-3.00*	-7.63*	3.13ns	-3.05ns	17.44*	20.94*	19.15*	17.07ns
P4XP8	78.52*	40.96*	43.48*	5.09ns	29.51*	14.34*	-16.36*	-9.47*	-13.30*	-6.60*	-5.45*	-6.05*	-11.61*	0.82ns	-6.37*	9.38*	19.76*	14.37*	-52.88*
P5XP6	110.03*	20.38*	41.48*	-1.57ns	14.81*	4.47ns	-18.02*	-3.91ns	-12.04*	0.08ns	-0.76ns	-0.34ns	-12.65*	-18.17*	-15.05*	5.80ns	-7.12*	-0.34ns	-37.31*
P5XP7	106.31*	29.75*	56.75*	0.56ns	-12.11*	-4.60*	-16.56*	-14.94*	-15.83*	-8.09*	-3.98*	-6.07*	-18.84*	-17.28*	-18.18*	17.55*	6.92*	12.45*	23.62*
P5XP8	81.53*	5.08ns	23.25*	-6.69*	-3.31ns	-5.47*	-22.42*	-33.71*	-27.43*	3.77*	1.76ns	2.77ns	-28.85*	-33.33*	-30.74*	7.69*	-0.57ns	3.79ns	-21.63*
LSD 5%	0.73	0.68	0.47	2.29	1.44	1.34	2.66	2.42	1.80	0.85	0.93	0.67	0.95	0.70	0.62	1.97	1.44	1.37	0.07

Table (6): General combining ability (GCA) estimates of yield components characters (5 lines and 3 tester) parents genotypes grown under normal and drought stress and their combined data

Character	Panicle length			Number of panicles/plant			1000-grain weight			Sterility %			Grain yield/plant			Harvest index		
Genotype	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C
P1	2.40*	1.81*	2.10*	4.12*	0.86*	2.49*	3.41*	4.50*	3.95*	-0.84*	-0.46*	-0.65*	2.40*	2.50*	2.45*	0.05ns	0.45ns	0.25ns
P2	-0.1ns	0.26*	0.07n	0.31*	-0.31*	0.00ns	1.89*	4.13*	3.01*	-0.44*	-0.29*	-0.36*	1.04*	-0.2ns	0.41*	0.90*	0.57*	0.74*
P3	-0.05ns	-0.1ns	-0.08s	-0.1ns	1.72*	0.81*	-4.56*	-7.05*	-5.80*	-1.32*	-2.20*	-1.76*	1.48*	2.39*	1.93*	1.08*	1.18*	1.13*
P4	-0.32*	-0.58*	-0.45*	-0.80*	0.68*	-0.06*	2.83*	4.63*	3.73*	0.69*	1.09*	0.89*	-1.36*	0.58*	-0.39*	-0.1ns	0.52*	0.19ns
P5	-1.90*	-1.38*	-1.64*	-3.51*	-2.95*	-3.24*	-3.56*	-6.21*	-4.89*	1.90*	1.86*	1.88*	-3.56*	-5.25*	-4.41*	-1.90*	-2.72*	-2.31*
L.S.D 5%	0.20	0.22	0.16	0.22	0.17	0.15	0.47	0.34	0.32	0.15	0.14	0.10	0.54	0.34	0.32	0.54	0.49	0.37
P6	0.38*	0.32*	0.35*	-1.43*	-0.38*	-0.91*	0.67*	0.49*	0.58*	0.37*	0.63*	0.50*	-2.27*	-0.69*	-1.48*	-0.58*	-0.2ns	-0.40*
P7	-0.99*	-0.69*	-0.84*	1.29*	0.87*	1.08*	-0.52*	-0.1ns	-0.33*	-0.97*	-1.06*	-1.02*	1.57*	1.13*	1.35*	-0.53*	0.14ns	-0.1ns
P8	0.61*	0.37*	0.49*	0.15ns	-0.49*	-0.17*	-0.1ns	-0.34*	-0.25s	0.60*	0.42*	0.51*	0.70*	-0.44*	0.13ns	1.11*	0.08ns	0.59*
L.S.D 5%	0.16	0.17	0.12	0.17	0.13	0.11	0.36	0.26	0.25	0.12	0.11	0.08	0.42	0.26	0.25	0.42	0.38	0.29

Table (9), Specific combining ability (SCA) estimates of root characters for the fifteen F1 combiners grown under normal and drought stress and their combined data

Genotypes	Sterility %			Grain yield /plant, g			Harvest index			Panicle length			Number of panicles/plant			1000-grain weight		
	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C
P1XP6	-0.1ns	-1.05*	-0.62*	0.13ns	0.67*	0.40*	-0.39ns	0.44ns	0.03ns	-1.65*	-1.13*	-1.39*	-0.59ns	-2.37*	-1.48*	0.11ns	-2.14*	-1.01*
P1XP7	0.2ns	0.24ns	0.2ns	0.34ns	0.18ns	0.26*	0.37ns	0.91*	0.64*	0.53*	0.26*	0.39*	-0.43ns	2.46*	1.02*	-0.51ns	-0.27ns	-0.39ns
P1XP8	-0.0ns	0.81*	0.40*	-0.46*	-0.85*	-0.65*	0.01ns	-1.35*	-0.67*	1.12*	0.87*	1.00*	1.02*	-0.09ns	0.46ns	0.40ns	2.41*	1.40*
P2XP6	-0.1ns	0.97*	0.41*	0.68*	1.90*	1.29*	0.24ns	0.31ns	0.27ns	-0.07ns	-0.43*	-0.25*	-0.18ns	-0.58ns	-0.38ns	-0.84ns	-0.48ns	-0.66*
P2XP7	0.1ns	-0.40*	-0.1ns	-0.18ns	-0.60*	-0.39*	0.10ns	-0.28ns	-0.09ns	0.13ns	0.10ns	0.12ns	0.91ns	2.07*	1.49*	0.41ns	0.11ns	0.26ns
P2XP8	0.02n	-0.57*	-0.28*	-0.50*	-1.30*	-0.90*	-0.34ns	-0.03ns	-0.19ns	-0.06ns	0.33*	0.13ns	-0.73ns	-1.50*	-1.11*	0.43ns	0.37ns	0.40ns
P3XP6	-0.73*	-0.39*	-0.56*	-1.35*	-1.04*	-1.19*	-0.54ns	0.19ns	-0.18ns	0.35*	0.84*	0.59*	-1.99*	-3.01*	-2.50*	-0.01ns	0.19ns	0.09ns
P3XP7	-0.81*	-0.84*	-0.83*	-0.27ns	-0.57*	-0.42*	-0.53ns	-0.60*	-0.57*	-0.72*	-0.24*	-0.48*	-0.72ns	0.27ns	-0.23ns	-0.79ns	-0.46ns	-0.62ns
P3XP8	1.55*	1.23*	1.39*	1.62*	1.61*	1.61*	1.08*	0.42ns	0.75*	0.37*	-0.59*	-0.11ns	2.72*	2.74*	2.73*	0.80ns	0.28bs	0.54ns
P4XP6	1.21*	1.16*	1.18*	-0.77*	-1.78*	-1.28*	1.47*	0.39ns	0.93*	0.33*	0.02ns	0.18*	1.70*	4.02*	2.86*	0.08ns	0.01ns	0.04ns
P4XP7	0.83*	0.54*	0.69*	0.33ns	0.58*	0.45*	-0.57ns	-0.85*	-0.71*	-0.14ns	-0.21ns	-0.18*	0.40ns	-3.74*	-1.67*	0.36ns	-0.87*	-0.25ns
P4XP8	-2.04*	-1.70*	-1.87*	0.44*	1.20*	0.82*	-0.91*	0.47ns	-0.22ns	-0.19ns	0.19ns	-0.001n	-2.10*	-0.28ns	-1.19*	-0.44ns	0.86*	0.21ns
P5XP6	-0.1ns	-0.69*	-0.41*	1.31*	0.25ns	0.78*	-0.79ns	-1.32*	-1.05*	1.04*	0.70*	0.87*	1.06*	1.93*	1.50*	0.66ns	2.42*	1.54*
P5XP7	-0.36*	0.45*	0.05ns	-0.21ns	0.41*	0.10ns	0.62ns	0.82*	0.72*	0.20ns	0.10ns	0.14ns	-0.16ns	-1.06*	-0.61*	0.53ns	1.49*	1.01*
P5XP8	0.49*	0.2ns	0.36*	-1.10*	-0.66*	-0.88*	0.16ns	0.51ns	0.33ns	-1.23*	-0.80*	-1.01*	-0.90ns	-0.87*	-0.89*	-1.19*	-3.91*	-2.55*
LSD 5%	0.35	0.38	0.28	0.39	0.29	0.25	0.81	0.59	0.56	0.26	0.24	0.17	0.94	0.59	0.55	0.94	0.86	0.64

Table (10): Specific combining ability (SCA) estimates of yield characters for the fifteen F1 combiners grown under normal and drought stress and their combined data

Characters	Root volume			Root : shoot ratio			Maximum root length			Number of roots		
	N	S	C	N	S	C	N	S	C	N	S	C
P1XP6	3.83*	3.34*	3.59*	0.02*	0.03*	0.02*	2.66*	0.58*	1.62*	6.48*	6.17*	6.33*
P1XP7	-1.89*	-1.61*	-1.75*	-0.01*	-0.01*	-0.01*	0.35ns	-0.39*	-0.02ns	-0.01ns	-0.01ns	-0.01ns
P1XP8	-1.94*	-1.74*	-1.84*	-0.01*	-0.02*	-0.02*	-3.01*	-0.19ns	-1.60*	-6.48*	-6.16*	-6.32*
P2XP6	-0.23ns	-0.18ns	-0.21ns	0.01ns	-0.02*	-0.01*	-1.84*	-0.02ns	-0.93*	-1.21ns	-1.15ns	-1.18ns
P2XP7	0.52ns	0.48ns	0.50ns	-0.001ns	0.04*	0.02*	1.63*	0.90*	1.26*	2.11ns	2.01ns	2.06ns
P2XP8	-0.29ns	-0.31ns	-0.30ns	-0.01ns	-0.02*	-0.01*	0.21ns	-0.87*	-0.33ns	-0.90ns	-0.85ns	-0.87ns
P3XP6	-3.30*	-2.82*	-3.06*	-0.002ns	-0.02*	-0.01*	-4.92*	1.06*	-1.93*	-3.29ns	-3.13ns	-3.21ns
P3XP7	-0.61ns	-0.50ns	-0.56ns	-0.04*	-0.05*	-0.04*	-1.95*	-3.58*	-2.76*	-7.36*	-7.00*	-7.18*
P3XP8	3.91*	3.32*	3.62*	0.04*	0.07*	0.05*	6.87*	2.52*	4.69*	10.65*	10.13*	10.39*
P4XP6	0.53ns	0.49ns	0.50ns	-0.01*	0.02*	0.01*	4.29*	-1.44*	1.42*	4.17ns	3.96ns	4.07*
P4XP7	1.29*	1.14*	1.22*	0.03*	0.03*	0.03*	-2.03*	1.11*	-0.46*	0.92ns	0.88ns	0.90ns
P4XP8	-1.81*	-1.63*	-1.72*	-0.02*	-0.04*	-0.03*	-2.26*	0.33*	-0.96*	-5.09*	-4.84ns	-4.97*
P5XP6	-0.83ns	-0.83ns	-0.83*	-0.01*	-0.01*	-0.01*	-0.19ns	-0.18ns	-0.19ns	-6.15*	-5.85*	-6.00*
P5XP7	0.69ns	0.49ns	0.59ns	0.02*	-0.01*	0.01*	2.00*	1.96*	1.98*	4.34ns	4.13ns	4.23*
P5XP8	0.13ns	0.35ns	0.24ns	-0.01ns	0.01*	0.004ns	-1.81*	-1.78*	-1.79*	1.81ns	1.72ns	1.77ns
L.S.D 5%	0.98	0.99	0.70	0.006	0.006	0.004	0.55	0.32	0.34	4.89	5.03	3.59

Table (7): The estimated heterosis percentages over mid parent (MP) and their significance for some physiological studied characters of the studied fifteen F1 crosses grown under normal, drought stress and their combined data

Character	Flag leaf area			Chlorophyll content			Nitrogen content			Potassium content			Relative water content			Water use efficiency			Leaf rolling			Leaf angle		
Genotype	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C
P1XP6	14.93*	21.93*	18.20*	3.48ns	5.60*	4.48*	1.13ns	4.67*	2.44*	6.79*	16.17*	10.93*	9.98*	9.98*	9.98*	49.44*	49.53*	32.74*	175*	6.33ns	22.22ns	83.53*	83.41*	83.47*
P1XP7	9.01*	15.77*	12.17*	5.25*	4.83*	5.05*	10.81*	30.67*	20.34*	17.75*	20.69*	18.85*	-9.06*	-9.06*	-9.06*	64.44*	52.09*	56.5*	150*	-9.09ns	11.11ns	47.96*	47.9*	47.94*
P1XP8	7.03*	13.54*	10.09*	-8.81*	0.32ns	-4.64*	1.17ns	7.97*	3.87*	0.00ns	6.75*	2.77*	16.33*	16.33*	16.32*	67.22*	45.23*	46.64*	550*	136.4*	188.9*	208.4*	208.3*	208.4*
P2XP6	21.83*	21.26*	21.54*	-2.49ns	-1.10ns	-1.82ns	4.12*	8.51*	5.77*	7.48*	3.04*	5.35*	-3.28*	-3.28*	-3.28*	39.15*	44.39*	24.68*	250*	-8.33ns	25ns	110*	110*	110*
P2XP7	16.40*	15.83*	16.12*	-5.50*	-6.35*	-5.90*	2.81*	1.30ns	2.70*	0.35ns	5.86*	2.96*	-1.76ns	-1.76*	-1.76*	56.08*	33.46*	43.29*	100ns	-41.7*	-25ns	119.1*	119.2*	119.2*
P2XP8	13.74*	12.91*	13.33*	-9.07*	-0.97ns	-5.35*	-7.93*	18.60*	4.08*	-12.04*	-13.77*	-12.60*	-9.64*	-9.64*	-9.64*	47.62*	24.48*	25.97*	400*	50*	90*	183.6*	183.7*	183.7*
P3XP6	9.55*	9.54*	9.55*	-10.94*	-9.91*	-10.45*	29.14*	28.46*	28.87*	23.60*	23.66*	23.79*	3.80*	3.81*	3.81*	26.5*	45.33*	21.46*	500*	188.9*	257.1*	304.6*	304.7*	304.7*
P3XP7	12.68*	12.69*	12.69*	-3.42ns	-4.66*	-4.02*	26.42*	36.36*	30.49*	27.70*	27.60*	27.79*	0.07ns	0.07ns	0.07ns	44.5*	32.38*	37.19*	450*	100*	185.7*	21.46*	20.47*	20.98*
P3XP8	10.55*	10.31*	10.43*	-5.72*	2.83ns	-1.79ns	16.55*	56.78*	33.08*	34.44*	34.85*	34.11*	13.06*	13.06*	13.05*	52.5*	58.92*	42.56*	500*	188.9*	257.1*	3.07ns	3.09ns	3.08ns
P4XP6	26.53*	26.93*	26.72*	-2.41ns	-0.98ns	-1.73ns	3.82*	5.30*	3.42*	13.89*	17.62*	15.83*	-1.74ns	-1.73ns	-1.73*	37.43*	74.3*	41.7*	350*	0ns	63.64*	267.2*	267.3*	267.2*
P4XP7	21.74*	22.13*	21.92*	3.63*	2.68ns	3.18*	2.42*	0.00ns	0.32ns	9.64*	10.28*	10.11*	-11.29*	-11.29*	-11.29*	47.59*	17.97*	30.04*	250*	-38.9*	13.64	191.1*	191*	191*
P4XP8	23.27*	23.40*	23.33*	-1.42ns	7.60*	2.72*	9.27*	17.50*	11.68*	3.31*	1.23*	2.32*	4.03*	4.03*	4.04*	34.76*	34.85*	29.6*	500*	44.44*	127.3*	152.9*	152.8*	152.8*
P5XP6	12.69*	13.34*	13.00*	-11.80*	-10.44*	-11.16*	-28.76*	-27.34*	-28.62*	-21.25*	-25.00*	-22.91*	-13.00*	-13.00*	-12.99*	2.58ns	30.37*	11.16*	650*	62.5*	133.3*	25.82*	25.82*	25.82*
P5XP7	8.16*	8.78*	8.46*	-15.45*	-16.25*	-15.84*	-17.39*	-15.60*	-15.79*	-8.58*	-7.14*	-7.44*	-8.81*	-8.81*	-8.81*	9.87*	-2.58ns	2.77*	600*	50*	136.4*	41.89*	41.88*	41.89*
P5XP8	7.87*	8.25*	8.06*	-20.90*	-13.26*	-17.41*	-12.24*	-0.86*	-6.42*	-13.46*	-13.97*	-13.82*	4.99*	4.99*	4.99*	5.15*	2.49ns	-2.37ns	750*	112.5*	183.3*	225*	225*	225*
L.S.D 5%	0.60	0.54	0.55	1.36	1.11*	1.00	0.006	0.006	0.005	0.01	0.01	0.01	1.46	1.56	1.16	0.02	0.02	0.02	1.28*	1.24	0.91	2.71	2.88	2.51

Table (8): General combining ability estimates of physiological characters (5 lines and 3 tester) parents grown under normal and drought stress and their combined data

character	Flag leaf area			Chlorophyll content			Nitrogen content			Potassium content			Relative water content			Water use efficiency			Leaf rolling			Leaf angle		
Genotype	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C
P1	1.05*	0.98*	1.02*	1.97*	1.82*	1.89*	0.05*	0.05*	0.05*	0.05*	0.07*	0.06*	4.17*	4.87*	4.52*	0.04*	0.08*	0.06*	-1.20*	-0.95*	-1.08*	-9.96*	-9.43*	-9.69*
P2	2.16*	2.02*	2.09*	1.56*	1.44*	1.50*	0.01*	0.01*	0.01*	-0.05*	-0.04*	-0.05*	-2.86*	-3.3*	-3.1*	0.02*	-0.01*	0.01*	-1.62*	-1.87*	-1.74*	18.18*	17.25*	17.71*
P3	-2.0*	-1.8*	-1.9*	-1.0*	-0.9*	-0.9*	0.05*	0.08*	0.07*	0.14*	0.12*	0.13*	5.90*	6.89*	6.39*	0.03*	0.07*	0.05*	0.72*	0.97*	0.84*	-21.84*	-20.75*	-21.29*
P4	2.23*	2.08*	2.16*	2.89*	2.67*	2.78*	-0.03*	-0.03*	-0.02*	0.02*	0.02*	0.02*	0.2ns	0.3ns	0.30*	-0.03*	0.02*	0.00*	-0.45*	-0.28*	-0.37*	12.47*	11.84*	12.15*
P5	-3.4*	-3.2*	-3.3*	-5.4*	-5.0*	-5.2*	-0.11*	-0.1*	-0.11*	-0.16*	-0.16*	-0.16*	-7.4*	-8.74*	-8.1*	-0.06*	-0.16*	-0.11*	2.55*	2.13*	2.34*	1.16*	1.10*	1.12*
L.S.D 5%	0.14	0.13	0.13	0.32	0.26	0.24	0.001	0.001	0.001	0.003	0.003	0.002	0.35	0.37	0.27	0.003	0.005	0.003	0.26	0.25	0.19*	0.55	0.59	0.51
P6	1.59*	1.49*	1.54*	0.30*	0.28*	0.29*	-0.01*	-0.03*	-0.02*	-0.04*	-0.04*	-0.04*	-0.2ns	-0.30*	-0.2*	-0.04*	-0.02*	-0.03*	-0.27*	-0.27*	-0.27*	10.29*	9.78*	10.03*
P7	-0.2*	-0.2*	-0.2*	0.26*	0.24*	0.25*	0.03*	0.03*	0.03*	0.06*	0.06*	0.06*	0.01ns	0.01ns	0.01ns	0.03*	0.03*	0.03*	-1.02*	-1.37*	-1.19*	-14.10*	-13.41*	-13.76*
P8	-1.3*	-1.2*	-1.2*	-0.5*	-0.5*	-0.5*	-0.02*	-0.01*	-0.02*	-0.01*	-0.02*	-0.02*	0.25ns	0.30*	0.27*	0.01*	-0.01*	0.00ns	1.28*	1.63*	1.46*	3.82*	3.63*	3.72*
L.S.D 5%	0.11	0.10	0.10	0.25	0.20	0.18	0.001	0.001	0.001	0.003	0.003	0.0017	0.42	0.26	0.25	0.42	0.38	0.29	0.20	0.20	0.14	0.43	0.46	0.40

Table (11): Specific combining ability (SCA) estimates of physiological characters for the fifteen F1 combiners grown under normal and drought stress and their combined data

Character	Flag leaf area			Chlorophyll content			Nitrogen content			Potassium content			Relative water content			Water use efficiency			Leaf rolling			Leaf angle		
Genotype	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C	N	S	C
P1XP6	0.69*	0.64*	0.66*	1.08*	1.00*	1.04*	-0.01*	-0.01*	-0.01*	-0.01*	0.01*	0.00ns	3.56*	4.16*	3.86*	-0.01*	-0.07*	-0.04*	-0.90*	-0.90*	-0.90*	-19.60*	-18.61*	-19.10*
P1XP7	-0.20ns	-0.19ns	-0.19ns	1.03*	0.95*	0.99*	0.02*	0.07*	0.04*	0.05*	0.02*	0.03*	-6.59*	-7.69*	-7.14*	-0.01*	0.07*	0.03*	-0.4ns	-0.05ns	-0.23ns	-6.32*	-5.95*	-6.14*
P1XP8	-0.49*	-0.45*	-0.47*	-2.11*	-1.96*	-2.03*	-0.01*	-0.05*	-0.03*	-0.03*	-0.02*	-0.03*	3.03*	3.53*	3.28*	0.02*	0.00ns	0.01*	1.30*	0.95*	1.13*	25.92*	24.56*	25.24*
P2XP6	0.64*	0.60*	0.62*	1.00*	0.92*	0.96*	0.02*	0.02*	0.02*	0.06*	0.03*	0.04*	1.18*	1.38*	1.28*	0.00ns	-0.02*	-0.01*	0.27ns	0.02ns	0.14ns	-6.68*	-6.36*	-6.52*
P2XP7	-0.05ns	-0.05ns	-0.05ns	-0.97*	-0.89*	-0.93*	0.003*	-0.03*	-0.01*	-0.01*	0.02*	0.00ns	6.52*	7.61*	7.06*	0.01*	0.06*	0.04*	-0.48*	0.12ns	-0.18ns	9.90*	9.42*	9.66*
P2XP8	-0.59*	-0.55*	-0.57*	-0.03ns	-0.03ns	-0.03ns	-0.03*	0.01*	-0.01*	-0.05*	-0.05*	-0.05*	-7.70*	-8.99*	-8.34*	-0.01*	-0.05*	-0.03*	0.22ns	-0.13ns	0.04ns	-3.22*	-3.06*	-3.14*
P3XP6	-1.38*	-1.29*	-1.34*	-2.07*	-1.92*	-1.99*	0.02*	-0.01*	0.01*	-0.04*	-0.04*	-0.04*	-1.12*	-1.31*	-1.22*	-0.03*	-0.09*	-0.06*	0.43ns	0.93*	0.68*	40.64*	38.60*	39.62*
P3XP7	0.84*	0.78*	0.81*	0.25ns	0.23ns	0.24ns	0.003*	-0.002ns	-0.001ns	-0.02*	-0.03*	-0.03*	0.36ns	0.42ns	0.39ns	-0.01*	0.01ns	0.00ns	0.68*	0.03ns	0.36*	-8.96*	-8.63*	-8.79*
P3XP8	0.54*	0.51*	0.52*	1.83*	1.69*	1.76*	-0.03*	0.02*	-0.01*	0.07*	0.06*	0.06*	0.76*	0.89*	0.82*	0.04*	0.08*	0.06*	-1.12*	-0.97*	-1.04*	-31.69*	-29.97*	-30.83*
P4XP6	0.02ns	0.01ns	0.01ns	-1.33*	-1.23*	-1.28*	-0.001ns	0.02*	0.01*	0.03*	0.04*	0.04*	1.27*	1.49*	1.38*	0.03*	0.12*	0.07*	0.10ns	0.18ns	0.14ns	8.34*	7.91*	8.12*
P4XP7	-0.41*	-0.38*	-0.40*	0.41ns	0.38ns	0.40ns	-0.02*	-0.03*	-0.02*	-0.02*	-0.02*	-0.02*	-2.23*	-2.60*	-2.41*	0.01*	-0.11*	-0.05*	-0.1ns	-0.47*	-0.31ns	10.40*	9.88*	10.14*
P4XP8	0.39*	0.37*	0.38*	0.92*	0.85*	0.89*	0.02*	0.01*	0.01*	-0.01*	-0.02*	-0.02*	0.95*	1.11*	1.03*	-0.04*	-0.01ns	-0.022*	0.05ns	0.28ns	0.167ns	-18.74*	-17.79*	-18.26*
P5XP6	0.04ns	0.04ns	0.04ns	1.32*	1.23*	1.28*	-0.03*	-0.01*	-0.03*	-0.04*	-0.05*	-0.04*	-4.89*	-5.71*	-5.30*	0.02*	0.06*	0.04*	0.10ns	-0.23ns	-0.07ns	-22.70*	-21.54*	-22.12*
P5XP7	-0.17ns	-0.16ns	-0.17ns	-0.72*	-0.66*	-0.69*	-0.01*	-0.01*	-0.01*	0.01*	0.01*	0.01*	1.93*	2.26*	2.10*	0.00ns	-0.03*	-0.02*	0.35ns	0.37ns	0.36*	-5.02*	-4.72*	-4.87*
P5XP8	0.14ns	0.13ns	0.13ns	-0.60*	-0.56*	-0.58*	0.04*	0.02*	0.03*	0.03*	0.03*	0.03*	2.96*	3.45*	3.20*	-0.02*	-0.03*	-0.02*	-0.4ns	-0.13ns	-0.29ns	27.72*	26.26*	26.99*
L.S.D 5%	0.24	0.22	0.22	0.55	0.45	0.41	0.003	0.002	0.002	0.006	0.006	0.004	0.60	0.64	0.47	0.005	0.008	0.005	0.45	0.44	0.32	0.96	1.02	0.89