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HETEROSIS ANALYSIS FOR PHYSIO-MORPHOLOGICAL TRAITS AND YIELD IN RELATION TO DROUGHT TOLERANCE IN RICE (*ORYZA SATIVA* L.)

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ABSTRACT

Drought stress is a serious limiting factor to rice production. The major setback in drought tolerance breeding is the poor understanding of genetics and inheritance of drought tolerance traits and complete ignorance about the physiological drought tolerance attributes. Alternatively, yield improvements in water-limited environments can be achieved by selecting for secondary traits contributing to drought resistance in breeding programs. Hence, the present investigation was undertaken to study the heterosis manifested by the 21 hybrids derived from seven parents for physio-morphological and yield traits associated with drought tolerance by half diallel analysis. Results revealed that, maximum desirable heterosis over mid parent was observed for number of roots plant^{-1} (67.74%) followed by water use efficiency (66.58%), number of panicles plant^{-1} (63.91%), root volume (63.65%) and root: shoot ratio (58.0%). Similar trend of desirable heterosis over better parents was observed for root volume (65.64%) followed by water use efficiency (63.85%), root: shoot ratio (57.44%), number of roots plant^{-1} (56.83%) and grain yield plant^{-1} (56.48%). Among 21 hybrids, Sakha101 × WAB450 had considerably higher desirable heterosis over mid parent and better parents for physio-morphological and yield traits associated with drought, whereas Sakha105 × WAB450, IRAT170 × Moroberekan, IRAT170 × Gaori and Gaori × WAB450 exhibited positive and significant favorable heterosis over mid parent and better parents for root traits.

Key words: Rice, Heterosis, Physio-morphological traits and Drought tolerance

INTRODUCTION

Rice (*Oryza sativa* L.), one of the important food crops, is grown on 154 million hectares world-wide in a wide range of environments, (IRRI, 2004). Drought stress is a serious limiting factor to rice production and yield stability in both rainfed and irrigated areas and 18 million tons of rice valued at US $ 3600 million is lost annually to drought, (O'Toole, 1999). The major setback in drought tolerance breeding is the poor understanding of genetics and inheritance of drought tolerance traits and complete ignorance about the physiological drought tolerance attributes. Alternatively, yield improvements in water-limited conditions can be achieved by selecting for secondary traits contributing to drought resistance in breeding programs. In Egypt, rice is one of the major water consuming crops and continues flooding is the only method for irrigation. Rice occupies about 22% of the total growing area in Egypt during summer season and it consumed about 20% of the total water resources. Because of the water resources in Egypt are limited, in addition to increasing population, the total water requirements for rice crop is a serious problem because of the limited irrigation water available from the River Nile. Some rice planted areas, especially those are located at the end of the terminal irrigation details in the northern part of the Nile Delta; suffer from shortage of irrigation water during different growth stages, which are considered to be one of the most serious constraints to rice production in Egypt (Abd Allah *et al.*, 2009).

The effectiveness of selection for secondary traits to improve yield under water limiting conditions has been demonstrated in maize, (Ribaut *et al.*, 1997), wheat, (Condon, *et al.*, 2004) and sorghum, (Sanchez *et al.*, 2002). Several putative traits contributing in drought resistance in rice have been documented, (Fukai and Cooper, 1995 and Nguyen *et al.*, 1997). Earlier reports have suggested the importance of many physio morphological traits for drought tolerance in rice. In rice, early genotype with high root volume and root length density at maturity gave higher yields, (Jeena and Mani, 1990). Therefore, a deep root system with high root volume would assist in developing drought resistant upland cultivars, (Lilley and Fukai, 1994). An ideal secondary trait should be easy to measure, highly heritable, genetically correlated with grain yield under stress and should show genetic variation in the target species, (Lafitte *et al.*, 2003). Three mechanism of drought tolerance viz., avoidance drought escape operates in tolerance to drought in rice. Drought tolerance and drought avoidance are operates mainly through physio-morphological and root traits respectively. Drought escape associated with (evolution) early duration. Hence, measurement of physio-morphological traits permits the rapid identification of potentially tolerant plant materials and cross combinations. Higher levels of days to 70 per cent RWC, chlorophyll stability index and lower levels of leaf rolling, leaf drying and drought recovery rate observed in drought tolerance lines than in the susceptible ones, (Michael and Rangasamy, 2002 and Anbumalarmathi, 2005). However, not many studies are available on exploitation of heterosis for the above physio-morphological traits in rice which is more important. Since, the survival alone during drought is not sufficient and crop needs to produce a reasonable yield for subsistence requirements or for economic reasons. Hence, present investigation was carried out to study the heterosis manifested by the hybrids over mid parent and better parents for physio-morphological and yield traits in relation to drought tolerance in rice.

MATERIALS AND METHODS

The present investigation was carried out at the Experimental Farm of the Rice Research and Training Center (RRTC), Sakha, Kafr EL-Shiekh, Egypt, during two successive rice growing seasons, 2009 and 2010. Seven genotypes; namely, Giza177, Sakha101, Sakha105, Gaori, IRAT170, Moroberekan, and WAB450-I-B-P-38-HB were chosen based on previous studies. These genotypes had a wide range of variations due to their different genetic background and drought tolerance as well. The introduced cultivars, IRAT170, Moroberekan and WAB450-I-B-P-38-HB, were used as drought tolerance and the cultivar, Gaori was used as moderate tolerance and Giza177, Sakha101 and Sakha105 were used as drought susceptible ones. The seven rice genotypes were grown in three sowing dates during 2009 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 in three rows, five meters long and 20 × 20 cm apart between plants and rows. A half diallel cross was carried out among the seven parents at flowering to produce F1 hybrids seeds. Bulk emasculation method was practiced by using hot water technique according to Jodan (1938) and modified by Butany (1961). A total of 21 crosses were made and the hybrid seeds were grown in 2010 rice growing season as F1 plants on 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 (every F1 cross planted between its parents). Each row was 5 meters long and contained 25 hills with 20 cm between rows. All the genotypes (seven parents and 21 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). Weeds were chemically controlled by applying two liters of Saturn/ feddan four days after transplanting. Nitrogen fertilizer was applied at the recommended rate and time of application. Shoot and root characters were recorded at maximum tillering stage while yield was recorded at ripening stage. Observations were recorded on fourteen characters namely, days to heading (days), plant height (cm), number of panicle plant^{-1}, flag leaf area (cm^2), specific leaf area (cm^2)/(g), relative water content (RWC), maximum root length (cm), root volume (cm^3), number of roots plant^{-1}, root: shoot ratio, water use efficiency (WUE), drought susceptibility index (DSI), harvest index (HI %) and grain yield plant^{-1} (g). The analysis of variance was computed for each trait according to Griffing (1956). The amount of heterosis as proposed by Mather (1949) and Mather and Jinks (1982) was determined as the increase of F_1 hybrid mean over the average of its two parents and over better parent. Appropriate L.S.D. values were calculated to test the significance of the heterosis effects for mid and better parent according to Wynne *et al.* (1970).

RESULTS AND DISCUSSION

Mean performance of genotypes:

Vegetative characters:

Mean performances of the genotypes for vegetative traits studied at drought condition are presented in Table (1). For **days to heading (DTH)**, among parents, Moroberekan was the highest parents and showed mean values under drought conditions (124.33). Whereas, the lowest mean values were belonged to Giza177 and Gaori (104.66 and 105.33) respectively. For crosses, Sakha101 × WAB450 gave the highest mean values (130.33). While, the lowest values for this trait was obtained from Giza177 × Gaori showed the lowest mean value (94.00) under drought stress.

With respect to **plant height (PLH)**, among parents, Moroberekan showed the highest mean values (146.33cm) under drought conditions. While, Sakha101 and Gaori gave the lowest values for plant height (74.33cm) for both parents. For crosses, Moroberekan x WAB450 showed the highest mean value under drought conditions (130.67cm). Whereas, the lowest mean values were belonged to Sakha101 × Gaori (62.00cm). The obtained results showed that most of all F_1 hybrids were taller than their parents, suggesting the strong effect of the hybrid vigor for this character under drought conditions.

For **number of panicles plant^{-1} (NPP)**, among parents, Moroberekan showed the highest mean value (14.667) under drought conditions. While, Sakha105 gave the lowest values for number of panicles per plant which was (9.33). For crosses, Sakha105 x WAB450 showed the highest values (21.00). Whereas, the lowest mean values belonged to Sakha101 x Gaori (6.00) under drought stress.

Table (1): Mean performances of the genotypes for vegetative traits studied at drought condition

Genotype	DTH	PLH	NPP	FLA	SLA	RWC
Giza177	104.667	83.000	10.667	19.833	129.527	0.897
Sakha101	120.333	74.333	11.667	11.273	98.567	0.857
Sakha105	111.000	79.333	9.333	13.363	109.840	0.833
IRAT170	110.333	111.333	12.667	29.833	147.690	0.943
Gaori	105.333	74.333	12.667	12.440	123.600	0.883
Moroberekan	124.333	146.333	14.667	29.393	135.000	0.980
WAB450	121.000	95.333	12.333	41.560	154.527	0.903
Giza177 x Sakha101	108.333	77.000	9.000	15.440	192.040	0.570
Giza177 x Sakha105	103.000	78.333	13.000	12.017	115.863	0.920
Giza177 x IRAT170	101.333	98.000	13.000	17.347	130.210	0.950
Giza177 x Gaori	94.000	78.333	9.333	12.960	125.327	0.913
Giza177 x Moroberekan	100.000	126.333	18.000	22.417	111.053	0.910
Giza177 x WAB450	105.333	91.667	12.667	21.793	142.400	0.943
Sakha101 x Sakha105	113.333	77.000	9.000	26.013	220.710	0.583
Sakha101 x IRAT170	99.000	112.000	17.667	29.477	225.693	0.867
Sakha101 x Gaori	120.333	62.000	6.000	10.707	197.770	0.800
Sakha101 x Moroberekan	124.333	122.667	15.667	27.203	188.283	0.627
Sakha101 x WAB450	130.333	99.333	20.000	35.733	222.707	0.703
Sakha105 x IRAT170	105.667	101.667	14.333	18.730	122.813	0.870
Sakha105 x Gaori	99.333	68.667	17.000	11.353	115.233	0.903
Sakha105 x Moroberekan	103.333	119.000	13.667	15.750	103.257	0.493
Sakha105 x WAB450	112.000	104.000	21.000	20.500	133.450	0.703
IRAT170 x Gaori	107.000	113.000	13.667	18.610	152.037	0.710
IRAT170 x Moroberekan	126.333	115.667	16.000	34.977	206.910	0.710
IRAT170 x WAB450	114.000	123.000	13.667	19.650	115.670	0.720
Gaori x Moroberekan	112.333	117.000	11.333	23.863	120.593	0.873
Gaori x WAB450	118.000	98.333	14.667	24.177	232.467	0.933
Moroberekan x WAB450	120.000	130.667	9.333	30.170	187.033	0.853
LSD 0.05%	**0.553**	**1.040**	**1.275**	**1.046**	**10.391**	**0.100**
LSD 0.01%	**0.810**	**1.524**	**1.869**	**1.534**	**15.228**	**0.146**

Abbreviations: **DTH**, Days to heading; **PLH**, Plant height; **NPP**, Number of panicle plant^{-1}; **FLA**, Flag leaf area; **SLA**, Specific leaf area and **RWC**, Relative water content.

With respect to **flag leaf area (FLA)**, among parents, WAB450 showed the highest mean value under drought conditions (41.560 cm^2). While, Sakha101 showed the lowest mean value which was 11.273cm^2. For crosses, Sakha101× WAB450 and IRAT170 × Moroberekan showed the highest values (35.733 and 34.977 cm^2). Meanwhile, the Sakha101 × Gaori and Sakha105 × Gaori scored the lowest mean values (10.707 and 11.353 cm^2).

Regarding **specific leaf area (SLA)**, the parent, WAB450 recorded the highest mean values ($154.527cm^2/g$) under drought conditions. Sakha101 recorded lowest mean values ($98.56cm^2/g$). For crosses, Gaori × WAB450 showed the highest mean value ($232.46cm^2/g$). While, Sakha105 x Moroberekan gave the lowest mean value ($103.25cm^2/g$).

Concerning **relative water content (RWC)**, the parent Moroberekan gave highest mean value (0.980) under drought conditions. While, the lowest mean value was belonged to Sakha105 (0.883). For crosses, the highest mean values were to Giza177 × IRAT170 and Giza177 × WAB450 (0.950 and 0.943), respectively. Meanwhile, the lowest values belonged to Sakha105 × WAB450 and Sakha105 × Moroberekan (0.447 and 0.493). These results indicating that the entries keep more water in their leaves under water stress.

For the vegetative characters, in general the results related to the drought effects showed that flowering delayed, this is due to slowed elongation of the panicle and supporting tissues (Lafitte *et al.*, 2004). Vegetative stage drought is usually the reason of this delay because of its timing in relation to timing of plant growth and developing. Also, plant height was affected by vegetative stage drought and cause in plant dwarfness than normal (Kamoshita *et al.*, 2008). Water deficit reduce resulted in reduction of number of panicles per plant due to plant weakness growth. Flag leaf area is an important trait for photosynthesis and drought stress reduced it and reflects on the photosynthesis processes. Also, reduction in flag leaf area reduces water lost (reduce evaporation surface), therefore plants may avoid drought (Passioura 1976, Turner 1986). Moreover, specific leaf area refer to leaf content of chlorophyll, reduction the value of this trait display the increase of chlorophyll percent in leaves, thereby increase growth. On the other hand, increase of relative water content play an important role in plant drought avoidance because it confers the plant ability to grow under drought stress.

Root characters:

Mean performances of the genotypes for root traits studied at drought conditions are presented in Table (2). For **maximum root length (MRL)**, generally maximum root length was reduced significantly under drought stress for all parents and their crosses. Among parents, WAB450 showed the highest mean values (22.500cm) under drought conditions. Whereas, the lowest mean values was belonged to Sakha105 (18.33cm). For crosses, Giza177 × Moroberekan showed the highest mean value (28.167cm). While, the lowest mean values was belonged to Sakha101 x Gaori (14.667cm).

Regarding **root volume (ROV)**, among parents, Gaori gave the highest mean value ($31.667cm^3$) under drought conditions. Whereas, the lowest mean values was to Giza177 ($16.333cm^3$). For crosses, the highest value was ($66.667cm^3$) for the cross Sakha105 × WAB450. While, the lowest mean values was belonged to Sakha101 x Gaori ($2.337cm^3$).

Table (2): Mean performances of the genotypes for root traits studied at drought conditions

Genotype	MRL	ROV	NRP	RSR
Giza177	19.600	16.333	98.333	0.220
Sakha101	19.833	18.667	79.333	0.277
Sakha105	18.333	18.333	99.667	0.173
IRAT170	21.333	21.333	190.333	0.42
Gaori	21.833	21.667	129.000	0.490
Moroberekan	21.333	23.333	117.000	0.233
WAB450	22.500	21.333	159.667	0.340
Giza177 x Sakha101	20.000	26.000	81.333	0.567
Giza177 x Sakha105	18.167	23.333	70.667	0.567
Giza177 x IRAT170	24.667	17.333	65.333	0.397
Giza177 x Gaori	19.167	28.333	116.000	0.633
Giza177 x Moroberekan	28.167	23.333	76.333	0.217
Giza177 x WAB450	23.833	23.333	96.667	0.313
Sakha101 x Sakha105	17.500	23.333	117.000	0.500
Sakha101 x IRAT170	18.833	23.333	62.333	0.443
Sakha101 x Gaori	14.667	2.337	47.667	0.497
Sakha101 x Moroberekan	15.000	16.667	67.333	0.300
Sakha101 x WAB450	25.333	58.333	158.667	0.400
Sakha105 x IRAT170	19.000	13.333	102.000	0.197
Sakha105 x Gaori	21.500	15.667	145.000	0.467
Sakha105 x Moroberekan	19.833	31.667	214.667	0.567
Sakha105 x WAB450	24.000	66.667	144.667	0.440
IRAT170 x Gaori	21.833	18.333	116.000	0.670
IRAT170 x Moroberekan	22.833	16.667	114.000	0.280
IRAT170 x WAB450	24.500	31.667	132.000	0.287
Gaori x Moroberekan	19.167	11.667	59.333	0.327
Gaori x WAB450	26.000	27.333	129.000	0.373
Moroberekan x WAB450	22.333	18.333	98.667	0.327
LSD 0.05%	1.484	3.674	15.481	0.077
LSD 0.01%	2.175	5.384	26.652	0.113

Abbreviations: MRL, Maximum root length; ROV, Root volume; NRP, Number of root plant^{-1}and RSR, Root to shoot ratio.

With respect to **number of root plant^{-1} (NRP)**, among parents, IRAT170 was the highest value (190.333) under drought stress. Meanwhile, the lowest mean value was belonged to Sakha101 (79.33). For crosses, the highest value was to Sakha105 x Moroberekan (214.667). While, the lowest mean value was to Sakha101 x Gaori (47.667) under drought conditions.

For **root: shoot ratio (RSR)**, among parents, Gaori gave the highest mean values (0.490) under drought conditions. Whereas, the lowest mean values belonged to Sakha105

(0.173). For crosses, the highest mean value was to and to IRAT170 x Gaori (0.670). While, the cross Giza177 x Moroberekan recorded the lowest mean value (0.197) under both conditions.

It is known that drought can affects inhibits root growth. Drought avoidance is 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. Similar results were found by Abd Allah et al 2009.

Yield characters:

Mean performances of the genotypes for yield traits studied at drought conditions are presented in Table (3).

For **grain yield plant^{-1} (GYP)**, among parents, Moroberekan gave the highest mean value (32.843g) under drought conditions. While, the lowest mean values was belonged to Sakha105 (15.580). For crosses, the highest mean values showed to Sakha101 x Moroberekan (49.620g). Whereas, the cross Sakha101 x Gaori recorded the lowest values (10.030g) drought conditions.

For **harvest index percent (HI %)**, the parents, the highest mean values belonged to Moroberekan and IRAT170 (36.913 and 36.10) under drought conditions respectively. Whereas, the lowest mean values belonged to Sakha105 and Giza177 (22.267 and 23.060), respectively. For crosses, the highest mean values under drought conditions were belonged to Moroberekan x Gaori and Sakha101 x Moroberekan (40.677 and 39.850 respectively). The lowest mean values showed to Giza177 x Sakha101 (24.870) and to Giza177 x Sakha105 (24.260). According to the results for yield characters which showed high reduction in its values under drought stress comparing with normal conditions, this indicate that yield characters affected by terminal drought which occurs towards the end of the growing season and sometimes begins well before flowering. Also, reduction in yield characters may be resulted in vegetative stage drought (Fukai *et al.* 2001, Tsubo *et al.* 2006, Ouk *et al.* 2006,2007), but this reduction may be less than terminal drought because of recovery growth in the later growing season (Kamoshita *et al.* 2008). Similar results were found by Abd Allah et al 2009.

Drought parameters:

Mean performances of the genotypes for drought parameters are presented in Table (3). For **water use efficiency (WUE)**, among parents, the highest mean value was belonged to WAB450 (985.360). While, the lowest mean value (467.390) was belonged to Sakha105. For crosses, the highest mean value was to Sakha101 x Moroberekan (1998.800), while the lowest mean value belonged to Sakha101 x Gaori (390.860).

Table (3): Mean performances of the genotypes for yield traits studied and drought parameters at drought conditions

Genotype	GYP	HI%	WUE	DSI
Giza177	20.193	23.060	621.610	0.327
Sakha101	21.387	23.593	615.860	0.537
Sakha105	15.580	22.267	467.390	0.480
IRAT170	29.820	34.193	733.973	-0.057
Gaori	27.463	35.697	698.870	0.223
Moroberekan	32.843	36.913	834.640	0.207
WAB450	29.293	36.100	985.360	0.107
Giza177 x Sakha101	17.697	24.260	530.953	0.597
Giza177 x Sakha105	15.490	24.870	464.690	0.043
Giza177 x IRAT170	25.047	32.640	751.437	0.013
Giza177 x Gaori	27.210	37.310	816.340	0.353
Giza177 x Moroberekan	32.793	33.570	983.857	0.480
Giza177 x WAB450	19.690	36.833	590.760	0.203
Sakha101 x Sakha105	19.630	27.400	588.920	0.193
Sakha101 x IRAT170	45.300	32.793	1749.157	0.390
Sakha101 x Gaori	10.030	28.200	390.860	0.510
Sakha101 x Moroberekan	49.620	39.850	1998.800	0.017
Sakha101 x WAB450	31.570	37.473	947.153	0.297
Sakha105 x IRAT170	41.403	38.607	1242.223	0.340
Sakha105 x Gaori	19.207	32.273	576.220	0.570
Sakha105 x Moroberekan	42.427	39.170	1272.890	0.150
Sakha105 x WAB450	40.080	37.670	1202.520	0.010
IRAT170 x Gaori	29.890	37.383	896.750	0.423
IRAT170 x Moroberekan	17.740	36.440	532.210	0.527
IRAT170 x WAB450	13.360	39.450	400.780	0.270
Gaori x Moroberekan	17.450	40.677	523.530	0.047
Gaori x WAB450	25.103	31.660	753.153	0.113
Moroberekan x WAB450	25.993	35.010	779.880	0.160
LSD 0.05%	**0.941**	**2.083**	**24.443**	**0.055**
LSD 0.01%	**1.378**	**3.053**	**35.822**	**0.080**

Abbreviations: WUE, Water use efficiency; DSI, Drought susceptibility index; GYP, Grain yield plant^{-1} and HI, Harvest index.

With respect to **drought susceptibility index (DSI)**, among parents, Sakha101 showed the highest mean value (0.537) and IRAT170 showed the lowest mean value (-0.075). For crosses, the highest mean value was 0.597 to Giza177 x Sakha101. Whereas, the lowest mean value was 0.010 to Sakha105 x WAB450.

Drought escape defined as the ability of plant to complete its life cycle before serious soil and plant water deficit develop (**O'Tool and Moya 1978, Begg 1980**). This mechanism involves good water use efficiency to rapid phonological development (early flowering and early maturity), therefore high values of water use efficiency under drought stress play an important role in plant drought escape. On the other hand, low values of drought susceptibility index reflect the plant behavior to tolerate drought by one or more mechanisms of drought at same time (**Gaff 1980**). From the obvious results, the plants which have high water use efficiency and in contrast low drought susceptibility index have well root characters and good ability to have yield potential.

Estimate of heterosis over mid parent and over better parent:

Heterosis expressed as the percentage deviation of F_1 mean values from better parents and mid parent.

Vegetative characters:

Table (4) showed the estimates of percentage heterosis over mid parent and over better parent for vegetative characters. **For DTH,** sixteen out of twenty one crosses showed negative highly significant heterosis effects over mid parent, ranged from -18.497 for Sakha101 x IRAT170 (P_2 x P_4) to 8.011 for Sakha101 x WAB450 (P_2 xP_7). The most desirable crosses for earliness were Giza177 x Moroberekan (P_1 x P_6) and Sakha105 x Moroberekan (P_3 x P_6). While, seventeen crosses exhibited negative highly significant heterosis effects over better parent under drought stress, ranged from -21.883 for Sakha101 x IRAT170 (P_2 x P_4) to 7.713 for Sakha101 x WAB450 (P_2 xP_7). The most desirable crosses for earliness were Sakha101 x IRAT170 (P_2 x P_4) and Giza177 x Moroberekan (P_1 x P_6).

Concerning to PLH, six crosses out of twenty one crosses showed negative highly significant heterosis effects over mid parent. The coveted combiner under drought stress was Gaori x Moroberekan (P_5 x P_6) (-34.592). While, fifteen crosses out of twenty one crosses recorded negative highly significant heterosis effects over better parent. Gaori x Moroberekan (P_5 x P_6) and IRAT170 x Moroberekan (P_4 x P_6) were the best crosses and gave the most desirable values.

As for NPP, from twenty one crosses fourteen recorded positive significant and highly significant heterosis effects over mid parent which ranged from 1.237 for Sakha105 x Moroberekan (P_3 x P_6) to 63.913 for Sakha101 x WAB450 (P_2 x P_7). The most desired crosses were Sakha101 x WAB450 (P_2 x P_7) and Sakha105 x WAB450 (P_3 x P_7) which recorded 63.913 and 61.565 under drought stress, respectively. Meanwhile, ten crosses showed positive highly significant heterosis effects over better parent under drought stress. The best crosses were IRAT170 x Moroberekan (P_4 x P_6) and Sakha105 x WAB450 (P_3 x P_7).

Table (4): Estimates of heterosis over mid parent and over better parent for vegetative characters

Cross	DTH		PLH		NPP	
	MP	BP	MP	BP	MP	BP
P1 X P2	-3.704**	-9.972**	-2.118**	-7.229**	-18.638**	-22.554**
P1 X P3	-4.482**	-7.207**	-3.491**	-5.623**	-18.750**	-20.407**
P1 X P4	-5.737**	-8.157**	0.858	-11.976**	2.629**	-17.023**
P1 X P5	-5.714**	-6.012**	-0.424	-5.623**	-14.122**	-20.429**
P1 X P6	-12.664**	-19.571**	10.174**	-13.667**	36.705**	14.891**
P1 X P7	-6.647**	-12.948**	2.804**	-3.845**	1.336*	-19.149**
P2 X P3	-2.017**	-5.817**	0.217	-2.941**	-40.000**	-44.897**
P2 X P4	-18.497**	-21.883**	20.647**	0.599	51.427**	29.268**
P2 X P5	6.647**	0.300	-16.592**	-12.592**	-27.216**	-38.049**
P2 X P6	1.635**	0.600	11.179**	-16.173**	28.766**	14.634**
P2 X P7	8.011**	7.713**	17.092**	4.196**	63.913**	46.338**
P3 X P4	-4.518**	-4.805**	6.644**	-8.682**	10.254**	-12.245**
P3 X P5	-8.167**	-10.511**	-10.628**	-13.445**	17.241**	4.084**
P3 X P6	-12.181**	-16.890**	5.466**	-18.679**	1.237*	-16.323**
P3 X P7	-3.448**	-7.438**	19.084**	9.091**	61.565**	49.800**
P4 X P5	-0.772**	-3.021**	21.724**	1.497*	22.387**	7.895**
P4 X P6	7.670**	1.609**	-10.219**	-20.956**	57.372**	49.995**
P4 X P7	-1.441**	-5.785**	19.033**	10.479**	43.863**	41.378**
P5 X P6	-2.177**	-9.652**	-34.592**	-38.383**	-2.863**	-10.531**
P5 X P7	4.271**	-2.479**	15.914**	3.147**	33.336**	15.789**
P6 X P7	-2.174**	-3.485**	8.139**	-10.706**	-6.670**	-12.506**
LSD 0.05%	**0.479**	**0.553**	**0.900**	**1.040**	**1.105**	**1.275**
LSD 0.01%	**0.701**	**0.810**	**1.320**	**1.524**	**1.619**	**1.869**

Abbreviations: DTH, Days to heading; **PLH**, Plant height and **NPP**, Number of panicle plant^{-1}.

$\mathbf{P_1}$, Giza177; $\mathbf{P_2}$, Sakha101; $\mathbf{P_3}$, Sakha105; $\mathbf{P_4}$, IRAT170; $\mathbf{P_5}$, Gaori; $\mathbf{P_6}$, Moroberekan; $\mathbf{P_7}$, WAB450.

Data in Table (4) revealed that six crosses showed highly significant and positive heterosis effects over mid parent for **FLA** and the desired cross was Sakha101 x Sakha105 (P_2 xP_3) (51.179). While, Sakha101 x Sakha105 (P_2 x P_3) and IRAT170 x Moroberekan (P_4 x P_6) gave positive highly significant heterosis effects over better parent and they were the best crosses from the whole combinations.

Regarding to SLA, six out of twenty one crosses recorded highly significant and negative heterosis effects over mid parents under drought stress. The best crosses were Giza177 x Moroberekan (P_1 x P_6) and Giza177 x IRAT170 (P_1 x P_4), recorded -28.260 and-19.196, respectively. On the other hand, nine crosses gave negative significant and highly significant heterosis effects over better parent. The desirable crosses were Giza177 x Moroberekan (P_1 x P_6) and Giza177 x Sakha105 (P_1 x P_3).

Six out of twenty one crosses recorded positive highly significant heterosis effects for **RWC** over mid parent. Giza177 x Sakha105 (P_1 x P_3) and Sakha105 x Gaori (P_3 x P_5) were the best crosses. While, six crosses recorded highly significant positive heterotic effects over better parent. Giza177 x WAB450 (P_1 x P_7) and Gaori x WAB450 (P_5 x P_7) were the best crosses.

Table 4: continued

Cross	FLA		SLA		RWC	
	MP	BP	MP	BP	MP	BP
P1 X P2	-0.727	-22.150**	20.604**	9.990	-25.006**	-26.455**
P1 X P3	-27.600**	-29.409**	-18.532**	-33.640**	6.358**	2.564**
P1 X P4	-30.145**	-21.853**	-19.196**	-25.423**	3.261**	0.742**
P1 X P5	-19.685**	-24.654**	-15.943**	-28.219**	2.584**	1.784**
P1 X P6	-8.922**	-23.734**	-28.260**	-36.395**	-3.037**	-7.143**
P1 X P7	-29.005**	-27.563**	-6.354	-18.441**	4.778**	4.430**
P2 X P3	51.179**	44.664**	32.807**	40.938**	-21.006**	-21.972**
P2 X P4	43.419**	-1.193*	33.299**	32.815**	-3.667**	-8.059**
P2 X P5	-9.695**	-13.931**	28.037**	22.008**	-8.046**	-9.400**
P2 X P6	33.787**	-7.451**	31.224**	29.469**	-21.737**	-26.020**
P2 X P7	35.268**	-14.021**	25.277**	41.939**	-20.114**	-22.148**
P3 X P4	-13.279**	-37.217**	-4.622	-16.844**	-2.027**	-7.741**
P3 X P5	-12.002**	-15.042**	-1.274	-6.769	5.245**	2.265**
P3 X P6	-26.326**	-26.416**	-15.653**	-23.513**	-25.615**	-39.694**
P3 X P7	-25.350**	-30.674**	11.502*	3.029	-19.009**	-22.148**
P4 X P5	-11.953**	-37.619**	12.084*	2.943	-22.234**	-24.708**
P4 X P6	18.114**	17.243**	26.387**	20.098**	-16.157**	-27.551**
P4 X P7	-44.953**	-32.719**	-16.549**	-21.681**	-21.993**	-23.648**
P5 X P6	14.087**	-18.814**	-6.734	-10.672*	-6.280**	-10.918**
P5 X P7	-10.456**	-21.826**	23.676**	29.474**	4.479**	3.322**
P6 X P7	-14.958**	-27.406**	21.409**	28.543**	-9.400**	-12.959**
LSD 0.05%	**0.906**	**1.046**	**8.999**	**10.391**	**0.086**	**0.100**
LSD 0.01%	**1.328**	**1.534**	**13.188**	**15.228**	**0.126**	**0.146**

Abbreviations: FLA, Flag leaf area; **SLA**, Specific leaf area; **RWC**, Relative water content.

P_1, Giza177; **P_2,** Sakha101; **P_3,** Sakha105; **P_4,** IRAT170; **P_5,** Gaori; **P_6,** Moroberekan; **P_7,** WAB450.

Heterosis or hybrid vigor was defined as the better performance of hybrid plants over their mid-parents (HMP) or over better-parent (HBP, heterobeltiosis). According to the results of heterosis over mid-parents for vegetative characters, Sakha101 x IRAT170 (P_2 x P_4), Giza177 x Moroberekan (P_1 x P_6) and Sakha105 x Moroberekan (P_3 x P_6) were the best crosses for days to heading under drought stress conditions, indicating that the crosses could have the ability to escape from drought. Concerning to plant height, the most desirable crosses were Gaori x Moroberekan (P_5 x P_6), Sakha101 x Gaori (P_2 x P_5), Sakha105 x Gaori (P_3 x P_5) and IRAT170 x Moroberekan (P_4 x P_6), indicating that the parents which involved these crosses were the most desirable combiners to improve dwarfness. While, Sakha105 x WAB450 (P_3 x P_7), Sakha101 x WAB450 (P_2 x P_7) and IRAT170 x Moroberekan (P_4 x P_6) were considered the best crosses for number of panicles per plant and could be utilized in breeding programs to enhance this trait. In addition, Sakha101 x Sakha105 (P_2 x P_3), Sakha101 x IRAT170 (P_2 x P_4) and Sakha101 x WAB450 (P_2 x P_7) were the most desirable crosses for flag leaf area, displaying the importance of these crosses in breeding programs to improve this trait. As for specific leaf area, Giza177 x Moroberekan (P_1 x P_6), Giza177 x IRAt170(P_1 x P_4) and Giza177 x Sakha105 (P_1 x P_3) were the most desired crosses under drought stress, so these crosses may be utilized in the breeding programs to improve this trait. Moreover, Giza177 x Sakha105 (P_1 x P_3) and Sakha105 x Gaori (P_3 x P_5) were the best crosses for relative water content.

Heterosis over better parent (heterobeltiosis) is very important because it describes the increased strength in hybrids over better-parent. From the above mentioned results, Sakha101 x IRAT170 (P_2 x P_4), Giza177 x Moroberekan (P_1 x P_6) and Sakha105 x Moroberekan (P_3 x P_6) were the best crosses for days to heading under drought stress, so they could be utilized in breeding programs for drought escape. While for plant height, Gaori x Moroberekan (P_5 x P_6), IRAT170 x Moroberekan (P_4 x P_6) and Sakha101 x Moroberekan (P_2 x P_6) were the most desirable crosses under drought stress, indicating the importance of these crosses in breeding programs to improve plant height. With respect to number of panicles per plant, the most desired crosses were Sakha105 x WAB450 (P_3 x P_7), IRAT170 x Moroberekan (P_4 x P_6) and Sakha101 x WAB450 (P_2 x P_7), displaying that the crosses could be useful in breeding programs to increase this trait. Two crosses showed positive estimates of heterobeltiosis for flag leaf area under drought stress, Sakha101 x Sakha105 (P_2 x P_3) and IRAT170 x Moroberekan (P_4 x P_6), indicating the importance of these crosses to improve this trait specially Sakha101 x Sakha105 (P_2 x P_3). Regarding to specific leaf area, Giza177 x Moroberekan (P_1 x P_6), Giza177 x Sakha105 (P_1 x P_3) and Giza177 x Gaori (P_1 x P_5) were the most desired crosses under drought stress, so these crosses could be useful in breeding programs to avoid drought. For relative water content, Giza177x WAB450 (P_1 x P_7) and Gaori x WAB450 (P_5 x P_7) were the most desirable crosses under drought stress, indicating that the parents which involved these crosses were the best combiners for improve this trait.

Root characters:

Table (5) showed the estimates of percentage heterosis over mid parent and over better parent for root characters. **For MRL,** twelve crosses exhibited positive highly significant heterosis effects over mid parent, and the best cross was Giza177 x Moroberekan (P_1 x P_6) (44.695). On the other hand, eight crosses gave positive significant and highly significant heterosis effects over better parent under drought stress. Giza177 x Moroberekan (P1 x P6) and Giza177x IRAT170 (P_1 x P_4) were the best crosses under drought stress and gave (36.773 and 19.743, respectively).

Regarding with ROV, fifteen crosses showed highly significant heterosis effects over mid parent, which ranged from 9.332 to 63.645. The best crosses under drought conditions were Sakha105 x WAB450 (P_3 x P_7) and Sakha101 x WAB450 (P_2 x P_7). While, ten crosses gave positive highly significant heterosis effects over better parent. Sakah105 x WAB450 (P_3 x P_7), Sakha101 x WAB450 (P_2 x P_7) and IRAT170 x WAB450 (P_4 x P_7) were the desirable crosses under drought conditions.

Table (5): Estimates of heterosis over mid parent and over better parent for root characters

Cross	MRL		ROV		NRP		RSR	
	MP	BP	MP	BP	MP	BP	MP	BP
P1 X P2	-5.734**	-8.396**	20.541**	25.804**	-41.826*	-48.516**	40.938**	46.429**
P1 X P3	-9.392**	-11.811**	34.616**	27.273**	-40.521**	-42.645**	39.718**	15.714**
P1 X P4	23.542**	19.743**	40.002**	6.123**	-54.525*	-34.710**	52.036**	53.455**
P1 X P5	-9.660**	-12.211**	18.054**	-10.528**	-50.498*	-55.097*	54.728**	56.520**
P1 X P6	44.695**	36.733**	17.647**	-1.411	-59.325*	-40.452**	-4.194**	-6.867**
P1 X P7	10.594**	5.924**	34.616**	27.273**	-39.203	-32.580*	11.786**	-7.941**
P2 X P3	-15.322**	-19.846**	19.656**	12.900**	30.726	17.391	9.890**	2.041**
P2 X P4	-8.502**	-13.741**	49.485**	12.900**	15.077	-21.429	49.410**	5.476**
P2 X P5	-32.822**	-32.822**	-31.069**	-52.620**	-73.993**	-42.092**	42.611**	18.333**
P2 X P6	-25.310**	-31.297**	-24.241**	-28.569**	-31.409	-42.450	-8.116**	-28.571**
P2 X P7	14.285**	12.591**	59.144**	62.252**	59.298**	52.001**	5.263**	-4.762**
P3 X P4	-2.145**	-2.564**	12.676**	-27.273**	58.549**	2.341	-40.573**	-59.796**
P3 X P5	4.033**	-1.525*	-37.332**	-50.526**	-6.452	-31.062	21.773**	-4.694**
P3 X P6	4.845**	1.708*	52.004**	35.718**	58.154**	50.392**	56.846**	15.714**
P3 X P7	14.286**	6.667**	63.645**	65.645**	41.590**	45.150	6.024**	-10.204**
P4 X P5	6.073**	0.500	-0.903	-42.107**	-3.064	-44.849	58.000**	57.437**
P4 X P6	21.239**	18.104**	16.284**	-28.569**	56.164**	-2.564	37.931**	20.172**
P4 X P7	17.132**	8.889**	57.616**	42.732**	67.743**	56.828**	11.891**	-15.588**
P5 X P6	-4.561**	-12.211**	-57.575**	-33.157**	-63.748**	-41.791**	28.235**	18.051**
P5 X P7	17.294**	15.556**	9.332**	-13.686**	-4.444	-38.669	20.908**	9.706**
P6 X P7	9.387**	-0.742	-12.000**	-42.107**	11.698	-15.669	14.136**	-3.824**
LSD 0.05%	1.285	1.484	3.182	3.674	10.387	15.481	0.067	0.077
LSD 0.01%	1.883	2.175	4.663	5.384	17.722	26.652	0.098	0.113

Abbreviations: MRL, Maximum root length; **ROV**, Root volume; **NRP**, Number of root plant^{-1}; **RSR**, Root to shoot ratio.
P_1, Giza177; **P_2**, Sakha101; **P_3**, Sakha105; **P_4**, IRAT170; **P_5**, Gaori; **P_6**, Moroberekan; **P_7**, WAB450.

Six out of twenty one crosses recorded positive highly significant heterosis effects for **NRP** over mid parent. The favorable crosses under drought stress were IRAT170 x WAB450 (P_4 x P_7) and Sakha101 x WAB450 (P_2 x P_7) (67.743 and 59.298) respectively. While, the crosses IRAT170 x WAB450 (P_4 x P_7), Sakha101 x WAB450 (P_2 x P_7) and Sakha105 x Moroberekan (P_3 x P_6) gave highly significant positive heterotic effects over better parent.

With respect to RSR, eighteen crosses showed positive highly significant heterosis effects over mid parent, ranged from 5.263 to 58.00. The coveted crosses under drought stress were IRAT170 x Gaori (P_4 x P_5), Sakha105 x Moroberekan (P_3 x P_6), Giza177 x Gaori (P_1 x P_5) and Giza177 x IRAT170 (P_1 x P_4) (58.00, 56.846, 54.728 and 52.036, respectively). Data in Table (5) revealed twelve out of twenty one crosses showed highly significant positive heterotic effects over better parent for **RSR** under drought conditions. IRAT170 x Gaori (P_4 x P_5), Giza177 x Gaori (P_1 x P_5) and Giza177 x IRAT170 (P_1 x P_4) were the best crosses.

From the previous results, Giza177 x Moroberekan (P_1 x P_6) and Giza177 x IRAT170 (P_1 x P_4) were the most desired crosses for maximum root length. While for root volume, the most desirable crosses were Sakha105 x WAB450 (P_3 x P_7), Sakha101 x WAB450 (P_2 x P_7) and IRAT170 x WAB450 (P_4 x P_7), indicating that the parents which involved these crosses were the best combiners to improve this trait. Regarding with number of root per plant, IRAT170 x WAB450 (P_4 x P_7), Sakha101 x WAB450 (P_2 x P_7) and Sakha105 x Moroberekan (P_3 x P_6) were considered the coveted crosses for this traits under drought stress. In addition, IRAT170 x Gaori (P_4 x P_5), Giza177 x IRAT170 (P_1 x P_4) and Giza177 x Gaori (P_1 x P_5) were the best crosses for root: shoot ratio under drought stress. Hence, these results displayed the ability of these crosses to avoid drought and may be utilized in breeding programs to improve root system.

Yield characters:

Table (6) showed the estimates of percentage heterosis over mid parent and over better parent for yield characters. **For GYP,** eleven out of twenty one crosses recorded positive highly significant heterosis effects over mid parent under drought conditions, ranged from 14.332 for Sakha101 x WAB450 (P_2 x P_7) to 53.469 for Sakha101 x IRAT170 (P_2 x P_4). Sakha105 x Moroberekan (P_3 x P_6) and Sakha101 x IRAT170 (P_2 x P_4) were the most desired crosses. On the other hand, nine crosses gave highly significant positive heterotic effects over better parent. Sakha101 x Moroberekan (P_2 x P_6), Sakha101 x IRAT170 (P_2 x P_4) and Sakha105 x Moroberekan (P_3 x P_6) were the best crosses under drought stress.

Eleven crosses showed positive highly significant heterosis effects over mid parent for **HI%**, ranged from 2.702 to 19.970. The best cross under drought stress was Sakha101 x Moroberekan (P_2 x P_6) (19.970). On the other hand, three crosses showed positive significant and highly significant heterosis effects over better parent under drought stress. Sakha101 x Moroberekan (P_2 x P_6) was the desirable cross (13.247).

According to the above mentioned results, Sakha105 x Moroberekan (P_3 x P_6), Sakha101 x Moroberekan (P_2 x P_6) and Sakha101 x IRAT170 (P_2 x P_4) were the most desirable crosses for all yield traits under drought stress. Thus, the parents that involved these crosses were the most desirable combiners to increase yield traits under drought stress conditions.

Drought parameters:

Table (7) showed the estimates of percentage heterosis over mid parent and over better parent for drought parameters. **For WUE,** nine crosses recorded positive significant and highly significant heterosis effects over mid parent. Sakha101 x Moroberekan (P_2 x P_6) and Sakha101 x IRAT170 (P_2 x P_4) were the best crosses, 66.580 and 63.469 respectively. While, five crosses exhibited positive highly significant heterosis effects over better parent. Sakha101 x Moroberekan (P_2 x P_6) and Sakha105 x Moroberekan (P_3 x P_6) were the desirable crosses to improve these trait.

With respect to DSI, ten crosses showed negative highly significant heterosis effects over mid parent. Sakha101 x Moroberekan (P_2 x P_6) and Gaori x Moroberekan (P_5 x P_6) were the best crosses, -93.200 and -88.452 respectively. While, fourteen crosses recorded negative highly significant heterosis effects over better parent. The best crosses were Sakha101 x Moroberekan (P_2 x P_6), Sakha105 x WAB450 (P_3 x P_7) and Gaori x WAB450 (P_5 x P_7).

From the obvious results of heterosis over mid parent, Sakha101 x Moroberekan, (P_2 x P_6) Sakha101 x IRAT170 (P_2 x P_4) and Sakha105 x Moroberekan (P_3 x P_6) were the most desirable crosses for water use efficiency. While, Sakha105 x WAB450 (P_3 x P_7), Sakha101 x Moroberekan (P_2 x P_6) and Gaori x Moroberekan (P_5 x P_6) were the most desired crosses for drought susceptibility index. Subsequently, it indicate that Sakha101 x Moroberekan (P_2 x P_6) was the most desirable cross for drought parameters and could be utilized in breeding programs to improve these traits. Results of heterobeltiosis for drought parameters showed that the most desirable cross for drought parameters was Sakha101 x Moroberekan, indicating that it could be utilized in breeding programs for improve these traits.

From the results of the present investigation and forgoing discussion, it is inferred that crosses viz., Sakha105 x Moroberekan (P_3 x P_6) and Sakha101 x IRAT170 (P_2 x P_4) had considerably higher desirable heterosis over mid parent and better parents for vegetative and yield traits whereas Sakha101 x WAB450 (P_2 x P_7), IRAT170 x WAB450 (P_4 x P_7), Sakha101 x Moroberekan (P_2 x P_6) and Sakha101 x IRAT170 (P_2 x P_4) exhibited positive and significant favorable heterosis over mid parent and better parents for root traits and drought parameters. These crosses could be used for drought tolerance variety development programs.

Table (6): Estimates of heterosis over mid parent and over better parent for yield characters.

Cross	GYP		HI%	
	MP	BP	MP	BP
P1 X P2	-41.655**	-46.116**	-5.588**	-11.460**
P1 X P3	-39.389**	-44.321**	2.702**	-4.687**
P1 X P4	-4.187**	-9.968**	-3.074**	-7.964**
P1 X P5	25.392**	-2.193**	8.778**	-1.102
P1 X P6	33.813**	17.876**	5.098**	-6.597**
P1 X P7	-21.565**	-29.224**	-4.611**	-16.496**
P2 X P3	-30.063**	-40.231**	2.494*	1.354
P2 X P4	53.469**	55.511**	3.974**	2.615*
P2 X P5	-45.746**	-66.864**	-31.080**	-32.679**
P2 X P6	46.576**	56.844**	19.970**	13.247**
P2 X P7	14.322**	-3.876**	-6.999**	-13.626**
P3 X P4	43.394**	49.247**	-1.880*	-4.226**
P3 X P5	-1.181*	-17.542**	-8.264**	-10.287**
P3 X P6	50.743**	52.145**	6.440**	1.550
P3 X P7	35.482**	42.069**	5.461**	-1.025
P4 X P5	39.290**	22.185**	6.738**	1.945
P4 X P6	-22.288**	-27.482**	-1.074	-7.767**
P4 X P7	-42.967**	-45.387**	6.596**	-2.195*
P5 X P6	-5.093**	-17.661**	-7.730**	-10.036**
P5 X P7	32.236**	12.132**	-3.256**	-7.248**
P6 X P7	19.289**	16.108**	5.775**	3.963**
LSD 0.05%	0.815	0.941	1.804	2.083
LSD 0.01%	1.194	1.378	2.644	3.053

Abbreviations: GYP, Grain yield plant[1] and **HI%**, Harvest index percent.

P_1, Giza177; **P_2,** Sakha101; **P_3,** Sakha105; **P_4,** IRAT170; **P_5,** Gaori; **P_6,** Moroberekan; **P_7,** WAB450.

Table (7): Estimates of heterosis over mid parent and over better parent for drought parameters.

Cross	WUE		DSI	
	MP	BP	MP	BP
P1 X P2	-41.653**	-36.116**	65.185**	63.235**
P1 X P3	-39.395**	-34.324**	-77.736**	-65.882**
P1 X P4	-4.191	-9.969	52.941**	-42.647**
P1 X P5	25.395*	-2.193	-7.424**	-34.161**
P1 X P6	33.813*	17.878	60.728**	53.494**
P1 X P7	-21.559	-29.220*	22.000**	-10.294**
P2 X P3	-23.193	-29.440*	-45.024**	-59.722**
P2 X P4	63.469**	47.514**	68.000**	54.627**
P2 X P5	-55.752**	-56.868**	34.211**	38.358**
P2 X P6	66.580**	63.850**	-93.333**	-93.976**
P2 X P7	14.324	-3.877	79.798**	32.836**
P3 X P4	53.393**	59.246**	60.630**	-29.167**
P3 X P5	-1.185	-17.550	12.131**	6.211**
P3 X P6	60.734**	62.135**	-40.352**	-48.750**
P3 X P7	55.489**	52.066**	-76.591**	-77.917**
P4 X P5	49.289**	22.177	76.389**	-21.118**
P4 X P6	-22.296	-27.489	78.788**	50.361**
P4 X P7	-42.973**	-45.396**	180.000**	53.125**
P5 X P6	-5.093	-17.666	-88.525**	-61.304**
P5 X P7	32.248*	12.141	-64.767**	-68.882**
P6 X P7	19.296	16.121	-16.522**	-42.169**
LSD 0.05%	14.443	18.225	0.055	0.063
LSD 0.01%	25.822	21.364	0.080	0.092

Abbreviations: WUE, Water use efficiency and **DSI**, Drought susceptibility index.

P_1, Giza177; **P_2,** Sakha101; **P_3,** Sakha105; **P_4,** IRAT170; **P_5,** Gaori; **P_6,** Moroberekan; **P_7,** WAB450.

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الملخص العربي

تحليل قوة الهجين للصفات الفسيو- مورفولوجية و المحصول المرتبطة بتحمل الجفاف فى الأرز

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١- مركز البحوث والتدريب في الأرز - معهد بحوث المحاصيل الحقلية - مركز البحوث الزراعية

يعتبر الاجهاد البيئى المائى (الجفاف) من العوامل الهامة المحددة لانتاج الأرز. ولكن النكسة الكبرى فى التربية لتحمل الجفاف هى الفهم السيئ لوراثه و توريث صفات تحمل الجفاف وكذلك الجهل التام للصفات الفسيولوجية المساهمة فى تحمل الجفاف. وبدلا عن ذلك يمكن زيادة المحصول تحت ظروف الاجهادات البيئية المائية (الجفاف) عن طريق الانتخاب للصفات الثانوية التى تساهم فى برامج التربية لتحمل الجفاف. ولهذا السبب فقد اجريت الدراسة الحالية لدراسة اهمية قوة الهجين باستخدام ٢١ هجين ناتجة من سبعة تراكيب وراثية ابوية من خلال الصفات الفسيو – مورفولوجية والمحصول المرتبطة بتحمل الجفاف.ولقد اظهرت النتائج ان افضل قيم لقوة الهجين مقارنة بمتوسط الأبوين كانت لصفات: عدد الجذور لكل نبات (٦٧,٧٤%) تلاها كفاءة استخدام المياه (٦٦,٨٥%)، عدد الداليات لكل نبات (٦٣,٩١%)، حجم الجذر (٦٣,٦٥%) و النسبة بين المجموع الجذرى للمجموع الخضرى (٥٨,٠٠%) ولقد لوحظ اتجاه مماثل لنتائج قوة الهجين المرغوبة مقارنة بأفضل الأبوين هى حجم الجذر (٦٥,٦٤%) تلاه صفة كفاءة استخدام المياه (٦٣,٨٥%)، النسبة بين المجموع الجذرى للمجموع الخضرى (٥٧,٤٤%)، عدد الجذور لكل نبات (٥٦,٨٣%) و وزن الحبوب / نبات (٥٦,٤٨%). من بين الـــ ٢١ هجين لقد اظهر الهجين Sakha101 x WAB450 تفوقا ملحوظا فى قيم قوة الهجين مقارنة بمتوسط الأبوين و كذلك مقارنة بأفضل الأبوين فى الصفات الفسيو - مورفولوجية و كذلك صفات المصول المرتبطة بتحمل الجفاف. فى حين أظهرت الهجن IRAT170 x Gaori, IRAT170 x Moroberekan, Sakha105 x WAB450 و Gaori x WAB450 فروق معنوية موجبة و مرغوب فيها كقيم لقوة الهجين مقارنة بمتوسط الأبوين و أفضل الأبوين لصفات الجذور.

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