GENETIC STUDIES OF SOME PHYSIOLOGICAL AND SHOOT CHARACTERS IN RELATION TO DROUGHT TOLERANCE IN RICE.

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ABSTRACT

The present investigation was carried out at the Experimental Farm of Rice Research and Training Center, Sakha, Kafr EL Sheikh, Egypt, during 2005, 2006 and 2007 rice growing seasons to study the inheritance of some physiological and chemical characters associated with drought tolerance in a diallel mating among eight rice Cultivars, beside 28 F_1 crosses. These Cultivars were IET1444, Moroberekan, BG-35-1, Hexi30, Giza178, Giza 182, Sakha101 and Sakha104. The characters studied were the number of days to heading , plant height, number of tillers /plant, panicle length, leaf rolling , leaf angle , flag leaf thickness, chlorophyll content, nitrogen content, potassium content, relative water content ,drought susceptibility index (DSI) and water use efficiency. The analysis of variance for all studied characters indicated highly significant mean squares for flag leaf angle, flag leaf area, chlorophyll content and relative water content, while, flag leaf thickness, potassium content, nitrogen content and water use efficiency under their combined data. Parents vs. crosses mean squares, as an indication to average heterosis overall crosses, were found to be highly significant for all characters studied, except for flag leaf thickness, potassium content, nitrogen content and water use efficiency under both environments and their combined data. The interactions of genotypes, parents and crosses with environment were detected to be highly significant for the studied characters, except, for flag leaf thickness, potassium content, nitrogen content and water use efficiency revealing that these genotypes differently behaved from one environment to another. The interactions of parents vs. crosses with environments were significant for the studied traits, except, for flag leaf area, flag leaf thickness, potassium content, nitrogen content and water use efficiency. Results indicated that the parents, IET1444, Moroberekan, BG35-1, Giza178 and Sakha 104, were found to be good combiners for most of the studied traits. The most desirable

specific combining ability effects for most of the studied characters were detected in the crosses, IET 1444 x Sakha 101, Moroberekan x Giza 178 and BG 35-1 x Sakha 101. The most pronounced useful heterotic effects were detected in the crosses, IET 1444 x Sakha 104, Moroberekan x Giza 178, Moroberekan x Sakha 101 and Giza 178 x Sakha 104 for the traits studied. Most of the crosses differed in potence ratio from one to another.

INTRODUCTION

Drought limits the agricultural production by preventing the crop plants from expressing their full genetic potential. Three mechanisms; namely, drought escape, drought avoidance and drought tolerance are involved in drought tolerance .

Various morphological, physiological and biochemical characters confer drought tolerance. Morphological and physiological characters show different types of inheritance pattern (monogenic and polygenic) and gene action (additive and non-additive), whereas, the genes responsible for biosynthesis of different compatible solutes have been identified and cloned from plants, yeast, mouse and human. Different breeding approaches for drought tolerance have emerged, with their merits and demerits. Efficient screening techniques are pre-requisite for success in selecting desirable genotypes through any breeding program (Pantuwan *et al.*, 2002).

Drought is actually a meteorological event, which implies the absence of rainfall for a period of time, long enough to cause moisture-depletion in soil and water deficit with a decrease of water potential in plant tissues (Staples and Kuhr, 1980). But, from agricultural point of view, its working definition would be the inadequacy of water availability, including precipitation and soil-moisture storage capacity, in quantity and distribution during the life cycle of a crop plant, which restricts the expression of full genetic potential of the plant. It acts as a serious limiting factor in agricultural production by preventing a crop from reaching the genetically determined theoretical maximum yield (Begg *and Turner,* 1976). The effect of drought on crop production and overall economy is well known. Most of the crops are sensitive to water deficits, particularly during flowering to seed development stage (Salter and Goode, 1976). Even crops grown in arid and semi-arid regions, such as pearl millet, sorghum and pigeon pea, are also affected by drought at the reproductive stage.

In genetic sense, the mechanisms of drought can be grouped into three categories; viz., drought escape, drought avoidance and drought tolerance (Levitt, 1972). However, crop plants use more than one mechanism at a time to resist drought. Drought escape is defined as the ability of a plant to complete its life cycle before serious soil and plant water deficits develop. This mechanism involves rapid phonological development (early flowering and early maturity), developmental plasticity (variation in duration of growth period depending on the extent of water-deficit) and remobilization of parenthesis assimilates to grain. Drought avoidance is the ability of plants to maintain relatively high tissue water potential, despite a shortage of soil-moisture, whereas, drought tolerance is the ability to withstand water-deficit with low tissue water potential. Mechanisms for improving water uptake, storing in plant cell and reducing water loss confer drought avoidance.

Drought avoidance is performed by maintenance of turgor through increased rooting depth, efficient root system and increased hydraulic conductance and by reduction of water loss through reduced epidermal (stomatal and lenticular) conductance, reduced absorption of radiation by leaf rolling or folding (Begg, 1980) and reduced evaporation surface (leaf area). Plants, under drought conditions survive by doing a balancing act between maintenance of turgor and reduction of water loss (Shashidhar *et al.*, 2000). The mechanisms of drought tolerance are maintenance of turgor through osmotic adjustment (a process, which induces solute accumulation in cell), increase in elasticity in cell and decrease in cell size and desiccation tolerance by protoplasmic resistance.

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 ditales 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. To overcome this problem, ways must be found to increase the productivity of water used for irrigation and find ways for saving more irrigation water. One of the important ways for saving irrigation water is the use of short duration rice cultivars. It is very important to find ways for saving more water without significant reduction in grain yield. It was started to overcome this problem in Egypt by developing short duration cultivars, such as Giza 177(released in 1995), Giza 178 (released in 1997), Shakha 101 (released in 1997), Sakha 102 (released in 1997), Sakha 103 (released in 1999), Giza 182 (released in 2000) and Sakha 104 (released in 2000). The second direction for saving irrigation water is developing drought tolerant lines to be grown in the areas affected by the shortage of irrigation water to reduce the total water requirements. This investigation was aimed to study the inheritance of some physiological and shoot characters associated with drought tolerance.

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 the three successive rice growing seasons, 2005, 2006 and 2007, to study the inheritance of some physiological characters associated with drought tolerance. Eight genotypes ; namely, IET1444, Moroberekan, BG-35-1, Hexi30, Giza178, Giza 182, Sakha101 and Sakha104, were chosen, based on previous studies. These genotypes had a wide range of variations due to their different genetic background. The introduced cultivars, IET1444, Moroberekan and BG-35-1, were used as drought tolerance and the cultivars, Sakha104 and Giza178, were used as moderate tolerance and Giza182, Sakha101 and Hexi30 were used as drought susceptible ones.

Seeds of such cultivars were grown in three successive sowing dates during 2005 season, with ten days intervals to overcome the difference of heading date among them. Thirty days after sowing, seedlings of each cultivar were individually transplanted in the permanent field in three rows, five meters long and 20 cm among plants and rows. One- half diallel cross was carried out among the eight parents to produce F_1 hybrid seeds. Bulk emasculation method was practiced by using hot water technique, according to Butany (1961). In 2006 season, a total of 28 crosses, beside their parents, were grown in a randomized complete block design (RCBD) with three replications, each replicate consisted of five rows for each parent and F_1 cross. Each row was 5 m long and contained 25 hills, with 20 cm among rows. 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. All genotypes, viz., eight parents and 28 F_1 crosses, were planted under both normal and drought conditions. Drought stress was imposed by using flush irrigation every twelve days without standing water after irrigation. Some shoot and physiological characters; i.e. number of days to heading , plant height, number of tillers /plant, panicle length, leaf rolling (was recorded by a visual estimation, based on methods proposed by De Data *et al.*,1988), leaf angle (measured at heading by separating the main tiller from the rest of plant), flag leaf thickness (measuring by micrometer in the medium flag leaf), chlorophyll content(total chlorophyll content was determined by using chlorophyll SPAD-502 meter), nitrogen (%) (N content in the leaves were estimated at vegetative stage, according to Hafez and Mikkelsen,1981), potassium content (extracted by ammonium acetate-EDTA, according to Cottenie *et al.,* 1982), relative water content (determined by the method of Barrs and Weatherly 1962), drought susceptibility index (DSI) (calculated for each line using the formula given by Saulescu *et al.* (1995) and water use efficiency (measured following Mitchel, 1978), these measurements were recorded at different stages of rice plants. Each plant was individually harvested to be grown in 2007 season as F_2 plants. In 2007 season, seeds of the eight parents, F_1 and F_2 crosses were evaluated under both normal and drought conditions in a randomized complete block design, with three replications. The same technique of 2006 was used, where all genotypes were planted (five rows for each parent and F_1 cross and twenty rows for each F_2 population) and all recommended cultural practices were used.

Statistical analysis

At first, the data were analyzed by the ordinary analysis of variance to test the significance of differences among the twenty eight genotypes. The genotypes mean squares were found to be significant. There was a need to proceed for further analysis followed by Griffing (1956). The combined analysis was calculated over the two environments to test the interaction of the different genetic components with the two environments, as two different environmental conditions. Homogeneity test was done, followed by Bartlett (1937), before proceeding the computations of the combined experiments and the error variances of the tests were homogenous. For each trait, the heterosis of an individual cross was determined as the increase of the F_1 hybrid mean over its better parent (heterbeltiosis), according to Wyanne *et al.* (1970). The degree and nature of dominance (potence ratio) of the studied traits, in F_1 crosses, were calculated. The data of each character of each F_2 hybrid population (individuals) were separately analyzed by the analysis of variance, according to Panse and Sukhatme (1957). The genetic parameters; i.e., phenotypic variance, genotypic variance and genetic coefficient of variation were computed, according to the formula suggested by Burton and Devane (1952). Heritability, in broad sense, and genetic advance upon selection, were computed according to Johanson *et al.* (1955).

RESULTS AND DISCUSSION

Mean performance:

The ordinary analysis of variance indicated highly significant differences among genotypes for all traits studied in their combined data. Means of the traits in their combined data are shown in Table (1).

For number of days to heading (Table1), the genotypes, Moroberekan, Giza 178, Sakha104, IET1444 x BG35-1, IET1444 x Sakha 101 and Moroberekan x Sakha 101, gave the highest mean values under both environments and their combined data. While, the parents, Hexi 30 and Giza 182, and the crosses, IET1444 x Giza 178, Hexi30 x Giza 178, Hexi 30 x BG35-1 and Hexi 30 x Giza 182, were found to be earlier than the others.

Concerning number of tillers /plant (Table1), the parents, IET1444, Moroberekan, BG35-1 and Giza 178, and the crosses, IET 1444 x Giza 178, IET 1444 x Giza 182, Moroberekan x Giza 178, BG 35-1 x Giza 178, BG 35-1 x Giza 182 and Giza 178 x Giza 182 gave the highest mean values for this trait and the values range from 20.40 to 26.50 tillers/plant. While, the genotypes, Hexi 30, Moroberekan x Sakha 104 and Hexi 30 x BG35-1, gave the lowest mean values and ranged from 12.66 to 26.83 tillers /plant.

For plant height, there was a significant difference among genotypes suggesting that the growth rates were different. IET1444, Moroberekan, Sakha 104 as well as IET1444 x Moroberekan, IET1444 x Giza 178, Moroberekan x Giza 182, Hexi 30 x Giza 178 and BG35-1 x Sakha 104 genotypes recorded the highest values at both environments and their combined data, compared to the others. The most desirable mean values towards dwarfing were obtained from the genotypes, Hexi 30, Giza 182, Giza 178, Sakha 101, and Moroberekan x akha104, BG35-1 x Giza 182,

Table 1: The genotypes mean performances of the combined data for the characters studied (normal and drought conditions).

Entries	Number of days to heading (day)	No. of tillers /plant	Plant height (cm)	Panicle length (cm)	Flag leaf area (cm)	Flag leaf angle
IET 1444	104.16	19.16	100.30	22.50	28.53	Narrow
Moroberekan	108.56	20.20	120.90	26.03	34	Narrow
Hexi 30	91.38	13.95	90.38	24.17	17.21	Wide
BG 35-1	106.73	16.03	99.28	24.17	19.52	Wide
Giza 178	107.21	20.81	96.19	20.92	25.42	Narrow
Giza 182	96.06	17.20	93.14	18.25	28.91	Narrow
Sakha 101	105.98	21.25	91.33	25.67	21.79	Wide
Sakha 104	109.91	18.93	104.20	21.50	21.96	Narrow
IET 1444 X Moroberekan	100.75	19.53	137.50	25.17	27.59	Wide
IET 1444 X Hexi 30	102.36	18.71	103.50	25.92	13.99	Wide
IET 1444 x BG 35-1	107.63	17.95	110.80	22.89	29.58	Narrow
IET 1444 x Giza 178	100.23	22.87	122.80	26.00	26.38	Wide
IET 1444 x Giza 182	102.43	23.00	110.30	23.33	20.59	Narrow
IET 1444 x Sakha 101	109.11	19.46	119.30	27.83	25.44	Narrow
IET 1444 x Sakha 104	105.71	19.90	129.30	24.33	22.77	Narrow
Moroberekan X Hexi 30	101.63	19.95	113.30	19.25	15.86	Wide
Moroberekan x BG 35-1	104.38	15.50	120.20	20.25	32.3	Narrow
Moroberekan x Giza 178	101.53	26.78	142.00	28.95	26.88	Narrow
Moroberekan x Giza 182	98.90	24.96	135.90	28.33	21.14	Wide
Moroberekan x Sakha 101	111.25	14.25	134.60	27.83	18.57	Wide
Moroberekan x Sakha 104	109.86	12.66	100.30	19.42	16.27	Narrow
Hexi 30 x BG 35-1	98.68	12.75	103.80	22.17	20.31	Wide
Hexi 30 x Giza 178	95.16	19.23	128.80	25.60	20.24	Narrow
Hexi 30 x Giza 182	96.00	20.16	121.40	23.00	17.22	Wide
Hexi 30 x Sakha 101	103.95	20.43	102.40	19.08	19.69	Narrow
Hexi 30 x Sakha 104	102.43	19.36	109.60	20.33	25.48	Wide
BG 35-1 x Giza 178	108.25	26.83	102.40	21.90	29.07	Wide
BG 35-1 x Giza 182	100.83	26.40	98.25	22.98	21.74	Narrow
BG 35-1 x Sakha 101	104.83	16.73	113.90	26.17	22.03	Narrow
BG 35-1 x Sakha 104	100.43	15.18	128.30	21.33	27.63	Wide
Giza 178 x Giza 182	103.90	23.13	93.21	23.25	14.03	Narrow
Giza 178 x Sakha 101	102.65	24.45	97.69	23.83	29.57	Narrow
Giza 178 x Sakha 104	101.00	23.71	97.04	23.42	26.77	Wide
Giza 182 x Sakha 101	104.00	15.93	114.30	23.50	20.68	Narrow
Giza 182 x Sakha 104	102.55	17.41	124.30	26.17	25.46	Wide
Sakha 101 x Sakha 104	102.93	24.11	104.60	23.58	23.13	Wide
LSD (at 0.05)	1.85	3.14	10.82	1.67	1.73	-
LSD (at 0.01)	2.47	4.17	14.39	2.21	2.29	-

Table 1: continued

Entries	Leaf rolling	Flag Leaf thickness (mm)	Chlorophyll content	Potassium content	Nitrogen content	Relative water content	Water use efficiency
IET 1444	2	0.24	39.35	0.31	0.31	93.75	0.82
Moroberekan	2	0.27	41.07	0.39	0.39	91.01	0.47
Hexi 30	8	0.22	45.82	0.27	0.27	89.08	0.44
BG 35-1	3	0.26	47.12	0.31	0.31	72.8	0.5
Giza 178	3	0.31	39.93	0.47	0.47	89.78	0.72
Giza 182	7	0.26	43.47	0.38	0.38	80.52	0.47
Sakha 101	8	0.24	45.73	0.47	0.47	67.59	0.58
Sakha 104	7	0.24	40.67	0.28	0.28	87.71	0.6
IET 1444 X Moroberekan	2	0.3	40.68	0.38	0.38	94.07	0.85
IET 1444 X Hexi 30	5	0.26	38.33	0.42	0.42	73.85	0.78
IET 1444 x BG 35-1	2	0.25	40.17	0.41	0.41	78.08	0.82
IET 1444 x Giza 178	5	0.29	41.62	0.54	0.54	78.93	0.83
IET 1444 x Giza 182	6	0.27	41.35	0.32	0.32	81.87	0.72
IET 1444 x Sakha 101	5	0.26	42.12	0.5	0.5	85.64	0.67
IET 1444 x Sakha 104	4	0.24	43.98	0.53	0.53	74.72	0.86
Moroberekan X Hexi 30	5	0.24	45.77	0.48	0.48	73.02	1.04
Moroberekan x BG 35-1	3	0.27	40.72	0.4	0.4	84.71	0.47
Moroberekan x Giza 178	4	0.35	51.15	0.45	0.45	78.89	1.08
Moroberekan x Giza 182	5	0.3	44.83	0.34	0.34	82.23	0.67
Moroberekan x Sakha 101	5	0.29	43.9	0.48	0.48	84.95	0.69
Moroberekan x Sakha 104	4	0.22	42.6	0.47	0.47	53.75	0.6
Hexi 30 x BG 35-1	5	0.23	41.35	0.55	0.55	71.08	0.66
Hexi 30 x Giza 178	4	0.22	42.95	0.41	0.41	70.42	0.74
Hexi 30 x Giza 182	7	0.27	45.68	0.44	0.44	79.49	0.8
Hexi 30 x Sakha 101	8	0.28	42.88	0.45	0.45	76.23	1.03
Hexi 30 x Sakha 104	8	0.24	42.37	0.33	0.33	80.01	0.64
BG 35-1 x Giza 178	3	0.27	39.88	0.4	0.4	73.49	0.63
BG 35-1 x Giza 182	4	0.23	42.6	0.42	0.42	79.65	0.98
BG 35-1 x Sakha 101	5	0.25	42.38	0.51	0.51	84.28	0.78
BG 35-1 x Sakha 104	4	0.23	43.55	0.39	0.39	84.35	0.72
Giza 178 x Giza 182	4	0.29	47.38	0.46	0.46	81.33	0.72
Giza 178 x Sakha 101	5	0.2	42.55	0.42	0.42	74.72	0.85
Giza 178 x Sakha 104	4	0.21	43.62	0.58	0.58	75.3	0.59
Giza 182 x Sakha 101	8	0.22	42.88	0.62	0.62	63.4	0.55
Giza 182 x Sakha 104	7	0.26	42.78	0.4	0.4	58.39	0.82
Sakha 101 x Sakha 104	8	0.24	48.6	0.32	0.32	76.39	0.71
LSD (at 0.05)	-	0.06	3.06	0.05	0.05	14.32	0.23
LSD (at 0.01)	-	0.07	4.07	0.06	0.06	19.05	0.31

Giza 178 x Sakha 101 and Giza 178 x Sakha 104. There was a highly significant reduction in plant height under stress condition in some rice genotypes studied. The maximum reduction was recorded by IET1444, Moroberekan, Hexi30 and BG35-1 compared with the control.

With respect to chlorophyll content (Table 1), the most desirable genotypes over the two environments and their combined data were Hexi30, BG35-1 and Moroberekan x Giza 178.

Concerning leaf rolling, the best genotypes were IET 1444, Moroberekan, BG 35-1, Giza 178, IET 1444 X Moroberekan, IET 1444 x BG 35-1 and BG 35-1 x Giza 178, which gave the lowest scores (1-3) indicating that these entries could be tolerant for drought stress. However, such values were not significantly different.

With respect to flag leaf area, Moroberekan, IET1444, Giza 182, IET 1444 x BG 35-1, Moroberekan x Giza 178, BG 35-1 x Giza 178, BG 35-1 x Sakha 104 and Giza 178 x Sakha 101 genotypes had the highest mean values. While, Hexi 30, IET1444 x Hexi 30 genotypes gave the lowest values for flag leaf area under both environments and their combined data. The most desirable mean values for flag leaf area were found in Moroberekan, IET 1444 x BG 35-1, Moroberekan x BG 35-1, BG 35-1 x Giza 178 and Giza 178 x Sakha 101 genotypes.

Concerning the flag leaf thickness, Moroberekan, Giza 182 and Moroberekan x BG 35-1 were the best genotypes under both environments and their combined data for this trait.

Concerning potassium content, the highest mean values were found in the parents BG35-1, Giza 178 and Sakha104, beside the crosses, IET1444 x BG35-1, Moroberekan x Giza 182, Hexi 30 x Giza Giza 178 Giza 182 x Sakha 101 and Giza 182 x Sakha 104, under both environments and their combined data.

Regarding nitrogen content, Table (1) shows that the highest mean values were produced from Moroberekan, Giza 178, Sakha 101, IET1444 x Sakha 104 , Hexi x BG35-1, Giza 178 x Sakha 104 and Giza 182 x Sakha 101 genotypes under both environments and their combined data.

As for as the relative water content was concerned , Table (1) indicates that the highest mean values were detected in the parents, IET 1444 and Moroberekan, beside IET1444 x Moroberekan, Moroberekan x Sakha101 and BG35-1 x Sakha101 crosses under both environments and their combined data. On the other hand, the lowest values of relative water content were obtained from Sakha 101 and

Moroberekan x Sakha 104 genotypes in both environments and their combined data.

The data presented in Table (1) showed that the highest mean values for water use efficiency were produced from genotypes IET1444, Giza 178, Moroberekan x Giza 178 and Hexi 30 x Sakha 101 under their combined data. On the other hand, the lowest values were obtained from the parent, Hexi 30, and Moroberekan x BG35-1 cross.

Variations and interactions:

The ordinary analyses of variance and combining ability analysis for physiological traits of the combined data are presented in Table (2).

Environments mean squares were detected to be highly significant for number of days to heading, number of tillers, plant height, panicle length, flag leaf area, flag leaf angle, flag leaf area, chlorophyll content and relative water content. While, flag leaf thickness, potassium content, nitrogen content and water use efficiency showed insignificant mean squares under their combined data. Parents vs. crosses mean squares, as an indication to average heterosis overall crosses were found to be highly significant for all characters studied except for flag leaf thickness, potassium content, nitrogen content and water use efficiency under both environments and their combined data.

The interactions of genotypes, parents and crosses with environments were detected to be highly significant for the studied characters, except, for flag leaf thickness, potassium content, nitrogen content and water use efficiency revealing that these genotypes differently behaved from one environment to another (Table 2).

The interactions of parents vs. crosses with environments (Table 2) were highly significant for the studied traits except for flag leaf area, flag leaf thickness, potassium content, nitrogen content and water use efficiency, indicating that the average hetrosis in all crosses was inconsistent under one two to conditions. These results are in agreement with those of Dingkuhna *et al.*(1999), Mohan *et al.* (2001), Cabuslary *et al.* (2002), El-Rafaee (2002), Yogameenakashi *et al.* (2003), Sheng *et al.* (2005), and Sibounheuanga *et al.* (2006).

Table 2: Mean square estimates of ordinary analysis and combining ability analysis for the studied characters of the combined data (normal and drought conditions).

S.O.V	df	Days to heading (day)	No. of tillers/ plant	Plant height (cm)	Panicle length (cm)	Flag leaf area (cm^2)	Flag leaf angle
Environments	1	143.00**	867.70**	198.00**	296.97**	647.92**	1962.00**
Reps. within environments	4	52.04**	263.64**	454.00**	66.27**	186.13**	360.58**
Genotypes	35	113.26**	96.54**	988.24**	44.70**	154.79**	735.09**
Parents	7	226.16**	55.04**	477.54**	41.44**	187.15**	701.94**
Crosses	27	88.04**	102.27**	921.32**	46.13**	147.66**	637.53**
Parents vs. crosses	1	3.90**	232.70**	637.01**	28.86**	120.66**	3601.20**
Genotypes X environments	35	6.09**	22.47**	263.52**	6.23**	6.69**	355.69**
Parents X environments	7	7.11**	17.58**	71.68**	2.64**	2.45**	216.10**
Crosses X environments	27	5.37**	24.11**	289.66**	6.76**	7.98**	391.55**
Parents vs. crosses X.envir.	1	18.37**	12.61**	900.52**	17.18**	1.674	364.58**
G.C.A.	7	57.61**	27.56**	235.28**	7.53**	39.92**	112.50**
S.C.A.	28	9.19**	13.22**	147.06**	7.42**	22.26**	124.22**
G.C.A x environments	7	59.26**	37.84**	371.43**	9.66**	42.22**	228.51**
S.C.A x environments	28	11.32**	20.01**	222.83**	9.49**	24.48**	242.75**
Error (Me)	140	0.95	3.74	43.92	1.03	1.116	59.01
G.C.A / S.C.A	-	1.26	2.08	1.59	1.01	1.793	0.906

** Significant at 0.01 levels of probability.
Chl. content= Chlorophyll content, Pot. content= Potassium content,
W.U.E=Water use efficiency .

Table 2: continued

S.O.V	df	Flag Leaf thickness (mm)	Chl. content	Pot. content	Nitrogen content	Relative water content	W.U.E
Environments	1	0.045	721.61**	2.390	0.200	2221.50**	0.112
Reps. within environments	4	0.015	185.89**	426.00**	4264	415.72**	0.009
Genotypes	35	0.006	45.36**	0.320	0.04	483.16**	0.161
Parents	7	0.005	56.14**	0.280	0.04	525.13**	0.110
Crosses	27	0.007	44.062**	0.150	0.03	421.99**	0.132
Parents vs. crosses	1	0.002	5.23**	5.140	0.26	1841.00**	1.271
Genotypes X environments	35	0.008	21.03**	0.060	0.01	459.56**	0.120
Parents X environments	7	0.011	17.786**	0.020	0.001	128.01**	0.099
Crosses X environments	27	0.007	22.36**	0.070	0.01	547.82**	0.125
Parents vs. crosses X.envir.	1	0.003	7.84**	0.100	0.001	397.44**	0.143
G.C.A.	7	0.001	8.52**	0.020	0.01	52.074**	0.015
S.C.A.	28	0.004	7.20**	0.060	0.01	87.64**	0.030
G.C.A x environments	7	0.006	11.07**	0.030	0.01	92.009**	1.202
S.C.A x environments	28	0.003	15.35**	0.080	0.01	269.14**	0.070
Error (Me)	140	0.001	3.51	13.90	13.9	76.59	0.201
G.C.A / S.C.A	-	1.492	1.1828	0.30	0.9	0.5942	0.50

** Significant at 0.01 levels of probability.

Chl. content= Chlorophyll content, Pot. content= Potassium content, W.U.E=Water use efficiency

.Hetrosis

Data in Table (3) revealed that highly significant and positive hetrosis was found in the crosses, Hexi 30 x Sakha 104, BG 35-1 x Giza 178, BG 35-1 x Sakha 101, BG 35-1 x Sakha 104, Giza 178 x Sakha 101, Giza 178 x Sakha 104, Giza 178 x Sakha 101 and Sakha 101 x Sakha 104 for flag leaf area at both environments and their combined. However, highly significant negative values were detected in the seventeen crosses. Similar results were found by El-Abd (1995), Panwar et al. (1997), Hammoud (1996), Abd-Allah

(2000), Cabuslary *et al.* (2002), El-Rafaee (2002), Yogameenakashi *et al.* (2003), Sheng *et al.* (2005), Zheng *et al.* (2005) and Sibounheuanga *et al.* (2006).

Four hybrid combinations exhibited highly significant positive heterotic effect for flag leaf thickness in the combined data. The most pronounced heterotic effects were detected in the crosses IET 1444 x Moroberekan, IET 1444 x Hexi 30, Hexi 30 x Sakha 101 and Moroberekan x Giza 178, and the values varied from 8.33 to 18.06% (Table 3).

The crosses, IET1444 x Sakha104, Moroberekan x Giza 178 and Giza 178 x Sakha104, exhibited highly significant positive heterotic effects for chlorophyll content. The values varied from 7.27 to 24.57% at both environments and their combined data. Similar results were reported by EL-Abd (1995) Dwivedi *et al.* (1998) and Abd-Allah (2000).

Concerning potassium content, nineteen out of the twenty-eight hybrid combinations exhibited highly significant positive heterotic effects which were found to vary from 9.54 to 102.00% over their respective better-parents. The most pronounced heterotic effects were detected in the crosses, Moroberekan x Hexi 30, IET 1444 x Moroberekan, IET 1444 x Hexi 30, IET 1444 x Giza 182 and Hexi 30 x Giza 182 which varied from 40.9 % to 102.00% (Table 3).

With regard to nitrogen content, twelve hybrid combinations showed highly significant positive heterotic effects, which varied from 16.30 to 64.60% over their respective better-parents at the combined data. The best desirable crosses were IET 1444 x Hexi 30, IET 1444 x BG 35-1, IET 1444 x Sakha 104, Hexi 30 x BG 35-1, Hexi 30 x Sakha 104 and BG 35-1 x Sakha 104(Table 3).

Highly significant and positive heterotic effect was detected for relative water content was observed only in BG 35-1 x Sakha 101 for this trait in the combined data. It valve giving 15.78 % (Table 3).

Concerning water use efficiency, highly significant and positive heterosis was found for several crosses, such as Moroberekan x Hexi 30 (121.00%), Moroberekan x Giza 178 (49.50%), Hexi 30 x Sakha 101 (77.00%), Giza 178 x Giza 182 (167.00%) and Giza 178 x Sakha 101 (216.00%) under both environments and their combined data(Table 3).

It could be concluded that the most desirable crosses, over the two environments, as well as their combined data for flag leaf area, were BG 35-1 x Sakha 104, Giza 178 x Sakha 101 and Hexi 30 x Sakha 104; for flag leaf thickness were IET 1444 x Moroberekan, IET 1444 x Hexi 30 and Moroberekan x Giza 178; for chlorophyll content were Moroberekan x Giza 178, Giza 178 x Giza 182 and Giza 178 x Sakha 104; for potassium content were IET 1444 x Moroberekan, IET 1444 x Hexi 30, IET 1444 x Giza 182 and Hexi 30 x Giza 182 ; for nitrogen content were IET 1444 x Hexi 30, IET 1444 x BG 35-1 and BG 35-1 x Sakha 104; for relative water content was BG35-1 x Sakha 101 and for water use efficiency were Moroberekan x Hexi

30, Giza 178 30 x Giza 182 , Giza 178 x Sakha 101 and Giza 178 x Sakha 104.

Table 3: Percentages of heterosis over better-parents for the characters studied in the combined data (normal and drought conditions).

Genotypes	Number of Days to heading (day)	No. of tillers/ plant	plant height (cm)	Panicle length (cm)	Flag Leaf area (cm2)	Flag Leaf thickness (mm)
IET 1444 X Moroberekan	-3.13**	1.94	6.97	-3.32**	-18.87**	16.03**
IET 1444 X Hexi 30	11.88**	-2.31	-5.95	-0.44	-58.84**	8.33**
IET 1444 x BG 35-1	3.49**	-6.32**	-0.47	-12.10**	-13.01**	-4.49**
IET 1444 x Giza 178	-3.62**	9.90**	12.00*	-0.12	-22.4**	-6.45**
IET 1444 x Giza 182	7.82**	20.04**	-2.29	-10.40**	-39.45**	2.56**
IET 1444 x Sakha 101	4.92**	-8.39**	15.32**	6.92**	-25.19**	8.33**
IET 1444 x Sakha 104	2.63**	3.86**	18.57**	-6.52**	-33.04**	0.69***
Moroberekan X Hexi 30	11.08**	43.01**	-8.60	-20.30**	-53.35**	-7.69**
Moroberekan x BG 35-1	-1.53	-3.31*	-8.74	-16.20**	87.79**	1.92**
Moroberekan x Giza 178	-2.84**	28.70**	10.84	28.67**	56.28**	12.90**
Moroberekan x Giza 182	4.10**	45.16**	5.459	25.93**	-26.87**	16.03**
Moroberekan x Sakha 101	3.97**	-32.90**	5.183	8.47**	7.96**	12.82**
Moroberekan x Sakha 104	6.66**	-33.10**	-19.40**	-13.70**	-5.43**	-16.03**
Hexi 30 x BG 35-1	7.85**	-20.50**	-3.46	-11.90**	4.05**	-12.82**
Hexi 30 x Giza 178	4.007**	-7.58**	27.01**	5.96**	-20.37**	-27.96**
Hexi 30 x Giza 182	4.91**	17.25**	21.14**	-4.80**	-40.45**	5.13**
Hexi 30 x Sakha 101	13.61**	-3.84	11.87**	-25.60**	-9.63**	18.06**
Hexi 30 x Sakha 104	11.95**	2.30	2.599	-15.80**	16.01**	5.07**
BG 35-1 x Giza 178	3.58**	28.94**	0.114	-9.35**	14.39**	-11.83**
BG 35-1 x Giza 182	6.14**	53.49**	-2.79	-4.87***	-24.79**	-10.26**
BG 35-1 x Sakha 101	-1.10	-21.30**	5.60	1.97	1.12	-3.85**
BG 35-1 x Sakha 104	-5.25**	-19.80**	16.01	-11.7**	25.83**	-10.26**
Giza 178 x Giza 182	9.36**	11.16**	-6.87	11.19**	-51.46**	-6.45**
Giza 178 x Sakha 101	-1.77	15.06**	0.09	-7.12**	16.36**	-34.95**
Giza 178 x Sakha 104	-3.35**	25.29**	-8.71	8.91**	5.34**	-31.18**
Giza 182 x Sakha 101	9.47**	-25.00**	16.49**	-8.42**	-28.46**	-14.1**
Giza 182 x Sakha 104	7.94**	-7.99**	8.967	21.97**	-11.93**	0.64*
Sakha 101 x Sakha 104	-0.07	13.49**	-1.59	9.69**	5.33**	0.001
LSD (at 0.05)	1.8	3.07	11.00	1.631	1.69	0.058
LSD (at 0.01)	2.4	4.045	14.00	2.144	2.22	0.076

Table 3: Continued

Genotypes	Chlorophyll content	Potassium content	Nitrogen content	Relative water content	Water use efficiency
IET 1444 X Moroberekan	-0.92	54.50**	-17.50**	0.34	3.86**
IET 1444 X Hexi 30	-16.30**	40.90**	61.30**	-21.20**	-4.84**
IET 1444 x BG 35-1	-14.70**	-15.00**	64.60**	-16.70*	0.06
IET 1444 x Giza 178	4.22**	-35.00**	-17.70**	-15.80*	1.13**
IET 1444 x Giza 182	-4.86**	44.80**	26.80**	-12.70	-12.40**
IET 1444 x Sakha 101	-7.90**	27.40**	-15.60**	-8.65	-18.10**
IET 1444 x Sakha 104	8.17**	11.50**	44.10**	-20.30**	5.46**
Moroberekan X Hexi 30	-0.09	102.00**	-12.00**	-19.80**	121.00**
Moroberekan x BG 35-1	-13.60**	9.92**	21.80**	-6.91	-6.75**
Moroberekan x Giza 178	24.57**	11.70**	0.35**	-13.30	49.50**
Moroberekan x Giza 182	3.16**	-23.00**	-31.20**	-9.64	-6.31**
Moroberekan x Sakha 101	-4.00**	35.30**	16.30**	-6.65	19.10**
Moroberekan x Sakha 104	3.75**	35.90**	4.27**	-40.90**	1.57**
Hexi 30 x BG 35-1	-12.20**	4.50**	40.30**	-20.20**	32.30**
Hexi 30 x Giza 178	-6.24**	30.20**	-4.26**	-21.60**	2.59**
Hexi 30 x Giza 182	-6.41**	65.20**	-14.00**	-10.80	73.00**
Hexi 30 x Sakha 101	-6.39**	15.70**	-33.70**	-14.40**	77.00**
Hexi 30 x Sakha 104	-7.52**	11.20**	41.70**	-10.20	7.67**
BG 35-1 x Giza 178	-15.30**	-1.10**	-11.30**	-18.10**	-12.10**
BG 35-1 x Giza 182	-9.57**	-12.00**	34.60**	-1.08	36.10**
BG 35-1 x Sakha 101	-10.00**	-11.00**	-16.70**	15.78**	34.80**
BG 35-1 x Sakha 104	-7.56**	-7.00**	52.2**	-3.83	22.30**
Giza 178 x Giza 182	9.03**	-3.70**	-1.77**	-9.40	167.00**
Giza 178 x Sakha 101	-6.95**	9.54**	-11.8**	-16.80*	216.00**
Giza 178 x Sakha 104	7.27**	28.30**	22.70**	-16.10*	118.00**
Giza 182 x Sakha 101	-6.22**	41.40**	31.20**	-21.30**	-5.89**
Giza 182 x Sakha 104	-1.56**	31.50**	5.70**	-33.40**	38.90**
Sakha 101 x Sakha 104	6.28**	28.90**	-31.9**	-12.90	19.70**
LSD (at 0.05)	1.186	0.16	0.05	14.04	0.23
LSD (at 0.01)	1.559	0.21	0.06	18.46	0.30

General combining ability effects:

Estimates of general combining ability effects of individual parents for physiological traits in the combined data are given in Table (4).

With respect to number of days to heading, the parental cultivars Hexi 30, Giza 178 and Giza 182 showed highly significant negative general combing ability effects, indicating that such cultivars could be considered as good combiners for the improvement of this trait. Regarding number of tillers / plant, the parents, IET1444 and Giza 178, were found to be good combiners under drought condition.

For plant height, Hexi30, BG35-1, Sakha 101 and Giza182 cultivars showed highly significant and negative general combing ability effects for both environments and their combined data, proving to be good combiners and ascertained their ability of developing short plants. For panicle length, positive general combining ability effects were found in the genotypes IET1444, Moroberekan and Sakha101 in the combined data, indicating that such rice cultivars could be used as good combiners for this trait.

The five rice cultivars, IET1444, Moroberekan, BG35-1, Giza178 and Sakha 104, showed highly significant positive general combining ability effects for flag leaf area. This result indicates that these parents could be considered excellent combiners for this trait. IET1444 and Sakha101 cultivars had highly significant positive general combing ability effects for flag leaf thickness for this trait, proving to be good combiners for flag this trait.

Moroberekan, Hexi 30, Giza182 and Sakha101 showed highly significant positive general combining ability effects for chlorophyll content under both environments and their combined data, proving to be good combiners for this character. For potassium content, BG 35-1, Giza 178, Sakha 101 and Sakha 104 exhibited desirable general combing ability effects, proving to be good combiners for this trait. Giza 178 and Sakha 101 showed desirable general combining ability effects for nitrogen content at the combined data, proving to be good combiners for this character. Concerning relative water content, IET1444 and Moroberekan showed highly significant positive values of general combining ability effects at the two environments and their combined data, indicating that these cultivars could be used as good combiners for this trait.

It is of interest to note, here, that the means of some parental cultivars agreed with their corresponding general combining ability effects for certain physiological traits. It could be concluded that IET1444, Moroberekan, BG35-1, Giza178 and Sakha 104 for flag leaf area, Moroberekan, Giza178 and Giza 182 for flag leaf thickness, Moroberekan, Hexi 30, Giza182 and Sakha101 for chlorophyll content, BG 35-1, Giza 178, Sakha 101 and Sakha 104 for potassium content, Giza 178 and Sakha 101 for nitrogen content, IET1444 and Moroberekan for relative water content and Giza 178 for water use efficiency might be considered as good combiner for physiological traits under two environments and their combined data. Hence, selection for improving such traits could be practiced either on mean performance or GCA effect basis with similar efficiency. Also, this agreement coincided the preponderance of additive genetic variance in this case.

Table 4: Estimates of general combining ability effects for the parental cultivars in the combined data (normal and drought conditions) for the studiedcharacters.

Genotypes	Days to heading(day)	No. of tillers/ plant	plant height (cm)	Panicle length (cm)	Flag Leaf area (cm^2)	Flag Leaf thickness (mm)
IET 1444	1.01	0.54	0.83	0.82	1.40*	0.01
Moroberekan	1.89**	-0.35	11.26**	0.90	1.72**	0.02
Hexi 30	-4.40**	-1.92*	-3.64*	-0.86	-4.22**	-0.01
BG 35-1	1.20*	-1.43*	-3.19*	-0.62	1.23*	-0.01
Giza 178	-0.50	3.10**	-1.86	0.25	1.43*	0.02
Giza 182	-2.60**	0.77	-2.68*	-0.52	-1.08*	0.01
Sakha 101	2.42**	0.02	-1.57	1.09*	-0.67	-0.01
Sakha 104	0.88	-0.74	0.86	-1.07	0.20	-0.02
LSD at 0.05 (gi)	1.04	1.36	2.52	0.99	1.00	0.19
LSD at 0.01 (gi)	1.54	2.01	3.72	1.46	1.49	0.27
LSD at 0.05 (gi-gj)	1.28	1.67	3.09	1.21	1.24	0.23
LSD at 0.01 (gi-gj)	1.90	2.47	4.58	1.80	1.83	0.34

*,**= Significant at 0.05 and 0.01 levels, respectively.Chlo. = Chlorophyll, Potass. = Potassium, effici.=efficiency

Table 4: Continued

Genotypes	Chlo. content	Potass. content	Nitrogen content	Relative water content	Water use effici.
IET 1444	-2.10**	-0.10	-0.01	4.62**	0.07
Moroberekan	0.38	-0.01	-0.01	2.52	-0.01
Hexi 30	0.30	-0.01	-0.02	-0.61	0.01
BG 35-1	-0.31	0.02	-0.01	-0.72	-0.04
Giza 178	0.11	0.05	0.04	1.53	0.04
Giza 182	0.65	-0.01	-0.01	-1.59	-0.03
Sakha 101	0.88	0.03	0.04	-2.76	-0.001
Sakha 104	0.09	0.05	-0.02	-3.01*	-0.03
LSD at 0.05 (gi)	1.34	0.31	0.17	2.89	0.37
LSD at 0.01 (gi)	1.98	0.45	0.25	4.28	0.54
LSD at 0.05 (gi-gj)	1.65	0.38	0.21	3.56	0.45
LSD at 0.01 (gi-gj)	2.43	0.56	0.30	5.267	0.67

*,**= Significant at 0.05 and 0.01 levels, respectively.Chlo. = Chlorophyll, Potass. = Potassium, effici.=efficiency

Specific combining ability effects:

Estimates of specific combining ability (SCA) effects for the hybrid combinations in the combined data for the studied traits are given in Table (5).

Twelve, out of the twenty-eight hybrid combinations showed highly significant negative specific combining ability effects for number of days to heading at the combined data. The crosses, IET 1444 x Moroberekan, IET 1444 x Giza 178, Moroberekan x Hexi 30, Moroberekan x Giza 182 and BG 35-1 x Sakha 104, were found to show useful heterosis at the combined data (Table 5). It is of interest to note that some of the rice cultivars which were involved in these superior five crosses, were found to be among the best combiners, while, others were among the poorest combiners for this trait.

For number of tillers/plant, ten hybrid combinations exhibited highly significant and positive specific combining ability effects at the combined data. Five of these crosses were found to show useful heterosis for this trait. For plant height, six hybrid combinations were detected to exhibit highly significant desirable specific combining ability effects at the combined data. Concerning panicle length, eight hybrid combinations exhibited significant positive specific combining ability effects at the combined data. Four crosses, namely IET 1444 x Sakha 101, Moroberekan x Giza 178, Moroberekan x Giza 182 and Moroberekan x Sakha 101 were found to show useful heterosis for this trait.

For flag leaf area, seven out of the twenty eight hybrid combinations showed highly significant and positive specific combining ability effects at the combined data. The highest SCA ability effects were detected from the crosses, IET 1444 x BG 35-1, Moroberekan x BG 35-1, Hexi 30 x Sakha 104, BG 35-1 x Giza 178, Giza 178 x Sakha 101 and Giza 182 x Sakha 104. Four out of these crosses showed highly significant heterosis, also, some of the parental cultivars which involved in these crosses, were found to be among the best general combiners for flag leaf area; i.e., IET1444, Moroberekan, BG35-1 and Giza 178, while, the others were among the poorest combiners for this trait.

With respect to flag leaf thickness, seven hybrid combinations showed not significant and positive specific combining ability effects in the combined data.

For chlorophyll content, four hybrid combinations showed highly significant positive specific combining ability effects for this trait in the combined data. The highest SCA effects were detected from the crosses, Moroberekan x Giza 178, Giza 178 x Giza 182 and Sakha 101 x Sakha 104. Some of these seven crosses showed useful heterotic effects (Table 5).

Concerning potassium content, three hybrid combinations showed significant and positive specific combining ability effects in the combined data. The best desirable cross was Moroberekan x Giza 182. Regarding the nitrogen content, two hybrid combinations; i.e., Hexi 30 x BG 35-1 and Giza 178 x Sakha 104, showed highly significant and positive specific combining ability effects for this trait in the combined data.

For relative water content, five hybrid combinations showed highly significant and positive specific combining ability effects for this trait in the combined data. The highest SCA effects were detected from the crosses, IET 1444x Moroberekan, IET 1444 x Sakha 101, Moroberekan x Sakha 101, BG 35-1 x Sakha 104, Giza 178 x Giza 182, Hexi 30 x Sakha 104 and Sakha 101 x Sakha 104. Some of these crosses showed useful heterotic effects. Concerning water use efficiency, four crosses out of twenty-eight exhibited highly significant and positive specific combining ability effects at the combined data. General and specific combining ability effects could indicate the excellent hybrid combinations obtained from crossing good by good, good by low and low by low general combiners. Consequently, it could be concluded that general combining ability effects of the parental lines were, generally, unrelated to the specific combining ability effects of their crosses.

It could be concluded that the most pronounced crosses, over the two environments and their combined data for flag leaf area, were IET 1444 x BG 35-1, Moroberekan x BG 35-1, Hexi 30 x Sakha 104, BG 35-1 x Giza 178, Giza 178 x Sakha 101 and Giza 182 x Sakha 104; for flag leaf thickness were seven hybrid combinations ; for chlorophyll content were Moroberekan x Giza 178, Giza 178 x Giza 182 and Sakha 101 x Sakha 104; for potassium content was Moroberekan x Giza 182; for nitrogen content were Hexi 30 x BG 35-1 and Giza 178 x Sakha 104; for relative water content were IET 1444 X Moroberekan, IET 1444 x Sakha 101, Moroberekan x Sakha 101, BG 35-1 x Sakha 104, Giza 178 x Giza 182, Hexi 30 x Sakha 104 and Sakha 101 x Sakha 104; for water use efficiency were Moroberekan x Giza 178, BG 35-1 x Sakha 104, Giza 178 x Giza 182 and Sakha 101 x Sakha 104. The obtained results are in harmony with those previously reported by El-Rafaee (2002), Yogameenakashi et al. (2003), Shehata (2004), Sheng *et al.* (2005).

Table 5: Estimates of specific combining ability effects for the crosses at the combined data (normal and drought conditions) for the studied characters studied.

Genotypes	Days to heading (day)	No. of tillers/ plant	plant height (cm)	Panicle length (cm)	Flag Leaf Area (cm^2)	Flag Leaf thicknes s (mm)
IET 1444 X Moroberekan	-5.13**	-0.39	11.30**	-0.14	1.20	0.03
IET 1444 X Hexi 30	2.73**	0.35	-8.78**	2.36**	-6.45**	0.01
IET 1444 x BG 35-1	2.45**	-0.90	-3.72	-0.89	3.68**	-0.01
IET 1444 x Giza 178	-3.29**	-0.50	7.45**	1.34	0.28	0.01
IET 1444 x Giza 182	1.21	1.94	-6.06**	-0.55	-3.00**	0.01
IET 1444 x Sakha 101	2.44**	-0.80	10.50**	2.37**	1.44	0.01
IET 1444 x Sakha 104	1.23	0.36	15.90**	0.99	-2.10**	0.01
Moroberekan X Hexi 30	-6.44**	-12.43**	-3.04	-4.38**	-4.90**	-0.02
Moroberekan x BG 35-1	-1.69*	-2.46	-3.65	-3.61**	6.08**	0.01
Moroberekan x Giza 178	-2.88**	4.29**	18.70**	4.21**	0.46	0.07
Moroberekan x Giza 182	-3.21**	4.79**	13.00**	4.36**	-2.77**	0.03
Moroberekan x Sakha 101	3.68**	-5.163**	11.60**	2.25**	-5.75**	0.03
Moroberekan x Sakha 104	4.49**	-5.90**	-20.50**	-4.00**	-8.92**	-0.03
Hexi 30 x BG 35-1	-1.14	-3.65**	-3.25	0.06	0.04	-0.01
Hexi 30 x Giza 178	-3.00**	-1.69	21.80**	2.62**	-0.25	-0.04
Hexi 30 x Giza 182	0.14	1.50	13.20**	0.79	-0.76	0.02
Hexi 30 x Sakha 101	2.63**	2.58*	1.46	-4.73**	1.32**	0.05
Hexi 30 x Sakha 104	3.3**	2.28	3.73	-1.33	6.23**	0.01
BG 35-1 x Giza 178	4.53**	5.41**	-1.48	-1.31	3.14**	0.01
BG 35-1 x Giza 182	-0.58	7.30**	-3.54	0.54	-1.68*	-0.03
BG 35-1 x Sakha 101	-2.04*	-1.60	3.68	2.11**	-1.79*	0.01
BG 35-1 x Sakha 104	-4.25**	-2.38	17.30**	-0.56	2.94**	0.01
Giza 178 x Giza 182	4.15**	-0.48	-11.80**	-0.07	-9.60**	0.01
Giza 178 x Sakha 101	-2.56**	1.58	-6.20**	-1.09	5.54**	-0.06
Giza 178 x Sakha 104	-2.02*	1.62	-9.82**	0.64	1.86*	-0.04
Giza 182 x Sakha 101	1.09	-4.60**	6.84**	-0.66	-0.84	-0.03
Giza 182 x Sakha 104	1.83*	-2.35	9.41**	4.16**	3.07**	0.02
Sakha 101 x Sakha 104	-3.24**	5.09**	-2.70	-0.02	0.33	0.01
LSD at 0.05	1.49	2.05	3.81	1.49	1.52	0.28
LSD at 0.01	2.01	2.77	5.15	2.01	2.05	0.38

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

Table 5: Continued

Genotypes	Chlo. content	Potass. content	Nitrogen content	Relative water content	Water use effici.
IET 1444 X Moroberekan	-0.70	0.16	-0.03	9.80**	0.08
IET 1444 X Hexi 30	-2.98**	0.01	0.02	-7.28**	-0.02
IET 1444 x BG 35-1	-0.53	0.3	0.02	-2.96	0.07
IET 1444 x Giza 178	0.51	0.16	0.08	-4.35**	0.02
IET 1444 x Giza 182	-0.3	0.13	-0.09	1.70	-0.04
IET 1444 x Sakha 101	0.23	-0.01	0.05	6.66**	-0.12
IET 1444 x Sakha 104	2.89**	-0.20	0.14	-4.02	0.11
Moroberekan X Hexi 30	1.98	-8.5**	-2.7**	-7.80**	0.32
Moroberekan x BG 35-1	-2.47*	0.13	-0.01	4.00	-0.2
Moroberekan x Giza 178	7.56**	0.05	-0.01	-4.07	0.33
Moroberekan x Giza 182	0.70	0.31	-0.07	2.38	0.01
Moroberekan x Sakha 101	-0.47	0.12	0.01	6.28**	-0.01
Moroberekan x Sakha 104	-0.98	0.02	0.08	-24.70**	-0.07
Hexi 30 x BG 35-1	-1.75	0.2	0.16	-6.50**	-0.03
Hexi 30 x Giza 178	-0.56	0.32	-0.03	-9.41**	-0.03
Hexi 30 x Giza 182	1.63	0.07	0.04	2.78	0.10
Hexi 30 x Sakha 101	-1.41	0.24	0.01	0.69	0.30
Hexi 30 x Sakha 104	-1.13	0.17	-0.05	4.72*	-0.06
BG 35-1 x Giza 178	-3.02**	0.003	-0.05	-6.24**	-0.09
BG 35-1 x Giza 182	-0.85	0.001	0.01	3.05	0.33
BG 35-1 x Sakha 101	-1.30	-0.20	0.06	8.85**	0.11
BG 35-1 x Sakha 104	0.66	-0.20	0.001	9.17**	0.08
Giza 178 x Giza 182	3.52**	-0.20	0.01	2.48	-0.01
Giza 178 x Sakha 101	-1.55	-0.10	-0.08	-2.96	0.10
Giza 178 x Sakha 104	0.32	0.16	0.14	-2.13	-0.14
Giza 182 x Sakha 101	-1.76	0.24	0.16	-11.20**	-0.14
Giza 182 x Sakha 104	-1.06	0.25	0.01	-15.90**	0.16
Sakha 101 x Sakha 104	4.52**	0.18	-0.12	3.25	0.02
LSD at 0.05	2.03	0.47	0.25	4.38	0.56
LSD at 0.01	2.74	0.63	0.34	5.91	0.75

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

Nature and degree of dominance (potence ratio):

The potence ratio values for number of days to heading (Table 6) were more than unity in the crosses, IET 1444 x BG 35-1, IET 1444 x Giza 178, IET 1444 x Sakha 101, IET 1444 x Sakha 104, Moroberekan x BG 35-1, Moroberekan x Giza 178, Moroberekan x Sakha 101, Moroberekan x Sakha 104, BG 35-1 x Giza 178, Giza 178 x Sakha 104, Giza 178 x Sakha 101, BG 35-1 x Sakha 104, Sakha 101 x Sakha 104, indicating the presence of over-dominance for these crosses at the combined data . Potence ratio values were less than unity in twelve crosses indicating the presence of partial dominance for this trait. However, it was found to be inconsistent from environment to environment and ranged from partial to over-dominance for the crosses studied.

Potence ratio values exceeded unity in fifteen crosses for plant height at the combined data, while, partial dominance was found in Moroberekan x Hexi 30 cross, since the potence ratio value was less than unity (-0.31), Table (6). The degree of dominance according to potence ratio in Table 6 indicated that panicle length behaved as an over- dominance trait, since its values were more than unity in fourteen crosses. Partial dominance was found in the crosses, IET 1444 x Giza 182, IET 1444 x Sakha 104, BG 35-1 x Giza 182, Giza 178 x Sakha 101 and Giza 182 x Sakha 101 in the combined data, since potence ratio values were less than unity.

The potence ratio values exceeded unity for panicle length in fourteen crosses at the combined data where their values were more than unity. While, five crosses; viz., IET 1444 x Giza 182, Moroberekan x Giza 182, BG 35-1 x Sakha 104, Giza 178 x Giza 182 and Sakha 101 x Sakha 104 showed partial- dominance and the other crosses showed inconsistent values. Five out of 28 crosses showed over-dominance in the combined data for flag leaf area since the potence ratio values were more than unity. While, two crosses; viz., BG 35-1 x Sakha 101 and BG 35-1 x Sakha 104, had partial dominance and the remaining crosses differed in potence ratio from environment to environment.

Chlorophyll content behaved as an over- dominance trait in eight crosses, since their values were more than unity. Three crosses; namely, IET 1444 x Giza 182, IET 1444 x Sakha 101 and BG 35-1 x Sakha 104, had partial dominance, where, the potence ratio was less than unity. The other crosses differed in potence ratio from environment to environment, where the degree of dominance was between over- to partial dominance. Eighteen out of 28 crosses exhibited over-dominance in the two environments and their combined data for chlorophyll content, since the potance ratios were more than unity. While, partial dominance was observed in IET 1444 x BG 35-1 and BG 35-1 x Giza 182 crosses and the others differed in potence ratio from environment to environment. Nitrogen content behaved as over- dominance, since its values were more than unity in thirteen crosses. The potence ratio was less than unity in six crosses at the two environments and their combined data, indicating partial dominance in these crosses.

Potence ratio estimates were more than unity in eleven crosses in both environments and their combined data for relative water content. The three crosses, i.e., IET 1444 x Sakha 101, Hexi 30 x Sakha 101 and Sakha 101 x Sakha 104, showed partial dominance at the combined data. While, the potence ratio differed from environment to environment for this trait in the other crosses. Potance ratio was more than unity in eleven out of twenty-eight crosses at the two environments and their combined data for water use efficiency, indicating the presence of over –dominance. While, the other crosses differed in potence ratio from one environment to another.

Table 6: Estimates of potence ratio for the crosses in the combined data (normal and drought conditions) for the studied character.

Genotypes	Days to heading (day)	No. of tillers/plant	Plant height (cm)	Panicle Length (cm)	Flag Leaf area (cm^2)	Flag Leaf thickness (mm)
IET 1444 X Moroberekan	-2.63	1.12	-1.82	0.51	-1.35	5.17
IET 1444 X Hexi 30	0.74	0.83	0.20	0.88	-1.38	3.00
IET 1444 x BG 35-1	2.63	0.23	-0.09	-2.36	0.39	-0.17
IET 1444 x Giza 178	-16.07	3.50	-6.86	0.99	-0.77	0.43
IET 1444 x Giza 182	0.65	4.92	-0.36	0.31	-4.27	1.67
IET 1444 x Sakha 101	2.41	-0.71	-4.43	10.75	-0.40	3.00
IET 1444 x Sakha 104	4.43	7.43	-11.02	0.25	-0.87	1.33
Moroberekan X Hexi 30	0.23	14.79	-0.32	-4.92	-1.16	0.01
Moroberekan x BG 35-1	-2.62	0.64	-0.02	-3.71	-12.02	0.01
Moroberekan x Giza 178	-2.70	2.55	-2.06	9.11	-1.36	2.60
Moroberekan x Giza 182	-0.40	4.77	-1.48	3.75	-20.58	-82.3
Moroberekan x Sakha 101	7.50	-0.71	-1.42	2.38	0.40	4.33
Moroberekan x Sakha 104	1.75	-1.14	1.80	-5.17	1.39	-1.78
Hexi 30 x BG 35-1	-0.01	-2.12	-0.23	-4.99	1.68	-0.67
Hexi 30 x Giza 178	-0.44	0.54	-9.93	1.89	-0.26	-0.93
Hexi 30 x Giza 182	-0.33	2.81	-15.22	0.61	-1.00	1.67
Hexi 30 x Sakha 101	0.61	0.78	-23.58	-7.77	0.09	5.33
Hexi 30 x Sakha 104	0.90	1.17	-1.39	-1.88	2.48	3.33
BG 35-1 x Giza 178	4.00	3.52	-1.07	-0.39	2.06	-0.47
BG 35-1 x Giza 182	0.06	16.73	-0.10	0.60	-0.53	-6.33
BG 35-1 x Sakha 101	-3.33	-0.73	-2.40	1.68	1.21	-0.33
BG 35-1 x Sakha 104	2.71	-1.58	-7.82	-1.13	5.65	-0.78
Giza 178 x Giza 182	0.87	2.29	3.33	2.76	-7.50	0.20
Giza 178 x Sakha 101	-2.48	15.55	-1.04	0.23	3.30	-2.10
Giza 178 x Sakha 104	3.67	-4.09	1.28	7.50	1.79	-1.42
Giza 182 x Sakha 101	0.50	-1.63	-17.97	0.42	-1.31	-2.67
Giza 182 x Sakha 104	0.89	-0.75	-2.70	1.24	0.01	1.11
Sakha 101 x Sakha 104	-1.03	3.47	-0.74	2.28	14.76	1.00

Table 6: Continued

Genotypes	Chlorophyll content	Potassium content	Nitrogen content	Relative water content	Water use efficiency
IET 1444 X Moroberekan	0.56	10.40	-0.71	1.24	1.18
IET 1444 X Hexi 30	-1.32	4.91	10.50	-7.5	0.80
IET 1444 x BG 35-1	-0.79	0.08	42.3	-0.5	1.00
IET 1444 x Giza 178	6.82	-1.60	-0.04	-6.45	1.19
IET 1444 x Giza 182	-0.03	27.60	3.90	-0.8	0.44
IET 1444 x Sakha 101	-0.13	3.59	0.08	0.38	-0.24
IET 1444 x Sakha 104	6.07	1.830	10.10	-5.3	1.39
Moroberekan X Hexi 30	0.98	20.40	0.22	-17.6	29.4
Moroberekan x BG 35-1	-1.11	1.50	3.13	0.31	0.04
Moroberekan x Giza 178	18.86	1.67	1.04	-18.7	3.46
Moroberekan x Giza 182	2.14	-2.20	-23.3	-0.67	0.65
Moroberekan x Sakha 101	0.22	3.33	2.92	0.48	2.84
Moroberekan x Sakha 104	8.70	2.98	1.30	-21.6	1.14
Hexi 30 x BG 35-1	-7.86	1.20	7.25	-1.21	5.61
Hexi 30 x Giza 178	0.03	2.44	0.80	-54.3	1.13
Hexi 30 x Giza 182	-0.17	6.52	0.03	-1.24	23.4
Hexi 30 x Sakha 101	-7.21	1.84	-0.58	-0.2	6.96
Hexi 30 x Sakha 104	-0.34	1.52	24.3	-12.3	1.57
BG 35-1 x Giza 178	-1.01	0.70	0.33	-0.92	0.21
BG 35-1 x Giza 182	-1.47	0.20	4.76	0.78	3.00
BG 35-1 x Sakha 101	-5.85	-0.70	0.02	5.42	4.36
BG 35-1 x Sakha 104	-0.10	-1.50	11.80	0.55	3.03
Giza 178 x Giza 182	3.22	0.69	0.81	-0.82	-3.76
Giza 178 x Sakha 101	-0.10	3.79	-10.30	-0.36	-2.76
Giza 178 x Sakha 104	9.10	34.7	2.12	-13	-1.00
Giza 182 x Sakha 101	-1.51	5.52	4.26	-1.65	0.43
Giza 182 x Sakha 104	0.52	3.50	1.43	-7.16	4.53
Sakha 101 x Sakha 104	2.13	7.87	-0.58	-0.13	24.2

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الملخص العربي

دراسات وراثية على بعض الصفات الفسيولوجية والصفات الخضرية المرتبطة بتحمل الجفاف فى الأرز

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أجريت هذه الدراسة في مزرعة مركز البحوث والتدريب في الأرز -سخا- كفر الشيخ- مصر خلال المواسم الزراعة 2005، 2006و 2007 لدراسة السلوك الوراثي لبعض الصفات الفسيولوجية والكيميائية المرتبطة بصفة تحمل الجفاف في الارز تم استخدام ثمانية أصناف من الأرز وهي أي إي تي 1444 ، وموروبريكن و هيكسي 30 و بي جي 35-1 و جيزه 178 و جيزة 182 و سخا 101 و سخا 104 . أجريت كل التهجينات الممكنة بين الاباء المذكورة لانتاج 28 هجين في الجيل الاول. وكانت الصفات المدروسة هي عدد الايام حتي التزهير ، طول النبات ، عدد الفروع/نبات ، طول السنبلة ، التفاف الورقة ، زاوية ورقة العلم، سمك ورقة العلم، محتوي الكلورفيل بالورقة، محتوي النتروجين بالورقة ، محتوي البوتاسيوم بالورقة ، محتوي الماء النسبي بالورقة ، دليل الحساسية للجفاف و كفاءة استخدام مياه الري.أظهر تحليل التباين لكل الصفات المدروسة معنوية عالية لصفات زاوية ورقة العلم و مساحة ورقة العلم و محتوي الكلوروفيل و محتوي الماء النسبى بالورقة بينما كانت صفات سمك ورقة العلم و محتوي البوتاسيم و محتوي النتروجين وكفاءة استخدام الماء غير معنوية. أظهرت النتائج أيضا تباين عالي المعنوية للاباء ضد الهجن لكل الصفات لكل الصفات المدروسة ماعدا سمك ورقة العلم و محتوي البوتاسيوم و محتوي النتروجين و كفاءة استخدام الماء تحت كل من البيئتين. ووجد تفاعلات

المدروسة عدا صفة سمك ورقة العلـم و محتـوي البوتاسـيوم و محتـوي النتروجين وكفاءة استخدام الماء مما يدل علي أن سلوك التراكيب الوراثيـة المستخدمة تختلف من بيئة الي أخري. أوضح تفاعل قوة الهجين لكل الهجن مع الظروف البيئية معنوية عالية لكل الصفات المدروسة ماعدا مساحة ورقة العلم و سمك ورقة العلم و محتوي البوتاسيوم ومحتوي النتروجين و كفـاءة استخدام الماء. أظهرت النتـائج أيـضا أن الابـاء أي إي تـي ١٤٤٤ و موروبريكن و بي جي ٣٥-١ و جيزه ١٧٨ و سخا ١٠٤ لها قدرة عامـة علي التالف جيدة لمعظم الصفات المدروسة. وكانت أفـضل القـيم للقـدرة الخاصة علي التالف لمعظم الصفات المدروسة للهجن أي إي تي ١٤٤٤ x سخا ١٠١ و موروبريكن x جيزه ١٧٨ و بي جي ٣٥-١ x سخا ١٠١. أظهرت الهجن أي إي تي ١٤٤٤ x سخا ١٠٤ و مـوروبريكن x جيـزة ١٧٨ و موروبريكن x سخا ١٠١ و جيزة ١٧٨ x سخا ١٠٤ قوة هجـين لكل الصفات المدروسة .اختلفت معظم هذه الهجن في درجة وإتجاه الـسيادة من ظروف بيئية الي أخري.