CATRINA (2009), 4 (3): 35 - 44

Combining Ability Analysis for Yield and Some Physiological Traits Related to Drought Tolerance in Rice

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ABSTRACT
The aim of this study was to investigate the differences in several adaptive mechanisms and estimating combining ability for drought tolerance in rice. For this objective, one-set of diallel mating design were made. The selected eight parents; (Sakha 104, Line 1368, Giza 178, Giza 177, IET1444, Sakha 101, Giza 159 and G 46B) and their twenty-eight F_1 crosses were grown in a randomized complete blocks design with three replicates. Two adjacent experiments were conducted, the first one was non stress (irrigated every 6-days) and the second one was water stress (irrigated every 9-days). The drought measurements recorded at anthesis stage, in addition, yield and some of its components. Mean squares associated with general and specific combining ability were highly significant for all drought measurements, except total amino acids at normal condition in the combined analysis where the values did not reach the level of significant. High GCA/SCA ratio variance was greater than unity for phenols, total amino acids, total soluble sugars, 1000-kernel weight, no. of grains/panicle and grain yield under both environments as well as their combined analysis, suggesting the importance of additive and additive x additive gene action in the expression of these traits. The parental varieties; Sakha104, IET1444 and Giza159 seems to be good combiners for most drought measurements under both environments as well as their combined analysis. These varieties could be considered as excellent parents in breeding program aimed to release high drought tolerant varieties. The best crosses under both irrigation treatments and the combined analysis were; (Sakha104 x Sakha101), (Sakha104 x G46B), (Giza177 x Sakha101) and (Giza177 x Giza159), where these crosses had highly $(\hat{S}_{ij})$ for most drought measurements.
Key words: Combining ability, drought, GCA, rice, SCA, stress, tolerance, yield.

INTRODUCTION

Rice is the preferred food by most Egyptians because it contributes about 20% to the per capita cereal consumption. It consumes about 18% of the total water resources; moreover, rice is also grown in very limited areas in the southern Delta and middle Egypt. The rice area is annually supposed to be over million feddans, but it highly increased during last five years due to better net return of rice comparing to other summer crops. In the middle of the 20^{th} century, the diallel cross technique was used by plant breeders for the genetic studies of continous variation. The application of diallel-cross technique was developed by Griffing (1956). Models and methods of the diallel analysis provides very useful information to plant breeders in making decisions concerning the type of breeding system and in selecting breeding materials that show the greatest promise for successful selection.

Drought is a major stress factor, which limits crop production in most areas of the world. Water stress leads to reactive oxygen production (Schwanz and Polle, 2001). Oxidative stress products include reactive oxygen species (ROS) which have a role in lipid peroxidation and membrane damage. Peroxidase decomposes H_2O_2 by oxidation of Co- substrates such as phenolic compounds and/or antioxidants (Sudha-kar *et al*., 2001).

When the water deficit occurs near the time of flowering rice, yield is dramatically reduced primarily as a result of increased spikelet sterility, which is closely related to minimum leaf or panicle water potential during the stress period for a single cultivar exposed to a range of water deficit treatments (Cruz and O'Toole, 1984). Yield reduction due to water stress depends very strongly on the timing of stress (Garrity and O'toole, 1994). The vegetative drought score, which is associated with genetic differences in leaf water potential and water extraction by roots, was not a good indicator of ability to tolerate stress at flowering (Puckridge and O'toole, 1981). Factors other than the ability to maintain plant water status also influence grain yield under stress.

Rice plants respond to drought by reducing production of new tillers and leaves, reducing leaf elongation, rolling of existing leaves and promoting leaf death (Hsiao *et al*., 1984; Turner *et al*., 1986). These responses reduce dry matter production and eventually grain yield.

The major objectives of the present investigation, were to assess the variations amongest a half diallel cross between eight rice varieties and/or lines for drought avoidance, drought tolerance characters and identify quick but reliable indices of selection for tolerance to water deficit.

MATERIALS AND METHODS

Choice the parents

To choice the parents, an experiment was carried out at El-Behira Governorate during season 2004. Seventeen rice *Oryza sativa* L. varieties and/or lines representing a wide range of diversity for several

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agronomic characters were selected for the study. The field experiment was laid out in (RCBD) with three replications, grains from each of these varieties and/or lines were sown at three irrigation treatments i.e., every 3 (continous flooding), 6 (normal irrigation) and 9 (stress) days intervals. Eight rice cultivars representing a wide range of diversity for several agronomic characters at tillering stage and drought resistance measurements were chosen according the previous evaluation stage to use it as parent in a half diallel mating design.

The names, pedigree and origin of these varieties and/or lines are presented in Table (1).

In the same growing season, another experiment was conducted at the farm of the Faculty of Agriculture, at Kafr El-Sheikh, Tanta University, where grains from each of the seventeen parental varieties and/or lines were sown at various sowing dates in order to overcome the differences in time of heading. All possible cross combinations without reciprocals were made between the selected eight parents giving total of twenty-eight F_1 crosses.

In summer season 2005, the eight parents and their twenty eight possible F_1 crosses were sown on 1^{st} May in the nursery. Thirty-days old seedlings were transplanted in plots., The eight rice cultivars and their resultant twenty eight crosses were planted using (RCBD) with three replicates in two field experiments conducted at the Faculty of Agriculture farm, at Tanta, Tanta university to evaluate them under two irrigation intervals, *i.e.*, irrigation every 6 and 9 days. Each plot consisted of one row, three meters long with 20 cm between rows and plants within row were 20 cm. apart to allowing a total of 15 plants per plot. The other cultural practices of growing rice were done as usual in the area. The mean temperature and relative air humidity as well as the wind speed in Tanta location during the growing season were recorded in Table (2).

The following paramaters were measured at anthesis stage: Total free amino acids, measured as described by Rosen (1957). Total soluble sugars, estimated as described by Dubois *et al*. (1956).

Total soluble indoles and phenols: a) Total soluble indoles was determined as the method of (Larsen *et al.*, 1962) and modified by (Selim *et al.*, 1978). b) Total soluble phenols was determined by using Folin Denis colorimetric (A.O.A.C., 1970) at 730 wave length.

Enzymes activity: a) Phenoloxidase, the method described by Broesh (1954) was used. b) Peroxidase activity was measured according to the method described by Fehrman and Dimond (1967).

Yield and some of its components: Data for the following traits were recorded as mean values of ten individual guarded plants per row (plot).

1. Number of panicles per plant, (bearing tillers/plant).
2. Number of grains per panicle.
3. 1000-kernel weight; in (g).
4. Grain yield per plant (g).

Statistical analysis

The data of all experiments were subjected to proper statistical analysis of variance according to Snedecor and Cochran (1967). The combined analysis was calculated for the data of the two experiments according to Cochran and Cox (1957). For comparison between means, Duncan's multiple range test was used, as proposed by Duncan (1955). General (GCA) and specific (SCA) combining ability estimates were obtained by employing diallel cross analysis Griffing (1956) designated as method 2 model I.

RESULTS AND DISCUSSION

Analysis of Variance

The present study was carried out to investigate the combining ability of eight parental rice varieties or lines by means of diallel cross system for some chemicals traits, yield and some yield components. To achieve this target, half diallel cross was studied. The analysis of variance for combining ability in both environments as well as their combined analysis are presented in Tables (3 and 4).

Table (1): Origin, type and characteristics of the rice cultivars used in the study.

No.	Entry	Origin and Parentage	Type	Characters
1	Sakha 104 (P1)	Egypt GZ 4096-8-1/GZ 4100-9-1	Japonica semidwarf	Tolerance to drought
2	Line 1368 (P2)	Egypt IR1615/31* BG94/2	Indica semidwarf	Moderate to drought
3	Giza 178 (P3)	Egypt Giza 175/Milyang 49	Indica/ Japonica	Moderate to drought
4	Giza 177 (P4)	Egypt Giza 171/Yamji No 1/ Pi No. 4	Japonica semidwarf	Susceptible to drought
5	IET1444 (P5)	India TNI/Co 29	Indica semidwarf	Tolerance to drought
6	Sakha 101 (P6)	Egypt Giza 176 / Milyang 79	Japonica semidwarf	Moderate to drought
7	Giza 159 (P7)	Egypt Giza 14/Agami M1	Japonica Tall	Tolerance to drought
8	G 46B (P8)	China maintainer for G46A WA Cytosterility	Indica semidwarf	Moderate to drought

The variance associated with General Combining Ability (GCA) as well as Specific Combining Ability (SCA) was highly significant for all traits under normal and stress conditions as well as the combined analysis, except SCA mean square for total amino acids in normal condition where it was not significant. This indicated that both additive and non-additive types of gene action were involved in determining the performance of single cross progeny for the traits in question. Tongmin and Xinggui (1991) found that GCA and SCA mean squares were significant for number of spikelets/panicle. Aly *et al.* (1981) reported that the additive and non-additive genetic variances were important in the heritance of grain yield.

To reveal the nature of genetic variance, which had greater role, GCA/SCA ratios were computed. Ratio of GCA/SCA variance was less than unity for indoles, phenoloxidase enzyme and peroxidase enzymes in both environments as well as their combined analysis. Also, for bearing tillers the ratio was less than unity in stress condition. This would indicate the importance of non-additive gene action in determining these characters mentioned before.

On the other hand, ratio of GCA/SCA variance was greater than unity for phenols, total amino acids, total soluble sugars, 1000-kernel weight, no. of grains/panicle and grain yield per plant at both environments as well as the combined analysis. In all above cases, the results suggested the importance of additive and additive x additive gene action in the expression of these traits. Similar results were observed previously by Murthy and Shivashankar (1992) which confirming that additive gene action was important for grain yield/plant. Narayan and SreRangasamy (1990), El-keredy *et al.* (1994), and El-Abd (1995) found that additive and non-additive were important in the inheritance of yield and its components. Ronggai *et al.* (1995) reported that GCA variance was more important than SCA one for 1000-grain weight.

Highly significant mean squares of the interaction between irrigation and both types of combining ability were detected for all traits, revealing that the magnitude of all types of gene action varied from environment to another, except total amino acids where the both types of GCA x I and SCA x I interaction were insignificant.

For all studied traits, peroxidase enzyme, 1000-grain weight and grain yield/plant only revealed that the ratio of GCA $_{normal}$/GCA $_{stress}$ variances exceeded the unity. This indicated that the normal irrigation regime is more suitable to estimate GCA variance than stress one for the traits in consideration. The other traits, where the same ratio less than unity, indicated that the stress environment (irrigation every 9 days) is more relevant for estimating GCA variance than the normal irrigation (irrigation every 6 days).

The ratio of SCA $_{normal}$ / SCA $_{stress}$ was exceeded unity for grain yield/plant, indicating the suitability of normal environment to estimate SCA variance than stress one for the trait in question. The other traits, where the same ratio was less than unity would indicate the suitability of stress condition to estimate SCA variance than normal ones for these traits.

It is fairly evident that, ratios for SCA x I/SCA were nearly similar with ratios for GCA x I/GCA for most traits. Such results indicated that additive and non-additive gene effects were similarly influenced by the irrigation treatments.

Table (2): Monthly average of temperature, relative humidity and evaporation mm/month during 2005 season, Gharbia governorate.

Months	Temperature C		R.H. (%)	Evaporation
	Min	Max		
May-05	16.7	29.7	47	7.1
Jun-05	19.9	30.6	52	7.6
Jul-05	21.5	32.3	60	7.8
Aug-05	21.9	32	65	7.6
Sep-05	19.3	31.6	64	6.3
Oct-05	17.1	27.9	63	4.8
Nov-05	13.5	23.7	66	2.9
Dec-05	11.6	19.9	70	2.1

Table (3): Observed mean squares from general and specific combining ability from diallel cross analysis for all studied traits at anthesis stage.

Source of variation	df		Total amino acids (mg/g dwt)			Total soluble sugars (mg/g dwt)			indoles (mg/g fwt)		
	I	Comb.	6 days	9 days	Comb.	6 days	9 days	Comb.	6 days	9 days	Comb.
Irrigation	-	1	-	-	112.49**	-	-	5499.83**	-	-	63.563**
Replicais / I	2	4	25.2**	22.034*	23.619**	33.095**	16.761*	24.928**	0.315*	0.031	0.173
Genotype	35	35	9.458**	30.024**	34.837**	52.876**	114.394**	153.024**	4.640**	6.262**	9.180**
GCA	7	7	4.010*	10.27**	13.09**	25.503**	64.306**	83.255**	1.157**	1.604**	2.149**
SCA	28	28	2.938	9.942**	11.24**	15.656**	31.588**	42.946**	1.644**	2.208**	3.288**
GCA X I	-	7	-	-	1.193	-	-	6.554**	-	-	0.613**
SCA X I	-	28	-	-	1.637	-	-	4.297**	-	-	0.564**
Error	70	140	1.504	1.552	1.528	1.722	1.595	1.658	0.032	0.035	0.034
GCA/SCA	-	-	1.365	1.033	1.164	1.629	2.036	1.939	0.704	0.726	0.653
GCAXI/GCA	-	-	-	-	0.091	-	-	0.079	-	-	0.285
SCAXI/SCA	-	-	-	-	0.146	-	-	0.1	-	-	0.172
GCAXI/SCAXI	-	-	-	-	0.72	-	-	1.52	-	-	1.08
GCAnormal/GCA stress	-	-	-	-	0.39	-	-	0.39	-	-	0.72
SCA normal/SCA stress	-	-		-	0.29	-	-	0.49	-	-	0.74

Table (3): cont.

Source of variation	df		Phenols (mg/100g fwt)			Phenoloxidaze enzyme (OD)			Peroxidase enzyme (OD)		
	I	Comb.	6 days	9 days	Comb.	6 days	9 days	Comb.	6 days	9 days	Comb.
Irrigation	-	1	-	-	56083.3**	-	-	0.55671**	-	-	0.08129**
Replicais / I	2	4	6744.3**	9369.5**	8056.91**	0.00005**	0.00053**	0.00029**	0.0003	0.0027**	0.00151**
Genotype	35	35	19319.9**	27455.6**	39592.7**	0.00041**	0.00090**	0.00111**	0.0024**	0.0066**	0.00741**
GCA	7	7	8138.5**	13264**	18510**	0.00012**	0.00016**	0.00023**	0.0002**	0.0012**	0.00097**
SCA	28	28	6015.33**	8123.7**	11869.4**	0.00014**	0.00033**	0.00041**	0.0001**	0.00248**	0.00284**
GCA X I	-	7	-	-	2892.9**	-	-	0.00006**	-	-	0.00035**
SCA X I	-	28	-	-	2269.6**	-	-	0.00007**	-	-	0.00061**
Error	70	140	1.306	1.815	1.56	0.000002	0.000001	0.000001	0.00003	0.00001	0.00002
GCA/SCA	-	-	1.353	1.633	1.559	0.841	0.490	0.552	0.163	0.466	0.341
GCAXI/GCA	-	-	-	-	0.156	-	-	0.259337	-	-	0.35689
SCAXI/SCA	-	-	Z	-	0.191	-	-	0.168536	-	-	0.21435
GCAXI/SCAXI	-	-	-	-	1.27	-	-	0.85	-	-	0.57
GCAnormal/GCA stress	-	-	-	-	0.61	-	-	0.75	-	-	0.16
SCA normal/SCA stress	-	-	-	-	0.74	-	-	0.42	-	-	0.04

*and ** significant at 0.05 and 0.01 respectively.

Table (4): Observed mean squares for GCA, SCA and their combined with environments for yield and some components.

Source of variation	df		No. of bearing tillers			No of grains/Panicle			1000 Kernel wieght (g)			Grain yield/plant (g)		
	I	Comb.	6 days	9 days	Comb.	6 days	9 days	Comb.	6 days	9 days	Comb.	6 days	9 days	Comb.
Irrigation	-	1	-	-	433.07**	-	-	3565.3**	-	-	125.97**	-	-	9247.79**
Replicais / I	2	4	31.095**	65.92**	48.505**	75.048**	222.03**	148.54**	43.542**	42.733**	43.138**	702.64**	988.49**	845.566**
Genotype	35	35	34.253**	53.57**	72.879**	1803.4**	2711.6**	4036.43**	21.007**	19.216**	36.251**	411.85**	355.002**	732.587**
GCA	7	7	13.69**	17.378**	27.42**	828.44**	1550.2**	2191.24**	20.43**	13.98**	31.91**	229.298**	179.54**	394.12**
SCA	28	28	10.85**	17.975**	23.51**	544.30**	742.3**	1134.04**	3.645**	4.512**	7.127**	114.280**	103.03**	206.71**
GCA X I	-	7	-	-	3.648**	-	-	187.385**	-	-	2.502**	-	-	14.718**
SCA X I	-	28	-	-	5.313**	-	-	152.562**	-	-	1.030**	-	-	10.599**
Error	70	140	0.8	0.456	0.628	3.518	2.083	2.801	0.26014	0.08385	0.172	1.867	1.321	1.594
GCA/SCA	-	-	1.262	0.967	1.166	1.522	2.088	1.932	5.605	3.099	4.477	2.006	1.743	1.907
GCAXI/GCA	-	-	-	-	0.133	-	-	0.086	-	-	0.078	-	-	0.037
SCAXI/SCA	-	-	-	-	0.226	-	-	0.135	-	-	0.144	-	-	0.051
GCAXI/SCAXI	-	-	-	-	0.68	-	-	1.22	-	-	2.43	-	-	1.38
GCAnormal/GCA stress	-	-	-	-	0.78	-	-	0.53	-	-	1.46	-	-	1.27
SCA normal/SCA stress	-	-	-	-	0.60	-	-	0.73	-	-	0.80	-	-	1.11

*and ** significant at 0.05 and 0.01 respectively.

General combining ability effects

The parents with higher positive significant GCA effects are considered as good combiner, while those with negative GCA effects are poor general combiners (Griffing, 1956; Phan and long, 1991; Rotton and Singh, 1991; and El-Keredy *et al.* 1992).

General combining ability effects ($\hat{g}_i$) of each parent for the drought measurements as well as the yield and some of its component contributing variation of drought resistance at both conditions as well as the combined analysis were presented in Table (5 and 6). Such effects were used to compare the average performance of each parent with other parents and facilitate selection of parents for further improvement to drought tolerance.

General combining ability effects ($\hat{g}_i$) in this study were found to be significantly differed from zero in all drought measurements. High positive values would be of interest under all the studied drought measurements in question. Only one parent; (Sakha104) for total amino acids, four parents; (Sakha104, Giza178, IET1444 and Sakha101) for phenols, two parents; (Sakha104 and Giza178) for indols, two parents; (Sakha104 and Giza159) for peroxidase enzyme, three parents; (Sakha104, IET1444 and Sakha101) for phenoloxidase enzyme, two parents; (IET1444 and Giza159) for number of bearing tillers and four parents; (Sakha104, Giza177, Sakha101 and Giza159) for grain yield were expressed as good combiners (Table 5 and 6).

Generally, the parental varieties Sakha104, IET1444 and Giza159 seems to be good combiners for most drought measurements in both environments and their combined analysis. Therefore, these varieties could be considered as excellent parents in breeding program aimed to release high drought tolerant varieties.

Specific combining ability effects

The data presented in Tables (7 and 8) showed the estimates of specific combining ability effects $(\hat{S}ij)$ of the parental combinations for total amino acids, total soluble sugars, phenols, indols, peroxidase enzyme, phenoloxidase enzyme, bearing tillers, 1000-kernal weight, number of grains per panicle and grain yield.

For total amino acids, four crosses gave highly and/or significant $(\hat{S}ij)$ at normal, stress environments and the combined analysis. The best cross was (Giza177 x Giza159) for this trait.

With regard to total soluble sugars, highly significant $(\hat{S}ij)$ were found in eight crosses under normal and stress conditions as well as the combined data. Three crosses; (Sakha104 x Sakha101), (Sakha104 x G46B) and (Giza177 x Giza159) had the highest $(\hat{S}ij)$ for this trait.

Nine and thirteen parental combinations expressed highly significant $(\hat{S}ij)$ for phenols and indols, respectively, at normal and stress environments as well as the combined analysis. Two parental combinations; (Sakha104 x G46B) and (Giza177 x Giza159) for phenols and two crosses; (Giza177 x Sakha101) and (Giza177 x Giza159) for indols gave the highest desirable $(\hat{S}ij)$. Ten parental combinations exhibited highly and/or significant $(\hat{S}ij)$ for peroxidase enzyme at both irrigation conditions and the combined over them. The best combinations were; (Sakha104 x Sakha101), (Sakha104 x G46B), (Giza177 x Sakha101) and (Giza177 x Giza159). While for phenoloxidse enzyme, five crosses gave highly significant $(\hat{S}ij)$ under normal and stress environments as well as the combined data. Two crosses; (Sakha104 x G46B) and (Giza177 x IET1444) gave the highest $(\hat{S}ij)$ for this trait.

With regard to number of bearing tillers, nine parental combinations exhibited highly and/or significant desirable $(\hat{S}ij)$ normal and stress as well as the combined analysis. The best crosses were (Sakha104 x G46B) and (IET1444 x Giza159) under the same conditions.

For 1000-kernel weight, highly significant $(\hat{S}ij)$ were obtained in eight parental combinations at both irrigation treatments and the combined analysis. Two crosses; (Giza178 x Giza159) and (Giza178 x G46B) gave the highest desirable $(\hat{S}ij)$ under the same conditions.

Table (5): Estimates of general combining ability effects of parents for all studied traits at anthesis stage under both environments as well as the combined analysis.

Parent		Total amino acids (mg/g dwt)			Total soluble sugars (mg/g dwt)			indoles (mg/g fwt)		
		6-days	9-days	Comb.	6-days	9-days	Comb.	6-days	9-days	Comb.
Saka 104	gi	1.316**	2.235**	1.776**	1.914**	3.306**	2.610**	0.246**	0.348**	0.297**
Giza 1368	gi	-0.624	-1.267**	-0.95**	-2.619**	-4.056**	-3.337**	-0.384**	-0.242**	-0.313**
Giza 178	gi	0.100	-0.374	-0.137	-0.478	-1.032**	-0.755**	0.149**	0.219**	0.184**
Giza 177	gi	-0.622	-0.37	-0.496**	-0.349	-2.056**	-1.203**	-0.661**	-0.611**	-0.636**
IET1444	gi	-0.234	-0.038	-0.136	1.038**	1.236**	1.137**	0.103	0.473**	0.288**
Saka 101	gi	-0.005	0.117	0.056	-0.844*	-0.022	-0.433**	0.057	0.359**	0.208**
Giza 159	gi	0.375	0.203	0.289*	2.135**	3.232**	2.683**	0.177**	-0.172**	0.002
G46B	gi	-0.306	-0.507	-0.406**	-0.796*	-0.609	-0.703**	0.312**	-0.374**	-0.031
L.S.D.(gi) 5%		0.722	0.733	0.286	0.772	0.743	0.297	0.105	0.111	0.042
1%		0.958	0.973	0.374	1.025	0.986	0.39	0.14	0.147	0.056
L.S.D. (gi-gj) 5%		1.091	1.109	0.542	1.168	1.124	0.564	0.159	0.167	0.08
1%		1.448	1.471	0.71	1.549	1.491	0.74	0.211	0.222	0.106

Parent		Phenols (mg/100g fwt)			Phenoloxidaze enzyme (OD)			Peroxidaze enzyme (OD)		
		6-days	9-days	Comb.	6-days	9-days	Comb.	6-days	9-days	Comb.
Saka 104	gi	38.81**	39.48**	39.15**	0.004**	0.003**	0.004**	0.005**	0.013**	0.009**
Giza 1368	gi	-28.31**	-56.86**	-42.58**	-0.004**	0.001*	-0.002**	-0.001	0.009**	0.004**
Giza 178	gi	26.83**	6.163**	16.498**	0.004**	-0.001**	0.001**	-0.006**	-0.017**	-0.011**
Giza 177	gi	-41.35**	-45.39**	-43.37**	-0.003**	-0.004**	-0.004**	-0.004*	-0.009**	-0.006**
IET1444	gi	10.47**	36.930**	23.702**	0.002**	0.004**	0.003**	0.003	-0.008**	-0.003**
Saka 101	gi	21.25**	8.060**	14.654**	0.001**	0.006**	0.004**	-0.001	0.003**	0.001*
Giza 159	gi	-16.57**	27.004**	5.216**	0.001*	-0.002**	-0.001**	0.005**	0.011**	0.008**
G46B	gi	-11.14**	-15.38**	-13.26**	-0.005**	-0.006**	-0.005**	-0.002	-0.002	-0.002**
L.S.D.(gi) 5%		0.673	0.793	0.289	0.001	0.001	0.0001	0.003	0.002	0.001
1%		0.892	1.052	0.378	0.001	0.001	0.0001	0.004	0.003	0.001
L.S.D. (gi-gj) 5%		1.017	1.199	0.547	0.001	0.001	0.001	0.005	0.003	0.002
1%		1.349	1.590	0.718	0.002	0.001	0.001	0.007	0.004	0.003

*and ** significant at 0.05 and 0.01 respectivelly.

Table (6): Estimates of general combining ability effects of parents for yield and its components under both environments as well as the environments as well as the combined analysis.

Parent		No.of bearing tillers			No. of grains/panicle			1000 Kernel wieght (g)			Grain yield/plant (g)		
		6-days	9-days	Comb.	6-days	9-days	Comb.	6-days	9-days	Comb.	6-days	9-days	Comb.
Saka 104	gi	1.245**	-0.164	0.541**	2.718**	1.496**	2.107**	2.484**	1.101**	1.792**	2.378**	2.924**	2.651**
Giza 1368	gi	-0.491	-0.303	-0.397**	-13.31**	-13.06**	-13.19**	-0.566**	-0.824**	-0.695**	-7.956**	-5.426**	-6.691**
Giza 178	gi	0.183	0.840**	0.512**	-8.955**	-7.566**	-8.261**	-1.308**	-1.388**	-1.348**	-1.686**	-0.228	-0.957**
Giza 177	gi	-0.772**	-1.888**	-1.330**	-9.505**	-15.76**	-12.63**	1.347**	1.122**	1.235**	-1.645**	-4.188**	-2.917**
IET1444	gi	1.630**	1.487**	1.558**	5.399**	8.564**	6.981**	-1.552**	-0.780**	-1.166**	3.368**	1.478**	2.423**
Saka 101	gi	-1.142**	-0.815**	-0.979**	6.829**	4.918**	5.873**	0.519**	1.105**	0.812**	5.514**	4.424**	4.969**
Giza 159	gi	0.896**	1.929**	1.413**	10.357**	22.538**	16.448**	0.306*	1.020**	0.663**	4.719**	5.398**	5.058**
G46B	gi	-1.549**	-1.086**	-1.318**	6.467**	-1.132**	2.667**	-1.231**	-1.357**	-1.294**	-4.691**	-4.382**	-4.536**
L.S.D.(gi) 5%		0.527	0.398	0.183	1.104	0.85	0.387	0.3	0.17	0.096	0.804	0.677	0.292
1%		0.698	0.527	0.24	1.465	1.127	0.507	0.398	0.226	0.126	1.067	0.898	0.382
L.S.D. (gi-gj) 5%		0.796	0.601	0.347	1.669	1.284	0.733	0.454	0.258	0.182	1.216	1.023	0.553
1%		1.056	0.797	0.455	2.215	1.704	0.962	0.602	0.342	0.238	1.613	1.357	0.726

*and ** significant at 0.05 and 0.01 respectivelly

Table (7): Estimation of specific combining ability for chemical traits under both environments as well as the combiend analysis.

Parent	Total amino acids (mg/g dwt)			Total soluble sugars (mg/g dwt)			indoles (mg/g fwt)		
	6-days	9-days	Comb	6-days	9-days	Comb	6-days	9-days	Comb
Saka 104 X Giza1368	-2.260*	-2.934*	-2.597**	-6.592**	-3.670**	-5.131**	-1.270**	-3.239**	-2.254**
X Giza 178	-0.857	-2.932*	-1.895*	-5.826**	-11.82**	-8.823**	-2.393**	-2.342**	-2.367**
X Giza 177	1.447	0.71	1.078	3.857**	-0.701	1.578	1.057**	1.071**	1.064**
X IET1444	1.203	1.647	1.425	2.850*	2.663*	2.756**	0.795**	0.776**	0.786**
X Saka 101	2.443*	7.151**	4.797**	5.962**	8.577**	7.269**	0.861**	0.951**	0.906**
X Giza 159	-2.753*	-4.335**	-3.544**	0.471	-0.052	0.21	0.413*	0.586**	0.500**
X G46 B	3.180**	5.868**	4.524**	6.904**	11.003**	8.954**	0.699**	1.756**	1.228**
Giza1368 X Giza178	-0.301	0.372	0.035	0.109	1.557	0.833	0.642**	0.722**	0.682**
X Giza 177	-0.019	-0.792	-0.406	0.609	1.042	0.825	-0.301	-0.604**	-0.453**
X IET1444	0.163	0.005	0.084	1.593	1.769	1.681*	0.831**	0.516**	0.673**
X Saka 101	-0.667	-0.26	-0.463	1.495	1.387	1.441	0.436**	1.019**	0.728**
X Giza 159	0.563	1.045	0.804	-1.204	-2.947*	-2.075*	0.768**	1.591**	1.179**
X G46 B	2.657*	0.876	1.766*	1.431	-3.880**	-1.225	-2.617**	-2.159**	-2.388**
Giza 178 X Giza 177	-1.003	-1.465	-1.234	-1.461	-3.249**	-2.355**	-0.749**	0.4	-0.175
X IET1444	2.921*	6.274**	4.597**	5.488**	7.813**	6.650**	0.353*	0.090**	0.222
X Saka 101	0.868	-1.185	-0.158	-3.748**	-4.398**	-4.073**	0.826**	0.967*	0.896**
X Giza 159	-0.25	-0.017	-0.134	2.116	2.500*	2.308**	0.429**	0.392**	0.411**
X G46 B	-0.79	-0.426	-0.608	4.626**	5.121**	4.874**	0.007	-1.082**	-0.538**
Giza 177 X IET1444	-1.009	-1.507	-1.258	3.383**	6.337**	4.860**	-0.972**	0.259	-0.357**
X Saka 101	-0.891	-0.666	-0.779	-3.729**	-4.499**	-4.114**	1.512**	1.160**	1.336**
X Giza 159	3.959**	8.788**	6.373**	4.497**	7.154**	5.825**	1.485**	2.022**	1.753**
X G46 B	-0.518	-1.156	-0.837	-2.683*	3.835**	0.576	0.889**	-0.381*	0.254*
IET1444 X Saka101	-0.426	-0.519	-0.473	1.818	4.495**	3.157**	-0.082	-0.516**	-0.299*
X Giza 159	-0.443	-1.628	-1.036	-0.256	-2.588*	-1.422	-2.355**	-2.357**	-2.356**
X G46 B	-1.72	-1.91	-1.815*	-4.757**	-9.016**	-6.887**	0.611**	1.365**	0.988**
Saka 101 X Giza 159	1.579	-0.218	0.681	3.581**	3.495**	3.538**	-2.391**	-1.937**	-2.164**
X G46 B	-0.555	-0.679	-0.617	-0.788	-1.429	-1.109	-0.578**	0.423*	-0.077
Giza 159 X G46B	-1.328	-1.31	-1.319	0.302	1.582	0.942	1.896**	-1.742**	0.077
L.S.D.(Sij) 5%	2.213	2.248	1.553	2.368	2.279	1.618	0.323	0.34	0.231
1%	2.936	2.982	2.037	3.141	3.023	2.122	0.428	0.45	0.303
L.S.D.(Sij-Sik) 5%	3.274	3.326	2.298	3.504	3.372	2.395	0.478	0.502	0.341
1%	4.344	4.413	3.014	4.648	4.473	3.14	0.634	0.667	0.448
L.S.D.(Sij-Slk) 5%	3.087	3.136	0.766	3.303	3.179	0.798	0.45	0.474	0.114
1%	4.095	4.16	1.005	4.382	4.217	1.047	0.598	0.628	0.149

* and ** significant at 0.05 and 0.01 levels of probability , respectively.

Table (7): Con.

Parent	Phenols (mg/100g fwt)			Phenoloxidaze enzyme (OD)			Peroxidaze enzyme (OD)		
	6-days	9-days	Comb	6-days	9-days	Comb	6-days	9-days	Comb
Saka 104 X Giza1368	-73.56**	-130.2**	-101.9**	-0.013**	-0.032**	-0.022**	-0.031**	-0.098**	-0.065**
X Giza 178	-79.17**	-139.4**	-109.3**	0.001	-0.009**	-0.004**	-0.062**	-0.082**	-0.072**
X Giza 177	75.918**	91.684**	83.801**	-0.010**	-0.016**	-0.013**	0.005	0.020**	0.012**
X IET1444	72.102**	56.877**	64.489**	0.010**	0.022**	0.016**	0.018**	0.052**	0.035**
X Saka 101	64.741**	86.639**	75.690**	0.013**	0.019**	0.016**	0.035**	0.049**	0.042**
X Giza 159	-110.4**	-75.74**	-93.08**	-0.015**	-0.016**	-0.016**	0.005	0.009**	0.007*
X G46 B	97.985**	110.21**	104.10**	0.027**	0.036**	0.031**	0.041**	0.065**	0.053**
Giza1368 X Giza178	34.649**	1.554	18.101**	-0.007**	0.008**	0.0005	0.01	0.020**	0.015**
X Giza 177	-68.24**	-111.8**	-90.01**	0.005*	-0.006**	-0.001	-0.021**	0.070**	0.025**
X IET1444	60.479**	103.03**	81.753**	0.011**	0.017**	0.014**	0.030**	0.019**	0.024**
X Saka 101	31.648**	83.700**	57.674**	0.003	-0.001	0.0012	0.008	0.002**	0.005
X Giza 159	45.361**	-27.49**	8.936**	0.006**	0.009**	0.007**	0.012*	0.001**	0.007*
X G46 B	-77.09**	49.379**	-13.85**	-0.024**	-0.014**	-0.016**	-0.003	0.004	0.001
Giza 178 X Giza 177	-97.99**	-37.98**	-67.98**	0.007**	0.0001	0.003**	0.014**	-0.006	0.004
X IET1444	16.813**	-1.617	7.598**	0.009**	-0.027**	-0.026**	-0.065**	-0.050**	-0.057**
X Saka 101	70.656**	17.661**	44.159**	0.001	0.003**	0.005**	0.045**	0.0004	0.023**
X Giza 159	6.607**	-19.75**	-6.573**	-0.002	0.019**	0.014**	0.011*	0.035**	0.023**
X G46 B	7.193**	-47.66**	-20.23**	0.012**	-0.005**	-0.002**	0.004	-0.037**	-0.016**
Giza 177 X IET1444	-14.9**	-113.6**	-64.25**	0.016**	0.028**	0.013**	-0.023**	-0.054**	-0.039**
X Saka 101	107.68**	142.95**	125.31**	-0.004*	0.016**	0.014**	0.027**	0.053**	0.040**
X Giza 159	161.77**	156.30**	159.03**	-0.001	0.025**	0.021**	0.033**	0.056**	0.045**
X G46 B	-55.55**	71.934**	8.194**	0.010**	-0.016**	-0.010**	-0.011*	-0.042**	-0.026**
IET1444 X Saka101	-43.21**	-31.86**	-37.53**	-0.006**	-0.007**	-0.004**	0.024**	0.023**	0.024**
X Giza 159	-118.9**	15.255**	-51.84**	-0.014**	-0.020**	-0.005**	0.009	-0.059**	-0.025**
X G46 B	108.07**	0.943	54.505**	-0.001	-0.013**	-0.010**	0.014**	0.009**	0.011**
Saka 101 X Giza 159	-22.00**	-40.91**	-31.46**	-0.007**	-0.020**	-0.017**	-0.066**	-0.063**	-0.064**
X G46 B	-20.94**	-60.26**	-40.59**	0.002	0.003**	0.001	-0.046**	-0.067**	-0.056**
Giza 159 X G46B	12.723**	61.893**	37.308**	0.003	-0.014**	-0.011**	0.015**	0.045	0.030**
L.S.D.(Sij) 5%	2.062	2.431	1.57	0.004	0.002	0.001	0.01	0.006	0.006
1%	2.735	3.225	2.058	0.005	0.002	0.002	0.014	0.008	0.008
L.S.D.(Sij-Sik) 5%	3.051	3.597	2.323	0.003	0.002	0.002	0.015	0.009	0.009
1%	4.047	4.771	3.045	0.004	0.003	0.003	0.02	0.011	0.011
L.S.D.(Sij-Slk) 5%	2.876	3.391	0.774	0.003	0.002	0.001	0.014	0.008	0.003
1%	3.816	4.499	1.015	0.004	0.003	0.001	0.019	0.011	0.004

* and ** significant at 0.05 and 0.01 levels of probability , respectively.

Fourteen parental combinations showed highly significant $(\hat{S}_{ij})$ for number of grains per panicle at normal, stress irrigation conditions and the combined over them. The best crosses were (Sakha104 x G46B), (Line 1368 x IET1444) and (Giza159 x G46B).

With regard to grain yield/plant, nine parental combinations showed highly significant positive $(\hat{S}_{ij})$ at both environments and the combined analysis. Only one cross; (Giza177 x Giza159) gave the highest desirable inter and intra-allelic interaction effects under the same conditions.

Results concerning general and specific combining abilities indicated that the excellent cross combinations were obtained from crossing good x good, good x poor combiners. If crosses showing high specific combining ability involve only one good combiner, such combination would throw out desirable transgressive segregates this provides that the additive genetic system present in the good combiner and complementary and epistatic effects present in the cross act in the same direction to reduce undesirable plant characteristics and maximize the character in view.

On the other hand, to get outstanding recombinants in segregating generations, the parents involved in the hybrid must be good combiners with insignificant$(\hat{S}_{ij})$of the hybrid, because selection of superior recombinants will be hinderd by significant $(\hat{S}_{ij})$. Therefore, it will be useful to select only such hybrids with non significant SCA effects and having parents with significant GCA effects Nadarajan, (1986), and Devaraj and Nadarajan, (1996). However, the best crosses at both irrigation treatments and the combined analysis were; (Sakha 104 x G46B) where $(\hat{S}_{ij})$ were possessed in all traits, except 1000-kernel weight. The cross; (Giza 177 x Sakha 101) expressed significant $(\hat{S}_{ij})$ for all traits, except total amino acids, total soluble sugars, no. of bearing tillers and 1000-kernel weight. The cross; (Sakha 104 x Sakha 101) exhibited significant $(\hat{S}_{ij})$ for all traits, except 1000-kernel weight and the cross; (Giza 177 x Giza 159) had significant $(\hat{S}_{ij})$ for all traits, except phenoloxidase enzyme and 1000-kernel weight. All these crosses exhibited $(\hat{S}_{ij})$ for these traits under normal, stress conditions and the combined analysis of both. However, it will be expected to obtain useful transgressive segregants from the progeny of these crosses in this case, the overdominance must be presence and responsible to heterotic effects and better parent heterosis must be significant for the traits in consideration. Morever, the breeding program which could be plan in segregating generations for the present materials should be bulk method aiming to reach some

Table (8): Estimation of specific combining ability for yield and someyiled componants under both environments as well as the combiend analysis.

Parent	No .of bearing tillers			No. of grains/panicle			1000 Kernel wieght (g)			Grain yield/plant (g)		
	6-days	9-days	Comb	6-days	9-days	Comb	6-days	9-days	Comb	6-days	9-days	Comb
Saka 104 X Giza1368	-3.559**	0.975	-1.292*	5.008**	-6.050**	-0.521	1.545**	-0.318	0.613*	-12.94**	-16.04**	-14.49**
X Giza 178	3.587**	0.015	1.801**	-6.862**	3.178*	-1.842	-0.013	0.231	0.109	-7.193**	-4.984**	-6.089**
X Giza 177	2.830**	-1.264*	0.783	12.100**	9.217**	10.658**	-0.863	0.606*	-0.129	9.290**	3.671**	6.481**
X IET1444	3.058**	3.352**	3.205**	1.798	-2.417	-0.309	1.808**	2.133**	1.970**	2.899*	-4.563**	-0.832
X Saka 101	2.156**	3.382**	2.769**	16.246**	12.870**	14.558**	0.884	1.338**	1.111**	13.042**	17.073**	15.057**
X Giza 159	-2.466**	-0.74	-1.603**	-15.07**	-25.96**	-20.52**	-2.758**	-3.337**	-3.048**	-7.595**	-9.940**	-8.768**
X G46 B	5.146**	2.941**	4.044**	31.101**	35.345**	33.223**	0.698	-0.570*	0.064	11.334**	15.649**	13.491**
Giza1368 X Giza178	1.947*	2.920**	2.434**	-5.203**	-0.809	-3.006**	1.410**	1.405**	1.407**	5.585**	2.159*	3.872**
X Giza 177	-1.3	-2.285**	-1.793**	-15.57**	-18.51**	-17.04**	-0.722	0.700**	-0.011	-10.14**	-7.665**	-8.903**
X IET1444	1.740*	1.674**	1.707**	27.921**	25.850**	26.886**	2.514**	2.812**	2.663**	5.256**	7.894**	6.575**
X Saka 101	2.859**	1.109	1.984**	12.879**	9.313**	11.096**	0.522	-0.193	0.164	-5.174**	-3.248**	-4.211**
X Giza 159	1.977*	-0.715	0.631	-2.233	-0.907	-1.57	1.853**	1.292**	1.573**	-2.001	-2.026	-2.014*
X G46 B	-1.879*	-0.74	-1.309**	-7.966**	-1.344	-4.655**	-3.467**	-3.640**	-3.554**	1.947	1.767	1.857*
Giza 178 X Giza 177	-0.585	-2.062**	-1.323**	-11.19**	1.597	-4.797**	-0.598	-1.551**	-1.075**	-5.315**	-0.918	-3.117**
X IET1444	-0.07	1.108	0.519	0.238	-8.244**	-4.003**	-0.929*	2.301**	0.686**	3.142*	5.344**	4.243**
X Saka 101	-0.743	9.921**	4.589**	12.175**	8.265**	10.220**	-1.606**	-0.979**	-1.293**	-3.683**	-2.951**	-3.317**
X Giza 159	4.788**	2.336**	3.562**	19.009**	15.296**	17.153**	3.753**	3.601**	3.677**	-8.104**	-6.568**	-7.336**
X G46 B	2.272**	-1.927**	0.173	13.305**	30.032**	21.669**	2.800**	3.064**	2.932**	-10.48**	-11.88**	-11.18**
Giza 177 X IET1444	0.704	0.051	0.377	28.801**	13.137**	20.969**	0.931*	0.962**	0.946**	-18.58**	-10.35**	-14.46**
X Saka 101	2.107*	0.061	1.084*	18.447**	27.829**	23.138**	-0.86	0.812**	-0.024	9.399**	7.494**	8.447**
X Giza 159	2.535**	5.461**	3.998**	3.394*	44.371**	23.883**	-0.642	-0.833**	-0.737**	30.698**	25.093**	27.895**
X G46 B	1.947*	4.256**	3.102**	30.234**	-25.41**	2.410*	0.77	-1.573**	-0.401	4.268**	5.083**	4.675**
IET1444 X Saka101	-0.337	-3.055**	-1.696**	-10.26**	-1.885	-6.073**	-0.206	-0.936**	-0.571*	-3.743**	-1.981	-2.862**
X Giza 159	4.200**	9.233**	6.717**	14.878**	39.382**	27.130**	1.023*	1.174**	1.098**	11.849**	10.955**	11.402**
X G46 B	-3.988**	-4.743**	-4.365**	-27.75**	-29.48**	-28.61**	-3.061**	-3.004**	-3.032**	1.751	-11.69**	-4.973**
Saka 101 X Giza 159	-1.562	-0.376	-0.969	19.512**	2.504	11.008**	-2.761**	0.314	-1.224**	-11.57**	-10.17**	-10.87**
X G46 B	-1.332	-2.574**	-1.953**	7.408**	34.959**	21.184**	0.51	0.246	0.378	-0.821	2.317*	0.748
Giza 159 X G46B	0.895	1.215	1.055*	35.249**	29.653**	32.451**	0.442	1.741**	1.091**	-0.483	4.214**	1.865*
L.S.D.(Sij) 5%	1.614	1.219	0.996	3.385	2.604	2.103	0.92	0.523	0.521	2.466	2.074	1.587
1%	2.141	1.617	1.306	4.49	3.455	2.758	1.221	0.693	0.683	3.271	2.752	2.081
L.S.D.(Sij-Sik) 5%	2.388	1.803	1.474	5.008	3.853	3.112	1.362	0.773	0.771	3.648	3.069	2.348
1%	3.168	2.392	1.932	6.644	5.112	4.08	1.807	1.026	1.011	4.84	4.071	3.079
L.S.D.(Sij-Slk) 5%	2.251	1.7	0.491	4.722	3.633	1.037	1.284	0.729	0.257	3.44	2.893	0.783
1%	2.987	2.255	0.644	6.264	4.82	1.36	1.703	0.967	0.337	4.563	3.839	1.026

* and ** significant at 0.05 and 0.01 levels of probability, respectively.

pure lines with high drought tolerance and high yielding ability.

It could be concluded that the presence of non-additive genetic variance offers scope for exploration of heterosis (Yadav *et al.,* 1999). Five parental combinations expressed highly significant for most traits. Therefore, these crosses i.e, (Sakha104 x IET1444), (Sakha104 x Sakha101), (Sakha104 x G46B), (Giza177 x Sakha101) and (Giza177 x Giza159) could be successfully used for breeding to drought tolerant on the basis of most previous drought measurements.

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Received July 20, 2008
Accepted May 20, 2009

تحليل القدرة على التآلف للمحصول وبعض الصفات الفسيولوجية المتعلقة بتحمل الارز للجفاف

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الملخص العربـــى

أجريت هذه الدراسة بهدف معرفة طبيعة المقاومة للجفاف فى الارز؛ ولتحقيق ذلك تم اختيار ثمانية أباء ضمن تجربة شملت 17 تركيبا وراثيا وتم دراسة الأتى:-

القدرة على التآلف و تفاعلها مع البيئة (التحليل الوراثى للصفات بواسطة الطريقة الثانية الموديل الاول لجريفنج (1956) لبعض صفات قياس الجفاف الهامة وكذلك صفات المحصول وبعض مكوناته فى الأرز.

نفذت التجربة فى مزرعة كلية الزراعة جامعة طنطا خلال موسمين زراعيين هما صيفى 2004 و 2005. فى السنة الأولى (صيف 2004) تم التهجين النصف الدائرى بين ثمانية أصناف من الأرز. وفى السنة الثانية (صيف 2005) تم تقييم الأباء الثمانية و الـ 28 هجين الناتجة عن التهجين التبادلى للاباء الثمانية فى تجربتين متجاورتين الاولى تروى كل 6 أيام والثانية تروى كل 9 أيام وقد صممت كل تجربة فى قطاعات كاملة العشوائية ذات ثلاث مكررات.

ويمكن تلخيص أهم النتائج فيما يلى:- (1) كانت النسبة بين التباين الراجع للقدرة العامة الى التباين الراجع للقدرة الخاصة على الائتلاف تفوق الوحدة لكل الصفات فيما عدا الاندولات وانزيمى الفينول اكسيديز والبيرواكسيديز فى كل من التجربتين والتحليل المشترك؛ مما يدل على ان جزء كبير من التباين الوراثى لهذه الصفات يرجع الى الفعل الجينى المضيف والمضيف X المضيف، (2) كان التفاعل بين كل من القدرة العامة والقدرة الخاصة على الائتلاف والرى عالى المعنوية لكل الصفات فيما عدا صفة الأحماض الكلية، (3) أوضحت النتائج أن الأباء سخا 104؛ IET1444؛ جيزة 159 كانت ذات قدرة عامة عالية على الائتلاف لمعظم صفات قياس الجفاف فى كل من التجربتين وكذلك التحليل المشترك ويمكن ادخال هذه الأباء فى برامج التربية التى تهدف لاستنباط اصناف مقاومة للجفاف، (4) كان أفضل الهجن هم: (سخا 104 x سخا 101)؛ (سخا 104 x G46B)؛ (جيزة 177 x سخا 101)؛ (جيزة 177 X جيزة 159) فى كل من التجربتين وكذلك التحليل المشترك, حيث أظهرت معنوية عالية للقدرة الخاصة على الائتلاف.