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GENETIC ANALYSIS FOR YIELD AND ITS COMPONENT TRAITS UNDER WATER STRESS CONDITION IN RICE (*Oryza sativa,* L.)

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ABSTRACT

Seven rice genotypes differed in their drought tolerance along with their 21 F_1 crosses obtained from a partial diallel crosses mating design were evaluated under water stress condition at the research farm of Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt during the two growing seasons of 2010 and 2011 to identify the superior parents and hybrids and to determine the appropriate breeding methods under this condition. The results indicated that, mean squares were highly significant for all studied traits indicating the presence of wide range of genetic variations among the parental lines used in this study. GCA/SCA ratio was greater than unity for panicles plant^{-1}; panicle weight and 1000-grain weight traits suggesting the preponderance of additive type of gene action in these materials. The ratio was less than unity for grain yield plant^{-1}, spikelet fertility percentage, filled grains panicle^{-1} and harvest index suggesting the preponderance of non-additive gene action. The drought tolerant parents: IRAT170; Moroberekan and Azuciena were the best general combiners for most yield and its component traits. High GCA effects showed the presence of favorable genes with additive type of gene action. Therefore, a multiple crossing program involving good general combiners found in the current study is recommended. Highly significant positive SCA effects were obtained by the cross Giza177 x Azuceina for all traits and the cross IR64 x Moroberekan for all traits except panicles plant^{-1}. Based on SCA effects among the 21 crosses, the desirable crosses were eight for grain yield plant^{-1}; seven for panicles plant^{-1}; five for panicle weight; six for 1000-grain weight; nine for filled grains panicle^{-1}; eight for spikelet fertility percentage and eleven for harvest index. F_1 hybrids were recommended because of their good SCA for yield and its component traits under water stress condition. The heritability estimates in broad sense were high for all traits and ranged from 86.3% for harvest index to 98.07% for filled grains panicle^{-1}. Low estimates of heritability in narrow sense were recorded for harvest index (14.62%); spikelets fertility percentage (16.03%) and grain yield plant^{-1} (17.53%). In contrary, the degree of dominance values were higher than unity for spikelets fertility percentage; harvest index and grain yield plant^{-1} traits indicating that the effect was of over-dominance type.

INTRODUCTION

Rice (*Oryza sativa*, L.) is one of the world's most important crops, providing a staple food for nearly half of the global population (FAO, 2004). In Egypt, rice is considered the second important cereal crop, following wheat, as a main food for the Egyptian population (Bastawisi *et al.,* 2003).

Drought is a severe abiotic stress which would cause serious losses in yield and productivity for most crops in arid and semi-arid regions (Atkinson *et al.,* 2000 and Massonnet *et al*., 2007). Thus, water stress is the major environmental factor that constrains the productivity and stability of crops (Araus *et al.,* 2002). It is estimated that, more than 50% of the world rice production area is affected by drought (Bouman *et al.,* 2005). Egypt is self-sufficient in rice, but due to a high population growth rate, presence of new diseases and pests, the ongoing process of climate changes and declines Egypt's share of the River Nile water; rice production would be declined to insufficient levels. The development of drought-tolerant varieties which maintain good yield under drought or water stress is of major priority for rice research for sustainable rice production.

There are three basic drought patterns affecting rice production i.e. early (occurring during vegetative growth, after establishment but before maximum tillering), intermittent, and late (occurring after panicle initiation) drought stresses. Yield reduction from early drought stress is often minimal and mainly results from a reduction in tillers number (Jongdee *et al*., 2006). Intermittent or continuous drought stress, occurring between the tillering and flowering stages, may greatly reduce yield as a result of reduced leaf expansion and photosynthesis (Fukai and Cooper, 1995). Late drought that occurs during later growing stages, especially during flowering, reduced spikelets fertility is the main factor contributing to yield loss (Liu *et al*., 2006).

Plants are most susceptible to water stress at the reproductive stage; Dramatic reduction of grain yield occurs when stress coincides with the irreversible reproductive processes, making the genetic analysis of drought tolerance at the reproductive stage crucially important (Boonjung and Fukai, 2000 and Pantuwan *et al.,* 2002).

Many studies on yield and its component traits in rice were reported by Abd Allah *et al.,* (2010); Muthuramu *et al.,* (2010) and Ali *et al.,* (2012); for general combining ability (GCA) and specific combining ability (SCA) and by Gaballah (2009); Ali *et al.,* (2012); Seyoum *et al.,* (2012) and Sohrabi *et al.,* (2012) for heritability in broad sense and in narrow sense.

The main objective of the present study was to assess combining ability; heritability and degree of dominance for yield and its component traits for several genotypes and their crosses under water stress condition and to identify the most desirable genotypes which would be used as a donor parents and as a best combiners in the rice breeding program.

MATERIALS AND METHODS

This study was carried out at the research farm of Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt during the two growing seasons of 2010 and 2011. Seven rice genotypes varied in their drought tolerance were utilized in this study. Name, pedigree, origin, type and some features of the studied genotypes are presented in Table 1. The parental genotypes were grown during 2010 growing season in three successive dates of planting of fifteen days intervals in order to overcome the differences in flowering time for each parent. At flowering stage the bulk emasculation method was practiced using hot water according to Jodon

(1938) and modified by Butany (1961). A partial diallel crossing was made among the seven parental genotypes to produce 21 F_1 hybrids. The F_1 seeds were separately harvested from each cross, and saved for sowing in the next season of 2011.

In 2011 growing season, seeds from each the genotype (crosses and their parents) were sown in the nursery. After thirty days from sowing, seedlings were individually transplanted in the permanent field in one row. Each row was five meters long with 20 cm between rows comprised 25 hills each thinned to single plant. The experiment was laid out in Randomized Complete Blocks Design (RCBD) with three replications. Plants were only irrigated every 12 days using flushing irrigation. All agricultural practices were carried out according to the recommendations of rice plantation. At reproductive stage, five plants were randomly selected from each genotype. Data were recorded on yield and yield component traits which included panicles plant^{-1}; panicle weight (g); 1000-grain weight (g); filled grains panicle^{-1}; spikelets fertility percentage (%); grain yield plant^{-1} (g) and harvest index (%).

Genetic analysis to estimate general combining ability (GCA) and specific combining ability (SCA) was performed using the Griffing (1956) method-2, model-1.

RESULTS AND DISCUSSION

Analysis of variance:-

The estimated values of mean squares for yield and its component traits are presented in Table 2. The mean squares of genotypes, parents and crosses were highly significant for all studied traits indicating the presence of wide range of genetic variations among the parental lines. The highly significant values of mean square of parents versus crosses for all studied traits indicated that heterosis was significant for these traits.

The results emphasized the importance of combining ability studies and indicated good prospects for selection of suitable parents and crosses for the development of appropriate varieties and hybrids. Both GCA and SCA variances were highly significant for all the studied traits indicating the importance of both additive and non-additive genetic variances in the inheritance of the studied traits (Rahimi *et al.,* 2010). GCA/SCA ratios were greater than unity for panicles plant^{-1}, panicle weight (g) and 1000-grain weight (g) suggesting the preponderance of additive type of gene action in the inheritance of these traits.

On the other hand, GCA/SCA ratios were less than unity for grain yield plant^{-1}, spikelet fertility percentage (%), filled grains panicle^{-1} and harvest index (%) suggesting the preponderance of non-additive type of gene action in the inheritance of these traits which might be resulted from dominance, epistasis and interaction effects. These results indicated that there is a very good prospect for the exploitation of non-additive genetic variances of yield traits through the production of hybrids. Similar results were also reported by Gopikannan and Ganesh (2013).

General combining ability effects (GCA):-

Combing ability analysis provides guide line for the assessment of relative breeding potential of the parents and help in the choice of the parents (Gnanasekaran *et al*., 2006) which may be hybridized either to exploit hybrid vigor by accumulating unfixable gene effects or to evolve into cultivars by accumulating fixable gene effects (Nadarajan and Gunasekaran, 2005). The additive gene effect is distinguished by GCA while, the non-additive effect is distinguished by SCA (Choukan, 2008)

The general combining ability effects (GCA) of each parent are shown for yield and yield component traits in Table 3. The results indicated the presence of desirable positive and highly significant GCA effects for the drought tolerant parents IRAT170 for most traits except for panicles plant^{-1} and spikelets fertility percentage (%) which showed undesirable either highly significant or non-significant negative estimates, respectively. The parental genotype Moroberekan showed the same trend for most traits except for panicles plant^{-1} and harvest index, while the parental genotype Azuciena showed the same for most traits except for panicles plant^{-1}; grain yield plant^{-1} and harvest index. Therefore, these parents were considered as good combiners for most yield and its component traits under drought condition.

The three parents i.e. IR64, Giza178 and IET1444 were found to be desirable showing highly significant positive GCA effect for panicles plant^{-1}, therefore these parents are considered as good combiners for this trait. Three parents i.e. Moroberekan, Azuceina and IRAT170 exhibited highly significant positive GCA effects for panicle weight (g); 1000-grain weight (g) and filled grains panicle^{-1}, therefore these parents are the best combiners for these traits. The parental genotype Giza177 showed significant positive GCA effect for 1000-grain weight.

The best combiners for spikelets fertility percentage (%) were the two parents: Moroberekan and Azuceina. In the same way, both parents: IRAT170 and Moroberekan were the best general combiners for grain yield plant^{-1}, where they revealed highly significant and significant positive GCA effects, respectively. In the case of harvest index, the drought tolerant parent IRAT170 followed by both Egyptian rice varieties; Giza177 and Giza178 were the best general combiners for this trait. Similar results under drought stress condition were obtained by Abd Allah *et al.,* (2010) for tillers plant^{-1}, Ali *et al.,* (2012) for panicles plant^{-1}, panicle weight, spikelets fertility percentage (%) and Muthuramu *et al.,* (2010) and Ali *et al.,* (2012) for grain yield plant^{-1}. High GCA effects indicate the presence of favorable genes with additive type of gene action. Therefore, a multiple crossing program involving good general combiner parents would be recommended as superior genotypes as proposed by Nadarajan and Gunasekaran (2005).

Specific combining ability effects (SCA):-

Estimates of specific combining ability effects (SCA) for yield and its component traits are presented in Table 4. Desirable and highly significant positive SCA effects for all traits were observed for the cross Giza177 x Azuceina, meanwhile the cross IR64 x Moroberekan exhibited highly significant positive SCA effects for all studied traits except for panicles plant^{-1}. For grain yield plant^{-1}; among 21 F_1 crosses, eight crosses i.e. Giza178 x

Moroberekan; Giza178 x Azuceina; IET1444 x IRAT170; Giza177 x Moroberekan; IR64 x Moroberekan; Giza177 x IET1444; IR64 x Azuceina and IR64 x IET1444 were found to be good specific combiners based on their significant positive SCA effects. These results are in agreement with those obtained by Panwar (2005); Petchiammal and Kumar (2007) and Saleem *et al.,* (2010) who reported several promising specific combiners based on their high mean performance and the magnitude at their SCA effects for grain yield plant^{-1} in rice. For other traits, significant positive SCA effects were observed for seven crosses i.e. Giza178 x IRAT170; IET1444 x Moroberekan; IR64 x IET1444; Giza177 x Azuceina; IET1444 x Azuceina; Giza178 x Moroberekan and IET1444 x IRAT170 for panicles plant^{-1}, five crosses i.e. IR64 x Moroberekan; Giza177 x Azuceina; IET1444 x IRAT170; Giza177 x IRAT170 and IRAT170 x Moroberekan for panicle weight, six crosses i.e. IR64 x Moroberekan; IR64 x IRAT170; IET1444 x Azuceina; Giza177 x Giza178; Giza177 x Azuceina and Giza177 x IET1444 for 1000- grain weight, nine crosses i.e. IRAT170 x Moroberekan; IR64 x Giza178; Giza177 x IET1444; Giza177 x Moroberekan; IET1444 x IRAT170; IR64 x Moroberekan; Giza177 x Azuceina; Giza178 x Azuceina and Moroberekan x Azuceina for filled grains panicle^{-1}, eight crosses i.e. Giza178 x IET1444; IR64 x Giza178; Giza177 x Azuceina;

Giza177 x IRAT170; Giza177 x Moroberekan; IR64 x Moroberekan; IRAT170 x Moroberekan and IR64 x Azuceina for spikelets fertility percentage and eleven crosses i.e. Giza177 x Azuceina; Giza178 x Azuceina; Giza177 x Moroberekan; Giza177 x IET1444; Giza178 x Moroberekan; IR64 x IRAT170; IR64 x Moroberekan; IR64 x IET1444; Giza177 x IRAT170; IET1444 x IRAT170 and IR64 x Giza178 for harvest index. Significant SCA effects were also reported by Panwar (2005) and Saleem *et al.,* (2010) for harvest index and Ali *et al.,* (2012) for panicles plant^{-1}, spikelets panicle^{-1}, spikelets fertility percentage (%), grain weight and grain yield plant^{-1}.

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Heterosis breeding is recommended for good specific combiners which were identified in the present investigation for yield and its component traits. High SCA effects show the predominance of non-additive gene effects mainly dominance gene effects (Nadarajan and Gunasekaran, 2005).

Crosses which show non-significant SCA effects but originated from parents having high GCA effects (additive gene effects) would be used for recombination breeding with early selection of desirable segregants (Nadarajan and Gunasekaran, 2005). These crosses were IR64 x Giza178 for panicles plant^{-1}; IRAT170 x Moroberekan for 1000-grain weight and grain yield plant^{-1}; IRAT170 x Azuceina for filled grains panicle^{-1} and Moroberekan x Azuceina for spikelets fertility percentage (%).

Crosses which indicated high estimates for SCA effects and derived from parents having high GCA effects would also be used in good recombination in to produce good hybrids. However, the selection of superior genotypes to develop good cultivars must be delayed to later generations to allow fixation of maximum homozygosity (Nadarajan and Gunasekaran, 2005). These crosses were IR64 x IET1444 for panicles plant^{-1}; IRAT170 x Moroberekan for panicle weight; Giza177 x Azuceina for 1000-grain weight; Moroberekan x Azuceina and IRAT170 x Moroberekan for filled grains panicle^{-1} and Giza177 x IRAT170 for harvest index.

Genetic components:-

The estimates of phenotypic variance (δ^2p); heritability in broad sense (h^2_b%); heritability in narrow sense (h^2_n%) and degree of dominance (d') are presented in Table 5.

Phenotypic variance:-

As shown in Table 5, the estimates of phenotypic variances ranged from 1.17 to 1653.5 revealing a wide range of variations among all the studied traits. The highest estimates of phenotypic variances were observed for filled grains panicle^{-1} and spikelet fertility percentage (%) traits. On the other hand, the lowest value of variance was obtained by panicle weight. The additive genetic variances were larger than both dominance and environmental variances for panicles plant^{-1}, panicle weight, 1000-grain weight and filled grains panicle^{-1} traits.

Heritability in broad sense (h^2_b%):-

The results in Table 5 showed that broad sense heritability estimates were high for all studied traits and ranged from 86.3% for harvest index to 98.07% for Filled grains panicle^{-1}. These findings are in agreement with those obtained by Gaballah (2009) and Ali *et al.,* (2012) who reported high estimates of heritability in broad sense for yield and yield component traits under water stress condition. Similar results were also obtained by Sohrabi *et al.,* (2012); Ullah *et al*., (2011) and Singh *et al.,* (2011) for grain yield plant^{-1} and spikelets panicle^{-1}; Sohrabi *et al.,* (2012) and Seyoum *et al.,* (2012) for 1000-grain weight; Sohrabi *et al.,* (2012) for spikelet fertility percentage; Ullah *et al*., (2011) and Babu *et al.,* (2012) for filled grains panicle^{-1}; Ullah *et al*., (2011) for panicles plant^{-1} and Singh *et al.,* (2011) for harvest index.

Table 5: Estimates of genetic components for all studied traits under drought condition.

Trait	δ^2e	δ^2p	δ^2A	δ^2D	h^2_b%	h^2_n%	d'
Panicles plant^{-1}	0.83	25.87	19.7	5.34	96.8	76.17	0.521
Panicle weight (g)	0.13	1.71	1.26	0.32	92.17	73.3	0.504
1000-grain weight (g)	0.56	15.44	11.62	3.26	96.35	75.26	0.530
Filled grains panicle^{-1}	31.87	1653.5	901.08	720.54	98.07	54.5	0.894
Spikelets fertility percentage (%)	7.23	298.73	47.88	243.62	97.58	16.03	2.256
Grain yield plant^{-1} (g)	1.64	50.37	8.83	39.9	96.75	17.53	2.126
Harvest index (%)	6.11	44.61	6.52	31.98	86.3	14.62	2.215

δ^2e= environmental variance; δ^2p = phenotypic variance; δ^2A= additive variance; δ^2D= dominance variance; h^2_b%= heritability in broad sense, h^2_n%= heritability in narrow sense and d'= degree of dominance.

Heritability in narrow sense (h^2_n%):-

The h^2_n heritability estimates were considered to be low when their values were below 30%; medium when their values ranged from 30 to 60% and high when their values were above 60% as reported by Babu *et al.,* (2012).

Low estimates of heritability in narrow sense ranged from 14.62 to 28.23% were recorded for harvest index; spikelets fertility percentage and grain yield plant^{-1}. The heritability estimates were medium for filled grains panicle^{-1} trait. The low estimates of heritability for these traits suggested that, the major part of phenotypic variation was due to non-additive and environmental variance, therefore phenotypic selection for such traits must be done in the late generations. These results agreed with those obtained by Ebrahim (2009) for harvest index and Ali *et al.,* (2012) for panicles plant^{-1} and grain yield plant^{-1}.

High estimates of heritability in narrow sense ranged from 66.24 to 76.17% were obtained for panicle weight; panicles plant^{-1} and 1000-grain weight traits. The high heritability estimates of these traits cleared that, a major part of the total phenotypic variance was due to additive genetic variance, thus effective phenotypic selection for these traits would be achieved with satisfactory degree of accuracy in early generations. Similar results were obtained by Ali *et al.,* (2012) for panicle weight and grain weight and Ebrahim (2009) for 1000-grain weight.

Degree of dominance (d'):-

The estimates of degree of dominance for all studied traits are presented in Table 5. When the value of a trait is equal to the unity, then the trait is under control of the complete dominance. When the value is more than unity, the trait is affected by over-dominance. On the other hand, when the value is less than unity this means that the trait is controlled by partial dominance. The degree of dominance values ranged from 0.504 to 2.256. The values were higher than unity for spikelets fertility percentage; harvest index and grain yield plant^{-1} traits indicating that their mode of inheritance was of over-dominance. Meanwhile, other traits exhibited values lower than unity suggesting that they were under partial-dominance effect. These results are in common agreement with those obtained by Ali *et al.,* (2012) for grain yield plant^{-1}; panicle weight; panicles plant^{-1} and spikelets panicle^{-1} under drought stress condition.

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التحليل الوراثي لصفات المحصول ومكوناته تحت ظرف الاجهاد المائي في الارز (*Oryza sativa,* L.)

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2- مركز البحوث والتدريب فى الارز – سخا – كفرالشيخ – مصر.
3- معمل البيوتكنولوجي - مركز البحوث والتدريب فى الارز – سخا – كفرالشيخ – مصر.

تم تقييم سبعة تراكيب وراثية ابوية من الارز متباينة لدرجة تحملها للجفاف بالاضافة الي 21 هجين الناتجة من التهجين فيما بينها بطريقة التهجين نصف الدوري تحت ظرف الاجهاد المائي خلال موسمي نمو 2010 – 2011 وذلك للوقوف علي الاباء والهجن المتفوقة وطريقة التربية المناسبة تحت هذا الظرف. واوضحت النتائج ان متوسطات المربعات كانت عالية المعنوية لجميع الصفات المدروسة مما يوضح وجود قدر عالي من التباينات الوراثية بين السلالات الابوية المستخدمة في هذه الدراسة. كانت النسبة بين القدرة العامة والقدرة الخاصة علي الائتلاف اكبرمن الوحدة لصفات عدد الداليات للنبات, وزن الدالية ووزن الالف حبة مما يشير الي تفوق الفعل الجيني التجميعي في وراثة هذه الصفات, بينما كانت النسبة اقل من الوحدة لصفات محصول النبات الفردي, النسبة المئوية لخصوبة السنيبلات, عدد الحبوب الممتلئة بالدالية و دليل الحصاد مما يشير الي تفوق الفعل الجيني الغير تجميعي في وراثة هذه الصفات. وكانت الاباء المتحملة للجفاف مثل Moroberekan , IRAT170 و Azuciena هي الافضل في القدرة العامة علي الائتلاف. كما تشير التاثيرات العالية للقدرة العامة علي الائتلاف الي وجود جينات مرغوبة ذات فعل جيني تجميعي لذلك فانه ينصح بادخال هذه الاباء ذات القدرة العالية علي الائتلاف في برنامج من التهجينات المتعددة. وكانت هناك قدرة خاصة علي الائتلاف ذات تاثيرات موجبة عالية المعنوية ظهرت في الهجينAzuceina x Giza177 لكل الصفات والهجين IR64 x Moroberekan لكل الصفات فيما عدا عدد الداليات للنبات. وبناءا علي تاثيرات القدرة الخاصة علي الائتلاف فقد كان عدد الهجن المرغوبة هي 8 هجن لصفة محصول النبات الفردي, 7 هجن لصفة عدد الداليات للنبات, 5 هجن لصفة وزن الدالية, 6 هجن لوزن الالف حبة, 9 هجن لعدد الحبوب الممتلئة بالدالية, 8 هجن للنسبة المئوية لخصوبة السنيبلات و 11 هجين لدليل الحصاد. هذا ويوصي بطريقة التربية من خلال انتاج الهجن الجيدة في قدرتها الخاصة علي الائتلاف والتي تم تحديدها في هذه الدراسة لصفات المحصول ومكوناته تحت ظرف الاجهاد المائي. وكانت تقديرات معامل التوريث في المدي الواسع مرتفعة لكل الصفات وقد تراوحت ما بين 86.3 % لصفة دليل الحصاد الي 98.07 % لصفة عدد الحبوب الممتلئة بالدالية. كانت هناك تقديرات منخفضة لمعامل التوريت في المدي الضيق لصفات دليل الحصاد (14.62%), النسبة المئوية لخصوبة السنيبلات (16.03%) ومحصول النبات الفردي (17.53%). كما كانت القيم الخاصة بدرجة السيادة اعلي من الوحدة لصفات النسبة المئوية لخصوبة السنيبلات, دليل الحصاد ومحصول النبات الفردي مما يوضح انها تحت تاثير السيادة الفائقة.

قام بتحكيم البحث

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Table 1: Name, origin, type, pedigree and some features of the parental genotypes.

Genotypes	Origin	Type	Parentage	Features
Giza177	Egypt	Japonica	Giza171/Yomji No1 // Pi No4	Drought sensitive
IR64	IRRI	Indica	IR5657-33-2-1/IR2061-465-1-5-5	Drought sensitive
Giza178	Egypt	Indica/Japonica	Giza175/Milyang 49	Moderately drought tolerance
IET1444	India	Indica	TN1 / CO29	Moderately drought tolerance
IRAT170	Côte d'Ivoire	Japonica	IRAT13 / Palawan	Drought tolerance
Moroberekan	Republic of Guinea	Tropical japonica	IR8-24-6 (M307H5)	Drought tolerance
Azuciena	Philippines	Japonica	-	Drought tolerance

Table 2: Mean square estimates of ordinary analysis and combining ability analysis for yield and yield

S.O.V. / Traits	df	Panicles plant^{-1}	Panicle Weight(g)	1000- grain weight (g)	Filled grains panicle^{-1}	Spikelet fertility Percentage (%)	Grain yield plant^{-1}(g)	Harvest Index (%)
Reps	2	0.22	0.36	0.18	60.80	7.30	22.77	2.38
Genotypes	27	74.05**	4.92**	44.16**	4480.12**	733.78**	112.52**	124.51**
Parents	6	100.76**	6.11**	61.17**	3046.54**	158.49**	58.11**	47.15**
Crosses	20	58.12**	4.64**	39.23**	5078.68**	789.86**	94.88**	152.16**
Parents *Vs.* Crosses	1	232.40**	3.34**	40.72**	1110.48**	3063.94**	791.69**	35.54**
G.C.A	6	89.50**	5.78**	52.87**	4086.73**	222.67**	35.46**	41.37**
S.C.A	14	6.16**	0.46**	3.82**	752.42**	250.86**	38.09**	41.54**
Error (Me)	54	2.48	0.40	1.69	95.62	21.70	18.33	4.92
G.C.A / S.C.A		**1.85**	**1.94**	**1.78**	**0.63**	**0.10**	**0.10**	**0.11**

***and**:Significant at 0.05 and 0.01 levels of probability,respectively.G.C.A=General combining ability and S.C.A=Specific combining ability.**

Table 3: Estimates of general combining ability effects (GCA) for yield and yield component traits for seven parents under drought conditions.

Parents / Traits	Panicles plant^{-1}	Panicle weight (g)	1000- Grain weight (g)	Filled grains panicle^{-1}	Spikelets Fertility percentage (%)	Grain yield plant^{-1} (g)	Harvest Index (%)
Giza177	-0.667*	-0.490**	0.574*	-18.058**	-4.703**	-2.574**	1.002*
IR64	2.763**	-0.589**	-1.030**	-18.243**	-4.622**	-0.755	-1.326**
Giza178	2.789**	-0.799**	-3.704**	-11.836**	0.555	-0.354	0.950*
IET1444	4.085**	-0.647**	-2.344**	-17.466**	-4.705**	-2.039**	-2.822**
IRAT170	-2.578**	0.609**	2.607**	12.683**	1.054	2.793**	3.820**
Moroberekan	-3.344**	0.999**	2.304**	31.905**	7.673**	1.662*	-0.958*
Azuceina	-3.048**	0.917**	1.593**	21.016**	4.748**	1.267	-0.666
LSD 0.05	0.563	0.227	0.465	3.493	1.664	1.529	0.792
LSD 0.01	0.750	0.302	0.619	4.652	2.216	2.037	1.055

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

Table 4: Estimates of specific combining ability effects (SCA) for yield and yield component traits of 21 crosses under drought condition.

traits / crosses	Panicles $plant^{-1}$	Panicle weight (g)	1000- grain weight (g)	Filled Grains $panicle^{-1}$	Spikelets fertility Percentage (%)	Grain Yield $plant^{-1}$ (g)	Harvest Index (%)
Giza177 x IR64	0.170	-1.020**	0.397	-32.806**	-27.501**	-2.528	-4.968**
Giza177 x Giza178	0.611	-0.646*	2.205**	-33.213**	-34.214**	-6.690**	-10.407**
Giza177 x IET1444	0.415	0.351	1.612**	28.417**	-4.284*	5.845**	5.135**
Giza177 x IRAT170	0.378	0.749**	-0.206	4.935	10.174**	2.764	3.413**
Giza177 x Moroberekan	-0.156	0.539	-1.003	26.713**	9.475**	5.901**	7.234**
Giza177 x Azuceina	2.448**	0.984**	1.675**	19.269**	10.813**	6.760**	8.219**
IR64 x Giza178	0.781	0.463	0.342	31.306**	13.515**	1.511	2.237*
IR64 x IET1444	2.985**	0.107	-4.384**	3.269	-3.229	4.223*	3.620**
IR64 x IRAT170	1.148	-0.289	2.964**	-25.213**	-6.025**	3.672	4.247**
IR64 x Moroberekan	0.681	1.128**	3.868**	22.565**	5.980**	5.876**	3.711**
IR64 x Azuceina	0.285	0.470	0.145	-7.213	3.891*	5.574**	-0.554
Giza178 x IET1444	-1.441*	0.228	0.423	-3.806	13.865**	3.625	3.517**
Giza178 x IRAT170	3.989**	-0.719*	-1.262*	-12.620**	-12.751**	-0.396	-5.098**
Giza178 x Moroberekan	2.089**	0.272	-1.625**	3.491	-2.279	6.931**	5.003**
Giza178 x Azuceina	-0.807	0.234	0.353	19.046**	-4.852**	6.473**	7.284**
IET1444 x IRAT170	1.726*	0.822**	0.312	23.343**	1.075	6.235**	2.444*
IET1444 x Moroberekan	3.759**	-0.967**	0.349	-47.880**	-23.086**	-7.991**	-12.219**
IET1444 x Azuceina	2.230**	-0.505	2.294**	-39.657**	-26.555**	-9.245**	-13.577**
IRAT170 x Moroberekan	0.156	0.653*	0.164	49.972**	3.431*	0.688	-1.251
IRAT170 x Azuceina	-0.974	-0.248	-0.758	4.528	-3.488*	-0.424	-0.499
Moroberekan x Azuceina	-0.307	-0.191	0.579	9.639*	2.821	-1.583	0.395
LSD 0.05	1.393	0.561	1.150	8.645	3.384	3.785	1.961
LSD 0.01	1.855	0.747	1.532	11.513	4.507	5.041	2.611

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