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IMPROVEMENT OF DROUGHT TOLERANCE IN RICE USING MOLECULAR GENETIC TECHNIQUE

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ABSTRACT

The present investigation was carried out in the greenhouse from October 2009 to March 2010 included two main conditions, i.e. normal irrigation and water stress every 15 days using Line x tester analysis through the parents (Sakha 102 and Agami) were used as testers, while; the cultivars Giza 171, Giza 172, Gaori and Giza 159 were used as lines, and markers assisted selection techniques used a random primer namely; A17, A18 and As-467468 as indication for drought tolerance in rice. The main characters studied were yield and its components;(heading date, plant height, number of panicles/plant, number of filled grains/panicle, 1000-grain weight and grain yield/plant) and some characters related to drought namely;(maximum root length, number of roots/plant, root volume, root xylem, vessels number and root dry weight), respectively under normal and drought conditions.

Heterosis over better parent, general and specific combining ability were studied as a genetic components. The most desirable mean value, positive and highly significant of heterosis, general and specific combining ability effects for all traits studied using line x tester design under the two conditions were shown in the genotypes; Agami, Gaori, Sakha 102 x Gaori, Agami x Gaori and Agami x Giza 159.

From the foreign discussion, it could be concluded that, the crosses; Agami x Gaori, Agami x Giza 159 and Sakha 102 x Gaori were contained of the bands number 1, 2 and 6 for A17 primer 3, 6 and 7 bands for A18 primer and the bands number 3, 4, 5, 7, 8 and 9 for As-467468 primer under drought conditions which indicated that these bands were found to be index for drought tolerance in rice. So these crosses would be effective and important for grown as lines of drought tolerance in rice.

INTRODUCTION

Rice is a vital crop for the entire world populations. This crop considered one of the major stable foods in the developing countries population. It is estimated that grain production in rice must be increased by 60% of the present amount, to meet the demand at 2020. The increased rice production can play a significant role in upgrading the economic status of many countries (Grover and Minhas, 2000)

Today, rice production takes place only in the Delta of the Nile River. Because of limited water resources, the government of Egypt has tried to limit the cultivated area, therefore, Egypt is today a major rice exporter according to FAO Statistics (2004).

These cultivars were different for the reaction of drought,so,the genotypes from these parents will be differently for water stress and will development the program of drought tolerance in rice.

The inter action between water stress and the behavior of cultivars will be effective to selection the lines of rice which make wide genetic basic for the populations of rice to development the resistance of drought.

. Rice is a herbal plant follows Gramineae or grass family, Genus Oryza and there are two species known as cultivated rice; the first is *Oryza glaberrima* or the African rice, and the second is *Oryza sativa* or the Asian rice. Most Egyptian cultivars belong to the latter, under subspecies; *japonica* and *indica.* Egypt is the leading rice producer in the near east region (10 tons per hectar) in 2006 (RRTC, 2007). Since its production was probably introduced into Egypt in the 7th Century In view of this, the major approach in this investigation was to identify variability in different drought adaptive mechanisms among *Oryza sativa* crosses with diverse genetic background.

The major objectives of the present investigation, are:

1. Study the inheritance and genetic parameters of grain yield and some characters related to drought .
2. Estimates the difference between moderates, susceptible and tolerance rice varieties using PCR analysis.

MATERIALS AND METHODS

The present investigation was carried out under greenhouse conditions (Temperature 30-32^{o}C, light period 12.5 hour/day) during the period from October (2009) to March (2010). This work aimed to study the genetic behavior of some yield and its components characters and some traits related to drought under normal and drought irrigation(15 days). Six rice genotypes with different reactions for drought were used in a line x tester design, where the cultivars Sakha 102 and Agami were testers, but the genotypes; Giza 171, Giza 172, Gaori and Giza 159 were lines. These cultivars were taken from RRTC (Rice Research and Training Center, Sakha, Kafrel-sheikh).

The parental genotypes were grown in three planting dates with ten days interval in order to over come the differences in flowering time between parents. Thirty days old seedling of each parent were individually transplanted in the field in ten rows. Each row as 5 m long and included 25 hills. At flowering time hybridization between parents was carried out using hot water technique and the aforementioned eight crosses were grown under two levels of irrigation; the first level was normal irrigation conditions of continuous flooding while; the second level was flash irrigation every 15 days without any standing water. The stress was applied two weeks after transplanting till harvesting. Individual plants of each entry were transplanted in two rows of one meter long with 20 cm between hills (thirty plants for each entry) and replicated three times in a randomized complete block design. The package of all other recommendations of rice planting was followed in the same season (2010).

Table 1: The main characteristics of the six rice genotypes used as parents in the line x tester design.

Genotypes	Parentages	Drought tolerance	Grain shape	Duration (Day)
Sakha 102	Giza 175/Gz-3-5-4-1	Sensitive	Short	135
Agami	Gz5432-2-1-1-1/Toiken93	Tolerance	Short	130
Giza 171	TN3/Gz438-7-1/Co19	Sensitive	Short	140
Giza 172	Giza 171/Gz247//IR18	Sensitive	Short	135
Gaori	Gz5591-1-1-1-1/Toikeng 7	Tolerance	Short	125
Giza 159	Gz4096-8-1/IR39422-163-1-3//G181	Moderate	Short	150

a,j, Japonica, I, Indica

Studied characters:

Thirty plant were taken from the parents and F_1 crosses at random from each replicate to determine all characters.

Yield and its components characters:

1) **Heading date (days):** It was determined as the number of days from sowing to the date of the first panicle exertion.
2) **Plant height (cm):** Length of the main calm was measured from the soil surface to the tip of the main panicle at maturity
3) **Number of panicles per plant:** Were determined by counting the number of panicles per plant, when all plants were at the ripening stage.
4) **Number of filled grains per panicle:** Filled grains of the main panicle with separated and counted.
5) **1000-grain weight (g):** Was recorded as the weight of 1000 random filled grains per plant.
6) **Grain yield per plant (g):** Was recorded as the weight of grain yield of each individual plant, and adjusted to 14% moisture content.

Some characters related to drought:

1. Maximum root length (cm): measured from the tillering plateau to the longest root tip.
2. Number of roots per plant: The total number of secondary and tertiary roots of each single plant was counted two cm below the tillering plateau.
3. Root volume: volume of all root system was determined in cubic centimeters using standard column.
4. Root xylem vessel number: The average vessel number of roots of the same plant was counted under the light microscope.
5. Root dry weight: all roots of each single plant were collected and oven dried at 55^oC for five days and weighted in grams.

Statistical analyses

Analysis of variance:

The analysis of variance and expected mean squares of the studied characters for hybrids and their parents were computed using IRRISTAT V.6 .

Estimation of heterosis:

The heterosis of an individual cross was determined for each trait as the increase of the F_1 hybrid mean over its better parent, (i.e. heterobeltiosis), as follows:

Heterosis over the better parent % = $\frac{\overline{F}_1 - \overline{B}.\overline{P}.}{\overline{B}.\overline{P}.}$ x 100

Where:

$\overline{F}_1$ = Mean value of the first generation.

$\overline{B}.\overline{P}.$ = Mean value of the better parent.

LSD. values were calculated to test the significance of the heterosis effects, according to the following formula suggested by Wyanne *et al.* (1970).

LSD for better parent heterosis = t $\sqrt{\frac{2MSe}{r}}$

Where:

t = Tabulated value at the specified level of probability for the experimental error.

MSe = The experimental error mean squares

r = Number of replications.

ANOVA for line x tester experiment:

The analysis of variance for line x tester design including parents and crosses was computed according to Virmani *et al.* (1997).

$GCA_L = \frac{Y_{i..}}{Tr} - \frac{Y_{..}}{LTr}$

$GCA_T = \frac{\sum Y_{.j.}}{Lr} - \frac{Y_{..}}{LTr}$

$SCA = \frac{Y_{ij.}}{r} - \frac{Y_{i..}}{Tr} - \frac{Y_{.j.}}{Lr} - \frac{Y_{..}}{LTr}$

Where:

$Y_{i..}$ = Total of i^{th} line over testers.

$Y_{..}$ = Grand total.

$Y_{.j.}$ = Total of j^{th} tester over lines.

$Y_{ij.}$ = Value of i^{th} line with j^{th} tester.

L,T,r = Number of lines, testers and replications, respectively.

LSD values were calculated according to Wyanne *et al.* (1970) as following:

LSD = t x $\sqrt{2MSe/r}$

Where:

t = Tabulated t-value at the specified level of probability for the experimental error and given degree of freedom.

MSe = The experimental error mean square value.

R = No. of replications.

Biochemical and molecular genetic analysis:

PCR-based DNA analysis:

DNA was extracted from the leaves of the selected plants of six parents and their F'1s generation which different reaction of drought tolerant, moderate and sensitive. The samples were single leaves for parents and first generation according to the method of Graham *et al* (1997).

Gel electrophoretic buffers

TBE buffer	10 x
Tris	10.80 g
Boric acid	5.50 g
EDTA	0.74 g
H_2O (dd)	up to 100 mL

Loading buffer

Tris	10.8 g
Boric acid	5.5g
EDTA	0.74 g
H_2O (dd)	up to 100 mL

Table 2: Random primer names, sequences and GC% used in RAPD analysis

Primer names	Sequences	GC%
1. A_{17}	5`ATGCCATATC3`	80
2. A_{18}	5`GGATTCCATC3`	83
3. $A_{s-467468}$	5`CCTGGAGGAA3`	87.5

Agarose gel electrophoresis

PCR amplification products were analyzed using 1.5% agarose gel electrophoresis in 1 x TBE buffer and stained with ethidium bromide. The run was performed at 100 V in Bio Rad submarine. The bands of amplified DNA were visualized under Ultra voilet light and the sizes of the fragments were estimated based on a DNA ladder of a 100 to 2000 base pairs, and photographed with gel documentation system.

Gel analysis:

Gels were photographed under Ultra voilet light with Polaroid film 667 and scanned with Bio-Rad video densitometer Model 620 at a wave length of 557 software data analysis for Bio-Rad model 620 USE densitometer and computer were used.

RESULTS AND DISCUSSION

Rice is one of the most important food crops allover the world as well as in Egypt. Meanwhile, rice consumes large quantities of water, which limited its cultivation in Egypt. Therefore, the achievement of modern Egyptian rice varieties with stable yield under water stress conditions would be of great importance.

A. Line x tester experiment

A.1. Yield and its components

A.2. Variations and interaction

The analysis of variance for line x tester design for yield and its components characters are tabulated in Table (3).

Highly significant variations were obtained between irrigation treatment for all studied yield traits. These significant variation indicate the effect of different drought stresses of these traits. In addition, highly significant variations were estimated between genotypes, parents, crosses, lines and testers for all studied traits.

Mean squares of the interactions between parents and crosses were highly significant for all studied traits and the same results were obtained for the interactions between lines and testers and their interactions. Similar results were obtained by El-Said (2007).

A.3. Mean performance

The genotypes mean values for yield and its components studied under all conditions are presented in Table (4).

For heading date, the earlier plants were obtained for the genotypes, Sakha 102 x Gaori , Agami x Gaori and Agami respectively under normal and drought conditions, The mean values were ranged between 87.5 to 91.32 day for normal condition and from 91.34 to 96.0 days for drought conditions. These results are in agreement with those reported by Weerakoon *et al.* (2008).

Regarding to plant height, the parents, Agami and Giza 172 and the crosses, Sakha 102 x Gaolri and Agami x Gaori gave the lowest mean values towards dwarfism and ranged from 85.0 to 95.30 cm under normal conditions and from 89.50 to 97.50 cm under drought conditions. These results are in good agreement with those obtained by Sedeek (2006) and El-Said (2007).

Concerning number of panicles/plant, the genotypes, Agami, Gaori, Giza 159, Sakha 102 x Gaori, Agami x Giza 171 and Agami x Gaori produced the highest number of panicles/plant under normal and drought conditions and the values were ranged from 25.0 to 37.38 panicle and from 12.76 to 33.74 panicle under normal and drought conditions, respectively.

With regard to number of filled grains/panicle, the highest mean values were obtained from the genotypes, Agami, Gaori, Sakha 102 x Giza 171, Sakha 102 x Gaori and Agami x Gaori under normal and drought conditions. The mean values were ranged from 256.0 to 320.71 under normal conditions and from 134.0 to 261.5 under drought conditions. Similar results were observed by and Weerakoon *et al.* (2008).

For 1000-grain weight, the genotypes, Agami, Gaori, Giza 159, Sakha 102 x Gaori, Agami x Giza 171 and Agami x Gaori showed the highest mean values for this trait under both normal and drought conditions. These findings are in harmony with those reported by El-Said (2007).

Concerning grain yield/plant, the parents, Agarmi and Gaori and the crosses, Sakha 102 x Gaori, Agami x Giza 172 and Agami x Gaori under all conditions showed the highest mean values. The values were ranged from 37.0 to 67.30 g under normal condition and from 30.0 to 60.7 g under drought conditions. These findings are in complete conformity with those has been reported by Weerakoon *et al.* (2008).

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From the foriegen discussion it could be conclouded that the best genotypes for the mean performance under all conditions were Agami, Gaori, Sakha 102x Gaori, Agami x Gaori and Agami x Giza 171.

A.4. Heterosis:

Estimates the percentage of heterosis over parent for yield and its components traits under normal and drought conditions are given in Table 5.

With respect to heading date, heterosis percentage were highly significant and negative in the crosses, Sakha 102 x Gaori and Agami x Gaori under both conditions, which indicated that additive gene action played an importance role to control this trait under drought conditions. Similar results were in conformity with that reported by Bindu and shashidhear. (2006).

For plant height, the cross Sakha 102 x Gaori only under normal and drought conditions showed highly significant and negative values of heterosis over better parent and was found to be useful for specific combining ability which in indicated that additive gene action played an importance role to control grain yield.

Concerning number of panicles/plant, the crosses Sakha 102 x Gaori, Sakha 102 x Giza 159 and Agami x Gaori under normal and drought conditions and the cross Sakha 102 x Giza 172 under drought conditions showed significant and highly significant positive heterosis over better parent and the values were ranged from 4.81 to 10.54% and 15.21% for normal and drought conditions, respectively which indicated that additive gene action played an importance role to control this trait. Similar results were obtained by Aidy *et al.* (2006).

For number of filled grains/panicle, heterosis percentage as deviation from better parents was highly significant and positive in the crosses Sakha 102 x Gaori and Agami x Gaori under normal and drought conditions and the crosses; Sakha 102 x Giza 171, Sakha 102 x Giza 159 and Agami x Giza 159 under normal conditions. The mean values were ranged from 5.46% to 52.8% and from 3.0 to 30.88% for normal and drought conditions, respectively. They observed the importance of additive gene action to control and inheritance of this trait.

With respect to 1000-grain weight, the crosses; Sakha 102 x Giza 172 under normal conditions, Sakha 102 x Gaori under both conditions and Agami x Gaori under drought conditions showed the highest values of heterosis under both conditions. These results are in confirm with Abdallah (2004) and Weerakoon *et al.* (2008)

For grain yield/plant, one and four crosses out of the eight crosses were exhibited highly significant and positive heterosis under normal and drought conditions, respectively. The best crosses were Sakha 102 x Giza 171 under all conditions as well as Sakha 102 x Gaori, Agami x Gaori and Agami x Giza 159 under drought conditions and the values were 27.82% and from 16.13% to 53.06% under normal and drought conditions, respectively, which indicated that additive gene action played an important role in the inheritance of grain yield/plant. Similar results were reported by Weerakoon *et al.* (2008).The best crosses for heterosis over better barents under all conditions were Agami x Gaori and Agami x Giza 159.

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A.5. Combining ability:

Estimates of GCA effects of the parental varieties at the normal and drought conditions are given in Table 6.

With regard to heading date, the two rice varieties Sakha 102 and Giza 171 showed highly significant and negative of general combining ability effects under normal conditions only proving to be excellent combiners for this trait and found that earliness was controlled by over-dominance. Similar results were obtained by Sedeek (2006).

For plant height, the varieties, Agami, Gaori and Giza 159 showed highly significant and negative of general combining ability effects under normal and drought conditions for this trait indicating, these three parents can be considered as a good combiners for this trait for drought tolerance in rice and found that plant height was mostly controlled by additive gene action and partial dominance.

Concerning to number of panicles/plant, the two rice varieties; Sakha 102 and Gaori showed highly significant and positive of general combining ability effects under normal and drought conditions which indicated that these two varieties could be considered as good combiner for this trait under all conditions, The GCA/SCA variances were found to be greater than unity and indicating that additive x additive types of gene action were of greater importance in the inheritance of this trait. . These findings were paralled with those obtained by Singh and Kumar (2005) and Weerakon *et al.* (2008).

Significant and highly significant positive of general combining ability effects were showed in the parents; Sakha 102, Agami, Giza 172, Gaori and Giza 159 for number of filled grains/panicle under normal and drought conditions.The results indicated that important additive gene action was present for the inheritance of this trait. Similar results were reported by Fahmi *et al.* (2004), El-Mowafi *et al.* (2005); Aidy *et al.* (2006), Weerakoon *et al.* (2008) and El-Mouhamady (2009).

For 1000-grain weight, the varieties; Sakha 102, Agami, Gaori and Giza 159 showed highly significant positive of GCA effects under normal and drought conditions for this trait, which indicated these parents could be considered as good combiners for drought tolerance in rice.

With respect to grain yield/plant, the parent Sakha 102, Agami, Giza 171, Giza 172, Gaori and Giza 159 estimated highly significant and positive of general combining ability effects under normal and drought conditions proving to be good combiners for this trait, which indicating the importance of both additive and non-additive variances in the expression of this trait in rice. These results are in line with those reported by Bindu and shashidhear (2006)and Weerakoon *et al.* (2008).

A.5.2.Specific combining ability effects:

Estimates of SCA effects for the parental combinations in the two conditions “normal and drought” are presented in Table 7.

For heading date, six out of eight hybrid combinations had negative and highly significant desirable SCA effects under normal and drought conditions. The best crosses were Sakha 102 x Giza 171 and Sakha 102 x Giza 159 and Agami x Giza 159 under normal conditions, Sakha 102 x Giza 171, Sakha 102 x Gaori and Agami x Giza 171 under drought conditions.

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These results are in agreement with those obtained by El-Said (2007), Weerakoon *et al.* (2008) and El-Mouhamady (2009).

Concerning plant height, significant and highly significant negative showed of SCA were found in the crosses; Sakha 102 x Gaori, Sakha 102 x Giza 159 and Agami x Gaori under both conditions and the crosses; Sakha 102 x Giza 172 and Agami x Giza 171 under drought and normal conditions, respectively, indicated that additive and additive x additive types of gene action were of greater importance in the inheritance of plant height. These crosses were found to be the useful crosses for heterosis. Similar results were obtained by Abd El-Lateef *et al.* (2006), Bindu and shashidhear. (2006), Weerakoon *et al.* (2008), and El-Mouhamady (2009).

With respect to number of panicle/plant, the crosses; Agami x Giza 171, Agami x Gaori and Agami x Giza 159 showed highly significant and negative values of SCA effects under drought conditions only. The results indicated that both additive and non additive gene action was important for this trait under drought conditions. These results come in the similar pointview with those reported by Aidy *et al.* (2006), El-Mowafi *et al.* (2005) and Weerakoon *et al.* (2008).

For number of filled grains/panicle, highly significant and positive of SCA effects were obtained from the crosses; Sakha 102 x Giza 171 and Agami x Giza 172 under normal and drought conditions and the cross Agami x Giza 159 under normal conditions. These crosses were found to be very important for drought tolerance in rice by the interaction between additive and additive x additive gene actions. Similar results were observed by Wyanne *et al.* (1970), Yoshida *et al.* (1976), and El-Mouhamady *et al.* (2009).

With respect to 1000-grain weight, three out of eight crosses exhibited significant and highly significant and positive of SCA effects under normal and drought conditions. These crosses were Sakha 102 x Gaori, Sakha 102 x Giza 159 and Agami x Giza 172 and were found to be useful for heterosis and help breeders for breeding rice for stresses under Egyptian conditions.

Concerning grain yield/plant, the crosses, Sakha 102 x Gaori, Sakha 102 x Giza 159, Agami x Gaori and Agami x Giza 159 showed highly significant and positive of SCA effects under normal and drought conditions which indicated that these crosses were found to be useful for drought tolerance in rice and indicating the importance of both additive and non-additive variances in the expression of these traits in rice. These results are in harmony with those reported by El-Said (2007), Weerakoon (2008) and El-Mouhamady (2009).

Estimates of SCA effects of the eight rice crosses under both conditions (normal and drought conditions) were calculated for all studied traits grain yield and related traits and presented in Table 7. Several crosses exhibited desirable SCA effects for the studied traits. The superior crosses, showing desirable SCA effects for earliness and short stature, were obtained from Sakha 102 x Gaori and Agami x Gaori. These crosses could be used in breeding programs as early and short stature donors either water stress nor non-stress conditions, depending on their non-additive gene effects.

In view of the present findings, it can be stated that the crosses

Sakha 102 x Gaori and Agami x Giza 159 might be recommended to be utilized in hybrid rice breeding for number of panicles/plant, number of filled grains/panicle and grain yield/plant under normal and drought conditions. The population would posses desirable genetic for grain yield and its associated traits. Also, this different origin of these parents would widen the genetic base for election.

B. Some characters related to drought:

B.1. Variation and interaction:

The analysis of variance for line x tester design for some characters related to drought are presented in Table 8.

Highly significant variations were obtained between irrigation treatments for these traits, these significant variations indicate the effect of different drought stress on these traits in addition, highly significant variations were estimated between genotypes, parent and crosses for these traits at the same time. Highly significant variances were obtained for lines, testers and lines x testers for all traits under both conditions for lines x testers only.

Mean squares of the interaction between parents and crosses were highly significant for these traits and the same results were obtained for the interaction between lines, testers and line x tester. Several investigators agreed this point view such as bdallah (2004), Abd El-Lateef *et al.* (2006), El-Said (2007) and Weerakoon *et al.* (2008).

B.2. Mean performance:

The genotypes mean performance for some characters related to drought under normal and drought conditions are shown in Table 9.

For maximum root length, the genotypes Agami, Gaori, Giza 159, Sakha 102 x Gaori, Sakha 102 x Giza 159, Agami x Giza 172 and Agami x Gaori gaved the highest mean values under normal and drought conditions and the values were ranged from 25.07 to 72.13 cm and from 18.78 to 63.52 cm under normal and drought conditions, respectively. Similar results were obtained by El-Mouhamady (2009).

With respect to number of roots/plant, the most desirable mean values for this trait were showed from the genotypes,

Agami, Giza 172, Gaori, Giza 159, Sakha 102 x Gaori, Agami x Giza 171, Agami x Giza 172 and Agami x Giza 159 under all conditions. The mean values were ranged from 127.3 to 782.7 and from 86.13 to 478.80 under normal and drought conditions, respectively. These results were observed by El-Said (2007) and Weerakoon (2008).

Concerning to root volume the highest mean values were showed from the genotypes, Agami, Gaori, Giza 159, Sakha 102 x Gaori, Agami x Gikza 171 and Agami x Gaori under all conditions. These findings are in confirm with those reported by Bindu and shashidhear(2006) and El-Mouhamady (2009).

Regarding for root xylem vessel number, the genotypes Agami, Giza 172, Gaori, Giza 159, Sakha 102 x Gaori, Agami x Giza 171 and Agami x Gaori were recorded the highest mean values for this trait under normal and drought conditions. The values were ranged from 8.93 to 52.18 and from 4.73 to 32.02 under normal and drought conditions, respectively. Similar trend was obtained by El-Said (2007) and El-Mouhamady (2009).

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In Table 9, the results showed that the most desirable mean values for root dry weight were obtained from the genotypes Agami, Gaori, Giza 159, Sakha 102 x Gaori, Sakha 102 x Giza 15, Agami x Giza 171, Agami x Giza 172 and Agami x Gaori under normal and drought conditions. These results are supported by El-Said (2007) and Weerakoon (2008).

B.3. Heterosis:

Table 10 shows the percentage of heterosis over better parents for some traits related to drought under normal and drought conditions.

With respect to maximum root length, seven crosses were showed highly significant and positive values of heterosis over better parent under all conditions. The best crosses were Sakha 102 x Gaori, Sakha 102 x Giza 159, Agami x Giza 172 and Agami x Giza 159 and the mean values were ranged from 11.86 to 67.47% and from 6.83 to 72.98% under normal and drought conditions. Which indicated that these parents considered a good combiners for hybridization to make a programme for drought tolerance. Similar results were obtained by Weerakoon *et al.* (2008).

Regarding number of roots per plant, the crosses; Sakha 102 x Gaori, Sakha 102 x Giza 159, Agami x Giza 172 and Agami x Giza 159 were highly significant and positive of heterosis over better parent under all conditions and the values were ranged from 3.31 to 176.28% and from 15.20 to 207.27% under normal and drought conditions. They observed the importance of additive gene action to control and inheritance of this trait.

Concerning root volume, highly significant and positive heterosis over better parent were observed from the crosses, Sakha 102 x Gaori, Sakha 102 x Giza 159, Agami x Giza 171 and Agami x Giza 172 under normal and drought conditions and Sakha 102 x Giza 172 under normal conditions only. These crosses were very important for selection program in developing the drought tolerance in rice. These results are in agreement with those reported by Abdallah (2004), Abd El-Lateef *et al.* (2006) and El-Mouhamady (2009).

For root xylem vessel number, the crosses, Sakha 102 x Gaori, Agami x Giza 171, Agami x Giza 172, Agami x Gaori and Agami x Giza 159 had highly significant and positive of heterosis over better parent for this trait under normal and drought onditions. The values were ranged from 14.08 to 164.87% and from 2.53 to 182.86% under normal and drought conditions, which indicated that , additive gene action played an important role in the inheritance of this trait.

with respect to root dry weight, seven out of eight crosses showed highly significant and positive of heterosis over better parent and the best crosses were Agami x Giza 171, Agami x Giza 172, Agami x Gaori and Agami x Giza 159 under normal and droughth conditions. Similar results were obtained byBindu and shashidhear (2006),Weerakoon *et al.* (2008) and El-Mouhamady (2009).

In view of the present findings, it can be stated that the crosses; Sakha 102 x Gaori, Sakha 102 x Giza 159, Agami x Gaori and Agami x Giza 159 might be recommended to be utilized in hybrid rice breeding. The population would posses desirable genetic for all traits studied under normal and drought conditions. Also, this different origin of these parents would widen the genetic base for selection.

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B.4. Combining ability effects

B.4.1. General combining ability effects:

Estimates of the GCA effects of individual parents lines for some characters related to drought in the two conditions (normal and drought) are listed in Table 11.

For maximum root length, two varieties, Agami and Gaori showed highly significant and positive of general combining ability effects under normal and drought conditions, proving to be excellent combiners for this trait under all conditions and was conditioned by homozygous recessive genes at a single locus. These results are in harmony with those reported by Abd El-Lateef *et al.* (2006) and El-Mouhamady (2009).

With regard to number of roots/plant, three cultivars out of six varieties had highly significant and positive of GCA effects under normal and drought conditions, these cultivars were Agami, Gaori and Giza 159. It seems to be the best combiners for this trait under all conditions. . The root system of rice has large plasticity, which is affected by environment as well as genetic variation and the important of additive and additive x additive gene actions. Similar results were shown by Weerakoon *et al.* (2008).

Concerning to root volume, four out of six parents showed highly significant and positive of GCA effects under normal and drought conditions. These cultivars were Sakha 102, Agami, Gaori and Giza 159 and were found to be good combiners for breeding rice of drought tolerance, In general, Japonica varieties had larger root system than Indica varieties. Generation mean analysis revealed significant additive and dominance gene effects for root length trait. The dominance x dominance type of non-allelic interaction was important for maximum root length and root volume .These results are in conformity with those reported by Bindu and shashidhear(2006), El-Said (2007) and Weerakoon etal.(2008).

for root xylem vessel number, the varieties; Agami, Giza 172 and Gaori showed highly significant and positive of GCA effects under normal and drought conditions for this trait. These parents were the best combiners under all conditions and very useful for inheritance highly tolerance of drought in rice.

Regarding root dry weight, highly significant and positive of GCA effects were observed from the parents; Sakha 102, Agami, Gaori and Giza 159 under normal and drought conditions for root dry weight, which indicated that these parents were important and good combiners for drought tolerance of rice. These results were in agreement with data reported by Bindu and shashidhear(2006)Abd El-Lateef *et al.* (2006), El-Said (2007), Weerakoon etal.(2008) and El-Mouhamady (2009).

It is noteworthy to indicate herein that the mean performance of some varieties favored their respectively GCA effects. Such cases included the parents; Agami, Giza 172, Gaori and Giza 159 for some characters related to drought. These findings indicated that the intrinsic performance of these parents and all lines gave a good index of their GCA effects. Therefore, selection for improving such traits could be practiced either on mean performance or GCA effects basis.

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B.4.2. Specific combining ability effects

Estimates of the SCA effects of crosses evaluated for some traits related to drought under normal and drought conditions are shown in Table 12.

For maximum root length and number of roots/plant, four out of eight crosses had highly significant and positively of SCA effects under all conditions. These crosses were Sakha 102 x Gaori, Sakha 102 x Giza 159, Agami x Gaori and Agami x Giza 159. The results indicated that these crosses were found to be useful for heterosis and important for the iheritaince of this trait under drought conditions in rice. Similar results were confirmed by Bindu and shashidhear (2006) and El-Mouhamady (2009).

With respect to root volume, the crosses; Sakha 102 x Giza 171, Sakha 102 x Giza 172, Sakha 102 x Gaori and Agami x Gaori showed highly significant and positive of SCA effects under all conditions and were found to be the best crosses for heterosis. , also, was found to be controlled by genes acting in a quantitative mannerand appeared to be controlled by a major dominant gene, acting in the direction of lesser root number. These findings were confirmed by Weerakoon *et al.* (2008).

The crosses; Sakha 102 x Gaori, Sakha 102 x Giza 159, Agami x Giza 172 and Agami x Gaori had highly significant and positive of SCA effects for root xylem vessel number and root dry weight under normal and drought conditions indicating the importance of additive and non-additive genetic variance in the inheritance of these characters and that selection for these traits would be effective in early segregating generations. Similar results were obtained by Parsons and michelmore(1997), Ravi *et al.* (2003), Bindu and shashidhear (2006)and El-Mouhamady *et al.* (2009).

From the previous results, it could be indicated that over the two conditions (normal and drought) the most desirable crosses for some traits related to drought were Sakha 102 x Gaori, Sakha 102 x Giza159, Agami x Gaori and Agami x Giza 159.

C. Marked assisted selection techniques:

Three molecular markers “Random” using as a RAPD-PCR namely; A17, A18 and As-467468 were produced specifically for drought tolerance.

The densitometric analysis of RAPD-PCR products of moderate, susceptible and resistance plants of rice using of A17 primer are presented in Table 13 and Figure 1.

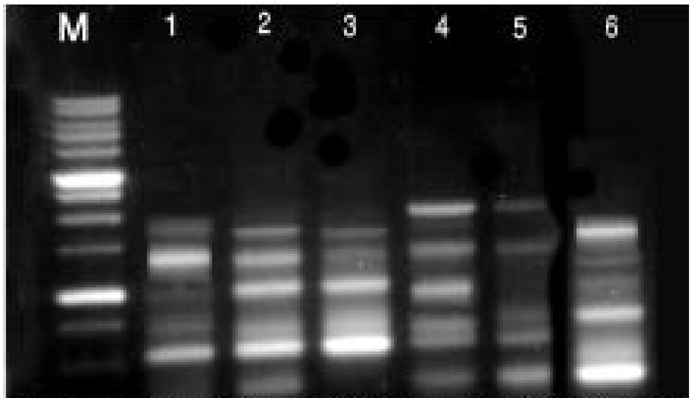
In Figure 1, the bands number 1, 2 and 6 were appeared in the genotypes; Giza 159, Agami x Gaori and Agami x Giza 159 in addition to the bands number 9 and 10 were appeared in the cultivar Agami which means that these bands were index for drought tolerance in this study. In Table 13, the bands number 5, 7 and 8 were common bands in the genotypes; Sakha 102, Agami, Giza 159, Agami x Gaori and Agami x Giza 159.

Finally, the overall estimated polymorphism using A17 primer for all studied genotypes was 80%. This high degree of polymorphism for these DNA markers could be very powerful tool for studying the phylogenetic relationships among rice genotypes. These findings are in agreement with those reported by Quirin *and* chandra(2005) and El-Said (2007).

Table 13: The densitometric analysis of RAPD-PCR products of moderate, susceptible and resistance genotypes of rice for drought against primer A17

Band No.	Base pairs	1	2	3	4	5	6
1	1750	-	-	+	+	+	+
2	1500	+	-	+	-	+	+
3	1000	+	-	+	+	+	+
4	950	-	-	+	-	-	+
5	600	+	+	-	+	+	-
6	550	-	-	-	-	-	+
7	400	+	-	+	-	+	+
8	350	+	+	+	+	-	+
9	300	-	+	-	-	-	-
10	250	-	+	-	-	-	-

4. Sakha 102 x Giza 171 (sensitive)
5. Agami x Gaori (Resistance)
6. Agami x Giza 159 (Moderate)
1. Sakha 102 (Sensitive)
2. Agami (resistance)
3. Giza 159 (moderate)



Fig(1): the denositometric analysis of rapd- pcr for moderate,suseptable and resistance genotypes of rice for drought using A17 primer.

In Table 14, the bands number 3, 6, 7 were appeared in the genotypes Agami, Giza 159, Agami x Gaori and Agami x Giza 159, while these bands were not appeared in the genotypes Sakha 102 and Sakha 102 x Giza 171, which means that these bands were index for development the drought tolerance for these genotypes. The molecular weight for these bands were 1350, 600 and 500 kDa for A18 primer.

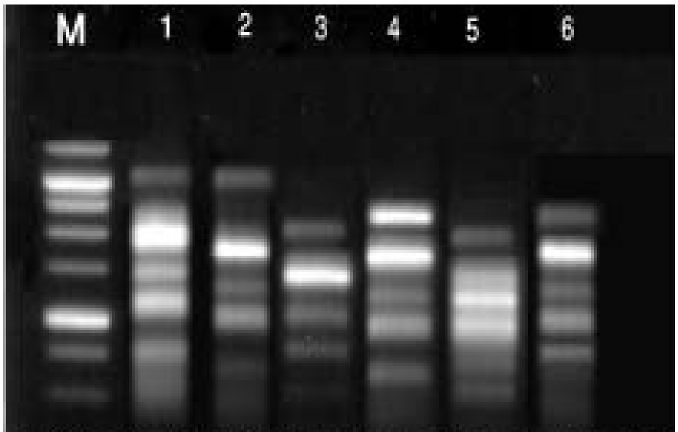
In Figure 2, the bands number 8, 9 and 10 were common bands in all the genotypes. The obtained results showed that RAPD-PCR techniques is a useful method for detecting polymorphism in rice. (Parsons and Michelmore 1997; Ravi *et al.*, 2003, Renn *et al.*, 2003 and Weerakoon *et al.*, 2008).

The densitometeric analysis of RAPD-PCR products of moderate, susceptible and tolerance plants of rice for drought using As-467468 primer are shown in Table 15 and Figure 3.

Table 14: The densitometric analysis of RAPD-PCR products of moderate, susceptible and resistance genotypes of rice for drought against primer A18.

Band No.	Base pairs	1	2	3	4	5	6
1	1800	+	-	+	+	+	-
2	1550	-	-	+	-	+	-
3	1350	-	+	+	-	+	+
4	1000	+	+	-	-	-	+
5	750	+	-	+	+	+	-
6	600	-	+	+	-	+	+
7	500	-	+	+	-	+	+
8	350	+	+	+	+	+	+
9	300	+	+	+	+	+	+
10	150	+	+	+	+	+	+

1. Sakha 102 (Sensitive) **4. Sakha 102 x Giza 171 (sensitive)**
2. Agami (resistance) **5. Agami x Gaori (Resistance)**
3. Giza 159 (moderate) **6. Agami x Giza 159 (Moderate)**



Fig(2): the denositometric analysis of rapd- pcr for moderate,suseptable and resistance genotypes of rice for drought using A18 primer.

The bands number 3, 4, 5, 7, 8 and 9 were observed in the cultivars Agami and Giza 159, while the bands 2, 3, 8 and 9 were shown in the cross Agami x Gaori, which means, that these bands were useful and related with drought in these genotypes.while,the bands number 2,3,4,5,6,7 and8 were observed in all the genotypes studied, respectively, Sakha 102, Agami, Giza159 ,Sakha 102 xGiza 171, AgamixGaori and AgamixGiza159 and the molecular weight for these bands ranged from 1600 kDa to 500 KDa.

Finally, the overall resimated polymorphism using As-467468 primer for all studied genotypes was 87%. This high degree of polymorphism for these DNA markers could be very powerful tool for studying the phylogenetic relationships among rice genotypes. These findings stand in comfermity with those recorded by sevsral workers among them El-Said (2007) and Weerakoon *et al.* (2008).

Table 15: The densitometric analysis of RAPD-PCR products of moderate, susceptible and resistance genotypes of rice for drought against primer As-467468.

Band No.	Base pairs	1	2	3	4	5	6
1	1600	-	-	-	+	+	-
2	1450	+	+	+	+	+	+
3	1300	+	+	+	+	+	+
4	1000	+	+	+	+	+	+
5	900	+	+	+	+	+	+
6	750	+	+	+	+	+	+
7	600	+	+	+	+	+	+
8	500	+	+	+	+	+	+
9	400	-	+	+	-	+	+
10	300	-	+	+	-	-	-

1. Sakha 102 (Sensitive)
2. Agami (resistance)
3. Giza 159 (moderate)
4. Sakha 102 x Giza 171 (sensitive)
5. Agami x Gaori (Resistance)
6. Agami x Giza 159 (Moderate)

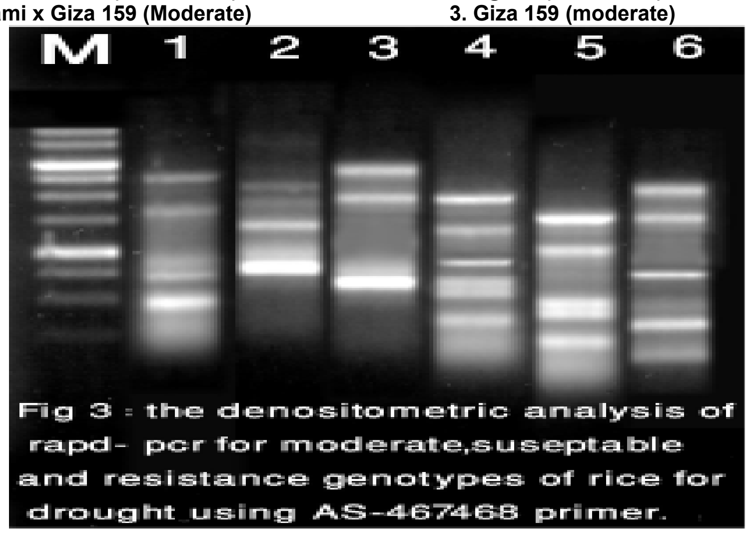


Fig 3 : the denositometric analysis of rapd- pcr for moderate,suseptable and resistance genotypes of rice for drought using AS-467468 primer.

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تحسين تحمل الأرز للعطش باستخدام تقنيات الوراثة الجزيئية

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اقيمت هذة الدراسة في الصوبة الزراعية مع توفير الحرارة و الاضاءة المناسبة لزراعة نبات الارز خلال شهر أكتوبر 2009م حتي شهر مارس 2010م مشتملة علي نوعين من الظروف الري العادي و(العطش)كل 15يوم (مستخدمة تحليل السلالة في الكشاف للاباء سخا 102 وعجمي ككشافات والاصناف جيزة171، جيزة172، جاوري وجيزة 159 كسلالات وتكنيك الانتخاب المساعد) المعلمات الوراثية (بواسطة البادئات الوراثية ا17 ،ا18 و اس864764 كدليل لتحمل العطش في الارز.

كانت اهم الصفات الاساسية المدروسة هي المحصول ومكوناته مثل تاريخ التزهير ،طول النبات بالاضافة الي عدد السنابل في النبات الواحد،عدد السنيبلات في السنبلة الواحدة، وزن الالف حبة و محصول الحبوب للنبات الواحد، بالاضافة لبعض الصفات المرتبطة بالعطش مثل اقصي طول للجذر،عدد الجذور للنبات الواحد،حجم الجذر، عدد الاوعية الخشبية في الجذر والوزن الجاف للجذر علي الترتيب تحت ظروف الري العادي والعطش.

وكانت المكونات الوراثية المدروسة و التي اشتملت علي قوة الهجين لاحسن اب وتاثيرات القدرتين العامة والخاصة علي التالف.وكانت اهم النتائج المتحصل عليها ان الاصناف عجمي، جاوري، والهجن سخا 102Xجاوري، عجمي Xجاوري، عجميX جيزة 159 قد اعطت احسن قيم للمتوسط وتقديرات موجبة وعالية المعنوية بالنسبة لقوة الهجين لاحسن اب والقدرتين العامة والخاصة علي التالف لكل الصفات المدروسة باستخدام تحليل السلالة في الكشاف

أوضحت كذلك الدراسة ان الهجن عجميXجاوري، عجمي X جيزة 159، سخا 102Xجاوري قد احتوت علي الحزم الوراثيةرقم٢،١ ،٦ للبادئ الوراثي أ 17، والحزم الوراثية رقم ٣ ،٦ ، ٧ للبادئ الوراثي أ 18، والحزم الوراثية ٣ ، ٤ ، ٥ ، ٧ ، ٨ ، ٩ للبادئ اس 864764 تحت ظروف العطش مما يؤكد ان هذه الحزم الوراثية كانت دليلا لتحمل العطش في الارز وبذلك يمكن التوصية بزراعتها في الاجيال الانعزالية للوصول للثبات الوراثي وبذلك يمكن ان تكون سلالات ارز مقاومة للعطش.

قام بتحكيم البحث

أ.د / محسن عبد العزيز بدوي	**كلية الزراعة – جامعة المنصورة**
أ.د / محمد عبد المنعم أحمد	**المركز القومي للبحوث**

Table 3: The mean square estimates of yield and its components characters for line x tester design under all conditions.

S.O.V	DF	M.S.											
		Heading date (days)		Plant height (cm)		No. of panicles/plant		No. of filled grains/panicle		1000-grain weight (g)		Grain yield/plant (g)	
		N	D	N	D	N	D	N	D	N	D	N	D
Replications	2	0.34	3.12	1.58	2.14	3.51	4.16	0.66	0.77	0.86	2.31	3.40	2.70
Genotypes	13	117.5**	54.0**	301.0**	277.0**	140.0*	350.0**	27.00**	105.0**	140.0**	370.0**	30.0**	26.0**
Parents	5	62.5**	33.16**	128.0*	136.50**	40.0**	400.0**	70.0**	33.18**	70.0**	70.13**	16.0**	50.0**
Crosses	7	14.3*	125.0**	92.0**	67.0**	91.30**	76.30**	17.0**	60.31**	50.0**	70.0**	114.0**	47.0**
Parent vs. crosses	1	610.0**	117.0**	86.0**	115.30**	70.0**	37.50**	78.0**	85.0**	60.0**	78.0**	30.0**	66.0**
Lines	3	570.0**	26.30**	16.88**	112.50**	19.0**	60.14**	70.0**	38.0**	81.0**	60.0**	11.01**	70.0**
Testers	1	70.0**	78.17**	18.0**	36.0**	18.0**	62.18**	117.0**	107.3**	68.0**	68.7**	40.0**	12.60**
Lines x Testers	3	63.20**	82.00**	79.08**	127.50**	21.30**	28.00**	27.0**	32.7**	17.0**	28.0**	50.0**	37.0**
Error	26	0.77	0.96	1.54	1.90	0.50	0.96	2.50	0.30	1.14	2.77	0.17	0.28

*** Significant at 0.05 level, ** Significant at 0.01 level,N:Normal and D:Drought.**

Table 4:The mean performance of yield and its components for line x tester experiment under all conditions

Characters / Genotypes	Heading date (day)		Plant height (cm)		No. of panicles/plant		No. of filled grains/panicle		1000-grain weight (g)		Grain yield/plant (g)	
	N	D	N	D	N	D	N	D	N	D	N	D
Sakha 102	122.0	128.0	115.0	118.7	23.40	14.20	133.20	115.00	27.00	22.71	30.12	17.60
Agami	91.0	96.0	85.0	90.14	35.00	27.40	256.00	220.70	33.00	27.80	56.32	40.00
Giza 171	133.0	140.0	127.0	133.00	21.00	12.33	170.40	133.90	16.32	12.73	24.00	19.60
Giza 172	137.0	146.0	92.0	89.50	17.70	14.80	200.10	158.40	24.00	19.50	30.37	20.40
Gaori	118.0	121.0	120.0	123.00	31.80	26.70	220.20	199.80	27.50	23.00	71.30	50.20
Giza 159	142.0	150.0	128.0	133.40	25.00	12.76	190.30	186.00	28.70	18.40	37.00	30.80
Sakha 102 x Giza 171	144.0	152.7	135.0	138.70	14.30	11.33	260.50	134.00	22.60	17.30	38.50	30.00
Sakha 102 x Giza 172	135.0	138.2	113.0	120.82	22.50	17.65	200.40	154.70	287.30	18.70	25.31	17.50
Sakha 102 x Gaori	87.5	91.34	94.27	97.00	35.00	32.80	320.71	261.50	30.40	26.50	66.32	58.30
Sakha 102 x Giza 1`59	150.0	154.31	117.08	120.50	27.40	23.00	236.40	200.00	26.30	21.70	34.50	28.00
Agarmi x Giza 171	133.0	140.0	128.13	131.70	31.50	24.00	243.00	196.60	30.21	24.00	41.60	28.30
Agami x Giza 172	128.3	131.0	107.3	110.00	16.77	9.14	198.70	160.18	25.30	19.00	42.18	30.00
Agami x Gaori	91.32	93.57	95.3	97.50	37.38	33.74	300.80	227.33	31.30	28.50	67.30	60.70
Agami x Giza 159	140.3	146.72	114.62	118.30	24.30	19.80	270.00	220.37	23.00	21.70	37.60	28.00
LSD at 0.05	0.74	0.93	1.49	1.84	0.48	0.93	2.42	0.29	1.10	2.68	0.16	0.27
LSD at 0.01	1.00	1.25	2.01	2.48	0.65	1.25	3.27	0.39	1.49	3.62	0.22	0.36

*** Significant at 0.05 level, ** Significant at 0.01 level,N:Normal and D:Drought.**

Table 5: Percentages of heterosis over-better parent (B.P) for yield and its components traits studied under normal and drought conditions.

Characters / Crosses	Heading date (days)		Plant height (cm)		No. of panicles/plant		No. of filled grains/panicle		1000-grain weight (g)		Grain yield/plant (g)	
	N	D	N	D	N	D	N	D	N	D	N	D
Sakha 102 x Giza 171	18.03**	19.29**	17.39**	16.84**	-38.8**	-20.2**	52.80**	0.07	-16.29**	-23.82**	27.82**	53.06**
Sakha 102 x Giza 172	10.65**	7.96**	22.82**	34.90**	-3.8**	19.25**	0.14	-2.33**	4.81**	-17.65**	-16.66**	-14.21**
Sakha 102 x Gaori	-25.80**	-24.50**	-18.02**	-18.28**	10.06*	22.80**	45.60**	30.88**	10.54**	15.21**	-9.98**	16.13**
Sakha 102 x Giza 1`59	22.95**	20.55**	1.80*	1.51	9.6**	61.97**	24.20*	-9.37**	-8.36**	-4.44**	-6.75**	-9.09**
Agarmi x Giza 171	46.15**	45.80**	50.74**	46.10**	-10.0**	-12.40**	-5.07**	-10.90**	-8.45**	-13.66**	-26.13**	-29.25**
Agami x Giza 172	40.98**	36.45**	26.25**	24.02**	-52.08**	-66.60**	-22.30*	-27.40**	-23.33**	-31.65**	-25.10**	-25.00**
Agami x Gaori	0.35	-2.53**	12.11**	8.16**	6.80**	23.13**	17.50*	3.00**	-5.15**	2.51**	-5.61**	20.91**
Agami x Giza 159	54.17**	52.8**	34.84**	31.24**	-30.5**	-27.70**	5.46**	-0.14	-30.30**	-21.9**	-33.23**	301.00**
LSD at 0.05	1.34	0.76	1.70	2.00	1.13	0.86	0.77	1.25	0.54	0.64	1.70	1.50
LSD at 0.01	2.14	1.03	3.00	2.54	1.89	1.07	0.89	1.70	1.03	1.11	2.00	1.83

*** Significant at 0.05 level, ** Significant at 0.01 level,N:Normal and D:Drought**

Table 6: Estimates of general combining ability effect for the parental varieties evaluated of yield and its components characters for line x tester experiment under normal and drought conditions

Characters / Parents	Heading date (days)		Plant height (cm)		No. of panicles/plant		No. of filled grains/panicle		1000-grain weight (g)		Grain yield/plant (g)	
	N	D	N	D	N	D	N	D	N	D	N	D
Testers												
Sakha 102	-1.70**	0.89**	0.07	0.33	2.81*	8.79**	1.02*	3.0*	4.0**	1.50**	1.50**	0.40*
Agami	2.77**	1.16**	-1.18**	-2.50**	-3.77**	-0.54	2.17**	8.65**	1.33**	1.70**	3.20**	1.80**
LSD at 0.05	0.30	0.28	0.50	0.41	1.50	1.43	0.33	0.07	0.80	0.51	0.04	0.30
LSD at 0.01	0.40	0.36	1.03	0.77	3.00	1.77	0.80	0.70	1.14	1.30	0.70	0.83
Lines												
Giza 171	-1.58**	6.14**	3.71**	1.18	-3.80**	0.11	0.27	-1.18**	0.87	1.17	0.03**	0.04**
Giza 172	0.34	3.02**	0.18	2.50**	-4.16**	-2.79**	1.80*	2.30**	0.89	-2.0**	0.50**	0.18**
Gaori	2.79**	5.89**	-2.49**	-8.37*	8.08**	3.80**	2.20**	0.56*	3.0**	1.80**	0.06**	0.71**
Giza 159	1.13*	0.07	-3.02**	-8.21**	-2.07**	-1.89**	3.70**	2.80**	2.70**	3.0**	0.77**	1.50**
LSD at 0.05	0.50	0.34	1.31	2.0	0.40	0.43	0.60	0.50	1.40	1.20	0.01	0.02
LSD at 0.01	1.39	1.27	2.37	2.20	1.70	1.50	2.03	1.77	2.0	1.70	0.02	0.04

*** Significant at 0.05 level, ** Significant at 0.01 level,N:Normal and D:Drought.**

Table 7: Estimates of specific combining ability effects for the crosses evaluated of yield and its components characters for line x tester experiment under normal and drought conditions.

Treatments / Crosses	Heading date (days)		Plant height (cm)		No. of panicles/plant		No. of filled grains/panicle		1000-grain weight (g)		Grain yield/plant (g)	
	N	D	N	D	N	D	N	D	N	D	N	D
Sakha 102 x Giza 171	-2.70**	5.80**	17.30**	21.32**	0.83	-1.74	9.20**	11.30**	-3.90*	-5.40**	-2.70**	-3.50**
Sakha 102 x Giza 172	54.80**	-12.70**	0.78	-8.70**	-4.70	-3.50**	-14.70**	-8.70**	-40.63**	-5.60**	-8.13**	-9.20**
Sakha 102 x Gaori	1.49**	-21.40**	-9.30*	-2.70**	-3.16	-0.78**	0.50	0.70	0.73*	6.53**	4.05**	3.80**
Sakha 102 x Giza 1`59	-10.09**	2.47**	-17.80**	-5.44**	-50.18**	-8.30**	-0.89*	-3.90**	0.84*	3.90**	8.16**	0.73*
Agarmi x Giza 171	-0.07	-31.15**	-0.78	30.14**	6.07	7.48**	-15.40**	0.73	-0.87*	-0.95*	-3.74**	-2.90*
Agami x Giza 172	17.62**	13.47**	0.43	56.07**	-9.80**	-13.70**	18.11**	30.40**	5.30*	3.57**	-4.13**	-5.30**
Agami x Gaori	15.74**	13.84**	-13.07*	-27.40**	0.54	0.87**	-13.15**	-16.0**	-20.30**	-11.71**	30.93**	40.11**
Agami x Giza 159	-1.37**	11.70**	50.30**	13.47**	3.19	4.02**	0.78*	0.39	-13.40**	-50.39**	4.37**	5.03**
LSD at 0.05	0.732	0.607	2.70	1.93	8.98	0.28	0.64	0.80	0.28	0.14	0.56	0.33
LSD at 0.01	1.320	1.032	17.30	0.980	7.41	0.35	8.50	3.70	11.34	2.71	0.89	3.11

*** Significant at 0.05 level, ** Significant at 0.01 level,N:Normal and D:Drought.**

Table 8: The mean square estimates of some characters related to drought for line x tester design under all conditions

S.O.V	DF	M.S.									
		Maximum root length (cm)		No. of roots/plant		Root volume		Root xylem vessel number		Root dry weight (g)	
		N	D	N	D	N	D	N	D	N	D
Replications	2	0.67	4.16	1.34	2.50	3.60	2.70	0.69	0.77	4.60	3.0
Genotypes	13	50.18**	33.60**	40.13**	60.07**	13.71**	23.00**	71.03**	62.00**	31.00**	34.50**
Parents	5	43.70**	41.70**	39.16**	50.18**	30.13**	61.13**	70.13**	12.70**	27.00**	14.68**
Crosses	7	16.80**	113.70**	92.00**	101.30**	41.30**	70.13**	68.03**	71.00**	100.30**	51.00**
Parent vs. crosses	1	530.13**	72.00**	84.00**	113.00**	42.00**	113.00**	129.00**	73.00**	102.00**	85.00**
Lines	3	830.08**	110.18**	33.00**	27.13**	62.00**	30.14**	27.00**	19.00**	22.70**	14.50**
Testers	1	13.78**	27.00**	51.00**	39.40**	11.70**	61.07**	50.30**	17.00**	19.70**	30.12**
Lines x Testers	3	93.00**	80.14**	7.12**	13.15**	22.70**	13.00**	11.70**	20.17**	19.00**	30.02**
Error	26	0.86	0.72	1.22	1.78	0.48	1.33	1.16	0.34	2.01**	2.32

* Significant at 0.05 level, ** Significant at 0.01 level,N:Normal and D:Drought.

Table 9:The mean performance of some characters related to drought for line x tester experiment under normal and drought conditions

Characters / Genotypes	Maximum root length (cm)		No. of roots/plant		Root volume		Root xylem vessel number		Root dry weight (g)	
	N	D	N	D	N	D	N	D	N	D
Sakha 102	28.16	25.32	127.30	86.13	36.70	27.80	13.70	11.04	3.12	1.87
Agami	43.07	36.72	410.32	277.50	39.13	32.07	19.70	11.32	6.70	5.63
Giza 171	32.14	26.36	138.40	126.03	21.20	14.33	8.93	4.73	2.50	1.83
Giza 172	28.73	21.65	171.50	113.07	25.50	19.60	11.50	5.32	3.70	2.82
Gaori	51.32	39.14	510.32	142.13	71.13	62.02	16.80	9.82	10.14	7.52
Giza 159	37.21	31.17	149.70	127.50	50.00	42.70	21.50	14.63	9.02	6.72
Sakha 102 x Giza 171	25.07	18.78	201.32	184.70	33.03	27.31	15.63	11.32	4.67	2.50
Sakha 102 x Giza 172	32.14	27.05	177.18	135.40	41.12	26.50	12.73	8.16	3.91	2.70
Sakha 102 x Gaori	62.14	54.20	782.70	436.73	82.11	71.39	23.17	18.50	11.20	8.56
Sakha 102 x Giza 159	54.72	39.82	413.60	278.50	75.00	54.08	28.32	13.92	9.70	8.03
Agarmi x Giza 171	49.72	47.73	466.18	319.70	52.00	41.32	41.32	31.50	13.78	11.50
Agami x Giza 172	72.13	63.52	672.00	478.80	47.30	41.70	36.17	30.49	18.90	13.14
Agami x Gaori	65.32	47.13	392.17	370.54	62.40	54.32	52.18	32.02	16.53	13.52
Agami x Giza 159	49.13	46.72	588.17	372.13	44.70	39.82	39.14	27.13	14.33	11.50
LSD at 0.05	0.83	0.69	1.18	1.72	0.46	1.28	1.12	0.32	1.94	2.24
LSD at 0.01	1.12	0.94	1.59	2.33	0.62	1.74	1.51	0.44	2.63	3.04

*** Significant at 0.05 level, ** Significant at 0.01 level,N:Normal and D:Drought.**

Table 10: Percentages of heterosis over better parent (B.P)_for some characters related to drought under normal and drought conditions

Characters / Crosses	Maximum root length (cm)		No. of roots/plant		Root volume		Root xylem vessel number		Root dry weight (g)	
	N	D	N	D	N	D	N	D	N	D
Sakha 102 x Giza 171	-21.99**	-28.75**	45.46**	46.55**	-10.00**	-1.76	14.08**	2.53*	49.67**	33.68**
Sakha 102 x Giza 172	11.86**	6.83**	3.31**	19.74**	12.04**	-4.67**	-7.08**	-26.08**	5.67**	-4.25**
Sakha 102 x Gaori	21.08**	38.47**	53.37**	207.27**	15.43**	15.10**	37.91**	67.57**	10.45**	13.82**
Sakha 102 x Giza 159	47.05**	27.75**	176.28**	118.43**	50.00**	26.65**	31.72**	-4.85**	7.53**	19.49**
Agarmi x Giza 171	15.43**	29.98**	13.61**	15.20**	32.89**	28.84**	109.74**	178.26**	105.67**	104.26**
Agami x Giza 172	67.47**	72.98**	63.77**	72.54**	20.87**	30.02**	83.60**	169.34**	182.08**	133.39**
Agami x Gaori	27.27**	20.41**	-23.15**	33.52**	-12.27**	-12.41**	164.87**	182.86**	63.01**	79.78**
Agami x Giza 159	14.07**	27.23**	43.34**	34.10**	-10.60**	-6.74**	82.04**	85.44**	58.86**	71.13**
LSD at 0.05	1.66	1.71	0.86	1.13	2.16	2.011	1.71	2.07	1.30	1.71
LSD at 0.01	2.03	2.14	1.32	1.67	2.41	2.76	1.89	2.56	1.86	2.63

*** Significant at 0.05 level, ** Significant at 0.01 level,N:Normal and D:Drought.**

Table 11: Estimates of GCA effects for the parental varieties evaluated of some traits related to drought under normal and drought conditions

Characters / Parents	Maximum root length (cm)		No. of roots/plant		Root volume		Root xylem vessel number		Root dry weight (g)	
	N	D	N	D	N	D	N	D	N	D
Testers										
Sakha 102	-0.03	-11.70**	-4.73**	-9.14**	5.37**	11.44**	-1.13**	-0.09*	5.09**	11.02**
Agami	13.76**	27.14**	15.13**	7.32**	13.73**	29.18**	15.67**	19.63**	7.18**	33.14**
LSD at 0.05	7.18	0.34	3.50	2.78	0.03	0.07	0.04	0.03	0.70	0.49
LSD at 0.01	9.71	2.36	4.03	3.72	0.08	1.03	0.32	0.16	0.85	1.03
Lines										
Giza 171	-0.71*	-1.03	0.05	1.37	3.27	1.32	-1.03	0.07	-0.04	-0.92
Giza 172	-3.47**	-3.07*	-0.04	-1.14	-0.07	-1.15	3.92**	14.72**	-1.07	-0.33
Gaori	8.21**	8.49**	20.30*	17.32**	34.30**	16.86**	7.31**	9.03**	71.18**	30.42**
Giza 159	-7.09**	-13.27**	4.16**	7.11**	7.29**	13.40**	-0.02	-1.03	8.67**	15.27**
LSD at 0.05	0.37	1.14	1.27	1.50	4.70	3.39	1.70	1.18	2.50	1.30
LSD. at 0.01	0.54	3.27	2.50	1.83	5.50	4.16	2.14	2.33	3.40	4.70

*** Significant at 0.05 level, ** Significant at 0.01 level,N:Normal and D:Drought.**

Table 12: Estimates of SCA effects for the crosses evaluated of some traits related to drought under normal and drought conditions

Characters / Crosses	Maximum root length (cm)		No. of roots/plant		Root volume		Root xylem vessel number		Root dry weight (g)	
	N	D	N	D	N	D	N	D	N	D
Sakha 102 x Giza 171	-1.17	0.34	-12.18**	-7.12**	17.30**	4.15**	-3.18**	-9.03**	-0.32	0.04
Sakha 102 x Giza 172	-2.15**	-1.16*	-1.78*	-0.04	8.30**	7.11**	-4.63**	-0.73	-0.50	-1.33
Sakha 102 x Gaori	13.70**	7.18**	4.63**	10.12**	3.19**	5.04**	4.67**	5.18**	3.99**	11.02**
Sakha 102 x Giza 159	3.49**	5.09**	2.73**	1.39**	0.07	-0.39	3.79**	9.18**	7.36**	4.79**
Agarmi x Giza 171	-0.07	-1.20*	-0.71	-0.34*	-1.09	-0.79	-0.31	-2.73**	0.02	-1.16*
Agami x Giza 172	-2.03*	-1.07*	0.02	-0.04	-0.54	0.27	2.90**	2.57**	11.03**	2.17**
Agami x Gaori	11.02**	9.14**	7.41**	6.03**	7.49**	13.04**	19.07**	4.76**	1.72**	1.98**
Agami x Giza 159	3.76**	5.18**	4.39**	12.04**	-1.11	-0.54	-1.33	-1.02	0.02	0.05
LSD at 0.05	1.36	0.78	1.78	0.29	1.13	1.17	1.39	1.14	0.93	1.03
LSD at 0.01	2.14	2.07	2.54	1.20	2.40	2.48	2.40	2.37	1.32	1.73

*** Significant at 0.05 level, ** Significant at 0.01 level,N:Normal and D:Drought.**