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# DEVELOPMENT OF SOME HIGH YIELDING RICE LINES TOLERANT TO DROUGHT STRESS CONDITIONS

**Abd Allah, A. A.**
**Rice Research and Training Center, Field crop Research Institute, Agriculture Research Center**

## ABSTRACT

In Egypt, rice is one of the major water consuming crops and continuous flooding is the most common methods for irrigation. The water requirement for the rice crop cause nowadays an acute problem because of the limited irrigation water available from the River Nile. The present study was carried out to develop new promising lines produce more rice with less water to be grown to the drought affected areas due to the shortage of irrigation water and at the end of the terminals which receives irrigation water irregularly. Some promising lines were derived from IET 1444/ Sakha 102, Sakha 101 / IR 65600 and Sakha 101 / Gaori populations. Attentions were paid to the traits more associated with drought tolerance among segregants, to identify genotypes that confer drought resistance through selection procedures. The progenies from each cross were advanced under drought conditions from $F_2$ generation using the pedigree method technique until $F_6$ generation. The best ten selected lines from Fn generation were promoted to the yield trial experiments during 2007 and 2008 seasons. Randomized complete block design with three replications was used. The amount of irrigation water applied was determined by using flow meter. In 2009 season, the lines were evaluated under different irrigation intervals (irrigation every four, eight and twelve days) to test their yield potential. These lines were found to be tolerant to drought conditions at different growth stages i.e. early and late vegetative stage, reproductive and ripening stage. These lines proved to possess useful traits associated with drought tolerance such as early maturity, medium tillering ability, intermediate plant height, deep and thick roots, high root volume, high root: shoot ratio, plasticity in leaf rolling and unrolling, in addition to high water use efficiency. Water saving ranged 50-55 % as compared to continuous submergence, with a rice yield of 7-9 tons/ ha. So, by using such lines, the total water requirements will be significantly reduced without significant reduction in the yield. Also these lines can be used as donor parents at reproductive stage to solve the problem of a lack of the donor parents in breeding rice for drought tolerance.

## INTRODUCTION

Rice is the staple food of about sixty percent of the world populations and is now planted on about 150 million hectares. It is grown in more than 100 countries of the world. One third of the world's population will experience severe water scarcity within the next 25 years according to a new study by a leading global water organization. The study, which is the first to look at the complete cycle of use and reuse of the world's fresh water, finds that the water sources that supply the world's wells, lakes, and rivers are disappearing (Wilson, 1999 and Jacob, 2006).

The abundant water environment in which rice grows best differentiates from that of other crops. Per capita, availability of water resources decline in many countries. In 2025, per capita availability of water resources in these countries are expected to decline more than the past decade (Wilson, 1999).

Thus, agriculture share of water will decline at an even faster rate because of increasing competition for available water from urban and industrial sectors. In the recent past, rice cultivation in several countries experienced water shortage problems. In some countries, inadequate water availability in the main producing areas, resulting from a three-year drought, affected paddy production in the last two years (FAO, 2004). Thus it is felt that, as in many other regions of the globe with water stress conditions, rice production in countries will also have to adopt strategies that allow more efficient water use in irrigation schemes. Thus agriculture share of water will diminish in both quantity and quality. The future of rice production will therefore depend heavily on developing and adopting strategies and practices that will use water efficiency in irrigation schemes. Such strategies and practices are also important for other parts of the world, particularly in some parts of Africa where demand for rice is high and water is less abundant than in Asia (Shinozaki, 2007).

Water productivity can be increased by increasing yield per unit area, i.e. by using better varieties or genotypes that produce high yields in drought-prone area or agronomic practices or by using suitable irrigation system (Millor, 2001).

In some cases, superior response to vegetative stage stress is associated with better performance under reproductive stage stress, but in many cases, the strategies that appear to be successful at the reproductive stage may be counterproductive when stress occurs at flowering (Pantuwan *et al.*, 2002).

Direct selection for improved yield under drought has been hampered by the unpredictability of drought events, which mean that selection pressure is generally inconsistent, and possibly contradictory, across years. Progress has been made, however, through the inclusion of tolerant parents in crossing (Chang *et al.*, 1982 and Pinheiro, 2003). More recently, the use of managed environments and targeted multilocation testing has been implemented to facilitate progress in breeding drought tolerant rice (Fischer *et al*., 2003). The success of these initiatives will be known within the next few years.

Because of the increasing needs of water for many other purposes than agriculture, and the susceptibility of rice plant to drought, appropriate line developed under the Egyptian conditions should be chosen to be grown. These promising lines must possess drought tolerance mechanisms such as escape, avoidance, tolerance and recovery (Asch *et al*., 2005). Short growth duration (generally defined by early flowering) constitutes an important attribute of drought escape, especially for conditions of a late-season drought stress. On the other hand, longer growth duration is often associated with high yield potential. Consequently, using drought escape as a solution should be associated with high yield. Early maturity leads to less, evapotranspiration because of the shorter time in the field. However, as growth duration is genetically linked with leaf characters and often with leaf size, early genotypes have a small leaf-area index. Thus, early genotypes show reduced evapotranspiration during most growth stages, up to the point where a full ground cover is achieved (Pantuwan *et al.*, 2002). For drought avoidance mechanism, at most growth stages, root-length density and total root length per plant is generally greater in a late cultivar than in the early one. This should be reflected in an advantage for the late genotype under conditions where extensive rooting is required.

Soil moisture stress affects plant height, tiller number, leaf area, dry weight of shoot and root and grain yield of rice. Water deficit during the reproductive stage is most damaging to rice crop (Abd Allah, 2004). Rice is sensitive to drought stress during flowering resulting in high floret sterility. When water deficit occurs near the time of flowering, rice yield is dramatically reduced, primarily as a result of increased spikelet sterility. In a conclusion, there are potential traits for improving drought resistance in drought tolerant rice, such as root traits, some shoot and physiological traits and grain yield. On the other hand, there is a need for further physiological and agronomic research to establish value for other potential traits, such as delayed senescence or stem reserve utilization.

Because of the area of the rice cultivation is restricted to the northern half of the Nile Delta; the area of cultivated rice has become limited as well as water recourses. We must turn to the cultivation of modern reclaimed land, as well as salt territories light. Also, some rice cultivated areas especially which are located at the end of the terminal in the northern part of the Nile Delta which suffer from shortage of irrigation water during different growth stages, which are considered to be one of the most serious constraints to rice production in Egypt. The most practical solution to this problem is the new rice varieties tolerate to drought to reduce the total water requirements. In an effort to conserve some of the water designated for agriculture, some promising lines can be produced to grow rice under water stress conditions instead of surface irrigation. If successful, a large percentage of water could potentially be saved.

This study aimed to develop new drought tolerant lines to produce more rice with less water, reduce the total water requirement in one hand and also, to tolerate the drought conditions occur in some rice growing areas due to the shortage of irrigation water on the other hand.

## MATERIALS AND METHODS

The present investigation was carried out at the farm of the Rice Research and Training Center, Sakha, Kafr EL Sheikh, Egypt during 2000 - 2009 rice growing seasons.

Genetic components of combining ability estimates of grain yield per plant in rice were investigated using six -parents complete diallel analysis. The parents producing high grain yield per plant under drought conditions were IET 1444, Gaori and IR65600. While those having low grain yield under drought conditions were used as Sakha101, Sakha102 and Giza 177 during 2000 season. The hybridization was achieved according to Mather and Jinks (1982) model to produce hybrid $F_1$ seeds to be grown in 2001. The experiment was conducted in a randomized complete block design with three replications. Grain yield per plant under drought conditions was recorded for combining ability analysis (Griffing, 1956).

The progenies from each cross were advanced from $F_2$ generation (2002 season) using the pedigree method technique until $F_6$ generation (2006 season) under drought conditions. Individual plant selection was made under drought conditions based on the traits associated with drought tolerance. Drought stress was imposed by using flush irrigation every 12 days without standing water. Among the crosses, sixty promising lines with early and medium duration were selected for estimating correlation coefficient and path analysis. The promising lines were derived from three populations i.e.; IET 1444/ Sakha 102, Sakha 101 /IR 65600 and Sakha 101 / Gaori. The best selected entries from $F_6$ generation (during 2006 rice growing season) were promoted to be grown under yield trials test experiment besides standard check i.e.; Giza 177, Sakha 101, Sakha 102 and IET 1444 rice cultivars. Two adjacent experiments were conducted under normal and drought conditions during 2007 and 2008 rice growing seasons for comparison. All plants of the promising lines and check varieties were individually transplanted in a randomized complete block design with three replications. Each plot consisted of ten rows for each line and parent. Weeds were chemically controlled by applying five liters of Saturn per hectare, four days after transplanting. Nitrogen fertilizers were applied at 165 kg N/ha.

**Physiological and shoot characters** such as plant height in cm (length of the main culm in centimeters was measured from the soil surface to the tip of the main panicle at maturity), tillers number per hill ( the total number of tillers per hill at maturity), leaf angle (measure the angle between the line and vertical axis with a protractor at heading), leaf rolling (was estimated by visual estimation based on methods proposed by De Data *et al.*, 1988), flag leaf area in c $m^2$ ( flag leaf area of 20 leaves were measured using leaf area meter (model L1 -3000A), flag leaf dry weight in gram ( the same leaves were transferred to the oven and dried at 70 c for 72h or to constant weight then the dry of each leaf were estimated), nitrogen% (N content in the leaves were estimated at vegetative stage according to Hafez and Mikkelsen,1981), sugar content ( was measured by estimating the total sugar in the stems at ripening stage) , water use efficiency (WUE) and relative water content (RWC was determined by the method of Barrs and Weatherly, 1962) were studied.

**Root characters** such as root length in cm (length of the root from the base of the plant to the tip of its longest root), root number per hill (number of all developed roots per plant), root volume in mL (volume (mL) of the root per plant was determined in cubic centimeter), root/ shoot ratio (ratio of the root dry weight to the shoot dry weight) and root thickness( the average diameter (mm) of tip portion , about 20 cm from the tip of three random secondary roots at the middle position of the root per plant were measured using a measuring magnifier were recorded at panicle initiation stage.

**Yield (t/ha) and its components** such as grain yield (t/ha), no. of panicles per plant (counting the number of panicles per plant when all plants were at the ripening stage), sterility % (the unfilled grains of the main panicle were separated and counted and sterility percentage was calculated), 100-grain weight in gram (it was recorded as the weight of 100 random rice grains per plant) were recorded at harvesting and drought susceptibility index (DSI) was calculated for each line using formula given by Saulescu *et al.*, (1995). DSI =

S / NS, where s and ns yield with stress condition (irrigation every 12 days) and normal irrigated, respectively.

In 2009 season, four adjacent experiments were applied; (1) flush irrigation at four day interval, (2) flush irrigation at eight day interval, (3) flush irrigation at twelve day interval to test the yield potential of the lines under irrigation intervals less than 12 days and (4) continuous flooding irrigation. The tested entries evaluated under every irrigation experiment in a randomized complete block design with three replications. Each experiment included the same set of the entries (10 lines) and was individually analyzed. Separation between experiments was done by using plastic sheet to prevent the water loss through seepage. Each plot consisted of seven rows; five meters long with 20 cm between rows and plants allowing a total of 25 plants per row. The other cultural practices of growing rice were practiced as recommended. The date of sowing was at the last week of April and each line was harvested individually in a bulk during the first week of September. The details of the soil physical and chemical properties are presented in Table 1.

**Table 1: Average of some physical and chemical properties of the soil in the experimental site (during 2007 and 2008 seasons).**

| Characters | Values |
|---|---|
| pH | 8.3 |
| EC (dS m-1) | 2 |
| **Soluble Cations (meq. L-1)** | |
| $Ca^{++}$ | 5.1 |
| $Mg^{++}$ | 2.1 |
| $K^{+}$ | 0.4 |
| **Soluble anions (meq. L-1)** | |
| $Na^{+}$ | 12 |
| $HCO_3$ | 3.5 |
| $Cl^{-}$ | 14.8 |
| **Mechanical analysis** | |
| $SO_4$ | 1.3 |
| Clay (%) | 56.1 |
| Silt (%) | 31.3 |
| Sand (%) | 12.6 |
| Texture | (Clayey) |

**Statistical analysis**

The data were statistically analyzed following Burton (1952) and Chang et al. (1974)**.** Some genetic parameters; i.e., phenotypic variance (PV), genotypic variance (GV), heritability in broad sense (Hb) were computed (Lush, 1949; Burton, 1951 and Johanson *et al.*, 1955). Means of the different lines were compared with their respective parents and control, using the least significant difference (LSD) method.

The combined analysis was conducted for the date of the two experiments (2007 and 2008 seasons). Before proceeding the computations of the combined experiments, it was necessary to determine whether the error variances of the tests are homogeneous. The test described by Bartlett (1937) was used. For comparison between means, Duncan's multiple range test was used (Duncan's, 1955). Path coefficient analysis was made between values of grain yield per plant and the most important characters responsible for drought tolerance according to Dewey and Lae (1959).

**Soil water relations**

Soil moisture content was gravimetrically determined in soil samples taken from consecutive depths of 15 cm down to a depth of 60 cm. Other soil samples were collected just before each irrigation and 48 hrs after irrigation. Field capacity was determined in the field. Wilting point and bulk density were determined according to Klute (1986) to a depth of 60cm. The average values are presented in Table 2.

The amount of irrigation water applied at each irrigation was determined on the basis of raising the soil moisture content to its field capacity plus 10% as a leaching requirements and it was measured by using flow meter. Also, irrigation water applied was calculated according to the equation of Michael (1978). Also, the water use efficiency was estimated. All these measurements together will allow the determination of the real drought tolerant lines rather than identification of lines that have a high yield potential under both normal and drought stress.

**Table 2: Soil constants determined before each irrigation (2007 and 2008 season).**

| Soil depth (cm) | Field Capacity (%) | Wilting Point (%) | Bulk density ( $g/cm^{3)}$ |
|---|---|---|---|
| 0-15 cm | 45.68 | 24.70 | 1.12 |
| 15-70 cm | 41.30 | 22.40 | 1.18 |
| 30-45 cm | 38.75 | 20.28 | 1.23 |
| 45-60 cm | 35.16 | 18.60 | 1.30 |
| Mean | 40.22 | 21.50 | 1.21 |

## RESULTS AND DISCUSSION

**Combining ability analysis**

Estimates of general combining ability (GCA in bold) and specific combining ability (SCA above diagonal) of grain yield /plant are presented in Table 3. Among the parents tested, highly desirable positive GCA values of LET 1444 and Sakha 102 which make them good combiners were found. These good combiners could produce progenies with high grain yield /plant as crossing with other parents. Significant reciprocal effects suggest the need for proper choices of male and female in hybridization programs to improve the trait. The largest SCA value was obtained in case of IET 1444 / Sakha 102 and IET 1444 / Giza 177. Then, 60 promising lines with mid-duration genotypes derived from these crosses were selected. Below diagonal values in Table 3 shows the reciprocal effect. Maternal effect was not significantly recognized except IR 6500 in terms of grain yield / plant.

Based on combining ability analysis for the target characters, 60 early and mid-duration lines derived from three populations, i.e. IET 1444 / Sakha 102, IET 1444 / Giza 177 and Gaori / Sakha 101 were advanced from the $F_2$ generation by selfing and selection (pedigree method) until the $F_6$ generation. Seeds from the $F_6$ plants of each line were collected and bulked to provide the seed source for yield trial experiment

**Table 3: General combining ability, specific combining ability and reciprocal effects of grain yield / plant in 6 x 6 diallel crosses (during 2001 season).**

| No. | Varieties | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 1 | IET 1444 | 5.100** | 1.80 | -6.20 | 15.30** | -19.70** | 12.50** |
| 2 | Gaori | -6.00 | 0.35 | -4.20 | -7.30 | 10.15 | -3.60 |
| 3 | Sakha 101 | -0.83 | 1.48 | 0.75 | -4.50 | 1.18 | 9.60 |
| 4 | Sakha 102 | -0.43 | 0.77 | -2.18 | 2.50** | 7.25 | -8.14 |
| 5 | IR 65600 | 13.76** | -25.00** | 3.10 | -21.00** | -3.400** | -0.20 |
| 6 | Giza 177 | 8.00 | 4.70 | -0.51 | 9.00 | 5.60 | -5.300** |

**** Highly significant**

**Path analysis and correlation coefficient**

Table 4 shows the correlation between field resistance to drought and plant characters. Nitrogen % (0.820), root length (0.558), root volume (0.610), root thickness (0.719) and relative water content (0.580) significantly and positively correlated with drought score. Positive but non-significant association were indicated between drought resistance and each of root /shoot ratio and 100-grain weight. When the correlations were partitioned into its components, flag leaf dry weight, nitrogen %, root thickness, relative water content and 100-grain weight each has a larger direct and positive influence on drought resistance (Table 4). A strong positive influence of tillers number /plant on drought score was reflected via flag leaf area (0.760). Also flag leaf area had a positive effect on drought score via flag leaf dry weight (0.510). Nitrogen % had positive effect on drought resistance via tillers number/ plant (0.770).

**Table 4: Direct (diagonal) and indirect effect of shoot and some yield characters on drought score of the selected rice lines (during 2006 season).**

| Characters | Days to heading (day) | Plant height (cm) | No. of tillers/ plant | Flag leaf area | Flag leaf dry weight (g) | Nitrogen (%) | Root length (cm) | Correlation with drought resistance |
|---|---|---|---|---|---|---|---|---|
| Days to heading(day) | -0.320 | -0.015 | 0.050 | -0.081 | -0.410 | 0.019 | -0.020 | -0.251 |
| Plant height(cm) | -0.015 | -0.850 | 0.218 | 0.315 | -0.110 | -0.111 | -0.160 | 0.071 |
| No. of tillers/plant | 0.08 | 0.140 | -0.630 | 0.760 | -2.112 | 0.115 | -0.170 | -0.370 |
| Flag leaf area | 0.030 | -0.220 | -0.328 | -0.740 | 0.510 | 0.140 | -0.141 | -0.040 |
| Flag leaf dry weight | -0.051 | -0.350 | -0.390 | 0.450 | 3.150 | 0.300 | -0.118 | -0.081 |
| Nitrogen (%) | -0.030 | 0.0280 | 0.770 | 0.144 | 0.010 | 4.180 | -0.230 | 0.820 |
| Root length (cm) | -0.017 | -0.275 | 0.150 | 0.110 | 0.031 | 0.070 | -0.380 | 0.558 |

Root volume had positive effect on drought resistance via root numbers/plant (o.510), root thickness (0.830), root /shoot ratio (0.620) and relative water content (0.750). Root thickness has positive effect on drought resistance via relative water content (o.555). A strong positive effect of root /shoot ratio on drought score was reflected via relative water content (0.810). Each of plant height, tillers number /plant, flag leaf area, roots number/plant and root/shoot ratio had a substantial negative and direct effect on drought resistance (Table 5).

**Table 5: Direct (diagonal) and indirect effect of root and some yield characters on drought score of the selected rice lines (during 2006 season).**

| Characters | Root volume | Root numbers | Root thickness | Root/ shoot ratio | Relative water content | 100-grain weight | Sterility % | Correlation with drought resistance |
|---|---|---|---|---|---|---|---|---|
| Root volume | 0.135 | 0.510 | 0.830 | 0.620 | 0.750 | 0.230 | -0.280 | 0.610 |
| Root number | 0.580 | -0.660 | -0.140 | 0.350 | 0.118 | 0.242 | 0.120 | -0.370 |
| Root thickness | 0.538 | 0.190 | 0.560 | -0.380 | 0.550 | 0.080 | 0.019 | 0.719 |
| Root/shoot ratio | 0.390 | 0.170 | 0.213 | -1.810 | 0.810 | 0.360 | 0.269 | 0.110 |
| Relative water content | 0.718 | 0.112 | 0.156 | 0.261 | 0.480 | 0.340 | 0.011 | 0.580 |
| 100-grain weight | 0.113 | 0.198 | 0.018 | 0.273 | 0.013 | 0.710 | -0.070 | 0.481 |
| Sterility % | 0.285 | 0.135 | 0.019 | 0.116 | 0.081 | 0.040 | -0.115 | -0.220 |

**Genetic parameters**

The analysis of variance (Table 6) showed significant differences amongst the genotypes for all characters and expressed considerable range of variation. Further, it was also observed that phenotypic and genotypic variance exhibited almost similar trend of variability (Table 6). The maximum range of variation was observed for number of panicles/ plant, relative water content and grain yield / plant indicating better scope for the genetic improvement in these characters. Estimates of heritability ranged from 46.00 (plant height) to 96.00 (days to heading). In general, high estimates of heritability were observed for all the characters studied. However, root thickness expressed maximum heritability (96.00%) followed by days to heading (93.00%) and relative water content (90.00%0 with low genotypic variance. This may be attributed to variety extent of environmental components involved in these traits (Bashar *et al.*, 2003 and Gomez and Kalamani 2003)**.** In the present study, it is very interesting to note that all characters having high values of genotypic variance with high heritability except three cases, i.e. plant height, root length and root thickness (Table 6). This implying that heritability was mainly owing to non-additive gene effect and the expected gain would be low. Genetic advance values were higher for 100- grain weight, relative water content and root: shoot ratio and the values were 32.83, 26.88 and 23.40, respectively. This indicated that heritability values were mainly owing to additive gene effect for these traits.

**Table 6: Genetic parameters of variation for some characters associated with drought tolerance in the promising lines.**

| Characters | Genotypic variance (%) | Phenotypic variance (%) | Heritability in broad sense (%) | Genetic advance |
|---|---|---|---|---|
| Days to heading(day) | 29.50 | 31.00 | 93.00 | 13.57 |
| Plant height(cm) | 96.20 | 212.00 | 46.00 | 14.00 |
| No. of panicles/plant | 135.00 | 230.00 | 58.00 | 22.86 |
| 100 grain weight(gram) | 190.00 | 226.00 | 84.00 | 32.83 |
| Relative water content | 120.00 | 132.00 | 90.00 | 26.88 |
| Root length( cm) | 0.80 | 1.16 | 69.00 | 1.93 |
| Root thickness(mm) | 38.00 | 39.00 | 96.00 | 15.58 |
| Root/shoot ratio | 90.00 | 100.00 | 90.00 | 23.40 |
| Grain yield(t/ha) | 50.00 | 65.00 | 76.00 | 15.93 |

## Mean performance

### Shoot characters

The ordinary analysis of variance showed highly significant differences among genotypes for all shoot characters studied in the two years (2007 and 2008 seasons) and their combined data. Means of shoot characters studied of the tested lines under drought conditions are shown in Table 7. In spite of the delay in heading occurring due to the shortage of irrigation water, the mean values of number of days to heading was lower than the check varieties in most of the tested lines. The earliest lines were GZ 8993-2-1-1-1 and GZ 7684-6-4-2-2 (97 days). While, the latest one was GZ 8743-8-2-1-1 (103 days) comparing with the check varieties Giza 177, Sakha 101 and IET 1444 (100, 113, 100 days, respectively). Early maturity has been shown to be an important trait under drought conditions (Cooper and Somrith 1997) because early flowering rice can escape the late season drought stress. However, although early maturity is an important character, it is associated with low yield potential (Lafitte, 2002). Flowering time was an important determinant of grain yield, earlier flowering genotypes escaped the sever stress and had higher grain yields indicating large genotypes by environment interactions (Pantuwan *et al.*, 2002). So we are focusing on early maturity lines which produce higher yield under drought conditions.

With respect to plant height, the values ranged between 80 cm for GZ 8452-7-6-5-2 and 110 cm for GZ8993-2-1-1-1 comparing with the check varieties Giza 177 ( 82 cm) and IET 1444 ( 90 cm) Table 7. The most desirable mean values towards dwarfing were obtained from the lines GZ8452-7-6-5-2 (80 cm), GZ7684-6-4-2-2(80 cm) and GZ8819-1-1-1-1(83 cm). According to the data obtained through two years (2007 and 2008 seasons), these lines remained a tall under drought conditions and therefore considered to be good candidate for drought tolerance. Change *et al.* (1974) and Abd Allah, (2004) reported that most drought resistant varieties remained tall during water stress while susceptible varieties were reduced in height. The stem length was decreased under water deficit conditions (Abd Allah, 2004). The plant height was reduced up to 25% in water stressed citrus seedlings (Wu *et al*., 2008). Stem length was significantly affected under water stress in most plants (Abd Allah, 2000 and Sankar *et al*., 2007).

Regarding number of tillers/plant, most of the studied lines had number of tillers/plant more than the international check variety IET 1444 and maximized in case of the lines GZ9333-8-1-2-8 ( 25 tillers/plant) and GZ 8452-7-6-5-2 ( 26 tillers/plant) Table 7. The values of the tested lines ranged from 19.00 to 26.00 tillers /plant comparing with the checks (from 12.00 to 19.00 tillers/plant). This result indicates that these lines will be more able to recover after a period of moisture stress. Tiller number is important for drought resistance, since a plant with more tillers may be more able to recover after a period of moisture stress (Chang *et al*., 1985). However, high tillering ability may also be undesirable character for drought resistance, since many tillers under drought conditions do not bear panicles. But based on the data obtained most of tillers of these promising lines bear panicles.

Five out of the ten tested lines had narrow leaf angle implying that these lines will reduce the areas exposed to solar radiation and therefore reduce evapotranspiration rate (Table 7). All these lines had drought scores ranged between 1 and 3 based on leaf rolling data as a symptom occurs due to the inability of leaves to sustain the evapotranspiration demand of the plant. This suggests a close relationship between leaf rolling and drought tolerance. Plants showing leaf rolling at early stages of stress appears to have poor drought tolerance (Blum, 1988). Concerning the flag leaf area, the results showed that it ranged between 12.00 and 25.00 (Table 7).

The lines GZ8993-2-1-1-1, GZ8743-4-3-2-1, GZ8743-8-2-1-1 and GZ7684-6-4-2-2 gave the desirable mean values of flag leaf area under drought conditions. Water deficit stresses mostly reduced leaf growth and in turn the leaf areas in many species of plant like soybean (Zhang *et al.*, 2004), rice (Wullschleger *et al.*, 2005) and many other crops (Farooq *et al*., 2009).

**Table 7: The mean performance (combined) of the most promising lines under drought conditions for shoot characters studied (2007 and 2008 seasons).**

| Entry | H.D | P.H | T.no. | L.ang. | L.roll. | F.l.a. | F.l.d.w. | N% |
|---|---|---|---|---|---|---|---|---|
| **GZ 9333-1-1-1-1** | 100.00 | 94.00 | 20.00 | Narrow | 1 | 12.00 | 2.00 | 2.10 |
| **GZ9333-1-1-2-3** | 98.00 | 100.00 | 22.00 | Narrow | 3 | 16.00 | 1.75 | 2.20 |
| **GZ8993-2-1-1-1** | 97.00 | 110.00 | 22.00 | Wide | 1 | 20.00 | 1.85 | 1.98 |
| **GZ9333-8-1-2-8** | 100.00 | 95.00 | 25.00 | Narrow | 3 | 15.00 | 1.73 | 2.00 |
| **GZ8452-7-6-5-2** | 102.00 | 80.00 | 26.00 | Wide | 3 | 16.00 | 1.89 | 1.78 |
| **GZ8743-4-3-2-1** | 100.00 | 93.00 | 23.00 | Narrow | 3 | 21.00 | 1.63 | 2.00 |
| **GZ8743-5-3-1-1** | 99.00 | 99.00 | 20.00 | Narrow | 3 | 16.00 | 1.46 | 2.59 |
| **GZ8743-8-2-1-1** | 103.00 | 107.00 | 21.00 | Narrow | 3 | 18.00 | 1.63 | 1.51 |
| **GZ8819-1-1-1-1** | 98.00 | 83.00 | 19.00 | Wide | 3 | 16.00 | 1.60 | 1.68 |
| **GZ7684-6-4-2-2** | 97.00 | 80.00 | 22.00 | Narrow | 1 | 19.00 | 1.82 | 2.058 |
| **Giza 177** | 100.00 | 82.00 | 12.00 | Wide | 7 | 25.00 | 1.10 | 1.22 |
| **Sakha101** | 113.00 | 87.00 | 15.00 | Wide | 5 | 22.00 | 1.35 | 1.30 |
| **IET1444** | 100.00 | 90.00 | 19.00 | Narrow | 3 | 18.00 | 1.65 | 1.42 |
| **LSD at 05** | 1.88 | 3.55 | 1.50 | - | 1.65 | 2.50 | 0.25 | 0.45 |

**H.D. = Days to heading, P.H = Plant height, T.no = No. of tillers/plant, L.ang. = Leaf angle, L. roll. = Leaf rolling, F.l.a. = Flag leaf area, F.l.d.w. = Flag leaf dry weight and N% = Nitrogen percent.**

Regarding the flag leaf dry weight, as shown in Table 7, the lines GZ 9333-1-1-1-1, GZ8993-2-1-1-1and GZ 8452-7-6-5-2 gave the highest mean values. Their respective values were 2.00, 1.85 and 1.89, respectively which were more than what the check varieties produced 1.10, 1.35 and 1.65 for Giza 177, Sakha 101 and IET 1444. Nitrogen % of all the tested lines exceeded the highest check variety, IET 1444 (1.42). The highest nitrogen % was obtained from GZ 9333-1-1-1-1 (2.10 %), GZ 9333-1-1-2-3 (2.20%) and GZ 8743-5-3-1-1 (2.59%). Price *et al*. (1999) and Toorchi *et al.* (2003) reported that shoot characters comprising of plant height, tillers numbers/plant, leaf angle, leaf rolling, flag leaf area, flag leaf dry weight and nitrogen% could be used as selection criteria in selecting drought resistant lines in many crops.

**Yield and its component characters**

The ordinary analysis of variance revealed highly significant differences among genotypes for most of yield and its component characters studied in the two years and their combined data. Means of yield and its component characters studied of the tested lines under drought conditions are shown in Table 8.

For number of panicles/plant (Table 8), all the selected lines possess high number of panicles/plant comparing with the check varieties. The mean values of panicles/plant ranged between 16.00 panicles/plant for GZ 8819-1-1-1-1 and 25.00 panicles/plant for GZ 8452 -7-6-5-2 comparing with 10.00 and 13.00 panicles / plant for the check varieties Giza 177 and Sakha 101, respectively. This finding means that most of tillers beard panicles under drought conditions for these promising lines. This may be due to total nitrogen concentration in both leaf and stem under drought conditions. Increasing total nitrogen concentration in both leaf and stem was reflected in a corresponding increase in protein-N in drought resistant lines and in ammonical- N in drought –susceptible lines. The accumulated protein-N under drought induced continuous tillers production in the drought resistant lines (CRRI, 1978).

For sterility %, the most desirable mean values towards this trait were observed by the lines GZ9333-1-1-2-3, GZ9333-8-1-2-8, GZ8819-1-1-1-1, these values ranged from 8.00% to 9.00% (Table 8). The highest mean values were detected by the lines GZ8743-4-3-2-1(13.00%) and GZ8743-5-3-1-1 (15.00%) which were lower than the check varieties Giza 177(17%) and Sakha 101(18.00%). The same trend was also found for 100-grain weight. It was minimized for GZ 5121-5-2 (2.30 g) and maximized for GZ 8372-5-3-2-1 (2.55 g), comparing with the two check varieties Giza 177 (2.30 g) and Sakha 101 (2.30 g). For stem sugar at booting stage, most of the selected lines, such as GZ8993-2-1-1-1, GZ9333-8-1-2-8, GZ8452-7-6-5-2, GZ8743-4-3-2-1 and GZ7684-6-4-2-2 were characterized by high stem sugar during the ripening stage, indicating the contribution of stem carbohydrate to grain filling. In spite of moisture stress at booting and flowering reduces dry matter production and induce sterility resulting in less dry matter accumulation and low concentration of non-reducing sugars in the stems, these lines had low sterility % implying that they are considered to be drought tolerant lines.. Bhattacharjee *et al.* (1971) reported that lines with high stem sugars resisted drought better than others because sugars translocated from stem to panicle have promoted normal grain filling under stress conditions. Regarding relative water content (RWC), all the tested lines had higher RWC than the check varieties (Table 8). Their respective values ranged from 45.00 for GZ 9333-1-1-1-1 to 68.00 for GZ 7684-6-4-2-2 comparing with the check varieties Giza 177 (32.00), Sakha 101 (25.00) and IET 1444 (38.00). All these lines had high water use efficiency( WUE) due to high productivity, the most desirable mean values for WUE were detected by the lines GZ 9333-1-1-1-1 (1.30), GZ9333-8-1-2-8 (1.40) and GZ8743-8-2-1-1 (1.35) . It could be concluded that by using such promising lines, the amount of irrigation water applied could be significantly reduced without significant reduction in rice yield. The mean values of grain yield /plant for the tested lines ranged between 29.00 g in GZ 8819-1-1-1-1 and 36.00 g in GZ 8452-7-6-5-2 which is almost from 7.00 to 8.56 t/ha comparing with the check varieties Giza 177 (16.0 g), Sakha 101 (18.0 g) and IET 1444 ( 22.00 g) which produced 3.80 , 4.28 and 5.23 t/ha, respectively.

**Table 8: The mean performance (combined) of the most promising lines under drought conditions for some physiological and yield and its components (during 2007 and 2008 seasons).**

| Entry | No. of pan./pl. | Str. (%) | 100-g.w (g) | Sugar (%) | R.W.C | W.U.E | GrainYield (t/ha.) |
|---|---|---|---|---|---|---|---|
| **GZ 9333-1-1-1-1** | 18.00 | 12.00 | 2.30 | 8.00 | 45.00 | 1.30 | 7.61 |
| **GZ9333-1-1-2-3** | 17.00 | 8.00 | 2.50 | 6.00 | 48.00 | 1.10 | 7.14 |
| **GZ8993-2-1-1-1** | 19.00 | 11.00 | 2.55 | 13.00 | 55.00 | 1.21 | 8.09 |
| **GZ9333-8-1-2-8** | 21.00 | 9.00 | 2.50 | 14.00 | 58.00 | 1.40 | 8.33 |
| **GZ8452-7-6-5-2** | 25.00 | 12.00 | 240 | 15.00 | 60.00 | 1.25 | 9.04 |
| **GZ8743-4-3-2-1** | 19.00 | 13.00 | 2.50 | 12.00 | 51.00 | 0.98 | 7.37 |
| **GZ8743-5-3-1-1** | 17.00 | 15.00 | 250 | 8.00 | 55.00 | 1.15 | 7.14 |
| **GZ8743-8-2-1-1** | 18.00 | 11.00 | 2.40 | 9.00 | 58.00 | 1.35 | 7.61 |
| **GZ8819-1-1-1-1** | 16.00 | 9.00 | 2.50 | 7.00 | 50..00 | 0.97 | 6.90 |
| **Gz7684-6-4-2-2** | 20.00 | 10.00 | 2.50 | 11.00 | 68.00 | 1.25 | 8.33 |
| **Giza 177** | 10.00 | 17.00 | 2.30 | 3.50 | 32.00 | 0.89 | 3.80 |
| **Sakha101** | 13.00 | 18.00 | 2.30 | 4.20 | 25.00 | 0.90 | 4.28 |
| **IET 1444** | 16.00 | 12.00 | 2.40 | 6.00 | 38.00 | 0.98 | 5.23 |
| **LSD at 0.05** | 1.90 | 1.10 | 0.25 | 1.50 | 4.25 | 0.15 | 0.65 |

**No. of pan. /pl. = Number of panicles per plant, Str. % = Sterility %, 100-g.w (g) = 100 grain weight, Sugar % = Sugar content, R.W.C = Relative water content and W.U.E = water use efficiency.**

## Root characters

The ordinary analysis of variance revealed highly significant differences among genotypes for all root characters studied in the two years and their combined data. Means of root characters studied of the tested lines under drought conditions are shown in Table 9. The root system plays an important role under water deficit conditions and the nature and extent of root development are major factors governing plant response to moisture conditions. For root length, most of the tested lines had taller roots than the check varieties. The maximum root length was obtained from GZ 9333-1-1-1-1 (34.00 cm) and the lowest value was obtained from GZ 8819-1-1-1-(25.00 cm). Deep rooted plants showed greater drought avoidance than shallow rooted ones.

From our screening field, we found that deep rooted plants generally survive in drought better than shallow rooted plants because they can effectively use more water stored at deeper soil horizons. Most of the tested lines as it is quite clear from the data (Table 9), were superior for number of roots /plant, root volume, root: shoot ratio and root thickness comparing with the check varieties. Fukai *et al.* (1999) found that the drought – tolerant rice varieties generally had a larger proportion of deep roots. Dry root weight was reported to be a useful measure of drought tolerance. Pantuwan *et al.* (2001) pointed out that plants having high root weight are likely to be more tolerant to drought. Toorchi *et al.* (2002) and Manickavelu *et al*. (2006) reported that significant reductions in mean root and shoot dry weights from well-watered to severely-stressed conditions, but higher root to shoot dry weight ratios were observed under severe stress conditions in drought tolerant lines.

Drought resistance includes drought escape (DE) via a short life cycle or developmental plasticity and drought avoidance (DA) via enhanced water uptake through good root system such as high root length, high root volume, high root thickness and high root to shoot ratio (Tripathy *et al*., 2000). Positive correlation between yield and the root system were detected in many previous studies, suggesting that root system played an important role for drought tolerance in the field and DT and DA were well separated under drought conditions (Venuprasad *et al.*, 2002).

Blum (1982) reported that the root depth, root volume, high root: shoot ratio and root thickness are important in maintaining high leaf water potential against evapotranspirational demand under water stress. So, the selection for desirable root characteristics will be major objective in breeding drought tolerant varieties of rice. It could be concluded that the promising lines were far better than the check varieties for root system, implying that these lines could be considered drought tolerant lines.

**Table 9: The mean performance (combined) of the most promising lines under drought conditions for root characters studied (during 2007 and 2008 seasons).**

| Entry | Root length (cm) | No. of roots/plant | Root volume (mL) | Root: shoot ratio | Root thickness |
|---|---|---|---|---|---|
| **GZ 9333-1-1-1-1** | 34.00 | 240.00 | 35.00 | 1.23 | 0.60 |
| **GZ9333-1-1-2-3** | 30.00 | 176.00 | 37.00 | 1.10 | 0.58 |
| **GZ8993-2-1-1-1** | 26.00 | 200.00 | 35.00 | 0.87 | 0.67 |
| **GZ9333-8-1-2-8** | 30.00 | 170.00 | 42.00 | 1.90 | 0.62 |
| **GZ8452-7-6-5-2** | 30.00 | 181.00 | 45.00 | 2.20 | 0.70 |
| **GZ8743-4-3-2-1** | 27.00 | 230.00 | 58.00 | 1.67 | 0.55 |
| **GZ8743-5-3-1-1** | 32.00 | 210.00 | 47.00 | 0.95 | 0.54 |
| **GZ8743-8-2-1-1** | 24.00 | 214.00 | 53.00 | 1.20 | 0.68 |
| **GZ8819-1-1-1-1** | 25.00 | 250.00 | 50.00 | 1.23 | 0.53 |
| **GZ7684-6-4-2-2** | 27.00 | 265.00 | 46.00 | 0.89 | 0.75 |
| **Giza 177** | 22.00 | 135.00 | 20.00 | 0.42 | 0.42 |
| **Sakha 101** | 25.00 | 156.00 | 25.00 | 0.43 | 0.40 |
| **IET 1444** | 28.00 | 168.00 | 35.00 | 0.88 | 0.48 |
| **LSD at 0.05** | 3.30 | 5.70 | 3.50 | 0.35 | 0.06 |

Data presented in Table 10 showed that grain yield differed among the lines within each treatment and also between the treatments. The mean values ranged from 10.30-13.00 t/ha for normal conditions; from 7.61-10.94 t/ha for irrigation every 4 days; from 7.44-9.52 t/ha for irrigation every 8 days and from 6.90-9.04 t/ha for irrigation every 12 days. These results indicated that the yield increased by decreasing the period of withholding. Regarding drought index as a ratio between the yield under drought condition (irrigation every 12 days) and the yield under normal condition, all the selected lines had high drought index comparing with the check varieties. The lines GZ8993-2-1-1-1 (0.74), GZ9333-8-1-2-8 (0.75) and GZ7684-6-4-2-2(0.75) gave high tolerance of stress conditions for grain yield. The mean values of drought index ranged from 0.74 to 0.75.

**Table 10: Grain yield of rice entries as influenced by irrigation intervals (2009 season).**

| Entries | Grain yield t/ha (continuous flooding)) | Grain yield t/ha (irrigation every 4 days) | Grain yield t/ha ( irrigation every 8 days) | Grain yield t/ha ( irrigation every 12 days) | Drought index (%) |
|---|---|---|---|---|---|
| GZ 9333-1-1-1-1 | 10.50 | 8.33 | 7.85 | 7.61 | 0.72 |
| GZ9333-1-1-2-3 | 10.30 | 7.85 | 7.61 | 7.14 | 0.69 |
| GZ8993-2-1-1-1 | 10.80 | 9.52 | 8.56 | 8.09 | 0.74 |
| GZ9333-8-1-2-8 | 11.00 | 10.71 | 9.04 | 8.33 | 0.75 |
| GZ8452-7-6-5-2 | 13.00 | 10.94 | 9.52 | 9.04 | 0.69 |
| GZ8743-4-3-2-1 | 10.60 | 8.33 | 7.61 | 7.37 | 0.69 |
| GZ8743-5-3-1-1 | 10.30 | 8.33 | 7.85 | 7.14 | 0.69 |
| GZ8743-8-2-1-1 | 10.50 | 9.04 | 8.33 | 7.61 | 0.72 |
| GZ8819-1-1-1-1 | 10.00 | 7.61 | 7.44 | 6.90 | 0.69 |
| GZ7684-6-4-2-2 | 11.00 | 10.47 | 9.04 | 8.33 | 0.75 |
| (Check)Giza 177 | 10.00 | 7.14 | 4.28 | 3.80 | 0.38 |
| (Check)Sakha101 | 12.00 | 7.61 | 5.95 | 4.28 | 0.35 |
| (Check)IET 1444 | 10.00 | 8.33 | 6.42 | 5.23 | 0.52 |
| Mean | 10.80 | 8.78 | 8.28 | 7.80 | 0.72 |
| Range | 10.30 -13.00 | 7.61- 10.94 | 7.44 -9.52 | 6.90 -9.04 | 0.35-0.75 |
| LSD at 0.05 | 0.35 | 0.55 | 0.52 | 0.62 | 0.16 |

The superiority in the previous lines for drought resistance may be due to high desirable for drought measurements i.e. flag leaf area, flag leaf dry weight, plasticity in leaf rolling and unrolling, nitrogen content, sugar content, relative water content, root volume, root length, root/shoot ratio and water use efficiency.

## CONCLUSION

Many rice varieties can tolerate drought at vegetative stage by a sustaining mechanism and recovery vigor. However, some of them become susceptible to drought at the flowering or reproductive stage. The promising lines obtained in the current investigation were found to be good candidates for drought tolerance at all stages of growth because they possessed many desirable traits associated with drought tolerance i.e. root characters such as deep roots, high root volume, high roots number, high root dry weight and high root: shoot ratio. They also have good shoot and physiological characters such as early duration (126-132 days), medium height (80-110 cm with less reduction in height under stress), higher tillers number, intermediate plant height, narrow leaf angle (erect leaves), unrolled leaves (better drought score from 1-3), desirable flag leaf area, high flag leaf dry weight, high nitrogen content in their leaves, high relative water content (maintenance of high water potential in leaf), high sugar content in their stems (high dry matter accumulation by flowering) and high water use efficiency. In addition, their superiority in yield and its components such as higher grain yield, higher panicle number, heavier grains weight and low sterility %. The total water requirement of these promising lines was found to be 7140 $m^3$/ ha under drought conditions comparing with normal conditions which ranged between 14280 $m^3$ /ha and 15470 $m^3$ /ha. By using such lines the total water requirements will be significantly reduced without a significant reduction in the yield. Also these lines can be used as a donor parents at reproductive stage to solve the problem of a lack of the donor parents in rice breeding program for drought tolerance. These lines produced from 7.00- 9.00 t/ha grain yield under drought conditions (flush irrigation every 12 days) with 50- 55% saving of irrigation water applied. These lines will be recommended to be new rice varieties tolerant to drought conditions in the near future.

## REFERENCES

Abd-Allah, A.A. (2004). A breeding study on drought tolerance in rice (*Oryza sativa* L.). Egyptian J. of Agri. Res. 82(1): 149-165.

Abd-Allah, A.A. (2000). Breeding studies on rice (*Oryza sativa* L.). Ph.D. Thesis, Fac. Agric. Menoufiya Univ., Shibin El-Kom, Egypt.

Asch, F; M. Dingkuhn; A. Sow and A. Audebert (2005). Drought-induced changes in rooting patterns and assimilate partitioning between root and shoot in upland rice. Field Crops Res., 93(2/3): 223-236.

Bashar, M.K.; A. Khaleda; K.M. Iftekharuddaula and M.S. Ali (2003). Genetics of leaf water potential and its relationship with drought avoidance components in rice (*Oryza sativa* L.). Online J. of Biological Sci., 3(9): 760-765.

Barrs, H. D. and P.E.Weatherley (1962). Are-experiment of the relative turgidity technique estimating water deficient inleaves.Asut.J.Biol.Sci. 15:413-428.

Bartlett, M.S. (1937). Properties of sufficiency and statistical tests. Proc.Roy.Soc. London Series A 160: 268-282.

Bhattacharjee, D.P., G.Ramakrishnayya and S.C.Paul (1971). Physiological basis of drought conditions. Oryza 8 (2 supp1.): 61-68.

Blum, A. (1982). Breeding program for improving crop resistance to water stress .In: Kramer, P.J., Rasper Jr., C.D., Crop Reactions to Water and Temperature Stress in Humid Climates, pp.373.

Blum.A. (1988). Plant breeding for Stress environments. CRC. Inc., Florida. USA

Burton, G.W. (1951). Quantitative inheritance in pearl millet. Agron.J.43:409-417.

Burton, G.W. and E.H. Devane (1952). Estimating heritability in tall fescue from replicated clonal material. Agron. J. 45:478-841.

Chang, T.T.; G.C. Loresto and O.Tagum (1974). Screening rice germplasm for drought resistance. SABRAO J. 6(1): 9-16.

Chang, T.T.; G.C. Loresto; J.C. O'Toole and J.L. Armenta (1982). Strategy and methodology of breeding rice for drought-prone areas. In 'Drought Resistance in Crops with Emphasis on Rice'. (Ed. IRRI) pp. 218-244.

Chang, T.T.; L. Jorge; A. Sato; C.X. Mao; R. Peiris and G.C. Loresto (1985). Genetic studies on the components of drought resistance in rice (*Oryza sativa L.*). International Rice Genetics Symposium 27-31 May 1985.

Cooper, M. and B. Somrith (1997). Implications of genotype by environment interaction for yield adaptation of rainfed lowland rice. Influence of flowering date on yield variation. In: Breeding strategies for Rainfed Lowland Rice in Drought prone Environments. Proceeding of an International Workshop held at Ubon Ratchatani. ACIAR, Canberra, pp.104-114. (C.F.computer search).

CRRI (Central Rice Research Institute). (1978). Annual report of 1978. Cent.Rice Res. Inst., Cuttack, India.

De Datta, S.K.; and J.A.Malabuyoc ( 1988). A field screening technique for evaluating rice germplasm for drought tolerance during vegetative stage. Field Crops Res., 19:123 –124.

Dewey, D. R. and K. H. Lue (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. Agron.J.51:515-518.

Duncan, D.B. (1955). Multiple range and multiple F-tests. Biometrics, 11: 1-42.

FAO [Food and Agriculture Organization of the United Nations]. (2004). FAO/ GIEWS Food crops and Shortages No. 1, February 2004. (C.F.computer search).

Farooq, M.; A. Wahid; N. Kobayashi; D. Fujita and S.M.A. Basra (2009). Plant drought stress: effects, mechanisms and management. *Agron. Sustain. Dev.*, 29: 185–212.

Fischer, K.; H. Lafitte; S. Fukai; G. Atlin and B. Hardy (2003). Breeding rice for drought-prone environments.' (International Rice Research Institute: Los Banos, Philippines). (C.F.computer search).

Fukai, S.; G. Pantuwan; B. Jongdee; M. Cooper (1999). Screening for drought resistance in rain fed lowland rice. Field Crops Res., 64: 61-78.

Gomez, S.M. and A. Kalamani (2003). Scope of landraces for future drought tolerance breeding programme in rice (*Oryza sativa* L.). Plant-Archive, 3(1): 77-79

Griffing, B. (1956). Concept general and specific combining ability in relation to diallel crossing systems.Aug. J. Biol. Sci., 9:463-493.

Hafez, A.R. and D. S. Mikkelsen (1981). Colorimeter determination of nitrogen for evaluating the nutritional status of rice. Soil Sci. and plant analysis, 12 (1): 61-69.

Lafitte, R. (2002). Relationship between leaf relative water content during reproductive stage water deficit and grain formation in rice. Field Crops Research, 76: 165-174.

Jacob, W. K. (2006). A biotic stress and water scarcity: Identifying and resolving conflicts from plant level to global level. Field Crops Research, 97: 3–18.

Johanson, H.W.; H.F. Robinson and R.F. Comstock (1955). Estimates of genetic and environmental variability in Soybeans. Agron. J. 47: 314-318.

Klute, A. (1986). Methods of soil analysis. Part 1, second ed. Physical and Mineralogical methods.

Lush, J.L. (1949). Heritability of quantitative characters in farm animals.Proc.8th Intral Cong. Genet.1948.Hereditas Suppl. Vol.: 356-375. (C.F.computer search).

Manickavelu, A.; N. Nadarajan; S.K. Ganesh and R.P. Gnanamalar (2006). Genetic analysis of biparental progenies in rice (*Oryza sativa* L.). Asian j. of Plant Sci., 5(1): 33-36.

Mather, K. and J. L. Jinks (1982). Biometrical genetics. Cambridge University Press, London, New York 381 pp.

Michael, A.M. (1978). Irrigation theory and practices. Vikas Publishing House PUTLTD New Delhi, Bombay .

Millor, J.W. (2001). Irrigation, agriculture and poverty reduction: general relationships and specific needs. In: Hussain, I., Biltonen, E. (Eds.), Managing Water for the Poor: Proceedings of the Regional Workshop on Pro-poor Intervention Strategies in Irrigated Agriculture in Asia, Bangladesh, China, India, Indonesia, Pakistan and Vietnam, International Water Management Institute, Colombo, Sri Lanka. (C.F.computer search).

Pantuwan G.; S. Fukai; M. Cooper; M. Rajatasereekul and J.C. O'Toole (2002). Yield response of rice (*Oryza sativa L*.) genotypes to different types of drought under rainfed lowlands - Part 3. Plant factors contributing to drought resistance. Field Crops Research, 73: 181-200.

Pantuwan, G.; S. Fukai; M. Cooper and J.C. O Toole (2001). Yield response of rice (Oryza sativa L.) genotypes to drought under rainfed lowland.3. Plant factor contributing to drought resistance. Field Crops Res. 73, pp.181-200.

Pinheiro, B. (2003). Integrating selection for drought tolerance into a breeding program: the Brazilian experience. In 'Breeding rice for drought-prone environments'. (Eds KS Fisher, HR Lafitte, S Fukai, B. Hardy and G. Atlin) pp. 81-92.

Price, A. and B. Courtois (1999). Mapping QTLs associated with drought resistance in rice: progress, problems and prospects. Plant Growth Regul., 29: 123–133.

Sankar, B.; C.A. Jaleel; P. Manivannan; A. Kishorekumar; R. Somasundaram and R. Panneerselvam (2007). Effect of paclobutrazol on water stress amelioration through antioxidants and free radical scavenging enzymes in Arachis hypogaea L. Colloids Surf. B: Biointerfaces, 60: 229–235.

Saulescu, N.N.; W.E.Kronstad and D.N.Moss (1995). Detection of genotypic differences in early growth response to water stress in wheat using the snow and tingey system. Crop Sci. 35:928-931.

Shinozaki, K. and K.Y. Shinozaki (2007). Gene networks involved in drought stress response and tolerance. J. Experimental Botany 58(2): 221-227.

Toorchi M.; H.E. Shashidhar; S. Hittalmani and T.M. Gireesha (2002). Rice root morphology under contrasting moisture regimes and contribution of molecular marker heterozygosity. Euphytica 126:251–257

Toorchi, M.; H. E. Shashidhar; T. M. Gireesha and S. Hittalmani (2003). Performance of backcrosses involving transgressant doubled haploid lines in rice under contrasting moisture regimes: yield components and marker heterozygosity. Crop Sci. 43: 1448–1456.

Tripathy, J. N.; J. Zhang; S. Robin and H. T. Nguyen (2000). QTLs for cell-membrane stability mapped in rice (*Oryza sativa* L.) under drought stress. Theor. Appl. Genet. 100: 1197–1202. (C.F.computer search).

Venuprasad, R.; H. E. Shashidhar; S. Hittalmani and G. S. Hemamalini (2002). Tagging quantitative trait loci associated with grain yield and root morphological traits in rice (*Oryza sativa* L.) under contrasting moisture regimes. Euphytica 128: 293–300.

Wilson, E. (1999). One third of world population will experiences sever water scarcity by 2025. Embargod for release with a.m.papers, March17, 1999 (C.F.computer search).

Wu, Q.S.; R.X. Xia and Y.N. Zou (2008). Improved soil structure and citrus growth after inoculation with three arbuscular mycorrhizal fungi under drought stress. *European J. Soil Biol*., 44: 122–128

Wullschleger, S.D.; T.M. Yin; S.P. Difazio; T.J. Tschaplinski; L.E. Gunter; M.F. Davis and G.A. Tuskan ( 2005). Phenotypic variation in growth and biomass distribution for two advanced-generation pedigrees of hybrid poplar. *Canadian J. For. Res*., 35: 1779–1789.

Zhang, M.; L. Duan; Z. Zhai; J. Li; X. Tian; B. Wang; Z. He and Z. Li (2004). Effects of plant growth regulators on water deficit-induced yield loss in soybean. Proceedings of the 4th International Crop Science Congress, Brisbane, Australia

## أستنباط سلالات من الأرز عالية الانتاجية ومتحملة لظروف الجفاف

**عبدالله عبدالنبى عبدالله**
**مركز البحوث والتدريب فى الأرز-سخا- معهد بحوث المحاصيل الحقلية-مركز البحوث الزراعية**

يعتبر الأرز من أهم المحاصيل المستهلكة لمياه الرى فى مصر ، وطريقة الرى بالغمر هى الطريقة الأكثر شيوعا فى مصر. وتعتبر الأحتياجات المائية لمحصول الأرز من أهم العوائق نظرا لمحدودية كمية المياه المتاحة من نهر النيل. أجريت هذه الدراسة لأستنباط سلالات جديدة من الارز عالية الأنتاجية وتستهلك كميات قليلة من مياه الرى ليمكن زراعتها فى المناطق المتأثرة بالجفاف بسبب نقص مياه الرى وكذلك فى المناطق التى تقع فى نهايات الترع والتى لا تصلها مياه الرى بصفة منتظمة. فى موسم ٢٠٠٠ تم اجراء التهجينات الممكنة بين أصناف متحملة للجفاف ولكن انتاجيتها منخفضة مثل الصنف أى اى تى ١٤٤٤، جاورى و أى ار ٦٥٦٠٠ وأصناف محلية عالية الانتاجية ولكنها حساسة لظروف الجفاف مثل الصنف سخا ١٠١ والصنف سخا ١٠٢ . تم أستخدام طريقة التربية بسجلات النسب بزراعة الأجيال ابتداء من الجيل الأول (موسم ٢٠٠١) وحتى الجيل السادس (موسم ٢٠٠٦) ، واجراء الانتخاب فى الأجيال الأنعزالية للصفات المرتبطة بتحمل الجفاف فى الحقل. فى موسم ٢٠٠٦ تم زراعة ٦٠ سلالة متميزة فى الجيل السادس ، حيث تم انتخاب أحسن ١٠ سلالات منها لتقييمها فى تجارب مقارنة المحصول خلال موسمى الزراعة ٢٠٠٧ و٢٠٠٨ تحت ظروف الجفاف ( الرى كل ١٢ يوم) باستخدام تصميم القطاعات الكاملة العشوائية فى ثلاثة مكررات. ثم تم عمل التحليل الأحصائى التجميعى لبيانات الموسمين. فى موسم ٢٠٠٩ تم اقامة أربعة تجارب لتقييم تلك السلالات تحت ظروف فترات رى مختلفة ( الرى كل ٤ أيام ، الرى كل ٨ أيام والرى كل ١٢ يوم بالأضافة الى الرى الغمر) ولأختبار محصول تلك السلالات تحت فترات رى أقل من ١٢ يوم ) ، حيث أستخدم تصميم القطاعات الكاملة العشوائية فى ثلاثة مكررات فى كل تجربة على حده حيث تم زراعة كل سلالة فى ٧ سطور ، طول السطر ٥ أمتار ومسافات زراعة ٢٠ سم بين النباتات وبين السطور ، بالاضافة الى التوصيات الفنية الموصى بها . تم تسجيل أهم الصفات المرتبطة بتحمل الجفاف خلال كل التجارب التى تم تنفيذها مثل صفات الجذر ( طول الجذر- حجم الجذر-عدد الجذور-سمك الجذر- نسبة الوزن الجاف للمجموع الجذرى الى المجموع الخضرى) ، بعض الصفات الخضرية والفسيولوجية ( طول النبات- عدد الفروع/نبات- زاوية ورقة العلم- التفاف الأوراق- مساحة ورقة العلم-الوزن الجاف لورقة العلم- نسبة النيتروجين فى الأوراق- محتوى السكر بالسيقان والأوراق- كفاءة استخدام مياه الرى- المحتوى النسبى للماء بالورقة ) وصفات المحصول ومكوناته ( محصول الحبوب/هكتار- عدد الفروع الحاملة للسنابل/نبات- النسبة المئوية للحبوب الفارغة- وزن المائة حبة ودليل الجفاف).

أوضحت النتائج أن تلك السلالات تتميز باحتوائها على معظم الصفات المرتبطة بتحمل الجفاف ، بالاضافة الى التبكير فى فترة النضج ( ١٢٧- ١٣٢ يوم من الزراعة وحتى الحصاد) وارتفاع كفاءة استخدام مياه الرى وأن محصول الحبوب لتلك السلالات تحت ظروف الجفاف ( الرى كل ١٢ يوم ) ، قد تراوح من ٧-٩ طن / هكتار ( من ٣-٣,٨ طن/ فدان) مع توفير من ٥٠-٥٥% من كمية مياه الرى المضافة خلال الموسم (٣٠٠٠ متر مكعب ماء/ فدان) مقارنة بالرى الغمر( ٦٠٠٠- ٦٥٠٠ متر مكعب ماء/ فدان ). أى أنه باستخدام تلك السلالات يمكن خفض الأحتياجات المائية لمحصول الأرز وبدون أن يحدث نقص معنوى فى الانتاجية كما أنه يمكن استخدام تلك السلالات كأباء معطية فى برنامج التربية لتحمل الجفاف والاجهادات البيئية الأخرى.