Development of High Yielding Rice Lines Tolerant to Drought and Heat Stress Conditions in Egypt

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Abstract: Shortage of irrigation water is a major production constraint of rice in some cultivated areas in Egypt, because our share in the River Nile water is not sufficient for both reclaiming and irrigation purposes. The limitation of water resources and increase the population had forced research workers to find ways for saving more irrigation water. The present study was carried out during the period from 2000 to 2011 rice growing seasons; to develop new promising lines, produce more rice with less water and tolerant to heat stress. These lines will be grown to the drought and heat stress affected areas due to the shortage of irrigation water and at the terminals which receives irrigation water irregularly as well as to face high temperature problem. Some promising lines were derived from Sakha102 /Morobereaken, Sakha 101/ Gaori and Giza 177/IET1444 populations. The selection was based on the traits more associated with drought and heat tolerance among sergeants, to identify genotypes that confer drought and heat resistance through selection procedures. The progenies from each cross were advanced under drought and heat conditions using the pedigree method technique. The best selected lines from Fn generation were promoted to the yield trial experiments annually. Randomized complete block design with three replications was used. The amount of irrigation water applied was determined by using flow meter. These lines proved to possess useful traits associated with drought and heat 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 around 40 % as compared to continuous submergence, with a rice yield of 7-9 tons/ ha. These lines could be grown under both water deficit and heat stress conditions by producing rice with less water without significant reduction in the yield.

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1. Introduction

Rice is grown on more than 148 million hectares in a wide range of ecosystems under varying temperatures and water regimes. About 28% of the world's rice is grown in rain-fed lowlands (**Chaves & Oliveira, 2004; Passioura, 2007**). These areas frequently experience severe water deficit due to uncertain and uneven rainfall distribution patterns, and yields are seriously affected by drought. Another 13% of the rice is grown under upland conditions without any surface water accumulation and is always prone to water stress during a part of the growing season. Drought stress is the major constraint to rice production and yield stability in the rain-fed regions **(Hongbo *et al.*, 2005).** Genetic improvement of adaptation to drought is addressed through the conventional approach by selecting for yield and its stability over locations and years. Such selection programs are slow in attaining progress because of the low heritability of yield under stress, the inherent variation in the field, and the limitation that there is usually only one experimentally drought crop per year **(Passioura, 2007**). Alternatively, yield improvements in water-limited environments could be achieved by identifying secondary traits contributing to drought resistance and selecting for those traits in a breeding program. The effectiveness of selection for secondary traits to improve yield under water-limiting conditions has been demonstrated in maize (**Zea mays L.) (Isendahl and Schmidt, 2006).**

A definition of drought generally accepted by plant breeders is: "a shortfall of water availability sufficient to cause loss in yield" or "a period of no irrigation that affects crop growth. Drought may happen at anytime during the growing season and may occur every year in some areas. Plant breeding is only one tool for alleviating drought stress. However, drought tolerant varieties developed through plant breeding are more accessible to farmers than costly agronomic practices or irrigation enhancements that might require large investments by farmers. Drought rice crops eliminate the need for flooding, instead using long root systems to extract moisture from the soil layers **(Kumar *et al.,* 2008).**

Drought resistance in rice is physiologically and genetically complex, and there are a number of traits which are thought to contribute to drought resistant mechanism. Lines which grow best during drought maintain high leaf water potential, and this tends to be associated with large root length **(Cha-um *et al.,* 207).**

Plant resistance to drought can be subdivided into escape, avoidance and tolerance strategies **(Kumar *et al*, 2006).** Escape strategies may rely on successful reproduction before the onset of severe stress, by means of a short life cycle, a higher rate of growth or the efficient storage and use of reserves for seed production. Dehydration avoidance, that is, the maintenance of a high (favorable) plant water status during stress, may be the result of minimized water loss (e.g. caused by stomatal closure, trichomes, reduced leaf area, senescence of older leaves, etc.) or maximized water uptake (e.g. by increased root growth). Finally, tolerance to low water potential (the maintenance of plant function at limited water availability and/or the recovery of plant water status and plant function after stress) may involve osmotic adjustments, but may also be the result of rigid cell walls or small cells. This study aimed to develop some drought tolerant lines, having high water use efficiency suitable to be grown under a period of no irrigation water.

2- Materials and Methods

Genetic components of combining ability estimates of grain yield per plant in rice were investigated using six -parents complete diallel analysis. The parents which performed well but having low grain yield per plant under drought conditions were IET1444, Gaori and Moroberaken. While those having high grain yield but susceptible to drought conditions used were Giza 177, Sakha102 and Sakha 101. The hybridization was achieved according to **Mather and Jinks model (1982)** to produce hybrid F1 seeds to be grown in 2001 season. 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 F2 generation using the pedigree method technique until F6 generation under drought conditions. Individual plant selection was made under drought conditions based on the traits associated with drought tolerance. The amount of water applied, at each irrigation was measured by flow meter on the basis of flush irrigation every 12 days; the total amount of irrigation water was 8570 m^3/ hectare.

Among the crosses, sixty promising lines with early and medium duration were selected for estimating correlation coefficient and path analysis. The best selected entries from F6 generation were promoted to be grown under yield trials test experiment besides standard check cultivars. Two adjacent experiments were conducted under normal and drought conditions at the farm of the Rice Research and Training Center, Sakha Kafr El-Sheikh, Egypt during 2010 and 2011 rice growing seasons for comparison. Physiological and shoot characters such as plant height in cm, tiller number per hill, leaf angle, leaf rolling, flag leaf area in cm^2, flag leaf dry weight in gram, nitrogen %,sugar content, water use efficiency and relative water content were studied. Root characters such as root length, root number per hill, root volume, root/ shoot ratio and root thickness were also studied. Yield (t/ha) and its components such as no. of panicles per plant, sterility % and 100- grain weight were recorded at harvesting and drought index (DI) was used to characterize relative stress resistance of all genotypes. The details of the climatic conditions are presented in Table (1).

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, wilting point and bulk density were determined according to **Klute (1986)** to a depth of 60cm.The average values are presented in Table (2).

Table (1): Sakha meteorological data during 2010 and 2011 seasons

Seasons	Months	Air temperature (^{o} C)			Relative humidity (%)			Wind speed (km/day)	Solar radiation (Mj/m^2)	Pan evaporation (mm)
		Max.	Min.	Mean	Max.	Min.	Mean			
2010	May	29.5	13.0	21.3	76.4	38.6	57.5	111.0	22.6	6.8
	June	31.7	17.7	24.7	82.2	47.0	64.6	109.0	28.1	7.8
	July	32.2	19.0	25.6	87.7	52.6	70.2	89.5	23.4	7.3
	August	32.4	19.4	25.9	88.4	53.0	70.7	77.0	21.2	6.8
	September	31.1	17.7	24.4	87.4	53.5	70.5	78.2	17.8	6.4
	October	29.1	13.4	21.3	76.2	52.1	64.2	91.5	12.0	4.6
2011	May	28.5	11.6	20.1	79.3	45.0	62.2	111.0	22.8	7.3
	June	31.7	17.0	24.4	81.4	47.0	64.2	117.0	23.0	8.3
	July	31.3	17.5	24.4	85.1	58.0	71.6	78.0	20.4	7.1
	August	33.0	18.6	25.8	91.6	59.0	75.3	65.0	22.3	6.5
	September	33.0	16.8	24.9	89.0	52.0	70.5	76.0	20.3	5.9
	October	29.0	13.4	21.2	76.0	49.5	62.8	70.0	15.2	4.7

Table 2: Some soil constants determined before each irrigation during 2010 and 2011 seasons

Soil depth (cm)	Field Capacity (%)	Wilting Point (%)	Bulk density (g/cm$^{3)}$
0-15 cm	45.68	24.70	1.12
15-30 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
Average	40.22	21.50	1.21

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. The amount of irrigation water applied was found to be 4000 m^3 per feddan comparing with 6000 m3 per feddan under continues flooding. 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.

The experiment was arranged in Randomized Complete Block Design (CRBD) with three replicates. The mean values obtained were compared using Duncan's New Multiple Range Test (**Duncan, 1955**). The combined analysis was conducted for each experiment of the two years (2010 and 2011 seasons). Before preceding 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. The correlations between characters were developed using Pearson's correlation coefficients.

3- Results and Discussion

Mean performance

Shoot characters:

Means of shoot characters studied of the tested lines under drought conditions are shown in Table (3). The mean values of number of days to heading were lower than the check varieties in most of the tested lines. The earliest lines were GZ 8452-6-1-3-1, GZ 8450-3-1-2-1, GZ 8452-6-1-3-2, and 8399-4-3-2-1 and GZ 8710-3-2-1-1 (the values ranged from 95-97 days). While, the latest one was GZ 8714-3-3-2-1 and GZ 8714-4-2-2-1 (102 and 103 days, respectively) comparing with the check variety IET 1444 (100 day). With respect to plant height, the values ranged between 87.20 cm for GZ 8452-6-1-3-1 and 103.20 cm for GZ 8714-7-3-2-1comparing with the check varieties IET 1444 (90 cm). The most desirable mean values towards dwarfing were obtained from the lines GZ 8452-6-1-3-1 (87.20 cm), GZ 8399-4-3-2-1 (88.00 cm) and GZ 8399-4-1-2-2 (90.00 cm). 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 GZ 8714-3-3-2-1 (22.80 tillers/plant), GZ 8710-3-2-1-1 (20.20 tillers/plant) and GZ 8452-6-1-3-1(20.0 tillers/plant). The values of the tested lines ranged from 14.20 to 22.80 tillers/plant comparing with the check (15.00 tillers/plant). This result indicates that these lines will be more able to recover after a period of moisture stress. 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. 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. Concerning the flag leaf area, the results showed that it ranged between 16.00 and 27.12. Regarding relative water content (RWC), all the tested lines had higher RWC than the check varieties (Table 3). Their respective values ranged from 56.00 for GZ 8714-5-2-2-1to 95.30 for GZ 8450-3-1-2-1comparing with the check variety IET 1444 (55.00). Nitrogen % of all the tested lines exceeded the check variety (2.50 %), this may be contributed to producing high no. productive tillers/plant.

Yield and its components:

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 (4).

For number of panicles/plant (Table 4), all the selected lines possess high number of panicles/plant comparing with the parents and the check variety. The mean values of number of panicles/plant ranged between 13.00 for GZ 8399-4-3-2-1and 19.40 for GZ 8714-3-3-2-1 panicles/plant comparing with 12.00 panicles / plant for the check variety IET 1444. 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 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 GZ 8399-4-1-2-2, GZ9333-8-1-2-8, GZ8819-1-1-1-1, the values were 6.40%, 7.11% and 7.53 %, respectively (Table 4). The highest mean values were detected by the lines GZ 8714-7-3-2-1 (12.20%) and GZ 8714-5-2-2-1 (13.17%) which were lower than the check variety IET 1444(14.00%). The same trend was also found for 100-grain weight. It was minimized for GZ 8399-4-1-2-2 (2.10 g) and maximized for GZ 8399-4-3-2-1 (3.19 g). For stem sugar at booting stage, most of the selected lines, such as GZ 8714-4-2-2-1, GZ 8399-4-3-2-1 and GZ 8450-3-1-2-1 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. 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 8710-3-2-1-1 (1.00), GZ 8452-6-1-3-2 (1.06), GZ 8714-4-2-2-1 (1.10) and GZ 8714-7-3-2-1 (1.14). 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 31.09g in GZ 8399-4-3-2-1and 38.19 g in GZ 8714-4-2-2-1 which is almost from 7.75 to 9.50 t/ha comparing with the check variety IET 1444 (22.00 g) which produced 5.50 t/ha, respectively.

Table 3: The mean performance (combined) of the most promising lines under drought conditions for shoot characters studied in 2010 and 2011.

Entry	H.D (days)	P.H (cm)	T.no.	L.ang.	L.roll.	F.l.a. (cm^2)	RWC (%)	N%
GZ 8399-4-1-2-2	98.00	90.00	16.20	Narrow	1.00	22.00	74.04	3.63
GZ 8399-4-3-2-1	97.00	88.00	14.20	Narrow	3.00	25.00	87.80	3.02
GZ 8450-3-1-2-1	97.00	93.60	18.40	Wide	3.00	19.26	95.30	3.47
GZ 8452-6-1-3-1	95.00	87.20	20.00	Narrow	1.00	18.62	90.00	3.54
GZ 8452-6-1-3-2	97.00	93.40	19.60	Wide	3.00	19.10	79.00	2.75
GZ 8710-3-2-1-1	95 000	93.00	20.20	Narrow	3.00	27.12	75.00	2.63
GZ 8714-3-3-2-1	102.00	94.20	22.80	Narrow	3.00	18.84	67.00	3.90
GZ 8714-5-2-2-1	99.00	100.80	17.00	Narrow	3.00	19.88	56.00	2.96
GZ 8714-7-3-2-1	101.00	103.20	19.60	Wide	1.00	16.18	57.00	3.09
GZ 8714-4-2-2-1	103.00	99.40	16.40	Narrow	1.00	25.52	95.00	2.89
IET 1444	100.00	90.00	15.00	Narrow	3.00	22.00	0.55	2.50
LSD at 0.05	0.11	0.40	0.33	-	3.00	4.00	5.00	1.10

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 RWC= Relative water content

Table 4: The mean performance (combined) of the most promising lines under drought conditions for some physiological and yield and its components (during 2010 and 2011 seasons).

Entry	No. of pan./pl.	Str. (%)	100-g.w (g)	Sugar content (%)	WUE (Kg/ m^3)	Grain yield (t/ha.)
GZ 8399-4-1-2-2	14.70	6.40	2.10	34.73	0.91	31.81
GZ 8399-4-3-2-1	13.00	10.00	3.19	30.05	0.89	31.09
GZ 8450-3-1-2-1	15.30	8.46	2.87	32.67	0.93	32.70
GZ 8452-6-1-3-1	18.20	11.54	2.70	26.50	0.94	32.94
GZ 8452-6-1-3-2	16.80	7.53	3.15	27.42	1.06	37.00
GZ 8710-3-2-1-1	16.60	7.11	2.50	25.56	1.00	35.48
GZ 8714-3-3-2-1	19.40	12.17	2.60	28.34	1.09	38.00
GZ 8714-5-2-2-1	15.00	13.17	2.30	29.37	0.92	32.17
GZ 8714-7-3-2-1	18.40	12.20	2.60	30.21	1.14	38.07
GZ 8714-4-2-2-1	16.20	10.12	2.60	30.22	1.10	38.19
IET 1444	12.00	14.00	2.40	24.00	0.65	22.00
LSD at 0.05	2.50	3.00	0.20	3.50	0.04	3.10

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 (5). 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 8714-5-2-2-1 (33.00 cm) and the lowest value was obtained from GZ 8714-3-3-2-1 (20.50 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 5), were superior for number of roots /plant, root volume, root: shoot ratio and root thickness comparing with the check variety. **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**).

Table 5: The mean performance (combined) of the most promising lines under drought conditions for root characters studied (during 2010 and 2011seasons).

Entry	Root length (cm)	No. of roots/plant	Root volume (mL)	Root: shoot ratio	Root thickness (cm)
GZ 8399-4-1-2-2	28.50	455.00	55.00	0.95	0.85
GZ 8399-4-3-2-1	22.00	492.50	75.00	0.38	0.61
GZ 8450-3-1-2-1	25.00	466.50	67.50	0.68	0.77
GZ 8452-6-1-3-1	28.50	181.00	80.00	0.60	0.82
GZ 8452-6-1-3-2	29.00	264.50	50.00	0.67	0.87
GZ 8710-3-2-1-1	26.00	184.00	35.00	0.36	0.71
GZ 8714-3-3-2-1	20.50	265.00	45.00	0.53	0.62
GZ 8714-5-2-2-1	33.00	114.00	25.00	0.78	1.15
GZ 8714-7-3-2-1	28.50	298.00	87.50	0.81	1.60
GZ 8714-4-2-2-1	27.50	270.00	35.00	0.75	0.89
IET 1444	28.00	198.00	35.00	0.75	0.48
LSD at 05	2.50	30.00	15.00	0.11	0.20

Genetic parameters:

The analysis of variance 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). Wide range of variation was observed for for all traits studied, indicating better scope for the genetic improvement in these characters. Estimates of heritability ranged from 62.22 (plant height) to 78.94 (root to shoot ratio). In general, high estimates of heritability were observed for all the characters studied.

However, root to shoot ratio expressed maximum heritability (78.94%) followed by 100-grain weight (77.41%) and relative water content 90.00% with high 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 plant height (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 except for days to heading and root length. 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)	25.00	33.00	75.75	8.87
Plant height(cm)	65.00	90.00	62.22	12.11
No. of panicles/plant	88.10	115.00	76.50	16.78
100 grain weight(gram)	120.00	155.00	77.41	19.74
Relative water content	90.00	120.00	75.00	16.92
Root length(cm)	0.45	0.70	64.28	1.29
Root thickness(mm)	35.00	49.00	71.40	10.23
Root/shoot ratio	75.00	95.00	78.94	15.66
Grain yield(t/ha)	50.00	65.00	76.00	15.93

The promising lines obtained in the current study 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 9520 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 40% saving of irrigation water applied. These lines will be recommended to be new rice varieties tolerant to drought conditions in the near future.

Evaluation under heat stress conditions:

Table (7): New Valley meteorological data during 2010 and 2011 seasons.

Seasons	Months	Air temperature (^{o} C)			Relative humidity (%)			Wind speed (km/day)	Solar radiation (Mj/m^2)	Pan evaporation (mm)
		Max.	Min.	Mean	Max.	Min.	Mean			
2010	May	29.5	13.0	21.3	76.4	38.6	57.5	111.0	25.6	8.0
	June	34.7	17.7	24.7	80.2	43.0	61.6	109.0	30.1	10.0
	July	35.2	20.0	27.6	81.7	50.6	66.1	89.5	28.4	9.5
	August	37.4	20.4	28.9	83.4	50.0	66.7	77.0	26.2	8.5
	September	33.1	19.7	26.4	80.4	48.5	64.4	78.2	20.8	8.0
	October	29.1	13.4	21.3	76.2	52.1	64.2	91.5	16.0	6.0
2011	May	28.5	11.6	20.1	79.3	45.0	62.2	111.0	24.0	9.0
	June	35.7	19.0	27.3	80.4	45.0	62.7	117.0	29.0	11.0
	July	38.3	19.5	28.9	81.1	51.0	60.0	78.0	29.0	9.5
	August	37.0	20.6	28.8	80.6	52.0	66.3	65.0	28.0	8.5
	September	33.0	16.8	24.9	83.0	50.0	66.5	76.0	21.0	8.5
	October	29.0	13.4	21.2	76.0	49.5	62.8	70.0	18.0	6.5

According to our strategy, the best selected lines coming from drought program are evaluated annually under New Valley conditions where the temperature there might reach more than 40 degree during summer season. The selection are done among them to identify the lines which having combined drought and heat tolerance. Among 50 lines, only three were found to be tolerant to heat stress (Table 8). These lines produced from 7.50 to 8.00 t/ha with shorter duration ranging between 113 and 120 days.

Table 8: The best selected lines for heat tolerance under New Valley, and Sakha (normal and drought) conditions.

Variety	No. panicles/plant (panicle)			Chlorophyll content (SPAD)			Days to heading (day)			Grain yield/plant (g)		
	H	D	N	H	D	N	H	D	N	H	D	N
GZ8399-4-3-2-1	15.00	15.00	19.00	34.74	46.98	45.00	80.00	97.00	100.0	31.00	33.00	50.00
GZ8452-6-1-3-2	15.00	16.80	19.00	35.88	45.32	44.00	85.00	97.00	96.00	30.00	37.00	48.00
GZ8714-7-1-1-2	17.00	18.00	22.00	34.28	41.74	46.00	78.00	102.0	103.0	32.00	35.00	45.00
Giza178	12.00	14.00	23.00	34.00	38.00	45.00	98.00	98.00	100.0	30.00	33.00	50.00

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