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Full Length Research Paper

Screening rice genotypes for drought resistance in Egypt

A. A. Abd Allah*, M. H. Ammar and A. T. Badawi

Rice Research and Training Center, Field Crop Research Institute, ARC, Egypt.

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A series of experiments were conducted under normal and drought conditions to examine the magnitude of yield response of diverse genotypes to drought stress and to identify traits that may confer drought resistance. Thirty-three local and exotic rice entries including 18 Egyptian genotypes (selected from Fn generation of the breeding for drought tolerance program, Rice Research and Training Center, Egypt), six Italian and nine Chinese rice varieties were grown at Rice Research and Training Center experimental farm for evaluation under normal as well as drought conditions during 2007 and 2008 rice growing seasons. Experiments were laid out in randomized complete block design with three replications. Analysis of variance indicated highly significant differences among the genotypes for all the traits studied. Many promising lines were found to be tolerant against drought stress at different growth stages i.e. seedling stage, early and late vegetative stage, panicle initiation stage and heading stage. These lines possess useful traits associated with drought tolerance such as early maturity (drought escape mechanism), medium tillering ability, medium plant height, root depth, root thickness, root volume, dry root: shoot ratio, plasticity in leaf rolling and unrolling (drought avoidance mechanism), in addition to crop water use efficiency and water application efficiency. The results showed that the genotypes viz. Giza 178, Giza 182, GZ5121, GZ 6296-12-1-2-1-1, GZ 8310-7-3-2-1, GZ 8367-11-8-3-2, GZ 8372-5-3-2-1, GZ 8375-2-1-2-1, GZ 8450-19-6-5-3, GZ 8452-7-6-5-2, GZ 1368-S-4, Augusto and SIS R215 were the best entries under drought conditions, where they possess many desirable traits which are useful for drought tolerance. Among the traits studied viz. number of tillers per plant, number of panicles per plant, 100 grain weight, panicle weight, revealed significant genotypic correlation with grain yield. Also, number of filled grains per panicle depicted the highest direct contribution of 0.630 and it also show highest indirect contribution of 0.867 followed by 100 grain weight (0.850) towards grain yield. Path coefficient analysis demonstrated that number of panicles per plant, 100 grain weight; number of filled grains per panicle, panicle weight should be improved in order to increase grain yield under both normal and drought conditions.

Key words: Drought stress, path analysis, rice, screening.

INTRODUCTION

The world's irrigated area per capita has decreased from a peak of 48 ha/1000 people in the late 1970 to about 42 ha/1000 people in 2002 (Gleick, 1993). Drought stress is a major constraint to rice production and yield stability and is generally avoided in irrigated rice production systems, but it is a consistent feature across much of the 63.5 million ha of rain fed rice sown annually, most of which is in tropical Asia, Africa and Latin America (Narciso and Hossain, 2002).

*Corresponding author. E-mail: abdnby@yahoo.com.

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 incon-sistent and possibly contradictory, across years. Progress has been made, however, through the inclusion of tolerant parents in crossing (Chang et al., 1982; Pinheiro, 2003). More recently, the use of managed environments and targeted multi-location 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. As the demand for water for domestic, municipal, industrial and environmental purposes rises in the future, less water will be available for agriculture. But the potential for new water resource development projects and expanding irrigated area are limited. Rice is the stable food for nearly half of the world population, most of who live in developing countries and the crop occupies one-third of the world total area planted to cereals and provides 35 - 60% of the calories consumed by 2.7 billion people. Rice is known to be more susceptible to shortage of irrigation water than most of other crops because rice is a semi aquatic plant species and is commonly grown in lowland paddies where there is standing water during all stages of growth (Inthapan and Fukai, 1988). In Egypt, rice is one of the major water consuming crops and continuous flooding is the only method for irrigation. Rice occupies about 22% of the total cultivated area in Egypt during summer season and it consumes about 20% of the total water resources. Due to the limited water resources in Egypt in addition to increasing population, the total water requirements for the rice crop is cussed problem. Some rice cultivated areas especially that located at the end of the canals terminal in the northern part of the Nile Delta 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. To overcome this problem, we must find ways to increase the productivity of water which is used for irrigation and find ways for saving more irrigation water. One of the important ways for that is the use of short duration varieties. It is very important to find ways for saving more water without significant reduction in yield. The second direction for saving irrigation water is developing drought tolerant lines to be grown in the areas affected by the shortage of irrigation water to reduce the total water requirements. This study was conducted to identify the most important traits associated with drought resistance in some elite rice genotypes in Egypt.

MATERIALS AND METHODS

Thirty-three rice entries, including 18 Egyptian genotypes (9 commercial varieties and promising lines selected from Fn generation of the breeding for drought tolerance program, 2005, Rice Research Program); six Italian and nine Chinese rice varieties were evaluated under normal and drought conditions during 2007 and 2008 rice growing seasons. Each genotype was planted in seven rows of five meters length each. Adopting spacing of 20 × 20 cm spaced plants; and two to three seedlings / hill. These materials were replicated three times in a randomized complete block design (RCBD) with the same set of genotypes in two experiments (under normal and drought conditions). On May 10th the genotypes were grown in the nursery for 30 days, after which they were transplanted under the stress as well as normal growing conditions. Drought stress was imposed by using flush irrigation (flush irrigation is one of the surface irrigation without standing water after irrigation) every 12 days to reach the soil moisture content to the filed capacity, from two weeks after transplanting to harvesting and recommended cultural practices were followed. Agro-physiological 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); panicle length in cm (the main panicle of each plant was measured from the base to the tip of the panicle excluding owns at complete maturity); tiller number per hill (the total number of tillers per plant); leaf angle (measure the angle between the line and vertical axis with a protractor); leaf rolling (was estimated by visual estimation based on methods proposed by De Data et al., 1988); flag leaf area in cm^2 (flag leaf area of 20 leaves were measured using leaf area meter (model L1 – 3000 A); flag leaf dry weight in g (the same leaves were transferred to the oven and dried at 70°C for 72 h or to constant weight , then the dry of each leaf were estimated); chlorophyll content (chlorophyll content was measured by using chlorophyll mater (SPAD-502) Minnolta Camera Co. Ltd., Japan); nitrogen% were studied (N content in the rice leaves were estimated according to Hafez and Mikkelsen [1981]). Root characters such as root depth 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 xylem vessel numbers (the average xylem vessel number of four roots of the same plant were recorded under light microscope) were recorded at panicle initiation stage. Yield (t/ha) and its components such as number of panicles per plant (counting the number of panicles per plant when all plants were at the ripening stage), number of filled grains per panicle (filled grains of the main panicle were separated and counted), sterility % (the unfilled grains of the main panicle were separated and counted and sterility percentage was calculated), 100-grain weight in g (it was recorded as the weight of 100 random rice grains per plant), and panicle weight in g were recorded (by using the main panicle weight of each plant) at harvesting. The drought stress was fully monitored, and the total amount of water consumed was estimated using water counters. The statistical analysis of variance and covariance carried out (Steel and Torrie, 1980). The heritability was estimated (Burton and Devane, 1953). Genotypic and phenotypic correlations were calculated as per by Kwon and Torrie (1964). The combined analysis was calculated over the two years to test the interaction of the different genetic components with the two years. The homogeneity of error variance was tested as described by Bartlett (1937).

The weather data, physical and chemical analysis of soil properties of the experimental field are given in Table 1.

Soil moisture content was gravimetrically determined on an oven dry basis. At each sampling date, duplicate soil samples were taken to a depth of 60 cm using an auger. The samples were immediately transferred in tightly closed aluminum cans to the laboratory where they were weighted, oven-dried at 105°C for 24h, and reweighed after which their moisture content was determined. Field capacity and permanent wilting percentage were determined. The bulk density was determined using the core method to a depth of 60 cm (Klute, 1986). The results are presented in Table 2.

The soil was clayey in texture, whereas particle size distribution was 56.1% clay, 31.30% silt, and 12.60% sand. Soil pH (1:2.5) was 8.3, and electrical conductivity of soil and irrigation water was 2.00.

RESULTS AND DISCUSSION

The analysis of variance for agro-physiological characters viz. plant height, number of tillers per plant, leaf angle, leaf rolling, flag leaf area, flag leaf dry weight; and root

Table 1. Weather data of Sakha Agricultural Research Station.

Month	Air temperature	Relative humidity (%)	Wind speed (m/s)	Evaporation pan (mm)	Rainfall (mm)	Solar radiation (mjm^2)
April	25.70	62.60	1.50	4.90	00	26.10
May	27.20	64.20	1.50	5.20	00	26.30
June	29.20	71.60	1.30	5.40	00	28.40
July	28.60	75.30	1.30	5.20	00	27.70
August	27.30	70.50	1.10	4.00	00	23.00

Table 2. Some physical and chemical properties of the soil in the experimental site.

Characters	Value
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)

characters (viz. root depth, root numbers/plant, root volume, root/ shoot ratio, and root xylem vessel number); and for yield and its component that is; number of panicles/plant, number of filled grains/panicle, sterility percentage and 100 grain weight of the two years of study are presented in Table 3. Years mean squares were highly significant for all the studied traits except leaf angle, 100 grain weight, panicle weight, shoot to root ratio, and root xylem vessel number. The genotypes and years interaction were not significant for all the characters studied.

The data presented in Tables 4,5,6,7 and 8 show that the genotypes; Giza 178, Giza 182, GZ 5121, GZ 6296-12-1-2-1-1, GZ 8310-7-3-2-1, GZ 8367-11-8-3-2, GZ 8372-5-3-2-1, GZ 8375-2-1-2-1, GZ 8450-19-6-5-3, GZ 8452-7-6-5-2, GZ 1368-S-4, Augusto and SIS R215 were the best under drought conditions, where it posses many desirable traits for drought tolerance such as shoot, root and yield and its components as well as desirable grain quality characters at the two rice growing seasons. Genotypes remained tall under water stress(80-100cm), had a moderate tillering ability(21-27 tiller), narrow leaf angle, good drought score(1-3), desirable leaf area (15-21), low sterility % (17 - 19), deeper roots (28 - 34 cm), high root volume (30 - 34 mL) , high nitrogen content in their shoot (1.40 - 2.82) and high grain yield (8 - 9 t/ha).

The mean values of genotypes mentioned in Table 4 ranged from 92 to 118 day, from78.60 to 119.20 cm, from 12.60 to 28.40 tillers, narrow to wide, from 1 to 7 score, from 10.00 to 25.60 cm, and from 1.53 to 2.00 g, for days to heading, plant height, no. of tillers/plant, leaf angle, leaf rolling score, flag leaf area, and flag leaf dry weight respectively. For days to heading, the genotypes, GZ 5310-20-3-3, GZ 6296-12-1-2-1-1, GZ8375-2-1-2-1, Augusto, Eurosis, SIS R215 and Luxor were the earlier plants. While, the genotypes Giza 14, GZ8372-5-3-2-1, Handao 297, IAPAR-9, Nong Xuan 2, Qinai, Zheng Zhou and L696 gave the highest mean values in the two

Table 3. Combined analysis of variances of the characters studied of rice genotypes.

S. O. V	df	Mean squares																
		Days to heading	Plant height	Flag leaf area	Tillers number	F.L. D.W	N %	No. of panicle	Sterility %	100 grain weight	RWC	WUM	Grain yield	Root length	No. of roots	Root volume	Root shoot ratio	Root thickness
Years	1	6.948	2.494	2.596	1.144	2.406	1.645	6.641	4.279	0.000	9.646	0.006	0.023	8.908	7.733	9.597	0.007	3.205
Reps/years	4	6.854	7.072	6.427	5.344	7.214	0.009	7.064	6.262	0.002	7.405	0.041	8.324	7.179	7.455	8.048	0.589	0.006
Genotype/years	24	49.108	340.771	33.308	45.124	37.717	0.465	42.330	30.533	0.021	429.435	0.090	126.149	34.586	6778.3	351.985	0.808	0.033
Genotypes	12	97.977	681.055	65.898	88.571	74.321	0.929	84.063	60.189	0.040	858.756	0.180	252.160	69.103	13556	703.918	1.612	0.067
Genotypes/year	12	0.239	0.487	0.719	1.677	1.114	0.000	0.596	0.876	0.002	0.114	0.000	0.138	0.069	0.084	0.051	0.004	4.316
Error/years	48	0.207	0.281	0.209	0.310	0.149	0.000	0.173	0.316	0.001	0.118	0.000	0.063	0.094	0.058	0.057	0.004	4.017

years and their combined data . Early maturity has been shown to be an important trait under stress conditions because early flowering rice can escape from the late season drought stress (Rajatasereekul et al., 1997; Cooper and Somrith, 1997). Maximum plant height was recorded in genotypes GZ 8372-5-3-2-1, GZ 8375-2-1-2-1 and TP 219, the values ranged from 116-119 cm), while shortest plant height was noted in genotype GZ 8452-7-6-5-2, SIS R215 and Eurosis , their values were ranged from 78.60 to 81 cm. Maximum number of tillers /plant were reported in genotypes GZ 8310-7-3-2-1, GZ 8375-2-1-2-1 and GZ 8452-7-6-5-2 (from 27.16-28.40), while the lowest number of tillers/plant was counted for the genotypes Handao 4, Nong Xuan 2 and Qinai (12-13 tiller). The genotypes nos.10, 11,15,18,20,21,22,23,24,25,27,28,29,32 and 33 had wide leaf angle comparison with the others. The genotypes GZ 1108-16-1, GZ 8310-7-3-2-1, GZ 8372-5-3-2-1, GZ 8399-1-1-1-1, Nong Xuan 2, TP 21and Zheng Zhou (Zaojing had good drought scores compared to the others. The desirable flag leaf area and flag leaf dry weight values were found in case of the genotypes Ciza 175, GZ 8372-5-3-2-1, GZ 8375-2-1-2-1, GZ 8452-7-6-5-2, IAPAR-9, Qinai and TP 21. Water deficit stress mostly reduced leaf growth and in turns the leaf areas in many species of plant (Wullschleger et al., 2005 and Zhang et al., 2004). It could be concluded that these genotypes were superior for agro-physiological characters studied (Table 4). In spite of water stress at tillering prolonged vegetative period, reduce plant height, tiller number, leaf length and induce leaf rolling, the data showed that these genotypes were earlier in heading, remained tall in height, having more tillers/plant and they were able to recover after the water stress condition was terminated , having smaller leaf canopy to minimize transpiration rate, have good drought score from 1 - 3 and desirable flag leaf area which contribute by the higher proportion of carbohydrate to grain filling after heading. So, shoot characters comprising of plant height, tiller number, number of leaves, leaf angle, plasticity in leaf rolling and unrolling, and root to shoot ratio could be used as selection criteria in selecting drought resistant cultivars in many crops.

With respect to yield and its components (Table 5), it is clear that the maximum number of panicles/plant was recorded in genotype GZ 8310-7-3-2-1, GZ 8399-1-1-1-1 and GZ 8452-7-6-5-2 (the values ranged from 23-25 panicles), while the lowest mean values of some traits were detected in genotypes Handao 4, Nong Xuan 2 and Qinai. Genotypes Ciza 178, GZ 6296-12-1-2-1-1, GZ 8372-5-3-2-1, GZ 8450-19-6-5-3 and GZ 1368-S-4 had the maximum number of filled grains/panicle, whereas it was minimized in genotypes Eurosis, Handao 29, Handao 29. The lowest sterility % were found in genotypes GZ 5310-20-3-3, GZ 1108-16-1 and GZ 8450-19-6-5-3 , while it was higher in genotypes Handao 11, Qinai, Zheng Zhou (Zaojing), and L 469 PB08. Genotypes GZ 5310-20-3-3, GZ 8310-7-3-2-1 and Augusto had the maximum 100 grain weight comparison with the others. The highest yield was recorded in the genotypes GZ 8450-19-6-5-3, GZ 8452-7-6-5-2, GZ 1368-S-4 (the values ranged from 8-10 t/ha), while the lowest grain yield were found with the genotypes Augusto, Handao 11 and TP 21.The outstanding performance of GZ 8452-7-6-5-2 for grain yield seems due to its superiority for total number of tillers/plant, no. of panicles/plant, heavier in grain weight, low sterility (%). Drought stress at the reproductive stage can have large effect on yield and yield components. Yambo, 1988; Wopereies, 1996 and Boonjung, (1996) reported that if drought stress develop soon after panicle initiation, the number of spikelet

Table 4. Mean values of shoot characters of the studied rice genotypes under drought stress condition.

No.	Entries	Origin	Days to heading (day)	Plant height (cm)	Tiller no./pl.	Leaf angle	Leaf rolling score	Flag leaf area	Flag leaf dry weight
1	Ciza 14	Egypt	110.00	106.00	21.00	Narrow	5	19.7	1.73
2	Ciza 175	Egypt	106.00	90.00	22.00	Narrow	5	21.1	2.00
3	Ciza 178	Egypt	102.00	97.00	25.00	Narrow	3	17.3	1.82
4	Ciza 182	Egypt	102.00	85.20	24.33	Narrow	3	18.0	1.81
5	Sakha 104	Egypt	105.00	102.00	20.50	Narrow	3	14.0	1.69
6	GZ 5121-5-2	Egypt	106.00	93.80	19.66	Narrow	3	12.0	1.58
7	GZ 5310-20-3-3	Egypt	98.00	101.40	20.66	Narrow	5	16.0	1.81
8	GZ 1108-16-1	Egypt	106.00	92.60	20.33	Narrow	1	20.0	1.65
9	GZ 6296-12-1-2-1-1	Egypt	97.00	86.00	17.66	Narrow	3	19.0	1.76
10	GZ 8310-7-3-2-1	Egypt	101.00	109.80	27.16	Wide	1	19.5	1.64
11	GZ 8367-3-2-1-1	Egypt	102.00	88.40	16.80	Wide	3	19.6	1.80
12	GZ 8367-11-8-3-2	Egypt	103.00	95.00	20.20	Narrow	2	11.0	1.76
13	GZ 8372-5-3-2-1	Egypt	107.00	119.20	21.50	Narrow	1	21.0	2.00
14	GZ 8375-2-1-2-1	Egypt	98.00	116.60	28.40	Narrow	3	14.0	2.00
15	GZ 8399-1-1-1-1	Egypt	107.00	98.20	24.60	Wide	1	15.0	1.64
16	GZ 8450-19-6-5-3	Egypt	107.00	94.40	23.60	Narrow	3	13.0	1.99
17	GZ 8452-7-6-5-2	Egypt	102.00	78.60	27.40	Narrow	3	17.0	2.00
18	GZ 1368-S-4	Egypt	107.00	93.40	23.80	Wide	7	10.0	1.89
19	Augusto	Italy	92.00	82.00	17.80	Narrow	3	18.0	1.50
20	Eurosis	Italy	92.00	81.00	14.80	Wide	5	19.0	1.65
21	SIS R215	Italy	95.00	80.80	19.60	Wide	3	10.0	1.80
22	Douradao	China	102.00	110.00	14.60	Wide	5	20.0	1.63
23	Handao 11	China	100.00	81.40	15.00	Wide	7	14.0	1.78
24	Handao 4	China	93.00	89.20	13.00	Wide	3	19.7	1.85
25	Handao 29	China	110.00	102.60	14.20	Wide	3	19.9	1.76
26	IAPAR-9	China	111.00	115.20	14.20	Narrow	3	21.7	2.0
27	Nong Xuan 2	China	114.00	100.00	13.00	Wide	1	25.6	1.85
28	Qinai	China	110.00	94.80	12.60	Wide	3	20.0	2.00
29	TP 21	China	108.00	117.00	16.80	Wide	1	15.0	2.00
30	Zheng Zhou (Zaojing)	China	113.00	91.60	18.00	Narrow	1	21.0	1.66
31	Luxor	Italy	98.00	83.40	18.80	Narrow	3	11.0	1.75
32	L 469 PB08	Italy	106.00	98.60	15.20	Wide	5	18.0	1.53
33	L 469 L469 PB08	Italy	112.00	84.20	16.33	Wide	3	13.0	1.63
	LSD at 0.05	-	2.50	3.40	1.80	-	1.00	0.80	0.22

Table 5. Mean yield and its component characters of the studied rice genotypes under drought condition.

No.	Entries	Origin	Panicle length (cm)	No. of panicles/plant	No of filled grains/pan.	Sterility %	100 grain weight (g)	Panicle weight (g)	Grain yield (t/ha)
1	Ciza 14	Egypt	21.85	20.83	121.00	12.00	1.50	1.80	5.52
2	Ciza 175	Egypt	24.45	19.33	100.00	11.00	1.80	2.30	4.80
3	Ciza 178	Egypt	23.25	22.33	135.00	10.00	2.30	2.50	7.20
4	Ciza 182	Egypt	22.70	18.66	131.00	13.29	2.30	3.50	7.00
5	Sakha 104	Egypt	21.60	18.33	110.00	9.72	2.30	3.40	6.70
6	GZ 5121-5-2	Egypt	19.40	18.16	118.00	15.00	2.30	2.70	7.70
7	GZ 5310-20-3-3	Egypt	20.00	17.33	111.00	8.00	2.80	2.90	7.20
8	GZ 1108-16-1	Egypt	23.05	16.33	120.00	7.00	2.40	1.80	6.00
9	GZ 6296-12-1-2-1-1	Egypt	18.75	16.5	135.00	13.00	2.40	2.40	6.50
10	GZ 8310-7-3-2-1	Egypt	19.15	24.33	131.00	9.00	2.80	2.10	7.20
11	GZ 8367-3-2-1-1	Egypt	22.30	13.4	128.00	16.00	2.50	3.20	6.75
12	GZ 8367-11-8-3-2	Egypt	19.80	17.4	117.00	19.00	2.50	2.80	7.50
13	GZ 8372-5-3-2-1	Egypt	21.95	18.25	139.00	11.00	2.60	2.70	7.50

Table 5. Contd.

No.	Entries	Origin	Panicle length (cm)	No. of panicles /plant	No of filled grains/pan.	Sterility %	100 grain weight (g)	Panicle weight (g)	Grain yield (t/ha)
14	GZ 8375-2-1-2-1	Egypt	22.30	2 1.00	127.00	19.00	2.20	2.80	7.10
15	GZ 8399-1-1-1-1	Egypt	20.10	23.00	103.00	17.00	2.60	2.90	7.00
16	GZ 8450-19-6-5-3	Egypt	20.25	21.00	141.00	8.50	2.50	2.80	9.60
17	GZ 8452-7-6-5-2	Egypt	22.55	25.00	133.00	12.00	2.40	3.50	10.0
18	GZ 1368-S-4	Egypt	22.45	21.8	136.00	18.00	2.60	2.40	8.00
19	Augusto	Italy	23.75	16.00	81.00	28.00	2.70	3.60	3.00
20	Eurosis	Italy	20.25	13.00	78.00	29.00	2.00	4.30	4.10
21	SIS R215	Italy	19.00	14.80	115.00	16.00	2.40	3.00	6.50
22	Douradao	China	22.20	13.00	107.00	26.00	2.30	3.20	3.60
23	Handao 11	China	18.15	14.00	75.00	45.00	2.50	2.90	3.12
24	Handao 4	China	20.10	11.00	91.00	32.00	2.50	2.90	3.80
25	Handao 29	China	21.05	12.80	77.00	35.00	2.30	2.70	3.80
26	IAPAR-9	China	23.65	12.80	110.00	31.00	1.90	2.20	3.30
27	Nong Xuan 2	China	22.00	11.00	95.00	42.00	2.60	3.20	4.80
28	Qinai	China	21.00	10.00	82.00	45.00	2.00	2.60	4.30
29	TP 21	China	24.60	15.00	99.00	33.00	2.20	3.40	4.20
30	Zheng Zhou(Zaojing)	China	18.35	16.00	107.00	40.00	2.50	2.10	4.30
31	Luxor	Italy	17.00	17.00	95.00	33.00	2.60	3.00	4.80
32	L 469 PB08	Italy	19.00	13.40	80.00	50.00	2.30	3.50	4.60
33	L 469 L469 PB08	Italy	14.70	12.50	88.00	38.00	2.00	2.40	4.80
	LSD at 0.05		1.62	2.80	5.50	4.82	0.23	0.18	0.50

developed is decreased, and this may result in reduction in grain number per panicle , coupled with reduced grain weight, and hence a reduction in grain yield. It could be concluded that, in spite of drought stress at reproductive stage is the most damaging to rice crop by the reduction of dry matter production and therefore, reduction of productive tillers, these genotypes having more panicles / plant indicating that most of their tillers bear panicles under drought conditions. This may be due to the increase in nitrogen content in their shoot. Also, drought stress at booting and flowering stages reduced number of filled grains/panicle and induced sterility (%), whereas, these genotypes have high number of filled grains/ panicle and low sterility (%). This may be due to higher sugar in their stems. Concerning root characters (Table 6), the maximum root depth was found in genotypes GZ 5121-5-2 (34 cm), GZ 6296-12-1-2-1-1 (35 cm), GZ 8452-7-6-5-2 (34 cm), and SIS R215 (35 cm), while it was lowest in genotypes Ciza 175 (19cm), Nong Xuan 2(16 cm), and Qinai (16 cm). Root size, morphology and root depth and length are important in maintaining high leaf water potential against evapotranspirational demand under water stress (Kamoshita, 2000). The highest mean values of root volume was found in genotypes Ciza 178 (35 mL), Ciza 182 (40 mL), GZ 5121-5-2 (35 mL) and GZ 8450-19-6-5-3 (45 mL) while, the genotypes Handao 4 (12 mL), Handao 29 (10 mL), and Nong Xuan 2 (13 mL) gave the lowest mean values of root volume. High root volume is indicative of the ability to permeate a large volume of soil and / or to have thick roots; generally a drought resistant variety possesses high root volume. The maximum root numbers was observed in genotypes Ciza 182(285), Sakha 104(310), SIS R215 (360), and L 469 PB08 (270), whereas it was minimum in genotypes Handao 11(118), and Handao 29(110). Root to shoot ratio was higher in Ciza 175(2.10), GZ 6296-12-1-2-1-1(2.00), GZ 8450-19-6-5-3(2.20), and SIS R215 (2.00), while Augusto (0.70), Handao 11(0.67), and Qinai (0.77) had low values. The varieties with high deep root: shoot ratio was more drought resistant (Kamoshita et al., 2002). A moderate stress tolerance in terms of shoot dry weight was noticed in rice (Lafitte et al., 2007). Root xylem vessel numbers were higher in genotypes GZ 8372-5-3-2-1(9), GZ 8450-19-6-5-3(9.50), and GZ 8452-7-6-5-2(9.50), while the genotypes Handao 4(4), and Luxor (4.40) have lower root xylem vessel numbers. Bigum (1985) observed that upland varieties had larger size and higher number of root xylem vessels than those of lowland varieties. From the forgoing discussion, it could be concluded that the genotypes GZ 5121-5-4, GZ 8450-19-6-5-3 and GZ 8452-7-6-5-2 had higher values in most root characters studied. So, it were effectively use more water stored at the deeper soil layers and therefore keep the water potential high by absorbing the water and conducting it to the shoot very efficiently and quickly (Table 7). Similar results were reported by Sharma et al., 1994 by using different genotypes. The data in Table 6 showed that the best selected lines were superior in chlorophyll content and nitrogen % in their shoot at early tillering, their values ranged from 31.68 to 44.90% and

Table 6. Mean root characters of the studied rice genotypes under drought stress condition.

No.	Entries	Origin	Chlorophyll content	Nitrogen %
1	Ciza 14	Egypt	37.32	2.30
2	Ciza 175	Egypt	40.08	2.70
3	Ciza 178	Egypt	40.10	2.50
4	Ciza 182	Egypt	38.50	2.40
5	Sakha 104	Egypt	36.24	1.70
6	GZ 5121-5-2	Egypt	35.88	1.60
7	GZ 5310-20-3-3	Egypt	35.10	1.34
8	GZ 1108-16-1	Egypt	35.76	1.30
9	GZ 6296-12-1-2-1-1	Egypt	39.78	2.14
10	GZ 8310-7-3-2-1	Egypt	40.82	2.20
11	GZ 8367-3-2-1-1	Egypt	36.64	2.29
12	GZ 8367-11-8-3-2	Egypt	35.52	0.91
13	GZ 8372-5-3-2-1	Egypt	36.42	2.24
14	GZ 8375-2-1-2-1	Egypt	43.24	2.35
15	GZ 8399-1-1-1-1	Egypt	40.26	2.45
16	GZ 8450-19-6-5-3	Egypt	44.08	2.70
17	GZ 8452-7-6-5-2	Egypt	41.44	2.82
18	GZ 1368-S-4	Egypt	37.00	1.40
19	Augusto	Italy	33.48	1.18
20	Eurosis	Italy	37.72	1.22
21	SIS R215	Italy	34.84	1.55
22	Douradao	China	31.68	2.08
23	Handao 11	China	33.28	1.95
24	Handao 4	China	42.40	1.22
25	Handao 29	China	44.90	1.73
26	IAPAR-9	China	36.42	1.76
27	Nong Xuan 2	China	36.08	2.03
28	Qinai	China	42.74	1.98
29	TP 21	China	35.32	0.91
30	Zheng Zhou (Zaojing)	China	42.70	1.02
31	Luxor	Italy	43.45	1.66
32	L 469 PB08	Italy	40.44	1.52
33	L 469 L469 PB08	Italy	43.40	1.27
	LSD at 0.05		2.90	0.40

Table 7. Chemical parameters mean performance of the tested materials under drought stress condition.

No.	Entries	Origin	Chlorophyll content	Nitrogen %
1	Ciza 14	Egypt	37.32	2.30
2	Ciza 175	Egypt	40.08	2.70
3	Ciza 178	Egypt	40.10	2.50
4	Ciza 182	Egypt	38.50	2.40
5	Sakha 104	Egypt	36.24	1.70
6	GZ 5121-5-2	Egypt	35.88	1.60
7	GZ 5310-20-3-3	Egypt	35.10	1.34
8	GZ 1108-16-1	Egypt	35.76	1.30
9	GZ 6296-12-1-2-1-1	Egypt	39.78	2.14
10	GZ 8310-7-3-2-1	Egypt	40.82	2.20
11	GZ 8367-3-2-1-1	Egypt	36.64	2.29

Table 7. Contd.

12	GZ 8367-11-8-3-2	Egypt	35.52	0.91
13	GZ 8372-5-3-2-1	Egypt	36.42	2.24
14	GZ 8375-2-1-2-1	Egypt	43.24	2.35
15	GZ 8399-1-1-1-1	Egypt	40.26	2.45
16	GZ 8450-19-6-5-3	Egypt	44.08	2.70
17	GZ 8452-7-6-5-2	Egypt	41.44	2.82
18	GZ 1368-S-4	Egypt	37.00	1.40
19	Augusto	Italy	33.48	1.18
20	Eurosis	Italy	37.72	1.22
21	SIS R215	Italy	34.84	1.55
22	Douradao	China	31.68	2.08
23	Handao 11	China	33.28	1.95
24	Handao 4	China	42.40	1.22
25	Handao 29	China	44.90	1.73
26	IAPAR-9	China	36.42	1.76
27	Nong Xuan 2	China	36.08	2.03
28	Qinai	China	42.74	1.98
29	TP 21	China	35.32	0.91
30	Zheng Zhou (Zaojing)	China	42.70	1.02
31	Luxor	Italy	43.45	1.66
32	L 469 PB08	Italy	40.44	1.52
33	L 469 L469 PB08	Italy	43.40	1.27
	LSD at 0.05		2.90	0.40

from 2.20 to 2.80 %, respectively.

According to the data presented in Table 8 the promising genotypes could be divided into two groups based on their yield response to stress condition; the first group includes GZ 8367-11-8-3-2, GZ 8372-5-3-2-1, GZ 8450-19-6-5-3, GZ 8452-7-6-5-2 and GZ 1368-S-4 that produce high yield under both normal and stress conditions, and the second group that includes GZ 6296-12-1-2-1-1, GZ 8375-2-1-2-1, Augusto, SIS R215, Douradao and TP 21 have narrow gab between normal and stress conditions. Roots and shoots are naturally interdependent measurements of root alone cannot be fully interpreted without considering the shoots.

Heritability, phenotypic and genotypic variances for most of the characters studied are presented in Table 9. The results revealed that genotypic differences among the genotypes studied were found. These genotypes were highly diversified for the performance and selection can be performed for various morph-genetic traits. Maximum variability is recorded in no. of roots/plant, root volume and plant height, respectively. It is observed that phenotypic variability was higher than genotypic variability for all traits. Moderate to high heritability estimates (57.00 - 94.00) were found for all the traits studied. These results were in agreement with those reported by Abd Allah (2004).

The association of grain yield with other characters was estimated by genotypic and phenotypic correlation coefficients (Table 10). Root xylem vessel number/ plant had significant correlations at genotypic level with all other traits except grain yield. At phenotypic level root xylem vessel number/ plant had no significant association with all other traits, while it has negative association with nitrogen percent and sterility percent. This result indicated that decrease in root xylem vessel number/ plant will bring increase in nitrogen percent and sterility percent. Hence results from the present study do not coincide with the findings of Khan et al. (1991), who reported negative correlation root xylem vessel numbers/plant and root to shoot ratio. Sharma and Reddy, 1991 observed positive correlation between root xylem vessel number/ plant and grain yield /plant, while Kupkanchanakul et al. (1991) reported negative correlation between root xylem vessel number/ plant and grain yield/plant. In this study non significant results might be due to differences in genetic constitution in breeding materials and different years of experimentation. Nitrogen percent had significant genetic and phenotypic correlation with all studied traits. Rangel et al. (1980) reported negative correlation between nitrogen percent and grain yield/plant. Root to shoot ratio had highly significant genotypic correlation with flag leave area, leaf angle, flag leave dry weight and grain yield character. Deshmukh and Chau (1992) reported positive and significant genetic association between root to shoot ratio and grain yield per plant. Flag leaf area had significant and positive genotypic and phenotypic correlation with leaf angle; flag leave dry weight and grain yield/plant. Leaf angle was

Table 8. Comparison yield mean values between the tested materials transplanted and drilled under normal and drought condition.

No.	Entries	Origin	Yield (Normal)(t/ha)	*Yield (Drought) transplanted (t/ha)	**Yield (Drought) drilled (t/ha)
1	Ciza 14	Egypt	10.80	5.52	3.50
2	Ciza 175	Egypt	12.50	4.80	4.30
3	Ciza 178	Egypt	10.50	7.20	4.20
4	Ciza 182	Egypt	9.50	7.00	4.25
5	Sakha 104	Egypt	12.10	6.70	5.10
6	GZ 5121-5-2	Egypt	10.60	7.70	6.50
7	GZ 5310-20-3-3	Egypt	10.00	7.20	4.60
8	GZ 1108-16-1	Egypt	10.40	6.00	4.85
9	GZ 6296-12-1-2-1-1	Egypt	7.50	6.50	5.75
10	GZ 8310-7-3-2-1	Egypt	11.00	7.20	3.60
11	GZ 8367-3-2-1-1	Egypt	10.80	6.75	5.00
12	GZ 8367-11-8-3-2	Egypt	10.00	7.50	3.80
13	GZ 8372-5-3-2-1	Egypt	10.60	7.50	3.50
14	GZ 8375-2-1-2-1	Egypt	7.90	7.10	6.75
15	GZ 8399-1-1-1-1	Egypt	12.50	7.00	3.10
16	GZ 8450-19-6-5-3	Egypt	11.80	9.60	6.60
17	GZ 8452-7-6-5-2	Egypt	11.00	10.0	5.00
18	GZ 1368-S-4	Egypt	13.00	8.00	3.40
19	Augusto	Italy	5.00	3.00	2.80
20	Eurosis	Italy	7.70	4.10	2.10
21	SIS R215	Italy	7.50	6.50	5.30
22	Douradao	China	4.00	3.60	2.00
23	Handao 11	China	4.60	3.12	1.00
24	Handao 4	China	6.60	3.80	1.50
25	Handao 29	China	5.82	3.80	1.60
26	IAPAR-9	China	5.04	3.30	1.10
27	Nong Xuan 2	China	9.30	4.80	3.75
28	Qinai	China	5.00	4.30	2.00
29	TP 21	China	4.33	4.20	3.10
30	Zheng Zhou (Zaojing)	China	6.24	4.30	3.70
31	Luxor	Italy	8.50	4.80	4.50
32	L 469 PB08	Italy	9.00	4.60	3.10
33	L 469 L469 PB08	Italy	9.50	4.80	3.50
	LSD at 0.05		0.70	0.40	0.38

Table 9. Heritability in broad sense and coefficient of variability estimates for the characters studied.

Traits	Variance components		Heritability
	Genotypic (%)	Phenotypic (%)	Hb (%)
Days to heading (day)	13	22	60
Plant height (cm)	113	120	94
Tiller no./plant	14	17	85
Flag leaf area (cm)	11	15	73
Flag leaf dry weight (g)	13	18	72
No. of panicles/plant	14	22	63
Sterility %	10	15	75
100 grain weight (g)	0.007	0.001	87
Grain yield (t/ha)	41	45	91
Root length (cm)	10	15	75
No. of roots/ plant	2256	2280	98
Root volume (mL)	116	120	88
Root / shoot ratio	0.26	0.45	57

Table 10. Genotypic and phenotypic correlation coefficients among grain yield and some traits related to drought tolerance in the studied genotypes.

Traits	Correlation	Root xylem vessel no.	Nitrogen %	Root/shoot ratio	Flag leaf area	Leaf angle	Sterility %	Flag leaf dry weight
Nitrogen%	Genotypic	0.480						
	Phenotypic	-0.256						
Root/sh.ratio	Genotypic	0.385	0.660					
	Phenotypic	0.343	0.850					
Flag leaf area	Genotypic	0.420	0.450	0.580				
	Phenotypic	0.220	0.330	0.514				
Leaf angle	Genotypic	0.110	0.780	0.315	0.825			
	Phenotypic	0.100	0.960	0.130	0.630			
Sterility%	Genotypic	-0.088	0.130	0.118	0.112	-0.475		
	Phenotypic	0.069	0.111	0.230	0.110	-0.425		
Flag leaf dry we	Genotypic	0.450	0.002	0.640	0.550	0.653	-0.380	
	Phenotypic	0.188	0.031	0.520	0.420	0.560	0.310	
Grain yield	Genotypic	0.069	0.670	0.830	0.618	0.940	-0.550	0.810
	Phenotypic	0.150	0.540	0.590	0.535	0.630	-0.460	0.620

Table 11. Direct and indirect effect of most important traits to grain yield in some rice genotypes under drought condition.

Traits	Genotypic correlation with yield	Plant height	No. of tillers/pl.	No. of panicles/pl.	100 grain weight	Panicle weight	Sterility %	No. of filled grain
Plant height	0.0056	(-0.044)	0.005	0.004	0.002	0.003	0.005	0.0045
No. of tillers/plant	0.092	-0.035	(-0.187)	0.023	0.122	0.032	0.003	0.006
No. of panicles/plant	0.734	0.006	0.009	(0.398)	0.054	0.094	0.085	0.008
100 grain weight	0.850	0.008	0.007	0.009	(0.615)	0.650	0.118	0.550
Panicle weight	0.611	0.004	-0.005	0.005	0.006	(0.478)	0.091	0.731
Sterility%	-0.450	0.001	0.004	-0.007	0.002	-0.740	(-0.220)	-0.005
No. of filled grain	0.867	0.002	0.006	0.003	0.005	0.736	0.164	(0.630)

highly positively genotypic and phenotypic correlated with flag leave dry weight and grain yield /plant, while it had negative genotypic and phenotypic correlation with sterility percent. Genotypic correlation was negative for sterility percent with flag leaf dry weight and grain yield. While phenotypic correlation was found between sterility percent and flag leave dry weight. Genotypic and phenotypic correlations were found between flag leave dry weight and grain yield.

Path coefficient analysis as an effect to assess the magnitude of contribution of most important traits related to grain yield in the form of cause and effect. Table 11 revealed the results of direct and indirect effects of various traits to grain yield. The direct effect of plant height was negative and low (-0.044). Indirect effect through no. of panicles/plant, 100 grain weights, panicle weight, sterility percent, and no. of filled grain were positive, but through no. of tillers/plant were negative. Maximum positive indirect effect (0.008) was observed through total number of tillers/plant. Highly significant genotypic correlation was present between grain yield with no. of panicles/plant, 100 grain weight, panicle weight and no. of filled grains/panicle, but the direct effect of the no. of tillers/plant was negative(-0.187). Positive indirect effect of no. of tillers/plant, no. of panicle/plant, 100 grain weight, panicle weight, sterility %, no. of filled grains/panicle were observed. Number of panicles/plant showed positive direct effect (0.398). Highly significant positive genotypic correlation (0.398) between number of panicles/plant and grain yield is present. Soares et al. (1990) reported that productive tillers/plant had direct effect on grain yield. Negative direct effect was reported by Buu and Trouong (1988). The differences in results may be attributed to the difference in genetic material and environmental conditions of the experiment. The direct effect of 100 grain weight was positive and also genotypic correlation between 100 grain weight and grain yield was positive (0.850). Panicle weight and number of filled grains/panicle directly affecting positively to grain yield. Its maximum positive indirect effect was through panicle weight 0.736.

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