Plant Production, Mansoura Univ.,Vol 12 (7): 795-804, 2021

Journal of Plant Production

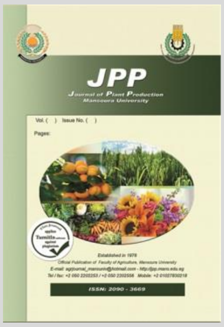
Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Evaluation of New Promising Rice Lines Under Water Deficit Conditions Based on Grain Yield, Quality and Stress Tolerance Indices

Cross Mark

Fatma A. Hussein*; Raghda M. Sakran and M. M. Elshenawy

Rice Research Department, Field Crops Research Institute (FCRI), ARC, Egypt.



ABSTRACT

Two field experiments were carried out at the Experimental Farm of Sakha Agricultural Research Station during 2019 and 2020 growing seasons, to evaluate 21 rice genotypes (18 new promising lines and three commercial check varieties) for grain yield, yield components and quality characters under normal and water deficit conditions. Moreover, eight stress tolerance indices were calculated based on grain yield under water deficit and normal conditions to differentiate the water deficit tolerant genotypes from sensitive ones. The results showed that the variances due to years, environments, genotypes and their interactions were significant for most studied traits. All mean values of the studied traits decreased under water deficit stress condition compared to those under normal condition. The earliest genotypes were L4, L15 and L12 under normal condition. Whereas under stress condition L11,Giza 179 and Sakha 107 were the earliest ones. The most desirable mean values towards dwarfness were recorded by the lines L1 and L9. While, L13 and L2 had the highest mean values towards tallness. Moreover, Line 2 recorded the most desirable estimates for grain quality characters across all environments. The lines L14, L12 and L3 gave the highest grain yield and stress tolerance index (STI), while L6 displayed the lowest grain yield and STI. Moreover, the results indicated that harmonic mean (HM) and yield index (YI) indices gave similar ranks for these lines which considered as water deficit tolerant genotypes. Accordingly, these lines could be used in breeding programs to transmit tolerance genes to commercial cultivars for reduced irrigation.

***Keywords**:* Rice, promising lines, water deficit, grain quality, stress tolerance indices

INTRODUCTION

Rice is one of the most important food crops that feed millions of people around the world (Tiwari *et al*., 2021). Rice is grown in many different regions of the world. In Egypt, rice is of particular importance, as it is the second most important economic crop after wheat, and it is widely accepted by farmers due to its economic importance as well as its nutritional importance. The world is now going through great changes in climatic conditions, as well as in the amount of available water, as the amount of water available for irrigation has begun to decrease in many regions of the world, which led to a change in the agricultural systems used by farmers to face this shortage (Yang *et al*., 2019). Water deficit can be defined as the absence of adequate moisture necessary for a plant to grow normally and complete its life cycle. The lack of adequate moisture leading to water deficit is a common occurrence in rainfed areas, brought about by infrequent rains and poor irrigation. Drought is one of the most severe abiotic factors limiting rice productivity in rainfed agriculture (Wu and Cheng, 2014). Rosales *et al.,* (2012) reported that reduction in water availability for plants results in a complex response characterized by a decrease in the water potential of its tissues, leading to several changes in different plant processes. O'Connell (2017) showed that the effects of drought in agriculture are aggravated due to the depletion of water resources and the increased food demand from an alarming world population growth. As well as Passioura and Angus (2010), Devincentis (2020), Daryanto *et al.*, (2020) and Salehi-Lisar *et al*.,(2020) indicated that the unpredictable nature of the drought is dependent upon various factors such as uneven and undependable distribution of rainfall, evapotranspiration, and water holding capacity around the rhizosphere. Moreover, in some cases plants are unable to uptake water from the soil, even though enough moisture is present in the root zone, a phenomenon known as physiological drought or pseudo-drought.

Quality of rice is an important criterion for the choice and demand by rice consumers and it is determined by physicochemical parameters, White and translucent grains are more preference by rice consumer (Amaka *et al*., 2014). The economic value of rice in the market depends upon its cooking and processing quality, which can be measured in terms of optimum cooking time, water uptake ratio, grain elongation, swelling index (Ekka *et al*., 2016). Amylose content is an important because it has a marked effect on the cooking, palatability characteristics, softness and stickiness of cooked rice (Kaur *et al*., 2017).

Drought tolerance breeding has a major priority in the Egyptian rice breeding programme to minimize water requirements and developing and releasing new rice varieties appropriate for water deficit conditions. Therefore, the objectives of this study were to (1) evaluate the performance of some new promising lines for grain yield, its components and quality characters under normal and water deficit conditions, (2) identify the water deficit

---

* **Corresponding author.**
E-mail address: fatma_awed2008@yahoo.com
DOI: 10.21608/jpp.2021.84186.1042

tolerant genotypes based on several stress tolerance indices for using it in future breeding programs.

MATERIALS AND METHODS

Two field experiments were conducted at the Experimental Farm of Sakha Agricultural Research Station, Kafr EL-Sheikh, Egypt, during 2019 and 2020 growing seasons. The plant materials consisted of 18 promising lines selected from the Fn generation of three crosses, in addition to three commercial Egyptian varieties of rice, which are tolerant to drought; Giza178, Giza179, and Sakha 107. The chosen crosses were produced from hybridization between Giza 178 × WAB880-1-32-1-2-P1-HB, GZ6296-12-1-2-1×IRAT170 (9 Fn genotypes) and IET1444×IRAT170 (8 Fn genotypes). Pedigree selection methods in segregated generation from F_2 to F_6 were used after hybridization to ensure their stability. The name, code and parentage of the studied genotypes are listed in Table 1.

Table 1. Name, code and parentage of the studied rice genotypes.

Code	Parentage
L1	Giza 178/ WAB 880-1-32-1-2-P1-HB
L2	GZ6296-12-1-2-1 / IRAT 170-1
L3	GZ6296-12-1-2-1 / IRAT 170-2
L4	GZ6296-12-1-2-1 / IRAT 170-3
L5	GZ6296-12-2-1-1/ IRAT 170-4
L6	GZ6296-12-2-1-1/ IRAT 170-5
L7	GZ6296-12-2-1-1/ IRAT 170-6
L8	GZ6296-12-2-1-1/ IRAT 170-7
L9	GZ6296-12-2-1-1/ IRAT 170-8
L10	GZ6296-12-2-1-1/ IRAT 170-9
L11	IET 1444 / IRAT 170-1
L12	IET 1444 / IRAT 170-2
L13	IET 1444 / IRAT 170-3
L14	IET 1444 / IRAT 170-4
L15	IET1444/ / IRAT 170-5
L16	IET1444/ / IRAT 170-6
L17	IET1444/ / IRAT 170-7
L18	IET1444/ / IRAT 170-8
Giza 178	Giza175/ Milyang 49
Giza 179	GZ 1368-S-5-4/ GZ 6296-12-1-2-1-1
Sakha 107	Giza177/ BL1

All selected rice genotypes (18 advanced lines and the three checks) were grown under full irrigated (normal 5500 m^3) and water deficit conditions (flash irrigation every 12 days 3500 m^3) in separated experiments using randomized complete block design (RCBD) with three replications. Each genotype was planted in seven rows per replicate using direct seeding method (dry seeds were sown in dry soil). Each row was 5.0 m long with the spacing of 20 × 20 cm among rows and hills. All cultural practices were applied as recommended by Recommendations of Rice Research and Training Center (RRTC). Soil samples were collected from the experimental site at a depth of 0 to 25 cm from soil surface before cultivation to study the soil mechanical and chemical properties of the experimental site according to Piper (1950). The mechanical and chemical analyses of the soil are presented in Table 2. The monthly maximum and minimum temperatures during the 2019 and 2020 growing season are presented in Table 3.

Table 2. Soil mechanical and chemical properties of the experimental site

Soil characteristics	Season	
	2019	2020
Soil texture (%)	Clayey	Clayey
Clay %	57.00	55.00
Sand %	12.00	12.00
Silt %	31.00	33.00
pH (1: 2.5 water suspension)	8.12	8.17
EC (dSm^{-1})	3.09	2.98
Organic matter	1.34	1.39
Total N (ppm)	585.60	580
Available P (ppm)	5.70	5.65
Exchangeable K (ppm)	440.50	441
Cations (meq/L.)		
Ca^{++}	6.30	6.22
Mg^{++}	4.40	4.25
Na^{+}	19.13	19
K^{+}	1.40	1.25
Anions (meq/L.)		
HCO3^{-}	6.50	6.00
Cl^{-}	8.80	8.15
SO4^{--}	15.63	15.00
CO3^{-}	--	--
Available micronutrients (ppm)		
Fe	6.00	6.03
Mn	3.70	3.41
Zn	1.00	1.05

Table 3. The monthly maximum and minimum temperature (˚C) as well as relative humidity (%) at Sakha Agricultural Research Station during 2019 and 2020 growing seasons.

Month	Sakha Agricultural Research Station					
	Air Temperature 2019		RH %	Air Temperature 2020		RH %
	Max	Min		Max	Min	
May	31.9	25.4	76.4	32.0	23.8	68.9
June	33.1	28.0	81.5	31.1	25.2	78.0
July	33.5	28.4	85.2	33.7	27.3	84.2
August	34.2	28.9	85.7	34.6	28.2	85.3
September	32.4	27.9	83.4	34.6	27.1	86.7
October	30.2	26.7	87.3	31.5	24.6	84.8

Data collection

A. Agronomic characters

Days to heading (day), plant height (cm), number of tillers plant^{-1}, number of panicle plant^{-1}, panicle weight (g), panicle length (cm), fertility %, 1000- grain weight (g) and grain yield m^{-2} (g) were measured according to Standard Evaluation System for Rice (IRRI 2002).

B. Grain quality characteristics

1- Hulling %

Duplicate 150 grams of rough rice from each variety were used for hulling percentage determination. It was calculated according to Khush *et al*, (1979) as follows:

$$\text{Hulling \%} = \frac{\text{Brown rice weight (g)}}{\text{Total rough rice weight (g)}} \times 100$$

2- Milling%

The objective of the rice milling is to remove the bran and germ with the minimum endosperm breakage. It was also determined on the basis of Ghosh *et al.*, (1971) as follows:

$$\text{Milling \%} = \frac{\text{Total milled rice weight (g)}}{\text{Total rough rice weight (g)}} \times 100$$

3- Head rice %

The whole grains (head rice) were separated according to the broken size(less than 1/4th of grain length) with rice-sizing device and then weighted . Head rice percentage was determined as follows:

$$\text{Head rice } \% = \frac{\text{Weight of head rice (g)}}{\text{Rough rice weight (g)}} \times 100$$

4- Gelatinization temperature (GT)

Such alkali spreading and clearing of starchy endosperm represented the GT which was visually rated on 7– point numerical scale adopted by Little *et al.*, (1958) scale.

5- Grain elongation of cooked rice

The length of cooked grains was measured in millimeters. Average length of row and cooked grains was calculated. The proportionate change (PC) in L/W ratio was calculated according Sood *et al.*, (1980).

6- Amylose content

Amylose content % was determined according to the methods of Williams *et al.*, (1958).

7- Grain shape

Grain size (length and width) was taken from 10 normal grains of each plot using a Micrometer. The length/width ratio (grain shape) was calculated from these values and the following scale as suggested Khush *et al.*, (1979).

Tolerance indices

Eight drought tolerance indices including mean productivity (MP), stress tolerance index (STI), geometric mean productivity (GMP), tolerance index (TOL), stress susceptibility index (SSI), harmonic mean (HM), yield index (YI) and yield stability index (YSI) were estimated for each genotype based on grain yield under stress (Ys) and non-stress (Yp) conditions. Names, equations and references of these indices are presented in Table 4.

Table 4. Drought tolerance indices used in the present study.

Drought tolerance indices	Equation	Reference
Stress Susceptibility Index (SSI)	$SSI = 1 - (Ys / Yp) / SI$, while $SI = 1 - (\hat{Y}s / \hat{Y}p)$	Fischer and Maurer (1978)
Geometric Mean Productivity (GMP)	$GMP = (Yp \times Ys)^{0.5}$	Fernandez (1992) and Kristin *et al.* (1997)
Mean Productivity (MP)	$MP = (Ys + Yp) / 2$	Rosielle and Hambling (1981)
Harmonic Mean (HM)	$HM = 2(Yp * Ys) / (Yp + Ys)$	Jafari *et al.* (2009)
Tolerance Index (TOL)	$TOL = (Yp - Ys)$	Rosielle and Hambling (1981)
Stress Tolerance Index (STI)	$STI = (Yp * Ys) / (\hat{Y}p)^2$	Fernandez (1992)
Yield Index (YI)	$YI = Ys / \hat{Y}s$	Gavuzzi *et al.* (1997)
Yield Stability Index (YSI)	$YSI = Ys / Yp$	Bouslama and Schapaugh (1984)

Data Analysis

Combined analysis of variance (ANOVA) was calculated according to Gomez and Gomez (1984) after testing the homogeneity of variance over the two years. Least significant difference (LSD) test was used to classify the significant differences between the proper items at probability level of 0.05 and 0.01.

RESULTS AND DISCUSSIONS

Analysis of variance

The analysis of variance (Table 5) showed that the mean squares due to years were not significant for all the studied traits, except for plant height and milled grain shape, which reflects unconsidered variations between the two years for these traits. Environments (E) mean squares were found to be highly significant for all studied characters, indicating that the performances of these genotypes differed from normal to stress conditions. These results agree with those obtained by Abd Allah *et al.*, (2010), Aboukhadrah *et al.*, (2015) and Ghazy *et al.*, (2021).

Mean squares due to genotypes (G) were significant for all studied traits. This indicates the wide diversity among the genetic materials used in the present study. Mean squares due to genotypes × environments (G × E) interactions were significant for all studied traits, suggesting that the tested genotypes varied from one environment to another and ranked differently from normal to stress conditions. Similar findings were reported by Raman *et al.*, (2012), Kamarudin *et al.*, (2018) and Yang *et al.*, (2019).

Genotypes × years (G × Y) interaction mean squares were significant only for plant height, fertility %, 1000-grain weight, hulling%, head rice%, elongation, paddy grain shape and milled grain shape. This indicates that the ranks of the evaluated genotypes changed across years for these traits. Mean squares due to genotypes × environments × years (G × E × Y) interactions were not significant for all the studied traits, except fertility %, head rice%, elongation and milled grain shape indicating that the performance of each genotype in one environment will be changed from one year to another.

Table 5. Combined analysis of variance of all the studied traits across years, environments and genotypes.

S.O.V.	df	Days to heading	Plant height (cm)	Number of panicles	Panicle length (cm)	Panicle weight (g)	Fertility %	1000- grain weight (g)	Grain yield (g/ m^2)
Years (Y)	1	0.32	82.01*	0.68	0.86	0.36	0.26	0.14	10.94
Rep/Y	4	6.26	10.18	6.79	7.31	0.23	2.55	1.56	839.88
Environments (E)	1	1452.48**	33321.48**	3936.57**	2088.98**	469.12**	15105.85**	1238.27**	26704345.72**
Y × E	1	0.05	18.22	2.68	9.62	0.01	6.41	5.50*	23.22
Error a	4	4.55	6.35	4.89	5.33	0.13	1.43	0.63	428.09
Genotypes (G)	20	275.45**	766.50**	5.42**	35.46**	1.89**	139.34**	45.23**	15385.25**
G × Y	20	1.57	10.96*	1.68	0.53	0.11	2.26*	1.13**	410.98
G × E	20	97.38**	293.41**	3.03*	10.89**	0.86**	69.17**	11.45**	8341.20**
G × Y × E	20	1.4	9.9	1.27	0.63	0.11	3.28**	0.51	100
Pooled Error (Eb)	160	1.66	6.06	1.73	1.99	0.12	1.33	0.52	419.61

Table 5. Continued.

S.O.V.	df	Hulling (%)	Milling (%)	Head rice (%)	Gelatinization temperature	Amylose content %	Elongation %	Grain Shape (paddy)	Grain Shape (milled)
Years (Y)	1	21.62	0.95	40.5	0.57	0.53	0.21	0.04	0.21*
Rep/Y	4	8.57	23.6	51.99	0.67	1.13	17.01	0.02	0.01
Environments (E)	1	1086.43**	1584.87**	1431.95**	26.68**	354.79**	946.72**	0.31*	0.01
Y × E	1	12.12	1.82	5.41	0.02	1.51	22.35	0	0.01
Error a	4	1.87	3.16	11.96	0.44	0.46	9.61	0.02	0.01
Genotypes (G)	20	55.67**	79.09**	115.68**	43.80**	4.75**	221.12**	0.36**	0.18**
G × Y	20	2.70*	3.54	14.81**	0.29	0.23	21.97**	0	0.03**
G × E	20	41.11**	46.48**	98.03**	11.70**	1.24**	116.00**	0.15**	0.05**
G × Y × E	20	2.33	4.1	17.23**	0.3	0.13	16.24**	0	0.03**
Pooled Error (Eb)	160	1.56	2.91	4.86	0.42	0.41	5.5	0.01	0.005

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

Interaction Effects

Means of the studied traits under normal and water deficit conditions across the two years are presented in Table 6. It is noteworthy that the mean values of all studied characters under normal irrigation were higher than those recorded under water deficit conditions, except elongation trait. These results are in good agreement with those reported by Abd Allah *et al.,* (2010), Sedeek *et al.,* (2012), Abd EL-Aty *et al.,* (2017), Elgamal *et al.,* (2018) and Mumtaz *et al.,* (2020).

Data in Table 6 indicated that the earliest genotypes were L4, L15 and L12 under normal conditions, whereas under stress conditions the earliest genotypes were L11, Giza 179 and Sakha 107. In contrast, latest genotypes were L9 and L10 under normal and stress conditions, respectively. For plant height, the shortest plants were obtained by L2 and Giza 179 while the tallest ones were given by the lines L2 and L 13 under normal conditions.

However, under stress conditions the shortest plants were obtained by the lines L1 and L15, while the tallest ones were recorded by L5 and L11. It is clear that plant height significantly decreased under water deficit conditions compared with normal conditions for all the tested genotypes. The reduction of stem elongation in rice plants could be considered as a tolerance mechanism, since it reduces the plant demand for water (Fischer *et al.,* 2003 and Chaves *et al.,* 2009). Number of panicles per plant was the highest in Giza 178, L4 and L3 under normal conditions, while under stress conditions the highest mean values were observed in the three check varieties Giza 179, Giza 178 and Sakha 107. Regarding panicle length, the line L3 and L12 under normal conditions as well as the lines L4 and L11 under stress conditions recoded the highest mean values for this trait. The highest mean values for panicle weight was recorded by the lines L11 and L3 under normal conditions as well as L12 and L 15 under stress conditions. Similarly, the highest desirable mean values for fertility percentage were exhibited by the genotypes L11 and L4 under normal conditions, and the check varieties Sakha 107 and Giza 179 under stress conditions. Likewise, the lines L17and L18 recorded the heaviest 1000-grain weight under normal and water deficit conditions, respectively. Grain yield differed significantly by irrigation treatments. It varied between 948 to 1120 g under normal conditions, and 329.5 to 490 g under water deficit conditions. The lines L9 and L6 exhibited the lowest values under normal and water deficit conditions, respectively. While L12 and L14 showed the highest values under both conditions. Generally, the results indicated that grain yield and its components significantly reduced under water deficit conditions compared to normal conditions. Similar finding were reported by Pantuwan *et al.,* (2002), Kamoshita *et al.,* (2004), Botwright *et al.,* (2008) and Gaballah *et al.,* (2021).

They found that water deficit at vegetative growth especially at booting stage and flowering stage cause spikelet sterility and poor grain filling resulting in lower grain weight and ultimately reduced rice grain yield.

Regarding hulling %, the genotypes L18 and the three check varieties; Giza 179, Giza 178 and Sakha 107 exhibited the highest mean values while, Lines L1 and L2 showed the lowest ones for this trait under both normal and stress conditions. Concerning milling %, the lines L2 and L7 under normal conditions as well as the lines L1 and L17 under water deficit conditions showed the highest mean values. The highest desirable mean values for head rice percentage were assigned for L2, Giza 178 and Sakha 107 under normal conditions. While, the lines L12, L2 and L1 presented the highest values under stress conditions. With respect to gelatinization temperature, the lowest mean values were obtained by the lines L12, L18 and L11 while the highest ones were detected by L6, Giza 178 and Sakha 107 under normal conditions. However, under stress conditions the lowest means were obtained by L1, L10 and L15, while the highest ones were recorded by the lines L14, L13 and L10. For amylose content %, the lines L6 and L7 had the highest values, while L2 had the lowest mean values under both conditions. Liu *et al.,* (2010) and Wang *et al.,* (2014) reported that amylose content in rice grains reduced under drought stress which is in accordance with our results.

The lowest values of elongation trait were exhibited by L4 and L17 and the highest values were shown by L8 and L11 under normal and stress conditions, respectively.

The line L13 gave the highest values for paddy and milled rice grain shape under normal conditions, while under stress conditions the lines L14 and L15 recorded the highest values for paddy and milled rice grains, respectively. In general water deficit treatment significantly reduced hulling %, milling %, head rice %, amylose content %, gelatinization temperature and grain shape. These results confirm that reported by Rayee *et al.,* (2021).

Table 6. Effect of the interactions between environments and genotypes for all agronomic characters over seasons.

Genotype	Days to heading (day)		Plant height (cm)		Number of Panicles		Panicle Length (cm)		Panicle weight (g)		Fertility %		1000 grain weight (g)		Grain yield g /m^2	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
L1	101.00	92.67	106.33	64.67	19.33	11.33	25.64	18.93	5.88	2.42	87.29	75.44	26.49	21.91	1086.83	457.67
L2	110.67	101.17	122.67	92.00	19.83	10.83	23.94	21.84	4.65	2.75	86.99	76.23	27.17	22.46	1044.83	478.17
L3	104.00	97.83	111.33	94.27	20.00	11.00	30.01	20.42	6.00	2.65	90.77	74.79	26.92	22.90	1107.17	469.17
L4	94.33	90.83	106.83	97.00	20.00	10.50	27.84	23.96	5.57	2.41	96.17	74.02	23.74	22.40	1051.67	441.83
L5	95.50	99.17	116.17	98.30	19.67	10.50	28.98	23.55	5.30	2.35	94.27	74.23	30.03	23.39	1076.17	393.17
L6	102.33	98.83	97.17	90.53	19.33	10.67	29.01	23.27	4.15	1.92	87.65	75.49	26.35	23.21	1042.83	329.50
L7	110.33	99.67	104.17	72.67	19.50	10.33	26.48	20.11	4.96	2.49	78.80	75.32	23.19	21.42	1104.00	374.17
L8	111.50	99.50	114.83	73.50	19.33	10.50	27.78	19.79	4.64	2.77	81.84	66.19	23.55	22.47	1046.67	390.33
L9	113.00	100.83	103.33	73.33	19.33	10.83	24.81	20.86	4.34	2.88	82.62	66.16	22.12	20.16	948.00	394.17
L10	112.50	103.33	102.83	73.83	19.17	10.50	26.77	18.18	5.07	2.44	90.51	75.09	24.82	22.00	1106.67	339.83
L11	103.33	89.50	113.00	97.63	17.67	10.33	26.34	19.28	6.03	2.60	96.34	72.83	28.95	23.63	1109.33	461.00
L12	95.00	100.67	113.00	96.33	18.17	11.83	25.35	20.09	5.97	3.15	95.73	75.63	27.56	22.67	1120.00	489.50
L13	95.67	96.33	117.33	97.33	18.17	11.33	25.72	20.80	5.24	2.76	86.84	75.53	29.50	23.14	1086.42	444.33
L14	102.33	100.83	106.17	96.29	17.67	10.50	26.68	20.91	5.90	2.90	86.57	76.28	28.62	23.33	1112.67	490.00
L15	94.33	97.17	106.00	71.47	18.50	11.00	27.47	20.48	5.51	2.91	90.16	74.20	30.77	22.89	1075.50	459.50
L16	98.17	98.17	103.00	83.88	17.33	10.67	27.81	20.07	5.75	2.76	85.54	75.39	28.00	23.87	1080.67	393.50
L17	99.67	100.17	111.50	95.37	17.83	10.50	23.91	21.63	5.35	2.77	92.48	74.55	31.15	23.66	1072.17	461.00
L18	100.67	98.83	106.00	87.80	18.33	11.50	24.91	20.12	5.69	2.73	94.68	75.27	31.02	25.41	1069.50	451.17
Giza 178	108.17	103.00	104.33	74.50	20.50	12.83	24.70	18.50	5.17	1.83	94.41	74.14	23.34	19.94	1062.67	352.33
Giza 179	97.67	88.33	95.83	73.83	19.67	12.83	23.03	17.93	4.88	1.90	94.06	77.67	26.13	19.78	1073.50	377.17
Sakha 107	96.83	89.33	101.83	76.17	19.17	12.17	21.52	17.05	4.67	2.01	93.84	77.95	26.25	21.95	1039.00	396.50
LSD 0.05	1.47		2.81		1.50		1.61		0.39		1.31		0.82		23.36	
LSD 0.01	1.94		3.71		1.98		2.12		0.52		1.74		1.09		30.83	

N: normal conditions; S: stress conditions (water deficit)

Table 6. Continued.

Genotype	Hulling %		Milling %		Head Rice %		Gelatinization temperature (GT)		Amylose content %		Elongation %		Grain Shape (paddy)		Grain Shape (milled)	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
L1	79.94	79.09	71.39	70.03	61.00	59.61	5.17	1.50	17.62	15.68	32.26	37.10	2.50	2.32	2.14	1.97
L2	81.11	78.03	73.83	68.32	66.15	59.72	6.50	5.67	16.83	14.97	38.69	44.92	2.26	2.36	1.89	1.97
L3	82.46	79.06	72.28	68.04	63.09	59.58	5.50	4.33	18.32	15.69	38.01	44.11	2.46	2.63	2.23	2.20
L4	80.78	74.56	70.71	64.59	60.55	47.94	5.67	5.50	18.33	15.44	32.23	38.68	2.45	2.36	1.98	1.92
L5	79.76	76.22	69.28	63.88	57.09	56.17	6.00	1.67	17.96	16.31	36.90	40.84	2.58	2.30	2.01	2.02
L6	82.11	79.04	72.08	68.70	60.24	57.78	6.67	5.67	20.01	16.90	37.97	47.15	2.19	2.32	1.90	1.86
L7	81.69	76.22	73.69	63.93	62.36	50.26	6.00	6.67	19.33	16.75	40.82	43.39	2.31	2.44	1.97	2.04
L8	81.63	78.33	70.93	67.80	61.56	58.73	1.67	7.67	18.32	15.64	47.19	49.33	2.30	2.47	2.05	2.01
L9	79.71	78.65	69.07	68.91	51.83	58.91	5.67	5.67	18.95	16.85	41.98	35.72	2.40	2.25	2.04	1.92
L10	77.02	73.39	64.78	62.12	50.33	52.22	5.83	5.83	19.62	16.43	40.56	36.77	2.30	2.56	2.02	1.92
L11	80.61	61.33	70.59	51.33	60.04	43.33	1.67	1.67	16.91	15.92	40.50	60.89	2.52	2.75	2.19	2.17
L12	81.28	78.44	71.42	67.91	58.86	59.94	1.50	1.67	17.63	15.80	39.86	35.95	2.73	2.85	2.06	2.15
L13	80.80	76.94	70.69	65.51	61.24	54.42	2.17	1.67	17.99	15.59	38.37	48.23	2.76	2.48	2.40	1.98
L14	80.87	77.11	70.11	65.58	59.33	52.94	2.67	1.50	17.37	15.51	45.33	41.46	2.68	2.96	2.16	2.25
L15	80.20	76.55	70.43	64.50	57.44	55.00	2.17	1.50	18.44	15.19	39.41	49.79	2.51	2.63	2.17	2.30
L16	80.24	77.61	70.54	68.08	61.48	55.55	1.67	1.50	18.93	15.31	41.96	50.47	2.37	2.80	1.88	1.97
L17	80.65	78.11	71.59	69.11	61.20	55.09	4.33	1.67	18.11	15.99	36.77	34.31	2.48	2.33	2.10	2.07
L18	78.26	73.98	65.61	62.95	51.54	54.30	1.50	1.50	19.14	16.20	36.58	38.26	2.64	2.84	2.27	2.24
Giza 178	81.27	75.61	70.82	62.67	65.67	53.67	6.67	5.50	17.73	15.74	34.17	41.01	2.47	2.93	1.97	2.03
Giza 179	80.47	77.81	72.50	66.83	62.44	56.28	6.50	4.83	18.46	16.28	38.00	39.97	2.37	2.48	1.83	2.07
Sakha 107	80.50	78.05	70.57	66.77	63.51	55.39	6.67	5.33	18.60	16.56	44.33	44.92	2.39	2.07	1.86	1.82
LSD 0.05	1.42		1.95		2.51		0.74		0.73		2.67		0.11		0.08	
LSD 0.01	1.88		2.57		3.32		0.98		0.96		3.53		0.15		0.11	

N: normal conditions; S: stress conditions (water deficit)

The interaction between genotypes, environments (normal and water deficit conditions) and seasons are shown in Table 7. The earliest genotypes in heading were L11, Giza 179 and Sakha 107 under water deficit treatment, while the lines L9 and L10 had the latest heading under normal irrigation treatment in both seasons. For plant height, L2 recorded the highest value and L6 gave the lowest one in both seasons under normal conditions. But under stress conditions, L1 recorded the lowest plant height in both seasons, while and L5 and L11 recorded the highest value in the 1st and 2nd season, respectively. Fertility % was higher under normal conditions than under stress. L12 and L4 had the highest mean values, while L8 recorded the lowest one under normal conditions. Otherwise, under stress conditions, L2 and L14 recorded the highest value and L8 and L9 recorded the lowest mean values both seasons. Concerning 1000-grain weight, L9 gave the lowest value under normal and stress conditions in the two seasons, while L15 gave the highest value under normal condition in 2019 season and L18 gave the highest value under normal and stress conditions in 2019 and 2020 seasons. For grain yield, L12 and L11 gave the highest yield under normal conditions and L9 gave the lowest grain yield in the two seasons, while L14 and L12 gave the highest grain yield and L6 gave the lowest grain yield under stress in both seasons.

Concerning milling %, L2 and L7 gave the highest value under normal conditions, while L17 and L1 gave the highest value under stress in both seasons. Besides, L2 under normal conditions as well as L17 and L2 under stress conditions had the highest head rice mean values in both seasons. For amylose content %, L2 and L11 under normal as well as L2 and L4 under stress conditions had the lowest desirable mean values, while L6 and L9 gave the highest mean values under normal and stress conditions in both seasons. Tian *et al*., (2009), Bao *et al*., (2006) and Jiranuntakul *et al.*, (2011) reported that, appearance amylose content is widely recognized as the most important factor affecting the Eating and cooking quality of rice grain. Cooked rice kernels with high Appearance amylose content (>25%) are dry, separate, less tender, and become hard upon cooling, whereas those with low (12–20%) are glossy, soft, and sticky. Intermediate Appearance amylose content (20–25%) rice is widely preferred in most rice-producing areas of the world since this kind of cooked rice is soft and flaky.

As for elongation %, L8 gave the highest mean and L1 gave the lowest one under normal conditions, but L11 exhibited the highest mean and L17 gave the lowest value under stress conditions in the two seasons. The data showed that L11 and L12 recorded the highest values for grain shape in paddy grains and L6 recorded the lowest values under normal conditions, while L14 gave the highest value and L9 gave the lowest value under stress conditions in the two seasons. With respect to grain shape in milled grains, L13 was the highest and L6 with L2 were the lowest under normal conditions. Under stress conditions, L15 and L18 gave the highest mean values, while L5 and L13 gave the lowest mean values in both seasons.

Table 7. Means of all studied traits of the 21 genotypes under non-stress and water deficit conditions during 2019 and 2020 seasons.

Genotype	Days to heading (day)				Plant height (cm)				Number of Panicles				Panicle Length (cm)			
	2019		2020		2019		2020		2019		2020		2019		2020	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
L1	101.00	93.33	101.00	92.00	105.67	62.67	107.00	66.67	18.67	11.33	20.00	11.33	25.27	18.53	26.02	19.32
L2	111.67	101.00	109.67	101.33	123.33	91.67	122.00	92.33	19.67	10.00	20.00	11.67	23.57	22.37	24.32	21.30
L3	105.33	98.00	102.67	97.67	111.33	92.87	111.33	95.67	19.67	10.00	20.33	12.00	29.63	20.86	30.38	19.98
L4	95.00	91.00	93.67	90.67	106.33	94.67	107.33	99.33	19.33	10.00	20.67	11.00	27.47	23.69	28.22	24.23
L5	95.33	99.33	95.67	99.00	117.67	101.27	114.67	95.33	21.00	10.67	18.33	10.33	24.63	21.03	24.98	20.68
L6	103.00	99.00	101.67	98.67	97.00	92.73	97.33	88.33	20.00	11.00	18.67	10.33	26.10	18.37	27.43	17.99
L7	110.67	100.00	110.00	99.33	103.67	72.67	104.67	72.67	20.00	10.00	19.00	10.67	26.17	19.86	26.52	18.70
L8	111.33	99.67	111.67	99.33	114.00	73.00	115.67	74.00	19.33	10.33	19.33	10.67	24.80	20.51	25.90	19.67
L9	113.00	100.67	113.00	101.00	102.00	74.33	104.67	72.33	20.00	10.67	18.67	11.00	25.93	20.49	25.50	21.10
L10	112.67	104.00	112.33	102.67	100.67	73.33	105.00	74.33	19.00	11.33	19.33	9.67	27.23	21.02	26.12	20.80
L11	103.33	89.00	103.33	90.00	112.33	94.93	113.67	100.33	17.33	10.33	18.00	10.33	28.60	24.24	29.35	22.85
L12	94.67	101.00	95.33	100.33	112.00	93.67	114.00	99.00	18.33	11.67	18.00	12.00	28.63	23.74	29.38	22.81
L13	95.00	96.33	96.33	96.33	118.33	96.00	116.33	98.67	18.33	11.00	18.00	11.67	26.17	19.82	26.79	20.40
L14	102.00	100.67	102.67	101.00	106.33	94.91	106.00	97.67	17.67	10.00	17.67	11.00	27.33	19.58	28.23	20.00
L15	95.33	96.67	93.33	97.67	105.67	70.60	106.33	72.33	18.33	10.67	18.67	11.33	27.43	21.17	27.50	19.80
L16	97.67	98.33	98.67	98.00	101.67	82.77	104.33	85.00	17.33	11.00	17.33	10.33	27.63	19.91	27.98	20.23
L17	98.67	99.67	100.67	100.67	112.67	92.07	110.33	98.67	18.33	10.00	17.33	11.00	23.73	21.83	24.08	21.43
L18	100.33	99.00	101.00	98.67	106.00	84.60	106.00	91.00	19.00	11.00	17.67	12.00	24.73	20.11	25.08	20.13
Giza 178	107.67	103.33	108.67	102.67	103.33	75.00	105.33	74.00	20.00	13.00	21.00	12.67	24.37	18.18	25.04	18.82
Giza 179	97.33	87.67	98.00	89.00	95.33	73.33	96.33	74.33	20.00	13.33	19.33	12.33	22.67	18.14	23.40	17.72
Sakha 107	96.67	89.33	97.00	89.33	102.00	76.00	101.67	76.33	19.33	13.00	19.00	11.33	21.25	17.19	21.79	16.92
LSD 0.05		2.08				3.97				NS				NS		
LSD 0.01		2.74				5.24				NS				NS		

Table 7.Continued.

Genotype	Panicle weight (g)				Fertility %				1000 grain weight (g)				Grain yield (g /m2)			
	2019		2020		2019		2020		2019		2020		2019		2020	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
L1	5.70	2.42	6.05	2.42	87.85	74.87	86.72	76.00	26.55	22.33	26.43	21.49	1089.33	456.67	1084.33	458.67
L2	4.69	2.82	4.62	2.69	86.99	77.90	86.98	74.55	27.18	22.21	27.17	22.71	1042.67	480.67	1047.00	475.67
L3	6.06	2.78	5.93	2.52	90.22	75.11	91.31	74.46	26.73	23.19	27.12	22.62	1108.67	471.67	1105.67	466.67
L4	5.67	2.48	5.47	2.34	95.67	74.92	96.66	73.12	23.67	23.04	23.80	21.76	1051.67	442.00	1051.67	441.67
L5	5.27	2.35	5.33	2.35	93.12	73.78	95.41	74.67	29.12	23.34	30.94	23.43	1070.67	397.00	1081.67	389.33
L6	4.35	1.94	3.94	1.90	87.83	75.10	87.47	75.88	26.30	23.70	26.40	22.72	1034.00	318.67	1051.67	340.33
L7	5.00	2.50	4.92	2.48	78.71	75.64	78.88	75.00	23.19	21.90	23.19	20.94	1101.67	383.33	1106.33	365.00
L8	5.02	2.85	4.26	2.68	82.17	66.58	81.52	65.79	23.52	22.93	23.58	22.01	1050.33	391.33	1043.00	389.33
L9	4.98	2.88	3.70	2.88	82.82	66.63	82.43	65.69	22.08	19.95	22.16	20.37	959.33	398.00	936.67	390.33
L10	4.96	2.44	5.17	2.43	90.35	75.37	90.68	74.81	24.97	22.63	24.67	21.36	1104.67	333.67	1108.67	346.00
L11	5.98	2.59	6.08	2.61	96.15	71.52	96.53	74.14	28.85	22.73	29.06	24.52	1106.00	454.00	1112.67	468.00
L12	5.90	3.34	6.03	2.96	96.20	75.97	95.25	75.29	27.16	22.56	27.96	22.78	1129.67	494.33	1110.33	484.67
L13	5.28	2.69	5.21	2.83	87.88	75.18	85.79	75.88	28.95	22.88	30.05	23.40	1090.33	441.33	1082.50	447.33
L14	5.92	2.94	5.87	2.86	85.70	76.04	87.44	76.51	28.78	23.85	28.46	22.82	1122.33	498.67	1103.00	481.33
L15	5.44	2.96	5.57	2.85	88.85	74.98	91.46	73.42	30.78	23.34	30.76	22.43	1081.33	462.67	1069.67	456.33
L16	5.81	2.75	5.69	2.78	86.24	75.45	84.84	75.33	27.99	24.04	28.00	23.69	1082.33	399.67	1079.00	387.33
L17	5.35	2.77	5.35	2.76	91.48	75.01	93.48	74.09	30.52	23.49	31.77	23.82	1077.33	456.33	1067.00	465.67
L18	5.66	2.76	5.72	2.71	93.77	76.54	95.59	74.00	30.00	25.30	32.04	25.52	1061.00	440.33	1078.00	462.00
Giza 178	5.22	1.83	5.12	1.83	94.63	73.55	94.19	74.72	23.41	19.94	23.26	19.94	1055.00	354.00	1070.33	350.67
Giza 179	4.78	1.93	4.98	1.88	93.85	77.67	94.27	77.67	26.49	19.81	25.77	19.75	1083.00	381.67	1064.00	372.67
Sakha 107	4.62	2.01	4.73	2.01	93.00	77.22	94.69	78.67	25.82	22.01	26.68	21.89	1025.67	386.00	1052.33	407.00
LSD 0.05		NS				1.86				1.16				33.03		
LSD 0.01		NS				2.45				1.53				43.60		

Table 7. Continued.

Genotype	Hulling %				Milling %				Head Rice%				Gelatinization temperature (GT)			
	2019		2020		2019		2020		2019		2020		2019		2020	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
L1	80.11	79.19	79.77	79.00	71.55	70.73	71.22	69.33	60.22	58.78	61.77	60.44	5.67	1.67	4.67	1.33
L2	81.00	78.50	81.22	77.55	73.89	68.86	73.77	67.78	64.00	58.12	68.29	61.33	6.67	5.67	6.33	5.67
L3	82.00	78.67	82.92	79.44	72.33	67.20	72.22	68.89	61.78	58.50	64.40	60.66	5.67	4.33	5.33	4.33
L4	82.00	74.67	79.55	74.44	71.00	65.22	70.41	63.96	60.22	49.67	60.88	46.22	5.67	5.67	5.67	5.33
L5	79.89	76.67	79.63	75.77	69.67	62.86	68.89	64.89	57.33	55.00	56.85	57.33	5.67	1.67	6.33	1.67
L6	82.44	79.74	81.77	78.33	72.67	69.07	71.49	68.33	59.22	56.67	61.26	58.89	6.67	5.67	6.67	5.67
L7	81.89	76.67	81.49	75.78	72.22	62.85	75.15	65.00	58.89	50.33	65.83	50.18	6.00	7.00	6.00	6.33
L8	81.55	78.67	81.70	78.00	71.33	67.59	70.52	68.00	61.00	55.66	62.11	61.79	1.67	7.67	1.67	7.67
L9	79.44	78.75	79.97	78.55	68.44	69.05	69.71	68.77	54.67	57.29	49.00	60.52	5.67	5.67	5.67	5.67
L10	78.00	74.66	76.04	72.11	65.67	61.57	63.88	62.67	53.00	53.11	47.67	51.33	6.33	6.00	5.33	5.67
L11	79.89	64.00	81.33	58.67	69.44	52.00	71.74	50.67	58.00	43.67	62.07	43.00	1.33	1.67	2.00	1.67
L12	81.22	78.67	81.33	78.22	70.89	68.37	71.96	67.44	59.00	58.67	58.73	61.22	1.67	1.67	1.33	1.67
L13	80.44	77.00	81.15	76.89	70.55	65.16	70.82	65.85	59.22	54.85	63.25	54.00	1.67	2.00	2.67	1.33
L14	80.67	76.33	81.08	77.89	69.33	63.27	70.88	67.89	58.00	53.00	60.65	52.88	2.67	1.33	2.67	1.67
L15	80.33	77.00	80.07	76.11	69.89	64.78	70.96	64.22	58.00	56.33	56.89	53.66	2.00	1.33	2.33	1.67
L16	80.33	77.22	80.15	78.00	69.78	68.61	71.29	67.55	58.00	55.00	64.96	56.11	1.67	1.67	1.67	1.33
L17	81.22	79.67	80.08	76.55	70.66	71.55	72.52	66.67	58.89	58.96	63.52	51.22	5.00	1.67	3.67	1.67
L18	78.33	75.17	78.19	72.79	66.11	62.61	65.11	63.28	53.00	54.55	50.07	54.05	1.67	1.67	1.33	1.33
Giza 178	81.99	76.67	80.55	74.55	70.86	62.33	70.78	63.00	66.00	52.67	65.33	54.67	6.67	5.33	6.67	5.67
Giza 179	79.44	78.33	81.50	77.29	72.66	67.33	72.33	66.33	61.88	54.67	63.00	57.89	6.33	5.00	6.67	4.67
Sakha 107	80.70	78.67	80.31	77.44	70.85	67.00	70.29	66.53	65.13	56.00	61.89	54.78	6.67	5.33	6.67	5.33
LSD 0.05	NS				2.75				3.55				NS			
LSD 0.01	NS				3.63				4.69				NS			

Table 7.Continued.

Genotype	Amylose content %				Elongation %				Grain Shape (paddy)				Grain Shape (milled)			
	2019		2020		2019		2020		2019		2020		2019		2020	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
L1	17.63	16.13	17.6	15.23	33.00	38.67	31.52	35.53	2.49	2.32	2.5	2.32	2.08	1.94	2.2	2.00
L2	16.61	14.83	17.04	15.1	37.11	35.72	40.26	54.13	2.26	2.36	2.25	2.36	1.88	2.00	1.9	1.94
L3	18.31	15.71	18.33	15.67	40.13	43.68	35.89	44.53	2.5	2.63	2.43	2.63	2.22	2.12	2.24	2.28
L4	18.14	15.82	18.52	15.06	30.85	39.03	33.61	38.33	2.45	2.36	2.45	2.36	1.98	1.95	1.98	1.88
L5	17.94	16.46	17.98	16.17	37.04	42.16	36.76	39.52	2.58	2.3	2.57	2.3	2.03	1.81	1.99	2.24
L6	20.01	17.21	20.01	16.58	38.33	48.65	37.61	45.65	2.18	2.32	2.21	2.32	1.84	1.9	1.97	1.83
L7	19.16	16.94	19.5	16.55	39.73	44.25	41.91	42.53	2.33	2.44	2.29	2.44	1.9	2.03	2.05	2.05
L8	18.4	15.84	18.24	15.43	48.04	48.61	46.34	50.05	2.31	2.47	2.28	2.47	1.89	1.98	2.2	2.03
L9	19.11	16.78	18.79	16.92	40.94	36.54	43.03	34.9	2.29	2.25	2.51	2.25	2.06	1.84	2.02	2.00
L10	19.68	16.52	19.55	16.34	40.33	35.6	40.78	37.94	2.29	2.56	2.31	2.56	1.93	1.91	2.1	1.93
L11	17.05	15.96	16.77	15.88	40.26	61.79	40.75	60.0	2.59	2.75	2.44	2.75	2.07	2.18	2.31	2.15
L12	17.51	15.81	17.76	15.78	42.00	35.89	37.71	36.01	2.67	2.85	2.8	2.85	2.1	2.16	2.03	2.13
L13	17.98	15.65	17.99	15.52	40.33	47.9	36.4	48.56	2.83	2.48	2.68	2.48	2.4	2.16	2.4	1.8
L14	17.15	15.27	17.6	15.76	47.76	40.26	42.89	42.67	2.68	2.96	2.67	2.96	2.13	2.26	2.19	2.24
L15	18.5	15.16	18.37	15.22	40.00	50.25	38.82	49.33	2.53	2.63	2.49	2.63	2.01	2.3	2.33	2.3
L16	18.89	15.37	18.97	15.24	43.67	49.36	40.26	51.58	2.36	2.8	2.39	2.8	1.85	1.96	1.92	1.97
L17	18.1	16.23	18.11	15.75	37.67	34.75	35.87	33.87	2.48	2.33	2.48	2.33	2.00	1.97	2.21	2.17
L18	19.11	16.59	19.17	15.8	35.86	38.00	37.29	38.52	2.66	2.84	2.63	2.84	2.29	2.13	2.25	2.35
Giza 178	17.6	15.6	17.85	15.88	33.67	41.45	34.67	40.57	2.48	2.93	2.47	2.93	1.99	1.89	1.95	2.16
Giza 179	18.17	16.37	18.75	16.19	38.00	40.18	38.00	39.77	2.36	2.48	2.37	2.48	1.86	2.04	1.8	2.09
Sakha 107	18.84	17.07	18.35	16.06	44.00	44.88	44.67	44.96	2.38	2.07	2.4	2.07	1.88	1.88	1.84	1.76
LSD 0.05	1.03				3.78				0.16				0.11			
LSD 0.01	1.36				4.99				0.21				0.15			

Tolerance indices

To investigate water deficit resistance indices for screening of rice genotypes under normal and water deficit condition during 2019 and 2020 growing seasons, grains yield m^{-2} were used for calculating different sensitivity and tolerance indices (Table 8). A suitable index must correlate to any measured parameter under both tested conditions as reported by Farshadfar *et al.*, (2013). Grain yield across genotypes exhibited significant differences between stress and normal irrigation conditions. The differences varied among rice genotypes (Table 8). The highest grain yield was given by L12 and L14 under normal and water stress conditions. The lowest grain yield under normal and water deficit conditions was shown by L9 and L6, respectively. Variations among the genotypes are in agreement with results of who reported that grain yield varied considerably from adequate to stress conditions and that genotypes had a high yield under adequate environment.

Based on the stress tolerance index (STI) and grain yield, L14 and L12 were drought tolerant with the highest STI and grain yield, while L6 displayed the lowest STI and grain yield. In general, similar ranks for the genotypes were observed by harmonic mean (HM) and yield index (YI), which suggests that these three parameters are equal for screening tolerant genotypes (Mevlut and Sait 2011). Moreover, L12 showed the highest MP, L14 recorded the highest HM, STI as well as GMP as compared with other genotypes suggesting more stress tolerance. Hence, these lines could be recommended for using under shortage water conditions. Moreover, it can be used in rice breeding program to transmit stress tolerance genes to the commercial varieties.

Table 8. Tolerance indices of grain yield m^{-2} measured for 21 rice genotypes cultivated under adequate and stress environments.

	Grain yield/ m^{-2}		Tolerance indices							
Genotypes	**N**	**S**	**TOL**	**MP**	**HM**	**GMP**	**SSI**	**STI**	**YI**	**YSI**
2019 season										
L1	1089.33	456.67	632.67	773	643.55	705.31	0.96	0.43	1.08	0.42
L2	1042.67	480.67	562.0	761.67	658	707.94	0.89	0.44	1.14	0.46
L3	1108.67	471.67	637.0	790.17	661.79	723.13	0.95	0.45	1.12	0.43
L4	1051.67	442.0	609.67	746.83	622.41	681.79	0.95	0.4	1.05	0.42
L5	1070.67	397.0	673.67	733.83	579.23	651.96	1.04	0.37	0.94	0.37
L6	1034.0	318.67	715.33	676.33	487.19	574.02	1.14	0.29	0.76	0.31
L7	1101.67	383.33	718.33	742.5	568.76	649.85	1.07	0.37	0.91	0.35
L8	1050.33	391.33	659.0	720.83	570.22	641.12	1.03	0.36	0.93	0.37
L9	959.33	398.0	561.33	678.67	562.6	617.91	0.96	0.33	0.95	0.42
L10	1104.67	333.67	771.0	719.17	512.52	607.12	1.15	0.32	0.79	0.3
L11	1106.0	454.0	652.0	780.0	643.75	708.61	0.97	0.44	1.08	0.41
L12	1129.67	494.33	635.33	812.0	687.72	747.28	0.93	0.49	1.17	0.44
L13	1090.33	441.33	649.0	765.83	628.34	693.69	0.98	0.42	1.05	0.41
L14	1122.33	498.67	623.67	810.5	690.52	748.11	0.91	0.49	1.18	0.44
L15	1081.33	462.67	618.67	772.0	648.05	707.32	0.94	0.43	1.1	0.43
L16	1082.33	399.67	682.67	741.0	583.77	657.7	1.04	0.38	0.95	0.37
L17	1077.33	456.33	621.0	766.83	641.11	701.16	0.95	0.43	1.08	0.42
L18	1061.0	440.33	620.67	750.67	622.37	683.52	0.96	0.41	1.04	0.42
Giza178	1055.0	354.0	701.0	704.5	530.12	611.12	1.09	0.32	0.84	0.34
Giza179	1083.0	381.67	701.33	732.33	564.42	642.92	1.07	0.36	0.91	0.35
Sakha107	1025.67	386.0	639.67	705.83	560.91	629.21	1.03	0.34	0.92	0.38
Mean	1072.71	421.04								
2020 season										
L1	1084.33	458.67	625.67	771.5	644.65	705.23	0.95	0.43	1.09	0.42
L2	1047.0	475.67	571.33	761.33	654.15	705.71	0.89	0.43	1.12	0.45
L3	1105.67	466.67	639.0	786.17	656.32	718.32	0.95	0.45	1.1	0.42
L4	1051.67	441.67	610.0	746.67	622.08	681.53	0.95	0.4	1.04	0.42
L5	1081.67	389.33	692.33	735.5	572.57	648.94	1.05	0.37	0.92	0.36
L6	1051.67	340.33	711.33	696.0	514.25	598.26	1.11	0.31	0.81	0.32
L7	1106.33	365	741.33	735.67	548.91	635.46	1.1	0.35	0.87	0.33
L8	1043.0	389.33	653.67	716.17	567.01	637.24	1.03	0.35	0.92	0.37
L9	936.67	390.33	546.33	663.5	551.04	604.66	0.96	0.32	0.93	0.42
L10	1108.67	346.0	762.67	727.33	527.4	619.35	1.13	0.33	0.82	0.31
L11	1112.67	468.0	644.67	790.33	658.87	721.61	0.95	0.45	1.11	0.42
L12	1110.33	484.67	625.67	797.5	674.79	733.58	0.92	0.47	1.15	0.44
L13	1082.5	447.33	635.17	764.92	633.06	695.87	0.96	0.42	1.06	0.41
L14	1103.0	481.33	621.67	792.17	670.2	728.64	0.92	0.46	1.14	0.44
L15	1069.67	456.33	613.33	763.0	639.74	698.66	0.94	0.43	1.08	0.43
L16	1079.0	387.33	691.67	733.17	570.04	646.48	1.05	0.36	0.9	0.36
L17	1067.0	465.67	601.33	766.33	648.37	704.89	0.92	0.43	1.1	0.44
L18	1078.0	462.0	616.0	770.0	646.8	705.72	0.94	0.43	1.09	0.43
Giza178	1070.33	350.67	719.67	710.5	528.26	612.64	1.1	0.33	0.83	0.33
Giza179	1064.0	372.67	691.33	718.33	552.0	629.7	1.07	0.35	0.88	0.35
Sakha107	1052.33	407.0	645.33	729.67	586.98	654.45	1.01	0.37	0.97	0.39
Mean	1071.69	421.23								

ABBREVIATIONS

MP, Mean productivity; STI, stress tolerance index; GMP, geometric mean productivity; TOL, tolerance index; SSI, stress susceptibility index; HARM, harmonic mean; YI, yield index; YSI, yield stability index; Ys, yield under stress; Yp, non-stress.

REFERENCES

Abd Allah, A.A., M.H. Ammar and A.T. Badawi (2010). Screening rice genotypes for drought resistance in Egypt. Journal of Plant Breeding and Crop Science, 2 (7):205- 215.

Abd El-Aty, M.S.M, E.A. Gallila, A.E. Draz and R.Y.A. EL-Agoury (2017). Estimation of genetic parameters using six populations of different rice crosses under normal and water stress conditions Egypt. J. Plant Breed. 21 (5): 1-17.

Aboukhadrah, S. H., A. A. Abd Allah, H. S. Gharib, and R. M. Sakran, (2015). Effect of soil water deficit on yield and its components at the different growth stages in rice (*Oryza sativa*). Egyptian Journal of Agronomy, 37(1), 79-92.

Amaka, M.O., M. Ngadi, C. Ejebe, N. Woin and A. Ndindeng Sali (2014). Physicochemical, Cooking Characteristics and Textural Properties of TOX 3145 Milled Rice. Journal of Food Research, 3(2): 82-90.

Bao J, S. Shen, M. Sun and H. Corke (2006). Analysis of genotypic diversity in the starch physicochemical properties of nonwaxy rice: apparent amylose content, pasting viscosity and gel texture. Starch—Sta¨rke. 2006; 58 (6):259–67.

Botwright, A., H.R. Latte and L.G. Wade (2008). Genotype and environment interactions for grain yield of upland rice backcross lines in diverse hydrological environments. Field Crops Research. 108:117-125.

Bouslama, M., and W.T. Schapaugh (1984). Stress tolerance in soybean. Part 1: evaluation of three screening techniques for heat and drought tolerance. Crop Sci. 24: 933-937.

Chaves, M.M., J. Flexa and C. Pinheiro (2009). Photosynthesis under drought and salt stress: regulation mechanisms from whole plant to cell. Annals of Botany 103: 551-560. China. JCSB 11:135–140

Daryanto, S., L. Wang and P.A. Jacinthe (2020). Global synthesis of drought effects on cereal, legume, tuber and root crops production: A review. Agric. Water Manag. 179, 18–33. [CrossRef]

Devincentis, A.J. (2020). Scales of Sustainable AgriculturalWaterManagement. Ph.D. Thesis, University of California, Davis, CA, USA.

Ekka,H., D. Padhee, L. Sharma, M. Diwakar, R. Lahari and S. Tiwari, (2016). Study of cooking quality of selected varieties of rice at varying temperature using induction heater. International Journal of Food Science and Nutrition, 1(2): 04-07.

Elgamal, W.H., W.F. Ghidan and A.M. Elmoghazy (2018). Utilization of new African rice varieties for breeding Egyptian cultivars tolerant to water deficit. J. Agric. Chem. and Biotechn. Mansoura Univ., 9 (3): 99 -104.

Farshadfar, E., M.M. Pour Siahbidi and S.M. Safavi (2013). Assessment of drought tolerance in land races of bread wheat based on resistance/ tolerance indices. Int. J. Adv. Biol. Biom. Res., 1(2):143-158.

Fernandes, G.C.J. (1992): Effective selection criteria for assessing stress tolerance. In: Proceedings of the International Symposium on Adaptation of Vegetables and Other Food Crops in Temperature and Water Stress Tolerance, Asian Vegetable Research and Development Centre, Taiwan, pp. 257-270.

Fischer, R.A., and R. Maurer (1978). Drought resistance in spring wheat cultivars: I. Grain yield responses. Aust. J. Agric. Res. *29*: 897-912.

Fischer, K.S., R. Lafitte, S. Fukai, G. Atlin and B. Hardy (2003). Breeding Rice for drought-Prone Environments. International Rice Research Institute, Los Baños, Philippines

Gaballah, M. M., Metwally, A. M., Skalicky, M., Hassan, M. M., Brestic, M., El Sabagh, A., & Fayed, A. M. (2021). Genetic Diversity of Selected Rice Genotypes under Water Stress Conditions. *Plants*, *10*(1), 27.

Gavuzzi, P., F. Rizza, M. Palumbo, R. G. Campanile, G. L. Ricciardi and B. Borghi (1997). Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Can. J. Plant Sci. Downloaded from cdnsciencepub.com by 154.182.73.234 on 06/29/21

Ghazy, M. I., K.F. Salem and A. Sallam (2021). Utilization of genetic diversity and marker-trait to improve drought tolerance in rice (*Oryza sativa* L.). Molecular Biology Reports, 48(1), 157-170.

Ghosh, A.K., B.B. Nanda, S. Govindaswamy and B.B.Nayak (1971). Influence of nitrogen on the physicochemical characteristics of rice grain. Oryza, 8, 87-98.

Gomez, k. A. and A. A. Gomez (1984). Statistical procedures for agricultural research. Second Edition. Second Edition. "An International Rice Research Institute book.""A Wiley-Interscience publication." Copyright by John Wiley & Sons, Inc.

IRRI (2002) "Standard Evaluation System for Rice". International Rice Research Institute (IRRI), P.O. Box 933, 1099 Manila, Philippines.

Jafari, A., F. Paknejad and M.J. Al-Ahmadi (2009) Evaluation of Selection Indices for Drought Tolerance of Corn (*Zea mays* L.) Hybrids. International Journal of Plant Production, **3**, 33-38.

Jiranuntakul W, C. Puttanlek, V. Rungsardthong, S. Puncha-arnon and D. Uttapap (2011). Microstructural and physicochemical properties of heat-moisture treated waxy and normal starches. Journal of Food Engineering.104 (2):246–58.

Kamarudin, Z. S., M. R.Yusop, M. T. M. Mohamed, M.R Ismail and A. R. Harun (2018). Growth performance and antioxidant enzyme activities of advanced mutant rice genotypes under drought stress condition. Agronomy, 8:2-15.

Kamoshita, A., R. Rofriguez, A.Yamauchi and L.Wade (2004). Genotypic variation in response of rainfed lowland to prolonged drought and rewatering. Plant Production Science. 7:406- 420.

Kaur, J., S.S. Mahal and K. Amarjeet (2017). Grain quality assessment of direct seeded basmati rice (*Oryza sativa* L.) under different irrigation regimes in Indian Punjab. Journal of Applied and Natural Science, 9(2): 663-668.

Khush, G.S., C.M. Paule and N.M. Dela Cruz (1979). Rice grain quality evaluation and improvement at IRRI. Proc. The Workshop on "Chemical Aspects of Rice Grain Quality". IRRI, Los Banos, Philippines.

Kristin, A.S, R.R. Senra, F.I. Perez, B.C. Enriquez, J.A.A. Gallegos, P.R. Vallego, N. Wassimi and J.D. Kelley (1997). Improving common bean performance under drought stress. *Crop Sci.*, 37: 43-50.

Little, R.R., G.B. Hilder and E.H. Dowson (1958). Differential effect of dilute alkali on 25 varieties of milled white rice. Cereal Chem, 35, 111-126.

Liu, D. H., J. L. Zhang, J. H. Cao, Z. H. Wang, C. Yu and D. M. Jin (2010). The reduction of amylose content in rice grain and decrease of Wx gene expression during endosperm development in response to drought stress. J. Food, Agric. Environ. Vol: 8 Issue: 3-4 Pages: 873-878 Part: 2

Mevlut, A., and C. Sait (2011). Evaluation of drought tolerance indices for selection of Turkish oat *(Avena sativa* L.) landraces under various environmental conditions.

Mumtaz, M. Z., Saqib, M., Abbas, G., Akhtar, J., & Ul-Qamar, Z. (2020). Drought stress impairs grain yield and quality of rice genotypes by impaired photosynthetic attributes and K nutrition. 水稻科学, 27(1), 5-9.

O'Connell, E. (2017).Towards adaptation of water resource Systems to climatic and socio-economic Chang. Water Resour. Manag. 31, 2965–2984. [CrossRef]

Pantuwan, G., S. Fukai, M. Cooper, Rajatasereekul and JC. O'Toole (2002). Yield responses of rice (*Oryza sativa* L.) genotypes to drought under rainfed lowlands Selection of drought resistant genotypes. Field Crops Research.73:169-180.

Passioura, J.B., and J.F. Angus (2010). Improving productivity of crops in water-limited environments. In Advances in Agronomy; Academic Press: Cambridge, MA, USA, Volume 106, pp. 37–75.

Piper, CS. (1950). Soil and Plant Analysis, University of Adelaide Press, Adelaide.

Raman, A., Verulkar, S., Mandal, N., Variar, M., Shukla, V. D., Dwivedi, J. L. and Kumar, A. (2012). Drought yield index to select high yielding rice lines under different drought stress severities. Rice, 5(1), 1-12.

Rayee, R., Xuan, T. D., Khanh, T. D., Tran, H. D., & Kifayatullah, K. (2021). Efficacy of Irrigation Interval after Anthesis on Grain Quality, Alkali Digestion, and Gel Consistency of Rice. Agriculture, 11(4), 325.

Rosales, M.A., E. Ocampo, R. Rodriguez-Valentin, Y. Olvera-Carrillo, J. Acosta- Gallegos and A.A. Covarrubias (2012). Physiological analysis of common bean (*Phaseolus vulgaris* L.) cultivars uncovers characteristics related to terminal drought resistance. Plant Physiology and Biochemistry 56: 24-34.

Rosielle, A.A., and J. Hamblin (1981). Theoretical aspects of selection for yield instress and non-stress environment. Crop Sci. 21: 943-946.

Salehi-Lisar, S.Y. and H. Bakhshayeshan-Agdam (2020). Agronomic Crop Responses and Tolerance to Drought Stress. In Agronomic Crops; Springer: Berlin/Heidelberg, Germany; pp. 63–91.

Sedeek, S.E.M., R.A. El-Namaky, S.A.A. Hammoud and H. B. ELHabet (2012). Genetical studies on root system and yield and its components traits under water limit condition in rice (*Oryza sativa* l.) j. Agric. Chem. and Biotechn. Mansoura Univ., 3 (12): 447-460.

Sood, B.C. and E.A. Siddiq (1980). Studies in component quality attributes of Basmati Rice, (*Oryza sativa* L.). Z.Pflanzenzuchtg, 84, 294 – 301.

Tian Z, Q, Qian, Q. Liu, M. Yan, X. Liu, C. Yan, *et al.*(2009). Allelic diversities in rice starch biosynthesis lead to a diverse array of rice eating and cooking qualities. Proceedings of the National Academy of Sciences of the United States of America. 106(51):21760–5. PubMed Central PMCID: PMC2793318. doi: 10. 1073/pnas.0912396106 PMID: 20018713

Tiwari, P., D. Srivastava, A.S. Chauhan, Y. Indoliya, P.K. Singh, S. Tiwari and C.S.Nautiyal (2021). Root system architecture, physiological analysis and dynamic transcriptomics unravel the drought-responsive traits in rice genotypes. Ecotoxicology and Environmental Safety, 207, 111252.

Wang, C. H., X. M. Zheng, Q. Xu, X. P. Yuan, L. Huang, H. F. Zhou, X. H. Wei and S. Gee (2014). Genetic diversity and classification of *Oryza sativa* with emphasis on Chinese rice germplasm. Heredity, 112 (5): 489-496.

Williams, V.R., W.T. Wu, H.Y. Tsai and H.G. Bates (1958). Varietal differences in amylose content of rice starch. J. Agric. Food Chem, 6:47-48.

Wu, W., and Cheng, S. (2014). Root genetic research, an opportunity and challenge to rice improvement. Field Crops Research, 165:111-124.

Yang, X., B. Wang, L.Chen P. Li and C. Cao, (2019). The different influences of drought stress at the flowering stage on rice physiological traits, grain yield, and quality. Scientific Rreports, 9(1): 1-12.

تقييم سلالات مبشرة من الأرز تحت ظروف نقص المياه على أساس محصول الحبوب وصفات الجودة و دلائل الإجهاد المائي

فاطمة عوض حسين ، رغده محمد سكران و مصطفى ممدوح الشناوي

قسم بحوث الارز – معهد بحوث المحاصيل الحقلية- مركز البحوث الزراعية - مصر

أقيمت تجربتان حقليتان فى المزرعة البحثية بمحطة البحوث الرزاعية - سخا خلال موسمى الزراعه 2019 و 2020 و ذلك لتقييم 21 تركيب وراثى (18 سلالة مبشرة و 3 أصناف مصرية للمقارنة) لمحصول الحبوب ومكوناته و صفات الجوده تحت ظروف الزراعه العادية وظروف نقص المياه. مع استخدام ثمانية من دلائل الجفاف المعتمدة على محصول الحبوب تحت ظروف نقص المياه وتحت الظروف العاديه لتحديد التراكيب المتحملة من الحساسة لنقص المياه. اظهرت النتائج معنوية التباين الخاص بالسنوات ، البيئات ، التراكيب الوراثية والتفاعل بينهم لمعظم الصفات المدروسة. انخفضت كل القيم المتوسطة للصفات المدروسة تحت ظروف نقص المياه بالمقارنة بالظروف العادية . كان هناك اختلافات عالية المعنوية بين التراكيب الوراثية لكل الصفات المدروسة. كانت السلالات 15، 4 و 12 الأكثر تبكيرا بين باقي السلالات تحت الظروف العادية، بينما تحت ظروف نقص المياه كانت السلالة 11، الصنف جيزه 179 و سخا 107 الأكثر تبكيرا. كانت السلالات 1و9 الأفضل لقصر النبات بينما السلالات 13و 12 الاعلى لمتوسط قيم الطول . علاوة على ذلك ، فقد سجلت السلالة 2 افضل القيم لصفات جوده الحبوب فى كل البيئات المدروسة. السلالات 12، 14و 3 سجلت أعلى محصول حبوب و دليل تحمل الجفاف(STI)، بينما السلاله 6 اعطت أقل محصول للحبوب و دليل تحمل الجفاف(STI) . علاوة على ذلك ، فقد أظهرت النتائج أن دليل التوافق(HM) ودليل الحصول (YI) سجلا نفس المعدل للسلالة التى تعتبر متحملة لنقص المياه. وتبعا لذلك ، فهذه السلالات يمكن استخدامها فى برامج تربية الأرز لنقل جينات التحمل لنقص مياه الرى للاصناف المحلية.