Performance of Some Rice (*Oryza sativa* L.) Cultivars under Water Shortage and High Temperature Stress
(Prestasi Beberapa Kultivar Padi (*Oryza sativa* L.) akibat Kekurangan Air dan Tekanan Suhu Tinggi)

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ABSTRACT

Water shortage and heat are the most devastating abiotic stresses threating global food security. To understand the behavior of germplasm under both abiotic stresses, thirteen rice genotypes were selected for the study to make evaluation under water shortage and heat stress condition. The results showed that the year mean squares were significant and highly significant for all agronomical traits except, flag leaf area, number of tillers plant^{-1}, number of panicles plant^{-1}, 100 grain weight, grain yield plant^{-1} and harvest index indicated overall wide differences of weather during both years. Environments mean squares were found to be highly significant over all traits were used, indicating that all environments showed significant differences. The highly significant differences were observed among genotypes and G x E interaction for all characteristics except, panicle length. Concerning the cultivars performance across three environments, the cultivars Giza 178, Giza 179, Sakha 107, Hybrid 1, Hybrid 2 gave the best desirable values over normal, drought and heat stress conditions so, these cultivars are considered to play vital role in breeding program to enhancement for drought and heat stresses and have high yield potential. The highly significant and positive correlation were found among the all traits under investigation except with flag leaf angle, leaf rolling and sterility percentage. The results will further help to utilize the genotypes for further crop improvement breeding programs.

Keywords: Grain yield; G x E interaction; high temperature stress; rice; water shortage

ABSTRAK

Kekurangan air dan cuaca panas adalah tekanan abiotik yang paling dahsyat yang mengancam keselamatan makanan global. Untuk memahami tingkah laku germplasma di bawah kedua-dua tekanan abiotik ini, tiga belas genotip padi dipilih untuk kajian bagi penilaiannya dalam keadaan kekurangan air dan di bawah tekanan panas. Hasil kajian menunjukkan bahawa purata kuadrat tahunan adalah signifikan dan sangat signifikan untuk semua trait agronomi kecuali, luas daun, jumlah penanaman tanaman^{-1}, jumlah tanaman panicles^{-1}, berat 100 butir, tanaman hasil gandum^{-1} dan indeks penuaian menunjukkan secara keseluruhannya terdapat perbezaan besar bagi cuaca dua tahun tersebut. Purata kuadrat persekitaran didapati sangat signifikan daripada semua sifat yang digunakan, menunjukkan bahawa semua persekitaran menunjukkan perbezaan yang signifikan. Perbezaan yang sangat ketara diperhatikan antara genotip dan interaksi G x E untuk semua ciri kecuali panjang bulir. Mengenai prestasi kultivar pada tiga persekitaran, kultivar Giza 178, Giza 179, Sakha 107, Hibrid 1, Hibrid 2 memberikan nilai yang paling diingini berbanding keadaan tekanan biasa, kemarau dan tekanan panas, maka kultivar ini dianggap berperanan penting dalam program pembiakan untuk peningkatan ketahanan terhadap tekanan kemarau dan panas serta berpotensi bagi penghasilan yang tinggi. Hubungan yang sangat signifikan dan positif dilihat antara semua sifat yang dikaji kecuali dengan sudut bendera daun, gulungan daun dan peratusan steril. Hasil kajian ini akan membantu dalam penggunaan genotip bagi menambahbaik program pembiakan tanaman.

Kata kunci: Hasil bijirin; interaksi G x E; kekurangan air; nasi; tekanan suhu tinggi

Introduction

Rice (*Oryza sativa* L.) among the most widely consumed cereal, utilized as a staple diet for approximately half of the world's population (Fiaz et al. 2019). It is imperative to increase the rice production to meet the caloric demands of rapidly increasing population (Ali et al. 2020). The

cultivation of rice spread over the tropics, subtropics, semiarid tropics and temperate regions of the world (Anis et al. 2018). However, environmental stresses, such as water deficit and temperature rises are major factors limiting plant growth and productivity (Wattoo et al. 2018). Drought remains one of the oldest and most serious problems in agriculture (Riaz et al. 2018). Among the crops, rice as a submerged crop, is probably more susceptible to drought stress than most other plant species. Rice consumes almost 80% of the total irrigation freshwater resources (Ashraf 2010). The shortage of irrigation water is one of the major obstacles for increasing rice production not only in Egypt but also worldwide (AbdAllah et al. 2013).

Cultivated rice is considered an especially drought sensitive crop varies with stage of growth (Hussain et al. 2018). Most common, young seedling and reproductive stage are particularly sensitive to water deficit and heat conditions (Palanog et al. 2014). It has been established that drought stress is a very important limiting factor at the initial phase of plant growth and establishment (Kusaka et al. 2005). It affects both elongation and expansion growth (Shao et al. 2008). Drought stress during the reproductive stage can have large effects on yield and its components. If drought stress develops soon after panicle initiation, the number of spikelets developed may decreased resulting in reduction of grain number per panicle coupled with reduced grain weight and hence a reduction in grain yield (Pantuwan et al. 2002). For increasing productivity per unit area, some drought tolerant cultivars have been introduced from foreign countries. The yield components related to final grain yield are severely affected by stress conditions (Gana 2011). For example, panicle length, spikelet/panicle and grain yield are significantly reduced by drought and heat conditions.

Heat stress is one of the abiotic stresses that limit plant production and productivity. High temperature is detrimental to both the vegetative and reproductive stage of rice (Fahad et al. 2017). Plant resistance to heat can be further subdivided into escape, avoidance, and tolerance. The yield of dry season rice crop decreased by 15% for each 1 °C temperature increase in the growth season mean temperature (Peng et al. 2004). Hence, counter measures are to be made as quickly as possible to improve yield safety in crops (Ghazy 2012). High temperature stress during the vegetative and reproductive growth phases caused greater and almost equal reduction in biomass and grain yield (Fahad et al. 2016). Among yield components, the number of panicles/plant and grains/panicle showed greater sensitivity to high temperature stress. To increase the yield potential and in order to reduce the production gap, improving the varietal adaptability and quality improvement are needed.

One of the principal objectives of any rice breeding improvement program based on to develop, cultivars that contains both high yield potential and tolerance to a wide range of adverse environmental conditions such as shortage of irrigation water and high heat stress (Ghazy 2017).

The major objectives of the present investigations were: to determine performance of some rice genotypes under both drought and heat stress conditions, identification of the most important traits associated with drought and heat tolerance in rice genotypes, and identification of some rice genotypes tolerant to both drought and heat stress conditions for further utilized as donors for future rice breeding program.

MATERIALS AND METHODS

Thirteen rice cultivars representing a wide range of diverse genetic materials for several agronomic, physiological characters and drought and heat tolerance levels were selected for the study. The names, pedigree and origin of these genotypes are presented in (Table 1).

TABLE 1. Origin, pedigree and type of the thirteen rice cultivars

No.	Cultivar	Pedigree	Origin	Type
1	Giza 177	(Giza 171 / Yomji No. 1 // Pi No. 4)	Egypt	*Japonica*
2	Giza 178	(Giza 175 / Milyang 49)	Egypt	*Indica / Japonica*
3	Giza 182	(Giza 181 / IR39422-161-1-3 // Giza 181)	Egypt	*Indica*
4	Giza 179	(GZ 1368-S-5-4 / GZ 6296-12-1-2)	Egypt	*Indica / Japonica*
5	Sakha 101	(Giza 176 / Milyang 79)	Egypt	*Japonica*
6	Sakha 102	(GZ 4096-7-1 / Giza 177)	Egypt	*Japonica*
7	Sakha 103	(Giza 177 / Suweon 349)	Egypt	*Japonica*
8	Sakha 104	(GZ 4096-8-1 / GZ 4100-9-1)	Egypt	*Japonica*
9	Sakha 105	(GZ 5581-46-3 / GZ 4316-7-1-1)	Egypt	*Japonica*
10	Sakha 106	(Giza 177 / Hexi 30)	Egypt	*Japonica*
11	Sakha 107	(Giza 177 / BL1)	Egypt	*Japonica*
12	Hybrid 1	(IR 69625A / Giza 178R)	Egypt	*Indica*
13	Hybrid 2	(IR 69625A / Giza 179R)	Egypt	*Indica*

Each experiment was designed in a randomized complete block design (RCBD) with three replications. Field experiments were conducted at two locations, at Sakha Research Station, Rice Research and Training Center (RRTC), Kafr EL-Sheikh Governorate and the second at El-Wady El-Jaded Research Station, El-Kharga, El-Wady El-Jaded Governorate, western Desert, Agriculture Research Center (ARC), Egypt, during the two successive seasons 2017 and 2018. Irrigation, fertilizer application and other management measures followed normal field production practices. The average air temperature (°C) and relative humidity (%) over ten days of each month during 2017 and 2018 rice growing seasons at the two locations shown in (Table 2).

TABLE 2. The monthly maximum and minimum temperature (°C) as well as relative humidity (%) at Sakha Agricultural Research Station and El-Wady El-Jaded Agricultural Research Station during 2015 and 2016 rice seasons

Month	Date	Kafr EL-Sheikh Governorate						El-Wady El-Jaded Governorate						
		Air Temp. 2015		RH %	Air Temp. 2016		RH %	Air Temp. 2015		RH %	Air Temp. 2016		RH %
		Min	Max		Min	Max		Min	Max		Min	Max	
May	1-10	17.27	29.15	63.90	20.98	28.89	61.45	30.10	38.01	18.31	31.01	37.50	27.00
	11-20	18.38	30.32	61.90	24.36	32.53	53.55	30.20	37.80	19.22	30.03	38.10	26.10
	21-31	20.71	30.10	61.70	22.93	29.72	58.40	30.10	38.00	21.19	30.10	37.90	27.87
June	1-10	20.19	30.03	64.85	26.70	33.40	55.40	31.30	39.50	20.71	35.20	41.70	28.11
	11-20	22.05	31.45	66.25	25.50	33.10	60.15	31.01	39.00	23.12	34.30	42.02	25.76
	21-30	21.98	31.09	65.00	26.80	34.20	61.15	31.60	38.50	22.12	34.00	41.80	24.89
July	1-10	21.80	31.30	68.15	26.50	33.90	70.55	32.20	40.20	22.34	32.40	40.20	26.00
	11-20	22.00	33.40	73.00	25.90	33.70	68.60	32.09	40.01	23.16	32.10	40.10	25.21
	21-31	23.30	34.30	69.75	26.00	32.90	69.75	31.80	40.12	23.65	33.01	40.00	25.00
August	1-10	26.20	35.90	68.00	26.20	34.30	71.20	34.06	42.10	25.81	32.05	41.03	27.65
	11-20	25.50	35.50	66.60	26.30	33.00	69.95	34.02	42.05	26.23	32.09	40.30	32.65
	21-31	23.30	33.90	67.75	25.50	33.40	70.30	34.30	41.89	24.11	32.10	40.04	31.00
September	1-10	23.20	35.10	66.00	24.30	33.27	69.55	32.21	41.00	24.17	29.30	38.30	29.00
	11-20	23.00	34.20	66.60	24.93	33.42	66.95	32.00	40.20	23.19	29.02	38.20	39.76
	21-30	24.30	34.50	64.60	23.63	31.09	67.45	32.13	40.80	24.18	30.00	38.03	29.07

Note: Min=Minimum; Max=Maximum; RH=Relative humidity

STUDIED TRAITS

Data of the morphological, physiological, and productivity characters were recorded from five randomly selected plants in all cultivars in each replication to estimate characters plant height (cm), days to heading (day), chlorophyll content (mgds-1), flag leaf area (cm²), flag leaf angle, leaf rolling, relative water content percentage (RWC %), panicle length (cm), number of tillers plant-1, number of panicles plant-1, 100-grain weight (g), sterility percentage (%), grain yield plant-1 (g) and harvest index (%).

STATISTICAL ANALYSIS

The data were analyzed by using the ordinary analysis of variance to test the significance of differences among

the thirteen genotypes. Statistical analysis was performed per site as well as when pooled over two locations. The combined analysis was calculated over the two years and for the three treatments (non-stress, drought and heat stress). Before the computations of the combined experiments, it is necessary to determine whether the error variance of the tests of homogenous are available to test the homogeneity of variance. The test described by Bartlett (1937) is the best and preferred. All statistical analysis was performed using analysis of variance technique by means of "MSTAT" computer software package.

RESULTS AND DISCUSSION

The analysis of variance for studied agronomical traits were given in (Table 3). Year mean squares were significant and highly significant for all agronomical traits except, flag leaf area, number of tillers plant[-1], number of panicles plant[-1], 100 grain weight, grain yield plant[-1] and harvest index which would indicate overall wide differences among the weather of both years. Environments mean squares were found to be highly significant over all traits were used, indicating that all environments showed significant differences. The highly significant differences were observed among genotypes and G × E interaction for all characteristics except, panicle length. For G ×

E interaction, it is referring to the genotypes which tested had varied range differences with them and their performance changing from environment to other and ranked differently from normal to stresses conditions. G × Y interaction had highly significantly mean sum of squares for most trait except, plant height, days to heading, leaf rolling, relative water content, panicle length, number of tillers plant[-1], number of panicle plant[-1], 100 grain weight, sterility percentage and grain yield plant[-1] which reflects consideration variation between the two years of study.

The similar results were in agreement with previous findings reported by Abdel-Hafez et al. (2016). It could be considered that some genotypes surpassed the others if the mean squares of genotypes were highly significant than the interaction mean squares of genotypes with years and therefore, we can identify the most superior genotypes. Genotypes × environments × years mean squares were highly significant for most studied traits excepts plant height, chlorophyll content, relative water content, panicle length, number of tillers plant[-1], number of panicles plant[-1], grain yield and harvest index indicating that each genotypes performance in one environment observed different than other environment which confirmed the results reported by Abdel-Hafez et al. (2017) and Gaballah et al. (2016).

TABLE 3. Sum of squares for some rice agronomical traits of combined analysis data

Source of variance	Df	Plant height (cm)	Day to heading (day)	Chlorophyll content (mgds[-1])	Flag leaf area	Flag leaf angle	Leaf rolling	Relative water content	Panicle length(cm)	Number of tillers\ plant	Number of panicles\ Plant	100-grain weight (g)	Sterility percentage (%)	Grain yield\ plant (g)	Harvest index (%)
Year (Y)	1	175.37**	424.41Ns	124.08**	3.17Ns	87.38**	22.65Ns	6.00Ns	17.55*	101.38**	82.94*	0.012Ns	0.00Ns	2.23Ns	9.36Ns
Environments (E)	2	1853.01**	8034.32*	2391.78**	26.37**	294.92**	310.73*	11271.70**	563.75**	1503.79**	1731.07**	9.15**	11893.25**	11864.56**	13047.34**
E x Y	2	13.23Ns	317.47**	624.35**	10.55*	53.85**	5.22*	28.13Ns	0.24Ns	.564Ns	2.73Ns	0.02Ns	0.53Ns	7.15Ns	14.47Ns
Blocks (EY)	12	24.17	4.22	741.50	4.43	10.83	0.914	27.10	12.57	2.44	2.21	0.018	2.18	7.46	15.41
Genotypes (G)	12	481.93**	362.00*	74.84**	46.79**	3492.15**	10.64Ns	536.90**	16.94**	32.13*	32.87Ns	0.19Ns	144.67Ns	345.30**	247.72**
G Xy	12	11.72ns	56.69Ns	19.20*	13.56**	24.44**	1.00Ns	14.18Ns	2.42Ns	2.85**	2.30Ns	0.01Ns	13.82Ns	7.51Ns	4.35*
G x E	24	64.52**	105.67**	19.27**	29.03**	801.25 **	7.19**	112.55**	2.50Ns	11.00**	18.41**	0.09**	72.03**	85.54**	59.33**
G x Y x E	24	8.69Ns	43.819**	10.73Ns	15.97**	9.89**	1.34**	6.82Ns	0.97Ns	.84Ns	1.09Ns	0.01**	8.20Ns	4.47Ns	1.52Ns
Pooled Error	144	17.64	3.35	10.71	3.31	9.046	0.38	17.36	4.32	2.10	2.27	0.038	5.48	13.67	8.59
Total	233														

Note: *,**and ns are significant at 0.05and 0.01 levels of probability and no significant, respectively

PLANT HEIGHT (cm)

The most desirable mean values the rice plant height towards dwarfism were obtained from Sakha101, Giza179, Giza182 and Sakha103 cultivars (Table 4). In general, rice cultivars have tolerance by assessing the plant height redaction after stress conditions. These results are in agreement with the results obtained by Abdel-Hafez et al. (2013), and Ghazy (2017, 2012) plant height values were maximum with cultivars, Sakha 102 (112.20, 88.83, and 77.67), hybrid 1(111.80, 84.17, and 80.67), Sakha 107 (108.50, 85.67, and 74.83) and Sakha 106 (106.70, 89.67, and 76.33) in non-stress, drought, and heat stress conditions, respectively. However, the shortest genotypes were Sakha 101, Giza 182, Sakha 103, and Giza 179 under normal condition. The same trend was observed under the stress conditions. There was highly significant reduction in plant height under drought and heat stress conditions in the most of the studied rice cultivars. The interaction between cultivars and environments was highly significant for plant height in (Table 5). Therefore, the shortest mean values were reported by cultivar Sakha 101 (63.33 cm) under heat stress condition, while the tallest mean values observed from Sakha 102 was interacted with normal condition.

DAYS TO HEADING (DAY)

The genotypes Sakha 101 followed by hybrid 2 followed by Sakha 104 then Giza 178 and hybrid 1 needed the highest mean of days to heading while, the genotypes Giza 177, Sakha 103, and Sakha 102 behaved the earlier for heading and maturity dates. The mean values ranged between 86.27 and 87.23 days. These findings are in close agreement with those reported by Abdel-Hafez et al. (2016) and Ghazy (2017). In general, drought stress and heat stress conditions caused earlier heading concerning the interaction between cultivars and three environments. The desirable mean values of day earliness over three environments where found with Giza 177, Giza 182, Sakha102, Sakha 103, and hybrid 1, on the other hand the least days to heading were reported with Sakha 101 and hybrid 2 over three environments normal, drought and heat Table 5. In general, high temperature induced shortening of development phases, reduced light perception over the shortened life cycle and perturbation of the processes associated with carbon assimilation. These results were in agreement with those found by Xing et al. (2008) and Zacharias et al. (2010).

CHLOROPHYLL CONTENT (mgdS^{-1})

With respect to chlorophyll content which is reflection of the functional available for assimilation during the growth period, recorded the Sakha 101 cultivar recorded the great stave to chlorophyll content without significant different with Sakha 105, Giza 182, and Sakha 104 cultivars. The lowest values recorded by the cultivars Giza 179, Giza 177, hybrid 1, hybrid 2 and Sakha 103. There was highly significant reduction in chlorophyll content under drought and heat stress conditions in most of the studied rice cultivars. The highest chlorophyll content was recorded with Sakha 101(47.23, 35.03, and 33.07 mgds^{-1}) and Giza 182 (45.98, 33.93, and 31.33 mgds^{-1}) under non-stress, drought stress and heat stress, respectively (Table 5). The results show that heat stress decreased significantly the total chlorophyll content that measured by SPAD. These results were in agreement with reported by AbdAllah et al. (2010).

FLAG LEAF AREA (cm^2)

Flag leaf area is important functional factor for photosynthesis, as simulation and transpiration along rice plant life. Giza 178 cultivar recorded the greatest values of flag leaf area with significant differences with other cultivars as shown in (Table 4). Sakha 105, Sakha 104, Sakha 102, and Sakha 103, rice cultivars gave the lowest flag leaf area with mean values ranged from 18.50 to 17.83 cm^2. There was highly significant reduction in flag leaf area under drought and heat stress conditions in studied rice cultivars (Table 5). AbdAllah et al. (2010) and Ghazy (2017) reported that the reduction in leaf area is a common drought and heat avoidance mechanism. The decrease in rice growth as a result of decreasing available soil moisture content may be attributed to inhibition of growth resulting massive and irreversible expansion of cell produced by meristematic divisions. Moreover, water stress causes losses in tissues, which reduces turgor pressure in the cell, thereby, inhibiting enlargement and division of cells causing reduction of plant growth, stem elongation and leaf expansion. Giza 179, Giza 178, and Sakha 101 displayed the superior values for flag leaf area under normal condition however, the lowest values were found to be with Giza 177 and Sakha 102 under heat condition. This data was similar with those found by Abdel-Hafez et al. (2013).

TABLE 4. Genotypes performance for yield and associated trait of combined data over normal, water deficit and heat conditions

Cultivars	Plant height (cm)	Days to heading(day)	Chlorophyll content (mg\ds-1)	Flag leaf area(cm2)	Flag leaf angle	Leaf rolling	Relative water content (%)	Panicle Length (cm)	Number of tillers plant⁻¹	Numb of panicles plant⁻¹	100 -grain weight (gm)	Sterility percentage (%)	Grain yield plant⁻¹ (g)	Harvest index (%)
Giza 177	87.22 cd	87.23 fg	33.57 g	19.28 de	Narrow	3.52 de	69.36 d	19.16 cd	13.33 cde	11.46 d	2.38 ab	20.43 b	26.94 de	29.77 bcd
Giza 178	84.78 d	94.79 c	36.73 b-e	23.21 a	Narrow	2.44 f	80.88 a	19.99 a-d	16.54 a	13.88 ab	2.24 bc	12.79 g	36.60 ab	34.44 a
Giza 182	82.00 e	88.98 f	38.08 abc	21.09 bc	Narrow	4.46 ab	73.77 c	18.47 d	14.22 cd	11.78 d	2.41 ab	18.26 cd	28.22 de	11.77 e
Giza 179	80.00 e	87.55 fg	32.81 g	21.94 b	Narrow	3.06 e	77.16 b	21.47 a	15.44 b	14.22 ab	2.44 ab	15.20 f	33.62 c	30.61 bc
Sakha 101	77.17 f	100.05 a	39.44 a	20.63 c	Wide	4.95 a	78.16 b	21.12 ab	13.83 cde	12.38 cd	2.51 a	18.99 bcd	32.72 c	25.51 e
Sakha 102	92.89 a	86.78 g	37.59 abc	18.06 ef	Wide	4.42 ab	73.33 c	19.73 bcd	13.83 cde	12.44 cd	2.41 ab	19.50 bc	28.69 de	30.00 bcd
Sakha 103	81.22 e	86.27 g	34.37 efg	17.83 f	Wide	4.47 ab	73.55 c	18.93 cd	13.05 de	11.72 d	2.17 c	18.35 cd	23.89 f	25.38 e
Sakha 104	90.83 ab	95.50 c	37.07 a-d	18.26 ef	Narrow	3.81 cd	77.22 b	20.19 abc	16.11 ab	13.52 bc	2.48 a	16.14 ef	29.84 d	27.77 d
Sakha 105	87.72 c	90.72 e	38.57 ab	18.50 ef	Wide	4.06 bc	67.00 d	19.33 cd	12.55 ef	11.55 d	2.39 ab	17.58 cde	25.47 ef	28.27 cd
Sakha 106	90.89 ab	88.72 f	36.07 c-f	19.26 de	Wide	4.45 ab	68.11 d	20.13 abc	11.94 f	10.37 e	2.42 ab	17.22 de	27.84 de	31.72 b
Sakha 107	89.67 bc	92.55 d	35.98 c-f	19.17 de	Wide	2.66 f	76.44 bc	18.52 d	14.49 c	13.16 bc	2.54 a	12.03 g	34.84 bc	34.27 a
Hybrid 1	92.22 ab	94.00 c	34.11 fg	20.61 c	Wide	3.41 de	66.11 d	19.89 bcd	14.33 cd	14.88 a	2.31 abc	21.83 a	37.95 a	35.55 a
Hybrid 2	90.72 ab	97.50 b	35.12 d-g	20.06 cd	Wide	3.45 de	62.88 e	21.10 ab	13.38 cde	14.22 ab	2.42 abc	19.02 bcd	33.19 c	34.00 a
Mean	86.712	91.56	36.12	19.84	41.90	3.79	72.62	19.84	14.08	12.74	2.397	17.491	30.75	30.158
CV (%)	4.84	2.01	9.06	9.18	7.18	16.338487	5.74	10.48	10.30	11.83	8.14	13.38	12.02	9.71

Note: CV % = coefficient of variation

FLAG LEAF ANGLE

The narrow flag leaf angle was observed in five genotypes Giza 177, Giza 178, Giza 182, Sakha 104, and Giza 179 while, wide flag leaf angle was detected in eight genotypes Sakha 101, Sakha 102, Sakha 103, Sakha 105, Sakha 106, Sakha 107, hybrid 1 and hybrid 2. The lowest flag leaf angle was recorded with Giza 178 (25.33, 23.33 and 21.83) under non-stress, drought and heat stress, respectively. While, the highest flag leaf angle was recorded with Sakha 102 (52,00, 47.17, and 46.50) under non-stress, drought and heat stress, respectively; Sakha 107 (51.00 and 4583) under non-stress and drought stress, respectively, and Sakha 105 (82.00) under heat stress conditions (Table 4). The results were in agreement with those reported by AbdAllah et al. (2013).

LEAF ROLLING

Leaf rolling, is considered the first symptoms of the stress conditions reaction. Giza 178, Sakha 107, and Giza 179 recorded the lowest scores, which ranged from 2.44 to 2.66 on the other hand, the highest scores were displayed by Sakha 103, Sakha 101, Giza 182, Sakha 106, Sakha 105, and Sakha 102 ranged from 4.95 to 4.06. The most desirable genotypes were Giza 178 and Giza 179, where they had the lowest scores of leafs rolling under drought and heat stress conditions indicating these genotypes could be used as a tolerant donours for drought and heat stress conditions (Table 4). According to the results obtained, the unrolled genotypes had higher leaf water potential compared to rolled ones. The basic mechanism for reducing the impact of stress conditions is early stomatal closure at the beginning of the period of water deficit. Stomatal closure reduces water loss, but also reduce the gas exchange between the plant and ambient air. The reduction in CO_2 intake results in reduced photosynthetic rate. This mechanism is useful to improve plant survival under stress conditions, but it is also associated with yield reduction. These results are in agreement with the results obtained by Ghazy (2017).

RELATIVE WATER CONTENT PERCENTAGE (RWC %)

The highest mean values of relative water content with significant difference were obtained by Giza 178 rice cultivar (80.88%) the lowest mean value was recorded by Hybrid 2 variety, displayed (62.88%). There was significant reduction in relative water content under

drought and heat stress conditions in most of the studied rice genotypes. On the other hand, the cultivars Sakha 104, Giza 179, and Sakha 101, gave the maximum reduction value of relative water content in the drought and Giza 178, Sakha 101, Giza 179, and Sakha 107, in the heat stress conditions compared with their non-stress plants (control) (Table 4). There was significant reduction in relative water content (RWC) under both drought and heat stress in all the genotypes studied. Significant differences in relative water content (RWC) in most tolerant and susceptible cultivars have also been observed. The reduction in relative water content (RWC) under both water stress and heat stress conditions was explained by Zheng et al. (2005). According to the results obtained in Table 5, RWC in rice leaves decreased as the level of soil moisture decreased and this may be due relative low root ability to absorb water from the soil or decreased hydraulic conductivity of soil under drought and heat stress conditions, which is reflected in reduction of plant growth. These results also, were reported by Sibounheuang et al. (2006), and Zulkarnain et al. (2009). The most desirable mean values for relative water content were recorded with Giza 178 (92.44, 88.80, 79.01) and IET 1444 (94.57, 90.11, 81.65) under non-stress, drought stress and heat stress conditions, respectively.

PANICLE LENGTH (CM)

The highly significant difference for panicle length were shown by Giza 179, Sakha 101, Hybrid 2, Sakha 104, and Sakha 106 cultivars. The highest values of panicle length ranged from 21.47 to 20.13 cm. While the cultivars Giza 182, Sakha 107, Giza 177, Sakha 105, Sakha 102, hybrid 1, and Giza 178 produced the lowest mean values ranged from (18.47 to 19.99 cm). The highest mean values of panicle length were obtained by the cultivar hybrid 2, Giza 179, Sakha 101, Sakha 104, Sakha 102, hybrid 1, and Sakha 106 under normal conditions and with significant differences between them under drought stress conditions. Moreover, the cultivar Giza 182, Sakha 107, Sakha 105, and Sakha 103 recorded the maximum reduction in panicle length compared with the control plants. There was highly significant reduction in panicle length under drought and heat stress conditions in most of the studied rice cultivars. Giza 178, Giza 179, Sakha 105, hybrid 2, Sakha 101, and Sakha 106 gave the highest panicle length under heat stress conditions, their values were 17.95, 17.77, 17.63, 17.58, 17.55, 17.17 cm, respectively. The most desirable genotypes for panicle length at the three environments were Giza 179, Hybrid 2, Sakha 101 Sakha 104, and Sakha 102 (Table 4). These results were in agreement with those found by Zakaria et al. (2002).

NUMBER OF TILLERS PLANT^{-1}

The cultivars, Giza 178, Giza 179, and Sakha 104 gave the highest mean values of number of tillers plant^{-1} and the values ranged from 15.44 to 16.54 tillers plant^{-1} compared with the other cultivars. Meanwhile, the genotypes Sakha 106, Sakha 105 and Sakha 103 gave the lowest mean values and ranged from 11.94 to 13.83 tillers plant^{-1}. Data presented in Table 5, clearly shows that during the occurrence of water and heat stress, number of tillers plant^{-1} decreased considerably. There was highly significant reduction in number of tillers plant^{-1} under drought and heat stress conditions in the most of the studied rice cultivars. The maximum reduction was recorded by Sakha 104, Sakha 102, Giza 182, and Sakha 107, in the drought stress conditions and Sakha 104, Giza 178, and Giza 179, in the heat stress conditions compared with control plants. The highest number of tillers plant^{-1} was recorded by Giza 178 (21.14, 14.50, and 14.00 tillers plant^{-1}) and Sakha 104 (20.83, 15.33, and 12.16 tillers plant^{-1}) under control, drought and heat stress conditions, respectively, these findings are in close agreement with those reported by Ghazy (2012).

NUMBER OF PANICLES PLANT^{-1}

Concerning number of panicles plant^{-1} the cultivars hybrid 1, hybrid 2, and Giza 179 gave the highest mean values that ranged from 14.22 to 14.88 panicles. While, the genotypes Sakha 106, Giza 177, Sakha 105, Sakha 103, and Giza 182 gave the lowest mean values and ranged from 10.37 to 11.78 panicles. Significant reduction in number of panicles plant^{-1} was observed under drought and heat stress conditions compared with the non-stress (control) in most of the studied rice cultivars. In Table 5, the most desirable number of panicles plant^{-1} was recorded by hybrid 1 and hybrid 2 in the two stress conditions and their control (normal) (Table 4). Number of panicles plant^{-1} was highest for hybrid 1 (23.66, 12.50, and 8.50 panicles plant^{-1}) and hybrid 2 (22.50, 12.00, and 8.16 panicles plant^{-1}) in non-stress, drought stress and heat stress conditions, respectively. The results were in agreement with those reported by Singh et al. (2010).

100-GRAIN WEIGHT (g)

The cultivars Sakha 107, Sakha 101, Giza 179, Sakha 104, Sakha 106, and hybrid 2 gave the highest mean values which ranged from 2.42 to 2.54 g. The genotypes Sakha 103, Giza 178, hybrid 1, Giza 177, and Sakha 105 gave the lowest 100-grain weight with regard to 100-grain weight, the cultivars Sakha 102, Giza 177, Sakha 104, Sakha 101, and Sakha 105 gave the highest mean values under normal

conditions compared with the other cultivars. The most desirable mean value towards this trait were recorded by the same cultivars under drought stress conditions. There was highly significant reduction in 100-grain weight under heat stress conditions in most of the studied rice cultivars (Table 5). The highest 100-grain weight were recorded with Sakha 107 (2.71 and 2.75 g), hybrid 2 (2.62 and 2.63 g) and Sakha 104 (2.82 and 2.61 g) under non-stress and drought stress, respectively, and for Sakha 107 (2.16 g) under heat stress conditions. The results were in agreement with those reported by Abdel-Hafez et al. (2017) and Ghazy (2017).

STERILITY PERCENTAGE (%)

The most desirable mean values of sterility % were observed by the genotypes Sakha 107, and Giza 178 where the values ranged from 12.03 to 12.79%. The highest mean values were detected by the genotypes Giza 177, hybrid 1, and Sakha 102 were ranged from 19.50 to 21.83%. The data in Table 5 showed that the cultivars hybrid 1, Giza 177, Giza 182, and Sakha 101 had the highest sterility percentage at drought and heat stress conditions, while, the lowest sterility percentage was recorded by the cultivars Giza 179, Sakha 107, and Giza 178. The same finding was reported by Abdel-Hafez et al. (2013) and Ghazy (2017). The previous studies have shown that the spikelets at anthesis that are exposed to temperatures > 35 °C for about 5 days during flowering period are sterile caused by poor anther dehiscence and low pollen productivity and hence low number of germinating pollen grains on the stigma (Prasad et al. 2006). From the results obtained it has been suggested that *Indicia* spp. are more tolerant to higher temperatures than *Japonica* spp. The most desirable mean values for sterility percentage were recorded with Giza 178 (11.54 and 19.47 %) and IET 1444 (12.08 and 19.31 %) under drought stress and heat stress conditions, respectively.

GRAIN YIELD PLANT[-1] (g)

The grain yield plant[-1], as shown in Table 4, the most desirable mean values were detected by the genotype's hybrid 1, Giza 178, Giza 179, Sakha 107, and hybrid 2 where yield plant[-1] ranged from 33.19 to 37.95 g. The lowest values were observed by the cultivars Sakha 103, Sakha 105, and Giza 177, respectively. It is worthy to notice that the genotypes hybrid 1, hybrid 2, Giza 179, Sakha 101, and Giza 178 were found to have the most desirable mean values for yield and its components under the three environments. The highest grain yield plant[-1] were recorded with hybrid 1 (58.16, 30.35, and 25.33 g), hybrid 2 (55.98, 23.33, and 20.28 g) and Giza 179 (46.00, 29.86,

and 25.02 g) in non-stress, drought stress and heat stress conditions, respectively. The results were in agreement with those reported by Abdel-Hafez et al. (2017).

HARVEST INDEX (%)

The harvest index percentage for genotypes hybrid 2, Sakha 106, Sakha 107, and Giza 179 gave the highest mean values over environments which ranged from 31.72 to 35.55 % compared with the other, while cultivars Giza 182, Sakha 101, and Sakha 103 gave the lowest mean values which ranged from 11.77 to 25.51 %. Harvest index values were highest for Sakha 107 (34.67 and 25.16 %) under drought stress and heat stress conditions and hybrid 1, hybrid 2, Giza 178, Sakha 101, and Sakha 104 (50.83, 47.16, 46.67, 46.50, and 45.67 %) under non-stress conditions respectively (Table 4). These results were in agreement with those reported by Ghazy (2012).

CORRELATION COEFFICIENT

The correlation coefficient among all studied traits over normal, drought, and heat stress conditions were calculated. The plant height was highly significant correlated and positive with harvest index, while the highly significant and negative correlation were found with flag leaf area, leaf rolling and relative water content. Day to heading were highly significant correlated and positive with 100-grain weight, while the highly significant correlation and negative observed were found with grain yield plant[-1], chlorophyll content, 100-grain weight. Chlorophyll content were highly significant correlated and positive with relative water content while the highly significant correlation and negative observed were with number of tiller plant[-1], 100-grain weight and grain yield plant[-1]. For flag leaf area were highly significant correlated and positive with grain yield plant[-1]. Moreover, the highly significant and negative correlation were reported with number of tiller plant[-1], flag leaf angle, and leaf rolling. Regarding flag leaf angle were highly significant correlated and positive with number of tillers plant[-1], while the highly significant and negative correlation were fund with leaf rolling, number of panicle plant[-1] and grain yield plant[-1]. Leaf rolling were highly significant correlated and positive with harvest index, therefore, the highly significant and negative correlation were found with number of panicle plant[-1], grain yield plant[-1], and number of tiller plant[-1]. Concerning relative water content were highly significant correlated and positive with number of tillers plant[-1], while the highly significant and correlation were observed with sterility percentage. These results were in agreement with those reported by Xing et al. (2008). Panicle length were highly significant correlated and positive with grain yield plant[-1],

otherwise the highly significant correlation was reported with number of panicles plant[-1], harvest index and number of tiller plant[-1], and the number of tillers were highly significant correlated and positive with number of panicle plant[-1], while the highly significant correlation and negative was found with grain yield plant[-1], and sterility percentage. Number of panicle plant[-1] were highly significant correlated and positive with grain yield plant[-1], whereas the highly significant negative correlation was resulted with harvest index. For 100 grain weight was highly significant correlated and positive with grain yield plant[-1], while the highly significant and negative correlation were found with sterility percentage. Sterility percentage were highly significant correlated and negative with grain yield plant[-1] and grain yield were highly significant correlated and positive with harvest index (Table 6). These results were in agreement with those reported by Gaballah et al. (2016).

TABLE 5. Interaction between cultivars and environments for yield and related traits over two years

Cultivars	Plant height (cm)			Day to heading(day)			Chlorophyll content (mg\ds-1)			Flag leaf area (cm2)			Flag leaf angle		
	NS	DS	HS	NS	DS	HS	NS	DS	HS	NS	DS	HS	NS	DS	HS
Giza 177	102.8 cde	85.50 ijk	73.33mno	94.66 def	92.19 e-h	74.83 no	39.30 cd	30.55 j-m	27.87 j-m	26.83bcd	19.17 jk	11.83 o	30.83 k	25.83 lm	25.33 lm
Giza 178	101.7 cde	83.67 jk	69.00 op	104.77 ab	100.61 c	79.01 m	44.83 ab	32.93 f-m	30.43 f-m	29.00 ab	23.17 fgh	17.45 kl	25.33 lm	23.33 lm	21.83 n
Giza 182	96.00 fg	84.50 ijk	65.50 pq	94.02 def	97.00 d	75.93 no	45.98 a	33.93 e-l	31.33 e-k	28.17 bc	22.77 gh	12.33 o	28.17 kl	24.83 lmn	26.50 lm
Giza 179	99.83 def	75.33 mn	64.83 pq	92.00 e-h	92.83 efg	77.83 mn	36.98 cdef	28.53 m	25.92 f-m	30.50 a	20.17 ij	15.17 lm	27.67 kl	36.50 j	26.50 lm
Sakha 101	93.50 gh	74.67 mn	63.33 q	107.50 a	105.33 ab	87.33 ij	47.23 a	35.03 d-j	33.07 d-i	28.33abc	19.00 jk	14.57 mn	51.33 ef	42.83 hi	69.17 b
Sakha 102	112.2 a	88.83 hij	77.67 lm	95.67 de	92.00 e-h	72.67 o	44.62 ab	34.07 e-l	29.08 e-l	24.83 d-g	17.50 kl	11.83 o	52.00 def	47.17 g	46.50 gh
Sakha 103	98.83 ef	74.83 mn	70.00 nop	92.50 e-h	91.33 fgh	75.00 no	38.38 cde	31.87 h-m	26.87 f-m	24.33 e-h	17.17 kl	12.00 o	52.83 def	43.67 ghi	55.33 d
Sakha 104	102.5 cde	95.00 fg	75.00 mn	102.83 bc	103.00 bc	80.67 lm	44.13 ab	33.08 f-m	30.98 e-l	25.33 def	17.44 kl	12.00 o	37.17 j	30.50 k	25.33 lmn
Sakha 105	102.7 cde	86.83 ij	73.67mno	95.33 def	91.67 e-h	85.16 jk	43.95 ab	35.10 d-ij	25.67 c-g	25.33 def	17.50 kl	12.67 no	45.00 ghi	58.83 b	82.00 a
Sakha 106	106.7 bc	89.67 hi	76.33 lm	94.50 def	89.00 hi	82.67 ki	43.60 ab	32.10 g-m	28.50 f-m	24.33 e-h	17.33 kl	16.12 lm	51.67 def	55.17 de	81.00 a
Sakha 107	108.5 ab	85.67 ijk	74.83 mn	93.16 ef	95.33 def	89.16 ghi	43.63 ab	31.80 h-m	28.50 f-m	22.00 hi	16.67klm	18.83 jk	51.00 f	45.83 ghi	27.50 kl
Hybrid 1	111.8 a	84.17 ijk	80.67 kl	105.16 ab	103.33 bc	73.50 o	40.63 bc	30.20 klm	30.50 i-m	23.83 fgh	19.17 jk	18.83 jk	26.67 lm	42.17 i	63.83 c
Hybrid 2	105.0 bcd	86.17 ijk	81.00 kl	104.67 ab	102.83 bc	85.00 jk	39.32 cd	36.38 c-h	29.67 lm	26.50cde	17.33 kl	16.33 lm	52.83 def	37.00 j	22.83 mn
X	95.027	84.21	72.70	98.21	96.65	79.90	42.50	32.73	29.10	26.10	18.79	13.68	40.96	39.51	44.12

Cultivars	Flag leaf angle			Leaf rolling			Relative water content			Panicle length (cm)			Number of tillers plant-1		
	NS	DS	HS	NS	DS	HS	NS	DS	HS	NS	DS	HS	NS	DS	HS
Giza 177	30.83 k	25.83 lm	25.33 lm	1.25 q	6.833abc	2.50 nop	82.50 ab	70.33 cd	55.25 h	21.92 a-e	18.95 f-k	16.62 jk	20.50 a	10.50 j-m	9.00 m
Giza 178	25.33 lm	23.33 lm	21.83 n	1.17 q	2.83 mno	3.33 l-o	85.16 ab	80.67 ab	76.83 b	21.95 a-e	20.07 c-i	17.95 h-k	21.14 a	14.50 ghi	14.00 fgh
Giza 182	28.17 kl	24.83 lmn	26.50 lm	1.73 pq	5.83 cf	5.83 c-f	84.33 ab	80.83 ab	56.16 gh	20.23 c-i	18.67 g-k	16.51 jk	18.16 bcd	14.33 fgh	10.16 jm
Giza 179	27.67 kl	36.50 j	26.50 lm	1.21 q	3.13 mno	4.83 f-i	86.00 a	81.33 ab	64.16 def	24.67 a	21.98 a-d	17.77 ijk	21.00 a	13.33 ghi	12.00 hk
Sakha 101	51.33 ef	42.83 hi	69.17 b	1.35 q	7.33 a	6.16 b-e	86.00 a	81.16 ab	67.33 cde	23.91 ab	21.90 a-e	17.55 ijk	19.67 abc	12.16 h-k	9.67 klm
Sakha 102	52.00 def	47.17 g	46.50 gh	1.26 q	6.50 a-d	5.50 d-h	83.67 ab	80.50 ab	55.83 gh	22.85 ab	19.42 d-j	16.92 jk	18.83 a-d	14.67 fgh	8.00 m
Sakha 103	52.83 def	43.67 ghi	55.33 d	1.23 q	7.04 ab	5.13 e-i	82.00 ab	76.67 b	62.00 efg	21.33 b-g	18.90 f-k	16.55 jk	17.50 cde	12.33 hij	9.33 lm
Sakha 104	37.17 j	30.50 k	25.33 lmn	2.26 opq	4.66 g-j	4.50 h-k	86.67 a	82.66 ab	62.33 efg	22.97 ab	20.69 c-h	16.91 jk	20.83 a	15.33 efg	12.16 hk
Sakha 105	45.00 ghi	58.83 b	82.00 a	1.20 q	6.50 a-d	4.50 h-k	80.83 ab	65.83 cde	54.33 h	21.27 b-g	19.09 e-k	17.63 ijk	16.50 def	13.16 ghi	8.00 m
Sakha 106	51.67 def	55.17 de	81.00 a	1.18 q	6.50 a-d	5.66 d-g	79.16 ab	70.83 c	54.33 h	22.60 ab	20.62 c-h	17.17 jk	17.00 de	10.16 jm	8.67 m
Sakha 107	51.00 f	45.83 ghi	27.50 kl	1.16 q	3.16 mno	3.67 jm	86.50 a	79.16 ab	63.66 def	20.93 c-g	18.47 g-k	16.17 jk	17.50 cde	14.33 fgh	11.65 i-l
Hybrid 1	26.67 lm	42.17 i	63.83 c	2.50 nop	4.25 i-l	3.50 k-n	81.66 ab	63.50 def	53.16 h	22.67 ab	20.67 c-h	16.33 jk	19.83 b	14.00 ghi	9.16 m
Hybrid 2	52.83 def	37.00 j	22.83 mn	2.33 0pq	4.53 h-k	3.50 k-n	80.67 ab	57.33 fgh	50.66 h	24.06 ab	21.67 b-f	17.58 ijk	16.67 def	13.00 ghi	10.50 j-m
X	40.96	39.51	44.12	1.52	5.07	4.5	83.47	69.13	59.69	22.41	20.08	17.05	18.85	13.17	10.21

Note: NS= Non- stress   DS= Drought stress   HS= Heat stress

TABLE 6. The correlation coefficient among the traits studied over normal, drought and heat condition

	Plant height (cm)	Day to heading (day)	Chlorophyll content (mgds⁻¹)	Flag leaf area (cm²)	Flag leaf angle	Leaf rolling	Relative water content	Panicle length (cm)	Number of tillers plant⁻¹	Numb of panicles plant⁻¹	100-grain weight (g)	Sterility percentage (%)	Grain yield plant⁻¹ (g)	Harvest index (%)
Plant height (cm)	1													
Day to heading (day)	-0.03	1												
Chlorophyll content (mgds⁻¹)	-0.02	0.56**	1											
Flag leaf area (cm²)	-0.42**	0.31**	0.25**	1										
Flag leaf angle	0.13	-0.03	-0.14	-0.53**	1									
Leaf rolling	-0.27**	-0.23**	0.13	-0.53**	0.52**	1								
Relative water content	-0.50**	0.16	0.53**	0.38**	-0.32**	-0.06	1							
Panicle length (cm)	0.16	0.47**	0.13	0.46**	-0.16	-0.61**	0.26**	1						
Number of tillers plant-1	-0.07	0.46**	0.38**	0.57**	-0.62**	-0.66**	0.56**	0.60**	1					
Numb of panicles plant-1	0.12	0.48**	0.04	0.47**	-0.47**	-0.77**	0.15	0.70**	0.83**	1				
100 -grain weight (g)	0.14	0.64**	0.38**	0.17	0.10	-0.18	0.03	0.46**	0.36**	0.40**	1			
Sterility percentage (%)	0.04	-0.27**	-0.24**	-0.44**	0.32**	0.62**	-0.51**	-0.44**	-0.57**	-0.33**	-0.41**	1		
Grain yield plant-1 (g)	0.09	0.59**	0.32**	0.68**	-0.35**	-0.73	0.28	0.82**	0.71**	0.82**	0.54**	-0.49**	1	
Harvest index (%)	0.63**	0.15	-0.12	0.25**	-0.14	-0.79	-0.25	0.63**	0.26**	0.53**	0.21	-0.36**	0.66**	1

Note: *,** significant and high significant at 0.05 and 0.01 probability, respectively

CONCLUSION

The abiotic stresses i.e. drought and heat are the most devastating factor affecting the food security around the globe. The available water resources are decreasing with the passage of time and there is need of sustainable approaches to tackle this problem. The studied rice cultivars displayed different abilities to resist drought under two different locations. Based on the present study, the rice cultivars Giza 178, Giza 179, Sakha 107, Hybrid 1, Hybrid 2 gave the best desirable values over normal, drought and heat stress so, these cultivars are considered to play vital role in breeding program to with stand against drought and heat stresses and have high yield potential.

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