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Evaluation of some Rice Genotypes (*Oryza sativa* L.) Under Normal and Heat Stress Conditions

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ABSTRACT

The aim of the current study was to evaluate 25 rice genotypes under normal at Sakha, Kafr El-Sheikh, Egypt and under heat stress conditions at New Valley, Egypt during two rice growing seasons of 2017 and 2018. Data were collected on eight traits i.e., flag leaf area, flag leaf angle, plant height, panicle length, panicles plant^{-1}, 1000-grain weight, fertility percentage and grain yield plant^{-1}. High amount of genetic variation was found among the studied genotypes under normal and heat stress conditions. All studied genotypes were negatively affected by high temperature. The most affected traits by heat stress were fertility percentage, grain yield plant^{-1}, flag leaf area and panicles plant^{-1} with average reductions of 73.59, 64.22, 42.46 and 41.31%, respectively. Correlation and path coefficient analysis showed that number of panicles plant^{-1} and fertility percentage were good indicators for grain yield under heat stress condition. Based on the HSI values of grain yield plant^{-1} and fertility percentage, both genotypes N22 and Giza178 could be identified as heat tolerant (HSI value was ≤0.5 for both traits). Based on the results of PCA analysis, the most desirable genotypes under heat stress were Giza178, N22, Bala, Dular, WAB56-104, Sakha104 and Egyptian Yasmin. According to the current investigation, it could be concluded that those eight genotypes could be used in breeding programs as donors for developing high yielding heat tolerant promising lines. In addition, Egyptian rice varieties; Giza178, Sakha104 and Egyptian Yasmin are suitable for cultivating under both normal and heat stress conditions in Egypt.

Keywords: Rice, heat stress, correlation coefficient, Path analysis, HSI and PCA.

INTRODUCTION

Rice *(Oryza sativa* L.*)* is one of the most important crops that provide food for nearly half of the world population. Egypt is one of the few countries, which produces high yielding rice varieties and succeeded to achieve one of the highest productivity per unit area through the last decade. Rice is the second largest consumed cereal crop after wheat and provides about 80% of the food calories requirements of more than half of the world's population (FAO, 2008). As a summer crop, rice is cultivated in many regions where relatively high temperatures occur during its growth cycle.

Heat stress is an important constraint for rice production and affects agricultural crops more frequently and more severely. The increase in the global average temperature of 1 °C reduced the average yield by 4.1 to 10.0% in different cereals (Wang *et al.*, 2012) and by 3.2 ± 3.7% in rice (Zhao *et al.*, 2017). Heat tolerance is defined as the ability of the plant to grow and produce economic yield under high temperature stress. It is a highly specific trait, where closely related species, even different organs and tissues of the same plant, may vary significantly in this respect (Hasanuzzaman *et al.*, 2013). The capacity of crop plants to overcome temperature stress has been interpreted in terms of avoidance, escape, or tolerance (Osmond *et al.*, 1987).

Heat stress exerts negative impacts during seed germination though the ranges of temperatures vary largely on crop species (Johkan *et al.*, 2011). In wheat, anther dehiscence and pollen fertility rate was significantly reduced by heat stress treatment (>33 °C) at heading stage leading to reduction in fertilization and subsequent spikelet fertility (Hurkman *et al.*, 2009 and Ahamed *et al.*, 2010). Rice is extremely sensitive to heat stress (more than 35ºC), especially during the gametogenesis (Jagadish *et al.*, 2013) and flowering stages (Prasad *et al.*, 2006 and Jagadish *et al.*, 2007). Physiological processes are negatively affected by heat stress, as well as reduce photosynthesis and increases respiration (Prasad *et al.*, 2017). In addition, harmful effects of heat stress appear on the plant root system resulting in disruption in pollination, flowering, root development, and root growth stages (Sehgal *et al.*, 2017 and Cho, 2018). According to Shi *et al.* (2013), high night temperature under field conditions adversely affects grain quality through a reduced non-structural carbohydrate pool size. Lyman *et al.* (2013) found that increasing heat stress during early grain development causes less rice production and lower grain quality, leading to a significant reduction in economic benefits.

The discovery of the physiological and genetic bases of heat stress responses provides new tools to study the heat tolerance of the cultivated crops by using natural genetic variation (Janni *et al.*, 2020). The aim of the current investigation was to evaluate the performance of 25 Egyptian and exotic rice genotypes under normal and heat stress conditions and to identify the most tolerable genotypes under both conditions.

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MATERIALS AND METHODS

Twenty five rice genotypes, including nine Egyptian cultivars, seven exotic genotypes and nine Egyptian rice promising lines were selected from the genetic stock of Rice Research and Training Center (RRTC), Egypt for the current study. The name, type and pedigree of the studied genotypes are listed in Table 1. This investigation was carried out during two rice growing seasons of 2017 and 2018 under two locations, Sakha Research Station at the Northern part of the Nile delta (as normal condition) and the Experimental Farm of New Valley Research Station, at the Southern part of Egypt (as heat stress condition). The monthly maximum and minimum temperatures during the two rice growing seasons in each location are shown in Table 2. Seeds of the studied genotypes were sown in the nursery on May 1st. After 30 days from sowing, seedlings of each genotype were individually transplanted in the permanent field in seven rows. Each row measured five meters long with 20 cm between rows comprising 25 hills per row. The studied materials were replicated three times in a Randomized Complete Block Design (RCBD) according to Snedecor and Cochran (1967). All agricultural practices were done as recommended. Data were collected from ten randomly selected plants from each replicate. The studied traits included grain yield plant^{-1} (calculated by weighting the grain yield of individual plant, then adjusted to 14 % moisture content), plant height (length of the main culm in centimeters measured from soil surface to the tip of the main panicle of plant at maturity), panicles plant^{-1} (determined by counting the number of panicles per individual plant), panicle length (length of the main panicle in centimeters measured from panicle base up to apiculus of the upper most spikelets of the panicle), 1000-grain weight (recorded by weighing 1000-random filled grains in grams) and spikelets fertility percentage (calculated as ratio of the number of fertile spikelets to the total number of spikelets per panicle). Flag leaf angle (the angle between the flag leaf and the stem at flowering stage (according to Zadoks *et al.*, 1974), flag leaf area in cm^2 (measured with a Licor area meter at flowering on main tillers).

Table 1. Name, pedigree, type and origin of the 25 studied rice genotypes

No.	Genotypes	Pedigree	Type	Origin
1	Sakha101	Giza176 / Milyang79	Japonica	Egypt
2	Sakha102	GZ4098-7-1 / Giza177	Japonica	Egypt
3	Sakha103	Giza177 / Suweon 349	Japonica	Egypt
4	Sakha104	GZ4096-8-1 / GZ4100-9-1	Japonica	Egypt
5	Sakha105	GZ5581-46-3 / GZ4316-7-1-1	Japonica	Egypt
6	Sakha106	Giza177 / Hexi30	Japonica	Egypt
7	Giza177	Giza171 / Yomjo No.1 / / PiNo.4	Japonica	Egypt
8	Giza178	Giza175 / Milyang49	Indica/Japonica	Egypt
9	Egyptian Yasmin	IR262-43-8-11 x KDML 105	Indica	Egypt
10	GZ9399-4-1-1-3-2-2	Giza178/GZ6296	Indica/Japonica	Egypt
11	GZ9399-4-1-1-2-1-2	Giza178/GZ6296	Indica/Japonica	Egypt
12	GZ10101-5-1-1-1	Sakha103/IRAT385	Japonica	Egypt
13	GZ10147-1-2-1-1	GZ6214-4-1-1-1/IRI385	Japonica	Egypt
14	GZ10154-3-1-1-1	Sakha101/Sakha105	Japonica	Egypt
15	GZ10264-9-2-1-2	Sakha101/SR22746-68-2-3-4-2-4	Japonica	Egypt
16	GZ10305-24-1-2-3	GZ7768-10-1-5-2/Milyang95	Japonica	Egypt
17	GZ10333-9-1-1-3	SKC23822/Yunlen4	Japonica	Egypt
18	GZ10364-22-3-1-2	BY-GC-3/Milyang95	Japonica	Egypt
19	CO39	Cul.240/Kannagi	Indica	India
20	IR50	IR2153-14-1-6-2/IR28//IR36	Indica	Philippine
21	(Nagina22) N22	Selection from landrace Rajbhog	Aus Indica	India
22	Bala	N22/TN-1	Indica	India
23	Dular	Local selection landrace	Aus Indica	India
24	WAB56-104	IDSA6/IAC164	Japonica	Africa Rice
25	IR64	IR2061-465-1-5-5/IR657-33-2-1 (GP-15/TN-1)	Indica	Philippine

Table 2. The monthly maximum and minimum temperature (˚C) as well as relative humidity (%) at Sakha Agricultural Research Station and New Valley Agricultural Research Station.

Month	Date	Kafr EL-Sheikh Governorate						New Valley Governorate					
		Air Temp. 2017		RH %	Air Temp. 2018		RH %	Air Temp. 2017		RH %	Air Temp. 2018		RH %
		Max	Min		Max	Min		Max	Min		Max	Min	
	1-10	30.7	25.4	62.5	30.6	23.3	59.2	37.7	20.0	24	41.0	21.8	24
May	11-20	30.3	26.3	61.2	29.7	23.7	59.9	40.3	25.2	23	39.3	22.7	24
	21-31	30.9	25.8	61.3	33.2	24.3	60.2	43.5	24.2	24	46.6	29.4	22
	1-10	32.6	27.7	62.6	32.5	24.7	61.1	41.2	27.2	24	39.9	24.3	23
June	11-20	31.9	27.8	67.9	32.7	25.6	62.4	41.6	25.2	25	43.5	25.6	21
	21-30	32.9	28.8	66.8	32.6	25.5	61.9	40.0	25.9	27	41.8	27.5	25
	1-10	34.7	29.4	70.9	33.9	25.7	66.7	42.0	26/0	25	41.7	25.0	25
July	11-20	34.5	29.1	69.0	34.2	25.1	66.9	43.0	26.4	24	40.2	24.7	23
	21-31	33.4	28.4	72.4	34.5	25.4	66.9	45.6	28.5	28	47.1	26.5	29
	1-10	34.2	28.8	72.0	34.3	25.5	67.8	41.8	27.1	29	42.1	26.7	28
August	11-20	33.9	29.2	71.5	33.9	25.2	66.2	42.1	25.2	30	41.6	27.2	29
	21-31	33.6	27.4	68.4	33.5	25.0	66.8	43.5	28.8	28	44.1	29.9	29
	1-10	33.1	25.9	68.4	33.3	24.2	66.2	38.0	22.9	35	39.8	26.7	35
September	11-20	33.6	26.0	68.3	32.6	24.0	62.7	39.9	23.8	31	37.2	23.2	32
	21-30	30.7	25.8	68.4	32.5	22.4	68.2	37.4	23.8	32	38.9	25.0	33

Heat susceptible index (HSI) was calculated for all studied traits for each genotype according to Fisher and Maurer, (1978) as follows:

$$HSI = (1 - (x_s/x_p))/((1 - (X_s/X_p))$$

Where; x_s and x_p are the mean values of the trait for each genotype under heat stress and normal condition, respectively; X_s and X_p are the mean values of trait over all genotypes under heat stress and normal condition, respectively. Based on the HSI value, the genotypes were ranked as tolerant (when HSI value is ≤0.5), moderately tolerant (when HSI value is more than 0.5 but ≤1.0), and susceptible (when HSI value is >1), according to Fisher and Maurer (1978).

Statistical analysis was carried out for all studied parameters for each growing season separately. The homogeneity of error variance was tested as described by Bartlett (1937). After confirmation of errors compatibility for the two seasons, combined analysis was applied using SPSS computer software and means were separated using Fisher's protected least significant difference (LSD) test at 0.01 and 0.05 levels of probability (Steel and Torrie, 1980). Correlation analysis was performed for all studied traits using the formula described by Gomez and Gomez (1984). The partitioning of phenotypic correlation of studied traits into direct and indirect effects on grain yield was performed using the procedure described by Dewey and Lu (1959). Principal Component Analysis (PCA) was carried out using covariance matrix (Jolliffe, 2005) and Statistical Package PAST (Hammer *et al.*, 2001) to visualize the differences among the studied genotypes.

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance Table 3 indicated that the mean squares due to years were highly significant for flag leaf angle and grain yield plant^{-1} but non-significant for other studied traits. The mean square estimates for environments were highly significant for grain yield plant^{-1}, fertility percentage and panicles plant^{-1}; and it was significant for flag leaf area, plant height, panicle length and 1000-grain weight, but it was non-significant for flag leaf angle. Highly significant mean squares, due to genotypes, were observed for all studied traits except for 1000-grain weight which revealed significant differences. The four traits of flag leaf angle, plant height, 1000-grain weight and fertility percentage exhibited highly significant mean squares due to genotypes x year's interaction. The mean squares due to genotypes x environments interactions were significant for all studied traits except flag leaf angle trait. The mean squares due to genotypes x years x environments interactions were highly significant for plant height, panicle length, 1000-grain weight and fertility percentage while, it was not significant for the remaining traits.

Table 3. Combined analysis of variance of all the studied traits across years, environments and genotypes.

S.O.V	d.f	Flag leaf area (cm^2)	Flag leaf angle	Plant height (cm)	Panicle length (cm)	Panicles plant^{-1}	1000-grain weight (g)	Fertility percentage (%)	Grain Yield plant^{-1} (g)
Years (Y)	1	0.69	268.85**	0.40	0.12	0.75	0.75	2.92	9.16**
Environments (E)	1	1165.93*	1795.85	25116.75*	3279.55*	4586.43**	4602.08*	309585.41**	79385.56**
Y * E	1	12.03*	14.52	11.60*	6.42*	1.20	2.65	4.51	2.15
Reps within Y * E	8	48.648	245.02	15.09	11.50	7.47**	1.74	3.35*	4.14**
Genotypes (G)	24	349.73**	3277.66**	1473.67**	19.68**	148.73**	7.95*	26.46**	23.57**
G * Y	24	1.92	710.00**	7.47**	1.74	3.35*	4.14**	72.21**	1.05
G * E	24	24.31**	15.40	148.73**	7.95*	26.46**	23.57**	1166.90**	112.94**
G * Y * E	24	2.785	9.97	10.39**	3.19**	2.90	3.18**	55.49**	0.97
Pooled error	192	1.89	10.94	2.52	1.46	2.021	0.71	1.99	0.84

***, ** Significant and high significant at probability 0.05 and 0.01, respectively.**

Mean performance

Mean performance for all studied rice genotypes under normal, heat stress and their combined data are showed in Table 4. It could be observed that all studied traits were negatively affected by heat stress. The most affected traits by heat stress were fertility percentage, grain yield plant^{-1}, flag leaf area and panicles plant^{-1}. For flag leaf area, the highest reduction percentages were observed in IR64 (55.2%) while the lowest was observed in Bala (32.8%). The highest mean values under combined data were obtained by Egyptian Yasmin and N22 with mean values of 39.49 and 34.59 cm^2, respectively, while the lowest mean values were obtained by GZ10101-5-1-1-1, Sakha102 and Sakha103 (17.39, 18.44 and 18.47 cm^2, respectively). For flag leaf angle, the lowest mean values were obtained by the genotypes Giza178, Egyptian Yasmin and Dular under heat stress condition. On the contrary, the highest mean values were observed for the promising lines GZ10364-22-3-1-2, GZ10264-9-2-1-2 and GZ10333-9-1-1-3 under all conditions. For plant height, the lowest reduction percentages were obtained by GZ9399-4-1-1-3-2-2 and Bala with mean values of 6.86 and 7.64%, respectively, while the highest reductions were observed in IR64, Sakha103, Sakha105 and Giza177 with mean values of 29.96, 29.59, 28.48 and 28.28%, respectively. Concerning panicle length, the lowest reductions were observed for the genotypes Bala, Dular and N22 (14.03, 14.89 and 14.95%, respectively), meanwhile the highest reductions were observed in GZ9399-4-1-1-3-2-2, Giza177, GZ10101-5-1-1-1, CO39 with mean values of 41.84, 36.91, 35.49 and 35.00%, respectively. For No. of panicles plant^{-1}, under heat stress condition and combined data, the highest mean values were scored by Giza178 (16.67 and 19.34 panicles, respectively) and N22 (15.67 and 18.50 panicles, respectively) while the lowest mean values were revealed by Sakha103 (8.62 and 14.31 panicles, respectively) and Giza177 (9.33 and 13.83%, respectively). For 1000-grain weight, high reduction percentage was observed for the studied genotypes (29.57% in average). Both genotypes Dular and Giza178 revealed the lowest reduction (9.85 and 16.13%, respectively), while the genotypes IR50 and GZ10264-9-2-1-2 showed the highest reduction (39.88 and 39.82%, respectively). Fertility percentage was highly affected by heat stress. The reduction percentage ranged from low (29.20%) in Giza178 to high (91.05%) for IR64 with general average of 73.59%. The highest fertility percentage under heat stress and combined data were scored by Giza178 (64.18 and 77.42%, respectively), N22 (61.73 and 78.32%, respectively) and Bala (53 and 73.05%, respectively). On the other hand, the lowest fertility percentage was exhibited by the genotypes Giza177 (7.47 and 49.73%, respectively), Sakha103 (8.50 and 50.22%, respectively) and GZ10305-24-1-2-3 (8.67 and 50.24%, respectively). Grain yield plant^{-1} was highly affected by heat stress. The reduction percentage ranged from 28.71% (for N22) to 78.57% (for GZ10101-5-1-1-1) with general average of 64.22%. The most desirable genotypes under heat stress were Giza178, N22, Sakha104 and Sakha106 with mean values of 31.24, 27.19, 21.39 and 20.10 g. Meanwhile, the most affected genotypes were Sakha103, GZ10101-5-1-1-1, IR64 and Giza177 with mean values of 9.20, 9.74, 10.18 and 10.71. Similar results for the harmful effects of high temperature on rice have been concluded Jagadish *et al.,* (2010). They found that high temperature affects rice plant at the reproductive and developmental stages by decreasing plant height and root growth, causing reduction in anther dehiscence and spikelets sterility, and limiting the process of pollination. Mohammed and Tarpley (2010) found that high night temperatures has reduced yield by affecting spikelets sterility and grain weight. Liu *et al.*, (2013) reported that high temperature, after heading stage, significantly reduced seed-setting rate, filled grains panicle^{-1}, 1000-grain weight, and grain yield of rice. Yang *et al.*, (2017) found that the heat stress reduced the grain yield with a range of 22–62% compared to the control as a result of significant reductions in pollen grain viability, number of pollen grains adhering to the stigma, pollen viability, number of spikelets per panicle, filling rate and 1000- grain weight.

Phenotypic correlation coefficient

Person correlation coefficient among all studied traits under normal, heat stress and their combined data are presented in Table 5. It could be observed that grain yield plant^{-1} showed highly significant positive correlation with panicles plant^{-1} under all conditions and fertility percentage under heat stress and combined data. As well as it showed significant positive correlation with panicle length under stress condition, positive but non-significant correlation with flag leaf area and plant height under heat stress condition. This result indicates the importance of these traits for selection genotypes for improving grain yield in rice breeding program for heat tolerance. Similar findings were reported by Prasanth *et al.*, (2017) who found that grain yield plant^{-1} was significantly positive correlated with panicle length under control condition, and with filled grains panicle^{-1} and fertility percentage under heat stress condition. Sridhar *et al.*, (2020) found that spikelet fertility was significantly positive correlated with both tillers plant^{-1} and grain yield plant^{-1} but significantly negative correlated with panicle length, pollen fertility and filled spikelets panicle^{-1} indicating that these traits are severely affected by heat stress condition. Yang *et al.*, (2017) reported that the lowest grain yield was correlated with both spikelets filling percentage and grain weight due to the high temperature stress.

Table 4. Mean performances of 25 rice genotypes under normal, heat stress and their combined data during 2017 and 2018 rice growing seasons.

Trait Genotype	Flag leaf area (cm^2)				Flag leaf angle				Plant height (cm)				Panicle length (cm)			
	N	HS	C	R%	N	HS	C	R%	N	HS	C	R%	N	HS	C	R%
Sakha101	26.10	17.01	21.56	34.83	60.00	50.00	55.00	16.67	92.00	70.00	81.00	23.91	24.03	17.00	20.52	29.26
Sakha102	23.14	13.73	18.44	40.67	70.00	75.00	72.50	-7.14	109.00	84.00	96.50	22.94	23.00	15.40	19.20	33.04
Sakha103	23.81	13.13	18.47	44.86	55.00	53.33	54.17	3.04	98.00	69.00	83.50	29.59	20.00	14.27	17.14	28.65
Sakha104	26.89	13.50	20.20	49.80	40.00	36.67	38.34	8.33	103.00	77.00	90.00	25.24	23.17	16.47	19.82	28.92
Sakha105	24.57	13.03	18.80	46.97	76.67	75.00	75.84	2.18	98.33	70.33	84.33	28.48	22.20	15.57	18.89	29.86
Sakha106	26.76	14.57	20.67	45.55	75.00	65.00	70.00	13.33	104.00	78.00	91.00	25.00	22.77	15.20	18.99	33.25
Giza177	24.96	12.40	18.68	50.32	40.00	35.00	37.50	12.50	99.00	71.00	85.00	28.28	21.13	13.33	17.23	36.91
Giza178	28.54	17.61	23.08	38.30	20.00	25.00	22.50	-25.00	97.00	77.00	87.00	20.62	23.80	17.67	20.74	25.76
Egyptian Yasmin	48.00	30.97	39.49	35.48	38.33	25.00	31.67	34.78	109.67	83.00	96.34	24.32	22.60	15.83	19.22	29.96
GZ9399-4-1-1-3-2-2	33.27	20.80	27.04	37.48	46.67	41.67	44.17	10.71	92.33	86.00	89.17	6.86	25.50	14.83	20.17	41.84
GZ9399-4-1-1-2-1-2	25.33	14.60	19.97	42.36	46.67	40.00	43.34	14.29	97.00	87.00	92.00	10.31	24.03	15.67	19.85	34.79
GZ10101-5-1-1-1	22.67	12.10	17.39	46.63	60.00	58.33	59.17	2.78	98.33	83.00	90.67	15.59	23.67	15.27	19.47	35.49
GZ10147-1-2-1-1	28.37	16.80	22.59	40.78	70.00	68.33	69.17	2.39	94.33	83.00	88.67	12.01	23.27	16.17	19.72	30.51
GZ10154-3-1-1-1	31.34	20.40	25.87	34.91	75.00	71.67	73.34	4.44	104.00	89.33	96.67	14.11	23.00	16.33	19.67	29.00
GZ10264-9-2-1-2	39.60	22.83	31.22	42.35	83.33	78.33	80.83	6.00	102.00	87.33	94.67	14.38	23.67	16.97	20.32	28.31
GZ10305-24-1-2-3	27.40	17.00	22.20	37.96	76.67	71.67	74.17	6.52	104.00	90.33	97.17	13.14	23.33	17.90	20.62	23.27
GZ10333-9-1-1-3	30.53	17.50	24.02	42.68	80.00	78.33	79.17	2.09	98.00	88.00	93.00	10.20	22.33	15.23	18.78	31.80
GZ10364-22-3-1-2	31.26	19.10	25.18	38.90	83.33	80.00	81.67	4.00	106.00	87.00	96.50	17.92	22.00	16.50	19.25	25.00
CO39	29.36	18.10	23.73	38.35	21.67	30.00	25.84	-38.44	102.33	93.00	97.67	9.12	22.57	14.67	18.62	35.00
IR50	26.77	15.30	21.04	42.85	66.67	60.00	63.34	10.00	103.00	85.00	94.00	17.48	21.67	16.17	18.92	25.38
N22	41.80	27.38	34.59	34.50	40.00	35.00	37.50	12.50	137.33	113.67	125.50	17.23	20.73	17.63	19.18	14.95
Bala	31.80	21.38	26.59	32.77	43.33	38.33	40.83	11.54	104.67	96.67	100.67	7.64	21.60	18.57	20.09	14.03
Dular	31.72	16.22	23.97	48.87	30.00	25.00	27.50	16.67	132.00	79.00	105.50	40.15	23.50	20.00	21.75	14.89
WAB56-104	40.60	20.80	30.70	48.77	40.00	43.33	41.67	-8.33	138.00	113.33	125.67	17.88	25.10	17.93	21.52	28.57
IR64	30.93	13.85	22.39	55.22	50.00	45.00	47.50	10.00	92.33	64.67	78.50	29.96	21.77	16.53	19.15	24.07
General mean	30.22	17.60	23.92	42.08	55.53	52.20	53.87	5.03	104.63	84.23	94.43	19.29	22.82	16.28	19.55	28.50
LSD 1%	2.20	2.88	1.57		7.69	5.89	3.77		2.23	1.49	1.81		1.43	2.79	1.38	
LSD 5%	2.93	3.84	2.07		10.25	7.85	4.97		2.98	1.99	2.38		1.91	3.72	1.81	

N, HS and C are Normal, Stress and Combined data, respectively; R% is reduction percentage.

Table 4. Continued…

Trait Genotype	Panicles plant^{-1}				1000-grain weight (g)				Fertility percentage				Grain yield plant^{-1}			
	N	HS	C	R%	N	HS	C	R%	N	HS	C	R%	N	HS	C	R%
Sakha101	23.00	12.67	17.84	44.91	29.50	21.00	25.25	28.81	95.78	19.70	57.74	79.43	50.50	14.92	32.71	70.46
Sakha102	21.00	12.67	16.84	39.67	28.50	21.33	24.92	25.16	93.86	13.00	53.43	86.15	43.87	11.70	27.79	73.33
Sakha103	20.00	8.62	14.31	56.90	25.20	17.80	21.50	29.37	91.93	8.50	50.22	90.75	39.91	9.20	24.56	76.95
Sakha104	22.33	12.33	17.33	44.78	26.83	21.00	23.92	21.73	93.72	25.72	59.72	72.56	46.07	21.39	33.73	53.57
Sakha105	22.00	11.00	16.50	50.00	28.83	18.83	23.83	34.69	92.00	16.77	54.39	81.77	45.44	14.69	30.07	67.67
Sakha106	21.67	12.33	17.00	43.10	28.60	19.17	23.89	32.97	91.78	21.47	56.63	76.61	45.57	20.10	32.84	55.89
Giza177	18.33	9.33	13.83	49.10	27.33	18.23	22.78	33.30	91.98	7.47	49.73	91.88	38.25	10.71	24.48	72.00
Giza178	22.00	16.67	19.34	24.23	22.57	18.93	20.75	16.13	90.65	64.18	77.42	29.20	46.53	31.24	38.89	32.86
Egyptian Yasmin	18.67	10.33	14.50	44.67	28.33	19.77	24.05	30.22	90.78	20.60	55.69	77.31	36.91	13.76	25.34	62.72
GZ9399-4-1-1-3-2-2	23.00	12.00	17.50	47.83	24.20	16.58	20.39	31.49	91.97	30.83	61.40	66.48	48.84	17.51	33.18	64.15
GZ9399-4-1-1-2-1-2	22.33	12.33	17.33	44.78	23.70	17.47	20.59	26.29	91.57	30.23	60.90	66.99	46.27	16.47	31.37	64.40
GZ10101-5-1-1-1	22.00	9.67	15.84	56.05	27.47	17.00	22.24	38.11	90.73	19.40	55.07	78.62	45.44	9.74	27.59	78.57
GZ10147-1-2-1-1	21.00	11.33	16.17	46.05	27.33	18.67	23.00	31.69	92.13	21.53	56.83	76.63	46.77	11.70	29.24	74.98
GZ10154-3-1-1-1	22.00	12.67	17.34	42.41	28.80	17.68	23.24	38.61	94.20	18.40	56.30	80.47	48.62	11.70	30.16	75.94
GZ10264-9-2-1-2	21.00	10.67	15.84	49.19	29.03	17.47	23.25	39.82	92.90	13.33	53.12	85.65	49.92	11.86	30.89	76.24
GZ10305-24-1-2-3	20.67	11.00	15.84	46.78	26.87	16.75	21.81	37.66	91.80	8.67	50.24	90.56	46.72	11.60	29.16	75.17
GZ10333-9-1-1-3	21.00	11.67	16.34	44.43	28.40	17.95	23.18	36.80	93.37	9.50	51.44	89.83	49.90	11.50	30.70	76.95
GZ10364-22-3-1-2	22.00	11.00	16.50	50.00	25.73	17.17	21.45	33.27	93.97	9.27	51.62	90.14	46.81	11.74	29.28	74.92
CO39	21.67	13.67	17.67	36.92	21.03	16.40	18.72	22.02	92.70	30.83	61.77	66.74	44.60	19.77	32.19	55.67
IR50	21.00	12.67	16.84	39.67	24.80	14.91	19.86	39.88	92.43	19.60	56.02	78.79	45.63	15.87	30.75	65.22
N22	21.33	15.67	18.50	26.54	21.03	15.67	18.35	25.49	94.90	61.73	78.32	34.95	38.14	27.19	32.67	28.71
Bala	17.00	11.00	14.00	35.29	25.17	17.37	21.27	30.99	93.10	53.00	73.05	43.07	42.30	17.47	29.89	58.70
Dular	18.00	15.67	16.84	12.94	22.33	20.13	21.23	9.85	92.93	49.60	71.27	46.63	35.08	18.79	26.94	46.44
WAB56-104	16.67	14.00	15.34	16.02	31.57	23.87	27.72	24.39	91.38	29.58	60.48	67.63	34.30	17.23	25.77	49.77
IR64	21.33	12.67	17.00	40.60	23.67	18.83	21.25	20.45	93.61	8.38	51.00	91.05	39.32	10.18	24.75	74.11
General mean	20.84	12.15	16.50	41.31	26.27	18.40	22.34	29.57	92.65	24.45	58.55	73.59	44.07	15.52	29.80	64.22
LSD 1%	2.07	2.83	1.62		1.27	1.17	0.96		1.09	9.55	1.61		2.19	1.42	1.04	
LSD 5%	2.76	3.78	2.14		1.69	1.56	1.27		1.46	12.74	2.12		2.92	1.89	1.38	

The correlation between grain yield and flag leaf angle was positive and significant under normal condition while it was negative and highly significant under heat stress condition indicating that genotypes with erect flag leaf are more desirable for cultivating in high temperature regions. A similar result was obtained by Gaballah and Abu El-Ezz (2019) who reported that flag leaf angle was highly significant positive correlated with leaf rolling and sterility %, and highly significant negative correlated with panicles plant^{-1}, panicle weight and grain yield plant^{-1} under normal and heat stress conditions. The correlation between grain yield and flag leaf area and plant height traits was negative under normal condition but it was positive under stress condition meaning that those traits are good indicators for tolerance under stress condition. A similar result was recorded by Sridhar *et al.*, (2020) who reported positive and significant correlation between plant height and grain yield in rice.

Flag leaf area was highly significant positive correlated with plant height under all conditions, while it was significantly positive correlated with fertility percentage under heat stress condition. Leaf angle showed highly significant positive correlation with 1000- grain weight under normal condition. On the other hand, it revealed highly significant negative correlation with fertility percentage under stress condition and combined data. The plant height trait was significantly positive correlated with fertility percentage under combined data. Panicle length was highly significant positive correlated with the panicles plant^{-1} under heat treatment and fertility percentage under heat treatment and combined data. The correlation between panicles plant^{-1} and fertility percentage was highly significant positive under heat stress condition and significantly positive under combined data.

Table 5. Phenotypic correlation coefficients among all studied traits under normal, heat stress and combined data

Trait	Location	Flag leaf angle	Plant height (cm)	Panicle length (cm)	Panicles plant^{-1}	1000 grain weight (g)	Fertility (%)	Grain yield plant^{-1} (g)
Flag leaf area (cm^2)	N	-0.214	0.566**	0.042	-0.295	-0.202	0.12	-0.345
	HS	-0.23	0.593**	0.327	0.352	-0.214	0.401*	0.304
	C	-0.234	0.588**	0.241	0.115	-0.221	0.362	0.043
Flag leaf angle	N		-0.169	-0.067	0.259	0.537**	0.020	0.488*
	HS		-0.049	-0.188	-.407*	-0.069	-0.556**	-0.552**
	C		-0.121	-0.154	-0.128	0.329	-0.549**	-0.095
Plant height (cm)	N			-0.066	-0.332	-0.014	0.185	-0.388
	HS			0.354	0.269	-0.063	0.385	0.252
	C			0.279	0.043	0.028	0.409*	0.056
Panicle length (cm)	N				0.015	0.358	-0.236	0.071
	HS				0.636**	0.195	0.647**	0.426*
	C				0.309	0.277	0.511**	0.266
Panicles plant^{-1}	N					-0.137	0.248	0.750**
	HS					0.178	0.725**	0.786**
	C					-0.308	0.443*	0.756**
1000-grain weight (g)	N						-0.034	0.175
	HS						-0.034	0.027
	C						-0.39	-0.274
Fertility percentage (%)	N							0.205
	HS							0.862**
	C							0.524**

*** and ** are significant and highly significant at 0.05 and 0.01 levels of probability, respectively. N, HS and C are normal, stress and combined data, respectively**

Path coefficient analysis

Path coefficient analysis is a reliable statistical technique used for estimating the contribution of each trait to grain yield, whether it has a direct influence on the grain yield or takes another pathway for ultimate effects (Ali *et al.,* 2009). According to Deway and Lu (1959), the first component of path analysis is the direct effect of a predictor trait on its response trait; meanwhile the second component is the indirect effect of a predictor trait on its response trait through other predictor traits. The direct and indirect effects of different studied traits upon grain yield are found in Table 6. The results indicated that the direct effect on grain yield plant^{-1} was high and positive for traits of panicles plant^{-1} and fertility percentage under heat stress and combined data, and positive for 1000-grain weight under all conditions. On the other hand, the flag leaf area and plant height traits had negative direct effect under all conditions. The direct effect on grain yield was positive for flag leaf angle under normal and combined data, while it was negative under heat stress condition. The panicle length had a positive direct effect under normal condition but negative indirect effect under both heat stress and combined data. The trait 1000-grain weight revealed positive indirect effect on grain yield through flag leaf angle under normal condition. Under stress condition, panicle length had positive indirect effect via panicles plant^{-1} and fertility percentage, flag leaf angle had negative indirect effect through panicles plant^{-1} and fertility percentage, the indirect effect was positive for panicle length and negative for leaf angle through both panicles plant^{-1} and fertility percentage, the traits flag leaf area, plant height and panicles plant^{-1} exhibited positive indirect effect on grain yield via fertility percentage but negative indirect effect via panicle length. The indirect effect of both flag leaf area and plant height through panicles plant^{-1} was negative under normal condition but positive under heat stress condition. Fertility percentage had positive indirect effect *via* panicles plant^{-1} under both conditions and negative indirect effect on grain yield *via* panicle length under stress condition.

Table 6. Direct and indirect effects of the studied traits on grain yield plant^{-1} under normal, heat stress and combined data

Traits	Location	Flag leaf area (cm^2)	Flag leaf angle	Plant height (cm)	Panicle length (cm)	Panicles plant^{-1}	1000 grain weight (g)	Fertility percentage (%)	r^2
Flag leaf area (cm^2)	N	-0.0195	-0.0511	-0.0788	0.0021	-0.1856	-0.0227	0.0105	-0.345
	HS	-0.0330	0.0007	-0.0144	-0.1180	0.1604	-0.0073	0.3157	0.304
	C	-0.0700	-0.0448	-0.0462	-0.0365	0.0733	-0.0198	0.1869	0.043
leaf angle	N	0.0042	0.2386	0.0235	-0.0033	0.1629	0.0603	0.0018	0.488*
	HS	0.0076	-0.0031	0.0012	0.0679	-0.1854	-0.0024	-0.4377	-0.552**
	C	0.0164	0.1915	0.0095	0.0233	-0.0816	0.0294	-0.2835	-0.095
Plant height (cm)	N	-0.0110	-0.0403	-0.1392	-0.0033	-0.2089	-0.0016	0.0163	-0.388
	HS	-0.0196	0.0002	-0.0243	-0.1278	0.1226	-0.0022	0.3031	0.252
	C	-0.0412	-0.0232	-0.0786	-0.0422	0.0274	0.0025	0.2112	0.056
Panicle length (cm)	N	-0.0008	-0.0160	0.0092	0.0497	0.0094	0.0402	-0.0207	0.071
	HS	-0.0108	0.0006	-0.0086	-0.3610	0.2898	0.0067	0.5093	0.426*
	C	-0.0169	-0.0295	-0.0219	-0.1513	0.1970	0.0248	0.2639	0.266
Panicles plant^{-1}	N	0.0058	0.0618	0.0462	0.0007	0.6291	-0.0154	0.0218	0.750**
	HS	-0.0116	0.0013	-0.0065	-0.2296	0.4556	0.0061	0.5708	0.786**
	C	-0.0081	-0.0245	-0.0034	-0.0468	0.6375	-0.0275	0.2288	0.756**
1000-grain weight (g)	N	0.0039	0.1281	0.0019	0.0178	-0.0862	0.1124	-0.0030	0.175
	HS	0.0071	0.0002	0.0015	-0.0704	0.0811	0.0343	-0.0268	0.027
	C	0.0155	0.0630	-0.0022	-0.0419	-0.1963	0.0894	-0.2014	-0.274
Fertility percentage (%)	N	-0.0023	0.0048	-0.0257	-0.0117	0.1560	-0.0038	0.0878	0.205
	HS	-0.0132	0.0017	-0.0093	-0.2336	0.3303	-0.0012	0.7872	0.862**
	C	-0.0253	-0.1051	-0.0321	-0.0773	0.2824	-0.0349	0.5164	0.524**

*** and ** are significant and highly significant at 0.05 and 0.01 levels of probability, respectively. N, HS and C are normal, stress and combined data, respectively**

Path coefficient analysis is usually used by plant breeders for identification of traits that can be exploited as selection criteria for improving grain yield (Bagheri *et al*., 2011). Depending on the results of path analysis in the current investigation, the maximum direct effect on grain yield plant^{-1} was exerted by panicles plant^{-1} under all conditions and fertility percentage under heat stress and combined data. So, these traits could be used as good indicators for high grain yield under both heat stress and non-stress conditions. The four traits of flag leaf area, leaf angle, plant height and panicle length had high indirect effect on grain yield under both stress and combined data through fertility percentage. These results are in agreement with those of Moosavi *et al*., (2015) who reported that panicles plant^{-1} and harvest index are good indicators of selection for grain yield due to their high direct effects and significant correlation with grain yield plant^{-1} in rice under warm conditions. Prasanth *et al.,* (2017) found that the most important traits that could be exploited in rice breeding programs for improving grain yield based on the results of both correlation and path analysis were panicle length, biomass plant^{-1}, and filled grains panicle^{-1} in control, and spikelets fertility percentage, filled grains panicle^{-1}, total grains panicle^{-1}, and No. of tillers plant^{-1} in heat stress condition. Sridhar *et al.,* (2020) reported that the three traits panicle length, plant height and grain yield plant^{-1} are important for improvement of spikelets fertility in rice under heat stress.

Heat susceptibility index (HIS)

The HSI values for the all studied traits of the genotypes under study are showed in Table 7. It could be observed that HSI values were ranged from 0.8 to 1.4 for flag leaf area, -6.4 to 5.8 for flag leaf angle, 0.4 to 1.6 for plant height, 0.5 to 1.5 for panicle length, 0.3 to 1. 4 for panicles plant^{-1}, 0.3 to 1.3 for 1000-grain weight, 0.4 to 1.2 for fertility percentage and from 0.4 to 1.2 for grain yield plant^{-1}. The lowest HSI values were observed for Bala, N22, Egyptian Yasmin, Sakha101 and GZ10154-3-1-1-1 (0.8 for each) in flag leaf area; Bala (0.4), GZ90399-4-1-1-3-2-2 (0.4) and CO39 (0.5) for plant height; N22 (0.5), Bala (0.5) and Dular (0.5) for panicle length; Dular (0.3), WAB56-104 (0.4), N22 (0.6) and Giza178 (0.6) for panicles plant^{-1}; Dular (0.3) and Giza178 (0.5) for 1000-grain weight; Giza178 (0.4), N22 (0.5), Bala (0.6), and Dular (0.7) for fertility percentage; and N22 (0.4), Giza178 (0.5) and Dular (0.7) for grain yield plant^{-1}. On the other hand, the highest HSI values were observed for Giza177 (1.4) and IR64 (1.3) for flag leaf area; IR64 (1.6), Sakha103 (1.6), Sakha105 (1.5) and Giza177 (1.5) for plant height; GZ9399-4-1-1-3-2-2 (1.5) and Giza177 (1.3) for panicle length; Sakha103 (1.4) and GZ10147-1-2-1-1 (1.3) for panicles plant^{-1}; IR50 (1.3) and GZ10147-1-2-1-1 (1.3), GZ10305-24-1-2-3 (1.3) and GZ10333-9-1-1-3 (1.3) for 1000-grain weight; IR64, CO39, Giza177, Sakha102, Sakha103, GZ10305-24-1-2-3, GZ10333-9-1-1-3, GZ10364-22-3-1-2 (1.2 for each) for fertility percentage, and CO39, Sakha103, GZ10147-1-2-1-1, GZ10154-3-1-1-1, GZ10264-9-2-1-2, GZ10305-24-1-2-3, GZ10333-9-1-1-3, GZ10364-22-3-1-2 (1.2 for each) for grain yield plant^{-1}.Based on the HSI value of both grain yield and fertility percentage, two genotypes; N22 and Giza178 were identified as heat tolerant (HSI value was ≤0.5 for both traits), eight genotypes; Bala, Dular, WAB56-104, Sakha104, Sakha106, Egyptian Yasmin, GZ9399-4-1-1-2-1-2 and GZ10101-5-1-1-1 were identified as moderately tolerant (HSI value was more than 0.5 but ≤1.0 for both traits) and 11 genotypes i.e. IR64, CO39, Giza177, Sakha101, Sakha102, Sakha103, GZ10147-1-2-1-1, GZ10264-9-2-1-2, GZ10305-24-1-2-3, GZ10333-9-1-1-3 and GZ10364-22-3-1-2 were identified as heat susceptible (HSI value was >1.0 for both traits). These results are in agreement with Prasanth *et al.,* (2017) who used HSI as criterion to select the heat tolerant lines. They found that the genotypes Nagina22 and a restorer line KMR3 were identified as highly tolerant based on the heat susceptibility index (HSI).

Table 7. Heat susceptibility index (HSI) for the studied traits in 25 rice genotypes

Traits Genotypes	Flag leaf area (cm^2)	Flag leaf angle	Plant height (cm)	Panicle length (cm)	Panicles plant^{-1}	1000 grain weight (g)	Fertility percentage (%)	Grain yield plant^{-1} (g)
Sakha101	0.8	2.8	1.3	1.0	1.1	1.0	1.1	1.1
Sakha102	1.0	-1.2	1.2	1.2	1.0	0.8	1.2	1.1
Sakha103	1.1	0.5	1.6	1.0	1.4	1.0	1.2	1.2
Sakha104	1.1	1.4	1.4	1.0	1.1	0.7	1.0	0.8
Sakha105	1.2	0.4	1.5	1.0	1.2	1.2	1.1	1.0
Sakha106	1.1	2.2	1.3	1.2	1.0	1.1	1.0	0.9
Giza177	1.4	2.1	1.5	1.3	1.2	1.1	1.2	1.1
Giza178	0.9	-4.2	1.1	0.9	0.6	0.5	0.4	0.5
Egyptian Yasmin	0.8	5.8	1.3	1.0	0.9	0.7	0.9	0. 9
GZ9399-4-1-1-3-2-2	0.9	1.8	0.4	1.5	1.1	1.0	1.1	1.0
GZ9399-4-1-1-2-1-2	1.0	2.4	0.6	1.2	1.1	1.1	0.9	1.0
GZ10101-5-1-1-1	1.1	0.5	0.8	1.2	1.1	0.9	0.9	1.0
GZ10147-1-2-1-1	1.0	0.4	0.6	1.1	1.3	1.3	1.1	1.2
GZ10154-3-1-1-1	0.8	0.71	0.8	1.0	1.1	1.1	1.0	1.2
GZ10264-9-2-1-2	1.0	1.0	0.8	1.0	1.0	1.3	1.1	1.2
GZ10305-24-1-2-3	0. 9	1.1	0.7	0.8	1.2	1.3	1.2	1.2
GZ10333-9-1-1-3	1.0	0.3	0.6	1.1	1.1	1.3	1.2	1.2
GZ10364-22-3-1-2	0.9	0.7	1.0	0.9	1.1	1.2	1.2	1.2
CO39	0.9	-6.4	0.5	1.2	1.2	1.1	1.2	1.2
IR50	1.0	1.7	0.9	0.9	1.0	1.3	1.1	1.0
N22	0.8	2.1	0.9	0.5	0.6	0.9	0.5	0.4
Bala	0.8	1.9	0.4	0.5	0.8	1.0	0.6	0.9
Dular	1.2	2.8	1.2	0.5	0.3	0.3	0.7	0.7
WAB56-104	1.2	-1.4	1.0	1.0	0.4	0.8	0.9	0. 8
IR64	1.3	1.7	1.6	0.8	1.0	0.7	1.2	1.1

Principal component analysis

Principal component analysis (PCA) is a multivariable statistical analysis that reduces the dimension of high-dimension data, in which fewer Eigen vectors can explain information of multivariate data as possible (Shlens, 2005). In the current study PCA was performed to study the genetic diversity among the studied rice genotypes based on the HSI values of the studied traits. The Eigen values and the percentage of variation for three principal components across 25 rice genotypes are found in Table 8. The results of PCA indicated that the first three principal components scored the maximum Eigen values and explained cumulative variation of 79.934% of the total variation among the studied traits. The maximum variability was scored by PC1 (43.816%), PC2 (22.710%) and PC3 (13.408%). The HSI of the traits panicle length, panicles plant^{-1}, 1000-grain weight, fertility percentage and grain yield plant^{-1} was positively associated to axes one (PC1), The HSI of the traits pant height and flag leaf area was positively associated to axes two (PC2), The HSI of flag leaf angle was positively associated to axes three (PC3). Similar results were obtained by Mahendran *et al.*, (2015) who studied the genetic diversity among 293 rice accessions under heat stress and found that the first five principal components exhibited high Eigen value of more than one and cumulative variance of 77.38%. Dhakal *et al.*, (2020) reported that among thirteen PCs, five PCs were significant with Eigen values >1 and cumulative variance of 84.67% of total variance. PC1 included the traits related to yield and its components.

Table 8. Eigen values, variation explained (%), cumulative variance (%) and Eigen vectors of the first three principal components based on the HSI of the studied traits in 25 rice genotypes

	PC1	PC2	PC3
Eigen value	3.505	1.817	1.073
% variance	43.816	22.710	13.408
Cumulative % variance	43.816	66.526	79.934
Eigen vectors based on HSI values of the studied traits			
Flag leaf area (cm^2)	0.089	0.623	-0.206
Flag leaf angle	-0.055	0.191	0.865
Plant height (cm)	-0.053	0.665	0.084
Panicle length (cm)	0.349	0.082	-0.365
Panicles plant^{-1}	0.476	-0.041	0.129
1000-grain weight (g)	0.408	-0.293	0.204
Fertility percentage (%)	0.485	0.199	0.004
Grain yield plant^{-1} (g)	0.486	0.007	0.105

As it is observed in Figure 1, PCA analysis divided the studied genotypes into four clusters based on HSI of the studied traits. The first cluster was found in the 4th quadrant and involved four genotypes i.e. Dular, WAB56-104, Sakha104 and Egyptian Yasmin. The second cluster was found in the 3rd quadrant and included three genotypes i.e. Giza178, N22 and Bala. The genotypes in the first and the second clusters had low to moderately HSI values for grain yield plant^{-1} (0.4 to 0.9), fertility percentage (0.4 to 1.0), 1000-grain weight (0.3 to 1.0), panicle length (0.5 to 1.0) and panicles plant^{-1} (0.3 to 1.1). The fourth cluster was found in the 1st quadrant and included IR29, Giza177, Sakha105, Sakha103, Sakha106, Sakha102, Sakha101 and GZ10101-5-1-1-1. All other genotypes gathered in the fourth cluster and included most of promising lines in addition to IR50 and CO39. The genotypes in the third and the fourth clusters had moderately to high HSI values for grain yield plant^{-1} (0.9 to 1.2), fertility percentage (0.9 to 1.2), 1000-grain weight (0.7 to 1.3), panicle length (0.8 to 1.5) and panicles plant^{-1} (1.0 to 1.4). The results of PCA analysis indicated the presence of high amount of genetic variability among the studied genotypes, and it was able to divide the genotypes into four groups based on their tolerance to heat stress. Based on HSI values and PCA analysis, genotypes in cluster 1 and 2 are the most desirable under heat stress due to the inverse relation between heat tolerance and the low to moderately HSI values of the studied traits Fisher and Maurer (1978).

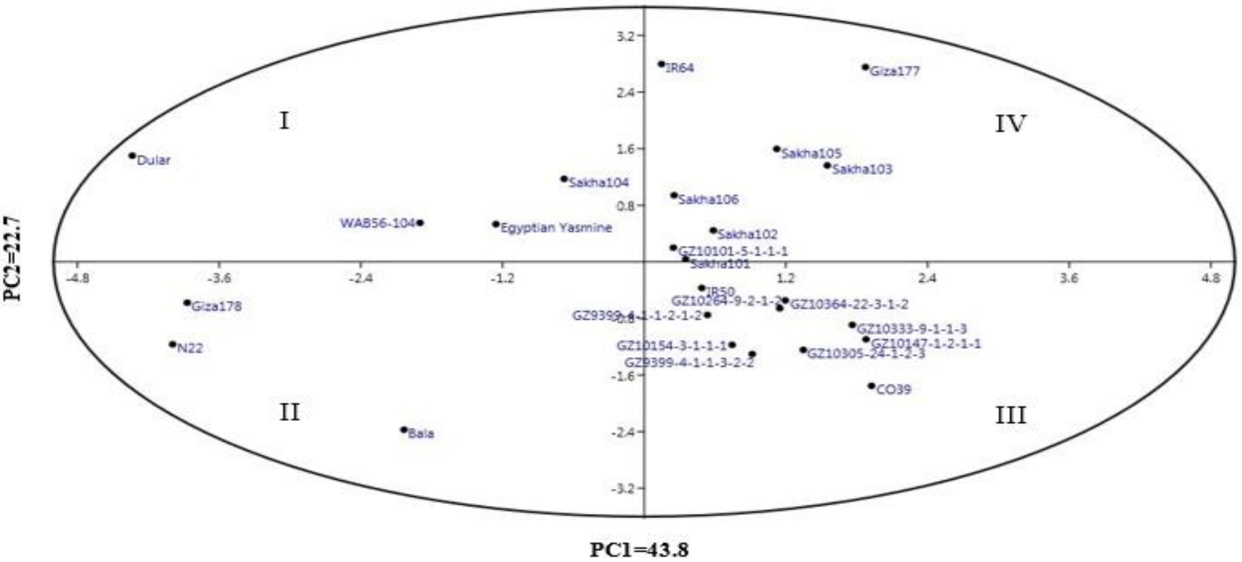

Figure 1. Biplot of the first and second principal components for 25 different rice genotypes based on HSI values of eight studied traits

CONCLUSION

High temperature is one of the most important abiotic stresses affecting crop production. Based on the results of the current study, rice grain yield was highly affected by heat stress as a result of high sterility percentage and the reduction in growth traits. PCA analysis was success in grouping the studied genotypes into four clusters based on the values of HSI of the studied traits. The most desirable genotypes in the current study were gathered in two clusters and revealed low to moderately HSI values.

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تقييم تراكيب وراثية مختلفه من الأرز تحت الظروف الطبيعية والإجهاد الحراري

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إستهدفت هذة الدراسه تقييم 25 تركيبا وراثيا من الأرز تحت ظروف النمو الطبيعية (سخا – كفر الشيخ – مصر) وظروف الإجهاد الحراري (الوادي الجديد – مصر) وذلك خلال موسمي الأرز2017 و 2018م. تم دراسه الصفات التاليه مساحة ورقة العلم (سم^2), زاوية ورقه العلم, طول النبات (سم), طول الدالية (سم), عدد السنابل لكل نبات, وزن الألف حبة (جم), النسبة المئوية للخصوبة (%) و محصول النبات الفردي (جم). أظهرت النتائج وجود قدر كبير من التباين الوراثي بين التراكيب الوراثية تحت الدراسة تحت ظروف النمو الطبيعية والإجهاد الحراري. تاثرت جميع التراكيب الوراثية سلبيا بإرتفاع درجة الحرارة. وكانت أكثر الصفات تآثرا بالإجهاد الحراري هي محصول النبات الفردي, النسبة المئوية للخصوبة, مساحة ورقة العلم و عدد السنابل لكل نبات، وكانت النسبة المئوية لمتوسط النقص لكل منها 73،59، 64،22 ، 42،46 ، و 41،31% علي الترتيب. وقد أظهرت نتائج تحليل الإرتباط ومعامل المرور أهمية صفتي عدد السنابل لكل نبات و النسبة المئوية للخصوبة كدلائل جيده للمحصول العالي تحت ظروف الإجهاد الحراري والتحليل المشترك. وإعتمادا علي قيم دليل الحساسية للإجهاد الحراري لصفتي محصول النبات الفردي والنسبة المئوية للخصوبة فإنه يمكن توصيف الصنفين جيزة 178 و N22 علي أنهما متحملان للإجهاد الحراري حيث كانت قيمة دليل الحساسية لهاتين الصفتين أقل من أو تساوي 0،5. وطبقا لنتائج تحليل المكونات الرئيسية (PCA) فقد كانت أفضل التراكيب الوراثية تحت الإجهاد الحراري هي جيزة 178, N22, Bala, Dular, WAB56-,سخا 104 و ياسمين المصري. هذا وبناءا علي النتائج المتحصل عليها في هذه الدراسة فإنه يمكن استنتاج أن أصناف الأرز المصرية جيزه 178, سخا 104 و ياسمين المصري هي أصناف مناسبة للزراعة تحت ظروف النمو الطبيعية وظروف الإجهاد الحراري في مصر. بالإضافة إلي ذلك فانه يمكن إستخدام هذه التراكيب الوراثية الثمانية كآباء في برامج التربية لإنتاج سلالات مبشرة عالية المحصول ومتحملة للحرارة.