American-Eurasian J. Agric. & Environ. Sci., 8 (3): 257-267, 2010
ISSN 1818-6769

Genotype-Environment Interactions for Seedling Vigor Traits in Rice (*Oryza sativa* L.) Genotypes Grown under Low and High Temperature Conditions

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Abstract: The present investigation was carried out at the experimental farm of Rice Research and Training Center, Sakha, Kafer El-Sheikh, Egypt. Genetic behavior of some rice genotypes was studied to evaluate seedling vigor under cold and high stress temperature. Three cytoplasmic male sterile lines (CMS) as female parents and three Egyptian restorer lines as male parents were used; theses lines were crossed according to line x tester mating design to produce nine F_1 hybrids. Two stress treatments were applied, high and low stress temperature under a growth chamber conditions to evaluate their effect on seedling height, no. of leaves, chlorophyll content, fresh seedling weight, dry seedling weight and water content. Line x tester analysis was applied to provide information about general combining ability (GCA) and Specific combining ability (SCA), estimating heterosis and various types of gene actions. The data revealed that the Egyptian varieties indica rice, Giza 178R, Giza 181R, Giza 182R, also the rice hybrids, IR69625A/Giza 181R and IR70368A/Giza182R were the most stable rice accessions under different temperature regimes conditions during seedling stages. This is considered one of the most important outputs of the current research. The most variable estimate was seedling height which could be considered the most appropriate estimate for seedling tolerant under different growth conditions for future studies of screening more rice accessions.

Key words: Rice (*Orza sativa* L.) · Restorer lines · Low and high temperature stress · Vigor · Line x tester analysis and G x E

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important grain foods and the second largest crop grown in the world in terms of both area and production. More than half of the world's population especially in developing countries depends on rice. The global warming and climate change is considered a serious problem in the world. It is expected to affect several countries, of which Egypt is included. High and low stress temperature are major limitations for plant growth and cause significant loss to crop production world wide, thus reliable protection of crops from cold damage has always been an elusive goal [1]. Low temperature is probably one of the most common environmental stresses encountered during germination by summer crops sown early in the season. The common symptoms brought about by low temperature are generally: 1- poor germination of seeds, 2- poor establishment of seedlings in the field, 3- yellowing of leaves and 4- sterility of spikelets [2]. On the other hand, reduced the fertility is recognize as one of the dangers symptoms as a results to exposure the plants to high temperature [3].

Rice is highly sensitive to low and high temperature, breeding for tolerance against cold and high temperature to avoid or adaptation plant is widely recognized as effective way to overcome the limitations to production in cold and high temperature areas [4- 7]. Breeding strategies based on selection of the parental varieties to obtain high hybrids, it is important to recommend several lines that can be less affected under different temperature especially at seedling stage, which is the most sensitive stage in the plant life cycle. Seedling vigor is the ability of a plant's to emerge rapidly from soil or

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water in rice [8]. The plant breeders have successfully improved cold and high stress tolerance of some crops in recent decades using seedling vigor as the main selection criteria [9] most of plant breeding programs designed to improve seedling vigor [10].

Breeding strategies for low and high stress temperatures tolerance have generally depended on screening technique looking for tolerance mechanisms, genetic diversity, genetic mode and heritability [9, 11]. Combing ability, liner x tester, heterosis and heritability were analyzed one of the powerful tools which are available to help the breeder to selection the desirable parents and crosses [12-14]. So, the aims of this study is to understanding of the response the rice genotypes (inbred and hybrid rice) to cold and high stress temperature by estimating the combining ability, heterosis, heritability and gene action for some seedling and physiological traits under these stress and identify the stability of theses genotypes under different temperature growth conditions at seedling stage.

MATERIALS AND METHODS

The present study was carried out at the farm and biotechnology laboratory of Rice Research and Training Center (RRTC) Sakha, Kafr EL-Sheikh, Egypt during three seasons. The genetic material used in these investigations involved three cytoplasm male sterile lines (CMS), three Egyptian restorer lines Viz, were used as testers (Table 1) and nine hybrids produced by crossed the lines according to line x tester mating.

Rice Seedling Growth Temperature Treatments: Fifteen seeds were taken from each 18 genotypes and treated for 50°C to break the dormancy and soaked in Petri dishes at 10°C for 48 h and incubated in 30°C in the dark. Five seeds per each replication were selected and grown in a seedling box (15x5 cm). The seedlings were treated on different temperature in three treatments. The first one the seedlings were grown for 25 days in a growth chamber in day light with the temperature of 25/18°C for day and night, respectively. The second one the seedling were grown also grown for 25 days in growth chamber in day light with the temperature of 25°C/18 °C for day and night, respectively for 10 days, the temperature of 22/16°C for day and night Respectively, for three days and the temperature of 18/14°C for day and night Respectively, for 10 days. The last one the seedling was grown for 25 days also in a growth chamber in day light with the temperature of 25/18°C for day and night, respectively, the temperature of 25/ 20°C for day and night respectively for three days and the temperature of 35/ 28°C for day and night, respectively, for 10 days.

Seedling Characteristics: Seedling height was determined as the length from the first leaf and seedling height were measured 25 days after seedling (DAS). For the number of fresh leaves, the fully green leaves were considered as green leave. It was counted per each plant. If more than 1/3 of the leaf is yellow, it well not be counted and considered as a dead leave. Fresh seedling weight (FSW) was measured at 25 DAS and measured as the weight of whole plant. Dry seedling weight (DSW), to measure the dry weight we kept the fresh seedlings in an oven dryer for 48 hr on 80°C and measured at 25 days after seedling. Chlorophyll content (Chl.), SPAD values of Minolta chlorophyll meter SPAD 502 (Minolta camera co Japan) were substituted for the second leaf [15]. For water content, the different values between shoot fresh and dry weight was calculated as an indicator of the amount water kept in each seedling.

Statistical Analysis: Heterosis relative to the better parent and mid parent was calculated according to Mather [16] and Mather and Jinks [17] for testing the significance of heterosis, LSD values were estimated according to formula suggested by Wyanne *et al.* [18]. Line x tester analysis was done as devolved by Kempthorne [19] to obtain information about general and specific combining ability and to estimate various types of gene effect. Some variance components were estimated based on the expectations of mean squares according to Kempthorne [19] and Virmani *et al.* [20]. Heritability estimates were obtained as described by Burton and Devan [21]. In order to test the stability of rice inbred lines and hybrids under different growth conditions at seedling stage, the software program IRRISTAT.W was used to calculate the GxE interaction.

Table 1: Cytoplasmic male sterile lines, restorer and hybrids used for the study

Genotypes	Cytoplasmic source	Origin
CMS lines (female parents) (1) IR58025A – (2) IR69025A- (3) IR70368A	Wild abortive	IRRI
Restorer Lines (male parents) (1) Giza 178R – (2) Giza 181R –(3) Giza 182R	Restorer	Egypt

Abbreviations: GCA General Combining Ability, SCA Specific Combining Ability, G x E Genotype x Environment, CMS Cytoplasm Male Sterile, FSW Fresh Seedling Weight, DSW Dry Seedling Weight, Chl. Chlorophyll, MP Mid Parent, BP Better Parent.

RESULTS AND DISCUSSION

Mean Performance: The mean performance for three lines, three testers and their nine F_1 hybrids grown in growth chamber under different temperatures (control, low and high temperature) and the data for seedling characters are presented in Table 2. Data indicated that the genotypes Giza182R exhibited high mean value under low temperature for seedling length, no. of leaves, SDW, Chl. content with mean value of 17.1 mm, 3.50 for no. of leaves, 0.024 g and 35.8 for SPAD, respectively. Similar results were obtained by Chauhan *et al.* [22].While the four hybrids IR70368A/Giza182R,IR58025/Giza182, IR69025A/Giza181R and IR58025/Giza181 exhibited the highest mean values for Seedling length, no. of leaves, SDW and Chl. content with mean value of 17.1mm, 3.56 for no. of leaves, 0.02 gm and 35.8 for SPAD, respectively. However, theses results were in general agreement with those reported by Chen *et al.* [23] and Ammar [24]. All genotypes which grown under high temperature such as, Giza178R, Giza182R, IR58025A/Giza181R and IR58025A/Giza178R exhibited high values for seedling length, number of leaves, fresh weight, dry weight and water content. They showed good tolerance for high temperature. The estimates were: 20.4, 18.0 and 19.0 and 18.5 mm, respectively for seedling length, 3.67, 3.56, 3.75 and 3.67 leaves, respectively for number of leaves, 0.13, 0.12, 0.12 and 0.12 g., respectively for fresh weight, 0.020, 0.023, 0.093 and 0.097 g., respectively for dry weight, 0.011, 0.094, 0.093 and 0.097., respectively for water content. But for chlorophyll content IR58025A, IR69625A, IR70368A/Giza178R and IR70368A/Giza182A showed the highest values 32.5, 31.7, 33.3 and 32.6. Similar results were obtained by Jagadish and Wheeler [3] and Feng *et al.* [7]. Significant variations were obtained among the parental line and their hybrids under different treatments of temperature, this difference are mainly due to the genetic factors [25].

Analysis of Variance: Analysis of variance and mean squares for seedling traits are shown in Table 3 for all genotypes grown at control, low and high temperature. The magnitude of mean squares showed highly significant differences for seedling length and significant differences for Chl. content in both the crosses and lines x testers. Similar results were obtained by Mckenzie *et al.* [26]. On the other hand, results showed insignificant differences for number of leaves and SFW. However, the other sources of variance showed insignificant differences for Chl. content, SDW and water content. Also, SFW and water content were significant for parents. The analysis variance for the seedling and physiological traits under low temperature revealed the presence of significant differences for all sources of variance for seedling length while chlorophyll content was only highly significant for parents. Moreover, seedling fresh weight and water content were highly significant for genotypes, parents and lines but, significant for parents. vs. crosses for the two characters. The crosses showed significant differences for water content. Analysis of variance for high temperature indicated that seedling length there were significance for parents while chl. content was significant for parents. Vs. crosses and SDW was significance for genotypes, crosses and lines. On the other hand, the other characters such as number of leaves, seedling fresh weight and water content were insignificant differences.

General Combining Ability Effects: The estimated values of GCA effects for each line and tester are presented in Tables 4 under control, high and low temperature. Significant differences of GCA effects were showed for all lines in under low temperature. IR58025A and IR70368A showed highly significant positive GCA effect for seedling length with values of 2.23 and 1.32, respectively. Also IR70368A showed significant positive GCA effect for SFW, SDW and water content. On the other hand, the tester's lines, Giza178R and Giza182R gave significant positive GCA effect for seedling length. And Giza182R exhibited highly significant positive GCA effect for SDW. This indicated that Giza182R could be an excellent donor to tolerance low temperature. Similar results were obtained by Cruz *et al.* [5].

Lines IR69625A showed significant positive GCA effects for SFW and SDW under high temperature with values of 0.028 and 0.005, respectively. IR70368A showed highly significant positive GCA effects for number of leaves and SDW. On the other hand, the parental line IR69625A showed significant positive GCA effect for SFW with value of 0.028 and highly significant positive GCA effect for SDW with value of 0.005. These mean that Giza181R was the best parental lines tolerance against high temperature stress.

Table 2: Mean performance for three lines, three taster and their nine F_1 respective crosses grown in growth chamber under control, low (L) and high (H) temperatures

	Seedling Length			No. of Eaves			Seedling fresh weight			Seedling dry weight			Chlorophyll ontent			Water content		
Genotypes	Cont.	L	H	Cont.	L	H	Cont.	L	H	Cont.	L	H	Cont.	L	H	Cont.	L	H
IR58025A	27.7	13.8	16.7	3.56	3.00	3.25	0.190	0.07	0.090	0.027	0.017	0.024	23.00	27.90	32.50	0.160	0.058	0.072
IR69625A	26.2	16.8	16.5	4.00	3.00	3.33	0.240	0.11	0.120	0.038	0.022	0.024	31.80	31.70	31.70	0.200	0.091	0.093
IR70368A	24.7	16.8	17.1	3.63	3.00	3.08	0.170	0.33	0.090	0.034	0.200	0.023	32.50	29.50	30.70	0.140	0.091	0.070
Giza178R	19.9	14.6	20.4	3.93	3.00	3.67	0.180	0.07	0.130	0.035	0.018	0.020	31.70	26.50	30.60	0.150	0.035	0.110
Giza181R	18.7	13.6	10.9	3.36	3.00	3.67	0.130	0.08	0.100	0.024	0.022	0.023	29.30	29.70	30.30	0.108	0.068	0.094
Giza182R	16.9	17.1	18.0	3.73	3.50	3.56	0.140	0.15	0.120	0.077	0.024	0.023	33.80	35.80	30.70	0.068	0.130	0.094
IR58025A X Giza178R	19.4	13.2	18.5	4.00	3.00	3.67	0.230	0.06	0.120	0.037	0.015	0.020	29.10	28.60	31.90	0.190	0.048	0.097
IR58025A X Giza181R	24.5	11.2	19.0	3.50	3.00	3.75	0.120	0.06	0.120	0.023	0.014	0.093	28.40	31.70	30.60	0.093	0.042	0.093
IR58025A X Giza182R	23.6	12.1	17.8	4.00	3.56	3.08	0.160	0.07	0.090	0.031	0.030	0.020	31.50	29.20	31.00	0.130	0.041	0.077
IR69625A X Giza178R	26.9	16.1	16.4	4.00	3.00	3.33	0.220	0.09	0.090	0.039	0.019	0.018	31.60	31.10	31.73	0.180	0.074	0.071
IR69625A X Giza181R	22.5	16.7	15.7	4.00	3.00	3.33	0.160	0.086	0.074	0.023	0.023	0.016	29.70	31.10	32.30	0.140	0.063	0.058
IR69625A X Giza182R	25.3	13.2	17.0	3.67	3.00	3.39	0.163	0.0.86	0.089	0.031	0.023	0.017	32.60	31.10	31.80	0.130	0.063	0.072
IR70368A X Giza178R	24.2	16.9	17.1	3.92	3.00	3.42	0.193	0.103	0.103	0.035	0.020	0.022	33.90	31.10	33.30	0.160	0.083	0.081
IR70368A X Giza181R	27.4	14.3	19.4	3.75	3.33	3.50	0.170	0.104	0.132	0.028	0.023	0.027	36.30	29.80	32.50	0.140	0.082	0.096
IR70368A X Giza182R	25.1	17.9	21.9	3.33	3.50	3.50	0.145	0.010	0.110	0.025	0.022	0.023	22.80	29.30	32.60	0.120	0.880	0.087
LSD 0.05	3.15	1.99	3.82	0.55	0.49	0.55	0.092	0.053	0.053	0.053	0.000	0.000	6.41	4.64	4.35	0.075	0.000	0.053
LSD 0.01	4.25	2.68	5.15	0.75	0.67	0.75	0.120	0.071	0.071	0.071	0.000	0.000	8.65	6.26	5.87	0.101	0.000	0.071

Table 3: Analysis of variance and mean squares estimates of line x tester analysis at the control, low and high temperatures

		Seedling length			No. of leaves			Seedling fresh weight		
Source of variance	df	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
Replication	2	0.34 $^{n-s}$	0.66**	2.89 ^{ns}	0.168 $^{n-s}$	0.04 ^{ns}	0.62*	0.001 $^{n-s}$	0.001 ^{ns}	0.002 ^{ns}
Genotypes	14	45.3 **	11.6**	5.23 ^{ns}	0.176 $^{n-s}$	0.07 ^{ns}	0.13 ^{ns}	0.004 $^{n-s}$	0.002**	0.001 ^{ns}
Parents	5	47.8 **	9.56**	6.58 *	0.172 ^{ns}	0.00 ^{ns}	0.17 ^{ns}	0.004 $^{n-s}$	0.003**	0.000 ^{ns}
Parents.vs.crosses	1	42.4 **	9.15**	2.01 ^{ns}	0.094 ^{ns}	0.106 ^{ns}	0.003 ^{ns}	0.000 $^{n-s}$	01.003*	0.001 ^{ns}
Crosses	8	44.0**	13.5**	4.78 ^{ns}	0.188 ^{ns}	0.125 ^{ns}	0.12 ^{ns}	0.003 $^{n-s}$	0.001	0.001 ^{ns}
Lines	2	51.5**	34.2**	10.05 ^{ns}	0.12 ^{ns}	0.078 ^{ns}	0.056 ^{ns}	0.000 $^{n-s}$	0.003**	0.002 ^{ns}
Testers	2	66.8**	6.74*	1.82 ^{ns}	0.225 ^{ns}	0.078 ^{ns}	0.099 ^{ns}	0.010 ^{ns}	0.000 ^{ns}	0.000 ^{ns}
Lines x testers	4	28.9*	6.06*	3.63 ^{ns}	0.204 ^{ns}	0.171	0.15 ^{ns}	0.002 $^{n-s}$	0.000 ^{ns}	0.000 ^{ns}
Error	28	3.55	1.43	5.204	0.112	0.087	0.11	0.003	0.001	0.001
		Seedling dry weight			Chlorophyll content			Water content		
Source of variance	df	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
Replication	2	0.000 ^{ns}	0.000 ^{ns}	0.000 ^{ns}	25.9 ^{ns}	7.58 ^{ns}	27.6*	0.001 ^{ns}	0.000ns	0.002 ^{ns}
Genotypes	14	0.001 ^{ns}	0.000 ^{ns}	0.0001*	28.6 ^{ns}	13.2 ^{ns}	5.66 ^{ns}	0.004 ^{ns}	0.002**	0.001 ^{ns}
Parents	5	0.001*	0.000 ^{ns}	0.000 ^{ns}	6.49 ^{ns}	31.5**	5.15 ^{ns}	0.006*	0.002**	0.001 ^{ns}
Parents.vs.crosses	1	0.001 ^{ns}	0.000 ^{ns}	0.000	16.2 ^{ns}	0.097 ^{ns}	11.3*	0.000 ^{ns}	0.003**	0.00 ^{ns}
Crosses	8	0.000 ^{ns}	0.03 ^{ns}	0.000*	43.9*	3.38 ^{ns}	5.27 ^{ns}	0.003 ^{ns}	0.001*	0.00 ^{ns}
Lines	2	0.000 ^{ns}	0.000 ^{ns}	0.0001*	6.47 ^{ns}	3.14 ^{ns}	11.4 ^{ns}	0.000 ^{ns}	0.00**	0.001 ^{ns}
Testers	2	0.000 ^{ns}	0.000 ^{ns}	0.000 ^{ns}	19.0 ^{ns}	1.74 ^{ns}	3.07 ^{ns}	0.007 $^{n-s}$	0.000 ^{ns}	0.00 ^{ns}
Lines x testers	4	0.001 ^{ns}	0.000 ^{ns}	0.000 ^{ns}	75.1*	4.31 ^{ns}	3.31 ^{ns}	0.001 ^{ns}	0.000 ^{ns}	0.000 ^{ns}
Error	28	0.001	0.0000	0.000	14.7	7.69	6.77	0.002	0.001	0.001

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

Table 4: Estimates of general combining ability effect (gi) of each line and tester at the control, low and high temperatures

	Seedling length			No. of leaves			Seedling fresh weight		
Parental lines	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
IR70368A	1.81**	2.23**	-0.92 ns	0.037 ns	0.086 ns	0.058 ns	0.0007 ns	-0.021*	0.009 ns
IR70368A	0.89 ns	0.91*	-1.15 ns	0.093 ns	-0.098 ns	-0.089 ns	0.002 ns	0.004 ns	0.028*
IR70368A	-2.71**	1.32**	0.23 ns	-0.13 ns	0.012 ns	0.031**	-0.007 ns	0.0 2*	0.009 ns
Giza178R	2.83**	0.98**	-0.19 ns	0.17 ns	-0.098 ns	0.031 ns	-0.667 ns	0.003 ns	0.000 ns
Giza181R	-0.25 ns	-0.37 ns	0.51 ns	-0.046 ns	0.012 ns	0.086 ns	0.005 ns	-0.001 ns	0.022 ns
Giza182R	-2.59**	0.82*	-0.32 ns	0.23*	0.086 ns	-0.117 ns	0.020*	-0.02*	-0.002 ns
LSD 0.05	1.29	0.82	1.56	0.23	0.20	0.23	0.02	0.02	0.021
LSD 0.01	1.74	1.10	2.10	0.31	0.27	0.31	0.03	0.03	0.029
	Seedling dry weight			**Chlorophyll content**			**Water content**		
Parental lines	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
IR70368A	-0.005 ns	-0.002**	0.0007**	-0.959 ns	-0.43 ns	-1.21 ns	-0.004 ns	-0.021*	0.007 ns
IR70368A	0.008 ns	0.004**	0.005**	0.65 ns	0.67 ns	0.18 ns	0.007 ns	0.004 ns	-0.013 ns
IR70368A	-0.003 ns	0.005**	0.0004**	0.31 ns	-0.25 ns	1.03 ns	-0.002 ns	0.02*	0.006 ns
Giza178R	0.038*	-0.003 ns	-0.002**	0.89 ns	-0.018 ns	0.565 ns	0.032*	0.006 ns	0.002 ns
Giza181R	-0.023 ns	-0.002 ns	0.003**	0.78 ns	0.45 ns	-0.60 ns	-0.018 ns	-0.001 ns	0.002 ns
Giza182R	0.35*	0.005**	-0.002**	-1.679 ns	-0.43 ns	0.036 ns	-0.014 ns	-0.015 ns	-0.003 ns
LSD 0.05	0.037	0.00	0.00	2.62	1.89	2.62	0.031	0.02	0.021
LSD 0.01	0.050	0.00	0.00	3.53	2.55	3.53	0.041	0.03	0.029

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

Specific Combining Ability (SCA) Effects: Estimates of SCA effects for 9 hybrid rice combinations under different temperatures stress are shown in Table 5. Estimates of SCA effects of each F_1 crosses under low temperature identified only one hybrid combinations had significant positive value of SCA effects for seedling length with value of 1.72 for IR69625A/Giza181R. With respect to SCA estimates for number of leaves, SFW, SDW, Chl. content and water content results showed that one hybrid gave significant positive SCA effect with value of 0.35, 0.05, 0.05, 0.05 and 0.05 for IR70368A/Giza182R. This is indicating that the hybrid is an excellent combination for theses traits under low temperature.

With respect to seedling length and no. of leaves only two hybrids showed significant positive SCA effect under high temperature with value of 0.05 and 0.499 for IR70368A/Giza182R and IR58025/Giza182R, respectively. On the other hand three hybrids exhibited positive effect significant for SFW with value of 0.037, 0.088 and 0.040 for IR58025A/Giza181R, IR58025A/Giza1 82R and IR70368A/Giza181R, respectively. But for Chl. and water content the results showed that all crosses were found to be insignificant. Theses results manifested that the hybrids IR58025/Giza182R could be considered as the best combination for no of leaves and SFW, IR70368A/Giza182R for seedling length and IR70368A/Giza181R and IR58025A/Giza181R for SFW under high temperature.

Estimate of Heterosis Effects: The estimates of heterosis from the better parent (BP %) and the mid-parents and (MP %) for seedling characters at different temperature are presented in Tables 6 and 7. The results exhibited that the estimates of heterosis as division of better parents (BP %) under low temperature were significant negative value for seedling length, chl. Content, SFW and water content with percentages -29.1, -18.3, -53.1 and -67.8%, respectively in hybrid IR58025A/Giza182R. Two hybrid combinations showed significant positive values IR58025A/Giza182R with percentages 18.5 and 24% and IR70368A/Giza181R with percentages 11.1 and 3.05% for no. of leaves and SDW, respectively. While under high temperature all crosses were found to be insignificant heterosis (BP %) for seedling length, no. of leaves, SFW, Chl. Content and water content except two hybrids showed significant negative estimates IR69625A/Giza178 with percentage of -19.3% for seedling length and IR58025A/Giza182R with percentage of -13.3% for no. of leaves. But only one hybrid such as IR58025A/Giza181R showed significant positive with

Table 5: Estimates of specific combining ability effect (sij) of each crosses at the control, low and high temperatures

	Seedling length			No. of leaves			Seedling fresh weight		
Crosses	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
IR58025A x Giza178R	0.75ns	0.019ns	-0.002ns	-0.009ns	-0.087ns	0.136ns	0.02ns	-0.002ns	0.006ns
IR58025A x Giza181R	-1.07ns	-0.02ns	-0.005ns	-0.28ns	-0.19ns	0.164ns	-0.03ns	-0.005ns	0.037*
IR58025A x Giza182R	0.34ns	0.009ns	0.006ns	0.29ns	0.28ns	0.499*	0.009ns	0.006ns	0.088**
IR69625A x Giza178R	-0.78ns	-0.006ns	0.0007ns	-0.065ns	0.099ns	-0.0496ns	-0.004ns	0.0007ns	0.0056ns
IR69625A x Giza181R	-2.23*	0.008ns	0.0007ns	0.157ns	-0.012ns	-0.105ns	0.004ns	0.0007ns	-0.0133ns
IR69625A xGiza182R	3.01**	-0.002ns	-0.0015ns	-0.68ns	-0.088ns	0.155ns	0.0004n	-0.0015ns	0.007ns
IR70368A xGiza178R	0.054ns	-0.013ns	0.0007ns	0.074ns	-0.012ns	-0.086ns	-0.016ns	0.0007ns	-0.011ns
IR70368A xGiza181R	3.30**	0.06*	0.004ns	0.12ns	0.21ns	-0.0585ns	0.065*	0.004ns	0.040*
IR70368A xGiza182R	-3.35**	-0.007ns	0.05**	-0.20ns	0.35*	0.145ns	5.009ns	0.05**	0.001ns
LSD 0.05	2.23	1.41	2.70	0.39	0.35	0.39	0.065	0.037	0.037
LSD 0.01	3.01	1.91	3.64	0.53	0.47	0.53	0.087	0.050	0.050
	Seedling dry weight			**Chlorophyll content**			**Water content**		
Crosses	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
IR58025A x Giza178R	-0.0003ns	-0.002ns	-0.0007**	-1.51ns	-0.002ns	0.848ns	0.019ns	-0.002ns	0.005ns
IR58025A x Giza181R	-0.001ns	-0.005ns	0.0015**	-2.048*	-0.005ns	-1.300n	-0.02ns	-0.005ns	0.005ns
IR58025A x Giza182R	0.002ns	0.006ns	-0.0007**	3.56ns	0.006ns	0.452ns	0.009ns	0.006ns	-0.010n
IR69625A x Giza178R	0.0007ns	0.0007ns	0.0015**	-0.52ns	0.0007ns	-0.796n	-0.006n	0.0007ns	0.0018n
IR69625A x Giza181R	-0.004ns	0.0007ns	-0.003**	-2.45ns	0.0007ns	0.972ns	0.008ns	0.0007ns	-0.011s
IR69625A xGiza182R	0.003ns	-0.0015ns	0.0015**	2.937ns	-0.0015ns	-0.176n	-0.002n	-0.0015ns	0.009ns
IR70368A xGiza178R	-0.0004ns	0.0007ns	-0.0007**	2.03ns	0.0007ns	-0.052n	-0.013n	0.0007ns	-0.007n
IR70368A xGiza181R	0.005ns	0.004ns	0.0015**	4.46*	0.004ns	0.329ns	0.06*	0.004ns	-0.006n
IR70368A xGiza182R	-0.005ns	0.05**	-0.0007**	-6.49**	0.05**	-0.276n	-0.007n	0.05**	0.0007n
LSD 0.05	0.037	0.00	0.00	4.53	3.28	3.08	0.053	0.037	0.037
LSD 0.01	0.050	0.00	0.00	6.12	4.42	4.15	0.071	0.050	0.050

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

Table 6: Estimates of heterosis from the better parent (BP %) at the control, low and high temperatures

	Seedling length			No. of leaves			Seedling fresh weight		
Crosses	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
IR58025A x Giza178R	14.3*	20.7ns	-9.25ns	1.69ns	20.7ns	0.00ns	20.7ns	-15.3ns	-8.87ns
IR58025A x Giza181R	-4.63ns	-37.8ns	0.53ns	-1.56ns	-37.8ns	2.27ns	-37.8ns	-37.6*	8.53ns
IR58025A x Giza182R	-8.26ns	-13.0ns	-1.23ns	7.14**	-13.0ns	-13.3*	-13.0ns	-53.1**	-16.6ns
IR69625A x Giza178R	-3.25ns	-9.65ns	-19.3*	0.00ns	-9.65ns	-9.09ns	-9.65ns	-17.7ns	-32.5ns
IR69625A x Giza181R	-14.3*	-33.02*	-17.5ns	-0.00ns	-33.02*	-9.09ns	-33.02*	-20.6ns	-36.2ns
IR69625A xGiza182R	-3.24**	-31.6*	-5.60ns	-8.33ns	-31.6*	-4.69ns	-31.6*	-43.2**	-23.9ns
IR70368Ax Giza178R	-2.22ns	3.57ns	-16.1ns	-0.42ns	3.57ns	-6.82ns	3.57ns	-6.77ns	-20.1ns
IR70368A x Giza181R	-1.58ns	0.49ns	2.70ns	3.21ns	0.49ns	-4.55ns	0.49ns	6.02ns	14.2*
IR70368A x Giza182R	-37.9**	-14.1ns	-7.23ns	-10.7	-14.1ns	-1.56ns	-14.1ns	-38.5*	-5.94ns
LSD 0.05	3.15	0.092	3.82	0.55	0.092	0.55	0.092	0.053	0.053
LSD 0.01	4.25	0.120	5.15	0.75	0.120	0.75	0.120	0.071	0.071
	Seedling dry weight			**Chlorophyll content**			**Water content**		
Crosses	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
IR58025A x Giza178R	20.7ns	-14.7**	-16. 7**	-8.2ns	20.7ns	-1.56ns	20.7ns	-17.3ns	-10.9ns
IR58025A x Giza181R	-37.8ns	-35.1**	-2.78**	-3.07ns	-37.8ns	-11.8*	-37.8ns	-38.4**	-10.6ns
IR58025A x Giza182R	-13.0ns	24.1**	-14.9**	-6.8ns	-13.0ns	-4.41ns	-13.0ns	-67.8 **	-18.3ns
IR69625A x Giza178R	-9.65ns	-13.6 **	-32.6**	-.063ns	-9.65ns	0.08ns	-9.65ns	-18.6ns	-35.1ns
IR69625A x Giza181R	-33.02*	-2.50**	-31.6 **	-6.60ns	-33.02*	1.97ns	-33.02*	-25.0ns	-37.4ns
IR69625A xGiza182R	-31.6*	-5.75**	-29.8**	-3.55ns	-31.6*	0.38ns	-31.6*	-50.3**	-23.4ns
IR70368Ax Giza178R	3.57ns	0.00**	-5.45**	4.31ns	3.57ns	8.47ns	3.57ns	-8.26ns	-25. 8ns
IR70368A x Giza181R	0.49ns	3.05**	17.6**	11.69ns	0.49ns	5.92ns	0.49ns	-10.1ns	13.3ns
IR70368A x Giza182R	-14.1ns	-10.3**	0.73**	-32.54*	-14.1ns	6.00ns	-14.1ns	-43.8 **	-7.84ns
LSD 0.05	0.092	0.00	0.000	6.41	0.092	4.35	0.092	0.053	0.053
LSD 0.01	0.120	0.00	0.000	8.65	0.120	5.87	0.120	0.071	0.071

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

Table 7: Estimates of heterosis from the mid parent (MP %) at the control, low and high temperatures

	Seedling length			No. of leaves			Seedling fresh weight		
Crosses	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
IR58025A x Giza 178R	28.8**	-4.35^{ns}	-0.52^{ns}	6.82^{ns}	0.00^{n-s}	6.02^{ns}	21.1^{ns}	-13.2^{ns}	4.34^{ns}
IR58025A x Giza 181R	10.3^{ns}	-16.0*	6.60^{ns}	1.20^{ns}	0.00^{n-s}	8.43^{ns}	-27.2^{ns}	-31. 9*	14.8^{ns}
IR58025A x Giza 182R	10.6^{ns}	-19.7**	2.28^{ns}	9.76^{ns}	18.5*	-9.39^{ns}	-1.94^{ns}	-37.1*	-8.36^{ns}
IR69625A x Giza 178R	17.0**	2.35^{ns}	-10.7^{ns}	0.84^{ns}	0.00^{ns}	-4.79^{ns}	1.44^{ns}	1.36^{ns}	-29.3*
IR69625A x Giza 181R	-0.13^{ns}	9.37*	-11.7^{ns}	8.68^{ns}	0.00^{ns}	-4.76^{ns}	-13.90^{n}	-11.3^{ns}	-33.6^{ns}
IR69625A x Giza 182R	17.6 **	-22.0**	-1.30^{ns}	-5.17^{ns}	0.00^{ns}	-1.61^{ns}	-14.9^{ns}	-35.0*	-23.9^{ns}
IR70368A x Giza 178R	8.35^{ns}	7.83^{ns}	-8.87^{ns}	3.52^{ns}	0.00^{ns}	1.23^{ns}	8.67^{ns}	13.8^{ns}	-7.17^{ns}
IR70368A x Giza 181R	12.0^{ns}	-6.47^{ns}	7.85*	7.23^{ns}	11.1*	3.70^{ns}	12.6^{ns}	3.99^{ns}	22. 8*
IR70368A x Giza 182R	-26.3 *	-5.09^{ns}	-4.80^{ns}	-9.50^{ns}	0.00^{ns}	5.44^{ns}	-7.58^{ns}	-28. 9^{ns}	5.04^{ns}
LSD 0.05	2.73	1.73	3.30	0.48	0.43	0.48	0.079	0.046	0.046
LSD 0.01	3.68	2.34	4.46	0.65	0.58	0.65	0.11	0.062	0.062

	Seedling dry weight			Chlorophyll content			Water content		
Crosses	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
IR58025A x Giza 178R	17.9^{ns}	-11.7**	-7.87**	6.39^{ns}	5.42^{ns}	4.62^{ns}	21.7^{ns}	-13.7^{ns}	7.27^{ns}
IR58025A x Giza 181R	-9.68^{ns}	-26.4**	-0.87**	17.78^{ns}	9.88^{ns}	-8.63^{ns}	-30.6^{ns}	-33.6*	19.5^{ns}
IR58025A x Giza 182R	-40.4^{ns}	46.9**	-12. 5**	10.92^{ns}	-8.29^{ns}	-1.72^{ns}	15.6^{ns}	-55.6**	-7.21^{ns}
IR69625A x Giza 178R	7.16^{ns}	-4.50**	-25.9 **	-0.47^{ns}	6.89^{ns}	5.14^{ns}	0.26^{ns}	2.99^{ns}	-29.9^{ns}
IR69625A x Giza 181R	-27.5^{ns}	-1.64*	-30.6 **	-2.78^{ns}	0.10^{ns}	4.34^{ns}	-11.2^{ns}	-13.9^{ns}	-34.4^{ns}
IR69625A x Giza 182R	-46.2^{ns}	-1.80**	-28.1**	-0.61^{ns}	-7.97^{ns}	1.96^{ns}	-1.67^{ns}	-42.1**	-22.8^{ns}
IR70368A x Giza 178R	-1.20^{ns}	5.49**	2.36**	5.61^{ns}	10.9^{ns}	12.2*	11.05^{ns}	15.9^{ns}	-9.43^{ns}
IR70368A x Giza 181R	-6.16^{ns}	7.57**	18.0**	17.47^{ns}	0.58^{ns}	6.70^{ns}	17.1^{ns}	3.05^{ns}	24.2^{ns}
IR70368A x Giza 182R	-55.4^{ns}	-1.89**	1.34**	-31.22**	-10.2^{ns}	6.01^{ns}	18.6^{ns}	-34. 4 *	6.07^{ns}
LSD 0.05	0.046	0.000	0.000	5.55	4.02	3.78	0.065	0.046	0.046
LSD 0.01	0.062	0.000	0.000	7.49	5.42	5.08	0.087	0.062	0.062

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

percentage of 14.2% for SFW. For SDW the results showed that the estimates of heterosis (BP%) were highly significant negative for seven hybrids and remaining two hybrids showed highly significant and positive value IR70368A/Giza181R with percentage of 17.6% and IR70368A/Giza182R with percentage of 0.73%. However theses results were in good agreement with those reported by Lee *et al.*[27]. On the other hand, the results in Tables 6 and 7 showed that the estimates of heterosis as deviation of mid parent under high temperature were significant positive for two hybrids IR58025A/Giza182R, IR70368A/Giza181R and IR69625A/Giza181R for no. of leaves and seedling length with percentage of 18.5, 11.1 and 9.37%, respectively. While high significant difference heterosis effect were detected for hybrids combination as (BP %) and the highest with percentage of 46.9% for the hybrid IR58025A/Giza182R. Under high temperature heterosis as (BP%) indicated that two crosses were significant positive such as IR70368A/Giza181R with percentage of 7.85, 22.8 and 18 % for seedling length, SFW and SDW, respectively and IR70368A/Giza178R with percentage of 2.36 and 12.2% for SDW and Chl. content, respectively. As deviation from mid parent value, indicates that all crosses were found to be insignificant for Chl. And water content under low and high temperature, respectively. Similar results were obtained by Manangkil *et al.* [28].

Estimates of Genetic Parameters and Heritability: The estimates of genetic parameters at control, low and temperature for seedling length, number of leaves, chlorophyll content, fresh weight, dry weight, water content were presented in Table 8. Data indicated that the estimates of the non-additive genetic variance (σ^2D) and the relative importance of SCA% for seedling length, no. of leaves and chl. content under control treatment were higher than those of additive genetic variance (σ^2A) and relative importance of GCA. On the other hand, the additive genetic variance and relative importance of GCA% were higher than that dominance genetic variance and the relative importance of SCA% for SFW, SDW and water content. These results were in general agreement with those reported by Akram *et al.* [29] Concerning heritability, the results cleared that the estimated values of heritability in broad sense (h^2b %) for seedling length were high but moderate for No. of leaves and chl.

Table 8: Genetic parameters at the control, low and high temperatures

	Seedling length			No. of leaves			Seedling fresh weight		
Genetic Parameters	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
Additive variance (σ^2A)	6.71	320.3	0.512	0.0111	-0.021	-0.0161	-0.0011.0	0.0003	0.00022
Dominant variance (σ^2D)	8.45	1.54	-0.525	0.031	0.028	0.0133	-0.00033	-0.0003	-0.00033
Environmental variance (σ^2E)	3.55	1.43	5.204	0.112	0.087	0.11	-0.003	0.001	0.001
Genotypic variance (σ^2G)	15.16	321.8	-0.013	0.04211	0.0073	0.029	-0.00143	0.0	-0.00011
Phenotypic variance (σ^2P)	18.71	323.23	5.19	0.15411	0.094	0.139	0.00157	0.001	0.00089
Broad sense heritability (h^2b%)	81.03	99.6	-0.25	27.32	7.77	21.1	-91.2	0.0	-12.5
Narrow sense heritability (h^2n%)	35.86	99.1	9.87	7.21	-21.98	-11.53	-70.2	30.0	24.97
Relative importance of GCA%*	44.26	99.5	-3938.5	26.4	-287.5	-55.5	76.92	0.0	-200
Relative importance of SCA%*	55.74	0.48	4038.5	73.62	383.6	45.86	23.08	0.0	300
	Seedling dry weight			Chlorophyll content			Water content		
Genetic Parameters	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.	Cont.	Low temp.	High temp.
Additive variance (σ^2A)	-0.000222	0.0	0.000011	-13.86	-0.42	0.86	0.00056	0.0	0.00011
Dominant variance (σ^2D)	0.0	0.0	0.0	20.13	-1.127	-1.15	-.000333	-0.0003	0.00033
Environmental variance (σ^2E)	0.001	0.0	0.0	14.7	7.69	6.77	0.002	0.001	0.0010
Genotypic variance (σ^2G)	-0.000222	0.0	0.000011	6.27	1.547	-0.29	0.000222	-0.0003	-0.00022
Phenotypic variance (σ^2P)	0.00078	0.0	0.000011	20.97	6.153	6.48	0.0022	0.00067	0.00078
Broad sense heritability (h^2b%)	-2.9	0.0	100	29.89	-25.14	-4.48	11.1	-0.049	-28.5
Narrow sense heritability (h^2n%)	-2.9	0.0	100	-66.1	-6.83	13.3	2.5	0.0	14.27
Relative importance of GCA%*	1	0.0	100	-221.1	-27.15	-296.55	250	0.0	-50.0
Relative importance of SCA%*	0	0.0	0.0	321.1	-72.85	396.6	-150	100	150.0

content and low for SDW, SFW and water content. However, heritability values in narrow sense (h^2n %) were relatively moderate for seedling length and low for number of leaves, chl. content, SDW, SFW and water content. Similar results were obtained by Li and Rutger [30].

Under low temperature, the data revealed that the additive genetic variance (σ^2A) and relative importance of GCA% for seedling length and SFW were higher than those of dominance SCA%. On the other hand, the dominance genetic variance (σ^2D) and relative importance of SCA% for number of leaves and chl. content were higher than those for additive genetic variance (σ^2A) and relative importance of GCA%. Concerning heritability, the results clearly showed that the estimated values of heritability in broad sense (h^2b %) were high for seedling length but it was low for number of leaves and other studied characters. However, heritability values in narrow sense were relatively high for seedling length and moderate for SFW but low for other studied characters.

The results under high temperature indicated that the estimates of the additive variance (σ^2A) and the relative importance of GCA% at high temperature for all studied characters except number of leaves and water content were higher than those of non-additive genetic variance (σ^2D) and the relative importance of SCA%. On the other hand, the dominance variance (σ^2D) and relative importance of SCA% for number of leaves and water content were higher than those of additive genetic variance and relative importance of GCA%. Concerning heritability, the results cleared that the estimated values of heritability in broad sense (h^2b %) were low for seedling length and moderate for number of leaves and low for chl. content and SFW and water content and high for SDW. However, heritability values in narrow sense (h^2n %), were relatively low for seedling length number of leaves, Chl. content and water content. On the other hand, it was and high for SDW and moderate SFW. The data is in a good an agreement with that reported by Abdelkhalik *et al.* [31] on the partial dominance effects on grain shape traits and seedling characteristics as an explanation for heterosis phenomena. Data supported the concept of using hybrid rice for stress conditions such as low/high temperature at seedling stage. Thus, the results at this study indicated that dominance variance played a major role in the inheritance of these traits and heritability demonstrated for low and high temperature tolerance was

Table 9: G x E Analysis for some parents and hybrids over the three environments

Genotypes	Environment	Seedling length	No. of leaves	Seedling fresh weight	Seedling dry weight	Chlorophyll content	Water content
IR58025A	Cont.	25.73a	4	0.1878	0.02722	32.02	0.1606
	HT	16.78b	3	0.09583	0.024	32.50	0.0718
	LT	13.09b	3	0.07444	0.01667	27.99	0.0578
IR69625A	Cont.	26.2a	4	0.2389	0.03763	31.84	0.2013
	HT	16.47b	3	0.1167	0.02375	31.71	0.0929
	LT	16.86b	3	0.1133	0.02222	31.71	0.0911
IR70368A	Cont.	24.77a	4	0.1692	0.03417	32.57	0.1350
	HT	17.13ab	3	0.0925	0.02292	30.72	0.0696
	LT	16.81b	3	0.1108	0.02	29.52	0.0908
Giza178R	Cont.	19.93	4	0.1867	0.035	31.78	0.1517
	HT	20.35	4	0.1283	0.01942	28.66	0.1089
	LT	14.58	3	0.07083	0.01792	26.51	0.0529
Giza181R	Cont.	18.76	3	0.1328	0.02444	29.32	0.1083
	HT	18.93	4	0.1075	0.02308	30.27	0.0844
	LT	13.66	3	0.0895	0.02183	29.73	0.0677
Giza182R	Cont.	16.93	4	0.1453	0.07708a	33.83	0.0683
	HT	18.05	4	0.1169	0.02264b	30.72	0.0943
	LT	17.08	3	0.1517	0.02417ab	35.78	0.1275
IR58025A x Giza178R	Cont.	29.41a	4	0.2267a	0.03667	29.09	0.1900a
	HT	18.47b	4	0.1169ab	0.02	31.99	0.0969ab
	LT	13.24b	3	0.0631b	0.01528	28.67	0.04778b
IR58025A x Giza181R	Cont.	24.53a	4	0.1167	0.02333	28.44	0.0933
	HT	19.03a	4	0.1167	0.02333	28.68	0.0933
	LT	11.23b	3	0.05583	0.01417	31.71	0.0417
IR58025A x Giza182R	Cont.	23.6a	4	0.1633	0.03111	31.59	0.1322
	HT	17.83ab	3	0.0975	0.02042	31.07	0.0771
	LT	12.11b	4	0.07111	0.03	29.24	0.0411
IR69625A x Giza178R	Cont.	26.99a	4	0.2158	0.03892	31.69	0.1769
	HT	16.43b	3	0.08667	0.016	31.73	0.0707
	LT	16.09b	3	0.09333	0.01917	31.12	0.0742
IR69625A x Giza181R	Cont.	22.45	4	0.16	0.0225	29.68	0.1375
	HT	15.63	3	0.07444	0.01625	32.33	0.0582
	LT	16.69	3	0.09	0.02167	30.75	0.0683
IR69625A x Giza182R	Cont.	25.35a	4	0.1633	0.03083	32.58	0.1325
	HT	17.04ab	3	0.08889	0.01667	31.83	0.0722
	LT	13.24b	3	0.02278	31.06	0.08611	0.0633
IR70368A x Giza178R	Cont.	29.41a	4	0.2267a	0.03667	29.09	0.1900a
	HT	18.47b	4	0.1169ab	0.02	31.99	0.0969ab
	LT	13.24b	3	0.0631b	0.01528	28.67	0.04778b
IR70368A x Giza181R	Cont.	24.53a	4	0.1167	0.02333	28.44	0.0933
	HT	19.03a	4	0.1167	0.02333	28.68	0.0933
	LT	11.23b	3	0.05583	0.01417	31.71	0.0417
IR70368A x Giza182R	Cont.	23.6a	4	0.1633	0.03111	31.59	0.1322
	HT	17.83ab	3	0.0975	0.02042	31.07	0.0771
	LT	12.11b	4	0.07111	0.03	29.24	0.0411

very encouraging and showed that genotypes were stable. It would be indicated that the results obtained in the study were in general agreement with the results reported by Ramalingam *et al.* [32] and El –Mowafi and Abd Elhady [33].

Genotypes over Environment Interactions (GxE): The analysis depended on the variation among the tested traits under different environments as shown in Table 9. Seedling height is considering the most variable trait under the different environments and accordingly can be considered as a good metrological marker for the stability, measurement, if its values are insignificant under the three regime temperature. Most of the indica inbred lines showed stability under the three growth conditions in terms of seedling length which is considered the key element in identifying the stability of the lines. For the hybrids, the most stable hybrids were IR69625A /Giza 181R and IR70368A /Giza 182.

CONCLUSION

It is concluded that cold or high tolerance during seedling stage is important for ensuring fast and uniform establishment of rice crop early in the season. Identifying the most stable rice varieties under the stress conditions is a key element to meet the global warming issues. Hybrid rice can be considered as one of the methods to meet this challenge.

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