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Line x Tester analysis economic traits in Tomato (*Solanum lycopersicum* L.) under high-temperature of Al-Kharj, Saudi Arabia conditions

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Abstract

Three tomato lines (Super Marmande L_1, Peto 86 L_2, Castle Rock L_3) were top-crossed with two testers (Nagcarlang T_1, Super strain B T_2) to produce 6 crosses. The combining ability and nature of gene action were determined for a number of economic traits to heat stress under Al-Kharj, Saudi Arabia conditions. Highly significant differences were found among genotypes (parents and crosses), lines, testers as well as a highly significant lines x testers interaction for most studied traits obtained from the combined data. Most of the top-crosses were significantly taller and higher yielding than both mid and better parent. In this respect, the maximum heterosis from mid and better parent in fruit set % were (32.57 – 29.89), (4.67 – 4.24) and (3.67 – 1.49) for the top-crosses (L_2 x T_2), (L_3 x T_1) and (L_3 x T_2), respectively. The three top-crosses (L_1 x T_1), (L_3 x T_1) and (L_3 x T_2) were the most promising hybrids in fruit yield plant^{-1} with a maximum heterosis of 22.91, 34.08 and 21.64, respectively. Meanwhile, the three top-crosses (L_1 x T_1), (L_1 x T_2) and (L_2 x T_1) were the most promising hybrids in flash thickness with a maximum heterosis of 10.62, 14.36 and 7.89, respectively. The three top-crosses (L_1 x T_1), (L_2 x T_1) and (L_2 x T_2) were the most promising hybrids in No. of branches plant^{-1} with a maximum heterosis of 6.71, 7.53 and 23.02, respectively. Results of GCA effects for each line and tester based on the combined data revealed that line Super Marmande L_1 was good general combiners for all studied traits except Flesh thickness, while line Beto 86 L_2 was good general combiners for flesh thickness only. Tester Nagcarlang T_1 was good general combiners for fruit set and fruit yield plant^{-1}, while, tester Super strain B T_2 was good general combiners for No. of loculus fruit^{-1}, flesh thickness and fruit weight. The highest desirable SCA effects for all studied traits were obtained from the top-crosses (L_1 x T_1), (L_1 x T_2), (L_2 x T_2), (L_3 x T_1) and (L_3 x T_2). These promising top-crosses obtained from (good x good), (good x poor) and (poor x poor) general combiners. The results showed that the both proportional contribution of lines and testers was larger than those of interaction for all studied traits except No. of branches plant^{-1}. The results indicated that the magnitudes of the additive genetic variance (σ^2A) were higher than those of non-additive ones (σ^2D) for the majority of studied traits indicating the importance of additive gene action in the inheritance of these traits. Therefore, additive gene effect was more influenced by heat stress than additive ones. The largest value of broad sense heritability (99.94%) was recorded for Fruit set, while the lowest value (96.60%) was observed for No. of loculus Fruit^{-1}. The estimates of narrow sense heritability ranged from 50.22% to 99.75% for No. of branches plant^{-1} and TSS, respectively. These findings ensure the predominance of additive genetic variance over non-additive one in the inheritance of these traits. These finding support the importance of additive gene action in the inheritance of these traits. Therefore, selection program can be used for improving the economic traits in tomato through subsequent generations.

Keywords: *Solanum lycopersicum* L, General Combining ability, Specific Combining ability, Heterosis, Heat stress.

INTRODUCTION

Tomato plant (*Lycopersicon esculentum*, Mill) is one of the important vegetable crops in Saudi Arabia as well as in the world. Tomato is usually cultivated in the open field in Saudi Arabia during September as the prevailing temperature is suitable for growth and development of the plant. Tomato plants grow rapidly, so expansion in cultivation of the plant can be achieved by sowing the seeds at spring during March, however, tomato plants are relatively sensitive to high temperature stress. Tomato fruit production is influenced by high-temperature stress, despite its capacity to thrive in a variety of climates because increases in day/night temperatures above 26/20 ◦C, respectively, can severely affect fruit setting and output (Lohar and peat 1998). Temperature increases have a deleterious impact on the pollen grain, particularly during the initial stage, resulting in poor pollen germination and reduced pollen tube growth (Raja *et al.*, 2019). High temperatures not only diminish flowering and fruit set on the plant but also impair the development and maturity of the fruit, lowering crop production (Alsamir *et al*., 2021). High temperature is a crucial problem in growing good crops of high temperature sensitive vegetables including tomato. It impairs different morphological criteria (Khalil and Moursy 1983 and Warrag 1999). High temperature affects wide spectrum of both biochemical and physiological responses within the plant cell. These results are expected and described by many researchers especially in the case of growing organs, since all the reactions in the plant already take place rapidly and further rise in temperature might easily disturb the balance (Fisher 1980). Other investigators reported that extreme and variation of high temperature can damage the intermolecular interactions needed for growth (Bita and Gerats 2013). Hybridization or heterosis breeding is considered as one of the tools that enable tomatoes to better cope with climate change, natural disasters, and disease outbreaks (Premalakshme *et al.*, 2005). There is a need for development of different genotypes of tomato crop having better yield to fulfill the demands of the increasing population. Tremendous progress has been achieved with regards to yield and other quality traits of tomato after following hybrid vigour (Kurian *et al.*, 2001; Ahmad *et al.*, 2011). Line × Tester technique is an important tool to calculate both specific and general combining ability (GCA and SCA) and to estimate gene actions of both parents. It is an efficient technique for evaluation of inbred or pure lines. This technique also helps the breeder to isolate the segregating genotypes and to select best genotypes for hybridization procedures (Kempthorne, 1957). Higher GCA variance is indicative of additive gene action while greater SCA variance point out the greater role of non-additive gene action (Fehr, 1993). The present investigation was carried out to understanding the genetic influences governing different characteristics in tomato fruits through Line × Tester analysis under heat stress conditions.

MATERIALS AND METHODS

This study was conducted in Al-Kharj city, Kingdom of Saudi Arabia. Three genotypes were crossed as lines (Super Marmande L_1, Peto 86 L_2, and Castle Rock L_3 (as female) with two as testers (Nagcarlang T_1 and Super Strain B T_2 (as male), in a line x tester method to give 6 F1-hybrids.Genotypes seeds (5 parents and 6 F_1 hybrids) are sown on nursery in Al-Kharj city, Kingdom of Saudi Arabia on February 20, 2017 and February 20, 2018. The temperatures in that area are shown in Fig.1. After about one month, the seedlings were transferred to the permanent land. It was planted on lines with a width of 0.8 m and a distance of 0.40 m between the plant and the other. A completely randomized block design was used in three replications, and a drip irrigation system was used to irrigate the experiment. Each experimental unit contained 9 lines (0.8 m wide and 12 m long with a total area of (7.2 m x 12 m= 86.4 m^2). The total amounts of fertilizer are 200 kg fed^{-1} N, 150 kg fed^{-1} P_2O_5, and 120 kg fed^{-1} K_2O. About half of P_2O_5 and K_2O were applied pre-planting while the remaining amounts were applied through the irrigation systems. In all treatments, uniform fertigation was applied to provide the fertilizer requirement using (N, P, K) liquid fertilizer. All agriculture practices were carried out as recommended for tomato growing in open fields.

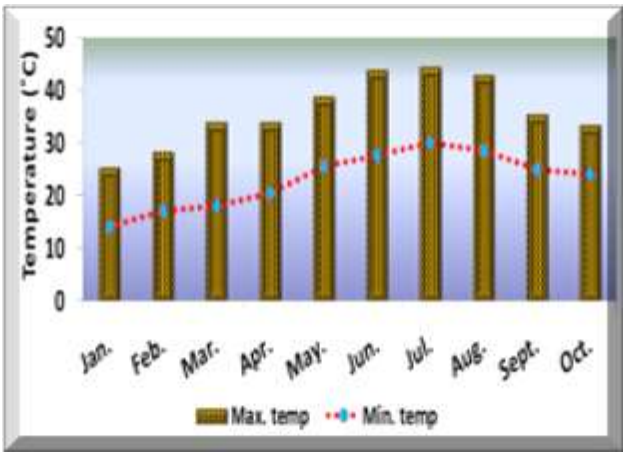

Fig. 1: Temperatures prevailing in Al-Kharj, Kingdom of Saudi Arabia, as average of 2017 and 2018 season (from January to October)

Measured characteristics

At 65 days after transplantation, ten plants were randomly selected from three replications to determine the following characteristics: plant height (cm), number of branches /$plant^{-1}$, Fruit Set (%), Flesh Thickness (mm), Number of Locules, Fruit diameter (cm), Fruit length (cm), Fruit yield $plant^{-1}$ (kg), Total soluble solids (TSS %), and fruit weight (g).

Statistical analysis

Statistical analysis of data obtained during the 2017 and 2018 growing seasons was performed. Top-cross method: Data were subjected to various conventional methods of statistical analysis according to computer program design for statistical analysis (Agrobase, 1993). Using an abroad based on type as a tester, the general combining ability of line x tester analysis is an extension of this method in which several testers are used (Kempthorne,1957). The amount of variance was expressed as a percentage of the average deviation of F_1 from the performance from the parent average (MP) and the best mean values (HP).

RESULTS AND DISCUSSION

Analysis of Variance

Combined analysis of variance for all studied traits is presented in table 2. Highly significant differences existed among genotypes (parents and their 6 top crosses) for all studied traits, revealing a large amount of variability among them, Parents *vs* crosses, as an indication of average heterosis over crosses, were highly significant for all studied traits. Using line x tester analysis, sum squares of crosses was further partitioned into lines (females), testers (males) and (line x tester) interaction. Highly significant differences were obtained among lines for all studied traits. The two testers differed significantly in all studied traits except Plant height (cm) and No. of branches $plant^{-1}$. However, lines x testers interaction was highly significant for all studied traits except Fruit Set (%) and Total Soluble Solids (TSS %), indicating that lines differed in their order performance in crosses with each tester. The results of this study appear to be consistent with what was found by (Shankar *et al.*, 2013). (Saeed *et al.*, 2014), (Dagade *et al.*, 2015), (Khalil *et al.*, 2015), and (Entsar M. I. Abo-Hamada (2017) in tomato crop.

Mean performance

Mean performance of the parental lines, testers and their respective top-crosses for all studied traits are shown in Table 2. The parental line L_1 showed the best mean value for plant height (cm), fruit set (%), fruit weight (g), fruit yield plant^{-1}, No. of locules fruit^{-1}and TSS (%). The parental line L_2 showed the best mean value for No. of branches plant^{-1} and flesh thickness (mm). The parental line L_2 showed the best mean value for No. of branches plant^{-1} and flesh thickness (mm). The results revealed that tester T_1 showed the best mean value for No. of branches plant^{-1}, fruit set (%) and fruit yield plant^{-1}. Meanwhile, tester T_2 exhibited the highest means of plant height (cm), fruit weight (g), No. of locules fruit^{-1} and flesh thickness (mm). Concerning the mean performance of the top-crosses, considerable variation was obtained among them for all studied traits. The top-cross (L_1 x T_1) had the highest mean value for Plant height (cm), Fruit set (%), Fruit yield plant^{-1}, and Total Soluble Solids (TSS %). Meanwhile, the top-cross (L_1 x T_2) had the highest mean value for Plant height (cm), No. of branches plant^{-1}, Fruit weight (g) and No. of locules fruit^{-1}. In addition, the top-cross (L_2 x T_2) had the highest mean value for Flesh thickness (mm). Therefore, these promising top-crosses could be used for further breeding studies to improve the economic traits in tomato

Estimates of heterosis

Estimates of heterosis above mid and better parent for each top cross for all studied traits are presented in table 3. The results showed that 6 and 2 out of 6 top-crosses exhibited desirable heterotic effects against mid and better parents, respectively for plant height (cm). In this respect, the three top-crosses (L1 x T1), (L2 x T1) and (L3 x T1) were the best hybrids over mid parents with the highest positive heterotic values of 8.18, 8.62 and 10.5, respectively, while the top-crosses (L1 x T2) and (L3 x T1) gave the maximum heterotic values of 6.93 and 9.47 versus the better parent. As for No. of branches plant^{-1}, the top-cross (L_2 x T_2) had the highest positive heterotic value of 23.02 and 13.06 from mid and better parents, respectively. Concerning fruit set (%), the results showed that 4 and 3 out of 6 top-crosses exhibited desirable heterotic effects against mid and better parents, respectively. The maximum heterosis values above mid and better parents in fruit set (%) were (32.57 – 29.89), (4.67 – 4.24) and (3.67 – 1.49) for the top-crosses (L_2 x T_2), (L_3 x T_1) and (L_3 x T_2), respectively. Respecting to fruit weight (g), 3 and 1 out of 6 top-crosses exhibited desirable heterotic effects against mid and better parents, respectively. In this respect, the three top-crosses (L_1 x T_1), (L_1 x T_2) and (L_2 x T_1) were the best hybrids over mid parents with the highest positive heterotic values of 14.48, 37.14 and 16.29, respectively, while the top-cross (L_1 x T_2) gave the maximum heterotic values of 8.05 versus the better parent. Concerning Fruit yield plant^{-1}, the results showed that 3 and 3 out of 6 top-crosses exhibited desirable heterotic effects against mid and better parents, respectively. The maximum heterosis values above mid and better parents in fruit yield plant^{-1} were (22.91 – 6.2), (34.08 – 13.2) and (21.64 – 18.84) for the top-crosses (L_1 x T_1), (L_3 x T_1) and (L_3 x T_2), respectively. As for No. of locules fruits^{-1}, the top-cross (L_3 x T_1) had the highest positive heterotic value of 8.07 and 5.01 from mid and better parents, respectively. Concerning flash thickness (mm), 4 and 3 out of 6 top-crosses exhibited desirable heterotic effects against mid and better parents, respectively. The maximum heterosis values above mid and better parents in flash thickness (mm) were

(10.62 –6.97), (14.36 – 2.50) and (7.89 – 2.77) for the top-crosses (L_1 x T_1), (L_1 x T_2) and (L_2 x T_1), respectively. Regarding to TSS (%), 5 and 1 out of 6 top-crosses exhibited desirable heterotic effects against mid and better parents, respectively. In this respect, the three top-crosses (L_1 x T_1), (L_1 x T_2) and (L_3 x T_1) were the best hybrids over mid parents with the highest positive heterotic values of 5.90, 6.51 and 4.51, respectively, while the top-cross (L_1 x T_1) gave the maximum heterotic values of 1.96 versus the better parent. Heterosis was also reported by several investigators for economic traits in tomatoes (Singh and Asati, 2011; Shalaby, 2013; Kumar *et al.*, 2013; Shankar *et al.*, 2013; Kalenahalli and Gowda, 2013 and Entsar, 2017). In general, the results showed that the majority of the top-crosses were significantly taller and higher-yielding than both mid and better parents which reflects the important role of non-additive genetic variance in the inheritance of these traits.

General Combining ability (GCA)

Estimates of general combing ability effects (gi) of each line and tester based on the combined data for all studied traits are presented in table 4. Concerning the studied traits, the parental line (L_1) was considered to be excellent general combiners for all studied traits except Flesh Thickness (mm). While the parental line (L_2) was considered to be excellent general combiners for Flesh Thickness (mm), whereas it was poor general combiner for the other studied traits. The results revealed that tester (T_1) proved to be good general combiner for Fruit Set (%) and Fruit Yield Plant^{-1}, whereas it was poor general combiner for the other studied traits. However, tester (T_2) proved to be good general combiner for Fruit Weight (g), No. of Locales Fruits^{-1} and flesh Thickness (mm), whereas it was poor general combiner for the other studied traits. It is interesting to notice that lines (L_1) and (L_2) and testers (T_1) and (T_2) possessed more desirable additive genes for most studied traits. These promising lines and testers could be utilized in tomato breeding program to improve these traits.

Contribution of lines (female), testers (male), and their interaction to total variance

The contribution of lines (female), testers (male), and their interaction to total variance was presented in Table for all traits and most important traits were shown in Fig. 2) . The proportional contribution of lines was larger than that of testers for all traits except for fruit set percentage. Furthermore, the contribution of lines was larger than that of lines x testers interaction in all characters except for number of branches and yield indicating the importance of selection of lines for hybridization. The contribution of line x tester was about 63.6 and 40% for number of branches yield, respectively depicting the importance of non-additive type of gene action. These results are in accordance with those reported by Mahmood *et al.* (2021) and Ullah *et al.* (2019).

Specific combining ability (SCA)

Estimates of specific combining ability effects (S_{ij}) of each top-cross from the combined data for all studied traits are given in table 5. The results showed that the studied traits exhibited significant specific combining ability effects in most cases either positive or negative signs. Out of 6 top-crosses 2, 2, 2, 1, 2, 3, 1 and 2 towards tallness (cm), high No. of Branches Plant^{-1}, high Fruit Set (%), high Fruit Weight, high Fruit Yield Plant^{-1}, high No. of Locules Fruit^{-1}, high Flesh Thickness (mm) and high TSS (%), respectively. The highest desirable SCA effects for all studied traits were obtained from the top-crosses (L_1 x T_1), (L_1 x T_2), (L_2 x T_2), (L_3 x T_1) and (L_3 x T_2).. It could be observed that the promising top-crosses in all studied traits were obtained from (good x good), (good x poor) and (poor x poor) general combiners. For instance, in the case of fruit set

(%) the best top-crosses were a result of crossing good x good general combiner (L_1 x T_1), good x poor general combiners (L_1 x T_2. L_2 x T_1 and L_3 x T_1) and poor x poor general combiner (L_2 x T_2 and L_3 x T_2). Consequently, it is not necessary that parents having high estimates of GCA effects would also give high estimates of SCA effects in their respective crosses. For instance, in the case of fruit set (%), the top-cross (L_1 x T_1) which including two good general combiners showed low SCA effects. On the contrary, the top-cross (L_2 x T_2) involving two poor general combiners give the highest SCA effect value for the No. of Branches plant^{-1} and Fruit Yield plant^{-1} traits which might be due to the genetic diversity between these parents. Generally, the promising top-crosses which exhibited desirable SCA effects, showed also high useful heterosis as previously mentioned for all studied traits. This finding indicates that non-additive gene action played an important role in the expression of these traits. Contribution of lines (female), testers (male), and their interaction to total variance.

The contribution of lines (female), testers (male), and their interaction to total variance was presented in Table 6 for all studied traits and Fig 2 for most important traits. The results showed that the both proportional contribution of lines and testers was larger than those of interaction of L X T for all studied traits except No. of branches plant^{-1}. Moreover, the result indicated that additive genetic variance was larger than those of non-additive genetic variance for all studied traits except No. of branches plant^{-1}.

Genetic parameters

The estimates of genetic parameters for all studied traits are presented in Table 6. The results indicated that the magnitudes of the additive genetic variance (σ^2A) were higher than those of non-additive ones (σ^2D) for the majority of studied traits indicating the importance of additive gene action in the inheritance of these traits. Therefore, additive gene effect was more influenced by heat stress than additive ones. These finding support the importance of additive gene action in the inheritance of these traits. Therefore, selection program can be used for improving the economic traits in tomato through subsequent generations. The estimates of broad sense heritability were higher than those of narrow sense for all studied traits. The largest value of broad sense heritability (99.94%) was recorded for Fruit set, while the lowest value (96.60%) was observed for No. of loculus Fruit^{-1}. The estimates of narrow sense heritability ranged from 50.22% to 99.75% for No. of branches plant^{-1} and TSS, respectively. These findings ensure the predominance of additive genetic variance over non-additive one in the inheritance of these traits. These results are agree with those obtained by (El-Gendy and El-Sherbeny 2005, Pal and Sabesan2009, El-Gendy *et al.*, 2012, Reddy *et al.*, 2012, Solankey et al. 2012, Reedy *et al.*, 2013, Hamad *et al.*, 2015, Verma and Sood 2015 and Paul *et al.*, 2017)

Table (1) The combined analysis of variance for tomato studied traits

S.O.V.	df	Plant Height (cm)	No. of Branches Plant^{-1}	Fruit Set (%)	Fruit Weight (g)	Fruit Yield Plant^{-1} (Kg)	No. of Locules Fruit^{-1}	Flesh Thickness (mm)	TSS (%)
Replications	2	0.48	0.0499	2.09	0.48	0.001	0.023	0.005	0.022
Genotypes	10	113.2**	0.765**	449.5**	825.9**	0.761**	1.097**	0.642**	0.275**
Parents (P)	4	191.3**	1.029**	357.6**	1754.5**	1.03**	2.05**	1.07**	0.346**
Crosses (C)	5	47.47**	0.359**	181.5**	239.8**	0.677**	0.51**	0.302**	0.20**
P *vs* C	1	129.3**	1.74**	216**	42.94**	0.100**	0.213*	0.652**	0.374**
Lines (L)	2	103.9**	0.325**	131.3**	535.4**	0.392**	0.890**	0.464**	0.473**
Testers (T)	1	0.122	0.004	624.2**	516.4**	0.457**	0.320**	0.396**	0.043**
L×T	2	14.7**	0.571**	10.36	79.7**	0.406**	0.224**	0.092**	0.0008
Error	20	1.046	0.012	0.292	3.448	0.007	0.036	0.017	0.0006

*, ** Significant at 5% and 1% level, respectively

Table (2) Mean performance of parental lines, testers and their 6 top-crosses for all studied trait

Genotypes	Plant Height (cm)	No. of Branches Plant^{-1}	Fruit Set (%)	Fruit Weight (g)	Fruit Yield Plant^{-1} (Kg)	No. of Locules Fruit^{-1}	Flesh Thickness (mm)	TSS (%)
Cross								
L1xT1	76.44	6.49	94.50	77.68	3.42	4.18	3.73	5.20
L1xT2	76.44	7.21	83.06	96.79	2.51	4.30	4.26	5.13
L2xT1	66.68	6.72	86.00	67.39	2.69	3.13	4.51	4.77
L2xT2	69.56	6.55	76.66	74.43	2.75	3.84	4.55	4.68
L3xT1	73.70	6.62	87.43	67.84	2.51	4.01	3.96	4.71
L3xT2	70.32	6.16	72.87	73.83	2.40	3.99	4.30	4.58
Line								
L1	79.47	6.38	63.95	92.98	2.13	5.30	3.26	5.10
L2	62.36	6.78	60.84	65.37	1.81	3.45	4.40	4.23
L3	73.85	6.52	60.44	76.02	1.70	4.55	3.86	4.38
Tester								
T1	61.85	5.78	86.47	30.61	2.42	3.40	3.49	4.72
T2	63.54	5.35	64.23	75.73	1.31	3.66	4.67	4.72
LSD	1.74	0.19	0.62	3.16	0.143	0.32	0.22	0.03

Table (3): Heterosis percentage over MP and BP for studied traits in tomato

Crosses	Plant Height (cm)		No. of Branches Plant^{-1}		Fruit Set (%)		Fruit Weight (g)	
	MP	HP	MP	HP	MP	HP	MP	HP
L1XT1	8.18**	-3.82**	6.71**	1.72**	15.79**	-1.02*	14.48**	-23.91**
L1XT2	7.37**	6.93**	6.95**	-0.93*	-12.68**	-24.32**	37.14**	8.05**
L2XT1	8.62**	-0.21	7.53**	1.43**	-1.97**	-16.26**	16.29**	-18.44**
L2XT2	6.89**	-3.82**	23.02**	13.06**	32.57**	29.89**	-3.46**	-12.42**
L3XT1	10.5**	9.47**	8.00**	-3.44**	4.67**	4.24**	-3.03**	-17.48**
L3XT2	2.37**	-4.78**	3.73**	-5.62**	3.67**	1.49*	-2.69**	-2.88**
Crosses	**Fruit Yield Plant^{-1} (kg)**		**No. of Locales Fruits^{-1}**		**Flesh Thickness (mm)**		**TSS (%)**	
	MP	HP	MP	HP	MP	HP	MP	HP
L1XT1	22.91**	6.2**	-3.83**	-21.02**	10.62**	6.97**	5.90**	1.96**
L1XT2	-27.48**	-50.3**	-8.56**	-9.18**	14.36**	2.50**	6.51**	0.99
L2XT1	-16.75**	-36.9**	0.92	-11.79**	7.89**	2.77**	3.44**	-0.35
L2XT2	-2.75*	-15.3**	-4.02**	-18.88**	7.36**	-8.85**	4.41**	0.46
L3XT1	34.08**	13.2**	8.07**	5.01**	0.22	-2.64**	4.51**	-0.85
L3XT2	21.64**	18.84**	-2.68*	-12.23**	0.78	-7.99**	0.81	-2.83**

*, ** Significant at 5% and 1% level, respectively.

Table (4) Estimates of general combining ability effects (g_i) of each line and tester from combined data for all studied traits.

Genotypes	Plant Height (cm)	No. of Branches Plant^{-1}	Fruit Set (%)	Fruit Weight (g)	Fruit Yield Plant^{-1} (Kg)	No. of Locules Fruits^{-1}	Flesh Thickness (mm)	TSS (%)
Lines								
L1	4.25**	0.23**	5.36**	10.9**	0.25**	0.33**	-0.22**	0.32**
L2	-4.07**	0.01	-2.09**	-5.4**	0.01	-0.42**	0.31**	-0.12**
L3	-0.18	-0.24**	-3.27**	-5.49*	-0.26**	0.09	-0.09	-0.20**
S.E (gca)	0.42	0.04	0.54	0.76	0.03	0.08	0.05	0.03
S.E.(gi-gj) line	0.59	0.06	0.77	1.07	0.05	0.11	0.08	0.05
Testers								
T1	0.08	-0.02	5.89**	-5.36**	0.16**	-0.13*	-0.15**	0.05
T2	-0.08	0.02	-5.89**	5.36**	-0.16**	0.13*	0.15**	-0.05
S.E.(gca)	0.34	0.04	0.44	0.62	0.03	0.06	0.04	0.03
S.E. (gi-gj) tester	0.48	0.05	0.63	0.88	0.04	0.09	0.06	0.04

*, ** Significant at 5% and 1% level, respectively.

Table (5) Estimates of specific combining ability effects (S_{ij}) of each top-cross from the combined data for all studied traits.

Item	Plant Height (cm)	No. of Branches Plant^{-1}	Fruit Set (%)	Fruit Weight (g)	Fruit Yield Plant^{-1} (Kg)	No. of Locules Fruit^{-1}	Flesh Thickness (mm)	TSS (%)
L1xT1	-0.346**	-0.081	-0.011	0.077	-0.171	0.296**	-0.113	-4.197**
L1xT2	0.346**	0.081	0.011*	-0.077	0.171	-0.296**	0.113	4.197**
L2xT1	0.101	-1.524**	-0.002	-0.220*	-1.221**	-0.192**	0.132	1.839
L2xT2	-0.101	1.524**	0.002	0.220*	1.221**	0.192**	-0.132	-1.839
L3xT1	0.246**	1.604**	0.013**	0.143	1.391**	-0.104*	-0.018	2.358*
L3xT2	-0.246**	-1.604**	-0.013**	-0.143	-1.391**	0.104*	0.018*	-2.358*
S.E(sca effects)	0.063	0.590	0.048	0.110	0.312	0.048	0.075	1.072
S.E. (sij-sil)	0.089	0.835	0.068	0.155	0.441	0.068	0.106	1.516

*, ** Significant at 5% and 1% level, respectively.

Table (6) Contribution of lines, testers, and their interaction and genetic components for studied tomato traits.

Item	Branches	Plant height (cm)	TSS	No. of Locules	Fruit set %	yield/plant (kg)	Flesh Thickness (mm)	Fruit weight
Contribution (%) of lines, testers, and their interaction								
Line	36.19	87.55	95.48	69.84	28.94	38.15	61.60	61.31
Tester	0.24	0.05	4.35	12.55	68.78	22.26	26.26	29.57
LxT	63.57	12.40	0.17	17.61	2.28	39.59	12.14	9.12
Contribution % of lines, testers, and their interaction for most important traits								
Genetic components								
Additive (σ^2A)	0.19	25.69	0.11	0.29	170.0	0.27	0.20	249.1
Dominance (σ^2D)	0.19	4.55	0.0001	0.06	3.36	0.13	0.02	25.41
σ^2A/σ^2D	1.03	5.64	1218	4.69	50.65	2.06	8.06	9.80
H^2_{Bs}	98.97	98.86	99.84	96.60	99.94	99.42	96.97	99.58
H^2_{Ns}	50.22	83.97	99.75	79.63	98.01	66.93	86.26	90.36

CONCLUSION

Through the results of the study, the line Supermarmande and the tester Nagcarlang, as well as Superstrain B, demonstrated the greatest favorable impacts for most of the important traits under heat stress, according to this study. As a result, their parents may be useful in future breeding programs. Nagcarlang x Supermarmand, Nagcarlang x Castel Rock, and Superstrain B x Peto86 showed substantial SCA effects for both fruit set and yield, as well as most characteristics under heat stress, among all crosses. As a result, these hybrids will be able to be utilized in future breeding programs.

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الملخص العربى

استخدام التهجين القمى بين سلالات من الطماطم لتحليل بعض الصفات الاقتصادية تحت ظروف الحرارة العالية فى منطقة الخرج بالمملكة العربية السعودية

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اجريت التهجينات بين ثلاثة سلالات طماطم هم (Super Marmande L1 و Peto 86 L2 و Castle Rock L3) مع اثنين من سلالات مختبره من الطماطم هما (Nagcarlang T1 و Super Strain B T2) وذلك لإنتاج 6 تهجينات عن طريث التهجين القمى. تم تحديد القدرة على التالف بين السلالات المستخدمة وطبيعة الفعل الجيني لعدد من الصفات الاقتصادية للإجهاد الحراري تحت ظروف منطقة الخرج بالمملكة العربية السعودية. وقد اظهرت النتائج ما يلى تم العثور على فروق ذات معنوية و دلالة إحصائية بين الطرز الوراثية (الاباء و الهجن) ، وكذلك بين السلالات ، و السلالت المختبرة وكذلك التفاعل بين السلالات × والسلالات المختبرة وان هناك قروق معنوية عالية الدلالة لمعظم الصفات المدروسة التي تم الحصول عليها من البيانات المجمعة. كما كانت معظم التهجينات المتخصل عليها اعطت نباتات طوياة بكثير وذات إنتاجية أعلى من كل من متوسط الابوين او احسن الاباء. في هذا الصدد ، كان الحد الأقصى من التغاير من متوسط الاباء وافضل الاباء في نسبة العقد المئوية ٪ (32.57 - 29.89) ، (4.67 - 4.24) و (3.67 - 1.49) والهجن ((L2 × T2، L3 × T1)) و (L3 x T2) على التوالي. وكانت التهجينات الثلاثة فى التهجين القمى (L1 x T1) و (L3 x T1) و (L3 x T2) هي أكثر أنواع الهجين الواعدة في نبات لمحصول الثمار بحد أقصى تغاير قدره 22.91 و 34.08 و 21.64 على التوالي. وفي الوقت نفسه ، كانت التهجينات الثلاثة فى التهجين القمى (L1 x T1) و (L1 x T2) و (L2 x T1) هي التهجينات الواعدة في سمك اللحم للثمار بحد أقصى من التباين 10.62 و 14.36 و 7.89 على التوالي. كانت التهجينات الثلاثة فى التهجين القمى (L1 x T1) و (L2 x T1) و (L2 x T2) هي الهجين الواعدة في عدد الفروع على النبات بحد أقصى 6.71 و 7.53 و 23.02 على التوالي. كما أظهرت نتائج تأثيرات القدرة العامه على التالف لكل خط وسلالة مختبرة ان بناءً على البيانات المجمعة أن السلالة Super Marmande L1 كان عبارة عن مزيج عام جيد لجميع الصفات المدروسة باستثناء صفة سمك اللحم ، بينما كان السلالة Beto 86 L2 عبارة عن أدوات دمج عامة جيدة لصفة سمك اللحم فقط. وكذلك كان السالة المختبرة Nagcarlang T1 عبارة عن أدوات جيدة لدمج لمجموعة صفات الثمار محصول الثمار ، بينما كان السلالة Super Strain B T2 عبارة عن أدوات دمج عامة جيدة لكل من سمك اللب ووزن الثمار. وقد تم الحصول على أعلى تأثيرات القدرة الخاصة على التالف المرغوبة لجميع الصفات المدروسة من التهجينات العلوية (L1 x T1) و (L1 x T2) و (L2 x T2) و (L3 x T1) و (L3 x T2). تم الحصول على هذه التهجينات العلوية الواعدة من (جيد × جيد) و (جيد × ضعيف) و (ضعيف × ضعيف). أظهرت النتائج أن كلا من المساهمة النسبية للخطوط والاختبارات كانت أكبر من تلك الخاصة بالتفاعل لجميع الصفات المدروسة باستثناء الرقم. مصنع الفروع -1. أشارت النتائج إلى أن مقادير التباين الجيني الإضافي (σ2A) كانت أعلى من تلك الخاصة بالغير مضافة (D2) لغالبية الصفات المدروسة مما يدل على أهمية عمل الجين الإضافي في وراثة هذه الصفات. لذلك ، كان تأثير الجينات المضافة أكثر تأثراً بالإجهاد الحراري من تأثير الجينات المضافة. تم تسجيل أكبر قيمة للوراثة بالمعنى الواسع (99.94٪) لمجموعة الفاكهة ، بينما سجلت أقل قيمة (96.60٪) لمجموعة الفاكهة. من loculus Fruit-1. تراوحت تقديرات الوراثة بالمعنى الضيق من 50.22٪ إلى 99.75٪ للرقم. من فروع المصنع -1 و المواد الصلبة الذائبة على التوالي. تضمن هذه النتائج غلبة التباين الجيني الإضافي على التباين غير الإضافي في وراثة هذه الصفات. تدعم هذه النتائج أهمية عمل الجين الإضافي في وراثة هذه الصفات. لذلك ، يمكن استخدام برنامج الانتقاء لتحسين الصفات الاقتصادية في الطماطم عبر الأجيال المتلاحقة.