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GENE ACTION AND COMBINING ABILITY IN TOMATO (*Lycopersicon esculentum* MILL.) BY LINE X TESTER ANALYSIS

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ABSTRACT

This investigation was conducted to study the possibility of improving some tomato traits. In this respect, during successive early summer seasons of 2008 – 2010 at Zifta distract, Middle- Delta Region, a line x tester analysis was made in tomato (*Lycopersicon esculentum* Mill.) with eleven femal parents (breed lines) and three male parents (testers) to determine the components of genetic variance, gene action and combining ability effects for some growth and fruit characters. All studied traits, i.e., plant height, main stem length, number of primary branches and leaves, early and total yield, as well as, average fruit weight, firmness, total soluble solids (TSS%) and vitamin C content of fruit have closer values of σ^2g and σ^2p. The G.C.V. and V.C.V%, which was confirmed by the estimated of G.C.V./P.C.V. ratios (ranged from 0.91 to 0.99) and broad sense heritability (h^2bs) values (ranged from 0.85 to 0.98), suggesting less effect of environmental and the large portion of σ^2p was due to the σ^2g on these traits.

The magnitude of variance due to general and specific combining abilites were highly significant indicating the importance of the additive (σ^2A) and non-additive (σ^2D) gene actions. However, the ratios of σ^2GCA/ σ^2SCA (<1) and σ^2A/σ^2D (<1) revealed the preponderance of non-additive variance in the inheritance of all the studied traits. The estimated average degree of dominance (0.76 and 0.90) revealed partial and complete dominance for average fruit weight and TSS % content, respectively, while revealed over-dominance (>1) for the remaining traits. The parental lines G.16, S.65, G.30 and the tester G.19 were found to be the most desirable general combiner (they possessed dominant genes) for seven, six, five and six traits, respectively. The cross combinations S.60 x G.19, S.125 x G. 19, G.30 x SSB and G.30 x Peto 86 considered the best specific combinations since showed significant SCA values for five traits. The results also suggested the possibility of improvement of these tomato traits through recurrent selection and hybrid breeding program.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is an important and widely grown solanaceous vegetable crop around the world including tropical, sub-tropical and temperate regions. The hybrid cultivars in tomato have generated increased interest among the breeders for the last few years. Cultivation of F_1 tomato hybrids in developed countries is primary reason of their higher productivity per unit area since they preferred over open pollinated varieties due to their higher yield and good quality. The genetic improvement of crop plants and exploitation of heterosis requires the selection of suitable parents and cross-combinations. Selection of the superior parents on the basis of varietal evaluation trials only is not a sound procedure, since these may not necessarily transmit their superior characters in hybrid combinations, but should be chosen on the basis of their combining ability. Combining ability has a prime importance in plant breeding since it provides information for the selection of parents and nature and magnitude of involued gene action. The variance of general combining ability (GCA) includes additive and additive x additive portions, while specific combining ability (SCA) includes the non-additive genetic portion. Therefore, combining ability is important in the development of breeding procedures and it is of notable use in crop hybridization either to exploit heterosis or to combine the favorable fixable genes which may be used for selection programes.

The line x tester analysis has appeared to be good one of the most appropriate approaches in preliminary screening of the materials for combining ability effects and variances since it can evaluate relatively more number of germplasm line at a time and not only evaluates the parents and crosses with respect to their combining abilities but also provides information regarding the suitable parents and breeding methodology being adopted for improving crop plants.

High values for genotypic coefficient of variation (GCV%) compared with the phenotypic coefficient of variation (PCV%) and high heritability in broad-sense (h^2BS) for plant height, number of primary branches, total yield, average fruit weight and ascorbic acid content were observed earlier by Asati *et al.* (2008), Anjum *et al*. (2009) and Suarma *et al*. (2009).

The magnitude of variance due to general specific combining ability (σ^2GCA & σ^2SCA) effects were previously found highly significant indicating the importance of both additive and non-additive gene action with the prevalence of a non-additive gene effect (σ^2GCA/ σ^2SCA<1) by several investigators for tomato plant fruit characteristics. Among of them were Amin *et al*. (2001), EL-Gazar *et al*. (2002 a & b), Hannan *et al,* (2007), Saidi *et al.* (2008) and Sekhar *et al*. (2010) for plant height, number of branches per plant and total yield per plant. The same mode of inheritance of average fruit weight was also reported by Garg *et al*. (2008), Saidi *et al.* (2008), and Saleem *et al*. (2009). Likewise, the importance of additive and non-additive gene actions in the inheritance of fruit firmness, total soluble solids (TSS%) content and ascorbic acid (vitamin C) content were established earlier by Bhatt *et al.* (2001), EL-Gazar *et al.* (2002a) and Garg *et al.* (2008). They also reported the predominance of non-additive gene action for the previous traits in their studies.

In Egypt, most of the area of tomato crop nowadays is still under F_1 hybrids which their seeds are imported form developed countries. At the same time little actual breeding efforts have been made for genetic improvement, as well as, F_1 hybrid seeds production compared with their made for field crops. Therefore, there is dire need for developing high yielding tomato hybrids or suitable true breeding varieties. In present studies efforts were made to gain information on the mode of inheritance of some desirable characters and to identify suitable breeding lines having good combining ability effects for developing local tomato hybrids and / or selection of suitable genotypes in segregating generations.

MATERIALS AND METHODS

This investigation is a continuation for a breeding programme started in 1997, aiming to develop some new tomato lines and hybrids with high productivity and quality (Kansouh, 2002). The present study was conducted from 2008 to 2010 at Kafr-Farses, Zifta district, Gharbia governorate. The used parental lines in this study were chosen from the mentioned original programme. Eleven lines, i.e., S.2, S.15, S.60, S.65, S.80, S.106, S.125, G.5, G.16, G30 and RIG.10 were used as female parents; and the line G.19 in addition to the cultivars Super strain B (SSB) and Peto 86, were used as male parents in a line x tester mating design. In the early summer season of 2008, the parents (lines and testers) were grown and seeds of the 33 F_1 top crosses were produced. The obtained F_1 hybrids and their parents were evaluated in the two successive summer seasons of 2009 and 2010. The seedlings were transplanted on February 15th in a randomized complete blocks design with three replicates. Each plot consisted of two rows, 1m wide and 6m long, and the plants were spaced at 40 cm. part. Routine cultural practices, similar to those used in tomato commercial production, were done as needed.

Data for plant height (cm.), main stem length (cm.), number of primary branches and leaves per plant, were recorded at the end of the flowering stage, For six plants per plot. Early yield (kg/plant) as the yield of the first three pickings, where all the plants gave at least one mature fruit. Total yield as the total weight (kg/plant) of all harvest mature fruits. Average fruit weight (gm.) by dividing the total fruit weight by total fruit number. Fruit firmness was measured by using a needle type pocket penetrometer. The percentage of total soluble solids (TSS %) content in fruit juice was determined by a hand refractometer. Ascorbic acid (vitamin C) content as mg./100 gm. fresh fruit weight, was determined by titration 2, 6 dichlorophenol - indophenol blue dy (Cox and Pearson, 1962). Data were recorded during the two seasons of 2009 and 2010, then the combined data over the two seasons were calculated and statistically analyzed. The statistical analysis was include analysis of variance, component of variance (Coefficient of variance, genotypic and phenotypic coefficient of variation), combining ability analysis, component of genetic variance (additive variance, σ^2A and dominance variance, σ^2D) were done as reported by Kempthorne (1957) and Singh and Chaudhary (1995), Degree of dominance was made according to Patel *et al*. (2004).

RESULTS AND DISCUSSION

A. Analysis of variance:

The analysis of variance for combining ability (Table 1&2), indicated that, the mean squares for the parents, hybrids, parents vs crosses contrast (Pvs C) and lines as well as testers and their interaction were highly significant for all the character studied, indicating a wide range of variability among the genotypes for all the traits. The lines expressed greater magnitude of mean squares than testers for number of leaves, total yield and fruit firmness, but was lower in magnitude for the remaining studied traits. However, both lines as well as testers mean square values were higher in magnitude than those of lines x testers interaction for all the studied traits, indicating that lines and testers were highly divergent which justifies the choice of these materials. The parents vs crosses (Heterosis) mean square which observed highly significant for all the studied traits indicated the expression of heterotic effects. In this respect, obtained results were in agreement with earlier reports of Sharma *et al*. (1999) for total yield, average fruit weight and TSS% content; Amin *et al*. (2001), for plant height, number of branches and Joshi *et al*. (2005) for fruit firmness. Also, our data were in agreement with the results of Garg *et al.* (2008) and Mondal *et al.* (2009) who found that, parents vs hybrids mean square values were significant indicating considerable amount of average heterosis reflected in the hybrids for same studied traits.

Table (1): Analysis of variance, coefficient of variance (C.V%), components of variance, heritability and components of genetic variance for some plant characteristics.

S. O. V.	Plant height	Main stem length	No. of branches	No. of leaves	Early Yield	Total yield
	Mean squares					
Entries	159.23**	244.09**	3.38**	436.17**	2.06**	2.77**
Parents (P)	223.04**	247.01**	3.40**	595.08**	0.86**	1.99**
Crosses (C)	119.49**	231.99**	2.17**	307.90**	1.77**	2.25**
Pus C (Heterosis)	601.38**	593.52**	41.99**	2475.20**	26.34**	29.72**
Lines (L)	205.17**	450.19**	3.21**	750.21**	0.97**	3.94**
Testers (T)	427.19**	577.04**	4.34**	102.10**	18.26**	3.17**
L X T	45.88**	88.39**	1.43**	107.32**	0.53**	1.32**
	Components of variance					
Mean	59.09	55.34	7.20	71.10	1.832	5.589
Range	41.17 - 71.13	38.90 – 74.58	4.50 – 9.10	41.30 – 98.50	0.11 - 3.55	3.388 - 7.500
C. V. %	3.50.	3.64	4.61	3.36	4.57	1.88
σ^2g	51.65	80.01	1.09	143.49	0.685	0.920
σ^2P	55.94	84.06	1.20	149.19	0.692	0.931
h^2BS	0.92	0.96	0.92	0.96	0.98	0.98
G. C. V. %	87.41	16.16	14.51	16.85	45.23	17.16
P. C. V. %	94.67	16.57	15.22	17.18	45.46	17.26
G. C. V. / P. C. V.	0.92	0.97	0.95	0.98	0.99	0.99
	Components of genetic variance					
σ^2 L	17.70	40.20	0.20	71.43	0.05	0.29
$\sigma^{2\,T}$	11.55	14.81	0.09	- 0.16	0.54	0.06
$\sigma^{2\,GCA}$ (σ^2average)	1.258	2.454	0.013	3.430	0.021	0.015
σ^2 LXT (σ^2 SCA)	13.863	28.113	0.440	33.870	0.173	0.435
σ^2 GCA / σ^2 SCA	0.09	0.09	0.03	0.10	0.12	0.03
σ^2 Additive (A)	2.516	4.908	0.026	6.860	0.042	0.030
σ^2 Dominance (D)	13.863	28.113	0.440	33.870	0.173	0.435
σ^2 A / σ^2 D	0.18	0.18	0.06	0.20	0.24	0.07
Degree of dominance	1.66	1.69	2.91	1.57	1.44	2.69
Pro. Cont * L %	53.66	60.64	46.23	76.14	17.05	54.64
" T %	22.34	15.55	12.51	2.07	64.34	8.80
" L x T %	24.00	23.81	41.26	21.79	18.61	36.56

Pro. Cont.* = Proportional contribution %

** = Significant at 0.01 level of probability.

Table (2): Analysis of variance, coefficient of variance (C.V%), components of variance, heritability and components of genetic variance for some fruit characteristics.

S. O. V.	Average fruit weight	Fruit firmness	TSS% content	Vitamin C content
	Mean squares			
Entries	4193.09**	28302.67**	2.81**	83.74**
Parents (P)	7617.03**	56671.64**	3.50**	1847.32**
Crosses (C)	2223.22**	9864.98**	2.40**	79.42**
Pus C (Heterosis)	22717.38**	249512.04**	7.25**	427.82**
Lines (L)	2959.02**	22132.71**	5.27**	147.29**
Testers (T)	17695.96**	20398.14**	7.36**	195.59**
L X T	308.05**	2677.79**	0.46**	33.86**
	Components of variance			
Mean	130.71	609.82	5.36	26.40
Range	95.97 – 251.99	383.50 – 773.50	2.86 – 6.86	17.67 – 36.09
C. V. %	6.79	3.04	6.98	8.92
σ^2g	1353.42	9320.01	0.89	26.07
σ^2P	1432.24	9662.64	1.03	31.61
h^2BS	0.94	0.96	0.86	0.82
G. C. V. %	28.15	15.83	17.60	19.43
P. C. V. %	28.95	16.12	18.93	21.30
G. C. V. / P. C. V.	0.97	0.98	0.93	0.91
	Components of genetic variance			
σ^2 L	294.55	2161.66	0.53	12.60
$\sigma^{2\,T}$	526.91	536.98	0.21	4.90
$\sigma^{2\,GCA}$ (σ^2average)	32.73	122.86	0.033	0.778
σ^2 LXT (σ^2 SCA)	76.41	778.39	0.106	9.440
σ^2 GCA / σ^2 SCA	0.43	0.16	0.31	0.08
σ^2 Additive (A)	65.46	245.72	0.066	1.556
σ^2 Dominance (D)	76.41	778.39	0.106	9.440
σ^2 A / σ^2 D	0.86	0.32	0.62	0.16
Degree of dominance	0.76	1.26	0.90	1.74
Pro. Cont* L %	41.59	70.11	68.76	57.96
" T %	49.75	12.92	19.20	15.39
" L x T %	8.66	16.97	12.04	26.65

Pro. Cont.* = Proportional contribution %

** = Significant at 0.01 level of probability.

B. Components of variance:

Mean, range, coefficient of variance (C.V%), genotypic and phenotypic of variance (σ^2g & σ^2p), heritability in broad sense (h^2bs), genotypic and phenotypic coefficient of variance (G.C.V & P.C.V%) and the ratio of G.C.V./ P.C.V. are shown in tables 1&2. Data obtained showed that, the variance was varied from trait to another, since the coefficient of variation (C.V%) was ranged from 1.88 to 8.92%. The highest C.V% value (8.92%) was recorded in vitamin C content, followed by (6.98 and 6.79%) in total soluble solids (TSS%) content and average fruit weight, respectively, suggesting that these three characters had the highest variation among the studied genotypes. On the contrary, the lowest variation (1.88%.) was observed for total yield character.

Regarding the genotypic and phenotypic variance (σ^2g and σ^2P), estimated σ^2g vs σ^2P for the studied traits were: 51.65 vs 55.94 for plant height; 80.01 vs 84.06 for main stem length; 1.09 vs 1.20 for number of branches; 143.49 vs 149.19 for Number of leaves; 0.685 vs 0.692 for early yield; 0.920 vs 0.931 for total yield; 1353.42 vs 1432.24 for average fruit weight; 9320.01 vs 9662.64 for fruit firmness; 0.89 vs 1.03 for TSS% content and 26.07 vs 31.61 for vitamin C content. In this respect, all the studied traits showed low values of difference between phenotypic and genotypic variance, which leaded to a close correspondence varies between genotypic and phenotypic coefficient of variations (G.C.V & P.C.V%). The estimated G.C.V vs P.C.V% were: 87.41 vs 94.67% for plant height; 16.16 vs 16.57% for main stem length; 14.51 vs 15.22% for number of branches; 16.85 vs 17.18% for number leaves; 45.23 vs 45.46% for early yield; 17.16 vs 17.26% for total yield; 28.15 vs 28.95% for average fruit weight; 15.83 vs 16.12% for fruit firmness; 17.60 vs 18.93% for TSS% content and 19.34 vs 21.30% for vitamin C content. Also, the G. C. V. / P.C.V. ratios for the studied traits showed high values which ranged from 0.91 (for vitamin c content) to 0.99 for both early and total yield. Estimates of broad sense heritability (h^2BS) were high for all the studied traits, since they ranged from 0.82 (for vitamin C content) to 0.98 (for both early and total yield).

Generally, the difference between the genotypic (σ^2g) and phenotypic (σ^2p) variances indicated the contribution of environmental variance effects. The smaller values of differences between σ^2p and σ^2g, the lesser will be the environmental effect on the character. Selection based on the phenotypic values will be effective only when the phenotypic values represented truly the genotypic values. In this respect, all the characters studied have closer values of σ^2g and σ^2p as well as G.C.V.% and P.C.V.%, which confirmed by the estimated G.C.V / P.C. V. ratios which ranged from 0.91 to 0.99, and broad sense heritability (h^2BS) which ranged from 0.82 to 0.98, suggesting less effect of environment on these traits and the large portion of σ^2p was due to the σ^2g, since they had 91 – 99% from the phenotypic variance. Hence, selection for these traits could be effective for improvement tomato. These results are confirmed the earlier Metwally *et al*. (1996), for early- and total-yield and average fruit weight; Joshi and Singh (2003); Asati *et al.* (2008) and Suarma *et al.* (2009) for plant height and branches, total yield, average fruit weight and ascorbic acid content in tomato.

C. Components of genetic variance (gene action):

By line x tester mating design used, the genetic variance could be translated or partitioned into components of genetic variance in terms of additive and non-additive genetic variances. Both of the lines variance (σ^2L) and testers variance (σ^2T) estimate the general combining ability variance (σ^2GCA) which considered as an indicator of additive (σ^2A) and additive x additive (σ^2AA + σ^2AAA + …) portions of genetic variance. While, the line x tester variance (σ^2L x T) which estimate the specific combining ability variance (σ^2SCA) reflected the non-additive genetic portions including dominance (σ^2D) and (σ^2DD + …), in addition to the maternal effect. However, Kallo (1988) mentioned that the additive (σ^2A) and dominance (σ^2D) were the most important portions. The variance of lines (σ^2L), testers

(σ^2T), average lines and testers (σ^2GCA or σ^2A), line x tester interaction (σ^2SCA or σ^2D), degree of dominance, and the proportional contribution of lines, tester and L x T were obtained for all the studied traits as shown in Tables 1&2. The results mentioned that the magnitude of (σ^2L) always were larger than the corresponding (σ^2T) for all the studied traits, except of early yield per plant and average fruit weight, indicating the importance of choice of the parents.

As mentioned before, the analysis of variance for combining ability revealed highly significant mean square values for lines, testers and line x tester interactions for all the studied traits. Then, the variance values for lines (σ^2L), testers (σ^2T) average lines by testers (general combining ability, i.e., σ^2GCA) and σ^2L x T (specific combining ability, i.e., σ^2SCA) are considered highly significant, suggesting the importance of both additive (σ^2A) and non-additive (σ^2D) gene actions in the inheritance of all studied traits. These information pointed out that the studied characters could be improve through selecting promising lines from superior hybrids. However, the ratio of σ^2GCA / σ^2SCA were found less than unity (<1) for all the studied traits, which revealed the preponderance of non-additive variance in the inheritance of these traits. The prevalence of the non-additive variance was further confirmed by calculated σ^2A/ σ^2D ratios which also found less than one for all the studied traits, suggesting that heterosis breeding as another approach is effective for improvement these traits. The estimated average degree of dominance was also more than one (>1), indicating over-dominance for all the studied traits with the exception of average fruit weight and total soluble solids (TSS%) content which showed partial and complete dominance, since they recorded less values (0.76 and 0.90), respectively. Lastly, estimated of the proportional contribution values showed that, the lines recorded greater proportion than both testers and L x T interactions for all the studied traits, except of early yield and average fruit weight. They showed proportion values ranged from 46.23 to 76.14%. Regarding early yield and average fruit weight, the testers used reflected the highest values (64.34 and 49.75%). Based the contribution of lines, testers and L x T interactions, it was evident that the variability among the crosses was mainly due to the contribution of lines only for majority of the traits studied, which also justifies of choice of the parents. Several previous studies in tomato also reported the significant of additive and non-additive genetic variances with predominance of non-additive gene action in the inheritance of studied same traits. Among those were Metwally *et al.* (1996), Amin *et al.* (2001), Bhatt *et al.* (2001), Joshi *et al*. (2005), Hannan *et al*. (2007), Garg *et al.* (2008), Saeed *et al*. (2008), Mondal *et al.* (2009) and Singh *et al.* (2010).

D. General and specific combining ability effects.

The estimates of GCA of the parents for different characters are presented in Table 3. Among the eleven diverse female lines, the good combiner parents for the studied traits were S.65, G.16 and G.30 (for plant height); S.65, S. 106, G.16 and G.30 (for main stem length); S.15, G.30 and RIG.10 (for number of primary branches); S.65, S.80 and S.106 (for Number of leaves); S.15, S.125, G.16 and RIG.10 (for early yield per plant); S.60, S.65, S.80, G.16 and G.30 (for total yield per plant); S.15, S.60, S.65, S.80

and S.106 (for average fruit weight); G.5, G.16, G.30 and RIG-10 (for fruit firmness); S.2, S.15, S.60, S.80 and G.16 (for TSS%) and S.2, S.60 and G.16 (for vitamin C content), since they showed significant positive GCA values. However, the highest significant positive GCA values among the line for the various traits were; S.60, for average fruit weight (23.59); S.80, for TSS% content (0.77); S.106, for main stem length and number of leaves per plant (14.66 and 19.50, respectively); G.16, for early yield and vitamin C content (0.62 and 7.90, respectively) and G.30 for plant height, number of primary branches, total yield per plant and fruit firmness (7.89, 1.14, 1.13 and 84.37, respectively) and they considered the best combiner parent for these traits. Generally, the line G.16 was found to be the most desirable general combiner. It possesses dominant genes for seven traits, followed by the S.65 and G.30 which were good general combiners for six and five traits, respectively. However, none of the parents was best combiner for all the traits indicating differences in genetic variability for different characters among the parents. Regarding the male parents (testers), G.19 was appeared the best general combiners, since showed significant positive GCA values for six traits, while the other two testers (SSB and Peto 86) recorded significant positive GCA values for two characters. Since high GCA effects is related to additive and additive x additive interaction and represents the fixable components of genetic variance. These data revealed that, these characters could be improved by using these lines in hybrid breeding programmes for the accumulation of favourable genes. In this respect, Metwally *et al.* (1996), Sharma *et al.* (1999), Gary *et al.* (2008) and Mondal *et al.* (2009) estimated the combining ability in some tomato traits by line x tester analysis and found that none of the parents was best combiner for all traits. They added that, the GCA effects are mainly attributed to additive and additive x additive interactions, which are fixable. Therefore, parent lines/cultivars with high GCA may be recommended for utilization in genetic improvement in tomato through varietal breeding.

Regarding specific combining ability effects (SCA), data are presented in Tables 4 and 5 for the various studied traits. The highest significant SCA effects were manifested by the crosses: S.65 x Peto 86, for plant height and main stem length (8.03 and 8.11, respectively); S.65 x G.19, for number of primary branches (0.98); S.125 x G.19, for number of leaves (9.91); G.30 x peto 86, for early yield (0.74); S.125 x SSB, for total yield (0.95); S.15 x G.19, for average fruit weight (14.77); S.15 x Peto 86, for fruit firmness (57.02); G5 x SSB, for TSS% content (0.46) and S.80 x SSB, for vitamin C content (5.11), and could be considered the best combinations for each trait. None of the combinations showed simultaneous significant SCA effects favourably for all the characters, but for some once.

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As whole, the cross combinations S.60 x G.19, S.125 x G.19, G.30 x SSB and G.30 x Peto 86 considered the best combinations, since they reflected significant SCA values for five traits, followed by the two combinations G.5 x SSB and RIG-10 x G.19 which showed good SCA effects for four traits. Regarding the relationship between the studied traits and number of crosses which showed significant SCA values, we can see eight ones for plant height, ten for both main stem length, number of branches and early yield, eleven for total yield, fifteen for total yield, two for both average fruit weight and TSS% content, seven for fruit firmness and six for vitamin C content. The SCA effect are considered as indicator for heterosis effects, the high amount of heterosis could be expected for total yield, followed by main stem length, number of branches, number of leaves and early yield and the heterosis breeding could be used with effective for these trait.

Table (4): Specific combining ability (SCA) effects for some plant characteristics.

	Plant height			**Main stem length**			**No. of branches**		
Lines	**SSB**	**G.19**	**Peto 86**	**SSB**	**G.19**	**Peto 86**	**SSB**	**G.19**	**Peto 86**
S.2	0.52	0.12	- 0.64	- 3.68	2.23	1.45	0.68**	- 0.52	- 0.16
S.15	1.40	- 0.66	- 0.74	2.10	- 2.33	0.23	0.07	- 0.34	0.27
S.60	- 1.16	5.79**	- 4.63	- 5.12	6.79**	- 1.67	- 0.14	0.52**	- 0.38
S.65	- 3.15	- 4.88	8.03**	- 1.68	- 6.43	8.11**	- 0.62	0.98**	- 0.36
S.80	- 3.27	3.68**	- 0.41	- 4.34	7.23**	- 2.89	- 0.45	- 0.16	0.61**
S.106	2.73*	0.68	- 3.41	0.43	- 1.66	1.23	0.21	- 0.02	- 0.19
S.125	- 2.94	3.68**	- 0.74	- 3.01	4.89**	- 1.88	- 0.15	0.95**	- 0.80
G.5	3.06*	- 0.65	- 2.41	2.99*	- 0.43	- 2.56	- 0.19	- 0.64	0.83**
G.16	- 0.71	- 0.43	1.15	3.43**	2.68*	- 6.11	- 0.26	- 0.30	0.57**
G.30	2.95*	- 6.43	3.4^{8**}	4.65**	-10.10	5.45**	0.71**	- 1.08	0.37*
RIG.-10	0.51	- 0.88	0.37	4.21**	- 2.87	- 1.34	0.12	0.65**	- 0.77
L.S.D 5% 1%		2.36 3.11			2.30 3.02			0.37 0.49	
Var (Sij - Skl)5% 1%		3.34 4.41			3.25 4.28			0.53 0.70	
Lines	**No. of Leaves**			**Early yield**			**Total yield**		
	SSB	**G.19**	**Peto 86**	**SSB**	**G.19**	**Peto 86**	**SSB**	**G.19**	**Peto 86**
S.2	3.83**	- 0.32	- 3.51	- 0.35	0.55	- 0.20	- 0.08	0.46**	- 0.38
S.15	2.84*	- 0.20	- 2.64	- 0.32**	- 0.48	0.16**	- 0.09	0.69**	- 0.78
S.60	- 1.15	4.69**	- 3.54	- 0.17	0.25**	- 0.08	- 0.68	0.11	0.57**
S.65	- 6.80	3.15*	3.66**	0.04	- 0.22	0.18**	- 0.26	0.55**	- 0.30
S.80	- 1.68	- 6.82	8.50**	0.25**	- 0.23	- 0.02	- 0.22	0.19**	0.03
S.106	- 1.57	- 5.32	6.89**	- 0.39	0.44**	- 0.05	- 0.07	- 0.38	0.45**
S.125	-11.24	9.91**	1.32	- 0.07	0.11$^{*\backslash}$	- 0.04	0.95**	- 1.14	0.19**
G.5	4.50**	- 2.95	- 1.55	0.07	0.01	- 0.08	- 0.35	0.22**	0.13*
G.16	1.64	0.77	- 2.42	0.38**	- 0.31	- 0.07	0.59**	- 0.80	0.21**
G.30	5.49**	- 4.46	- 1.04	0.03	- 0.77	0.74**	0.59**	- 0.75	0.16**
RIG.-10	3.83**	1.88	- 5.71	- 0.23	0.67**	- 0.44	- 0.58	0.88**	- 0.30
L.S.D 5% 1%		2.71 3.57			0.10 0.13			0.12 0.16	
Var(Sij - Skl)5% 1%		3.84 5.06			0.14 0.18			0.17 0.22	

$^{*, **}$ **Significant at 0.05 and 0.01 levels of probability, respectively.**

On the contrary, the low amount of heterosis could be expected for average fruit weight and TSS% content. This opinion was also confirmed by previously estimated degree of dominance values which were 0.76 for average fruit weight (partial dominance) and 0.90 for TSS% content (complete dominance), while were more than one (over-dominance) for the remaining traits (Tables 1 &2). In this respect, Saeed *et al.* (2008) reported that, SCA involves dominance and additive x dominance, dominance x dominance interactions, which are non-fixable and are of significance in hybrid breeding only. So, SCA effects are useful to predict the potential of a particular cross in exploiting heterosis.

Table (5): Specific combining ability (SCA) effects for some fruit characteristics.

	Average fruit weight			**Fruit firmness**		
Lines	**SSB**	**G.19**	**Peto 86**	**SSB**	**G.19**	**Peto 86**
S.2	- 0.92	- 8.16	9.08	3.41	27.95**	- 31.36
S.15	- 2.86	14.77**	-11.91	-27.14	- 29.88	57.02**
S.60	12.23*	1.45	-13.68	-15.42	11.88	3.54
S.65	- 0.24	8.31	- 8.08	4.58	32.23	- 36.81
S.80	-12.80	7.82	5.18	3.91	- 37.78	33.86**
S.106	1.74	- 7.92	6.18	- 8.09	- 23.78	31.87**
S.125	-12.93	7.44	5.49	23.57*	- 22.72	- 0.85
G.5	10.29	-13.92	3.63	9.52	- 12.72	3.19
G.16	1.32	- 4.20	2.89	3.43	22.18*	- 25.61
G.30	5.70	- 0.90	- 4.80	1.91	4.88	- 6.78
RIG.-10	- 1.53	- 4.54	6.07	0.14	28.17**	- 27.31
L.S.D 5% 1%		10.13 13.36			21.14 27.87	
Var (Sij - Skl) 5% 1%		14.33 18.89			29.92 39.44	
Lines	**TSS %**			**Vitamine C**		
	SSB	**G.19**	**Peto 86**	**SSB**	**G.19**	**Peto 86**
S.2	0.43*	0.15	- 0.58	0.97	- 1.43	0.46
S.15	0.40	- 0.59	0.19	4.76**	- 5.58	0.82
S.60	- 0.49	0.24	0.25	- 4.64	3.21	1.43
S.65	- 0.13	0.19	- 0.07	- 2.02	2.96*	- 0.94
S.80	0.39	- 0.23	- 0.16	5.11**	- 1.16	- 3.95
S.106	- 0.19	0.39	- 0.20	- 2.76	3.39*	- 0.63
S.125	- 0.44	0.14	0.30	- 1.05	- 1.19	2.24
G.5	0.46*	- 0.25	- 0.21	- 1.06	0.55	0.51
G.16	- 0.14	- 0.25	0.39	- 2.49	3.55**	- 1.06
G.30	- 0.30	0.01	0.29	0.16	0.04	- 0.20
RIG.-10	0.03	0.22	- 0.25	3.00*	- 4.31	1.30
L.S.D 5% 1%		0.42 0.56			2.68 3.54	
Var (Sij - Skl) 5% 1%		0.60 0.79			3.80 5.01	

$^{*, **}$ **Significant at 0.05 and 0.01 levels of probability, respectively.**

Generally, most of the significant SCA crosses effects (more than 50%) mainly involved high x low GCA parents, while the remaining ones involved the other types of GCA effects, i.e., high x high, high x medium, medium x medium, medium x low and low x low. In this respect, Singh *et al.* (2007) mentioned that crosses involving high x low general combiners mostly produced desirable specific combining ability effects for most of the characters. High SCA effects manifested by crosses where both their parents were high x high or high x medium GCA might be attributed to sizeable additive x additive gene action, which are fixable (heritable) portion. These hybrids such as S.15 x G.19 for number of branches, S.15 x SSB for early yield and S.60 x G.19 for plant height, suggesting the role of cumulative effects of favourable genes and could be used both for hybrid development (heterosis) as well as varietal breeding, since may give rise to the transgressive segregations in the advanced generation. Crosses showing high significant positive SCA effects and involving parents with high and low GCA values such as S.125 x G.19 and G.30 x Peto 86 for plant height, main stem length, number of primary branches and early yield, besides expressing the favourable additive effect of the high parent, manifested some complementary gene interaction effects with a higher SCA. However, heterosis displayed by such crosses may be due to additive x dominance types of gene action and may be used also for hybrid breeding as well as pure line selection. Meanwhile crosses showing high significant positive SCA (heterosis) effects and involved both two parents as low general combiner (low x low), such as G.5 x SSB for plant height suggesting the role of dominance x dominance of non-allelic gene action producing over-dominance and are non-fixable (complementation of genes), and could be used for breeding hybrid only. These results are in close conformity with those of Amin *et al.* (2001), Bhatt *et al.* (2001), Hannan *et al.* (2007), Saeed *et al*. (2008) and Singh *et al.* (2010).

E. Breeding strategy.

It may be concluded from the present study that the good combiner lines, S.65, G.16, G.30 and G.19 may be used in further breeding programmes for utilization in genetic improvement of tomato, as new cultivars. Also the high SCA crosses combination with high x high or high x medium GCA effects may be used for both hybrid development (heterosis) as well as varietal breeding, while the high SCA crosses with low x low GCA effects could be used for breeding hybrid. Likewise, all the characters studied may be improved by selection provided there is sufficient genetic variability in the germplasm since the large portion of σ^2P was due to σ^2g in these traits. In the same time, the studied characters may be improved by heterosis breeding when were predominantly governed by non-additive gene action. Therefore, for genetic improvement of tomato for the studied traits in these materials, we can suggested the possibility of development of superior tomato inbred lines through recurrent selection program.

Then these superior lines could be used to obtain vigorous F_1 hybrids. This breeding strategy find favour in the Egyptian conditions wherein the proportion of the total tomato area is still under the imported seeds from the other countries.

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القدرة على التآلف والفعل الجينى فى الطماطم بواسطة التلقيح القمى

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أجريت هذه الدراسة بمركز زفتى – غربية بإقليم وسط الدلتا خلال الموسم الصيفى المبكر فى الفترة من ٢٠٠٨ – ٢٠١٠ باستخدام طريقة التهجين القمى لعدد ١١ سلالة (ناتجة من برنامج تربية سابقة) مع ٣ كشافات وذلك لدراسة الفعل الجينى والقدرة على التآلف فيها.و تم تقييم الهجن القمية مع ابائها لمدة عامين في تجربة مصممة بطريقة القطاعات الكاملة العشوائية في ثلاث مكررات .

أظهرت الدراسة وجود تطابق إلى حد كبير بين قيم كل من التباين الوراثى مع التباين البيئى وبين معامل الاختلاف الوراثى مع معامل الاختلاف البيئى فى كل الصفات المدروسة وهى ارتفاع النبات ,طول الساق الرئيسى , عدد الافرع والأوراق للنبات و المحصول الكلى والمبكر ومتوسط وزن الثمرة و صلابة الثمرة و المواد الصلبة الذائبة الكلية وفيتامين ج.

وقد أظهرت الدراسة أيضاُ أهمية كل من الفعل المضيف والغير مضيف للجينات فى وراثة كل الصفات المدروسة مع الأخذ فى الاعتبار سيادة الجزء الغير مضيف للجينات. كما أظهرت حسابات درجة السيادة وجود سيادة جزئية فى صفة متوسط وزن الثمرة وسيادة كاملة فى صفة المواد الصلبة الذائبة الكلية بينما أظهرت وجود سيادة فائقة فى باقى الصفات المدروسة.ووجود السيادة الفائقة تشجع علي انتاج الهجن علي نطاق تجاري والاستغناء عن استيرا د بذور هجن الطماطم من الخارج.

أظهرت النتائج أن السلالات جى ١٦ ، إس ٦٥، جي٣٠ والكشاف جى ١٩ تعتبر أحسن السلالات من حيث القدرة العامة على التآلف لأنها احتوت على جينات سائدة فى ٧، ٦، ٥، ٦ صفات على التوالى – بينما أظهرت الهجن إس ٦٠ x جى ١٩، إس ١٢٥ x جى ١٩، جى ٣٠ x سوبر استرين بى وجى ٣٠ x بيتو ٨٦ أنها أحسن توافقات خاصة لأنها أعطت قيم معنوية للقدرة الخاصة على التآلف فى خمس من الصفات المدروسة. وفى النهاية أوضحت الدراسة إمكانية تحسين الصفات تحت الدراسة من خلال كل من الانتخاب الدورى والتربية لقوة الهجين.

قام بتحكيم البحث

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Table (3): General combining ability (GCA) effects for some plant and fruit characteristics.

Lines	Plant height	Main stem length	No. of branches	No. of leaves	Early yield	Total yield	Average Fruit weight	Fruit firmness	TSS%	Vitamin C
S.2	0.33M	-3.23L	0.18M	-7.49L	-0.17L	-0.82L	-19.60L	3.34M	0.53**H	1.56**H
S.15	-1.88L	-0.01L	0.46**H	-3.60L	0.09**H	-0.17L	13.09**H	-31.78L	0.52**H	0.99M
S.60	1.00M	-6.45L	-0.60L	-5.61L	0.02M	0.72**H	23.59**H	-29.21L	-0.03L	4.86**H
S.65	2.67**H	3.77**H	-0.09L	14.74**H	-0.25L	0.18**H	18.73**H	-10.55L	0.69**H	0.55M
S.80	-6.88L	-7.24L	-0.29L	1.60*H	-0.27L	0.69**H	17.01**H	-32.89L	0.77**H	-2.57L
S.106	1.12M	14.66**H	0.08M	19.50**H	0.01M	-0.86L	10.52**H	-79.22L	-0.18L	-2.99L
S.125	-7.89L	-7.90L	-1.08L	-9.84L	0.23**H	-0.08L	- 0.91L	-39.55L	-0.40L	-0.24L
G.5	-0.56L	0.44M	-0.38L	-2.28L	-0.51L	-0.24L	-25.01L	28.42**H	0.21M	-6.46L
G.16	66.22**H	4.99**H	0.06M	-5.38L	0.62**H	0.19**H	-10.14L	50.50**H	0.57**H	7.90**H
G.30	7.89**H	6.77**H	1.14**H	-0.16L	-0.17L	1.13**H	- 0.90L	84.37**H	-1.54L	-4.06L
RIG.10	-2.00L	-5.79L	0.51**H	-1.49L	0.41**H	-0.73L	-26.38L	56.56**H	-1.14L	0.47M
L.S.D 5%	1.36	1.32	0.21	1.56	0.05	0.07	5.84	12.22	0.24	1.55
1%	1.80	1.74	0.28	2.06	0.07	0.09	7.69	16.10	0.32	2.04
Var(gi-gj)5%	1.93	1.86	0.31	2.21	0.08	0.10	8.27	17.27	0.35	2.19
1%	2.55	2.45	0.41	2.92	0.10	0.13	10.90	22.77	0.50	2.89
Testers:										
SSB	-2.62L	-3.43L	-0.31L	1.53**H	0.41**H	-0.11L	-02.17L	-17.58L	0.14*H	1.55**H
G.19	4.11**H	4.65**H	0.39**H	0.39M	-0.85L	0.35**H	24.17**H	28.45**H	-0.53L	-2.81L
Peto 86	-1.47L	-1.22L	-0.08L	-1.92L	0.44**H	-0.24L	-22.00L	-10.87L	0.39**H	1.26**H
L.S.D 5%	0.71	0.69	0.10	0.81	0.03	0.04	3.04	6.38	0.13	0.81
1%	0.93	0.91	1.30	1.07	0.04	0.05	4.02	8.41	0.17	1.07
Var (gi-gj)5%	1.01	0.98	0.16	1.14	0.04	0.05	4.31	9.02	0.18	1.15
1%	1.33	1.28	0.21	1.51	0.05	0.07	5.68	11.89	0.24	1.51

$^{*,\ **}$ **Significant at 0.05 and 0.01 levels of probability, respectively.**
L = Negative values = Low GCA status
M = Unsignificant positive values = Medium GCA status
H = significant positive values = High GCA status.