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HETEROSIS AND COMBINING ABILITY IN TOMATO BY LINE X TESTER

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ABSTRACT

Six diverse lines of tomato were crossed with six testers in line x tester mating fashion to study heterosis relative to mid parents, better parent and check hybrid and combining ability for some plant and fruit characteristics. The experiment work was conducted at the Exp. Farm, Fac. of Envir. Agric. Sci., El Arish, Suez Canal Univ., Egypt, during the period from 2012 to 2014. For heterotic effect, heterosis over mid-parents, better parent and check hybrid were detected in many traits, viz.; plant height, number of branches, total yield/plant and total fruit number. On the other hand, no heterosis was detected for fruit firmness based on check hybrid. The magnitude of SCA variance was greater than GCA variance suggesting the predominance of non-additive gene action for all studied traits. Among the lines, the good general combiner was AVTO9802 for total yield/plant and fruit firmness and AVTO1008 for average fruit weight. Among six testers, Super Marmand exhibited the highest significant GCA effects for plant height and number of branches/plant, FM–9 was the best for total yield/plant and Castle Rock for average fruit weight and fruit firmness. The estimates of specific combining ability effects (SCA) show superior specific combinations, AVTO1003 x Super Marmand for plant height, AVTO1002 x Peto 86 for number of branches, AVTO1003 x Rio Grande for total fruit number, AVTO0101 x Super Strain B for average fruit weight, AVTO1002 x Super Marmand for TSS%, AVTO0101 x Castle Rock for ascorbic acid content and AVTO1002 x Rio Grande for fruit firmness. Therefore, from general and specific combining ability and some genetic parameters suggested the importance of heterosis breeding for effective utilization of non-additive genetic variances, which had predominant role for the improvement of for some plant and fruit characteristics traits in tomato crop.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most economically important vegetable crops grown in Egypt, for fresh consumption and processing. With the rapid increase in this crop, there is a need for development of hybrids and varieties with high yield, quality and tolerant to stress environments. Genetic analysis provides a guide line for the assessment of relative breeding potential of the parents or identify best combiners which could be utilized to exploit heterosis F1. Exploitation of hybrid vigour and selection of better parents on the basis of combining ability and gene action has equal importance in breeding approaches for the crop improvement.

Heterosis breeding as a tool for genetic improvement in tomato has been studied by several researchers. Heterosis over better parent was detected by Dev *et al*. (1994) for plant height and total fruit number; Hegazi *et* *al*. (1995) for total fruit number, total yield and TSS%; Kumar *et al*. (1997) for total fruit number; Youssef (1997) and Salib (1999) for total yield, TSS% and ascorbic acid content and Khalil (2009) for total yield. Heterosis over mid-parents and better parent was also observed by Singh and Singh (1993) for total yield; Abd Allah (1995) for plant height and TSS%; Dharmatti *et al*. (1997) for total yield; Amin *et al*. (2001) and Zanata (2002) for number of branches. Significant positive heterosis over mid-parent and check hybrid was observed by Zanata (1994) for plant height, number of branches, total fruit number and total fruit weight; Kansouh and Masoud (2007) and Kansouh (2013) for number of branches and total yield. On the other hand, negative heterosis over the better parent was observed for average fruit weight (Zanata, 1994; Hegazi, 1995; Youssef, 1997; Salib, 1999; Khalil, 2004; Sakhar *et al*., 2010; Kansouh, 2013) and fruit firmness (Salib, 1999; Kansouh, 2013).

Combining ability has a prime importance in plant breeding since it provides the breeder to decide upon the choice of parents for the hybridization and also gives information on gene actions, which helps in understanding the nature of inheritance of traits. So many studies on tomato showed that, non-additive gene action was predominant among them, Abd Allah (1995) for total yield; Hegazi *et al*. (1995) for plant height; Dod *et al*. (1995) for ascorbic acid content; Youssef (1997) for number of branches, total yield, total fruit number and TSS%; Kumar *et al*. (1997) for total fruit number; Saleem *et al*. (2009) for total yield, total fruit number and average fruit weight; Narasimhamurthy and Ramanjini (2013) for plant height, number of branches, fruit firmness, TSS% and total yield; Shankar *et al*. (2013) for total yield and Masry (2014) for plant height, number of branches, total fruit number, total yield, average fruit weight, TSS% and ascorbic acid content. However, additive gene action was more important in the inheritance of fruit firmness (Zanata, 1994), plant height (Abd Allah, 1995; Shankar *et al*., 2013) and average fruit weight (Kumar *et al*., 1997; Youssef, 1997; Shankar *et al*., 2013). Therefore, the main objective of this research was to study some genetic parameters; viz., heterosis relative to mid-parents, better parent and check hybrid, potence ratio, general and specific combining ability for some plant and fruit characteristics of tomato.

MATERIALS AND METHODS

The experiment work was carried out at the Experimental Farm, Faculty of Environmental Agricultural Sciences, El Arish, Suez Canal University, Egypt, during the period from 2012 to 2014. The genetic materials used in this study were six heat tolerant lines introduced from Asian Vegetable Research and Development Center (AVRDC); viz., AVTO1003, AVTO1002, AVTO9803, AVTO1008, AVTO0101 and AVTO9802 used as female parents. Six cultivars of tomato were used as testers; viz., Castle Rock, Peto 86, FM–9, Super Strain-B, Super Marmand and Rio Grande. The common hybrid in El-Arish region "Alissa F_1" was used as a check hybrid.

In the first season of 2012, crossing was made among parental genotypes using six lines as female, while the six *cvs*. were used as testers to produce 36 F_1. In the second season of 2013, the resulted 36 F_1 were planted to produce 36 F_2 seeds (data unpublished) and crosses among parents were done to produce enough F_1 seeds again. In the third season of 2014, all genotypes (six lines, six testers, 36 F_1, 36 F_2 and check hybrid Alissa F_1) were evaluated under the open field conditions. Seedlings were transplanted on April 1st. A randomized complete block design with three replicates was used in season of 2014, each replicate contained 85 genotypes, the plot area was 12 m^2 (10m long and 1.20 m width). Drip irrigation system was used, dripper lines were spaced 1.2 m between each other, plants spaced 50 cm in the same row. Other normal agricultural practices for tomato production were done as recommended in the open field in North Sinai region.

Data were recorded for plant height (cm) and number of branches/plant after four months from transplanting on 5 plants chosen randomly from each plot. Total fruit weight/plant (kg) and total fruit number /plant were calculated from all harvested fruits. Average fruit weight (g) was calculated by dividing total weight of all harvested fruits over total number of fruits. From each plot five fruits were taken randomly from the third harvest to determine total soluble solids percentage (TSS %) by a hand refractometer; ascorbic acid content (mg /100g fruit fresh weight) was determined according to the methods of A.O.A.C. (1975) and fruit firmness (kg/cm^2) was measured by using a needle type of pocket penetrometer.

Data were calculated and statistically analyzed as out lined by Cochran and Cox (1957). Heterosis was estimated as a percent increase or decrease of F_1 performance from the mid-parents (MP), better parent (PB) and check hybrid (CH). General combining ability (GCA) and specific combining ability (SCA) were analyzed according to the method of Kempthorne (1957). Narrow sense heritability estimated according to Burton and Devan (1953). Average degree of dominance (ADD) in F_1 population $=\left(\sigma^2 D / \sigma^2 A\right)^{0.5}$. Heterosis over the better parent (BP %) was only calculated for the crosses that showed significant positive MP% values.

RESULTS AND DISCUSSION

Heterosis degree.

Data presented in Table 1 show that, 24 crosses out of 36 ones significantly exceeded their mid-parents in plant height, suggesting degrees of dominance toward the high parent. On the other hand, the remaining crosses (12 ones) showed no dominance, since they exhibited insignificant values of heterosis. Estimated heterosis values over better parent, 14 crosses showed significant positive heterosis values, indicating over dominance for the taller parent. The rest crosses recorded insignificant positive values, indicating complete dominance for the high parent. Relative to heterosis over the check hybrid, 24 crosses exhibited significant positive values ranging from 15.528% in the cross (6x10) to 104.969% in the cross (6x11).

Table1: Average degree of heterosis over mid-parents (M.P.), better parent (B.P.), check hybrid (C.H.) and potence ratio (p) for plant height and number of branches/plant.

Crosses	Plant height			Number of branches \ plant		
	M.P.	B.P.	C.H.	M.P.	B.P.	C.H.
1x7	15.957*	15.957		10.497		
1x8	21.217**	17.736*		7.955		
1x9	28.850**	22.973**		-6.509		
1x10	1.105			18.519		
1x11	106.64**	103.100**	93.323**	33.333**	16.949	58.621**
1x12	31.68**	28.710**	23.913**	18.717		27.586*
2x7	1.543			30.570**	24.752*	44.828**
2x8	6.097			44.681**	34.653**	56.322**
2x9	-1.046			-10.497		
2x10	-13.333*			4.598		
2x11	25.341**	17.163**	28.261**	15.982		45.977**
2x12	-4.000			21.608*	19.802	39.080**
3x7	12.860			14.444		
3x8	35.520**	22.399**	31.522**	29.143**	28.409*	29.885*
3x9	35.935**	20.809**	29.814**	23.810*	18.182	
3x10	19.655**	10.405	18.634**	25.466*	14.773	
3x11	54.943**	46.098**	56.988**	23.301**	7.627	45.977**
3x12	11.433			7.527		
4x7	19.916**	0.225	36.953**	14.706		34.483**
4x8	40.612**	14.886**	56.988**	14.573		31.034**
4x9	38.567**	11.641*	52.553**	29.167**	10.714	42.529**
4x10	15.768**	-3.636	31.677**	21.081*	0.000	28.736*
4x11	9.980		27.484**	-9.565		
4x12	14.933**	-2.045	33.851**	34.286**	25.893**	62.069**
5x7	14.629**	-0.711	24.419**	19.000*	10.185	36.782**
5x8	55.018**	31.103**	64.286**	4.615		
5x9	44.833**	20.694**	51.242**	37.234**	19.444	48.276**
5x10	25.718**	8.426	35.870**	-0.552		
5x11	21.620**	7.001	34.084**	25.664**	20.339*	63.218**
5x12	32.446**	17.100**	46.739**	35.922**	29.630**	60.920**
6x7	38.523**	14.145**	61.646**	19.417*	7.895	41.379**
6x8	-14.000**			-16.418		
6x9	8.414		22.050**	25.773**	7.018	40.230**
6x10	-0.601		15.528*	15.508		
6x11	73.115**	44.737**	104.969**	26.724**	24.576**	68.966**
6x12	29.243**	8.553	53.727**	22.642**	14.035	49.425**
L.S.D.0.05	7.076	8.171		1.066	1.231	
0.01	8.478	9.790		1.278	1.475	

***,** Significant at 0.05 and 0.01 levels of probability, respectively. Lines: 1- AVTO1003 2- AVTO1002 3- AVTO9803 4- AVTO1008 5- AVTO0101 6-AVTO9802. Testers: 7- CastleRock 8- Peta 86 9- FM – 9 10-Super Strain B 11-Super Marmand 12-Rio Grande.**

Similar results were observed by Dev *et al.* (1994), Zanata (1994) and Abd Allah (1995) for plant height.

Regarding number of branches/plant, obtained data (Table 1) show that, 17 F_1 hybrids had insignificant heterosis values based on mid-parents, indicating no dominance for this trait. However, the remaining 19 ones reflected mid-parents heterosis with significant values ranging from 19.00% (5x7) to 44.681% (2x8), suggesting dominance toward the high number/plant. Estimated heterosis values relative to better parent in these crosses (19 ones) showed over dominance for the large number of branches/plant in seven crosses, since they gave significant positive values ranging from 20.339 % (5x11) to 34.653% (2x8), the remaining crosses (12 ones) showed complete dominance for the large number of branches/plant, where they reflected insignificant values. Heterosis over the check hybrid was detected in 21 crosses with significant positive values ranging from 27.586% (1x12) to 68.966% (6x11). These results agreed with those of Zanata (2002), Kansouh and Masoud (2007) and Kansouh (2013) who showed heterosis over mid-parents, better parent and commercial hybrid for this trait.

Concerning total yield/plant, data in Table 2 showed that 16 crosses showed no-dominance for this trait, since they recorded insignificant heterosis values relative to their mid-parents, while 20 crosses reflected dominance toward the high yield, since they exhibited significant positive heterosis values over their mid-parents. From these crosses 10 ones out yielded their respective better parent, suggesting over dominance (hybrid vigour) for total yield. The remaining crosses (10 ones) showed complete dominance, where they exhibited insignificant values of heterosis over better parent. Compared with commercial hybrid, no superiority was detected over the check hybrid. However, no significant differences were observed for total yield in 24 crosses when compared with the check, since they have insignificant positive values of heterosis ranged from 2.222% in the cross 4x12 to 27.778% in the cross 6x9. These crosses could be evaluated in other seasons and locations in North Sinai to determine the best hybrids which gave high yield and good quality. In this concern, many researchers found heterosis relative to mid-parents, better parent and check hybrid among studied hybrids (Singh and Singh, 1993; Zanata, 1994; Dharmatti *et al*., 1997; Kansouh and Masoud, 2007; Kansouh, 2013).

As for total fruit number/plant, obtained data (Table 2) showed that most studied crosses (21 ones) significantly exceeded their respective mid-parents values, suggesting dominance toward the high fruit number/plant. However, the other crosses (15 ones) exhibited no-dominance for this trait. The estimated values of heterosis based on better parent showed over dominance in 15 F_1's with significant heterobiltiosis values ranged from 24.563% in the cross 2x10 to 95.140% in the cross 1x12. The rest crosses reflected complete dominance in six ones toward the high fruit number. Compared with the check hybrid, 16 F_1's showed significant superiority over Alissa F_1, with values ranging from 22.287% (in the cross 1x9) to 98.866% (in the cross 1x12). Similar results were obtained by Zanata (1994), Hegazi *et al.* (1995) and Kumar *et al.* (1997).

Table 2: Average degree of heterosis over mid-parents (M.P.), better parent (B.P.), check hybrid (C.H.) and potence ratio (p) for total yield and total fruit number/plant.

Crosses	Total yield\plant			Total fruit number\ plant		
	M.P.	B.P.	C.H.	M.P.	B.P.	C.H.
1x7	0.000			-22.971*		
1x8	27.458		4.444	38.423**	27.403**	54.424**
1x9	31.861*	11.170	16.111	34.893**	19.996	22.287*
1x10	10.156			-0.551		
1x11	20.168			47.841**	12.287	
1x12	78.166**	58.140**	13.333	111.874**	95.140**	98.866**
2x7	60.456**	48.592**	17.222	62.771**	49.384**	39.074**
2x8	16.883			57.749**	39.456**	69.034**
2x9	20.000		10.000	63.048**	51.053**	40.627**
2x10	-23.420			38.073**	24.563*	
2x11	41.833*	25.352		99.899**	56.734**	45.917**
2x12	23.967			79.726**	72.692**	60.773**
3x7	60.000**	42.857*	22.222	-9.073		
3x8	42.500**	37.349*	26.667	-7.719		40.956**
3x9	28.655*	17.021	22.222	-12.034		
3x10	28.826			-18.595**		
3x11	44.487**	23.377	5.556	15.377		36.824**
3x12	57.480**	29.870	11.111	3.794		40.172**
4x7	97.309**	81.818**	22.222	59.937**	54.541**	
4x8	27.612			2.580		
4x9	42.759**	10.106	15.000	44.969**	38.703**	
4x10	74.672**	57.480**	11.111	39.629**	37.445**	
4x11	108.531**	101.835**	22.222	80.079**	55.694**	
4x12	82.178**	80.392**	2.222	6.655		
5x7	55.056**	41.781*	15.000	35.789**	17.506	25.086*
5x8	-15.385			-6.139		
5x9	11.377		3.333	21.202*	5.803	
5x10	31.136			-10.979		
5x11	64.706**	43.836*	16.667	97.632**	47.915**	57.457**
5x12	52.846**	28.767	4.444	21.008*	9.277	
6x7	19.732			-7.737		
6x8	27.907		22.222	43.301**	38.192**	67.502**
6x9	25.683		27.778	32.033**	12.582	26.729**
6x10	43.607**	23.034	21.667	11.937		
6x11	40.767**	13.483	12.222	87.928**	38.116**	55.472**
6x12	38.129*	7.865	6.667	8.532		
L.S.D.0.05	0.390	0.450		8.293	9.575	
0.01	0.467	0.539		9.936	11.473	

***,** Significant at 0.05 and 0.01 levels of probability, respectively. Lines: 1- AVTO1003 2-AVTO1002 3-AVTO9803 4- AVTO1008 5- AVTO0101 6-AVTO9802. Testers: 7-CastleRock 8- Peta 86 9- FM – 9 10-Super Strain B 11-Super Marmand 12-Rio Grande.**

For average fruit weight, data obtained in Table 3 showed that from 36 F_1's studied, 21 crosses exhibited no-dominance and dominance toward the small fruits, where they gives insignificant and significant negative heterosis values relative to their mid-parents. However, 15 crosses exhibited dominance toward the heavy fruits, since they have significant positive heterosis values based on mid-parents. From these crosses, seven ones reflected over dominance toward the high parent, indicating hybrid vigour for average fruit weight with values ranged from 19.266% in the cross 4x7 to

54.958% in the cross 4x12. The remaining crosses showed complete and partial dominance in seven and one crosses, respectively. On the other hand, only two crosses 4x12 and 5x10 significantly exceeded the check hybrid by heterosis values of 21.10% and 23.45%, respectively for average fruit weight. However, seven crosses significantly not differ compared with the check hybrid, where they have insignificant positive values of heterosis over the check hybrid.

Table 3: Average degree of heterosis over mid-parents (M.P.), better parent (B.P.), check hybrid (C.H.) and potence ratio (p) for average fruit weight and TSS%.

Crosses	Average fruit weight			T.S.S%		
	M.P.	B.P.	C.H.	M.P.	B.P.	C.H.
1x7	28.132**	16.555		7.500		
1x8	-7.888			2.273		9.756*
1x9	-4.055			2.703		
1x10	10.928			-1.682		
1x11	-24.025**			0.000		
1x12	-15.980			-2.500		
2x7	0.191			-6.818		
2x8	-26.760**			-16.667**		
2x9	-27.935**			12.195**	-6.122	12.195**
2x10	-44.154**			-6.213		
2x11	-32.460**			10.870**	4.082	24.390**
2x12	-30.462**			-20.455**		
3x7	55.345**	19.644*	2.625	-2.381		
3x8	46.497**	17.283		-10.870**		
3x9	19.302**	-19.300**	6.000	-7.692		
3x10	34.690**	0.640		-1.599		
3x11	-4.092			-4.545		
3x12	45.153**	24.289		2.381		
4x7	24.813**	19.266*	2.300	5.000		
4x8	23.575**	22.745*		6.818		14.634**
4x9	-0.382		4.350	24.324**	12.195**	12.195**
4x10	26.236**	15.733	8.500	11.255**	4.878	
4x11	12.300		8.075	0.000		
4x12	69.134**	54.958**	21.100**	7.500		
5x7	14.066			-2.273		
5x8	-10.645			-4.167		12.195**
5x9	-13.543			12.195**	-6.122	12.195**
5x10	45.022**	31.680**	23.450**	-3.869		
5x11	-21.525**			-13.043**		
5x12	29.424**	19.739		-9.091**		
6x7	29.689**	28.032**	5.000	7.317		
6x8	-11.340			-4.444		
6x9	-6.803			0.000		
6x10	27.575**	23.680**		-1.639		
6x11	-27.774**			0.000		
6x12	29.087**	12.241		7.317		
L.S.D.0.05	5.263	6.078		0.563	0.650	
0.01	6.307	7.282		0.675	0.779	

***,** Significant at 0.05 and 0.01 levels of probability, respectively. Lines: 1- AVTO1003 2- AVTO1002 3- AVTO9803 4- AVTO1008 5- AVTO0101 6-AVTO9802. Testers: 7- CastleRock 8- Peta 86 9- FM – 9 10-Super Strain B 11-Super Marmand 12-Rio Grande.**

In this concern, many researchers found heterosis over mid-parents and check hybrid among studied hybrids (Salib, 1999; Khalil, 2004; Sakhar *et al*., 2010; Kansouh, 2013), however they showed negative heterosis over better parent for average fruit weight.

With regard to total soluble solids percentage (TSS%), data in Table 3 show that, 31 F_1's reflected no-dominance or dominance toward the low TSS %, since they gave insignificant or significant negative heterosis values based on mid-parents. The remaining crosses (five ones) showed dominance toward the high percent of TSS. From these five crosses, only one cross (4x9) showed heterosis over the better parent, indicating over dominance toward the high parent, while complete dominance was detected in four crosses. Relative to heterosis over the check hybrid, significant heterosis values were observed in seven crosses with values ranged from 9.756% (1x8) to 24.390% (2x11). These results supported the findings of Abd Allah (1995), Hegazy et al. (1995) who showed heterosis over mid-parents, better parent and check hybrid.

For ascorbic acid content, data presented in Table 4 showed that all the studied crosses except three ones reflected significant positive heterosis values over mid-parents, indicating dominance toward the high content of ascorbic acid. Values ranged from 29.730% in the cross 5x10 to 230.435% in the cross 1x8. Estimated values of heterosis based on better parent for these crosses showed over dominance in 18 ones toward the high parent, while the rest 15 ones reflected complete dominance for the content, since they gave insignificant heterosis values. Relative to check hybrid, only two crosses 1x8 and 1x11 exhibited significant positive values (31.034% and 24.138%, respectively). Similar results were observed by Zanata (1994), Abd Allah (1995), Yossef (1997), Salib (1999) and Masry (2014) who found heterosis in their studies on tomato for this trait.

Regarding fruit firmness, data in Table 4 illustrate that, nine crosses showed significant positive heterosis values based on mid-parents, indicating dominance toward the firmest fruits. However, no dominance was observed in 27 crosses, where they showed insignificant heterosis values. Relative to the better parent, four crosses (3x8, 3x11, 6x8 and 6x11) showed heterobiltiosis values of 26.882%, 30.108%, 38.542% and 27.082%, respectively, suggesting over dominance in these crosses toward the firmest fruit. The rest five crosses showed complete dominance toward the firmest fruit, since they exhibited insignificant heterosis values. On the other hand, no superiority was detected over the check hybrid, however no significant difference was observed in only one cross (6x10 compared with check hybrid), since it had insignificant

Table 4: Average degree of heterosis over mid-parents (M.P.), better parent (B.P.), check hybrid (C.H.) and potence ratio (p) for ascorbic acid content and fruit firmnees.

Crosses	Ascorbic acid content (mg /100 g fresh weight)			Fruit firmness (Kg/cm^2)		
	M.P.	B.P.	C.H.	M.P.	B.P.	C.H.
1x7	55.556**	40.000*		-1.550		
1x8	230.435**	216.667**	31.034**	31.481**	13.600	
1x9	109.091**	91.667**		2.682		
1x10	178.261**	166.667	10.345	-17.333**		
1x11	227.273**	200.000**	24.138**	17.308*	-2.400	
1x12	209.091**	183.333**	17.241	3.937		
2x7	70.370**	53.333**		-3.053		
2x8	100.000**	91.667**		-1.818		
2x9	145.455**	125.000**	-6.897	-16.226**		
2x10	47.826**	41.667		-32.895**		
2x11	163.636**	141.667**	0.000	-7.547		
2x12	109.091**	91.667**		11.628		
3x7	35.135**	13.636	-13.793	16.814**	-0.752	
3x8	87.879**	40.909**	6.897	28.261**	26.882**	
3x9	37.500**	0.000		8.297		
3x10	51.515**	13.636	-13.793	-13.060*		
3x11	31.250*	-4.545		37.500**	30.108**	
3x12	37.500**	0.000		-4.505		
4x7	63.636**	50.000**	-6.897	-18.248**		
4x8	51.724**	22.222		8.621		
4x9	64.286**	27.778		-30.686**		
4x10	79.310**	44.444**	-10.345	-27.215**		
4x11	92.857**	50.000**	-6.897	-20.536**		
4x12	121.429**	72.222**	6.897	-11.852*		
5x7	41.463**	11.538	0.000	5.350		
5x8	35.135**	-3.846	-13.793	12.438		
5x9	22.222			-25.203**		
5x10	29.730**	-7.692	-17.241	-31.930**		
5x11	-16.667			-5.699		
5x12	38.889**	-3.846	-13.793	-34.728**		
6x7	48.387**	43.750**		17.904**	1.504	
6x8	70.370**	43.750**		42.246**	38.542**	
6x9	38.462*	12.500		12.931		
6x10	48.148**	25.000		18.081**	-8.571	4.575
6x11	84.615**	50.000**	-17.241	36.313**	27.083**	
6x12	-7.692			-1.333		
L.S.D.0.05	5.845	6.749		0.259	0.299	
0.01	7.003	8.087		0.310	0.358	

***,** Significant at 0.05 and 0.01 levels of probability, respectively. Lines: 1- AVTO1003 2- AVTO1002 3- AVTO9803 4- AVTO1008 5- AVTO0101 6-AVTO9802. Testers: 7- CastleRock 8- Peta 86 9- FM – 9 10-Super Strain B 11-Super Marmand 12-Rio Grande**

heterosis value of 4.575%. These findings are in agreement with Salib (1999), Zanata (2002), Kansouh and Masoud (2007) and Kansouh (2013) who reported that heterosis over the better parent was absent for fruit firmness and the presence of some heterosis in some crosses was due to the partial dominance.

Combining ability.

Results of the analysis of variance for combining ability (Table 5) revealed that, the mean squares of general combining ability (GCA) and specific combining ability (SCA) were significant or highly significant for all studied traits, except TSS%, indicating that both additive and non-additive variances were important for the inheritance of these traits. For TSS%, GCA was insignificant, while SCA was highly significant, suggesting that non-additive gene action play the main role in the inheritance of this trait. In all studied traits, the variance due to SCA was higher than that of GCA, suggesting the predominance of non-additive gene action in the inheritance of these traits. These results were confirmed by the estimated average degree of dominance (ADD), which was higher than unity for all traits (Table 5), indicating that over dominance (non-additive gene action) influenced the manifestation of these traits. Moreover, low values of narrow sense heritability for all studied characters (Table 5) confirmed the above results that preponderance of non-additive gene action. Therefore, these characters could be improved by hybrid breeding method. The results were in conformity with Abd Allah (1995), Hegazi *et al*. (1995), Youssef (1997), Dod *et al*. (1995), Kumar *et al*. (1997), Saleem *et al*. (2009), Narasimhamurthy and Ramanjini (2013), Shankar *et al*. (2013) and Masry (2014) who reported that, non-additive gene action was predominant and play the main role in the inheritance of all traits under study.

Table 5: Analysis of variance and components of genetic variance for some plant and fruit characteristics.

S.O.V	df	plant height	No. of branches/ plant	Total fruit weight\ plant(kg)	Total fruit number\ plant	Average fruit weight (g)	T.S.S%	Ascorbic acid content(mg /100 g fresh weight)	Fruit firmness (Kg/cm^2)
Mean squares									
Crosses	35	628.645**	3.307**	0.283**	479.551**	182.217**	1.127ns	158.171**	0.253**
Lines	5	1276.906*	2.637 ns	0.570*	637.681ns	585.142**	1.254ns	399.644*	0.758**
Testers	5	1122.283*	8.481**	0.271ns	959.993*	308.302**	0.987ns	70.756ns	0.247ns
Lines x testers	25	400.264**	2.406**	0.228*	351.837**	76.414**	1.129**	127.360**	0.154**
Error	94	25.402	0.577	0.120	34.887	16.337	0.161	17.331	0.034
Component of variance									
σ^2G.C.A		4.734	0.018	0.001	2.483	2.057	0.000	0.599	0.002
σ^2S.C.A		16.437	0.610	0.036	105.650	20.026	0.323	36.676	0.040
σ^2A		9.468	0.035	0.002	4.967	4.115	0.000	1.198	0.004
σ^2D		16.437	0.610	0.036	105.650	20.026	0.323	36.676	0.040
A.D. dominance		1.32	4.17	4.09	4.61	2.21	57.17	5.53	3.21
h^2n.s.		6.24	4.19	2.74	4.06	13.91	0.03	2.74	7.02
Contribution (%) of lines		38.209	11.392	28.795	18.996	45.875	15.896	36.095	42.712
Testers		26.956	36.640	13.677	28.598	24.171	12.515	6.390	13.926
Line x testers		34.835	51.968	57.528	52.406	29.954	71.590	57.514	43.363

Ns, *, **: non-significant, significant at the 0.05 and 0.01 levels of probability, respectively

The estimated of GCA effects provides a measure of general combining ability of each genotype, thus aids in selection of superior parents for breeding programs. The estimated effects of six lines and six testers have been presented in Table 6. The obtained data revealed that, none of the parents was the best general combiner for all traits. Among the lines, the good general combiner was AVTO0101 for plant height, AVTO9802 for total yield/plant and fruit firmness, AVTO1002 for total fruit number/plant, AVTO1008 for average fruit weight and TSS% and AVTO1003 for ascorbic acid content. However, AVTO0101 was the good combiner for number of branches/plant which gave insignificant positive GCA effects. Among six testers, Super Marmand exhibited the highest significant GCA effects for plant height and number of branches/plant, FM – 9 was the best for total yield/plant. Whereas, Peto 86 showed the highest significant GCA effects for total fruit number, TSS% and ascorbic acid content, CastleRock was proved to be good combiner for average fruit weight and fruit firmness.

Table 6: Estimate of general combining ability effects for some plant and fruit characteristics.

Parents	plant height	number of branch/plant	Total fruit weight (kg)	Total fruit number	Average fruit weight (g)	Total soluble solids (%)	Ascorbic acid content(mg /100 g fresh weight)	fruit firminsess (Kg/cm2)
Lines (♀)								
1- AVTO1003	-3.630**	-0.648**	-0.211**	0.407	-3.180**	-0.269**	8.000**	0.209**
2- AVTO1002	-14.533**	0.074	-0.194*	9.574**	-9.321**	0.176	-1.333	-0.045
3- AVTO9803	-1.353	-0.259	0.172*	1.185	1.405	-0.269**	-0.444	0.031
4- AVTO1008	5.501**	0.241	0.111	-8.537**	7.333**	0.343**	1.778	-0.136**
5- AVTO0101	7.033**	0.352	-0.055	-3.259**	0.714	0.176	-1.778	-0.297**
6-AVTO9802	6.982**	0.241	0.176*	0.630	3.049**	-0.157	-6.222**	0.239**
Testers (♂)								
7- CastleRock	-3.030**	0.074	0.043	-6.093**	4.335**	0.009	0.001	0.152**
8- Peta 86	-1.323	-0.426**	-0.027	7.130**	-5.009**	0.343**	3.111**	0.095*
9- FM – 9	-1.235	-0.426**	0.190*	-1.148	3.105**	-0.102	-2.889**	-0.051
10-Super Strain B	-8.686**	-0.815**	-0.188*	-10.815**	3.512**	-0.324**	-0.889	0.025
11-Super Marmand	14.946**	0.963**	0.012	6.074**	-4.001**	0.176	0.889	-0.176**
12-Rio Grande	0.672	0.630**	-0.029	4.852**	-1.943*	-0.102	-0.222	-0.045
S.E. (Lines)	1.188	0.179	0.082	1.392	0.953	0.095	0.981	0.043
S.E.(Testers)	1.188	0.179	0.082	1.392	0.953	0.095	0.981	0.043

***,** Significant at 0.05 and 0.01 levels of probability, respectively.**

Table 7: Estimates of specific combining ability effects for some plant and fruit characteristics.

Crosses	plant height	N. of branch /plant	Total fruit weight\plant	Total fruit number\plant	Average fruit weight (g)	Total soluble solids (%)	Ascorbic acid content (mg /100 g fresh weight)	Fruit firmness (Kg/cm^2)
1x7	-5.762	-0.185	-0.478**	-18.796**	3.482	0.213	-12.889**	-0.206
1x8	-6.552	-0.019	0.225	6.315	-0.007	0.546**	6.667**	0.105
1x9	-4.056	-1.019*	0.214	-0.074	3.419	-0.676**	-7.333**	0.111
1x10	-7.689**	0.370	-0.081	-5.407	0.713	-0.120	2.667	-0.125
1x11	22.845**	0.926*	-0.264	-10.630**	-0.121	0.046	6.222**	0.040
1x12	1.214	-0.074	0.384	28.593**	-7.486**	-0.009	4.667	0.075
2x7	2.808	0.426	0.364	3.704	3.690	-0.231*	-0.889	0.048
2x8	2.101	1.593**	0.124	3.481	2.604	-0.565**	-4.000	-0.211*
2x9	-2.570	-1.407**	0.087	-1.241	1.927	0.546**	7.333**	-0.015
2x10	0.214	-0.352	-0.478**	-2.241	-9.666**	0.102	-8.000**	-0.241*
2x11	-1.169	-0.130	0.069	-5.796	4.783*	1.269**	6.222**	-0.110
2x12	-1.384	-0.130	-0.167	2.093	-3.338	-1.120**	-0.667	0.529**
3x7	-4.873	-0.241	0.092	2.759	-0.042	0.213*	0.889	0.055
3x8	3.670	0.593	0.245	-0.796	4.425	-0.454**	5.778**	-0.121*
3x9	2.666	0.259	-0.052	-3.519	2.541	-0.676**	-0.222	0.125*
3x10	4.116	0.315	-0.071	1.481	-2.525	0.213*	1.778	-0.077
3x11	1.068	0.204	-0.177	-1.074	-1.933	0.046	-5.333*	0.200*
3x12	-6.647**	-1.130**	-0.036	1.148	-2.467	0.657**	-2.889	-0.181
4x7	1.440	-0.074	0.156	12.815**	-6.100**	-0.398**	1.333	-0.111
4x8	10.484**	0.093	-0.264	-9.741**	0.694	0.269**	-8.444**	0.180
4x9	8.016**	0.759	-0.125	3.537	-4.050	0.713**	-1.111	-0.174
4x10	4.263	0.481	0.180	9.870**	-2.794	-0.065	0.889	0.070
4x11	-21.619**	-1.963**	0.184	-2.352	4.552	-0.565**	0.444	-0.169
4x12	-2.584	0.704	-0.132	-14.130**	7.698**	0.046	6.889**	0.203
5x7	-6.822*	-0.185	0.185	9.870**	-3.381	-0.231**	7.556**	0.316**
5x8	12.868**	-0.685	-0.488**	-11.352**	-3.604	0.435**	-0.889	0.124*
5x9	5.780*	0.981**	-0.165	-0.407	-3.228	0.880**	1.111	-0.080
5x10	4.981	-0.963**	0.143	-5.407	9.805**	-0.231*	1.778	-0.069
5x11	-19.608**	0.259	0.250	12.370**	-2.115	-0.731*	-12.000**	0.029
5x12	2.800	0.593	0.074	-5.074	2.524	-0.120	2.444	-0.320**
6x7	13.209**	0.259	-0.319	-10.352**	2.351	0.435**	4.000	-0.103
6x8	-22.571**	-1.574**	0.158	12.093**	-4.112	-0.231**	0.889	-0.076
6x9	-9.836**	0.426	0.040	1.704	-0.609	-0.787**	0.222	0.034
6x10	-5.885*	0.148	0.305	1.704	4.468	0.102*	0.889	0.441**
6x11	18.483**	0.704	-0.061	7.481**	-5.166*	-0.065	4.444	0.009
6x12	6.601*	0.037	-0.123	-12.630**	3.069	0.546**	-10.444**	-0.306**
S.E (SCA)	2.910	0.439	0.200	3.410	2.334	0.232	2.404	0.106

***,** Significant at 0.05 and 0.01 levels of probability, respectively. Lines: 1- AVTO1003 2- AVTO1002 3- AVTO9803 4-AVTO1008 5- AVTO0101 6-AVTO9802. Testers: 7- CastleRock 8- Peta 86 9- FM – 9 10-Super Strain B 11-Super Marmand 12-Rio Grande.**

The estimates of specific combining ability effects (Table 7) showed that, seven crosses exhibited significant positive values of SCA effects for plant height, the cross 1x11 reflected the highest value (22.845), followed by 6x11 (18.483). For number of branches/plant, only three crosses (1x11, 5x9 and 2x8) showed significant positive values of SCA effects (0.926, 0.981 and 1.593 respectively). None of 36 crosses showed significant positive SCA effects for total yield/plant, however 19 crosses exhibited insignificant positive values of SCA effects, the highest value was reflected by the cross 1x12 (0.384) followed by 2x7 (0.364) and 6x10 (0.305). Seven crosses displayed significant SCA effects for total fruit number/plant, the cross 1x12 was the best SCA value (28.593), followed by 4x7 (12.815). Only two crosses (4x12 and 5x10) were found to be the best combinations for average fruit weight since showed the highest SCA values (7.698 and 9.805, respectively). For TSS%, 13 crosses exhibited significant positive SCA effects, the lowest cross was 6x10 (0.102), while the highest one was 2x11 (1.269). Out of 36 crosses, seven ones showed significant positive values of SCA effects for ascorbic acid content, the best crosses have SCA effects were 5x7 (7.556), 2x9 (7.333) and 4x12 (6.889). For fruit firmness, six crosses showed significant positive values of SCA effects, the hybrids 2x12 and 6x10 gave the highest values (0.529 and 0.441, respectively).

- **Contribution of parents (%).**

Data presented in Table 5 showed that, the contribution of lines towards the total variance was higher than that of testers or line x testers for plant height and average fruit weight. However, testers contributed more than lines for number of branches/plant and total fruit number/plant. Line x tester interaction contributed higher values than both lines and testers for number of branches/plant, total yield and total number/plant, TSS%, ascorbic acid content and fruit firmness.

In conclusion, the results obtained from general and specific combining ability and some genetic parameters indicate the importance of heterosis breeding for effective utilization of non-additive genetic variances, which had predominant role for the improvement of the studied traits in tomato crop.

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قوة الهجين والقدرة على التألف في الطماطم بواسطه التلقيح القمي

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أجريت هذه الدراسة بمزرعة كليه العلوم الزراعية البيئية بالعريش- جامعه قناة السويس- مصر, خلال الفترة من ٢٠١٢ حتى ٢٠١٤. استخدم في الدراسة سته سلالات من الطماطم وسته كشافات وتم التهجين بينها بنظام السلالة x الكشاف, بهدف دراسة قوه الهجين بالنسبة لمتوسط الأبوين, الأب الأفضل, والهجين المقارن, وتقدير القدرة العامة والخاصة على التألف لبعض صفات النبات والثمرة في الطماطم. وكانت أهم النتائج المتحصل عليها ما يلي:

ظهرت قوة الهجين بالنسبة لمتوسط الابوين, الاب الافضل, والهجين المقارن لصفات ارتفاع النبات, عدد الافرع, المحصول الكلى/نبات, وعدد الثمار/نبات. لم تظهر قوة هجين على اساس الهجين المقارن لصفه صلابه الثمرة. تفوق تباين القدرة الخاصة على تباين القدرة العامة على التألف لجميع الصفات تحت الدراسة, مما يشير الى اهميه الفعل الجيني الغير مضيف في توريث كل الصفات المدروسة. اوضحت نتائج تأثيرات القدرة العامة ان السلالة ايه في تو ٩٨٠٢ ذو قدره ائتلافيه عالية لصفات المحصول الكلى/نبات وصلابه الثمرة, والسلالة ايه في تو ١٠٠٨ هي الافضل لصفه متوسط وزن الثمرة. كانت افضل الكشافات سوبر مارمند لصفات ارتفاع النبات وعدد الافرع, واف ام-٩ لصفة المحصول الكلى/نبات, و كاستل روك لمتوسط وزن الثمرة وصلابتها. أما تأثيرات القدرة الخاصة على التآلف فأظهرت تفوق الهجن ايه في تو ١٠٠٣x سوبر مارمند, ايه في تو ١٠٠٢x بيتو ٨٦, ايه في تو ١٠٠٣x ريو جراند, ايه في تو ٠١٠١x سوبر استرين بي, ايه في تو ١٠٠٢x سوبر مارمند, ايه في تو ٠١٠١x كاستل روك, و ايه في تو ١٠٠٢x ريو جراند في صفات ارتفاع النبات, عدد الافرع, عدد الثمار/نبات, متوسط وزن الثمرة, نسبه المواد الصلبة الذائبة, اسكوربيك اسيد, وصلابه الثمرة, على التوالي. اوضحت تقديرات القدرة العامة والخاصة على التألف, متوسط درجه السيادة, ودرجه التوريث اهمية طريقة التربية بالتهجين لتحسين جميع الصفات تحت الدراسة في محصول الطماطم.