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COMBINING ABILITY AND HETEROSIS FOR SOME ECONOMIC TRAITS IN TOMATO (*Lycopersicon esculentum* MILL.)

Ghobary , H. M. M. and K. Y. Ibrahim
Veget. Res. Dept., Hort. Res. Inst., Agric . Res. Center, Cairo, Egypt.

ABSTRACT

Line x tester experiment was conducted to evaluate the performance of 21 hybrids along with 10 parents in tomato. Variance due to genotypes, crosses and lines x testers was significant or high significant for most studied traits. The estimate of variance of *gca*, *sca*, their ratio and degree of dominance indicated that the preponderance of non-additive gene action for all the studied traits suggesting that selection might not be made in the early generations and recurrent selection with periodic intercrossing appeared to be the best method. Narrow sense heritability was low for traits i.e., plant height and T.S.S.% and high for fruit shape index , while was moderate for the other studied traits . Contribution of lines towards the total variance was more than that of testers. Based on mean performance and *gca* effects, line MNS_1 and tester Peto 86 were better for yield and its various components. Considering mean performance, *sca* effects and heterobeltiosis, three hybrids i.e., MNS_1 x Peto 86, CIN2498E x Super Marmande and CIN2498E x Peto 86 were superior for yield and recommended for heterosis breeding after further evaluation .

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is an important vegetable crop in Egypt and is grown on 537208 feddans with the production of 8639024 tonnes and average yield of 16.08 tonnes per feddans (Ministry of Agriculture, statistics ., 2007) .

The tomato productively could be generally improved through either improving the applied culture practices or using improved cultivars or F_1 hybrids. Therefore, producing superior local hybrids of tomato are urgently needed, since the prices of the improved hybrid of tomato are usually very high.

Genetic analysis provides a guide line for the assessment of relative breeding potential of the parents or identify best combiners in crops (Khattak *et al.,(* 2004);Weerasingh *et al.*, (2004) and Sulodhani Devi *et al.*, (2005)) which could be utilized either to exploit heterosis in F_1 or the accumulation of fixable genes to evolve variety. Hybrid vigor in tomato was first observed by Hedric and Booth (1907). Since then a number of workers have reported heterosis in tomato (Bhatt *et al.*, (1998) and Bhatt *et al.*, (2001)). Kumar *et al.,* (2003) reported 60% hybrid vigor in tomato. Even though many studies have been made on combining ability, gene action and heterosis, yet the pace of work on development of tomato hybrid seed on commercial basis have been limited due to lack of superior combiners in Egypt. As a result, import of tomato hybrid is a routine.

Line × Tester technique (Kempthrone, (1957)) is a useful tool for preliminary evaluation of genetic stock for use in hybridization programme with a view to identify good combiners, which may be used to build up a population with favorable fixable gene for effective yield improvement. In this study efforts have been made to identify parents suitable for tomato hybrid seed production through the use seven lines and three testers .

MATERIALS AND METHODS

The experimental materials consisted of ten determinate pure lines of tomato obtained from Asian Vegetable Research and Development Center (AVRDC) in Taiwan and Companies Fito (Italy), Peto seed and Asgrow (USA) .All the studied lines and cultivars belong to the species *Lycopersicon esculentum* Mill.. Seven female genotypes (designated as lines) viz., FLA7156, MNS_6, MNS_5, MNS_1, CLN2498D, CLN2498E and CLN2498F and three male genotypes (designated as testers)viz., Marglobe , Peto 86 and Super Marmande were crossed to generate 21 F_1 hybrids following line × tester mating design in 2008. The hybrids were evaluated along with parents following randomized complete block design with three replications at the experimental field of El- Baramoon horticultural research farm, Dakahlia Governorate during 2009. Each replicate contained 31 experimental plots . Each experimental plots contained of two redge of 4.5 meter long and 1 meter wide .The plants were spaced at 30 cm. apart on one side ridge. Standard cultural practices and plant protection measures were adapted to raise healthy crop. The observation of ten important characters was recorded from five randomly selected plants from each plot. Measurements were recorded on plant height, number of branches/plant, number of fruits /plant, average fruit weight, total yield /plant, fruit shape index, flesh thickness, number of locules / fruit, total soluble solids (T.S.S. %) and fruit firmness.

Genotype means were used for the analysis of variance (Steel and Torrie, (1980)).Analysis of combining ability and other genetic parameters was performed according to Singh and Chaudhary (1999). Heritability values were categorized low (<0.3), moderate(0.3-0.6) and high (>0.6) while genetic advance low (>0.1), moderate (0.1-0.2) and high(>0.2) as given by Johnson *et al.*, (1955). The distribution of crosses in relation to general combining ability (*gca*) and specific combining ability (*sca*) effects was worked out by taking combining ability effects as significant positive (high = *h*), non-significant(average = *a*) and significant negative (low = *l*).

RESULTS AND DISCUSSION

The results of the analysis of variance and the estimated mean square of all tested genotypes are presented in Table 1. The results, generally, indicated that the mean squares of genotypes were found highly significant for most studied traits, partitioning the genotypes into parents, crosses and their interactions gave highly significant mean squares for parents in seven traits ,high significant in two traits and non significant in one trait. Whereas, the mean squares of crosses appeared significant or highly significant in seven traits and insignificant in the other three studied ones; i.e. flesh thickness , number of locules / fruit and T.S.S.% .

T1

The estimated values of mean squares of the comparison between parents and crosses were found highly significant in five traits and insignificant in the other five. Lines exhibited highly significant variation for plant height, number of branches/plant, number of fruits /plant , average fruit weight and total yield/plant, whereas, testers were highly significant for plant height , number of fruits /plant, fruit shape index and fruit firmness.

The sizeable magnitudes of genotypes mean squares indicated to presence of considerable differences among these genotypes , therefore it become statically valid for the required genetic diversity for the success of the planned crosses and their genetic variance analysis.

Line x tester analysis used in this study makes it possible to obtain estimates for some different genetic parameters, required for judging further breeding programs and the general and specific combining ability components are of these parameters .

General combining ability (*GCA*) estimates the average performance of a line in hybrid combinations with other lines and specific combining ability (*SCA*) estimates the deviation of a particular cross from the expectation based on the average performances of the lines involved. The value of $\sigma^2 gca$ was less than that of $\sigma^2 sca$ in all traits; therefore non-additive type of gene action was pre -dominant. As a result the ratio of $\sigma^2 gca / \sigma^2 sca$ was also less than 1 and the degree of dominance $(\sigma^2 D / \sigma^2 A)^{1/2}$ was greater than 1 for all the traits. For all studied traits showed the preponderance of non-additive gene action as recorded by Chandha *et al.*, (2001), Dharmatti *et al.,* (2001) and Bayomy (2002).

Narrow sense heritability was moderate for most studied traits but low for plant height and high for fruit shape index . Since improvement in yield is the most important parameter for which low breeding value or additive gene action was depicted due to low heritability in addition to preponderance of non-additive gene action as revealed by other genetic parameters as well. Therefore selection in early generation would be ineffective and recurrent selection with periodic intercrossing is advocated.

The contribution of lines towards the total variance was higher than that of testers for all the traits. Line × tester contributed significantly in all the studied traits. Uneven contribution of lines, testers and their interactions had also been found by different investigators (Chandha *et al.*, (2001) and Manivannan and Sekar, (2005)).

Estimates of general combining ability effects of lines and testers have been shown in Table 2. None of the parents proved to be good general combiner for all the traits. The obtained high positive values would be of interest in all studied traits. The parental line FLA7156 showed significant or highly significant values for the effects of GCA for number of branches / plant, flesh thickness and T.S.S.% , indicating that FLA7156 was a good combiner for these traits. The parental line MNS_6 was a good combiner for number of fruits / plant ; since it had significant positive value for GCA effect on this trait. The line MNS_5 was a good combiner for number of branches / plant . The line MNS_1 was a good combiner for total yield / plant , average fruit weight and flesh thickness. The line CLN2498D was a good combiner for T.S.S.%.

T2

The line CLN 2498E had significant or highly significant positive values for the effects of GCA for plant height , total yield /plant, average fruit weight , number of locules / fruit and fruit firmness , indicating that it was a good combiner for these traits . The line CLN2498F had highly significant positive values for total yield / plant and number of fruits / plant ; therefore, it can considered a good combiner for both traits. Concerning testers, data in Table 2 showed that the cultivar Marglobe was a good combiner for total yield / plant, average fruit weight and number of locules / fruit, since its estimated values for GCA effects on these traits were found significant or highly significant with positive signs. The cultivar Peto 86 was poor general combiner for the all studied traits. The cultivar Super Marmande was appeared to be a good combiner for number of fruits/plant, fruit shape index and fruit firmness.

Three parents viz., MNS_1, CLN2498E and CLN2498F among lines and Marglobe among testers displayed desirable gca effects for yield and its various traits. Harer and Bapat (1982) and Premalatha *et al.*, (2006) reported that the *per se* performance of the parents with the nature of combining ability provides the criteria to choose the parents for hybridization. These four parents may be used in multiple crossing program for the identification of superior genotypes. The high gca effects are attributed to additive gene effects of additive x additive interaction effects and represent a fixable portion of genetic variation (Sarma *et al.,* (2004)).

Estimates of specific combining ability effects of the hybrids are presented in Table 3. The values of sca effects of plant height were positive and significant or highly significant for the four F_1 hybrids of the crosses FLA7156 x Super Marmande , MNS_6 x Peto 86, CLN2498F x Marglobe and MNS_1 x Marglobe with values 6.032, 4.745, 4.333 and 3.032 respectively. The estimated values of sca effects on number of branches / plant were positive and significant or highly significant for the crosses FLA7156 x Super Marmande, MNS_6 x Marglobe, MNS_5 x Peto 86, CLN2498E x Peto 86 and CLN2498Fx Super Marmande with values 0.270, 0.762, 0.635, 0.539 and 0.381 respectively . Seven crosses displayed positive and significant or highly significant sca values for number of fruit per plant , the hybrid CLN2498Ex Peto 86 was at the top with highest sca value of 17.619. In case fruit weight, MNS_1xPeto 86 showed maximum sca effects (33.661) followed by FLA7156 x Super Marmande (19.856). For yield per plant, the sca effect of hybrid FLA7156 x Super Marmande (1.861) was highest followed by CLN2498D x Marglobe (0.854), CLN2498F x Marglobe (0.749), MNS_1xPeto 86 (0.744), CLN2498F x Peto 86 (0.629), FLA 7156 x Peto 86 (0.487) and CLN2498Fx Marglobe (0.329).The crosses MNS_1xPeto 86, CLN2498DxSuper Marmande and CLN2498Fx Peto 86 gave significant and highly significant sca effects (1.914, 0.882 and 0.098, respectively) for fruit shape index. The four crosses MNS_1 x Super Marmande, CLN2498E x Peto 86, CLN2498F x Peto 86 and CLN2498Dx Marglobe gave significant positive values for sca effects on flesh thickness (0.087, 0.071, 0.066 and 0.061, respectively). For number of locules/fruit, the positive and significant or highly significant sca effects were exhibited by three crosses MNS_6xPeto 86, CLN2498Dx Super Marmande and CLN2498Fx Super Marmande with values 0.444, 0.508 and 0.286, respectively.

T3

Many crosses ,i.e., FLA 7156 x Marglobe , MNS_6 x Super Marmande, MNS_5 x Marglobe , MNS_1 x Peto 86, CLN2498E x Peto 86 , CLN2498E x Marglobe and CLN2498F x Super Marmande had significant or highly significant positive values for sca effects on T.S.S.% with values 0.011, 0.036, 0.044, 0.041, 0.030, 0.011 and 0.025, respectively. The estimated values of sca effects on fruit firmness were positive and significant or highly significant for the crosses MNS_5 x Marglobe (0.897), MNS_1 x Peto 86 (0.310) , MNS_1 x Super Marmande (0.190), CLN2498E x Marglobe (0.408) and CLN2498E x Peto 86 (0.201).

Significant differences due to specific combining ability effects in all characters suggested that a major proportion of the variations were controlled by dominant properties of genes (Griffing, (1956)). The distribution of crosses in relation to *gca* effects of parental combinations (*h* × *h, h* × *a, h* × *l, l* × *h, l* × *a, l* × *l, a* × *h, a* × *a* and *a* × *l*) showed that almost all types of *sca* effects were obtained from any kind of *gca* effects and hence performance of hybrids was independent of parents. Similar results were reported in earlier studies (Bhatt *et al.*, (2004) ; Thakur *et al.*, (2004) and Hariprasanna *et al.*, (2006)). The crosses having one parent with high *gca* effects and other parent with low *gca* effects are expected to throw desirable transgressive segregates if the additive genetic system present in high combiner and complementary epistatic effects in same direction (Iqbal and Khan, (2003)). Best crosses involved at least one parent with high *gca* effects can be used as a selection criteria for the identification of superior genotypes. Parents with high *gca* did not necessarily produced hybrid with high *sca* (Sharma *et al.*, (1999)), but combination of parents with average or low gca usually produced hybrids with high *sca*. In our results, the best crosses viz: MNS_1 × Super Marmande for plant height , MNS_6 x Super Marmande for number of branches/plant , CLN2498E x Peto 86 for number of fruits /plant , FLA7156 x Super Marmande and CLN2498D x Super Marmande for total yield / plant had *l* × *a*, *l* × *a, l* × *a* and *a* × *a gca* parental combinations respectively. In these hybrids, non-additive i.e. dominant and epistatic type of gene action was suggested as reported in potato (Iqbal and Khan, (2003)).

Estimates of heterobeltiosis (high-parent heterosis) percent are presented in Table 4. For plant height , heterosis estimates were positive and significant or highly significant for the crosses CLN2498D x Marglobe, MNS_1x Marglobe and MNS_5 x Marglobe with values 20. 62 , 11.16 and 9.69 %, respectively .For number of branches/ plant , seven crosses exhibited desirable heterobeltiosis with rang of 8.00 to 20.00 % , cross CLN2498D x Marglobe and MNS_1 x Marglobe showed minimum and MNS_5 x Marglobe and MNS_6 x Marglobe maximum desirable heterobeltiosis. Nine crosses manifested significant or highly significant and desirable positive heterobeltiosis (10.83 to 37.22 %) for number of fruits /plant, hybrid MNS_1 x Marglobe displayed minimum heterobeltiosis while CLN2498F x Peto 86 showed maximum heterobeltiosis . For average fruit weight, seven crosses exhibited desirable heterobeltiosis with range 7.51 to 28.69 %, hybrid CLN 2498E x Peto 86 showed minimum and MNS_1 x Peto 86 maximum desirable heterobeltiosis.

T4

Fourteen crosses manifested significant or highly significant desirable heterobeltiosis(18.79 to 48.55 %) for total yield/plant , hybrid MNS_1 x Super marmande displayed minimum heterobeltiosis, while MNS_1 x Peto 86 showed maximum heterobeltiosis. For fruit shape index, three crosses namely MNS_1 x Super Marmande \, FLA7156 x Super Marmande and MNS_6 x Super Marmande exhibited 33.33, 22.22 and 22.22 % heterobeltiosis, respectively. Similarly , for flesh thickness, three crosses namely MNS_5 x Marglobe, CLN2498D x Marglobe and MNS_1 x Super Marmande exhibited 25.00 , 25.00 and 20.00% heterobeltiosis ,respectively . Ten crosses exhibited desirable heterobeltiosis with range of 6.00 to 23.26% for number of locules / fruit , cross FLA7156 x Super Marmande showed minimum and MNS_1 x Marglobe maximum desirable heterobeltiosis. For T.S.S. , only two crosses namely MNS_1 x Peto 86 and CLN2498D x Peto 86, exhibited 6. 00 and 6. 00% heterobeltiosis ,respectively . Three crosses i.e., MNS_1 x Super Marmande, FLA7156 x Super Marmande and MNS_6 x Super Marmande showed 31.25 , 25.00 and 18.75% respectively desirable heterobeltiosis for fruit firmness . Three crosses viz., MNS_1 x Peto 86, CLN2498E x Peto 86 and CLN2498E x Super Marmande displayed high heterobeltiosis of 48.55, 44.51 and 44.46%, respectively for total yield . These hybrids were emerged from $h \times l$ and $h \times a$ gca parental combination and had higher value of mean performance and sca effects. Duvick (1999) reported that high degree of heterosis did not essentially correlate to sca effects, therefore , genotype x environment interaction might be conducted as suggested by Fox et. al. (1997) . Keeping in view mean performance , sca effects and heterobeltiosis , the hybrids MNS_1 x Peto 86 , CLN2498E x Peto 86 and CLN2498E x Super Marmande may be recommended for heterosis breeding after further evaluation.

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القدرة على التالف وقوة الهجين لبعض الصفات الاقتصادية في الطماطم

حامد محمد محمد غبارى و خالد يونس إبراهيم

قسم بحوث الخضر- معهد بحوث البساتين- مركز البحوث الزراعية- القاهرة –مصر

أجريت هذه الدراسة بهدف اختيار أباء لها قدرة عالية على التآلف فى الصفات الهامة للطماطم لاستخدامها فى انتاج هجن اثناء موسمي ٢٠٠٨ , ٢٠٠٩ بالمزرعة البحثية بالبرامون – دقهلية واستخدم في هذه الدراسة ١٠ أباء تم التهجين بينهم بنظام التزاوج line x tester حيث تم التهجين بين ٧ سلالات وثلاثة أصناف لإنتاج ٢١ هجينا ثم قيمت الآباء والهجن الناتجة منها في الموسم الصيفي ٢٠٠٩

وكانت أهم النتائج المتحصل عليها :

- التباين الراجع إلى الآباء والهجن والتفاعل بينهما كان معنوي او معنوي جدا لمعظم الصفات المدروسة.
- تقدير تباين القدرة العامة والخاصة والنسبة بينهما يشير إلى أن التأثير الغير اضافى كان هو السائد لمعظم الصفات المدروسة مما يوضح أن الانتخاب في الأجيال المبكرة غير مجدي وان الانتخاب المتكرر والتهجين الدوري هما الأكثر فاعلية .
- درجة التوريث على النطاق الضيق كانت منخفضة لصفتي ارتفاع النبات والمواد الصلبة الكلية الذائبة بينما كانت مرتفعة لصفة شكل الثمرة في حين كانت متوسطة لباقي الصفات.
- مساهمة السلالات في التباين الكلى كان اكبر من مساهمة الأصناف الاختيارية .
- بناءا على متوسط السلوك المظهري وتأثير القدرة العامة على التالف تبين أن السلالة MNS_1 والصنف الاختباري Peto 86 كانوا هم الأعلى للمحصول ومكوناته .
- بناءا على متوسط السلوك المظهري وتأثير القدرة الخاصة على التالف وقوة الهجين كانت الهجن MNS_1 x Peto 86 و CLN2498 x Super Marmande وCLN2498E x Peto 86 متفوقة فى المحصول ويوصى بها للتربية بقوة الهجين و التقييم فيما بعد .

قام بتحكيم البحث

أ.د / محمود محمد زغلول	**كلية الزراعة – جامعة المنصورة**
أ.د / محاسن عبد الحكيم محمد	**مركز البحوث الزراعية**

Table 1: Analysis of variance based on mean squares and estimate of genetic components in tomato.

S.O.V.	d.f	Plant height (cm.)	No. of branches/ plant	Number of fruits /plant	Average fruit weight (g.)	Total yield /plant (Kg.)	Fruit shape index	Flesh thickness (mm.)	No. of locules/ fruit	T.S.S. %	Firmness
Rep.	2	24.59	2.78	13290.19**	5003.29**	4.79*	0.06	0.08*	3.38	0.01	3.13**
Genotypes	30	384.48**	43.16**	16353.83**	23383.35**	83.23**	1.15**	0.40	66.13**	0.10	3.48
Parents	9	1418.53**	12.00**	4538.03**	5420.54**	12.68*	0.55**	0.17*	51.37**	7.49**	0.57
Crosses	20	758.98**	27.43**	8940.98**	17557.99**	52.63**	0.59*	0.23	13.05	0.06	2.84*
Parents x Crosses	1	-1793.04**	3.73**	2874.82**	404.82	17.93**	0.01	0.00	1.72	-7.45**	0.07
Lines	6	196.98**	10.54*	3113.87**	6010.41**	14.78**	0.10	0.07	5.05	0.02	0.49
Testers	2	64.41**	2.67	727.65**	939.17	3.16	0.25**	0.00	3.43	0.01	0.88**
Lines x Testers	12	497.59**	14.22*	5099.46**	10608.41**	34.69**	0.24	0.16	4.57	0.03	1.46
Error	60	238.46	39.23	2536.82	13127.62	34.77	0.96	0.56	39.29	0.26	3.98
σ^2 gca		-0.09	0.01	0.56	-0.16	-0.01	0.01	-0.01	0.01	-0.01	0.01
σ^2 sca		12.50	0.18	127.56	221.88	0.77	0.01	0.01	-0.09	-0.01	0.01
σ^2 A		-0.18	0.01	1.15	-0.32	0.01	0.01	-0.01	0.01	-0.01	0.01
σ^2D		12.50	0.18	127.56	221.88	0.77	0.01	0.01	-0.09	-0.01	0.02
$(\sigma^2D/\sigma^2A)^{1/2}$		8.24	4.21	10.53	26.42	7.42	1.58	1.00	2.55	1.23	1.38
h^2_n %		0.29	0.33	0.49	0.44	0.41	0.68	0.57	0.55	0.22	0.34
Contribution (%)of lines		25.95	38.43	34.83	34.23	28.08	17.40	28.63	38.68	32.73	17.31
Contribution (%) of testers		8.49	9.72	8.14	5.35	6.00	41.72	12.82	26.27	5.46	31.17
Contribution (%) of lines x testers		65.59	51.85	57.04	60.42	65.92	40.88	58.55	35.14	61.82	51.52

*** and ** Significant at p= 0.05 and p= 0.01,respectively.**

Table 2: General combining ability effects and mean performance (in parenthesis) of parents for different parameters in tomato .

Parents	Plant height (cm.)	No. of branches / plant	Number of fruits /plant	Average fruit weight(g.)	Total yield /plant (Kg.)	Fruit shape index	Flesh thickness (mm.)	No. of locules / fruit	T.S.S. %	Firmness
Lines										
FLA7156	-3.640**(41.0)	0.540*(5.0)	-11.571**(43.3)	-4.686*(65.5)	-0.751**(2.299)	0.005(0.9)	0.041**(0.6)	0.079(3.7)	0.022*(5.0)	-0.106*(1.4)
MNS_6	-1.793*(43.7)	-0.238(4.7)	2.207*(45.3)	-12.139**(54.5)	-0.476**(2.486)	-0.254**(0.9)	-0.059**(0.4)	-0.254**(3.3)	-0.022*(5.3)	0.081(1.6)
MNS_5	`1.207(37.3)	0.651**(4.0)	-1.682(25.3)	-3.277(46.7)	-0.290*(1.858)	-0.004(1.1)	-0.005(0.4)	-0.254**(3.7)	-0.011(4.7)	-0.068(1.6)
MNS_1	0.540(43. 0)	-0.238(5. 0)	-3.793**(28.7)	16.492**(44.7)	0.330*(1.887)	0.073**(0.9)	0.039*(0.4)	-0.023(3.7)	0.011(5.0)	0.068(1.3)
CLN2498D	1.529(41.7)	-0.015(4.3)	0.651(32.0)	-0.341(52.1)	0.102(2.109)	-0.004(1.3)	-0.024*(0.4)	0.023(3.3)	0.022*(5.0)	-0.117*(1.7)
CLN2498E	1.651*(24. 0)	-0.127(5.3)	0.249(19. 7)	12.170**(42.6)	0.712**(1.513)	-0.049*(1.1)	0.011(0.5)	0.635**(3.7)	-0.011(5.0)	0.116*(1.6)
CLN2498F	0.429(39.7)	-0.571*(4.7)	13.762**(38.0)	-8.225**(60.3)	0.376**(1.481)	0.028(1.2)	-0.004(0.5)	-0.143(3.3)	-0.011(4.7)	0.023(1.4)
Testers										
Marglobe	1.222*(41.3)	-0.095(5.0)	-1.936(51.7)	4.848**(83.8)	0.233*(2.746)	-0.072(1.0)	0.007(0.4)	0.286*(4.3)	0.011(5.3)	-0.083(1.7)
Peto 86	0.032(52. 0)	-0.190(6.3)	-2.841*(58.3)	-0.250(73.2)	-0.302*(2.768)	-0.009(1.0)	-0.008(0.6)	-0.001(5.3)	-0.008(4.3)	-0.085(1.8)
Super Marmande	-1.253*(47.0)	0.286(5.7)	4.778**(53. 3)	-4.599**(75.2)	0.070(2.688)	0.081*(0.8)	0.008(0.5)	-0.286*(5.0)	-0.003(5.7)	0.167**(1.6)
L.S.D at 0.05 for										
gi lines	0.678	0.164	0.828	1.745	0.098	0.019	0.009	0.061	0.008	0.038
gi-gi lines	1.655	1.077	2.668	4.719	0.815	0.167	0.258	0.380	0.185	0.142
gi testers	0.488	0.110	1.099	0.129	0.088	0.033	0.008	0.112	0.006	0.037
gi-gi testers	0.939	0.404	2.676	3.909	0.265	0.070	0.022	0.304	0.014	0.123

Table 3: Specific combining ability effects and mean performance (in parenthesis) of hybrids for different parameters in tomato .

Hyprids	Plant height (cm.)	Number of branches / plant	Number of fruits /plant	Average fruit weight(g.)	Total yield /plant (Kg.)	Fruit shape index	Flesh thickness (mm.)	No. of locules / fruit	T.S.S.%	Firmness
FLA7156 x Marglobe	-4.444**(38.7)	-0.349*(5.7)	-12.953**(25.0)	-10.326**(54.1)	-1.375**(2.329)	0.031(1.0)	-0.014(0.5)	-0.174(4.7)	0.011*(5.3)	-0.172*(1.3)
FLA7156 x Peto 86	-1.588(40.3)	0.079(6.0)	-2.048(35.0)	-9.928**(49.8)	0.487**(2.682)	-0.082(1.0)	0.011(0.5)	0.111(4.7)	-0.003(5.0)	-0.104(1.3)
FLA7156 x Super Marmande	6.032**(46.7)	0.270*(5.8)	14.999**(59.7)	19.856**(84.9)	1.861**(3.402)	0.051 (1.1)	0.005(0.5)	0.064(5.3)	-0.008(5.0)	0.278**(2.0)
MNS_6 x Marglobe	-0.445(44.3)	0.762**(6.0)	13.602**(65.3)	-2.476(54.5)	-0.583**(3.562)	-0.013(0.9)	0.039(0.4)	0.159(4.7)	-0.011*(4.7)	-0.033(1.6)
MNS_6 x Peto 86	4.745**(48.3)	-0.809**(4.4)	-15.159**(35.7)	3.089*(55.0)	-0.570**(2.874)	-0.296**(0.9)	-0.083*(0. 3)	0.444**(5.3)	-0.026**(4.3)	-0.024(1.6)
MNS_6 x Super Marmande	-4.302**(38.0)	0.048(5.8)	1.555(60. 0)	-0.611(46.9)	0.012(2.804)	0.044(1.1)	0.045(0.4)	-0.603**(4. 0)	0.036**(5.0)	0.057(1.9)
MNS_5 x Marglobe	-2.445*(45.3)	-0.127(6.0)	-2.509(45.3)	-0.151(65.7)	-0.275*(2.890)	0.040(1.0)	0.059(0.5)	0.159(4.7)	0.044**(5.3)	0.897**(1.6)
MNS_5 x Peto 86	0.745(47.4)	0.635**(5.8)	4.396*(51.3)	-7.193**(53.6)	-0.290*(3.712)	-0.016(1.0)	-0.036(0.4)	0.111(4.0)	-0.037**(4.3)	-0.675**(1.4)
MNS_5 x Super Marmande	-1.698(47.1)	-0.508**(5.8)	-1.889(52. 7)	7.347**(83.9)	0.192(3.194)	-0.023(1.1)	0.021(0.5)	-0.269(4. 3)	-0.008(4.7)	0.014(1.7)
MNS_1 x Marglobe	3.032*(47.8)	0.095(5.4)	11.602**(57. 3)	-19.670**(66.1)	0.045(3.740)	-0.024(1.0)	-0.079*(0.4)	0.271(5.3)	-0.011*(5.0)	-0.120(1.7)
MNS_1 x Peto 86	-2.254*(43.8)	-0.143(5.9)	-12.159**(72. 0)	33.661**(94.2)	0.744**(4.112)	1.914**(1.0)	-0.007(0.5)	-0.111(4. 7)	0.041**(5.3)	0.313**(1.3)
MNS_1x Super Marmande	1.698(46.4)	0.048(5.7)	0.555(53. 0)	-13.989**(82.2)	-4.429**(3.193)	0.083(1.2)	0.087*(0.6)	-0.158(4. 7)	-0.030**(4.7)	0.190*(2.1)
CLN2498D x Marglobe	2.333*(50.3)	0.539**(5.4)	4.158*(54. 3)	13.929**(82.8)	0.854**(2.283)	0.039(1.0)	0.061*(0.5)	-0.396*(5. 0)	-0.022**(5.0)	0.039(1.5)
CLN2498D x Peto 86	-1.810(45.0)	-0.033(5.3)	1.730(51. 0)	-18.206**(45.6)	-0.739**(3.411)	0.046(1.0)	-0.021(0.4)	-0.398*(5.0)	0.030**(5.3)	-0.074(1.5)
CLN2498DxSuper Marmande	-0.524(35.0)	-0.509**(5.3)	-5.889*(51. 0)	4.277*(83.6)	-0.117(3.277)	0.882**(1.0)	-0.040(0.4)	0.508**(4. 7)	0.003(5.0)	0.111(1.6)
CLN2498E x Marglobe	0.111(38.3)	-1.016**(5.3)	-3.619(46. 3)	0.418 (81.7)	0.329*(3.675)	-0.102*(0.8)	-0.068*(0.4)	-0.063(5.0)	0.011*(5.0)	0.006(1.7)
CLN2498E x Peto 86	2.301*(49.3)	0.746**(6.0)	5.619*(74. 7)	2.416(78.7)	-0.611**(4.000)	0.042(1.0)	0.071*(0.6)	-0.111(5. 7)	-0.003(4.7)	-0.241(1.9)
CLN2498ExSuper Marmande	-2.413*(43.3)	0.270*(6.2)	-2.000(64. 7)	-2.834(89.1)	0.121(3.883)	0.059(1.1)	-0.002(0.5)	0.175(4. 7)	-0.008(4.7)	-0.244**(1.7)
CLN2498F x Marglobe	4.333**(41.3)	0.095(5.9)	-10.286**(53. 0)	18.280**(79.2)	0.749**(3.925)	0.031(1.0)	0.007(0.5)	0.048(4. 7)	-0.022**(4.7)	0.408**(1.5)
CLN2498F x Peto 86	-2.143*(43.7)	-0.477**(5.4)	17.619**(80. 0)	-4.239*(51.7)	0.629**(3.580)	0.098*(1.1)	0.066*(0.5)	-0.333*(4.7)	-0.003(4.7)	0.201*(1.8)
CLN2498FxSuper Marmande	-2.191*(42.4)	0.381*(5.8)	-7.333**(62. 7)	-14.039**(37.4)	-1.379(2.289)	-0.128* (1.0)	-0.073*(0.4)	0.286* (5. 7)	0.025**(5.0)	-0.151*(1.7)
L.S.D at 0.05 for										
Sij	0.855	0.103	1.616	1.255	0.110	0.040	0.025	0.112	0.003	0.062
Sij-Ski	2.204	0.666	9.014	8.154	0.756	0.091	0.118	0.669	0.047	0.291

Table 4: Heterobeltiosis percent of hybrids for different parameters in tomato .

Hybrids	Plant height (cm.)	No. of branches/ plant	Number of fruits/ plant	Average fruit weight (g.)	Total yield /plant (Kg.)	Fruit shape index	Flesh thickness (mm.)	No. of locules/ fruit	T.S.S. %	Firmness
FLA7156 x Marglobe	-6.30	14.00**	-51.64**	-35.44**	-15.19**	0.00	-16.67**	9.30**	0.00	-23.53**
FLA7156 x Peto 86	-22.50**	-4.76	-39.97**	-31.97**	-3.11	0.00	-16.67**	-11.32**	0.00	-27.78**
FLA7156 x Super Marmande	-0.64	1.75	12.01**	12.90**	26.56**	22.22**	-16.67**	6.00*	-12.28**	25.00**
MNS_6 x Marglobe	1.37	20.00**	26.31**	-34.96**	29.72**	-10.00**	0.00	9.30**	-11.32**	-5.88
MNS_6 x Peto 86	-7.12	-30.16**	-38.77**	-24.86**	3.83	-10.00**	-50.00**	0.00	-18.87**	-11.11**
MNS_6 x Super Marmande	-19.15**	1.75	12.57**	-37.63**	4.32	22.22**	-20.00**	-20.00**	-12.28**	18.75**
MNS_5 x Marglobe	9.69*	20.00**	-12.38**	-21.60**	5.24	-9.09**	25.00**	9.30**	0.00	-5.88
MNS_5 x Peto 86	-8.85*	-7.94*	-12.01**	-26.78**	34.10**	-9.09**	-33.33**	-24.53**	-8.51**	-22.22**
MNS_5 x Super Marmande	0.21	1.75	-1.13	11.57**	18.82**	0.00	0.00	-14.00**	-17.54**	6.25
MNS_1 x Marglobe	11.16**	8.00*	10.83*	-21.12**	36.20**	0.00	0.00	23.26**	-5.66*	0.00
MNS_1 x Peto 86	-15.77**	-6.35	23.50**	28.69**	48.55**	0.00	-16.67**	-11.32**	6. 00*	-27.78**
MNS_1x Super Marmande	-1.28	0. 00	0.56	9.31*	18.79**	33.33**	20.00**	-6.00*	-17.54**	31.25**
CLN2498D x Marglobe	20.62**	8.00*	5.03	-1.19	-16.86**	-23.08**	25.00**	16.28**	-5.66*	-11.76**
CLN2498D x Peto 86	-13.46**	-15.87**	-12.52**	-37.70**	23.23**	-23.08**	-33.33**	-5.66*	6. 00*	-16.67**
CLN2498D x Super Marmande	-25.53**	-7.55	-4.32	11.17**	21.91**	-23.08**	-20.00**	-6.00*	-12.28**	-5.88
CLN2498E x Marglobe	-7.26	0.00	-10.44*	-2.51	33.83**	-27.27**	-20.00**	16.28**	-5.66*	0.00
CLN2498E x Peto 86	-5.19	-4.76	28.13**	7.51*	44.51**	-9.09**	0.00	7.55*	-6. 00*	5.56
CLN2498E x Super Marmande	-7.87	8.77**	21.39**	18.48**	44.46**	0.00	0.00	-6.00*	-17.54**	6.25
CLN2498F x Marglobe	0.00	18.00**	2.51	-5.49	42.93**	-16.67**	0.00	9.30**	-11.32**	-11.76**
CLN2498F x Peto 86	-15.96**	-14.29**	37.22**	-29.37**	29.36**	-8.33*	-16.67**	-11.32**	0.00	0.00
CLN2498F x Super Marmande	-9.79*	1.75	17.64**	-50.27**	-17.43**	-16.67**	-20.00**	14.00**	-12.28**	6.25

*** and ** Significant at p= 0.05 and p= 0.01,respectively.**