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LINE × TESTER ANALYSIS FOR COMBINING ABILITY AND HETEROSIS IN TOMATO UNDER LATE SUMMER SEASON CONDITIONS

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ABSTRACT

Combining ability and heterosis were studied in a line x tester cross in tomato (*Solanum lycopersicum* L.) during 2008 to 2010 at the Experimental Farm, Horticulture Department, Faculty of Agriculture. The experimental materials comprised four lines (females), viz., CLN 2123, CLN 2400A, CLN 2498E, CLN 2400B and two testers (males), viz., peto86, CastleRock and 8F_1s obtained from the crossing testers with each line. Analysis of variance revealed highly significant differences among all the F_1 hybrid means and their respective six parental values for all examined traits. Positive heterosis over better parent was observed in some crosses for most of studied characters except average fruit weight, which had negative values. Heterosis over better parent ranged from 12.7 to 66.2 for total yield. The mean squares due to general combining ability (GCA) and specific combining ability (SCA) were also highly significant. Among parents, peto86 and CLN2498E proved the best combiners for plant height, fruit set. The parents Peto86 and CLN2400A were the best combiners for early and total yield. While, CastleRock cv. was the best combiner for average fruit weight and fruit firmness. The best specific cross combinations were CastleRock x CLN 2123, CastleRock x CLN2400B, Peto 86 x CLN2400A and Peto 86 x CLN2498E for total yield per plant.

Keywords: *Solanum lycopersicum* L, Combining ability, Heterosis, Late summer season.

INTRODUCTION

Tomato is one of the most popular and widely grown vegetable crops in the world. The top five producing countries are China, USA, India, Turkey and Egypt (FAOSTAT, 2009). Tomato productivity could be generally improved through either improving the applied cultural practices or using improved cultivars of F_1 hybrids. It is adapted to a wide range of climates. However, fruit set is limited to somewhat narrow range. Temperature higher than 34/20 (day/night) or a period of 4 hours at 40°C will cause blossom drop in most cultivars (Metwally *et al*. 1988). The maximum (day) and minimum (night) temperature in Egypt are frequently getting higher than 30 °C and 20°C, respectively, during the summer season. Therefore, it seriously reduces fruit set. Tomato hybrids are now being commercially worldwide since hybrids are superior to open-pollinated cultivars for earliness, yield and quality. The mating design (Line x Tester) suggested by Kempthorne (1957) has been extensively used to estimate GCA and SCA variances and their effects. Also, it is used in understanding the nature of gene action involved in the expression of economically important quantitative traits. Heterosis over better parent on tomato was reported for plant height and number of branches by Amin *et al*. (2001) and for early and total yield by Khalil (2004).

Meanwhile, such a type of heterosis was found absent for average fruit weight in study conducted by El-Gazar *et al*. (2002) and Khalil (2004), indicating that all crosses produced smaller fruits than their better parent. The genetic materials used in the present study included two groups of tomato cultivars. The first group is heat-sensitive with large-fruited and the second group is heat-tolerant with small-fruited. Therefore, the hybridization between the two groups will improve fruit size and maintain fruit setting ability (Scott *et al*., 1986). Therefore, mating design used would make it impossible to cross between materials originated in the same group (Kempthorne, 1957). Combining ability analysis is an important technique to understand the genetic potential of parents and their hybrids. It also provides the information on gene effects to help us in formulating an effective breeding strategy. Considering this, an investigation was undertaken to identify the best parental combination having high yield and quality.

MATERIALS AND METHODS

The experiments were conducted in the Experimental Farm of Horticulture Department, Faculty of Agriculture, Kafrelsheikh University.

The experimental materials comprised four lines (females), viz., CLN 2123, CLN 2400A, CLN 2498E, CLN 2400B and two testers (males), viz., peto86, CastleRock and 8F_1s obtained from the crossing testers with each line. The lines introduced from Asian Vegetable Research and Development Center (AVRDC) in Taiwan.

Seeds were sown in seedling trays on 1st May 2009 and 2010. The seedlings were transplanted on 5th June on 40 cm apart. The experiments were laid out in a randomized block design with three replications. Each plot consisted of two ridges, each 6 m long and 1.25 m wide, thus making an area of 15 m^2. Routine cultural practices, similar to those used in tomato commercial production, were done as needed.

Data were recorded for plant height (cm) and number of branches per plant after 60 days from transplanting for five plants per plot, early yield (kg/plant) as the yield of the first three pickings. Total yield was recorded as the total weight (kg/plant) of all harvested fruits. Average fruit weight (g) was calculated by dividing the total fruit weight by total fruit number. Fruit firmness was measured by using a needle type pocket penetrometer (Mod FT011 (0-11lbs). The percentage of total soluble solids (TSS%) content in fruit juice was determined by a hand refractometer.

Statistical analyses

Data were recorded during two seasons of 2009 and 2010, then, the combined data over the two seasons were calculated and statistically analyzed. Analysis of variance was performed and estimates of variance components were calculated for each trait. All the data were analyzed by line x tester analysis for estimating the combining ability effects as suggested by Kempthorne (1957). The amount of heterosis was expressed as the deviation percentage of the F_1 mean performances from the mid-parent (MP) and better parent (BP) average values.

RESULTS AND DISCUSSION

Test of significance

Data in Table (1) show that tests of significance indicated that the mean squares of genotypes were significant for all studied traits except total yield, indicating the presence of adequate genetic variability and the genetic inference could be calculated as the genotypes are partitioned into parents, crosses and their interactions. The mean squares of parents, crosses and parent × crosses interaction were significant in all studied traits except total yield and indicated the presence of considerable differences among these genotypes and therefore, it become statistically valid for the required diversity for the success of the planned crosses (Brar and Sukhija, 1977).

Table (1): Analysis of variance and mean squares of factorial mating design (LXT) for various traits in tomato.

genotypes	d.f	Plant height	Branches /plant	Fruit set (%)	Early yield	Total yield	Average fruit wt.	firmness	TSS
Replications	2	28.6	3.1	10.6	0.1	0.01	5.5	0.12	0.10
Genotypes	13	533.5**	7.59**	176.5**	0.26**	7.9	598**	1.48**	0.39**
Parents	5	869**	7.96**	76.4**	0.1**	10.7	1334**	1.57**	0.35**
Crosses	7	288.9**	8.36**	94.2**	0.29**	6.8	140.8**	1.22**	0.42**
Parents× rosses	1	567.9**	0.39	12253**	1.1**	1.6	112.1**	2.82**	0.36
Lines	3	44.8	1.17	34.7**	0.14**	7.9	191.8**	1.53*	0.38*
Tester	1	1001**	20,2**	477**	1.12**	11.3	297.5**	0.63	0.81**
Lines X Tester	3	295.7**	11.6**	26.1**	0.18**	4.3	37.5**	1.11*	0.34*
Error	26	61.3	1.43	5.5	0.01	0.1	5.57	0.24	0.1

The performance of parents and their F_1 hybrids

Data presented in Table (2) show that line CLN 2123E had the tallest plants and line CLN 2400A had the highest number of branches per plant. The cross between Peto 86 and CLN2123E had the highest fruit set percentage (71.2%). Cross between Peto 86 and CLN2400A produced the highest early yield. Each of crosses Peto 86 x CLN 2400A and Peto86 x CLN 2498E produced the highest total yield. CastleRock cv produced the largest average fruit weight. For fruit firmness, the crosses between CastleRock and CLN 2498E or CLN 2400B appeared to be the best F_1 hybrids in fruit firmness. Data illustrated that the percentage of total soluble solids in fruit juice ranged from 3.9% for CastleRock cultivar to 5.2 % for the cross Peto 86 x CLN2400B. Generally the first group cultivars had low fruit set percentage, large fruit and high fruit firmness, while the second group (heat tolerant) lines had high fruit set percentage, small fruits and low fruit firmness. Previous studies reported also significant differences for this trait among F_1 crosses (El-Gazar *et al*. 2002, Dawa *et al*. 2007 and Kansouh and Masoud 2007).

Table (2): Mean performance of parents and hybrids for various traits in tomato

genotypes	Plant height (cm)	Branches /plant (no.)	Fruit set (%)	Early yield (Kg/plant)	Total yield (Kg/plant)	Average fruit wt. (g)	Firmness lbs	TSS %
Tester								
1 CastleRock	70.3	5.0	49.6	0.42	3.63	100	3.6	3.9
2 Peto 86	66.7	7.0	50.1	0.77	3.55	73.1	3.5	4.7
Lines								
3 CLN 2123	104.7	5.7	52.8	0.48	2.3	38.1	1.8	4.6
4 CLN 2400A	59.3	9.0	58.8	0.73	3.4	57.9	3.0	4.1
5 CLN 2498E	70.0	4.7	62.3	0.70	2.2	59.1	2.9	4.6
6 CLN 2400B	58.3	5.3	55.7	0.63	3.2	53.3	3.8	4.6
Crosses								
1x3	62.3	6.0	55.1	0.96	3.17	56.3	3.2	4.8
1x4	54.0	4.3	62.7	0.72	4.56	63.1	3.5	4.7
1x5	53.0	3.3	65.2	0.71	2.06	66.3	4.2	3.9
1x6	61.3	6.3	60.7	0.52	4.09	69.4	4.3	4.4
2x3	65.7	5.0	70.2	0.92	3.11	47.3	3.9	4.7
2x4	73.7	7.0	69.9	1.47	5.9	63.0	2.7	4.8
2x5	82.3	8.7	71.2	1.30	5.26	59.2	3.0	4.6
2x6	60.7	6.7	68.6	0.94	4.0	57.5	4.4	5.2
LSD	2.62	0.54	4.3	0.1	1.2	5.1	0.92	0.84

Heterosis

Data presented in Tables (3 and 4) show that heterosis over the mid or better parent for plant height was absent for all crosses except the crosses Peto 86 x CLN2400A and Peto 86 x CLN2498E. Heterosis over mid-parents was 16.9 and 20.4 for the crosses Peto 86 x CLN2400A and Peto 86 x CLN2498E, respectively, while heterosis over better parent was 10.44% and 17.57% for the crosses Peto 86 x CLN2400A and Peto 86 x CLN2498E, respectively.

For number of branches per plant, heterosis over mid parents was 12.15, 22.3, 37.0 and 8.9 for the crosses CastleRock x CLN2123, CastleRock x CLN2400B, Peto 86 x CLN2498E, and Peto 86 x CLN2400B, while heterosis over better parent was 5.3, 18 and 24.2 for the crosses CastleRock x CLN2123, CastleRock x CLN2400B and Peto 86 x CLN2498E, respectively. These results indicated that both additive and non-additive gene effects were important in the inheritance of number of branches per plant (Shalaby *et al*. 1983).

The results in Table (3) show that significant amount of heterosis over the mid-parents for fruit set percentage ranged from 9.7% to 36.4%, as the largest amount of 36.4% came as a result of hybrid Peto 86 x CLN2123. The lowest positive value of heterosis over the better parent was 14.3% in the cross Peto 86 x CLN2498E, while the largest value of 34.7% resulted from the cross Peto 86 x CLN2123. Tomato is adapted to a wide range of climates while fruit set is limited to a somewhat narrow range (Rick, 1976). For optimum fruit setting, tomato plants require night temperature of 14-20 °C and day temperature of 25-30 °C. When might or day temperature was higher or lower than this rang fruit setting was reduced or completely terminated (Metwally *et al*. 1988).

For early yield, significant amount of heterosis over the mid-parents was positive and highly significant with the value of 13.3% in the cross CastleRock x CLN2123. However, five F_1 hybrids from eight ones gave significant or highly significant with positive values heterosis over the better parent. Heterotic effects were due to over dominance as reported by Khalil *et al*. (1988).

Regarding, total yield, most of the crosses showed dominance towards the high total yield, since they revealed significant positive heterosis values over mid parents (Table 4). Singh and Asati (2011) found heterotic effect over better parent for plant height and yield per plant.

For average fruit weight, dominance towards the small fruit was detected in all crosses, since they significantly decreased in average fruit weight than their mid parent values. Generally, no hybrid vigor was detected for average fruit weight in the tested hybrids. Similar results were obtained by Hatem (2003) and Khalil (2004), since no heterosis was observed for tomato average fruit weight in their tomato materials.

Firmness of tomato fruits is an important character, since firm fruits are desired for handling and marketing. Heterosis over mid-parent was present in 6 crosses from 8 ones. While, heterosis over better parent was present in four crosses from 8 ones (Table 4). Hatem (1994) reported that both of heterosis over mid- and better parent was absent, therefore, the mean of F_1 crosses was similar to their mid parent and Khalil *et al*. (1988) noticed partial dominance for the soft fruit.

In respect to total soluble solids percentage, three and two crosses from 8 ones had positive with significant values from heterosis over mid-parents and better parent, respectively. These results support the findings of Amin *et al*. (2001) and Bhatt et al. (2001), who found heterosis over the better parent for total soluble solids content in their studies.

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

crosses	Plant height		Branches /plant		Fruit set (%)		Early yield	
	MP	BP	MP	BP	MP	BP	MP	BP
1x3	-28.8**	-40.5**	12.2	5.3	9.7	8.5	113.3**	100**
1x4	-16.7	-23.2**	-38.5**	-52.2**	24.9*	15.1*	26.3*	-1.4
1x5	-24.4**	-24.6**	-31.9*	-34.0**	16.5*	4.6	26.7*	1.4
1x6	-4.66	-12.8	22.3	18.8	15.3*	8.9	0.0	-17.4
2x3	-23.3**	-37.2**	-21.3	-28.6	36.4**	34.7**	48.0**	19.5
2x4	16.9	10.5	-12.5	-22.2	26.0**	18.8*	96.0**	90.9**
2x5	20.4*	17.6	37.0**	24.2**	24.5**	14.3*	78.1**	68.8**
2x6	-2.88	-8.9	8.9	-4.3	26.3**	22.2**	34.2**	22.1

1 CastleRock 2 Peto 86 3 CLN 2123 4 CLN 2400A 5 CLN 2498E 6 CLN 2400B

Table (4): Heterosis percentage over MP and BP for total yield and fruit quality traits in tomato

crosses	Total yield		Average fruit wt.		firmness		TSS	
	MP	BP	MP	BP	MP	BP	MP	BP
1x3	7.1	-12.7	-18.5*	-43.7**	18.5	-11.1	13.6	5.0
1x4	29.9**	25.6**	-20.1**	-36.9**	6.1	-2.8	16.4**	13.1
1x5	-29.2**	-43.2**	-16.6*	-33.7**	29.2**	19.4*	-8.2	15.2*
1x6	19.9*	12.7	-9.5	-30.6**	16.2	13.1	1.6	-5.6
2x3	6.5	-12.4	-14.9*	-35.3**	44.4**	11.4	-0.2	-2.1
2x4	70.0**	66.2**	-3.8	-13.8*	-16.9	-22.8	7.2	0
2x5	83.2**	48.2**	-10.4*	-19.0	-6.2	-14.2	-1.7	-3.5
2x6	18.7*	12.7	-9.0	-21.3*	20.5*	15.8*	10.6*	9.0*

1 CastleRock 2 Peto 86 3 CLN 2123 4 CLN 2400A 5 CLN 2498E 6 CLN 2400B

Combining ability

General combining ability (GCA) studies have successfully led to making choice of suitable parent. The estimation of GCA effects (Table 4) shows that CastleRock cv. was a good combiner for average fruit weight and fruit firmness. Peto 86 was a good combiner for most traits, i.e., plant height, number of branches per plant, fruit set percentage early and total yield and TSS content. Line CLN 2400A was a good combiner for early and total yield and average fruit weight traits. Line CLN 2498E was a good combiner for plant height, fruit set percentage and average fruit weight traits. While, Line CLN 2400B was a good combiner for number of branches per plant, average fruit weight, fruit firmness and TSS content traits. In this respect, Sharma *et al*. (1999) 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.

Specific combining ability is the manifestation of non-additive component of genetic variance and associated with interaction effects, which may be due to dominance and epistatic component of genetic variation that are non-fixable in nature. Such non-fixable components are potential parameters for heterosis breeding which is very much useful in tomato where commercial exploitation of heterosis is feasible. The estimation of sca effects (Table 5) show that, the crosses CastleRock x CLN 2400B and Peto86 x CLN 2498E had positive and significant values for plant height. The crosses CastleRock x CLN 2123, CastleRock x CLN 2400B and Peto86 x CLN 2498E had positive and highly significant values for number of branches per plant. The crosses CastleRock x CLN 2498E and Peto86 x CLN 2123 had positive and significant or highly significant values for fruit set percentage. The crosses Peto86 x CLN 2123, Peto86 x CLN 2400A and Peto86 x CLN 2498E had positive and highly significant values for early yield. However the crosses CastleRock x CLN 2123, CastleRock x CLN 2400B, Peto86 x CLN 2400A and Peto86 x CLN 2498E had positive and highly significant values for total yield.

Table (5): Estimation of general combining ability effects for various traits in parental lines and testers of tomato

Genotype	Plant height	Branches /plant	Fruit set (%)	Early yield	Total yield	Average fruit wt.	firmness	TSS
Castle rock	-6.45**	-0.92**	-4.45**	-0.22**	-0.68**	3.52**	0.16**	-0.18**
Peto 86	6.45**	0.92**	4.45**	0.22**	0.68**	-3.52**	-0.16**	0.18**
S.E.	2.26	0.34	0.67	0.013	0.03	0.68	0.14	0.10
CLN 2123	-0.12	-0.42	-2.77**	-0.01	-1.02**	-8.47**	-0.10	0.13**
CLN 2400A	-0.29	-0.25	0.95	0.15**	1.62**	2.77**	-0.53**	0.10
CLN 2498E	3.54*	0.08	2.80**	0.06**	-0.49**	2.48**	0.06	-0.37**
CLN 2400B	-3.13	0.58*	0.98*	-0.21**	-0.11**	3.21**	0.69**	0.16*
S.E.	3.19	0.48	0.96	0.02	0.04	0.96	0.2	0.12

Table (6): Estimation of specific combining ability effects for various traits in lines and testers of tomato

genotype	Plant height	Branches /plant	Fruit set (%)	Early yield	Total yield	Average fruit wt.	Firmness	TSS
1x3	4.79	1.42**	-3.09**	-0.29**	0.71**	1.01	-0.49*	0.27*
1x4	-3.37	-0.41	0.86	-0.16**	-0.53**	-3.44**	0.27	0.13
1x5	-8.21*	-1.75**	1.47*	-0.08**	-0.91**	-0.01	0.44*	-0.67**
1x6	6.79	0.75*	0.76	0.01	0.73**	2.43**	-0.21	-0.23*
2x3	-4.79	-1.41**	3.09**	0.29**	-0.71**	-1.01	0.49*	-0.27**
2x4	3.37	0.42	-0.86	0.16**	0.53**	3.44**	-0.27	-0.13
2x5	8.21*	1.75**	-1.47*	0.08**	0.91**	0.01	-0.44*	0.67**
2x6	-6.79*	-0.75*	-0.76	-0.01	-0.73**	-2.43**	0.21	0.23*
S.E.	6.4	0.67	1.35	0.03	0.05	1-36	0.28	0.17

1 CastleRock 2 Peto 86 3 CLN 2123 4 CLN 2400A 5 CLN 2498E 6 CLN 2400B

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قوة الهجين والقدرة على التآلف فى نظام التزاوج القمى فى الطماطم تحت ظروف الموسم الصيفى المتأخر

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تم دراسة القدرة على التآلف وقوة الهجين بأستخدام التلقيح القمى فى الطماطم بأسسخدام 4 سلالات(CLN2400A , CLN2400B, CLN2123 and CLN2498E) وكشافين (كاسل روك ، بيتو 86) فى تجارب حقلية فى مزرعة كلية الزراعة جامعة كفر الشيخ خلال الفترة من 2008 الى 2011 ، حيث تم التهجين بين السلالات والكشافين بإسخدام التهجين القمى لإنتاج ثمانية هجن. تم تقييم الهجن الناتجة والأباء فى تجربتين حقليتين خلال الموسمين الصيفيين المتأخرين لعام2010 و 2011 فى تصميم قطاعات كاملة العشوائية فى ثلاث مكرارات ويمكن تلخيص النتائج كالآتى:

- وجدت إختلافات عالية المعنوية بين قيم متوسطات التراكيب الوراثية فى جميع الصفات.
- وجدت قيم موجبة ومعنوية لقوة الهجين بالنسبة للأب الأعلى فى بعض الهجن لبعض الصفات المدروسة فيما عدا متوسط وزن الثمرة التى كانت قيم قوة الهجين لها سالبة. وتراوحت قوة الهجين بين 12,7-66,2 بالنسبة للمحصول الكلى.
- أثبت التحليل الإحصائى أن التباين الراجع الى القدرة العامة والخاصة على التآلف كان معنويا لمعظم الصفات تحت الدراسة .
- أوضحت النتائج أن الكشاف بيتو 86 والسلالة CLN2498E أفضل الأباء للقدرة العامة على التآلف لصفات ارتفاع النبات ونسبة العقد. والصنف بيتو 86 والسلالة CLN2400A بالنسبة للمحصول المبكر والكلى ، بينما كان الكشاف كاسل روك الأفضل لصفة متوسط وزن الثمرة وصلابة الثمار.
- كان التهجين بين الكشاف بيتو86 وكلا من السلالة CLN 2400A والسلالة CLN 2498E وأيضا التهجين بين الكشاف كاسل روك وكلا من السلالة CLN 2123 والسلالة CLN 2400B أفضل التواليف بالنسبة للمحصول الكلى.

قام بتحكيم البحث

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