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LINE × TESTER ANALYSIS FOR ESTIMATION OF COMBINING ABILITY IN TOMATO

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ABSTRACT

Hybrid development under Egyptian conditions is within tasks of Plant Breeding and Conservation Program of Desert Research Center (DRC). Eight genotypes (Five lines and three tasters) and fifteen F_1 hybrids of tomato were evaluated in season 2022/2023 at Baloza Research Station, DRC, North Sinai. The experimental design was randomized complete blocks design with three replicates. The results indicated that variances due to genotypes, parents, crosses and line × tester were significant for all studies traits, except TSS% in crosses. The highest value of yield per plant was recorded for L3 (2.87kg), T1 (3.27kg) and L2× T1 (5.10kg) in the lines, testers and crosses, respectively. The L1 proved to be good general combiner for all traits, except TSS%. The cross L1× T3 registered significant and positive SCA effects for plant height, fruit weight and yield per plant. Lines contribution was higher than tasters and line × tester interactions for most traits. All traits showed non-additive gene action, except TSS% which showed additive gene action. Additive and non-additive gene action were observed for yield per plant. Heritability estimates in narrow sense were low for all studied traits.

Key words: ***Solanum lycopersicum, Combining ability, Gene action, Heritability.***

INTRODUCTION

Tomato (*Solanum lycopersicum*) is a premier vegetable and globally grown crop all over the year. It is originated from Peru-Ecuador Bolivia region of the Andes in South America. It is recognized as an important commercial and dietary vegetable crop and occupies a prominent position among vegetables, due to its export value (Singh *et al* 2014).

Line × Tester technique is an important tool to calculate both general and specific combining ability (GCA and SCA) and to estimate gene actions controlling inheritance of tomato traits. It is an efficient technique for evaluation of inbred or pure lines. This technique also helps the breeder to isolate the segregating genotypes and to select the best genotypes for hybridization procedures (Kempthorne 1957). Bayomi (2002) studied heterosis and gene action in varietal crosses of tomato and found that additive gene effects appeared to be relatively more important than the non-additive gene effects for most studied traits. Heritability estimates in broad sense were high for all studied traits. Heritability estimates in narrow sense were moderate to low for all studied traits. Mondal *et al* (2009) studied line × tester analysis of combining ability in tomato. They found that both additive and non-additive gene action were operative for the control of fruits/plant, fruit weight, locules /fruit and diameter of fruit. Savale *et al* (2017) studied heterosis in 8 lines × 4 testers for tomato fruit quality traits. They reported significant differences among the genotypes for all the traits. There was high heterosis in most of the hybrids traits supporting the role of non-additive gene effects. Al-Daej (2018) studied line × tester analysis of heterosis and combining ability in tomato fruit quality traits. He reported that the magnitude of additive variance was more pronounced for all the seven characters of interest of fruit quality. Akram *et al* (2019) studied line × tester analysis for studying various agronomic and yield related traits of tomato. They found predominance of non-additive gene action was observed for all the traits, except days to 50% flowering and maturity. Tester's contribution towards total variance was higher in comparison to lines. Line × tester contributed significantly in plant height, clusters plant, fruit length, fruit width and average fruit weight. Singh *et al* (2021) studied line × tester analysis for yield and its component traits in tomato. They found that the ratio of specific combining ability and general combining ability variance was greater than unity, specifying non-additive genetic control for all studied traits.

The objective of this study was the evaluation of 23 genotypes of tomato (8 parents + 15 crosses) for combining ability of some traits.

MATERIALS AND METHODS

In this study, tomato genotypes were obtained from plant breeding and conservation program of Desert Research Center (DRC). It were 5 lines [STel7/1/3(L1), SA_1-7/2/3(L2), SK_2-5/2/3(L3), SC_{1-0}-5/2/3(L4) and $SY_{2,2,1}$-7/1/3(L5)] and 3 testers [SR_2-7/1/3(T1), SS_{5-1}-7/1/3(T2) and Edkawy (T3)].

The trial was set up during two seasons. In the first 2021/2022 5 lines were crossed with 3 testers of tomato by hand emasculation and pollination at greenhouse program in Saint Catherine of South Sinai, DRC. In the second 2022/2023 23 genotypes of tomato (5 lines, 3 testers and their 15 crosses) were evaluated at Baloza Research Station, DRC, North Sinai.

The tomato genotypes (5 lines, 3 testers and their 15 crosses) were grown in a randomized complete blocks design with three replications in 75 cm × 50 cm spacing keeping 15 plants in each plot. Thirty days old seedlings were transplanted in the field on 15th October

2022 in Baloza Research Station, DRC, North Sinai. A drip irrigation system was used. Normal agricultural treatments were applied. Plant height (cm), average fruit weight (g), number of locules/fruit, total soluble solids percentage (TSS% determined by using Hand Refractometer and expressed as percentage of the juice) and yield per plant (kg) were recorded from five randomly selected plants from each genotype in a plot.

Statistical analysis: Statistical procedures were done according to the analysis of variance for a randomized complete blocks design. The treatment means were compared using least significant difference test at 5% and 1% levels of significance (Steel and Torrie, 1980). Combining ability analysis was done as per Kempthorne (1957). Heritability estimates were obtained as described by Burton and Devan (1953).

RESULTS AND DISCUSSION

Mean of squares for genotypes and its components (parents, crosses, parents vs. crosses, lines, testers and line×tester) are shown in Table (1).

Table 1. Mean squares of Line × tester for five traits of 23 genotypes of tomato (5 lines, 3 testers and their 15 crosses) under Baloza, North Sinai conditions, season 2022/2023.

SOV	df	Plant height	Fruit weight	No. of locules/fruit	T.S.S.	Yield/plant
Replications	2	0.304	39.36	0.101	0.119	0.055
Genotypes	22	1040.99**	2651.53**	4.513**	0.895**	3.657**
Parents	7	734.76**	2538.52**	9.595**	1.452**	1.634**
Par. vs crosses	1	1553.93**	2601.31**	4.359**	0.001^{NS}	21.579**
Crosses	14	1156.69**	2711.63**	1.984**	0.680**	3.388**
Lines	4	488.63**	4201.92**	3.111**	1.537**	7.581**
Tester	2	6123.76**	4976.07**	4.422**	1.444**	6.867**
Line × Tester	8	248.95**	1400.37**	0.811**	0.151^{NS}	0.623**
Error	44	6.30	35.47	0.117	0.066	0.035

^{NS}, **: Nonsignificant, Significant at the 0.05 and 0.01 levels of probability, respectively.

Highly significant differences were observed for all studied traits among different genotypes which indicate the presence of considerable amount of genetic variability that can be exploited. Also parents, parents vs. crosses, lines and testers were highly significant for all of traits. Similar results were reported by Mondal *et al* (2009), Kumari and Sharma (2012) and Singh *et al*. (2014). Mean squares of crosses and the interaction component (Line×Tester) were highly significant for all of traits except TSS%. Vekariya *et al* (2019) also reported highly significant variances for interaction component with respect to all traits in tomato.

The results presented in Table (2) indicate clearly that, significant differences were recorded among the different tomato genotypes in all traits. The average plant height was 85.87, 92.78 and 98.40 cm in the lines, testers and crosses, respectively. L4, T3 and L1× T3 gives the highest value of plant height (93.33, 122.00 and 140.33 cm) in the lines, testers and crosses, respectively. While, L1, T2 and L3× T1 were recorded the lowest value of plant height trait. The average fruit weight was 82.6, 100.89 and 103.4g in the lines, testers and crosses, respectively. The highest value of fruit weight was recorded for L3 (117.67g), T3 (135.00g) and L2× T1 (138.00g) in the lines, testers and crosses, respectively. While, L4, T1 and L4× T3 gives the lowest values of fruit weight in the lines, testers and crosses, respectively. Generally, L1and T1 was recorded good average fruit weight in their crosses. Gustavo *et al* (2006) found that Fruit weight ranged from 0.9 to 98.5g. Alam *et al* (2010) found that fruit weight was between33.97 and 56.02 g. Kumar *et al* (2015) found that fruit weight ranged from 53.0 to 149 g. Bayomi *et al* (2019) found that fruit weight ranged from 52.5 to 152.7 g. The average number of locules per fruit was 3.2, 4.6 and 3.2 in the lines, testers and crosses, respectively. The highest value of number of locales/fruit was recorded for L2 (4.7), T3 (7.3) and L1× T2 (5.0) in the lines, testers and crosses, respectively. While, L4, L5, L4× T1 and L5× T1 genotypes gives the lowest values of number of locules/fruit (2.00) in the lines and crosses, respectively. Yesmin *et al* (2014) found that the number of locules per fruit ranged from 2.2 to 5.06.

Table 2. Mean performance for five traits of 23 genotypes of tomato (5 lines, 3 testers and their 15 crosses) under Baloza, North Sinai conditions, season 2022/2023.

Genotypes	Plant height	Fruit weight	No. of locules/fruit	T.S.S.	Yield/ plant
Lines					
L1	83.67	83.33	4.0	4.33	2.77
L2	71.00	100.67	4.7	5.17	2.77
L3	91.00	117.67	3.3	5.00	2.87
L4	93.33	53.00	2.0	4.67	1.03
L5	90.33	58.67	2.0	4.83	2.10
Mean	85.87	82.6	3.2	4.80	2.31
Testers					
T1	81.00	66.67	2.3	4.83	3.27
T2	75.33	101.00	4.3	5.17	2.23
T3	122.00	135.00	7.3	6.67	2.47
Mean	92.78	100.89	4.6	5.56	2.66
Crosses					
L1× T1	93.67	114.33	3.0	5.03	4.97
L1× T2	80.33	131.67	5.0	4.43	4.10
L1× T3	140.33	126.33	3.3	5.10	4.47
L2× T1	78.00	138.00	3.0	5.13	5.10
L2× T2	83.33	135.00	4.0	5.47	4.17
L2× T3	112.33	73.67	4.7	5.90	4.87
L3× T1	74.00	135.33	3.0	5.23	5.07
L3× T2	81.00	99.33	3.0	5.03	4.37
L3× T3	114.33	83.00	3.3	5.67	3.10
L4× T1	93.62	113.33	2.0	4.43	2.97
L4× T2	91.33	97.33	3.0	4.30	2.60
L4× T3	129.33	61.00	3.0	4.83	2.03
L5× T1	90.00	77.67	2.0	4.73	3.17
L5× T2	102.00	63.00	3.0	5.17	2.37
L5× T3	112.33	72.00	3.0	5.67	2.47
Mean	98.40	103.40	3.2	5.09	3.72
LSD 5%	3.58	8.49	0.49	0.37	0.27
LSD 1%	4.78	11.34	0.55	0.49	0.36

Kumar *et al* (2015) found that number of locules per fruit ranged from 2.0 to 5.0. Bayomi *et al* (2019) found that number of locules per fruit ranged from 3.57 to 7.37. The average total soluble solids (T.S.S. %) was 4.^0, 5.56 and 5.09 in the lines, testers and crosses, respectively. The highest value of total soluble solids was recorded for L2, T3 and L2× T3 in the lines, testers and crosses, respectively. While, L1, T1 and L4× T2 gives the lowest values of total soluble solids in the lines, testers and crosses, respectively. Gustavo *et al* (2006) found that soluble solid content ranged from 3.7 to 5.8. Alam *et al* (2010) found that total soluble solids ranged from 3.71 to 4.39. Bayomi *et al* (2019) found that total soluble solids ranged from 3.1 to 4.9. The average of yield per plant was 2.31, 2.66 and 3.72 kg in the lines, testers and crosses, respectively. The highest value of yield per plant was recorded for L3 (2.87kg), T1 (3.27kg) and L2× T1 (5.10kg) in the lines, testers and crosses, respectively. While, L4, T2 and L4× T3 gives the lowest values of yield per plant in the lines, testers and crosses, respectively. Alam *et al* (2010) found that the total fruit yield per plant was between 1.20 and 1.73 kg. Yesmin *et al* (2014) found that the total fruit yield per plant ranged from 2.03 to 2.94 kg. Kumar *et al* (2015) found that the total fruit yield per plant was between 420 and 1805 g. Bayomi *et al* (2019) found that the total fruit yield per plant ranged from 1.22 to 2.05 kg.

Testers and lines general combining ability (GCA) estimates which assisted in the selection of better parents regarding suitable breeding programs are shown in Table 3. For plant height, the tester T3 expressed its superiority with GCA effects of 23.311 whereas in lines L1 and L4 showed GCA effects of 6.356. For fruit weight, the line L1 expressed its highest with GCA effects of 21.511 whereas in taster T1 showed GCA effects of 16.733. In case of number of locules/fruit, the line L2 expressed its highest with GCA effects of 0.667 while in tester T2 showed GCA effects of 0.378. T.S.S% the line L2 expressed its highest with GCA effects of 0.458 while in tester T3 showed GCA effects of 0.358. For yield per plant, the line L1 expressed its highest GCA effects of 0.924 whereas in tester T1 showed GCA effects of 0.667.

Table 3. General combining ability (GCA) effects of five lines and three testers for five traits of tomato under Baloza, North Sinai conditions, season 2022/2023.

Parents	Plant height	Fruit weight	No. of locules/fruit	T.S.S.	Yield/plant
Lines					
L1	6.356**	21.511**	0.556**	-0.220*	0.924**
L2	-7.200**	12.956**	0.667**	0.424**	0.458**
L3	-8.644**	9.289**	-0.111	0.236**	0.591**
L4	6.356**	-12.044**	-0.556**	-0.553**	-1.053**
L5	3.133**	-30.711**	-0.556**	0.113	-0.920**
S.E. $_{(gi)}$	0.837	1.985	0.114	0.086	0.063
S.E. $_{(gi-gj)}$	1.184	2.807	0.161	0.121	0.088
Testers					
T1	-12.489**	16.733**	-0.622**	-0.162*	0.667**
T2	-10.822**	2.667	0.378**	-0.196**	-0.067
T3	23.311**	-19.400**	0.244**	0.358**	-0.600**
S.E. $_{(gi)}$	0.648	1.538	0.088	0.086	0.048
S.E. $_{(gi-gj)}$	0.917	2.175	0.125	0.094	0.069

*** and ** indicate significant at 0.05 and 0.01 probability levels, respectively.**

The L1 proved to be good general combiner for all traits, except T.S.S. While, The T1 proved to be good general combiner for fruit weight and yield per plant. The T3 proved to be good general combiners for plant height and T.S.S. Specific combining ability (SCA) effects of different hybrid combinations are shown in Table 4. Out of 15 crosses, three, four, three, one and five crosses registered significant and positive SCA effects for plant height, fruit weight, number of locules/fruit, total soluble solids percentage and yield per plant, respectively. In general, the cross L1× T3 was good for plant height, fruit weight and yield per plant.

Table 4. Specific combining ability (SCA) effects of fifteen F_1 crosses for five traits of tomato under Baloza, North Sinai conditions, season 2022/2023.

Crosses	Plant height	Fruit weight	No. of locules/fruit	T.S.S.	Yield/plant
L1× T1	1.378	-26.511**	-0.156	0.340*	-0.211
L1× T2	-13.622**	4.889	0.844**	-0.227	-0.344**
L1× T3	12.244**	21.622**	-0.689**	-0.113	0.556**
L2× T1	-0.733	5.711	-0.267	-0.204	0.389**
L2× T2	2.933*	16.778**	-0.267	0.162	0.189
L2× T3	-2.200	-22.489**	0.533**	0.042	-0.578**
L3× T1	-3.289*	24.711**	0.511*	0.084	0.222*
L3× T2	2.044	-15.222**	-0.489*	-0.082	0.256*
L3× T3	1.244	-9.489**	-0.022	-0.002	-0.478**
L4× T1	1.378	6.044	-0.044	0.073	-0.233*
L4× T2	-2.622	4.111	0.044	-0.027	0.133
L4× T3	1.244	-10.156**	0.089	-0.047	0.100
L5× T1	1.267	-9.956**	-0.044	-0.293	-0.167
L5× T2	11.267**	-10.556**	0.044	0.173	-0.233*
L5× T3	-12.533**	20.511**	0.089	0.120	0.400**
S.E. $_{(Sij)}$	1.450	3.438	0.179	0.148	0.108
S.E. $_{(Sij - Sik)}$	2.050	4.863	0.279	0.210	0.153

*** and ** indicate significant at 0.05 and 0.01 probability levels, respectively.**

The proportional contributions to the total variance of crosses by lines, testers and their interaction (Line × Tester) are provided in Fig 1. The contribution of testers towards total variance was higher than lines for plant height. Lines contributed more than line × tester interactions in the fruit weight. Lines contribution was higher than testers and line × tester interactions in number of locules/fruit, total soluble solids percentage and yield per plant. The present results are corroborated with the previous research findings of Manivannan and Sekhar (2005) and Kumar and Sharma (2012) who also found uneven contributions. Ghobary and Ibrahim (2010) also observed a similar finding in tomato.

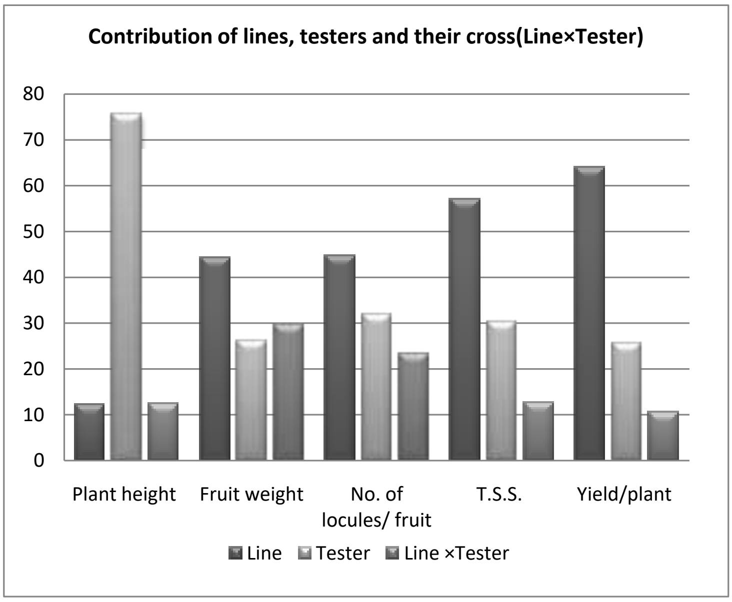

Fig 1. Contribution of line, tester and their cross (Line × Tester) in the expression of studied traits.

Estimation of genetic components is shown in Table 5. All traits showed non-additive gene action except T.S.S% additive gene action. Additive and non-additive gene action was observed for yield per plant. All traits revealed the fact that their SCA variance was higher than GCA variance therefore, heterosis breeding may be rewarding for genetic improvement of traits. These results are in agreement with previous findings of Pandey *et al* (2006), Singh *et al* (2008) and Singh and Asati (2011). Heritability estimates in broad sense were high for all studied traits except T.S.S%. Heritability estimates in narrow sense were low for all studied traits. Bayomi (2002) also reported the similar finding in tomato.

Table 5 Estimation of genetic component for five traits of 23 genotypes of tomato (5 lines, 3 testers and their 15 crosses) under Baloza, North Sinai conditions season 2022/2023.

Parameters	Plant height	Fruit weight	No. of locules/fruit	T.S.S.	Yield/plant
VA	64.18	92.72	0.08	0.04	0.20
VD	80.88	454.97	0.23	0.03	0.20
VA/VD	0.79	0.20	0.35	1.33	1.00
VGCA	32.092	46.358	0.041	0.019	0.098
VSCA	80.882	454.968	0.232	0.028	0.196
VGCA/VSCA	0.397	0.101	0.177	0.678	0.50
H^2 B%	95.84	93.92	72.95	49.83	91.74
H^2 N%	42.40	15.90	19.24	28.40	45.85

VA = Additive variance, VD = Dominance variance, VGCA = General combining ability variance, VSCA = Specific combining ability variance, H^2B = Broad sense heritability, H^2N = Narrow sense heritability

CONCLUSION

This study is an important step for Plant Breeding and conservation Program of Desert Research Center to identify the best genotypes for hybrids production in future and suitable for agriculture under Egyptian desert conditions. All traits showed significant differences among genotypes. For yield per plant, the line L1 and T1 expressed its highest GCA effects. The cross L1× T3 registered significant and positive SCA effects for plant height, fruit weight and yield per plant. Lines contribution was higher than testers and line × tester interactions in number of locules/fruit, total soluble solids percentage and yield per plant. Additive and non-additive gene action was observed for yield per plant. All traits revealed the fact that their SCA variance was higher than GCA variance therefore, heterosis breeding may be rewarding for genetic improvement of studied traits. Heritability estimates in narrow sense were low for all studied traits.

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تحليل السلالة × الكشاف لتقدير القدرة على الائتلاف فى الطماطم

خالد السيد مجاهد بيومى

وحدة تربية النبات- قسم الأصول الوراثية- مركز بحوث الصحراء

يدخل تطوير الهجن من الطماطم تحت الظروف المصرية ضمن مهام برنامج تربية وصون النباتات بمركز بحوث الصحراء. تم فى هذه الدراسة تقييم خمسة عشر هجين وأبائهم (خمسة سلالات وثلاث كشافات) بمحطة بحوث بالوظة- مركز بحوث الصحراء بشمال سيناء خلال موسم النمو ٢٠٢٢- ٢٠٢٣. كان التصميم الإحصائي المستخدم هو القطاعات الكاملة العشوائية مع إستخدام ثلاث مكررات. أشارت النتائج إلى وجود تباينات معنوية بين التراكيب الوراثية والأباء والهجن والسلالة×الكشاف لجميع الصفات ماعدا صفة نسبة المواد الصلبة الذائبة الكلية فى الهجن. سجلت السلالة L3 (٢،٨٧ كجم) والكشاف T1(٣،٢٧ كجم) والهجين $L_2\times T_1$ (٥،١٠ كجم) أعلى قيم لمحصول النبات. سجلت السلالة L1 أعلى تأثيرات للقدرة العامة على التآلف لجميع الصفات ماعدا صفة نسبة المواد الصلبة الذائبة الكلية. سجل الهجين L1× T3 أعلى قيم موجبة ومعنوية لتأثيرات القدرة الخاصة على التآلف لصفات إرتفاع النبات ووزن الثمرة ومحصول النبات . أظهر تأثير فعل الجين غيرالمضيف تفوق لجميع الصفات ماعدا صفة نسبة المواد الصلبة الذائبة الكلية حيث تفوق فعل الجين المضيف. بينما تساوى فعل الجين المضيف وغير المضيف لصفة محصول النبات. كانت كفاءة التوريث بمعناها الضيق منخفضة لجميع الصفات تحت الدراسة.

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