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GENETIC STUDIES ON SOME IMPORTANT CHARACTERS IN TOMATO.
2- ESTIMATES OF COMBINING ABILITY FOR YIELD COMPONENTS AND SOME FRUIT CHARACTERS

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ABSTRACT: *Combining ability for some traits .i.e, early and total yield, as well as, some fruit characteristics were studied in 15 F_1 crosses and their parental genotypes in tomato. In 2012 six tomato genotypes were crossed, without reciprocals, to form a set of diallel crosses. The evaluation was conducted for several traits in 2013 at Exprimental Farm, Fac. Of Agriculture, Minufiya University, Egypt. Both additive and non-additive gene effects were involved in the inheritance of the studied traits. Estimated GCA/SCA ratio exhibited that the additive gene actions were more important than the non-additive ones in the genetic mechanism for yield and its components. None of the parents found to be good general combiner GCA for all traits. However, the good combiner parents were* Bl.5 and Bl.14 *for earliness, as early ripening and early yield and total yield as fruit number and weight, average fruit weight, fruit firmness and* pericarp thickness. Bl.14 *for TSS and Bl.18 for breeding to both vitamin C and titratable acidity. As a whole, the parent* Bl.14 *could be considered as the best combiner for breeding to most studied traits.*

None of the F_1 combinations showed favorable specific combining ability for all studied traits. Out of 15 F_1 crosses, seven ones gave significant positive SCA values for total yield. These crosses resulted from poor X *poor and poor* X *good combiners parents. The crosses* Roma X Bl.5, Super Beef Steak X Bl.14 *and* Roma X Bl.14, *which resulted from poor X good combining parents might be due to" additive X dominance" type of interaction with epistasis gene action and non-fixable genetic component for total yield per plant. On the other hand, the crosses* Super Beef Steak X Bl.18, Super Beef Steak X Endless Summer, Bl.5 X Bl.18 *and* Endless Summer X Bl.18 *resulted from poor X poor effect due to non-additive gene action and non-fixable genetic component for total yield. This findings indicate possibility to obtain desirable transigressive sigregants and hybrid vigour for such crosses by adopting cycle of selection or biparental breeding program.*

Key words: *Combining ability, diallel , GCA, SCA, good combiners, earliness, fruit characteristics.*

INTRODUCTION

Tomato (*Solanum lycopersicum,* L.) is the most widely grown vegetable crop of the world. The cultivated area in Egypt, reached 91404 feddans (fed. 4200 m2) which produced 8544993 tons with an average of 16.586 tons/feddan in 2010*. Efforts are being made to increase tomato productivity by developing superior varieties. The entire genetic variability observed in the analysis for each traits was partitioned into its components, i.e. GCA and SCA as defined by Sprague (1966). He stated that GCA effects were due to additive types of gene action and SCA effects were due to the non-additive (dominance or epistasis) gene action.

Combining ability studies provide useful information for the selection of suitable genotypes for an effective hybridization, and at the same time, it also elucidates the

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nature and magnitude of different types of gene action involved (Asati *et al*., 2007). According to Ahmad *et al*., (2009) combining ability studies are more reliable as they provide useful information for the selections of parents in terms of performance of the hybrids and elucidate the nature and magnitude of various types of gene actions involved in the expression of quantitative traits. Hence, the present study was carried out to study the combining ability effects which would help to asses the prepotency of parents in hybrid combinations.

Most studies on combining ability effects showed that both additive and non-additive gene effects were found in the inheritance of the studied traits (Khalil, 2004 and Farzane *et al*., 2012). Some researchers found the predominancy of GCA to be more important than that of SCA (Khalil, 2004; Manna and Paul, 2012; Kumar *et al*., 2013 and Reddy *et al*., 2013) for many traits ,i.e. fruit yield, fruit number, average fruit weight, fruit length, fruit width, flesh thickness, locule number, total soluble solids, ascorbic acid and titratable acidity. In other words, those traits are mostly controlled by additive gene actions.

On the other hand, other investigators suggested that SCA effects were more important (Khalil, 2004 for total soluble solids and vitamin C content; Biswas *et al*., 2005 and Kumar *et al*., 2013 for average fruit weight, TSS, V.C and titratable acidity). The non-additive gene effects play the main role in controlling these traits.

MATERIALS AND METHODS:-

The genetic materials used were started by six tomato genotypes, viz, the cultivars Super Beef Steak (1), Endless Summer (2) and Roma (3) (from USA) and three lines which were developed in previous studies by Khalil (2009), these lines were Bl.5 (4), Bl.14 (5) and Bl.18 (6).

In the summer season of 2012, the six parental genotypes were planted in the field and all possible crosses, without reciprocals, were made to generate F_1 populations. In the summer season of 2013, the 15 F_1's with their six parents, as well as, the check cv. Super Badr were evaluated in a randomized complete block design experiment with three replicates at the Experimental Farm, Faculty of Agriculture, Minufiya University, Shebein El- Kom, Egypt. The plot contained two rows of 4.00 meters long and one meter wide with spacing of 40 cm. within plants. The field practices were in accordance with the usual procedures followed with tomato management. The other normal agricultural practices for tomato production, i.e., irrigation, fertilization, weeding, and pests control were practiced as recommended in the area. The studied traits were, No. of days from transplanting to flowering, No. of days from transplanting to ripening, early fruit weight, total fruit No./ plant, total fruit weight/ plant (Kg.), average fruit weight (gm.), fruit shape index (L/D), fruit firmness (gm./cm2) as determined by the fruit and vegetable tester (John Chatillon & Sons Inc. Kew Gardens, New York, U.S.A), pericarp thickness, total soluble solids which was determined by a hand refractometers, ascorbic acid (V.C) and titratable acidity (A.O.A.C, 1990).

Data were statistically analyzed using the standard method of a randomized complete block design and the least significant differences (L.S.D.) were estimated according to Snedecor and Cochran (1990). The analysis of general and specific combining abilities were done according to method (2) model (1) of Griffing (1956).

RESULTS AND DISCUSSION

The analysis of variance for combining ability showed the existence of significant variation for the studied characters, indicating a wide range of variability among the studied genotypes. Highly significant variation due to general (GCA) as well as specific (SCA) combining abilities were observed, indicated the importance of additive and non-additive types of gene actions in inheritance for all traits. Similar results were reported by Khalil (2004) and Farzane *et al*., (2012).

Estimated GCA:SCA ratio values revealed that the additive gene effects were more important than the non-additive ones for the inheritance of all studied traits, except total soluble solids content (TSS). The estimated values for all traits ranged from 0.79 (for TSS) to 14.86 (for days to fruit ripening) as shown in Table (1). These findings agreed those of Manna and Paul (2012), Kumar *et al*., (2013) and Reddy *et al*., (2013). With regard to the predominance of non-additive gene action, similar results were found by Khalil (2004); Biswas *et al*., (2005) and Kumar *et al.,* (2013) for TSS.

Table (1): Mean squares for combining ability (GCA and SCA) for some characters in tomato.

Characters / Source of variation	No. of days from transplanting to flowering		No. of days from transplanting to ripening.		Early fruit weight.		Total fruit No./ plant.	
	MS	F	MS	F	MS	F	MS	F
GCA	95.13	271.81**	962.43	965.49**	138166.8	727.88**	314.233	81.42**
SCA	74.27	212.20**	64.77	64.97**	74103.46	390.39**	103.40	26.79**
GCA/SCA	1.281		14.860		1.865		3.039	

*Significant at 0.05 level of probability.
**Significant at 0.01 level of probability.

Table (1): Con.

Characters / Source of variation	Total fruit weight/ plant		Average fruit weight		Fruit shape index.		Fruit firmness	
	MS	F	MS	F	MS	F	MS	F
GCA	2.38	99.95**	8083.64	6410.66**	0.14	371.86**	7573.88	29.44**
SCA	1.11	46.51**	12.11.59	960.84**	0.06	155.41**	5575.13	21.67**
GCA/SCA	2.149		6.672		2.392		1.359	

*Significant at 0.05 level of probability.
**Significant at 0.01 level of probability.

Table (1): Con.

Characters / Source of variation	Pericarp thickness		Total soluble solids		Ascorbic acid (V.C)		Titretable acidity	
	MS	F	MS	F	MS	F	MS	F
GCA	1.91	7.25**	0.449	4.116**	93.88	795.57**	0.010	160.06**
SCA	0.98	3.71**	0.569	5.212**	12.36	104.71**	0.002	25.05**
GCA/SCA	1.955		0.790		7.598		6.39	

*Significant at 0.05 level of probability.

**Significant at 0.01 level of probability.

Effect of GCA:

Regarding effect of GCA , nature and magnitude of combining ability effects provide guidline in identifying the better parents and their utilization. Obtained GCA effect values of the parents (Table 2) revealed that none of the parents found to be good general combiner for all characters. However, the good combiner parents were: Bl.5, Bl.14 and Bl.18 for earliness (days to flowering and early fruit yield). Roma, Bl.5 and Bl.14 for total yield as fruit number and weight. The parents Bl.14, Super Beef Steak, Bl.18 and Bl.5 for average fruit weight, while Bl.5 and Bl.14 for fruit firmness and pericarp thickness. The parents Bl.14 (for TSS), Roma and Bl.18 (for breeding to both vitamin C and titretable acidity).

It is clear that the parent Bl.14 could be considered as the best combiner for breeding to most traits, Bl.18 for breeding to earliness, average fruit weight, vitamin C, fruit firmness and titretable acidity, Bl.5 for earliness, total yield, pericarp thickness and fruit firmness.

Table (2): Estimated general combining ability (GCA) effects for the parental lines regarding some characters in tomato.

Characters / Parents	No. of days from transplanting to flowering	No. of days from transplanting to ripening.	Early fruit weight.	Total fruit No./ plant.	Total fruit weight	Average fruit weight
1	-0.625**	-9.083**	-105.375**	-14.875**	-0.194**	39.142**
2	11.625**	33.042**	-361.5**	-8.750**	-1.229**	-32.421**
3	-5.500**	-24.958**	-36.939**	13.875**	-0.537**	-95.821**
4	-1.250**	1.417**	145.313**	7.875**	0.456**	8.442**
5	-3.125**	1.417**	302.813**	5.125**	1.556**	46.154**
6	-1.125**	-1.833**	55.688**	-3.250**	-0.052	34.504**

* Significant at the 0.05 level of probability according to " T " test.
** Significant at the 0.01 level of probability according to " T " test.

Table (2): Con.

Characters / Parents #	Fruit shape index.	Fruit firmness	Pericarp thickness	Total soluble solids	Ascorbic acid (V.C)	Titretable acidity
1	-0.108**	-68.458**	-0.584**	0.25*	5.781**	0.099**
2	0.046**	14.917**	-0.459*	0.063	-4.656**	-0.029**
3	0.440**	-65.583**	-0.958**	-0.563**	7.244**	-0.078**
4	-0.147**	40.790**	0.667**	-0.037	-7.931**	0.043**
5	-0.091**	27.792**	1.292**	0.6**	-1.869**	-0.002
6	-0.140**	50.542**	0.042	-0.313**	1.431**	-0.033**

* Significant at the 0.05 level of probability according to "T" test.
** Significant at the 0.01 level of probability according to "T" test.
# 1= Super Beef Steak, 2=Endless Summer, 3=Roma, 4=Bl.5, 5=Bl.14 and 6=Bl.18.

Effect of SCA:

None of the hybrids exhibited favorable SCA effects for all characters (Table 3). Significant SCA effects in favorable direction was observed in many crosses. The number of crosses were 10 for date to flowering,9 for date to fruit ripening,8 for early yield, 9 for fruit number,7 for total fruit yield,7 for average fruit weight,6 for fruit firmness,4 for pericarp thickness, 3 for TSS,8 for vitamin C and 6 crosses for titretable acidity. This result getting support from the findings of Mahendrakar (2004), Hannan *et al*., (2007) and Singh *et al*., (2010).

Table (3): Estimates of specific combining ability (SCA) effects for the studied F_1 crosses regarding some characters in tomato.

Parents #	Characters	SCA effect				
		2	3	4	5	6
1	Earliness to flowering.	-7.571**	-3.446**	-4.700**	-3.821**	460.179**
	Earliness to ripening.	-15.911**	-24.911**	2.714**	1.714	966.964**
	Early fruit weight.	777.589**	-146.973**	-392.223**	653.277**	7545.402**
	Total fruit number.	29.768**	5.143**	-10.857**	7.893**	400.268**
	Total fruit weight.	2.469**	-0.863**	-0.755**	2.280**	45.667**
	Average fruit weight.	-30.230**	-23.830**	-43.093**	54.195**	1852.545**
	Fruit shape index.	0.242**	-0.422**	0.134**	-0.111**	12.737**
	Fruit firmness.	-120.41**	9.089	-72.286**	135.714**	4151.964**
	Pericarp thickness.	0.375	-0.125	2.250**	-0.375	91.875**
	Total soluble solids content.	-0.4125	0.213	-0.913**	-1.450**	82.463**
	Vitamin C content	4.768**	-3.932**	1.743**	5.280**	461.080**
	Titretable acidity	-0.150**	-0.131**	0.048**	0.033**	4.614**
2	Earliness to flowering.		-13.696**	-21.946**	-12.071**	-21.071**
	Earliness to ripening.		-14.036**	2.589**	-6.411**	-6.161**
	Early fruit weight.		133.152**	-211.098**	209.402**	187.527**
	Total fruit number.		-10.982**	0.018	5.768**	-1.857**
	Total fruit weight.		-0.818**	-0.640**	-4.337**	0.418**
	Average fruit weight.		10.732**	-73.030**	104.757**	-2.893**
	Fruit shape index.		-0.276**	0.010	-0.235**	0.243**
	Fruit firmness.		-166.286**	77.339**	-174.661**	-148.411**
	Pericarp thickness.		1.750	2.125**	-1.500**	-1.250**
	Total soluble solids content.		0.200	2.475**	-0.163	-0.050
	Vitamin C content		-0.795**	-2.520**	-3.782**	6.318**
	Titretable acidity		-0.023**	0.015*	0.010	0.012
3	Earliness to flowering.			-3.821**	-2.946**	5.054**
	Earliness to ripening.			-10.411**	-0.411	-6.161**
	Early fruit weight.			704.339**	369.839**	-65.536
	Total fruit number.			26.393**	31.143**	-4.482**
	Total fruit weight.			3.508**	2.127**	-0.893**
	Average fruit weight.			11.170**	-38.343**	-49.993**
	Fruit shape index.			-0.333**	-0.178**	-0.851**
	Fruit firmness.			66.839**	3.839	76.089**
	Pericarp thickness.			-3.375**	1.000*	0.250
	Total soluble solids content.			1.300**	-1.338**	1.575**
	Vitamin C content			10.380**	7.118**	4.018**
	Titretable acidity			-0.036**	0.019*	0.001

* Significant at 0.05 level of probability according to the (T) test.

** Significant at 0.01 level of probability according to the (T) test

Table (3): Con.

Parents	Characters	SCA effect				
		2	3	4	5	6
4	Earliness to flowering.				2.804**	1.804**
	Earliness to ripening.				-1.786	-7.536**
	Early fruit weight.				-420.911**	-380.286**
	Total fruit number.				0.143	7.518**
	Total fruit weight.				-3.122**	1.215**
	Average fruit weight.				-80.305**	118.045**
	Fruit shape index.				-0.102**	0.185**
	Fruit firmness.				27.464	117.714**
	Pericarp thickness.				-1.625**	-1.375**
	Total soluble solids content.				0.738*	-1.150**
	Vitamin C content				-0.007	-3.207**
	Titretable acidity				-0.032**	-0.021**
5	Earliness to flowering.					4.679**
	Earliness to ripening.					0.464
	Early fruit weight.					-83.786**
	Total fruit number.					1.268**
	Total fruit weight.					-0.313*
	Average fruit weight.					7.332**
	Fruit shape index.					0.100**
	Fruit firmness.					-117.286**
	Pericarp thickness.					-1.00*
	Total soluble solids content.					-0.388
	Vitamin C content					3.330**
	Titretable acidity					-0.016**

* Significant at 0.05 level of probability according to the (T) test.
** Significant at 0.01 level of probability according to the (T) test
# 1= Super Beef Steak, 2=Endless Summer, 3=Roma, 4=Bl.5, 5=Bl.14 and 6=Bl.18.

The magnitude of SCA effects having a vital importance in selecting the cross combinations with higher probability of obtaining desirable transgressive segregations (Kumar *et al.*, 2013). The estimated SCA effects for total fruit yield per plant ranged from 0.418 in the cross Endless Summer X Bl.18 (P2 X P6) to 45.66

in the cross Super Beef Steak X Bl.18 (P1 X P6). Seven F_1's showed significant SCA values for this trait. These crosses were Super Beef Steak X Bl.18, Roma X Bl.5, Super Beef Steak X Endless Summer, Super Beef Steak X Bl.14, Roma X Bl.14, Bl.5 X Bl.18 and Endless Summer X Bl.18 with SCA values of 45.67, 3.51, 2.47, 2.28, 2.13, 1.22 and 0.418, respectively. The best five F1 crosses regarding total yield recorded desirable significant SCA effect values for many other traits as follows: the cross Super Beef Steak X Bl.18 recorded for all traits, except days to flowering and ripening ; Roma X Bl.5 for all traits, except pericarp thickness; Super Beef Steak X Bl.14 for all traits, except number of days to fruit ripening, pericarp thickness and acidity; Super Beef Steak X Endless Summer for earliness (days to flowering, ripening and early yield), fruit number and vitamin C content ; and the F_1 Roma X Bl.14 for earliness, pericarp thickness and vitamin C content.

The crosses Roma X Bl.5, Super Beef Steak X Bl.14 and Roma X Bl.14 resulted from poor X good combining parents, this might be due to "additive X dominance" type of interaction with epistasis gene action and non-fixable genetic component for total yield per plant. Meanwhile, the crosses Super Beef Steak X Bl.18**,** Super Beef Steak X Endless Summer, Bl.5 X Bl.18 and Endless Summer X Bl.18 resulted from poor X poor GCA parents due to non-additive gene interaction and non-fixable genetic component for total yield per plant as explained by Kumar *et al*., 2013. These findings indicate possibility to obtained desirable transgressive segregants and hybrid vigour from such crosses by adopting cycle of selection or by parental breeding program.

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دراسات وراثية لبعض الصفات الهامة فى الطماطم
2- قياس القدرة على التآلف لمكونات المحصول وبعض الصفات الثمرية

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المُلخص العربي

أُجريت التجارب الخاصة بهذة الدراسة فى عامى 2012 و 2013 فى مزرعة التجارب بكلية الزراعة – جامعة المنوفية. فى العام الأول تم زراعة الآباء واجراء التهجين بينهما فى اتجاه واحد لإنتاج بذور الجيل الأول. فى العام الثانى 2013 تم تقييم الهجن وآبائها ومعهم الصنف Super Badr (للمقارنة) لعدد من الصفات. وأوضحت النتائج وجود كلٍ من التأثيرات الإضافية والغير إضافية فى وراثة جميع الصفات المدروسة. حسابات النسبة بين التأثير الإضافى والغير إضافى أشارت إلى أن التأثيرات الإضافية أكثر أهمية فى وراثة صفات المحصول ومكوناته.

حسابات القدرة العامة على التآلف للآباء أشارت إلى عدم وجود أب واحد يمكن اعتباره قرين مفضل للتربية لجميع الصفات – وبصفة عامة فإن السلالتين Bl.5و Bl.14 هما الأفضل للتربية وتحسين صفات التبكير ، متوسط وزن الثمرة ، صلابة الثمار ، وسمك اللحم. والسلالة Bl.14 للمواد الصلبة الذائبة الكلية ، والسلالة Bl.18 لمحتوى الثمار من فيتامين ج والحموضة المنخفضة . بناءاً على هذة النتائج يمكن اعتبار السلالة Bl.14 قرين مفضل للتربية لمعظم الصفات التى تم دراستها.

وأيضاً أظهرت حسابات القدرة الخاصة على الإئتلاف أنه لا يوجد هجين واحد ذو قدرة خاصة لجميع الصفات ، فلكل هجين قدرة خاصة على التآلف لصفة أو أكثر . ووأوضحت النتائج أن سبعة هجن أعطت قيماً عالية ومعنوية بالنسبة لصفة المحصول الكلى وهذة الهجن هى :

(Super Beef Steak x Bl.14)، (Super Beef Steak x Endless Summer)،

(Bl.5 x Bl.18) ،(Super Beef Steak x Bl.18) ،(Endless summer x Bl.18) ،(Roma x Bl.5) ،(Roma x Bl.14).

من هذه الهجن ثلاثة نتجت من أبوين أحدهما منخفض والآخر عالى ومعنوى فى قدرته العامة على التآلف وهى : (Roma x Bl.14) ،(Roma x Bl.5) ،(Super Beef Steak x Bl.14) وقد يرجع هذا إلى وجود تأثير " إضافى × سيادى" مع وجود تفوق لصفة كمية المحصول . وباقى الهجن وهى (Super Beef Steak x Endless Summer) ، (Endless summer x Bl.18) ، (Super Beef Steak x Bl.18) ، (Bl.5 x Bl.18) نتجت من آباء تملك قدرة عامة على التآلف ضعيفة وقد يعزى ذلك إلى تفاعلات جينية لا إضافية لصفة المحصول . وهذه النتائج تُمكن من التحسين عن طريق استغلال الإنعزالات فائقة الحدود فى الجيل الثانى وكذلك استغلال ظاهرة قوة الهجين فى عشائر الجيل الأول .