GENETIC ANALYSIS AND HETEROSIS FOR SOME QUANTITATIVE TRAITS IN TOMATO (*SOLANUM LYCOPERSICUM* L.)

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ABSTRACT: *This study was conducted during three successive early summer seasons of 2016- 2018 at the experimental farm of both faculty of Agricultural, Menoufia University, Shebin El-Kom and Bahga Agricultural development company, Anshas, sharkia. The present investigation was aimed to obtain more information on combining ability and degree of heterosis for some plant and fruit characters. Four breeding lines and one cultivar of tomato (Solanum lycopersicum L.) and their ten F₁'s resulted from a half – diallel cross were evaluated and the component of genetic variance , combining ability and the extent of heterosis were determined for some tomato traits ,i.e., number of primary branches and leaves , early and total yield , average fruit weight and fruit firmness. The analysis of variance reflected significant differences among the studied genotypes for all the traits studied. Estimation of the magnitude of variance due to general and specific combining ability effects (σ² GCA & σ² SCA) showed that both additive and non-additive gene effects were significant and important in inheritance of all studied traits, except average fruit weight. However, the estimated genetic parameters revealed that the additive gene effects were more important and play the main role in the inheritance of early and total yield, average fruit weight and fruit firmness and could be improved by varietal breeding program. While, the non-additive genetic variance was found predominance for number of branches and leaves and improving these two traits could be occurred by heterosis breeding. The two lines MON-8 and MON-9 were considered as the best general combiner parents, since they recorded positive GCA effects for four traits. The cross combinations MON-8 x MON-9 and MON-9 x MON-15 were the best specific combinations, since they recorded significant SCA values for five and four traits. Relative heterosis (MPH%) was observed for all studied traits, except, average fruit weight, while heterobeltiosis (BPH%) was observed in some crosses for number of branches and leaves as well as early and total yield. Based on the standard heterosis (SH %) expressed by the hybrids MON-8 X MON-9 and MON-9 X MON-15 were found to be superior since significantly exceeded the commercial hybrid (control).*

Key words: General and specific combining ability, tomato, heterosis, degree of dominance, relative heterosis and heterobeltiosis.

INTRODUCTION

Recently the use of hybrid cultivars has increased dramatically that in all countries, since hybrid seeds are superior to open- pollinated varieties for earliness, yield, fruit quality and other important attributes. The breeders goal is to develop new hybrids characterized by high yield with good traits continually. This work required three important stages; production of new promising lines, determining the combining ability of these lines to chose the superior parents, and lastly production of the hybrid seeds in bulk of the promising F₁ hybrids. Also the choice of breeding

method would be largely guided by the nature of gene action and the relatively magnitude of additive and non- additive variance in a breeding populations.

Combining ability has a prime importance in plant breeding since it provides information for the selection of parents and regarding the nature and magnitude of involved gene action. General combining ability (GCA) is owing to the activity of genes which are largely additive in their effects as well as additive x additive interactions. While, specific combining ability (SCA) is regarded as an indication of loci with dominance variance (non-additive effects) and epestatic gene action. Diallel cross (half or complete) has appeared to be good one of the most appropriate approaches in preliminary screening the materials for GCA and SCA. High values for both GCA and SCA (additive and non-additive) variances with the prevalence of additive effects (σ^2A /σ^2 D > 1) were observed by several investigators for tomato. Among them, Aboshama *et al.* (2015) for number of branches per plant; Kansouh (2013a) and Enang *et al* . (2015) for number of leaves per plant; Ramadan *et al.* (2014) and Aboshama *et al.* (2015) for early yield ; Farzane *et al.* (2012) and Mahmoud and El-Eslamboly (2014) for total yield. Respecting the order, Kansouh (2013a), Savale *et. al.* (2017) and Al-Daej (2018) for average fruit weight; Khansouh (2013a) and Al-Daej (2018) for fruit firmness reported the preponderance of additive gene action in these traits.

On the other hand, other authors reported the predominance of non-additive gene action in the inheritance of the same traits in other genotypes of tomato. Among them were Kansouh and Zakher (2011) and Babu *et al.* (2018) for number of branches; Kansouh and Zakher (2011) and Aminu and Mala (2015) for number of leaves; Kansouh and

Zakher (2011) and Kumari and Srivastava (2017) for early yield; Shende *et al.* (2012) and Ramana *et al.* (2017) for both total yield and average fruit weight . Also, the studies of Rakesh (2016) reported the prevalence of a non-additive gene action in the inheritance of fruit firmness in tomato.

Heterosis for yield, its components and fruit quality traits were extensively studied in tomato. In this respect, heterosis over the better parent as heterobeltiosis (BPH%) was reported by yadav *et al.* (2013) and Sahu *et al.* (2016) for number of primary branches per plant; Kansouh and Masoud (2007) and Kansouh (2013b) for number of leaves ; Khalil (2009) and Jaiprakash Narayan *et al.* (2018) for early and total yield . Regarding average fruit weight, Shende *et al.* (2012) and Masry (2014) found BPH% (heterobeltiosis). Meanwhile, most investigators such as Kansouh (2013 b) and AL-Daej (2018) reported no-dominance for average fruit weight since the studied hybrids reflected intermediate values. The same trend was observed for fruit firmness by Kansouh (2013 b), and AL-Daej (2018), since most studied crosses showed intermediate values between their parents (no-dominance) and some crosses reflected partial dominance towards the highest fruit firmness.

However, In many cases, the better parent of hybrid may be inferior to the best commercial check cultivar. Therefore, it will be desirable to estimate hybrid vigour (heterosis) in relation to the used commercial check cultivar. The superiority of F1 over the commercial check is known as useful / standard / economic heterosis. Respecting the order, Kansouh (2013b), Savale *et al.* (2017) and Jaiprakash Narayan *et al.* (2018) for number of branches and early and total yield; Kansouh and Masoud (2007) and Kansouh (2013b) for both fruit

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weight and firmness recorded significant commercial (standard) heterosis in tomato for the previous mentioned traits.

Keeping these points in mind, the present investigation was planned to obtain more information on combining ability and gene action to identify some lines / cultivars having good combining effect for some plant and fruit characters. Also, to determine the heterosis degree to determine some promising local tomato F1 hybrids suitable to Egypt conditions.

MATERIALS AND METHODS

The present study was carried out during three successive early summer seasons of 2016 – 2018. Four new breeding lines of tomato (*Solanum lycopersicum* L.), which were developed by Mona, R Khalil, i.e., MON-5, MON-8, MON-9 and MON-15 as well as, the cultivar Endless Summer were used in this study. In the season 2016 a 5x5 without reciprocals was made to obtain 10 F_1 hybrids at the experimental farm, Faculty of Agriculture, Minoufia university, Shibin EL-Kom. The obtained F_1 crosses and their parents, in addition to the commercial hybrid Alissa F_1 (as control) were evaluated in the two successive early summer seasons of 2017 and 2018 at the experimental farm of Bahga Agricultural development company, Anshas, Sharkia governorate. The seedlings were transplanted on February 15th in a randomized complete blocks design with three replicates. Drip irrigation system was used and each plot consisted of three rows, 1.50 m width and 10 m length (45 m^2), each row had one dripper line and the plants were spaced at 5o cm. apart (60 plants / plot). Routine cultural practices, similar to those used in tomato commercial production were done as needed.

Data for number of primary branches and leaves per plant , were recorded at the end of the flowering stage on ten guarded plants per plot ; early yield (ton / fed.) as the yield of the first three harvests, total yield (ton / fed.) as the total weight of all harvested fruits (early and total yield were recorded firstly as kg / plot and ton / fed. was calculated); average fruit weight (gm.) by dividing the total fruit weight by total fruit number ; fruit firmness (g / cm2) was measured by using a needle type pocket penetrometer. Data were recorded during the two seasons (2017 and 2018), then the combined data over the two seasons were done whenever the homogeneity of variances was detected. Analysis of variance, combining ability analysis, component of genetic variance (additive, $\sigma^2 A$, and non-additive, $\sigma^2 D$) were done as reported by Griffing (1956) method II, model I and Singh and Chaudhary (1995). Degree of dominance ($2\sigma^2 D$ / $\sigma^2 A)^{0.5}$ was made according to Kearsey and Pooni (1996). Average degree of heterosis (ADH %) was calculated over mid-parents (MPH %) and better parent (BPH %) according to Mather and Jinks (1971). Heterosis also was calculated as standard heterosis (SH %) based on commercial / standard hybrid as follow :

$$SH\% = \frac{\overline{F_1} - \overline{CH}}{\overline{CH}} x100$$

Where :

$\overline{F_1}$, and $\overline{CH}$ = The means of F_1 generation, and commercial hybrid (control), respectively.

Heterosis over the better parent (BPH %) was only calculated for the crosses that showed significant positive MPH% values. Type of dominance (no, partial, complete and over) was obtained according to the dominance line (Kansouh, 2014) .

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RESULTS AND DISCUSSION

A. Mean performances of the F1 hybrids and their parents:

Highly significant differences among the parental genotypes and the crosses were detected for all studied traits (Table 1). For number of primary branches per plant, the parental genotypes values ranged from 4.61 (Endless Summer) to 6.68 branchs / plant (line MON-9). Meanwhile, a range from 5.53 (cross MON-15 x Endless Summer) to 8.16 branchs/plant (cross MON-8 x MON-9) was detected by the crosses. The overall mean value of the hybrids (6.89 branchs/plant) exceeded that of the parental genotypes (5.69 branchs / plant) by 21.09 % indicating that, the resulted F_1 hybrids gave higher number than those of their parents. Compared with the commercial F_1 hybrid Alissa (control), the two hybrids MON-8 x MON-9 and MON-9 x MON-15 were similar to the control in this respect. The same trend was observed for number of leaves per plant , since the same two lines and hybrids , i.e. , MON-8 , MON-9 , MON-8 x MON-9 and MON-9 x MON-15 recorded the highest number of leaves (70.83 , 75.27 , 93.02 and 88.39 , respectively). The overall mean value of the crosses (73.82) significantly exceeded that of the parental genotypes (61.36) by 20.32 %. Also, insignificant differences were detected between the two crosses MON-8 x MON-9 and MON-9 x MON-15 (the highest number of leaves) and the control (Alissa F1).

For early yield, the parental genotypes and their crosses varied widely in this respect. The parents produced early yield mean values ranged from 2.247 (cv. Endless Summer) to 8.120 ton/ fed. (line MON-9) with an overall mean value of 5.23 ton/fed., while for F_1 hybrids, they ranged from 3.778 (cross MON-8 x Endless Summer) to 10.103 (cross MON-5 x MON-9) with a general value of 6.07 ton/fed. , which significantly exceeded the parental genotypes by overall mean value of 16.06 %. However, the cross MON-5 x MON-9 was considered the best hybrid which showed the highest early yield (10.103 ton / fed.) among the resulted F_1 hybrids and significantly exceeded the commercial hybrid F_1 Alissa (control) by 24.39 %. Regarding total yield (Table 1), the parental genotypes and their hybrids varied widely in this respect. The total yield values ranged from 13.250 (Endless Summer) to 21.648 (line MON-8) in the parents with an overall mean of 17.794 ton/fed. , while for F_1's the range was from 15.198 (cross MON-15 x Endless Summer) to 25.508 (cross MON-9 x MON-15) with a general value of 19.199 ton/fed. The two crosses MON-8 x MON-9 and MON-9 x MON-15 performed significant better total yield (24.827 and 25.508 ton/fed.) than those of the parents and the other hybrids showed insignificant differences compared with the control (Alissa F_1 hybrid) .

Average fruit weight reflected also a great variation among the studied genotypes (Table 1). The fruits recorded average fruit weight ranged from 91.64 (line MON-9) to 170.42 (line MON-5) with an overall mean of 132.96 gm. , while the tested F_1 crosses ranged from 110.46 (cross MON-9 x Endless Summer) to 152.72 (cross MON-5 x MON-15) with a general mean of 134.06 gm. Regarding fruit firmness, the line MON-15 produced the firmest fruits (648.33 gm/cm^2.), followed by the line MON-8 with a value of 621.67 gm/cm^2. Among the studied crosses, MON-8 x MON-15 followed by MON-15 x Endless Summer recorded the firmest values (631.67 and 621.67 gm/cm^2., respectively).

Table (1): Mean performances of the evaluated F1 hybrids and their parents for some plant and fruit characteristics based on combined analysis.

Entries	No. of branches /plant	No. of leaves /plant	Early yield (ton/fed.)	Total yield (ton/fed.)	Av. fruit weight (g)	Fruit firmness (g/cm^2)
parents						
MON-5	5.38	61.61	6.327	18.147	170.42	523.33
MON-8	6.67	70.83	5.260	21.648	133.33	621.67
MON-9	6.68	75.27	8.120	19.378	91.64	458.33
MON-15	5.12	51.52	4.235	16.550	138.17	648.33
Endless Summer	4.61	47.58	2.247	13.250	131.26	578.33
Mean	5.69	61.36	5.23	17.794	132.96	566.00
Crosses						
MON-5 x MON-8	7.12	84.43	6.262	20.820	150.33	576.67
MON-5 x MON-9	7.01	75.29	10.103	18.980	132.25	511.67
MON-5 x MON-15	6.08	68.04	5.153	17.857	152.72	598.33
MON-5 x Endless Summer	7.05	72.28	4.837	15.723	149.18	568.33
MON-8 x MON-9	8.16	93.02	7.655	24.827	116.54	576.67
MON-8 x MON-15	6.64	61.42	4.862	19.143	137.12	631.67
MON-8 x Endless Summer	7.18	78.02	3.778	17.583	135.49	591.67
MON-9 x MON-15	8.08	88.39	7.948	25.508	121.21	611.67
MON-9 x Endless Summer	6.05	62.67	6.238	16.353	110.46	511.67
MON-15 xEndless Summer	5.53	54.65	3.865	15.198	135.33	621.67
Mean	6.89	73.82	6.07	19.199	134.06	580.00
Alissa *	8.02	90.83	8.122	25.265	120.43	671.67
LSD : 5 %	0.62	9.28	0.661	2.520	10.06	23.14
1 %	0.89	13.44	0.892	3.648	13.57	31.23

* Commercial F1 hybrid (control)

Generally, the obtained data showed that, the two lines MON-8 and MON-9 could be considered as the best parental lines, since they reflected the best values for four traits. Also, the hybrid MON-9 x MON-15 followed by MON-8 x MON-9 are considered as the best hybrids, they recorded the best results for four and three traits, respectively. Also, the mentioned two crosses showed insignificant differences compared with the commercial F₁ hybrid Alissa (control) for the studied traits. These two lines /

hybrids may be used as new local genotypes after further evaluation in different locations.

B. Components of genetic variance, heritability, General and specific combining ability effects:

The analysis of variance for combining ability (Table 2) revealed significant mean square values for general and specific combining ability effects, indicating that both additive and

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non-additive (σ^2A & σ^2D) gene action played significant role for the expression of all the studied traits, expect average fruit weight which showed insignificant SCA mean square value. However, for number of branches and leaves per plant, the variance due to specific combining ability (σ^2SCA) was higher than those of general combining ability (σ^2GCA) and the ratio of additive and dominance variance (σ^2A / σ^2D) which also found less than one (0.64 and 0.88, respectively) revealed the preponderance of non-additive genetic variance in the inheritance of these two traits. The estimated average degree of dominance also supported the predominance of non-additive gene action, where found more than one (1.8 and 1.5, respectively) which indicating over – dominance for these traits. Also, estimates of the proportional contribution values concerning (σ^2A and σ^2D) from the total genetic variance (σ^2g) which showed σ^2A/σ^2g vs σ^2D/σ^2g values

of 39.07 vs 60.93 and 46.95 vs 53.05 for number of branches and leaves, respectively, also revealed that the large portion of the genotypic variance (σ^2g) was due to non-additive effects (σ^2D) .

The additive (σ^2 A) and dominance (σ^2D) variances were the most important portions of components of genetic variance as reported by Kalloo (1988). Also, the general combining ability variance (σ^2GCA) considered as an indicator of additive (σ^2A) genetic variance, while the specific combining ability variance (σ^2SCA) reflected the dominance (σ^2D) genetic ones (non-additive). Lastly, high values for broad since heritability (H^2BS) for number of branches and leaves (0.86 and 0.81, respectively), while low values of narrow since heritability (H^2NS) were found 0.34 and 0.38, respectively, supported again the importance of non-additive effects in the two traits.

Table (2): Mean squares and components of genetic variance for some plant and fruit characteristics based on combined analysis.

S.O.V.	No. of branches	No. of leaves	Early yield	Total yield	Average fruit weight	Fruit firmness
Mean squares						
GCA	1.708**	329.34**	12.657**	27.622**	1244.8**	8944.7**
SCA	0.796**	116.48**	0.744**	5.052**	5.278^{NS}	369.4**
Components of genetic variance						
σ^2GCA	0.234	44.91	1.801	3.788	176.11	1268.6
σ^2SCA	0.730	101.51	0.692	3.950	-6.787	305.5
σ^2A	0.468	89.82	3.602	7.576	352.24	2537.4
σ^2D	0.730	101.51	0.692	3.950	-6.787	305.5
σ^2A/σ^2D	0.64	0.88	5.2	1.9	51.9	8.3
Degree of dominance	1.8	1.5	0.6	1.02	-0.19	0.49
σ^2A/σ^2g	39.07	46.95	83.88	65.72	98.11	89.25
σ^2D/σ^2g	60.93	53.05	16.12	34.72	-1.89	10.75
H^2BS	0.86	0.81	0.96	0.77	0.91	0.94
H^2NS	0.34	0.38	0.81	0.51	0.89	0.83

*, ** significant at 0.05 and 0.01 levels of probability, respectively

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These information regarding components of genetic variance pointed out that number of branches and leaves could be improved through heterosis breeding (F_1 hybrids). These results are in accordance with those of Singh and Asati (2011), Masry (2014), Ramana *et al.* (2017) and Babu *et al.* (2018) for number of branches; Kansouh and Zakher (2011), Aminu and Mala (2015) for number of leaves .

Regarding early and total yield, average fruit weight and fruit firmness , the larger σ^2A values compared with σ^2D ones which were : 3.602 vs 0.692, for early yield ; 7.576 vs 3.950, for total yield; 352.24 vs -6.787, for average fruit weight and 2537.4 vs 305.5 for fruit firmness which reflected σ^2A/σ^2D ratios more than one, indicating that, the additive gene action was predominance and play the main role in the inheritance of these traits. Also , estimates of the proportional contribution values concerning σ^2A and σ^2D from total genetic variance (σ^2g) which showed σ^2A/σ^2g vs σ^2D/σ^2g values of , 83.88 vs 16.12 , for early yield ; 65.72 vs 34.72 , for total yield ; 98.11 vs -1.89, for average fruit weight and 89.25 vs 10.75 for fruit firmness also indicated that the large portion of the genotypic variance (σ^2g) was due to additive effect (σ^2A). Likewise, high heritability values were obtained for these traits, since heritability in broad since (H^2_{Bs}) ranged from 0.77 (total yield) to 0.96 (early yield) and ranged from 0.51 (total yield) to 0.89 (average fruit weight), regarding narrow since heritability (H^2_{Ns}). Generally, these informations regarding components of genetic variance points out that early and total yield, average fruit weight and fruit firmness traits could be improved through selecting promising lines from superior hybrids, since the additive genetic variance, which are fixable (heritable) was prevalence and play the

main role in the inheritance of these four traits. Several previous studies in tomato also reported the significant of additive and non-additive genetic variances with predominance of additive gene action in the inheritance of the studied same traits. Among those were Mahmoud and EL-Eslamboly (2014) and Aboshma *et al.* (2015) for early yield; Farzane *et al.* (2012) and Mahmoud and EL-Eslamboly (2014) for total yield; Kansouh (2013a) and Savale *et al.* (2017) for average fruit weight; Muttappanavar *et. al.* (2014) and AL-Daej (2018) for fruit firmness.

The estimates of general combining ability (GCA) effect of the parents for different characters are presented in Table (3). The good combiner parents for the studied traits were, MON-8 and MON-9 for number of branches, leaves and total yield; MON-5 and MON-9 for early yield; MON-5 and MON-15 for average fruit weight; MON-8 and MON-15 for fruit firmness, since they showed significant positive GCA values. The line MON-8 and MON-9 were found to be the most desirable, where they possess dominant genes for four traits. These two lines could be used effectively in breeding for yield and other traits by hybrid breeding programs for the accumulation of favorable genes. Then, these traits could be improved by selection among the segregating generations from the superior hybrids, since high GCA effect is related additive and additive x additive interaction and represents the fixable components of genetic variance (Mondal *et al.* 2009; Kansouh and Zakher, 2011 and Kansouh 2013a).

For specific combining ability (SCA) effects, data are presented in Table (4). The cross MON-9 X MON-15 could be considered the best combination, since it recorded the highest significant positive SCA values for all studied traits except average fruit weight, followed by the F_1

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combination MON-8 X MON-9 which showed good SCA effects for four traits. These two crosses involved the line MON-9 as one parent, which previously showed significant positive GCA effects for four traits and considered good combiner parent.

Table (3): General combining ability effects (GCA) of the parental Genotypes for some plant and fruit characteristics based on combined analysis.

Genotypes	No. of branches	No. of leaves	Early yield	Total yield	Average Fruit weight	Fruit Firmness
MON-5	-0.133M	0752M	0.604**H	-0.387M	17.593**H	-21.476**L
MON-8	0.499**H	8.220**H	-0.224**L	1.898**H	0.567M	24.000**H
MON-9	0.531**H	7.414**H	1.918**H	1.720**H	-19.778**L	-46.238**L
MON-15	-0.339**L	-6.067**L	-0.637**L	-0.226M	2.932**H	44.000**H
Endless Summer	-0.559**L	-7.892**L	-1.649**L	-3.004**L	-1.315M	-0.286M
L.S.D. 5%	0.146	2.224	0.158	0.602	1.992	5.534
1%	0.212	3.226	0.213	0.872	2.885	7.466
var (gi-gj) 5%	0.233	3.517	0.207	0.952	3.151	8.749
1%	0.337	5.101	0.301	1.378	4.562	11.804

*, ** significant at 0.05 and 0.01 levels of probability, respectively.
H = Significant positive values = High GCA effects
M = Insignificant values = Medium GCA effects
L = Significant negative values = low GCA effects

Table (4): Specific combining ability (SCA) effects of the F_1 crosses for some plant and fruit characteristics based on combined analysis.

Crosses	No. of branches	No. of leaves	Early yield	Total yield	Average fruit weight	Fruit Firmness
MON-5 x MON-8	0.265	8.220*	0.101	0.579	-1.523	-1.190
MON-5 x MON-9	0.121	-2.541	1.785	-1.083	0.738	4.048
MON-5 x MON-15	0.061	3.686	-0.610	-0.261	-1.505	0.476
MON-5 x Endless Summer	1.247**	9.752**	0.086	0.384	-0.792	14.761*
MON-8 x MON-9	0.638**	10.147**	0.184	2.478**	2.055	23.571**
MON-8 x MON-15	-0.015	-7.971*	-0.054	-1.260	-0.079	-11.667
MON-8 x Endless Summer	0.751**	10.447**	-0.125	-0.041	2.541	-7.381
MON-9 x MON-15	1.396**	17.371**	0.874**	5.283**	4.356	38.571**
MON-9 x Endless Summer	-0.461*	-6.521*	0.176	-1.093	-2.147	-17.143*
MON-15 x Endless Summer	-0.063	-1.063	0.358	-0.303	0.019	2.619
L.S.D. 5%	0.382	5.745	0.407	1.554	5.147	14.287
L.S.D. 1%	0.555	8.333	0.550	2.251	7.452	19.275

*, ** significant at 0.05 and 0.01 levels of probability, respectively

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Generally, the cross MON-9 X MON-15, which considered the best combination, involved parents with high x low and high x medium GCA effects. Also, most of the significant SCA crosses mainly involved high x low GCA effects. Therefore, such crosses can be used to isolate desirable segregates, as well as, in hybrid breeding for the respective characters. In this respect, since the SCA effects are considered as indicator for heterosis effects, the high amount of heterosis could be expected for number of branches and leaves which showed significant positive SCA values for four and five crosses among ten studied ones. While, low amount of heterosis could be expected for average fruit weight, since no significant SCA values were observed. This- observations was agree with the estimated degree of dominance value (Table 2) which were more than one (1.8 and 1.5) for number of branches and leaves (over-dominance), while it was (-0.19) for average fruit weight which confirmed the low amount of heterosis for this trait. Then, the heterosis breeding could be used as effective method for breeding to number of branches and leaves, while selection method could be used for average fruit weight. These results are in agreement with those of Singh *et al.* (2010) and Kansouh (2013a).

C. Average degree of heterosis (ADH%) :

For number of branches per plant (Table 5), all F_1 crosses, except MON-9 x Endless Summer, showed relative heterosis, since they recorded significant ADH% values based on mid-parents (MP), reflecting dominance towards the high number of branches. The estimated ADH% values in relation to the better parent (BPH) for these crosses showed over-dominance for four ones, where they recorded significant positive BPH% values ranged from 13.01% (cross MON-5

x MON-15) to 31.04% (cross MON-5 x Endless Summer). Complete dominance for the high branch number was detected in the remaining five crosses, since they showed insignificant BPH% values. Relative to the commercial hybrid (CH) as standard hererosis (SH %) the two crosses MON-8 x MON-9 and MON-9 x MON-15 showed insignificant SH% values. According to the obtaind data for this trait, the non-additive was predominance and played the main role in the inheritance of number of branches par plant, since dominance type (Table 5) reflected complete and over dominance in nine crosses.

Regarding number of leaves per plant, obtained date (Table 5) showed the same trend, since most studied crosses (six from ten ones) showed dominance towards the high number of leaves, since they recorded significant positive MPH % values. Among of them, four crosses showed over-dominance, since recorded significant positive BPH % values (heterobeltiosis), while complete dominance was detected in two ones, since they reflected insignificant BPH % values. However, four crosses showed no-dominance for the trait since they recorded insignificant MPH % values. According to dominance type this trait was under additive and non-additive gene action with preponderance of non-additive effects, since the distribution of the crosses were four ones showed no-dominance (additive) while six crosses revealed complete-and over-dominance (non-additive). The obtained data supported that of combining ability (Table 2), which showed significant role regarding additive and non-additive gene action for the expression of both number of branches and leaves per plant with the prevalence of non-additive effects. these results, regarding average degree of heterosis, are in accordance with those of Tiwari and Lal (2004), Yadav *et al.*

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(2013) and Sahu *et al.* (2016) , for number of branches; Kansouh and Masoud (2007) and Kansouh (2013b) for number of leaves who found heterosis for number of branches and leaves relative to the mid- and better- parents in tomato .

Table (5): Average degree of heterosis (ADH%) based on mid-parents (MP), better parent (BP), commercial hybrid (CH), and dominance type for number of branches, leaves and early yield in the studied crosses based on combined analysis.

Crosses	ADH %			Dominance type
	MP	BP	CH	
plant/ No. of branches				
MON-5 x MON-8	18.17**	6.75	-11.22**	Complete dominance
MON-5 x MON-9	16.25**	4.94	-12.59**	Complete dominance
MON-5 x MON-15	15.81**	13.01*	-24.19**	Over dominance
MON-5 x Endless Summer	41.14**	31.04**	-12.09**	Over dominance
MON-8 x MON-9	22.25**	22.16**	1.76	Over dominance
MON-8 x MON-15	12.64**	-0.45	-17.21**	Complete dominance
MON-8 x Endless Summer	27.30**	7.67	-10.47**	Complete dominance
MON-9 x MON-15	36.95**	20.96**	0.75	Over dominance
MON-9 x Endless Summer	7.17		-24.56**	No-dominance
MON-15 xEndless Summer	13.67*	8.01	-31.05**	Complete dominance
plant/No. of leaves				
MON-5 x MON-8	28.10**	19.76**	-6.60	Over dominance
MON-5 x MON-9	10.01		-17.10**	No-dominance
MON-5 x MON-15	20.29*	10.43	-25.09**	Complete dominance
MON-5 x Endless Summer	32.39**	17.32*	-20.42**	Over dominance
MON-8 x MON-9	27.34**	23.58**	2.41	Over dominance
MON-8 x MON-15	0.40		-32.37**	No-dominance
MON-8 x Endless Summer	31.78**	10.15	-14.10*	Complete dominance
MON-9 x MON-15	39.43**	17.43**	-2.68	Over dominance
MON-9 x Endless Summer	2.03		-31.00**	No-dominance
MON-15 xEndless Summer	10.29		-39.83**	No-dominance
plant/Early Yield				
MON-5 x MON-8	8.09		-22.90**	No-dominance
MON-5 x MON-9	39.86**	24.42**	24.39**	Over dominance
MON-5 x MON-15	-2.42		-36.56**	No-dominance
MON-5 x Endless Summer	12.82		-40.45**	No-dominance
MON-8 x MON-9	14.42**	-5.73	-5.75	Complete dominance
MON-8 x MON-15	2.41		-40.14**	No-dominance
MON-8 x Endless Summer	0.65		-53.48**	No-dominance
MON-9 x MON-15	28.66**	-2.12	-2.14	Complete dominance
MON-9 x Endless Summer	20.34**	-23.17**	-23.19**	Partial dominance
MON-15 xEndless Summer	19.25*	-8.73	-52.41**	Complete dominance

*, ** significant at 0.05 and 0.01 levels of probability, respectively

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For early yield, data in Table 5 illustrated that, five F_1's showed no-dominance (additive), since they recorded insignificant MPH % values. While, the remaining five hybrids reflected different degrees of dominance (partial, compete and over) towards the high early yield parents, since they showed significant positive MPH % values. Among of them, the cross MON-9 x Endless Summer showed partial dominance (additive and non-additive), since it recorded significant positive and negative MPH% and BPH% values, respectively (20.34 and -23.17%). Other three crosses revealed complete dominance (non-additive) towards the high early yield, while, hybrid vigour (heterobeltiosis) was detected in the cross MON-5 x MON-9 , with significant positive BPH% values (24.42 %), suggested non-additive effects . Also, the two crosses, MON-8 x MON-9 and MON-9 x MON-15 showed insignificant heterosis values (-5.73 and -2.12%, respectively) relative to the commercial hybrid Alissa F_1 (control).

With regard to total yield eight crosses showed insignificant MPH% values suggesting no-dominance (additive gene effects) for the trait (Table 6). Meanwhile, two crosses, i.e., MON-8 XxMON-9 and MON-9 x MON-15 revealed over-dominance (heterobeltiosis) for the high total yield, suggesting non-additive gene effects, since they recorded significant positive MPH% and BPH% values (21.03, 41.99% as MPH% and 14.68, 31.63% as BPH%, respectively). In this respect, the mentioned two crosses showed the same total yield compared to the Alissa F_1 hybrid (control), with insignificant SH% values (-1.73 and 0.96%). The obtained results are in agreement with those of Khalil (2009), Kansouh and Masoud (2007), Kansouh

(2013b) Sahu *et al.* (2016), Kumar *et al.* (2017) and Jaiprakash Narayan *et al.* (2018) who found heterosis, MPH% (relative heterosis) and BPH% (heterobeltiosis) for early and total yield in some F1 tomato hybrids.

Regarding average fruit weight (Table 6), all the studied crosses showed no-dominance for this trait, since they gave insignificant MPH% values suggesting that weight of fruit in these materials was mostly governed by additive gene effect. However, of the tested ten crosses, three ones produced average fruit weight similar to those of the commercial hybrid Alissa F_1. Insignificant CH% values were obtained. Likewise, no hybrid vigour (over-dominance) or standard heterosis (SH%) were obtained for fruit firmness trait, since most tested crosses (seven from ten studied) showed insignificant MPH% values, suggesting no-dominance (additive gene effects) for this trait. From the remaining three crosses, the combination MON-5 x MON-9 reflected complete dominance for the firmest fruit, with significant positive MPH% value (4.25 %) and insignificant BPH% value (-2.23 %). Respecting the order, partial dominance toward the firmest fruit was detected in the two crosses MON-8 x MON-9 and MON-9 x MON-15, since they recorded significant positive MPH% values (6.79 and 10.54%) while showed significant negative BPH% values (-7.24 and -5.65 %, respectively). Similar results also were reported by Sekhar *et al.* (2010) and Kansouh (2013b) who reported that heterosis over the better parent for average fruit weight and fruit firmness was absent and most crosses studied showed values intermediate between their parents, while the presence of some heterosis in some crosses was due to the partial dominance.

Table (6): Average degree of heterosis (ADH%) based on mid-parents (MP), better parent (BP), commercial hybrid (CH), and dominance type for total yield, average fruit weight and fruit firmness in the studied crosses based on combined analysis.

Crosses	ADH %			Dominance type
	MP	BP	CH	
Total yield/plant				
MON-5 x MON-8	4.64		-17.59**	No-dominance
MON-5 x MON-9	1.16		-24.87**	No-dominance
MON-5 x MON-15	2.93		-29.32**	No-dominance
MON-5 x Endless Summer	0.16		-37.77**	No-dominance
MON-8 x MON-9	21.03**	14.68**	-1.73	Over dominance
MON-8 x MON-15	0.23		-24.23**	No-dominance
MON-8 x Endless Summer	0.77		-30.41**	No-dominance
MON-9 x MON-15	41.99**	31.63**	0.96	Over dominance
MON-9 x Endless Summer	0.24		-35.27**	No-dominance
MON-15 x Endless Summer	2.00		-39.85**	No-dominance
Average fruit weight				
MON-5 x MON-8	-1.01		24.82**	No-dominance
MON-5 x MON-9	0.93		9.81**	No-dominance
MON-5 x MON-15	-1.02		26.81**	No-dominance
MON-5 x Endless Summer	-1.01		23.87**	No-dominance
MON-8 x MON-9	3.60		-3.23	No-dominance
MON-8 x MON-15	1.01		13.86**	No-dominance
MON-8 x Endless Summer	2.42		12.51**	No-dominance
MON-9 x MON-15	5.49		0.65	No-dominance
MON-9 x Endless Summer	-0.89		-8.28	No-dominance
MON-15 x Endless Summer	0.46		12.37**	No-dominance
Fruit firmness				
MON-5 x MON-8	0.73		-14.14**	No-dominance
MON-5 x MON-9	4.25*	-2.23	-23.82**	Complete dominance
MON-5 x MON-15	2.13		-10.92**	No-dominance
MON-5 x Endless Summer	3.18		-15.39**	No-dominance
MON-8 x MON-9	6.79**	-7.24**	-14.14**	Partial dominance
MON-8 x MON-15	-0.52		-5.96**	No-dominance
MON-8 x Endless Summer	-1.39		-11.92**	No-dominance
MON-9 x MON-15	10.54**	-5.65**	-8.93**	Partial dominance
MON-9 x Endless Summer	-1.28		-23.82**	No-dominance
MON-15 x Endless Summer	1.36		-7.44**	No-dominance

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

Regarding dominance type for early and total yield, average fruit weight and fruit firmness (Table 5 and 6), the distribution of the crosses showed that, the large number of the tested crosses showed no-dominance (additive gene effects), while partial dominance (additive and non-additive effects) was detected in some crosses and little few number showed complete – and over – dominance (non-additive effects), suggesting that , the additive gene action was prevalence and play the main role in the inheritance of these four traits . This opinion was supported the combining ability estimates (Table 2) which suggested the prevalence of additive genetic variance for these four traits. Therefore, these four characters could be improved by varietal breeding through selection methods, while for number of branches and leaves, since non-additive genetic variance was preponderance, these two traits could be improved by F1 hybrid (heterosis) breeding program.

These results regarding average degree of heterosis and genetic variance effects (additive and non-additive) were agreement those of Goyal and Kumar (1988), Mohanty and Mishra (1999) and Kansouh (2014) who revealed that, the high degree of heterosis (complete and over-dominance) reflected the presence of high non-additive effects, meanwhile absence of heterosis (no-dominance) could be considered as a criterion of additive effects. Therefore, heterosis study of the hybrids may be considered as one of the modern practices to determine additive and non-additive genetic variances as the combining ability method.

CONCLUSION

Analysis of variance showed that additive genetic variance was more important and play the main role in the inheritance of early and total yield,

average fruit weight and fruit firmness and varietal breeding through selection methods may be more effective to improved these traits in tomato. While, number of branches and leaves traits could be improved by heterosis breeding, since the non-additive genetic variance play the main role in the inheritance of these traits. The hybrid breeding method based on standard heterosis can be used efficiently to improve tomato yield and quality in Egypt by developing superior local hybrids.

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التحليل الوراثى وقوة الهجين لبعض الصفات الكمية فى الطماطم

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الملخص العربى

أجريت هذة الدراسة خلال ثلاث مواسم من (٢٠١٦– ٢٠١٨) فى العروة الصيفى المبكر فى مزرعة التجارب كلية الزراعة بشبين الكوم – جامعة المنوفية فى الموسم الأول وشركة بهجة الزراعية بأنشاص محافظة الشرقية فى الموسم الثانى والثالث. بهدف الحصول على مزيد من المعلومات عن القدرة على التآلف والتفاعل الجينى لتحديد بعض السلالات أو الأصناف التى تملك قدرة عالية على التآلف لبعض صفات النبات والثمار . وأيضاً بهدف قياس درجة قوة الهجين لبعض الصفات فى الهجن الناتجة لتحديد أفضل الهجن للاستخدام التجارى. تم زراعة أربعة سلالات طماطم وصنف واحد فى الموسم الأول وأجرى التهجين بينهم فى اتجاه واحد للحصول على بذور الجيل الأول (١٠ هجن) اللازمه للدراسة. وفى الموسم الثانى والثالث زرعت العشرة هجن مع آبائها الخمسه والهجين التجارى Alisa للمقارنة فى تجربة تقييم لعدد من الصفات مثل عدد الأفرع ،عدد الأوراق ، المحصول المبكر والكلى ، متوسط وزن الثمرة وصلابة الثمار ، وتم قياس مكونات التباين الوراثى والقدرة على التآلف وقوة الهجين لهذة الصفات المدروسة وكانت النتائج كالآتى:

١– تحليل التباين أوضح أن هناك فروق معنوية بين التراكيب الوراثية (الآباء والهجن) فى جميع الصفات.

٢– أظهرت الدراسة أن السلالتين MON-8 ، MON9 أفضل الآباء التى لها قدرة عامة على التآلف والهجن MON-8 × MON-9 ، MON-15 × MON-9 هما الأفضل بالنسبة للقدرة الخاصة على التآلف حيث سجلت قيم موجبة وعالية المعنوية.

٣– كانت قوة الهجين على أساس متوسط الأبوين (MPH%) معنوية فى كل الصفات عدا متوسط وزن الثمرة ، وعلى أساس الأب الأفضل فى الصفة (BPH%) فقد لوحظت فى بعض الهجن لصفات عدد الأفرع ، عدد الأوراق ، المحصول المبكر والكلى . أما بالنسبة لقوة الهجين على أساس الكنترول (SH%) فقد ظهر تفوق الهجن MON–9 × MON–15، 8 × MON–9 .

٤– وأوضحت حسابات القدرة العامة والخاصة على التآلف أن التأثير الإضافى والإضافى للجينات كان معنوى وهام لكل الصفات عدا صفة متوسط وزن الثمرة. الجزء المضيف يمثل ٧, ٦٥– ٩٨,١ من التباين الوراثى الكلى ، بينما يمثل الجزء الغير مضيف ١,٩– ٣٤,٧ من التباين الوراثى الكلى وهذا يشير إلى أن الفعل المضيف للجينات كان أكثر أهمية ويلعب دوراً رئيسياً فى وراثة كلٍ من المحصول المبكر والكلى ومتوسط وزن الثمرة والصلابة ويمكن تحسينها عن طريق برامج التربية المتنوعة. بينما لوحظ التأثير غير الإضافى فى صفة عدد الأفرع وعدد الأوراق ولتحسين هاتين الصفتين يكون عن طريق إنتاج الهجن، أى استخدام ظاهرة قوة الهجين.