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Performance, Manifestation of Heterosis and Combining Ability for Growth, Productivity and Fruit Quality of Indeterminate Tomato

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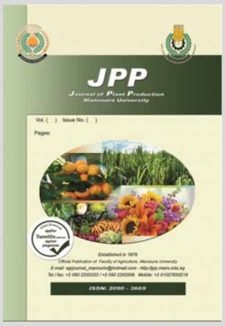

ABSTRACT

Six parental lines of indeterminate tomato were used in half diallel model to study performance, degree of heterosis and combining ability.This study was conducted at the Experimental Farm, Faculty of Environmental Agriculture Sciences, Arish University during two successive seasons of 2018/2019 and 2019/2020. Results revealed that the parental lines IRS-43-2, VR-6 and VL-5-4 exhibited the best values for most studied characters,however the cross combinations IRS-43-2 x VR-6, IR-44-2 x VR-6 and VR-6 x VL-5-4 were the best among the crosses.Hybrid vigour was observed in many traits, the significant positive heterosis over the check hybrid was detected in all characters and the highest values were reflected by the crosses VR-6 x VL-5-4 for growth traits and IRS-43-2 x VR-6 for early yield, total yield and Vit. C content. Variances of combining ability and genetic components revealed that additive gene action played the main role in the inheritance of fruit set percentage, total yield plant^{-1}, average fruit weight, fruit shape and Vit. C. Based on GCA effects, the good combiner was Vl-5-4, for growth traits; IRS-43-2 and VR-6 for early yield, total yield, number of locules, and Vit. C. The highly significant positive values of SCA effects observed in crosses VR-6 x VL-5-4 for growth traits and Vit. C; IRS-43-2 x VL-5-4 for early yield; and IR-44-1 x VL-7-4 for total yield and average fruit weight. Three promising crosses (IRS-43-2 x VR-6; IR-44-2 x VR-6; VR-6 x VL-5-4) could be used commercially as local hybrids after testing in multi locations and seasons.

Keywords: indeterminate tomato, half diallel, heterosis, combining ability, gene action.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) occupies an important situation among solanaceous and fruit vegetable crops due to its economic and nutritional value. Its fruits are rich in substances like minerals, organic acid, sugar and vitamins; therefore, it is considered as protective food. Moreover, the demand of indeterminate tomato F_1 hybrids have increased due to the previous benefits in addition to the national projects of horizontal expansion and one hundred thousand greenhouse that adopted by government.

Successful cultivation of indeterminate tomato under greenhouses required choosing the suitable hybrids. Producing new hybrids and/or cultivars of tomato characterized by vigorous growth, high production, and quality traits that could be essentially in any breeding program to meet the increasing demand for tomato by farmers, consumers and processors (Radzevicius *et al*., 2013).

In self fertilization crops, heterosis breeding is apparently the probably method for improving productivity. Heterosis pointed to the superiority of F_1 hybrids over mid-parents, better parent and best commercial hybrid for one or more traits. Expression of heterosis depends upon some factors, viz., heterozygosity, allelic and non-allelic interaction and over dominance. So, heterosis increases as a result of higher number of heterozygous alleles (East and Hayes, 1912). Furthermore, studies of heterosis are useful in giving an idea about types of gene action which in turn can be exploit further for improvement of important characters (Jain and Sastry, 2012; Kansouh, 2014a)

Heterosis phenomenon was investigated on tomato by many researchers. Mid parent, better parent and check hybrid heterosis were observed for plant height and total yield (Marbhal *et al*., 2016; Sahu *et al*., 2016), for Vit. C content (Kumari and Manish, 2011). Heterosis over the better parent was also found for leaves number and total yield (Khalil and Mahmoud, 2019), for early and total yield (Mahmoud and El-Eslamboly, 2014; Mahmoud, 2015), for average fruit weight (Garg *et al*., 2008; Farzane *et al*., 2012; Islam *et al*., 2012). However, many tomato breeders reported that no heterosis over the better parent for average fruit weight was detected (Solieman *et al*., 2013; Kansouh, 2014b; Mahmoud and El-Eslamboly, 2014; Mahmoud, 2015; Khalil and Mahmoud, 2019), where they showed partial dominance toward the parents produced small fruits.

In past, many plant breeders studied varied crops and noticed that, performance of parents is not constantly a true guide of its potential in cross combination. Therefore, the study of combining ability is an appropriate tool to give information about the best parent that combine with another parent to produce new potential and productive populations. General GCA and specific SCA combining ability aid the breeder to select the parents for hybridization programs, as well as to isolate the superior genotypes in segregation populations and also give idea on type of gene action.

Information about nature and magnitude of gene action (fixable and non-fixable) that controlled the

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important traits is essential to formulate the suitable breeding strategy to achieve genetic improvement of tomato crop. Griffing (1956) studied the relationship between different components of variances of general and specific combining ability, where GCA pointed to additive variance and interallelic interaction (addi. x addi.), however, SCA pointed to dominance (non-additive) and epistatic variance. Several studies on combining ability of tomato revealed predominance of non - additive gene action such as reported by Saleem *et al*., (2009), Rajkumar *et al*.,(2018) and Vekariya *et al*., (2019), for plant height; Kansouh and Zakher (2011), Aminu and Mala (2015) and Khalil and Mahmoud (2019), for number of leaves; Vekariya *et al*., (2019), for fruit shape index. However, another studies revealed that additive gene effects played the main role in the inheritance as reported by Garg *et al.* (2008), Kumar *et al*., (2013), Shanker *et al*. (2013) and Al-Daej (2018), for average fruit weight; Droka *et al.* (2012), for total yield and Vit. C content; and Shende *et al*. (2012) for total yield; Mahmoud and El-Eslamboly (2014) and Khalil and Mahmoud (2019), for early yield, total yield and average fruit weight.

So far, no such researches were done with regard to producing indeterminate tomato F_1 hybrids under greenhouse in Egypt. Hence, the present research aimed to study performance, heterosis and combining ability for some important traits. Also, determine the promising F_1 hybrids suitable for greenhouse cultivation in Egypt.

MATERIALS AND METHODS

The present investigation was carried out in a plastic greenhouse at The Experimental Farm, Faculty of Environmental Agriculture Science, Arish University during successive seasons of 2018/2019 and 2109/2020. The genetic materials consisted of six lines of indeterminate tomato (IRS-43-2 (P1), IR-44-1(P2), IR-44-2 (P3), VR-6(P4), VL-5-4 (P5) and VL-7-4(P6)) which were chosen from breeding program started from 2012/2013 to 2017/2018 to develop some new indeterminate tomato lines (Mahmoud and Khalil, 2019). Parental lines were crossed in 6x6 half- diallel mating system to develop 15 F_1 hybrids during 2018/2019. The parents and their F_1 hybrids as well as “Myla F_1” (Syngenta Co.) as check hybrid was evaluated during 2019/2020 in a randomized complete blocks design in three replications. Drip irrigation system was used, each plot had one bed (1.5 m width x 8 m length) which had two dripper lines at 40 cm apart, while the distance between plants in the same row was 50 cm. Transplants were transplanted at 1st November in 2019/2020. The soil of experiment was sandy loam with pH of 8.0 and EC of 1.10 dSm^{-1}, however irrigation water has EC of 5.88 dSm^{-1} and PH of 7.17. All agriculture practices were done according to that recommended for tomato production under plastic greenhouse.

Data were recorded on ten randomly chosen plants for plant height and number of leaves/plant (keeping in mind all genotypes are indeterminate growth habit and need to remove all axillary shoots constantly). Fruit set percentage as average of the first four clusters. Early yield $plant^{-1}$ from the first three pickings and total yield $plant^{-1}$ for all pickings. However, average fruit weight was calculated by dividing total yield on total fruit number. Five fruits were taken randomly to measure fruit shape index (L/D), number of locules $fruit^{-1}$ and Vit. C content as described in A.O.A.C. (1990).

The obtained data were analyzed for variance using MSTATC V.2.10 and means were compared according to Duncan (1958). Estimation of average degree of heterosis (ADH) based on mid-parents (MPH), better parent (BPH) and check hybrid heterosis (CHH). Heterosis over the better parent estimated only for the hybrids exhibited significant positive MPH values. Type of dominance was described according to dominance line of Kansouh (2014a). Combining ability analysis and components of genetic variances were analyzed according to Griffing (1956) method II model I. Degree of dominance was determined using the following equation: $(\sigma^2 D/ \sigma^2 A)^{0.5}$.

RESULTS AND DISCUSSION

Mean performance of parents and their F_1 hybrids

High significant differences were appeared among evaluated genotypes for all studied traits (Table 1). Presented data indicate that none of parental lines and F_1 hybrids was superior for all characters. For plant height, the tallest plants of parents were observed with P_5 (244.1 cm) followed by P_6 (223.0 cm), however, the shortest one was P_2 (176.2 cm). Crosses recorded values varied from 212.3 to 266.3 cm, the taller hybrid was P_4 x P_5 (266.3 cm), followed by P_5 x P_6 (256.0 cm). These hybrids involved at least one or two of the best parents for this trait. The grand mean of F_1 hybrids exceeded that of parents and check hybrid “Myla F_1” by 29.7 and 17.1%, respectively, indicating that most of F_1 hybrids gave taller plants compared with their parents and check.

Concerning number of leaves, the parental line P_6 produced the highest value (40.0), while the lowest one reflected by both lines P_2 (27.3) and P_4 (28.0) with no differences between them (Table 1). The crosses recorded wide values ranged from 28.7 to 49.5, the cross P_4 x P_5 showed the highest value (49.5) with no differences than P_3 x P_5 (47.8) and P_5 x P_6 (47.6). Most F_1 hybrids surpassed their parents and check hybrid, where, mean of hybrids surpassed that of parents by 22.4% and check by 15.7%.

As for fruit set percentage presented data in Table 1 show that the line P_4 recorded the highest percentage (94.4%) followed by P_1 (92.6%), these lines have moderately growth (plant height and number of leaves). On the other hand, the line P_5 gave the lowest percentage (86.4%) which has high vigorous growth; this may be due to negative correlation between high growth and fruit setting. The crosses percentage ranged from 87.1% to 93.7%, the crosses contained either two high parental lines (P_1 x P_4) or one of them (P_4 x P_5) both exhibited the highest fruit setting (93.7% and 93.4%, respectively). The average of all parents, hybrids and check hybrid was approximately equal with values of 90.6, 91.1 and 91.3, respectively.

Results in Table 1 clear that early yield of parental lines showed values ranged from 1.5 to 2.3 kg $plant^{-1}$, both lines P_1 and P_4 recorded the highest early yield (2.2 and 2.3 kg $plant^{-1}$, respectively) with no differences between them. However, the crosses exhibited means varied from 1.5 kg for the cross P_2 x P_3 and 2.8 for the cross P_1 x P_4. The mean of the check hybrid exceeded that of parents and F_1 hybrids, in spite of this increase, there are six hybrids (P_1 x P_4, P_1 x P_5, P_1 x P_2, P_2 x P_6, P_2 x P_4 and P_4 x P_5) significantly surpassed “Myla F_1” by 33.5, 19.0, 9.5, 9.5, 4.8 and 4.8%, respectively. Most of these crosses included at least one or two of high parents, so those could be considered as promising hybrids for early yield of indeterminate tomato.

Regarding total yield plant^{-1}, evaluated lines exhibited wide variation ranged from 5.0 kg. Plant^{-1} for P_5 to 6.9 kg plant^{-1} for P_4 with an average 5.9 kg plant^{-1} (Table 1). The line P_4 possessed the highest productivity followed by both of P_1 and P_2. The average mean of “Myla F_1” surpassed the overall mean of hybrids by 3.2%, nevertheless, four crosses (P_1 x P_2, P_1 x P_5, P_2 x P_4 and P_2 x P_6) had equally significant values with the commercial hybrid, also three ones (P_1 x P_4, P_3 x P_4 and P_4 x P_5) were out yielded commercial hybrid by 12.9, 8.1 and 8.1%, respectively. These superior hybrids need to evaluate for important traits in multi locations and different climatic conditions for utilizing in tomato production under greenhouse.

In general, the previous results indicated that the best lines for vigorous growth were P_5 and P_6, however, for high early and total yield plant^{-1}, both of parental lines P_1 and P_4. For the crosses, the best promising hybrids for high performance were P_4 x P_5 and P_5 x P_6, for growth; and P_1 x P_4 and P_4 x P_5 for early and total yield.

Great variations were observed among evaluated entries for average fruit weight (Table 1). The lines values ranged from 59.4 to 104.0 with a grand mean of 86.6. The heaviest fruits (104.0) were obtained by line P_1, followed by both of P_3 (99.1) and P_4 (96.6) with no apparent differences between them. For crosses, the mean values ranged from 58.8 for cross P_5 x P_6 to 93.8 for cross P_3 x P_4 with general mean 75.4. The grand mean of lines exceeded that of F_1 hybrids grand mean and check (Myla F_1) hybrid, also the average F_1 hybrids was less compared to Myla F_1 hybrid. On the other hand, there are four crosses (P3 x P6, P1 x P3, P1 x P4 and P3 x P4) significantly surpassed that of “Myla F_1” by 4.2, 8.1, 13.4 and 22.5 %, respectively.

Table 1. Mean performances of the evaluated indeterminate tomato F_1 hybrids and their parents for some plant traits.

Characters Genotypes	Plant height (cm)	No. leaves /plant	Fruit set (%)	Early yield (kg/plant)	Total yield (kg/plant)	Average fruit weight (g)	Fruit shape index	No. locules/ fruit	Vit. C content (mg/100g fresh weight)
IRS-43-2 (P1)	200.5m	32.3k	92.6bcd	2.2cde	6.4c	104.0a	0.79j	3.7a	31.1bc
IR-44-1 (P2)	176.2n	27.3l	89.4jk	1.9fgh	6.1cde	81.0e	0.90ij	3.1d	27.1ef
IR-44-2 (P3)	217.1kl	33.8jk	90.7hi	1.8ijk	5.8fg	99.1b	0.93hi	3.1d	23.6ij
VR-6 (P4)	202.3m	28.0l	94.4a	2.3cd	6.9a	96.6bc	1.03fhg	3.5abc	32.0b
VL-5-4 (P5)	244.1d	37.0i	86.4l	1.5m	5.0j	59.4j	1.53d	3.1cd	21.1l
VL-7-4 (P6)	223.0ij	40.0h	90.0ij	1.9ghi	5.4i	79.4ef	2.07b	2.1g	22.8jk
Mean	210.5	33.1	90.6	1.9	5.9	86.6	1.21	3.1	26.3
Crosses									
P1 xP2	225.0hi	35.0ij	92.2def	2.3bc	6.3cd	75.3gh	0.93hi	3.7a	31.3bc
P1 x P3	237.7ef	36.7i	91.2e-h	2.1def	5.9def	82.8e	0.95ghi	3.1d	28.3d
P1 x P4	233.3fg	37.2i	93.7ab	2.8a	7.0a	86.9d	1.07fg	3.2bcd	33.2a
P1 x P5	245.7cd	46.7bcd	92.4cde	2.5b	6.1cde	67.1i	1.45de	2.3efg	25.9fg
P1 xP6	233.3fg	42.3fg	89.9ijk	1.8hij	5.7gh	76.3fg	2.10b	2.4ef	24.6hi
P2 x P3	217.0kl	32.0k	90.6hi	1.5lm	5.9ef	73.8gh	0.97ghi	3.2bcd	30.0c
P2 x P4	225.3hi	28.7l	92.7bcd	2.2cd	6.2cde	74.1gh	1.07fg	3.1d	31.8b
P2 x P5	240.3de	44.0ef	87.1l	1.6klm	5.5hi	62.2j	1.70c	2.3efg	24.1hi
P2 x P6	212.3l	28.8l	91.0f-i	2.3bc	6.3cde	77.2fg	2.10b	1.4h	25.9fg
P3 xP4	245.0cd	44.3def	91.9d-g	1.8ijk	6.7b	93.8c	1.13f	3.3bcd	31.8b
P3 xP5	249.7lc	47.8ab	88.8k	1.6lm	5.8fg	71.8h	1.80c	2.2fg	25.1gh
P3 x P6	240.7de	46.7bcd	90.8ghi	2.0efg	5.6ghi	79.8ef	2.07b	2.4efg	23.3ijk
P4 x P5	266.3a	49.5a	93.4abc	2.2cde	6.7b	74.8gh	1.52d	2.2fg	32.0b
P4 x P6	229.3gh	40.3gh	91.0f-i	1.9fgh	5.8fg	76.6fg	2.17b	2.3efg	30.5c
P5 x P6	256.0b	47.6abc	89.9ijk	1.7jkl	5.1j	58.8j	2.34a	2.4efg	22.2k
Mean	237.1	40.5	91.1	2.0	6.0	75.4	1.56	2.63	28.0
Myla F1	233.3fg	35.0ij	91.3e-h	2.1def	6.2cde	76.6fg	1.39e	2.6e	28.0de

Fruit shape index expressed as length / diameter (L/D) showed widely variations among the evaluated genotypes (Table 1). The shape varied from oblate fruits (L/D = 0.79) in line P_1 to long date fruits (L/D = 2.07) in line P_6. The remaining lines give different shapes like circular and cylindrical fruits. Out of 15 F_1 hybrids, six crosses (P_1 x P_2, P_1 x P_3, P_1 x P_4, P_2 x P_3, P_2 x P_4 and P_3 x P_4) exhibited circular fruits, four ones (P_1 x P_5, P_2 x P_5, P_3 x P_5 and P_4 x P_5) showed cylindrical shape and five ones (P_1 x P_6, P_2 x P_5, P_3 x P_6, P_4 x P_6 and P_5 x P_6) produced long date fruits compared with the check hybrid which have obovate fruits (L/D = 1.39).

As for number of locules fruit^{-1}, presented data in Table 1 revealed that locules number varied from 2.1 to 3.7 with an average of 3.1 for parents. The highest number was detected in both lines P_1 and P_4 (3.7 and 3.5, respectively) with no significant differences between them, followed by both of P_2 and P_3 with the same value (3.1). For crosses, the values ranged from 1.4 to 3.7 with a grand mean of 2.6 which statistically equal that of the check hybrid (2.6). The cross P_1 x P_2 recorded the highest number of locules (3.7), followed by P_1 x P_4 (3.2), P_2 x P_3 (3.2) and P_3 x P_4 (3.3) with no differences between them. This result clears the relation between fruit shape and number of locules, since oblate and circulate fruit shape have higher number of locules compared to cylindrical and long fruits.

Regarding Vit. C content, the evaluated entries showed wide variations (Table 1), the highest fruit content (31.1 and 32.0) was observed in both lines P_1 and P_4, respectively, with over mean of 26.3, which was less than F_1 hybrids (28.0) and check hybrid (28.0). However, the resulted F_1 hybrids ranged from 22.0 to 33.2, the cross P_1 x P_4 gave the highest content (33.2) followed by the crosses P_1 x P_2, P_2 x P_4, P_3 x P_4 and P_4 x P_5, with no differences among them. The average of F_1 hybrids are statistically equal that of check, indicating that heterosis over check was found in most crosses. Similar results were previously reported by many researchers (Kumari and Manish, 2011; Kansouh, 2013 and 2014b; Mahmoud and El-Eslamboly, 2014; Sahu *et al*., 2016; Al-Daej, 2018; Khalil and Mahmoud; 2019) who found significant differences among studied genotypes for growth, yield and fruit characters of tomato.

Average degree of heterosis (ADH)

Concerning plant height, presented data in Table 2 clear that all studied crosses (15 ones) showed dominance toward the taller plants, since they had significant positive values based on mid parent heterosis (MPH). Calculated better parent heterosis (BPH) for 15 F_1 hybrids exhibited over dominance for the taller parent in 11 ones, since they showed significant positive BPH values, indicating hybrid vigour in this trait, three ones showed complete dominance because they have insignificant values of BPH, the rest one cross reflected partial dominance to high parent. The highest values of MPH and BPH recorded by the crosses P_1 x P_2 (19.46%) and P_1 x P4 (15.32%), respectively. Heterosis over the check hybrid (CH) was detected in seven crosses with significant positive values ranged from 3.00% for the cross P_2 x P_5 to 14.14% for the cross P_4 x P_5. Previous results showed that most crosses revealed over dominance (11 ones) that expressed non - additive gene effect, indicating that inheritance of this trait was under control of non - additive genes. Earlier results of Marbhal *et al.* (2016), Sahu *et al.* (2016), Khalil and Mahmoud (2019), Rehana *et al.* (2019) and Sonagara *et al.* (2020) found heterosis over mid parents, better parent and check hybrid for plant height.

For number of leaves plant^{-1}, the desired significant values of MPH were observed in 12 crosses with values ranged from 11.04 for the cross P_1 x P_3 to 52.31% for the cross P_4 x P_5, indicating dominance toward the high number of leaves (Table 2). While, two crosses (P_2 x P_3 and P_2 x P_4) showed insignificant MPH values, indicating no dominance, the remaining cross P_2 x P_6 exhibited dominance toward the low parent, that showed significant negative value of MPH. Out of 12 crosses, 11 and 1 cross reflected over dominance and complete dominance toward the high parent, since they presented significant positive and insignificant values of BPH, respectively, suggesting that inheritance of this trait was under control of non - additive gene effects. The extent of BPH % varied from 5.75 for the cross P_1 x P_6 to 33.78% for the cross P_4 x P_5. Ten crosses revealed heterosis over the check hybrid with significant values ranged from 6.29 to 41.43%. The crosses P_4 x P_5 recorded the highest values (41.43%), followed by the cross P_3 x P_5 (34.86%). These results are confirmed by studies of Kansouh (2013 and 2014b), Khalil and Mahmoud (2019).

Table 2. Percentage of heterosis over mid-parents (M.P.), better parent (B.P.), check hybrid heterosis (C.H.) and dominance type for plant height, number of leaves /plant and fruit set percentage traits of indeterminate tomato.

Crosses	Plant height				Number of leaves \ plant				Fruit set (%)			
	M.P.H	B.P.H	C.H.H	Dominance type	M.P.H	B.P.H	C.H.H	Dominance type	M.P.H	B.P.H	C.H.H	Dominance type
P_1xP_2	19.46**	12.22**	-3.56**	Over dominance	17.45**	8.36*	0.00	Over dominance	1.32*	-0.43	0.99	Co. dominance
P_1 x P_3	13.84**	9.49**	1.89	Over dominance	11.04**	8.58**	4.86	Over dominance	-0.49		-0.11	No dominance
P_1 x P_4	15.84**	15.32**	0.00	Over dominance	23.38**	15.17**	6.29*	Over dominance	0.21		2.63**	No dominance
P_1 x P_5	10.53**	0.66	5.32**	Co. dominance	34.78**	26.22**	33.43**	Over dominance	3.24**	-0.22	1.20*	Co. dominance
P_1 xP_6	10.18**	4.62**	0.00	Over dominance	17.01**	5.75*	20.86**	Over dominance	-1.53**		-1.53*	Par. dominance
P_2 x P_3	10.35**	-0.05	-6.99**	Co. dominance	4.75		-8.57**	No dominance	0.61		-0.77	No dominance
P_2 x P_4	19.05**	11.37**	-3.43**	Over dominance	3.80		-18.00**	No dominance	0.87		1.53*	No dominance
P_2x P_5	14.35**	-1.56	3.00**	Co. dominance	36.86**	18.92**	25.71**	Over dominance	-0.91		-4.60**	No dominance
P_2 x P_6	6.36**	-4.80**	-9.00**	Par. dominance	-14.41**		-17.71**	Par. dominance	1.45**	1.11	-0.33	Co. dominance
P_3 xP_4	16.83**	12.85**	5.02**	Over dominance	43.37**	31.07**	26.57**	Over dominance	-0.70		0.66	No dominance
P_3 xP_5	8.28**	2.29*	7.03**	Over dominance	33.33**	27.57**	34.86**	Over dominance	0.28		-2.74**	No dominance
P_3 x P_6	9.38**	7.94**	3.17**	Over dominance	26.56**	16.75**	33.43**	Over dominance	0.50		-0.55	No dominance
P_4 x P_5	19.31**	9.09**	14.14**	Over dominance	52.31**	33.78**	41.43**	Over dominance	3.32**	-1.06	2.30**	Co. dominance
P_4 x P_6	7.83**	2.83*	-1.71	Over dominance	18.53**	0.75	15.14**	Co. dominance	-1.30*		-0.33	Par. dominance
P_5 x P6	9.61**	4.88**	9.73**	Over dominance	23.64**	28.65**	36.00**	Over dominance	1.93**	-0.11	-1.53*	Co. dominance
L.S.D.0.05	4.32	4.99			1.88	2.17			0.93	1.07		
0.01	5.78	6.67			2.51	2.90			1.25	1.44		

***,** Significant at 0.05 and 0.01 levels of probability, respectively. Lines: IRS-43-2 (P_1), IR-44-1(P_2), IR-44-2 (P_3), VR-6(P_4), VL-5-4 (P_5) and VL-7-4(P_6)**

Data in Table 2 show that, for fruit set percentage, most crosses (8 ones) exhibited insignificant values of MPH, indicating no dominance. The rest 7 ones showed significant negative values in two crosses, indicating dominance to low parent and 5 ones showed significant positive MPH values which ranged from 1.32% for cross P_1 x P_2 to 3.32% for cross P_4 x P_5, indicating dominance to high percent for fruit setting. Calculated BPH% for these crosses (5 ones) revealed that, none of hybrids showed significant values in desirable direction, where they gave insignificant values, indicating complete dominance. It's clear that additive gene effects controlled the inheritance of this trait, whereas most crosses (8 ones) exhibited no dominance. Relative to check hybrid, only four crosses (P_1

x P_4, P_4 x P_5, P_2 x P_4 and P_1 x P_5) reflected heterosis with significant values (2.63, 2.30, 1.53 and 1.20%, respectively). Similar findings were reported by Shalaby (2012), who supported the above results, whereas showed heterosis over mid and better parent.

Early yield plant^{-1} presented in Table 3, revealed that six F_1 hybrids showed significant positive MPH values ranged from 8.11% for cross P_3 x P_6 to 35.14% for cross P_1 x P_5, suggesting dominance to high early yield. The remaining nine crosses exhibited no dominance (five ones) and partial dominance to low early yield (four ones). Estimated of BPH was observed in only three crosses (P_1 x P_4, P_1 x P_5 and P_2 x P_6) which gave significant positive BPH values, indicating over dominance (hybrid vigour) in these crosses toward high parent. Complete dominance to high early yield was found in the rest three crosses (P_1 x P_2, P_3 x P_6 and P_4 x P_5). Heterosis over "Myla F_1" was found only in four crosses (P_1 x P_4, P_1 x P_5, P_1 x P_2 and P_1 x P_2), which presented significant positive values (33.33, 19.05, 9.52 and 9.52%, respectively). It is appeared from the previous results that all types of dominance were found in the resulted F_1, where no over complete and partial dominance were reflected by 5, 3, 3 and 4 crosses, respectively, indicating non - additive gene was more important compared to additive one.

Regarding total yield plant^{-1}, six crosses showed dominance to high total yield, since they recorded significant positive MPH values varied from 5.26% for cross P_1 x P_4 to 12.61% for cross P_4 x P_5 (Table 3). No dominance and dominance to low total yield were observed in 7 and 2 crosses, respectively. None of the studied crosses (six ones) revealed significant positive BPH values (no hybrid vigour), whereas they showed complete (five ones) and partial (one cross) dominance, indicating that additive gene effect was more important than non-additive one for this trait. Three crosses (P_1 x P_4, P_3 x P_4 and P_4 x P_5) exhibited significant positive values of heterosis over check "Myla F_1" (12.90, 8.06 and 8.06%, respectively). Earlier studies showed heterosis over mid parent, heterobeltiosis and stander hybrid for early yield and total yield (Garg *et al.*, 2008; Shalaby, 2012; Mahmoud and El-Eslamboly, 2014; Mahmoud, 2015; Khalil and Mahmoud, 2019; Rehana *et al.,* 2019; Sonagara *et al.*, 2020).

Table 3. Percentage of heterosis over mid-parents (M.P.), better parent (B.P.), check hybrid heterosis (C.H.) and dominance type for early yield/plant, total yield/plant and average fruit weight traits of indeterminate tomato.

Crosses	Early yield/plant				Total yield/plant				Average fruit weight			
	M.P.H	B.P.H	C.H.H	Dominance type	M.P.H	B.P.H	C.H.H	Dominance type	M.P.H	B.P.H	C.H.H	Dominance type
P_1 xP_2	12.20**	4.55	9.52*	Co. dominance	0.80		1.61	No dominance	-18.59**		-1.70	Par. dominance
P_1 x P_3	5.00		0.00	No dominance	-3.28		-4.84*	No dominance	-18.46**		8.09**	Par. dominance
P_1 x P_4	24.44**	21.74**	33.33**	Over dominance	5.26**	1.45	12.90**	Co. dominance	-13.36**		13.45**	Par. dominance
P_1 x P_5	35.14**	13.64**	19.05**	Over dominance	7.02**	-4.69*	-1.61	Par. dominance	-17.87**		-12.40**	Par. dominance
P_1 xP_6	-12.20**		-14.29**	Par. dominance	-3.39		-8.06**	No dominance	-16.79**		-0.39**	Par. dominance
P_2 x P_3	-18.92**		-28.57**	Par. dominance	-0.84		-4.84*	No dominance	-18.09**		-3.66	Par. dominance
P_2 x P_4	4.76		4.76	No dominance	-4.62**		0.00	Par. dominance	-16.60**		-3.26	Par. dominance
P_2 x P_5	-5.88		-23.81**	No dominance	-0.90		-11.29**	No dominance	-11.46**		-18.80**	Par. dominance
P_2 x P_6	21.05**	21.05**	9.52*	Over dominance	9.57**	3.28	1.61	Co. dominance	-3.80*		0.78	Par. dominance
P_3 xP_4	-12.20**		-14.29**	Par. dominance	5.51**	-2.90	8.06**	Co. dominance	-4.14**		22.45**	Par. dominance
P_3 xP_5	-3.03		-23.81**	No dominance	7.41**	0.00	-6.45*	Co. dominance	-9.40**		-6.27**	Par. dominance
P_3 x P_6	8.11*	5.26	-4.76	Co. dominance	0.00		-9.68**	No dominance	-10.59**		4.18	Par. dominance
P_4 x P_5	15.79**	-4.35	4.76	Co. dominance	12.61**	-2.90	8.06**	Co. dominance	-4.10*		-2.35	Par. dominance
P_4 x P_6	-9.52**		-9.52*	Par. dominance	-5.69**		-6.45**	Par. dominance	-12.95**		0.00	Par. dominance
P_5 x P_6	0.00		-19.05**	No dominance	-1.92		-17.74**	No dominance	-15.27**		-23.24**	Par. dominance
L.S.D.0.05	0.06	0.09			0.21	0.24			2.87	3.32		
0.01	0.07	0.12			0.28	0.33			3.84	4.44		

***,** Significant at 0.05 and 0.01 levels of probability, respectively. Lines: IRS-43-2 (P_1), IR-44-1(P_2), IR-44-2 (P_3), VR-6(P_4), VL-5-4 (P_5) and VL-7-4(P_6)**

With regard to average fruit weight, data in Table 3 illustrate that none of the evaluated crosses showed ADH based on mid parent, whereas all crosses exhibited significant negative values, indicating dominance to small fruit weight. Estimated of BPH revealed that all obtained F_1 crosses gave significant negative values, suggesting partial dominance toward the low parent. Consequently, all crosses produced fruits significantly low in weight compared to the high parents (no hybrid vigor), indicating that additive gene effects were more important in the inheritance of this trait. On the other hand, the crosses P_3 x P_4, P_1 x P_4 and P_1 x P3 exhibited significant positive heterosis over the slandered hybrid by values of 22.45, 13.45 and 8.09%, respectively. These results are in conformity with the findings of Shalaby (2012), Kansouh (2013 and 2014b), Solieman *et al*. (2013), Mahmoud (2015) and Khalil and Mahmoud (2019), who found partial dominance toward the low parent, indicating no heterosis over mid and better parent. However, significant positive heterosis over the check hybrid (CH) was observed by Kumar *et al.* (2012), Kansouh (2013 and 2014b) and Khalil and Mahmoud (2019).

For fruit shape index, presented data in Table 4 clear that most resulted F_1 hybrids (12 ones) reflected significant positive MPH values varied from 10.88 to 46.85%, suggesting dominance for this trait. The rest crosses (3 ones) showed no dominance, since they exhibited insignificant MPH values. Hybrid vigour (over dominance) was detected only in three crosses (P_2 x P_5, P_3 x P_5 and P_5 x P_6), which presented significant positive BPH values. However, nine crosses reflected complete dominance for this trait, indicating that non - additive gene effect was more important compared with additive one. Out of 15 crosses, eight ones revealed significant positive heterosis over check hybrid by values ranged from 9.35 for cross P_4 x P_5 to 68.35% for cross P_5 x P_6.

Obtained data in Table 4 illustrate that for number of locules/fruit nine crosses showed significant negative values of MPH, indicating dominance to low number of locules. However, dominance to high number of locules was reflected by only the cross P_1 x P_2 with a significant positive value (8.82%) of MPH. the remaining five hybrids showed no dominance. None of studied hybrids showed BPH, indicating no hybrid vigour for this trait, where partial dominance toward the low parent was observed in most crosses (9 ones). Previous result suggested that this trait was under control of additive gene. Relative to heterosis over standard hybrid, six crosses exceeded significantly the standard hybrid "Myla F_1" with values ranged from 19.23 % for both crosses P_1 x P_3 and P_2 x P_4 to 42.31% for the cross P_1 x P_2. Ghobary and Ibrahim (2010), found in a study on tomato, that three and ten crosses showed significant positive heterobeltiosis for fruit shape index and number of locules. Also, Sonagara *et al.* (2020) observed BPH for number of locules/fruit.

For Vit. C content, data in Table 4 clear that six crosses exhibited insignificant values of MPH, indicating no dominance in these crosses. However, eight crosses significantly exceeded the mid – parents with values ranged from 5.23%, for P_1 x P_4 to 20.53%, for P_4 x P_5, suggesting dominance in these crosses for this trait. From eight crosses, P_2 x P_3, P_3 x P_5 and P_1 x P_4 showed heterobeltiosis (over dominance) with values of 10.70, 6.36 and 3.75%, respectively, the rest crosses presented complete dominance (4 ones) and partial dominance (one cross), since, they exhibited insignificant and significant negative BPH% values, respectively. It is obvious that most studied crosses (7 ones) showed complete and over dominance, indicating the importance of non – additive gene for this trait. Heterosis over the check hybrid was found in seven crosses with significant positive values ranged from 7.14 % for P_2 x P_3 to 18.57% for P_1 x P_4. Analogous findings were reported for this trait by Kumari and Manish (2011) and Mahmoud and El-Eslamboly (2014)

Table 4. Percentage of heterosis over mid-parents (M.P.), better parent (B.P.), check hybrid heterosis (C.H.) and dominance type for fruit shape index, no. locules/fruit and Vit. C content traits of indeterminate tomato.

Crosses	Fruit shape index				No. locules/fruit				Vit. C content			
	M.P.H	B.P.H	C.H.H	Dominance type	M.P.H	B.P.H	C.H.H	Dominance type	M.P.H	B.P.H	C.H.H	Dominance type
P_1 xP_2	10.06		-33.09**	No dominance	8.82*	0.00	42.31**	Co. dominance	6.87**	0.00	11.07**	Co. dominance
P_1 x P_3	10.47		-31.65**	No dominance	-8.82*		19.23**	Par. dominance	3.47		1.07	No dominance
P_1 x P_4	17.58**	3.88	-23.02**	Co. dominance	-11.11**		23.08**	Par. dominance	5.23**	3.75*	18.57**	Over dominance
P_1 x P_5	25.00**	-5.23	4.32	Co. dominance	-32.35**		-11.54	Par. dominance	-0.77		-7.50**	No dominance
P_1 xP_6	46.85**	1.45	51.08**	Co. dominance	-17.24**		-7.69	Par. dominance	-8.72**		-12.14**	Par. dominance
P_2 x P_3	6.01		-30.22**	No dominance	3.23		23.08**	No dominance	18.34**	10.70**	7.14**	Over dominance
P_2 x P_4	10.88*	3.88	-23.02**	Co. dominance	-6.06		19.23**	No dominance	7.61**	-0.62	13.57**	Co. dominance
P_2 x P_5	39.92**	11.11**	22.30**	Over dominance	-25.81**		-11.54	Par. dominance	0.00		-13.93**	No dominance
P_2 x P_6	41.41**	1.45	51.08**	Co. dominance	-46.15**		-46.15**	Par. dominance	3.81		-7.50**	No dominance
P_3 xP_4	15.31**	9.71	-18.71**	Co. dominance	0.00		26.92**	No dominance	14.39**	-0.62	13.57**	Co. dominance
P_3 xP_5	46.34**	17.65**	29.50**	Over dominance	-29.03**		-15.38*	Par. dominance	12.30**	6.36*	-10.36**	Over dominance
P_3 x P_6	38.00**	0.00	48.92**	Co. dominance	-7.69		-7.69	No dominance	0.43		-16.79**	No dominance
P_4 x P_5	18.75**	-0.65	9.35*	Co. dominance	-33.33**		-15.38*	Par. dominance	20.53**	0.00	14.29**	Co. dominance
P_4 x P_6	40.00**	4.83	56.12**	Co. dominance	-17.86**		-11.54	Par. dominance	11.31**	-4.69*	8.93**	Par. dominance
P_5 x P_6	30.00**	13.04**	68.35**	Over dominance	-7.69		-7.69	Np dominance	1.14		-20.71**	No dominance
L.S.D.0.05	0.10	0.12			0.27	0.31			0.98	1.13		
0.01	0.14	0.16			0.36	0.41			1.31	1.51		

***,** Significant at 0.05 and 0.01 levels of probability, respectively. Lines: IRS-43-2 (P_1), IR-44-1(P_2), IR-44-2 (P_3), VR-6(P_4), VL-5-4 (P_5) and VL-7-4(P_6)**

Combining ability and genetic components

Analysis of variance for combining ability revealed highly significant mean squares for general GCA and specific SCA combining ability for all characters under study (Table 5), indicating that both additive (σ^2A) and non - additive (σ^2D) gene action played significant role in heredity of all characters. The variance due to specific combining ability (σ^2SCA) was higher than those of general combining ability (σ^2GCA) for plant height, number of leaves plant^{-1}, early yield and number of locules, indicating the predominance of non-additive gene in the inheritance of these traits. This result was confirmed by the ratio of σ^2GCA/ σ^2SCA which was less than 0.50 for the previous traits. The above results were further supported by the ratio of σ^2A / σ^2D which also was less than one, also the ratio of non - additive variance to total genetic variance (σ^2D/ σ^2G) was larger compared to ratio of additive variance to total genetic variance (σ^2A σ^2G). Estimates average degree of dominance for these traits was more than unity, indicating over dominance (non- additive gene action). Finally, these results pointed to utilize heterosis breeding method for improving these traits, where non - additive gene actions play the essential role. Similar trend of findings was reported by Saleem *et al.* (2009), Ghobary and Ibrahim (2010), Kansouh and Zakher (2011), Kansouh (2014b), Aminu and Mala (2015), Khalil and Mahmoud (2019) and Vekariya *et al.* (2019) who reported that non -additive gene action was predominance for heredity of previous traits.

Data in the same Table revealed prevalence of additive gene action in the inheritance of fruit set percentage, total yield plant^{-1}, average fruit weight, fruit shape and Vit. C content. This result is supported by the large variance of GCA compared to SCA (1.46 vs. 1.38; 0.11 vs.0.09; 54.76 vs.52.36; 0.11 vs. 0.06; and 6.37 vs. 3.38, respectively). Also, the ratio of σ^2GCA/ σ^2SCA which was more than one (1.06, 1.22, 1.05, 1.83 and 1.88, respectively). Moreover, σ^2A / σ^2D ratios were more than one (2.12, 2.44, 2.09, 3.67 and 3.77, respectively), the large portion of additive variance from genetic variance

(σ^2A/σ^2G) compared with dominance one (σ^2D/σ^2G) supported the above results. Finally, estimates degree of dominance supported the previous results, which was less than 0.690 for these traits. Generally, since additive gene action was predominance and plays the main role, so these characters could be improved through selecting superior lines among segregating generations of the best combinations to increase the frequency of desirable alleles. These results were confirmed by studies of Garg et al. (2008), Droka et al. (2012), Shende et al. (2012), Kumar et al. (2013), Mahmoud and El Eslamboly (2014), Khalil and Mahmoud (2019), who reported that selection in early generation for previous traits is more effective for developing new lines of tomato.

Table 5. Mean squares and variance components for growth, yield and fruit characteristics of indeterminate tomato.

Characters	Mean squares		Variance components								
	GCA	SCA	σ2gca	σ2sca	σ2gca / σ2sca	σ2A	σ2 D	σ2A / σ2D	σ2A/ σ2g	σ2 D/ σ2g	Degree of Dominance
plant height	972.58**	250.90**	121.17	247.72	0.49	242.34	247.72	0.98	49.50	50.50	1.011
No. leaves	107.05**	34.74**	13.31	34.15	0.39	26.62	34.15	0.78	43.80	56.20	1.133
Fruit set Percentage	11.80**	1.52**	1.46	1.38	1.06	2.92	1.38	2.12	67.93	32.07	0.687
Early yield (kg/plant)	0.25**	0.07**	0.03	0.07	0.43	0.06	0.07	0.86	47.36	52.64	1.080
Total yield (kg/plant)	0.91**	0.10**	0.11	0.09	1.22	0.22	0.09	2.44	70.93	29.07	0.640
Average fruit weight (g)	439.41**	53.72**	54.76	52.36	1.05	109.52	52.36	2.09	67.65	32.35	0.691
Fruit shape	0.89**	0.07**	0.11	0.06	1.83	0.22	0.06	3.67	77.46	22.54	0.522
No. locules/fruit	0.83**	0.22**	0.10	0.22	0.45	0.20	0.22	0.91	48.39	51.61	1.033
Vit. C content	51.10**	3.52**	6.37	3.38	1.88	12.74	3.38	3.77	79.06	20.95	0.515

General combining ability effects (GCA)

The estimates of general combining ability effects of parents presented in Table 6 show that, none of the studied parents was the good combiner for all traits. The good parents exhibited significant positive GCA effects in desired direction for each trait was as follow: P_5 and P_3 for plant height, P_5 and P_6 for number of leaves and fruit shape index, P_4 for fruit set percentage, P_1 for early yield, P_4 and P_1 for total yield, number of locules and Vit. C content and P_3 and P_4 for average fruit weight. The parents showed high GCA effects for any trait could be useful, whereas GCA effects due to additive (fixable) gene action, therefore these parents can be recommended for utilization in hybridization programs for developing new crosses of indeterminate tomato.

Table 6. General and Specific combining ability effects for growth, yield and fruit characteristics of indeterminate tomato.

Characters Genotypes	Plant height	No. leaves/plant	Fruit set (%)	Early yield (kg/plant)	Total yield (kg/plant)	Average fruit weight (g)	Fruit shape index	No. locules/fruit	Vit. c content
					gca effects				
IRS-43-2(P1 (P1)	-3.8**	-0.77**	0.99**	0.24**	0.22**	5.77**	-0.27**	0.34**	1.62**
IR-44-1 (P2)	-16.8**	-5.70**	-0.54**	-0.03	0.04*	-3.21**	-0.20**	0.07**	0.59**
IR-44-2 (P3)	2.2**	0.80**	-0.25*	-0.17**	-0.07**	6.24**	-0.18**	0.13**	-0.86**
VR-6 (P4)	-0.4	-1.58**	1.85**	0.19**	0.52**	6.14**	-0.15**	0.22**	3.84**
VL-5-4 (P5)	17.4**	5.12**	-1.54**	-0.17**	-0.36**	-12.10**	0.21**	-0.22**	-2.63**
VL-7-4 (P6)	1.4*	2.13**	-0.51**	-0.06**	-0.35**	-2.85**	0.59**	-0.53**	-2.56**
					sca effects				
P1 xP2	16.11**	3.09**	0.79**	0.10*	0.03	-5.87**	-0.06*	0.53**	1.58**
P1 x P3	9.81**	-1.71**	-0.49	0.03	-0.26**	-7.82**	-0.06*	-0.14**	0.03
P1 x P4	7.97**	1.17*	-0.09	0.37**	0.26**	-3.62**	0.03	-0.13**	0.23
P1 x P5	2.57*	3.97**	1.99**	0.43**	0.23**	-5.18**	0.05	-0.59**	-0.59*
P1 xP6	6.25**	2.56**	-1.53**	-0.38**	-0.18**	-5.23**	0.32**	-0.18**	-1.97**
P2 x P3	2.07	-1.49*	0.43	-0.29**	-0.08	-7.84**	-0.11**	0.24**	2.76**
P2 x P4	12.93**	-2.40**	0.43	0.05	-0.37**	-7.44**	-0.04	0.05	-0.14
P2 x P5	10.13**	6.20**	-1.78**	-0.19**	-0.19**	-1.11	0.24**	-0.31**	-1.37**
P2 x P6	-1.79	-6.01**	1.09**	0.40**	0.59**	4.64**	0.26**	-0.90**	0.36
P3 xP4	13.63**	6.70**	-0.66*	-0.22**	0.24**	2.81**	0.00	0.19**	1.31**
P3 xP5	0.53	3.50**	-0.37	-0.05	0.22**	-0.96	0.31**	-0.48**	1.08**
P3 x P6	7.61**	5.39**	0.61*	0.23**	0.01	-2.21*	0.20**	0.04	-0.79**
P4 x P5	19.70**	7.59**	2.13**	0.18**	0.53**	2.14*	0.00	-0.56**	3.28**
P4 x P6	-1.23	1.37*	-1.29**	-0.23**	-0.38**	-5.31**	0.27**	-0.15**	1.71**
P5 x P6	7.67**	1.97**	0.99**	-0.07	-0.21**	-4.87**	0.08**	0.39**	-0.12
S.E (gi)	0.58	0.25	0.12	0.02	0.02	0.38	0.01	0.02	0.12
S.E (sij)	1.30	0.56	0.27	0.04	0.04	0.85	0.03	0.05	0.28

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

Specific combining ability effects (SCA)

Specific combining ability effects indicate the superior cross combination which can be used for developing new hybrids with high hybrid vigour for characters. It included non - additive gene effects, additive x dominance and dominance x dominance interaction (non - fixable) which are important in breeding of hybrids.

Estimated SCA effects presented in Table 6 show that, similarly none of the crosses was constantly good for all characters. The combinations exhibited highly significant SCA effects were P_4 x P_5, P_1 x P_2 and P_3 x P_4 for plant height, P_4 x P_5, P_3 x P_4 and P_2 x P_5 for number of leaves plant^{-1}, P_4 x P_5, P_2 x P_6 and P_1 x P_5 for fruit set percentage, P_1 x P_5, P_2 x P_6 and P_1 x P_4 for early yield plant^{-1}, P_2 x P_6, P_4 x P_5 and P_1 x P_4 for total yield plant^{-1}, P_2 x P_6, P_3 x P_4 and P_4 x P_5 for average fruit weight, P_1 x P_6, P_3 x P_5 and P_4 x P_6 for fruit shape index, P_1 x P_2, P_5 x P_6 and P_2 x P_3 for number of locules and P_4 x P_5, P_2 x P_3 and P_4 x P_6 for Vit. C content. The best cross combinations which showed significant positive values of SCA effects for traits under study exhibited most types of GCA effects, viz., high x high, medium x high, high x poor, poor x poor, poor x high and medium x poor, indicating using different breeding method for improving these characters. Generally, in most cross combinations showed high SCA effects involved one or both of good GCA effects for studied traits referring to non - additive gene action in genetic control of these characters and could be exploit in heterosis breeding programs.

CONCLUSION

From the present study, it could be concluded that the parental lines P_4, P_1 and P_5 displayed the highest values for most studied traits based on mean performance and **GCA** effects. However, the cross combinations P_1 x P_4 and P_4 x P_5 were the best for growth, early and total yield and for some fruit traits, followed by the cross P_3 x P_4 for most fruit traits. This superiority was observed in high performance and SCA effects. Therefore, the three crosses can be considered promising for genetic improvement for important traits of indeterminate tomato. The same crosses reflected significant positive heterosis over the check “Myla F_1”. So, it is recommended for commercial cultivation of tomato under greenhouse after evaluation in multi locations and seasons. Non - additive gene action was predominance for the inheritance of plant height, number of leaves plant^{-1}, early yield and number of locules, indicating heterosis breeding for the improvement these traits. However, selection among segregating generations was effectively for improvement of fruit set percentage, total yield plant^{-1}, average fruit weight, fruit shape and Vit. C content.

REFERENCES

Al-Daej, M. I. 2018. Line x tester analysis of heterosis and combining ability in tomato (*Lycopersicon esculentum* Mill). Pakistan J. Biol. Sci. 21 (5) 224-231.

Aminu, D. and K.K. Mala. 2015. Combining ability estimates for tomato (*Solanum lycopersicon* L.) resistance to nematode (*Meloidogyne spp*) in the Sudan Savannah of Nigeria. J. Agri. Econ. Environ. and Social Sci., 1(1): 40-45.

AOAC. 1990. Official Methods of Analysis. Associaion of Official Analytical Chemists, Washington DC. USA, 15th Ed., 123-126.

Droka, D.; K. Raj; J. Subodh and R. K. Yadav. 2012. Genetic studies of quality traits in tomato (*Solanum lycopersicum* L.) under low temperature, Veg. Sci., 39(2): 189-191.

Duncan, D.B. 1958. Multiple Rang and Multiple F Test. Biometrics, 11: 1-42.

East, E.M. and H. K. Hayes. 1912. Heterozygosis in evolution and plant breeding. USDA Bureau of Plant Industry Bulletin, 243: 1-58.

Farzane, A.; N. Hossein; A. Hossein; M. K. Amin and V. Navid. 2012. The estimate of combining ability and heterosis for yield and yield components in tomato (*Lycopersicon esculentum* Mill.). J. Bio. and Environ. Sci., 6(17):129-134.

Garg, N.; S. Devinder Cheema and S. D. Ajmer. 2008. Genetics of yield, quality and shelf life characteristics in tomato under normal and late planting conditions. Euphytica, 159:275–288

Ghobary, H. M. M and K. Y. Ibrahim. 2010. Combining ability and heterosis for some economic traits in tomato (*Lycopersicon esculentum* MILL.). J. Pl. Pro., Mansoura Univ., 1(5): 757 – 768.

Griffing, B. 1956. Concepts of general and specific combining ability in relation to diallel crossing system. Aust. J. Biol. Sci., 9: 463-493.

Islam, M. R.; S. Ahmad and M. M. Rahman. 2012. Heterosis and qualitative attributes in winter tomato (S*olanum lycopersicon* L.) Hybrids. Bangladesh J. Agri. Res., 37(1): 39-48.

Jain, S.K. and E.V.D. Sastry. 2012. Heterosis and combining ability for grain yield and its contributing traits in bread wheat (*Triticum aestivum* L.). Res. & Reviews. 1:17-22.

Kansouh, A. M. 2013. Developing new tomato hybrids at Middle Delta region of Egypt. Egypt. J. Appl. Sci., 28 (11): 744-758.

Kansouh, A. M. 2014a. Association of hybrid performance, heterosis and dominance type in pepper (*Capsicum annuum* L). J. Pl. Prod., Mansoura Univ., 5(8): 1471-1490.

Kansouh, A. M. 2014b. Breeding new local tomato hybrids at West Delta region of Egypt. J. Pl. Prod., Mansoura Univ., 5(8): 1455-1469.

Kansouh, A. M. and A. G. Zakher 2011. Gene action and combining ability in tomato (*Lycopersicon esculentum* Mill.) by line x tester analysis. J. Pl. Prod., Mansoura Univ., 2(2): 213-227.

Khalil, Mona. R. and M. I. Mahmoud. 2019. Genetic analysis and heterosis for some quantitative traits in tomato (*Solanum lycopersicon* L.). Menoufia J. Pl. Prod., 4(8): 287-302.

Kumar R.; K. Srivastava; N. P. Singh; N. K. Vasistha; R. K. Singh and M. K. Singh 2013. Combining ability analysis for yield and quality traits in tomato (*Solanum lycopersicum* L.). J. of Agri. Sci. 5 (2): 213-218.

Kumar, R.; K. Srivastava; J. Somappa; S. Kumar and R.K. Singh. 2012. Heterosis for yield and yield components in tomato (*Lycopersicon esculentum* Mill). Elec. J. Pl. Bre., 3(2): 800-805.

Kumari S. and K. S. Manish. 2011. Exploitation of heterosis for yield and its contributing traits in tomato (*Solanum lycopersicum* L.). Inte. J. of Farm Sci., 1(2): 45-55.

Mahmoud A. M. A. and A. A. S. A. El-Eslamboly. 2014. Genetic analysis to find suitable parents for development of cherry tomato hybrids under greenhouse conditions. Egypt. J. Pl. Bre., 19(1):55 – 70 .

Mahmoud A.M.A. 2015. Genetic analysis to select good combiners for TYLCV-tolerance and yield components in tomato. Annals of Agri. Sci., Moshtohor, 53(2) :221–232

Mahmoud I.M. and M. R. Khalil. 2019. Breeding for developing new indeterminate lines of Tomato (*Solanum lycopersicum* L.) by selection. Menoufia J. Plant Prod., 4 (6): 233 – 245.

Marbhal, S.K.; S.A. Ranpise and M.N. Bhalekar. 2016. Stability analysis in cherry tomato for quantitative traits. Int. Res. J. of Multidisciplinary Studies, 1(2): 1-3.

Radzevicius, A.; P. Viskelis; J. Viskelis; R. Bobinaite; R. Karkleleine and D. Juskeviciene 2013. Tomato fruit quality of different cultivars grown in Lithuania. Int. J. Bio., Veterinary, Agri. and Food Eng. 7 (7).

Rajkumar, G.; V. Premalakshmi; V. Thiruvengadam and P. Irene Vethamoni. 2018. Combining ability analysis of indeterminate tomato F_1 hybrids suitable for polyhouse cultivation. Electronic J. Pl. Bre., 9(3) : 1157–1162.

Rehana S.; M. Z. Ullah; N. Zeba; N. Narzis; A. Husna and A. B. Siddique. 2019. Estimation of heterosis for yield and yield attributing traits in tomato crossed with line and tester method. Progressive Agri., 30 (2): 179-185.

Sahu, M.; K.K. Sahu; A. Tirkey; D. Upadayay and N. Mehta. 2016. Heterosis and inbreeding depression for agro-morphological characters in tomato, *Lycopersicon esculentum* Mill. Inte. J. Farm Sci., 6(2): 51-64.

Saleem, M. Y.; M. Asghar; M. A. Haq; T. Rafique; A. Kamran and A. Khan. 2009. Genetic analysis to identify suitable parents for hybrid seed production in tomato (*Lycopersicon esculentum* Mill.). Pak. J. Bot., 41(3): 1107-1116.

Shalaby, T. A. 2012. Line × tester analysis for combining ability and heterosis in tomato under late summer season condition. J. Pl. Pro., Mansoura Univ., 3 (11): 2857

Shankar, A.; R.V.S.K. Reddy; M. Sujatha and M. Pratap. 2013. Combining ability and gene action studies for yield and yield contributing traits in tomato (*Solanum lycopersicum* L.). Helix., *6:* 431 – 435.

Shende, V.D.; T. Seth; S. Mukherjee and A. Chattopadhyay. 2012. Breeding tomato (*Solanum lycopersicum* L.) for higher productivity and better processing qualities. Sabrao J. Bre. Gen., 44 (2): 302-321.

Solieman, T.H.I.; M.A.H. El-Gabry and A.I. Abido. 2013. Heterosis, potence ratio and correlation of some important characters in tomato (*Solanum lycopersicum L.*). Sci. Hort., 150: 25–30.

Sonagara, M. K.; J. N. Patel; R. R. Acharya and D. D. Sharma. 2020. Exploitation of heterobeltiosis in tomato (*Solanum lycopersicum* L.). Int. J. Curr. Microbiol. App. Sci., 9(4): 674-685.

Vekariya, T.A.; G. U. Kulkarni; D. M. Vekaria; A. P. Dedaniya and J. T. Memon. 2019. Combining ability analysis for yield and its components in tomato (*Solanum lycopersicum* L.). Acta Scientific Agri., 3(7): 185-191.

سلوك الأداء وقوه الهجين والقدرة على التالف لصفات النمو والمحصول وجودة الثمار في الطماطم غير المحدودة

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استخدمت ستة سلالات من الطماطم غير المحدودة في نظام التهجين الدوري في اتجاه واحد لدراسة سلوك الأداء وقوه الهجين بالإضافة إلى القدرة على التالف لصفات النمو، والمحصول، وجوده الثمار. أجريت التجربة بالمزرعة البحثية بكلية العلوم الزراعية –جامعه العريش خلال موسمي 2019/2018 و2020/2019 م. تم تقييم الآباء والخمسة عشر هجين جيل أول والهجين التجاري "مايلا F_1 " تحت الصوبات البلاستيكية باستخدام تصميم القطاعات كاملة العشوائية في ثلاث مكررات. أظهرت النتائج وجود اختلافات عالية المعنوية بين جميع التراكيب الوراثية المستخدمة لجميع الصفات المدروسة، وكانت أفضل الآباء هي: أي أرأس-43-2, في أر-6, في إلـ -5-4 فى حين كانت أفضل الهجن أي أر أس 43-2 x في أر -6، أي أر-44-2 x في أر-6 و في أر-6 x في ال5-4 لمعظم الصفات تحت الدراسة. ظهرت قوه الهجين فى معظم الصفات المدروسة، كما وجدت قوه هجين معنوية على أساس الهجين التجاري فى كل الصفات، وكانت أفضل الهجن في أر-6 x في إل 5-4 بالنسبة لصفات النمو، وأي أر أس 43-2 x في أر -6 للمحصول المبكر/النبات، وفيتامين سى، و أي أر أس 43-2 x في أر-6 للمحصول الكلى/النبات، و أى ار44-2 x في أر -6 لمتوسط وزن الثمرة. أظهرت تباينات القدرة على التالف والمكونات الوراثية سيادة وأهميه الفعل الجيني المضيف فى توريث صفات نسبه العقد، والمحصول الكلى/نبات، ومتوسط وزن الثمرة، وشكل الثمرة ، ومحتوى الثمار من فيتامين سى. بينما كان الفعل الجيني الغير مضيف هو الأهم فى توريث صفات ارتفاع النبات، وعدد الأوراق/نبات، والمحصول المبكر/نبات، وعدد المساكن. كانت أفضل الآباء للقدرة على التالف في إلـ -5-4 لصفات النمو، وأي أر أس 43-2 ، و في أر-6 للمحصول المبكر/نبات، والمحصول الكلى/نبات، وعدد المساكن و فيتامين سى، فى حين كانت أفضل الهجن التي أظهرت قيم موجبه معنوية هي في أر-6 x في إل-5-4 لصفات النمو وفيتامين سى، وأي أر اس43-2 x في إلـ 5-4 للمحصول المبكر/نبات، وأي أر 44-1 x في إلـ 7-4 للمحصول الكلى/نبات و متوسط وزن الثمرة. لذا تم اختيار أفضل ثلاث هجن (أي أر اس43-x2 في أر -6؛ أي أر -44-2 x في أر-6؛ و في أر -6 x في إل 5-4) لاستخدامها كهجن محليه للطماطم الغير محدودة بعد تقييمها واختبارها في عده مواقع ومواسم.