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ESTIMATING HETEROSIS AND COMBINING ABILITY FOR *IN VIVO* AND *IN VITRO*, TRAITS USING DAILLEL CROSS ON *TOMATO (SOLANUM LYCOPERSICUM.)*

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Abstract: *Combining ability and heterosis studies were performed for in vivo and in vitro traits in a diallel cross involving seven tomato breeding lines. Mean squares of genotypes, parents and resuled twenty one hybrid combinations were found to be highly significant for all in vivo and in vitro studied traits. Mean square estimates of parent vs. crosses were found to be highly significant for all studied traits except plant heigh, early yield, callus induction and callus fresh weight. Both general (GCA) and specific combining ability (SCA) variances were found to be highly significant for all in vivo and in vitro studied traits. The GCA/SCA ratios were found to be less than unity for number of cluster per plant, earliness of flower, callus induction, callus fresh weight and callus dry weight. The line (P3) was considered to be good general combiner for all traits except fruit weigh, early yield, T.S.S and callus induction. The correlation coefficient was positive and highly significant between in vitro and in vivo characters. Information generated from this study can be useful for selecting parents and hybrids to maximize the yield and its components in tomato.*

Key words: *Tomato (Solanum lycopersicum.), diallel cross, heterosis, combining ability, in vivo and in vitro traits.*

INTRODUCTION

Tomato (*Solanum lycopersicum*.) is one of the most important vegetable crops in the world. It is considered as the second vegetable crop in the world after potato (Bhatia *et al.,* 2004 and Foolad, 2004). It belongs to family Solanaceae (2n=2x=24). The species originated in the South American Andes and it is used as a food originated in Mexico, and spread throughout the world following the Spanish colonization of the Americas. Tomato is a rich source of vitamin A, C and minerals like Ca, P and Fe (Dhaliwal *et al.,* 2003).

Diallel crosses have been widely used in genetic research to investigate the inheritance of important traits among a set of genotypes. These were devised, specifically, to investigate the combining ability of the parental lines for the purpose of identification the superior parents for use in tomato hybrid breeding programs. Analysis of diallel data is usually conducted according to the methods of Griffing (1956) which partition the total variation of diallel data into GCA of the parents and SCA of the crosses (Yan and Hunt, 2002).

Various breeding techniques have been advocated considering the breeding behaviour of crop species. Out of these hybrids breeding is prominent and used in the improvement of vegetable crops. Heterosis in tomato was the first observetion by Hedrick and Booth (1968) for higher yield and number of fruits per plant. Choudhary *et al.* (1965) emphasized the extensive utilization of heterosis to step up tomato production. Heterosis manifestation in tomato is in the form of the greater vigour, faster growth and development, earliness in maturity, increased productivity (Yordanov, 1983). So a speedy improvement can be brought about by exploiting heterosis for various yield contributing traits as well as earliness.

Biotechnology offers several valuable techniques such as cell, anther and tissue culture which develop the breeding methods to improve the genetic characters including drought tolerance in the economical crops. Tissue culture generates a wide range of genetic variation in plant species, which can be incorporated in plant breeding programs. By *in vitro* selection, mutants with useful agronomic traits, i.e., salt or drought tolerance or disease resistance can be isolated in a short duration. However, the successful use of somaclonal variation is very much dependent on its genetic stability in the subsequent generations (Mercado *et al*., 2000, El-Aref, 2002). To achieve remarkable gains in the biotechnology of tomato using embryo culture, combining abilities for *in vitro* and *in vivo* traits are necessary.

The main objectives of the present study were to (1) Evaluate the general performance of the parental lines and their hybrids, (2) Estimate GCA and SCA effects as well as heterosis for some *in vivo* and *in vitro* traits, (3) Determine the relationship between *in vivo* and *in vitro* studied traits and (4) Identify the best lines which can be used in tomato breeding programs.

MATERIALS AND METHODS

Field Experiments

This study was carried out in three seasons during the years of 2011, 2012 and 2013 at private farm, Ashmoun, Minoufiya, Egypt. Seven imported tomato genotypes (Fruhe lieba, Budai torpe, Imune, Chrestensen edeirot, Kanadische zwergtomate (Mendel), IC 6504 p1, and Fakel) were grown to obtain their true-selfed seeds and crossed to establish the experimental materials for this investigation. These materials were provided from Australian Tropical Grains Germplasm Collection and Center for Genetic Resources the Netherlands (CGN) by Dr. khaled. F. salem, Genetic Engineering and Biotechnology Research Institute GEBRI, (Table 1).

In the first season the flowers were selfed to give true selfed seeds. At the suitable ripening stage tomato fruits were harvested and extracted their seeds by hand maceration, washed, cleaned and air dried to be used in crossing programme to dveloped the required genetic material. By the end season new seeds were obtained for seven selfed parental cultivar. The second season hybridiztion and selfing among the seven parental were carried out, in a diallel cross system in one direction at the proper stage of flower-bud development to obtain enough seeds of all possible combinations (21 hybrids)and new enough seeds of the seven selfed-parental lines. The third season the seven parents and twenty one F_1 hybrids (7+21=28) were evaluated under open field conditions. In the three experimental seasons the seeds were sown in January and the seedlings were transplanted in March. The experiment was arranged in a randomized complete blocks design (RCBD), with three replicates. The experimental plot consisted of three rows, five meters long with one meter wide and 50 cm within row. Data were recorded on an individual plant basis for the parents and their F1 crosses. At maturity, five guarded plants were selected at random for subsequent measurements as following: Plant height (cm), number of all branches per plant, number of cluster per plant, fruit weigh (gm), total soluble solids (T.S.S), number of fruits per plant, early yield and total yield per plant (kg).

Tissue culture experiments

This experiment carried out in tissue culture lab, Genetic Engineering and Biotechnology Research Institute (GEBRI), Sadat City University, Sadat City, Egypt.

Surface sterilization

Seeds of tomato lines were washed with continuously running tap water for 15 min. Under laminar flow cabinet, seeds were disinfected with 20% of Clorex (Sodium hypochlorite 5.25%) for 15 min. and then rinsed three times with sterile distilled water. After surface sterilization, the seeds were inoculated on MS Murashige & Skoog (1962) medium and incubated at 25°C.

Table (1): Details of the seven tomato genotypes.

Accession name	Mark	Accession number	Origin	Growth habit
Fruhe lieba	**P1**	CGN14436 37	Germany	Indeterminate
Budai torpe	**P2**	09 H56 01704	Hungary	Determinate
Imune	**P3**	09 H56 01325	Italy	Indeterminate
Chrestensen edeirot	**P4**	09 H56 01711	Germany(DDR)	Determinate
Kanadische zwergtomate	**P5**	09 H56 01316	Canada	Determinate
IC 6504 p1	**P6**	312201	Australia	Determinate
Fakel	**P7**	09 H56 01728	SUN	Indeterminate

Media preparation and callus induction

One media protocol with 3 replications for each genotype was used in this study. The basal medium contained the inorganic salts of Murashige and Skoog (1962) supplemented with 1.5 mg/L 2,4-D, 30 g/L sucrose and 7 g/L agar to study the callogenic response in tomato explant. The cultures were incubated at 28 ± 2 ºC under 16 h light and 8 h dark. The callus induction was measured as the percentage of seeds that produced callus according to Lee *et al*. (2009). Data were recorded for the following callus characteristics according to (Hunt, 1978):

Callus formation percentage was recorded as: $= \frac{\text{Number of callused seeds}}{\text{Total Number of cultured seeds}}$ x 100

Also, Callus fresh weight (CFW) and callus dry weight (CDW) (gm) were recorded.

Statistical analysis

Better-parent heterosis (BPH) for each trait of individual cross was expressed as the percentage increase of F_1 performance above the better-parent (BP) performance. Heterosis over the better-parent % was estimated as follows:

BPH % = $\frac{F1 - BP}{BP} \times 100$

Where: $F_{1\,=}$ mean value of the first generation and BP = mean value of the better-parent.

General (GCA) and specific combining ability (SCA) analysis were computed according to Griffing (1956) designated as Method 2, Model 1.

Simple phenotypic correlation coefficients between *in vivo* and *in vitro* traits were calculated according to (Zar, 1999).

RESULTS AND DISCUSSION

The genotypes mean performances for all studied traits are presented in Table 2.

For Plant height trait, the parent P7 revealed the highest mean value (155) followed by the parents P3 (143) sinse they have indeterminate. On the contarary, **P4** recorded the lowest mean value (26). For hybrids, the highest mean value for plant height was obtained with P1 x P3 (166.67). The presented results about number of branches and clusters per plant reflected that the parent P3 has the highest mean values (21.67 and 34.67) for the two traits respectively. The cross P1 x P6 gave the highest mean values with 50 clusters and 21.67 branches per plant which did not significantly differ about 22.00 for P3 x P4. In the case of fruit weight**,** the parent P6 recorded the highest mean value (91.17gm). The hybrids P4 x P6 and P5 x P6 recorded

the highest mean values without significant differences (70.00 and 69.00) respectively. For number of fruits per plant, among parents, P3 scored the highest mean value (72.00), while P4 scored the lowest mean value (11.67). For hybrids, the cross P1 x P3 gave the highest mean value (92.00). In the case of early yield, the parent P1 showed the highest mean value (0.67kg), while the lowest mean value was (0.05 kg) for P2. The cross P5 x P6 gave the highest mean value (0.56kg) followed by P4 x P6 which gave (0.55kg). Regarding Total yield, the parent P5 recorded the highest mean value (2.03kg), while the parent P4 recorded the lowest mean value (0.55kg). Among hybrids, P1 x P6 recorded the highest mean value (3.17kg) without significantly difference from P1 x P2 that recorded (3.16kg). Meanwhile, P2 x P6 recorded the lowest mean value (1.51). With regard to total soluble solid (T.S.S), the parent P7 showed the highest mean value (5.70), while the lowest mean value (3.70) was for P3. Meanwhile, the cross P2 x P4 gave the highest mean value (5.93), While P5 x P7 recorded the lowest mean value (3.67).

For callus induction, callus fresh weight and dry weight, among parents, P1 scored the highest mean value for callus induction (85), callus fresh weight (2.92) and callus dry weight (0.33) meanwhile the lowest mean value for callus induction (45), callus fresh weight (0.23) and callus dry weight (0.05) scored by P6. On the other hand, the cross P3 x P4 recorded the highest means value for callus induction (86.67), callus fresh weight (2.84) and callus dry weight (0.77). Whereas, the lowest mean value was revealed by the cross P4 x P7 for callus induction (4.33), callus fresh weight (0.67) and callus dry weight (0.01).

1. Heterosis

Useful heterosis, expressed as the percentage deviations of the 21 F_1 hybrids mean performance over their respective better–parents (desirable) for each studied traits *in vivo* and *in vitro* are presented in Table (3). In general, the obtained results clearly indicat that a particular hybrid was not able to show heterosis effects for all studied traits. The heterosis effects were observed in all studied traits but the degree of heterosis showed variations from trait to trait. High positive values of heterosis would be of interest in most traits under investigation except for earliness of flowering sinse the negative values would be useful for the tomato breeder's point of view.

Table (2): Mean performances for *in vivo* and *in vitro* traits of parental genotypes.

	In vivo								In vitro		
Parents	Plant height	No. of all branches per plant	No. of clusters / plant	Fruit weight	No. of fruits per plant	Early yield	Total yield	T.S.S	Callus induction %	Callus fresh weight	Callus dry weight
P1	121.67	19.00	20.00	42.33	46.67	0.67	1.98	5.07	85.00	2.92	0.33
P2	74.00	11.33	16.33	55.33	29.67	0.05	1.64	4.97	48.33	0.62	0.07
P3	143.33	21.67	34.67	26.83	72.00	0.26	1.93	3.70	70.00	1.81	0.11
P4	26.00	9.33	13.33	47.00	11.67	0.39	0.55	4.10	66.67	0.79	0.07
P5	50.00	12.00	20.67	50.33	40.33	0.15	2.03	3.97	76.67	1.18	0.05
P6	36.33	10.00	23.00	91.17	14.00	0.38	1.28	3.80	45.00	0.23	0.04
P7	155.00	18.33	30.33	38.33	31.67	0.13	1.22	5.70	83.33	2.37	0.18
L.S.D.at 0.05	14.14	3.60	5.14	1.60	5.33	0.39	0.37	0.24	19.67	0.60	0.19

Table (2): Continues, Mean performances for *in vivo* and *in vitro* traits of crosses genotype .

	In vivo								In vitro		
Crosess	Plant height	No. of branches per plant	No. of clusters per plant	Fruit weight	No. of fruits per plant	Early yield	Total yield	T.S.S	Callus induction %	Callus fresh weight	Callus dry weight
P1 x P2	92.67	17.33	35.00	51.00	62.00	0.35	3.16	4.07	53.33	0.76	0.07
P3	166.67	20.67	36.33	31.17	92.00	0.39	2.87	4.90	53.33	0.88	0.04
P4	93.33	16.00	20.33	40.00	46.67	0.48	1.87	4.73	60.00	0.87	0.05
P5	116.00	17.00	33.00	50.33	48.33	0.23	2.43	5.87	40.00	1.55	0.39
P6	135.00	21.67	50.00	61.33	51.67	0.14	3.17	4.53	53.33	1.72	0.08
P7	131.67	16.67	35.33	39.67	47.00	0.41	1.87	5.00	66.67	2.74	0.23
P2 x P3	105.00	17.67	48.00	41.50	60.00	0.20	2.49	3.83	66.67	2.23	0.26
P4	96.67	16.33	23.33	56.67	37.33	0.26	2.12	5.93	66.67	0.77	0.04
P5	99.00	15.67	23.67	61.73	29.33	0.22	1.81	5.67	60.00	2.11	0.20
P6	81.67	14.33	20.67	68.67	22.00	0.41	1.51	5.03	73.33	2.31	0.24
P7	120.00	17.33	30.67	39.67	45.00	0.33	1.79	4.57	66.67	1.30	0.31
P3 x P4	141.67	22.00	39.33	39.67	55.67	0.42	2.21	4.87	86.67	2.84	0.77
P5	93.33	17.67	28.00	39.00	67.33	0.26	2.63	4.97	46.67	2.32	0.17
P6	114.67	18.67	31.67	51.33	44.33	0.24	2.28	4.03	73.33	1.81	0.19
P7	95.00	17.33	27.33	42.33	52.00	0.20	2.21	4.00	73.33	1.20	0.10
P4 x P5	60.67	10.00	22.33	50.67	37.33	0.43	1.90	4.30	56.67	1.13	0.05
P6	34.33	10.00	25.67	70.00	32.33	0.55	2.27	4.07	80.00	1.15	0.12
P7	71.67	12.67	24.00	51.17	38.00	0.52	1.68	3.90	4.33	0.67	0.01
P5 x P6	28.00	9.00	19.00	69.00	31.67	0.56	2.18	3.97	60.00	1.66	0.27
P7	70.67	10.67	35.67	65.67	38.33	0.16	2.52	3.67	66.67	1.22	0.03
P6 x p7	41.00	10.00	16.50	65.17	32.00	0.33	2.09	4.03	60.00	0.37	0.03
L.S.D. at 0.05	21.52	2.08	6.43	2.80	2.86	0.01	0.37	0.19	27.15	0.79	0.17

Table 3

For plant height, three hybrids showed significant positive desirable heterosis, which ranged from 21.33% for the hybrid P4 x P5 to 33.78% for the hybrid P2 x P5.

Regarding number of branches per plant, four hybrids exhibited high and positive heterosis over better parents which ranged from 14.05% to 44.13% for the hybrids of P1 x P6 and P2 x P4 respectively. For number of cluster per plant, eleven hybrids showed significant desirable heterosis which ranged from 8.04% to 117.39% for the hybrids of P4 x P5 and P1 x P6, respectively. Concerning fruit weigh, four hybrids showed significant positive desirable heterosis which ranged from 8.87% to 30.47% for the hybrids of P4 x P7 and P5 x P7, respectively. The hybrid P4 x P6 gave the highest level of heterosis percentage for number of fruits per plant 130.93% and for total yield 77.34%. As for early yield, seven hybrid combinations had significant positive desirable, which ranged from 6.67% to 153.85% for the hybrids P5 x P7 and P2 x P7, respectively. With regard to total soluble solids (T.S.S), eight crosses showed significant desirable heterosis which ranged from 1.20% to 25.18% for the hybrids P2 x P6 and P3 x P5, respectively. On the other hand, the hybrid P2 x P5 showed relatively distinguishable level for earliness of flowering, number of branches/plant, plant height and early yield .

For callus induction, the hybrid P2 x P6 only exhibited highly significant positive heterotic effects with 51.73%. For callus fresh weight, eight crosses showed significantly desirable heterosis which ranged from 0.18% to 272.58% for P3 x P6 and P2 x P6, respectively. Concerning callus dry weight, ten crosses showed significantly desirable heterosis which ranged from 21.88% to 327.78% for the hybrid P1 x P5 and P2 x P7, respectively. Similar results were obtained by Devi *et al.,* (1994), Kurian *et al.,* (2001)**,** Joshi and Thakur (2003), Rai *et al.* (2003), Premalakshme *et al.* (2006), Abdel-Hady (2006), Etedali *et al.*,(2012), Chattopadhyay *et al.,* (2012) and Yadav *et al.,* (2014). For most studied traits.

2- Combining ability

Both general (GCA) and specific (SCA) combining ability variances were found to be highly significant for all in vivo and in vitro studied traits. The GCA/SCA ratios for number of cluster per plant, earliness of flowering, callus induction, callus fresh weight and callus dry weight traits were less than unity,which indicated that the non-additive gene actions had a greater importance in the inheritance of in vivo and in vitro traits. For number of branches per plant, plant height, fruit weigh, T.S.S, early yield, total yield and number of fruits per plant the GCA/SCA was found more than unity, which indicating that additive gene action had a greater importance in the inheritance of this traits. For in vivo traits, similar results were obtained by Dhaliwal *et al.,* (2004), Duhan *et al.,* (2005), Abdel-Hady (2006), Premalakshme *et al.,* (2006), Hannan *et al.,* (2007), Saleem *et al.,* (2009), and Singh *et al.,* (2010).

2. a. General combining ability (GCA)

Estimates of the GCA effects of the parental line in each trait are presented in Table 4. High positive GCA effects would be of interest in most traits under investigation except for earliness of flowering and plant height as the negative values would be useful for the tomato breeder's.

Significant positive GCA effects were found for all other studied traits. Based on GCA estimates, it could be concluded that the best combiners for plant height,were P1, P3 and P7; for number of branches and clusters per plant, were P2, P3 and P4; for fruit weigh, were P2, P5 and P6; for number of fruits per plant were P1 and P3; for early yield were P1, P4 and P6; for total yield, were P1, P3 and P5; with regard to total soluble solid (T.S.S) were P1 and P2 which registered significant highest positive GCA effects. Proving to be good combiners for these traits. Generally, the parental tomatoes lines P3 was considered to be good general combiner for most *in vivo* studied characters for improving tomato breeding program. The results are in accordance with Dhaliwal *et al.,* (2004), Duhan *et al.,* (2005), Mirshamsi *et al.,* (2006), Premalakshme *et al.,* (2006), Hannan *et al.,* (2007), Saleem *et al.,* (2009), Sekhar *et al.,* (2010), Singh *et al.,* (2010) and Kumar *et al.,* (2013). In re-

spect of *in vitro* traits, significant positive GCA effects were found for all studied traits. Based on GCA estimates, it could be concluded that the best combiners for callus induction was only P4, for callus fresh weight were P1, P3 and P5, for callus dry weight were P1, P2, P3 and P4 showed a significant positive GCA effects. Generally, the parental tomato line P1, P3 and P4 were considered to be good general combiner for most *in vitro* studied characters for improving tomato breeding programs. The results are in accordance for *in vitro* traits with those of Kurian *et al.,* (2001), Abdel-Hady *et al.,* (2004). Abdel-Hady (2006) and Etedali *et al.,* (2012).

Table (4): Estimates of general combining ability effects of tomato genotypes for *in vivo* and *in vitro* traits.

Parents	Plant height	No. of branches per plant	No. of cluster per plant	Earliness of flower	Fruit weigh	No. of fruits per plant
P1	79.08**	-0.10	-4.89**	2.11**	-17.47**	31.16**
P2	0.52	3.02**	6.22**	3.33**	6.44**	-10.84**
P3	87.19**	6.35**	8.89**	-2.67**	-37.31**	55.94**
P4	-63.70**	3.24**	4.44**	0.22	-2.81**	-25.62**
P5	-57.92**	-3.98**	-9.22**	-0.11	8.83**	-4.84**
P6	-78.03**	-7.65**	-5.44**	-1.44**	52.41**	-35.17**
P7	32.86**	-0.87	0.00	-1.44**	-10.09**	-10.62**
L.S.D. at 0.05	8.09	0.99	2.43	0.63	1.00	2.09

*and ** significant at the $P < 0.05$ and the $P < 0.01$ levels of probability, respectively.

Table (4): cont.

Parents	Early yield(kg)	Total yield(kg)	T.S.S	Callus induction %	Callus fresh weight(gm)	Callus dry weight (gm)
P1	0.24**	0.95**	0.96**	1.11	0.43*	0.07*
P2	-0.25**	-0.11	0.89**	0.01	-0.38*	0.07*
P3	-0.12**	0.69**	-0.78**	-6.67	1.01**	0.10**
P4	0.28**	-1.11**	-0.12**	14.44**	-0.95**	0.09**
P5	-0.15**	0.35**	0.01	-8.89	0.16	-0.19**
P6	0.13**	-0.14	-1.03**	-4.44	-0.80**	-0.05
P7	-0.13**	-0.63*	0.07	4.44	0.52**	-0.09*
L.S.D. at 0.05	0.07	0.14	0.08	9.89	0.33	0.06

*and ** significant at the $P < 0.05$ and the $P < 0.01$ levels of probability, respectively

2. b. Specific combining ability (SCA)

Specific combining ability effects for F_1 the new genetic combinations in each trait are presented in Table 5. For plant height, twelve hybrids showed significant positive SCA effect. The three hybrid combinations, P2 x P4, P2 x P5 and P4 x P5 showed significant positive useful heterosis Table 3, these crosses could be of practical importance in a breeding program. As for number of branches per plant, eight hybrid combinations were exhibited highly significant positive SCA effects. Six of eight hybrids P1 X P3, P1 x P4, P1 x P5, P1 x P6, P3 x P4 and P3 x P5 showed significant positive useful heterosis (Table 3). As for number of clusters per plant, eight hybrids P1 x P3, P1 x P5, P1 x P6, P1 x P7, P2 x P3, P3 x P4, P3 x P6 and P5 x P7 showed highly significant positive SCA effects and useful heterosis except the hybrid P3 x P6. Moreover the three tomato genotype P2, P3 and P4 proved to be good combiners for number of cluster per plant. For fruit weight, nine studied hybrids combinations exhibited highly significant desirable SCA effects. Also four of twelve hybrids P2 x P4, P3 x P7, P4 x P7 and P5 x P7 showed a significant positive useful heterosis (Table 3). Seven of twelve hybrids showed significant positive useful heterosis (Table 3). For number of fruits per plant, eleven hybrid combinations exhibited highly significant desirable SCA effects, the seven hybrids P1 x P2, P1 x P3, P1 x P6, P2 x P4, P2 x P7, P4 x P6 and P4 x P7 exhibited highly significant positive useful heterosis (Table 3). Concerning early yield, five studied hybrids combinations exhibited highly significant desirable SCA effects and useful heterosis except the hybrid P2 x P6. With regard to total yield, eleven studied hybrids combinations exhibited highly significant desirable SCA effects and useful heterosis. With regard to total soluble solid (T.S.S), nine of twenty one crosses showed highly significant desirable SCA effects. As for callus induction percentage, five crosses exhibited significant desirable SCA effects. Also, one of these superior crosses exhibited useful heterosis Table 3. For callus fresh weight, nine crosses showed significant desirable SCA effects, while seven of these nine superior crosses exhibited useful heterosis (Table 3). Concerning callus dry weight, four of twenty one hybrid combinations studied showed significant positive SCA effects and exhibited useful heterosis (Table 3). These hybrid combinations could be of practical importance in a breeding program.

In general, the hybrid P3 x P4 could be considered as the most superior cross in its SCA effects for all *in vivo* and *in vitro* traits under study, indicating that these genetic materials could be useful in tomato breeding programs. This finding was also found by Kurian et al., (2001), Prata *et al.,* (2003), Dhaliwal *et al.,* (2004), Duhan *et al.,* (2005), Abdel-Hady (2006), Mirshamsi *et al.,* (2006), Premalakshme *et al.,* (2006), Hannan *et al.,* (2007), Ahmad *et al.,* (2009), Saleem *et al.,* (2009), Sekhar *et al.,* (2010), Singh *et al.,* (2010), Etedali *et al* (2012) and Kumar *et al* (2013).

3. Correlation between *in vitro* and *in vivo* characters.

Phenotypic correlations estimates between *in vitro* and *in vivo* traits are presented in Table (6). The obtained data reveal that, phenotypic correlation was positive and highly significant between *in vitro* and *in vivo* characters. These indicate that the tissue culture technique might be valuable for predicting the combining ability. Our results are in agreement with those obtained by El-Shouny *et al* (1999), Abdel-Hady *et al.* (2004) and Abdel-Hady (2006)

In conclusion, this study indicated that the *in vitro* traits are very effective for prediction of heterosis. Results recorded in this study may be contributed to the development of an effective method to select components for heterosis and combining ability of quantitative traits in tomato breeding program.

Table 5

Table (6): Correlation coefficients between *in vivo* traits and *in vitro* traits.

	Plant height	No. of branches per plant	No. of cluster per plant	Earli-ness of flower	Fruit Weigh (gm)	No. of fruits per plant
Callus induction	0.180	0.215	0.062	0.131	-0.152	-0.022
Callus fresh weight	0.534**	0.544**	0.376*	0.018	-0.358**	0.233
Callus dry weight	0.320*	0.304*	0.188	0.023	-0.224*	0.066

Table (6): Cont.

	Early yield	Total yield	T.S.S	Callus induction	Callus dry weight	Callus fresh weight
Callus induction	-0.224	-0.158	0.010	1		
Callus fresh weight	-0.250	0.084	0.339	0.564**	1	
Callus dry weight	-0.016	-0.005	0.277*	0.253	0.495**	1

*and ** significant at the $P < 0.05$ and the $P < 0.01$ levels of probability, respectively.

REFERENCES

Abdel-Hady, M. S. (2006). Heterosis and combining ability effects for callus growth of wheat (*Triticum durum*, Desf.) *in vitro.* J. Appi. Sci. Res. 2 (6): 360-363.

Abdel-Hady, M. S., A. A. Abdel-sattar and I. M. Mahmoud. (2004). Prediction of heterosis and combining ability in maize using tissue culture. Bull. N.R.C. (Cairo). 29 (1): 109-119.

Ahmad, S., A.K.M. Quamruzzaman and M. U. Nazim (2009). Combining ability estimates of tomato (Solanum lycopersicum) in late summer. SAARC J. Agri. 7(1): 43-56

Bhatia, P., N. Ashwath, T. Senaratna and D. Midmore (2004). Tissue culture studies of tomato (Lycopersicon esculentum). Plant Cell Tissue Organ Culture, 78:121 Cancer, 122 (10): 2330-6

Chattopadhyay, A. and A. Paul (2012). Studies on heterosis for different fruit quality parameters in tomato.International Journal of Agriculture Environment Biotechnology 5(4): 405-410.

Choudhary, B., R. S. Punia and H. S. Sangha (1965). Manifestation of hybrid vigour in F1 and its correlation in F2 generation of tomato (Lycopersiconesculentum Mill).Indian Journal of Horticulture 22: 52-59.

Devi, H., R. S. Rattan and M. C. Thakur (1994). Heterosis in tomato.The Horticulture Journal7 (2): 125-132.

Dhaliwal, M. S., S. Singh, D. S. Cheema and P. Singh (2004). Genetic analysis for important fruit characters of tomato by involving lines possessing male sterility genes. Acta Hort., 637, 123-131.

Dhaliwal, M.S., S. Singh and D.S. Cheema (2003). Line x tester analysis for yield and processing attributes in tomato. J. Res., 40(1): 49-5

Duhan, D., P. S. Partap, M. K. Rana and M. S. Dahiya (2005). Heterosis study for quality characters in a line x tester set of tomato. Haryana J. Hort. Sci., 34, 371-375.

El-Aref, H. M. (2002). *In vitro* selection of salt-tolerant tomato plants and the changes in gene expression under salinity stress. Assiut J. Agric. Sci. 33 (1): 23-46.

El-Shouny, K.A., A. A. Mohamed and S.M. Abdel-Rahman (1999). Prediction of heterosis and combining ability in maize

through tissue culture techniques. Annal. Agric. Sci. (Cairo) 44: 537-548.

Etedali, F. and A. Khandan (2012). Determination of hybrid vigor and inheritance for Regeneration in rapeseed (Brassica napus), International journal of Agronomy and Plant Production. Vol., 3 (4), 145-153

Foolad, M. R. (2004). Recent advances in genetics of salt tolerance in tomato. Plant Cell, Tissue Organ Cult. 76: 101-119.

Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel sytem. Aust. J. Biol. Sci., 9, 463-493.

Hannan, M.M., M.B. Ahmed, U.K. Roy, M.A. Razvy, A. Haydar, M.A. Rahman, M.A. Islam and R. Islam (2007). Heterosis, Combining Ability and Genetics for Brix%, Days to First Fruit Ripening and Yield in Tomato (Lycopersicon esculentum Mill.). Middle-East Journal of Scientific Research 2 (3-4): 128-131

Hedrick, U.P. and N.O. Booth (1968). Mendelian characters in tomato.Proceedings of American Society Horticulture Science 5: 19-24

Hunt, R. (1978). Plant growth analysis. Edward Arnold Ltd, London. pp 67.

Joshi, A. and M.C. Thakur (2003). Exploitation of heterosis for yield and yield contributing traits in tomato (Lycopersicon esculentum Mill.). Progressive Horticulture 35: 64-68.

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.). Journal of Agricultural Science; Vol. 5, No. 2; 2013

Kurian, A., K. V. Peter and S. Rajan (2001). heterosis for yield components and fruit character in tomato. Journal of Tropical Agriculture 39 : 5-8

Lee, K.W., G.J. Choi, K.Y. Kim, H.C. Ji, H.S. Park, S.H. Yoon and S.H. Lee (2009). High frequency plant regeneration from mature seed derived callus of Italian ryegrass (*Lolium multiflorum*) cultivars. Afr J Biotech 8:6828–6833.

Mercado, J. A., C. Sancho, B. Jimenez, U. Peran, A. Pliego and M. Quesada (2000). Assessment of *in vitro* growth of apical stem sections and adventitious organogenesis to evaluate salinity tolerance in cultivated tomato. Plant Cell Tiss. and Org. Culture 62: 101-106.

Mirshamsi, K. A., M. Farsi, F. Shahriari and H. Nemati (2006). Estimation of heterosis and combining ability for yield components and earliness in seven tomato lines using diallel crossing method. Agricultural Sciences and Technology Journal, Vol. 20 (3): 1-12.

Murashige, T. and F. Skoog (1962). A revised medium for rapid growth and bioassays with tobacco tissue cultures. Physiol. Plant 15: 473-497.

Pratta, G., R. Zorzoli and L. A. Picardi (2003). Diallel analysis of production trait among domestic, exotic and mutant germplasm of lycopersicon. Genet. and Mol. Res. 2:206-213.

Premalakshme, V., T. Thangaraj, D. Veeraragavathatham and T. Arulllugam (2005). Heterosis and combining ability in tomato (Solanum Lycopersicum L.) Veg. Sci. 32(1):47-50.

Premalakshme, V., T. Thangaraj, D. Veeraranathatham and T. Arumagam (2006). Heterosis and combining Ability analysis in tomato (Solanum lycopersicom Mill.). Wettsd. For yield and yield contributing traits. Vegetable Science, 33(1), 5-9.

Rai Mathura, A. K. Singh, R. S. Pan and V. S. R. Krishna Prasad (2003). Combining ability of quality and yield and tomato (Lycopersicon esculentum Mill.). Veg. Sci. 30(101:21-24.

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

Sekhar, L., B.G. Prakash, P.M. Salimath, P. Channayya, O. H. Sridevi and A. A. Patil (2010). Implication of heterosis and combinig ability among productive Single cross Hybrids in tomato. Elec. J. Plant Breeding, 1(4):706-711

Singh, S. P., M. C. Thakur and N. K. Pathania (2010). Reciprocal cross differences and combining ability studies for some quantitative traits in tomato (Lycopersicon esculentum Mill.) under mid hill con-

ditions of Western Himalayas. Asian Journal of Horticulture, 5(1), 172-176.

Yadav, R. K., V.B.S. Chauhan, RajKumar and T. K. Behera (2014). Studies on Heterosis for yield and its Attributing Traits in Tomato (Solanumlycopersicum L.) International Journal of Agriculture, Environment & Biotechnology. Citation: IJAEB: 7(1): 95-100

Yan, W. and L. A. Hunt (2002). Biplot analysis of diallel data. Crop Sci. 42: 21–30.

Yordanov, M. (1983). Heterosis in tomato.Theoretical and Applied Genetics 6: 189- 219.

Yordanov, M. (1983). Heterosis in tomato.*Theoretical and Applied Genetics* **6**: 189- 219.

Zar, J.H.C. (1999). Biostatistical analysis, 4th edition. Prenice-Hall, Inc., New Jersy, USA

تقدير قوة الهجين والقدرة على الائتلاف لبعض الصفات الحقلية والمعملية بإستخدام التهجينات التبادلية على الطماطم

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الملخص العربى

أجرى هذا البحث بحقل خاص بمركز أشمون منوفية– مصر خلال الأعوام **٢٠١١، ٢٠١٢، ٢٠١٣** وقد استخدم لتنفيذ هذا البحث سبع سلالات من الطماطم هي Fruhe lieba, Budai torpe, Imune, Chrestensen edeirot, Kanadische zwergtomate(Mendel), IC 6504 p1, and Fakel أجرى التهجين التبادلي بينهما (ماعدا العكسى) فى الموسم **٢٠١٢** ولقد تم تقييم الأباء والهجن فى موسم **٢٠١٣** وتم تحليل البيانات باستخدام طريقة جرفنج للأباء والهجن (١٩٥٦) الطريقة الثانية الموديل الأول ولقد اجرى هذا البحث بهدف:

تقييم الاداء والمواصفات للآباء والهجن تحت الظروف البيئية المحلية .

(١) تقدير القدرة العامة والخاصة على الائتلاف وقوة الهجين لبعض الصفات الحقلية والمعملية.

(٢) دراسة العلاقة بين الصفات الحقلية والمعملية تحت الدراسة.

(٣) تحديد أفضل السلالات والتي يمكن استخدامها في برنامج تربية الطماطم.

وكانت الصفات تحت الدراسة هى (طول النبات، عدد الأفرع على النبات، عدد العناقيد الزهرية على النبات، ميعاد تفتح أول زهرة ،متوسط وزن الثمرة، المواد الصلبة الكلية ،الوزن الطازج و الجاف للكالس،النسبة المئوية لتكوين الكالس، وفيما يلى ملخص لأهم النتائج المتحصل عليها:

١- كانت قيم التباين الراجعة الى التراكيب الوراثية (والأباء والهجن) عالية المعنوية لجميع الصفات الحقلية والمعملية تحت الدراسة.

٢- كانت قيم التباين الراجعة الى قوة الهجين عالية المعنوية لجميع الصفات تحت الدراسة ما عدا صفات طول النبات والمحصول المبكر و نسبة تكوين الكالس و الوزن الطازج للكالس.

٣- ولقد تم الحصول على قوة هجين عالية المعنوية ومرغوبة بالنسبة لكل الصفات وقد وجد ان جميع الاصناف تحت الدراسة قد اشتركت فى تكوين هجن متفوقة.

٤- كانت قيم التباين الوراثى الراجع لكل من القدرة العامة والخاصة على الائتلاف عالي المعنوية لجميع الصفات تحت الدراسة.

٥- اظهرت النسبة بين تباينى القدرة العامة والقدرة الخاصة على الائتلاف تأثير اكبر للقدرة العامة على الائتلاف لبعض الصفات تحت الدراسة مثل أرتفاع النبات، وزن الثمرة، عدد الثمار على النبات، المواد الصلبة الكلية.

٦- كانت السلالة Imune (P3) افضل الاباء لمعظم الصفات الحقلية و المعملية مثل عدد العناقيد الزهرية على النبات، عدد الافرع على النبات ، عدد الثمار على النبات ، المحصول المبكر، المحصول الكلى للنبات، المواد الصلبة الكلية، الوزن الطازج للكالس،الوزن الجاف للكالس.

٧- أظهرت الدراسة وجود ارتباط موجب عالي المعنوية بين بعض الصفات الحقلية والمعملية تحت الدراسة .

٨- توضح هذه الدراسة أهمية استخدام الصفات المعملية فى التنبؤ بقوة الهجين لإنتاج هجن او إنتاج سلالات طماطم جديدة فى برامج التربية لصفة المحصول ومكوناته وتوفير للوقت والنفقات لاختيار الآباء الداخلة فى التهجين.

Table (3): Percentage of heterosis of the 21 F1 hybrids over their better-parents for each trait.

Crosess	Plant height	No. of branches per plant	No. of clusters per plant	Fruit weight	No. of fruits per plant	Early yield	Total yield	T.S.S	Callus induction %	Callus fresh weight	Callus dry weight
P1 x P2	-23.84*	-8.77**	75.00**	-7.83**	32.85**	-47.26**	59.60**	-19.72**	-37.25**	-67.39**	-77.08**
P3	16.28	-4.63**	4.80	-26.37**	27.78**	-41.79**	44.95**	-3.35**	-37.25**	-62.21**	-87.50**
P4	-23.29*	-15.79**	1.65	-14.89**	0.00	-28.36**	-5.56**	-6.71**	-29.41*	-62.50**	-84.38**
P5	-4.66	-10.53**	59.65**	0.00	3.56	-65.67**	19.70**	15.77**	-52.94**	-33.05**	21.88**
P6	10.96	14.05**	117.39**	-32.73**	10.71**	-79.10**	60.10**	-10.65**	-37.25**	-25.86**	-76.04**
P7	-15.05	-12.26**	16.50**	-6.29**	0.71	-38.81**	-5.56**	-12.28**	-21.57	-7.86**	-29.17**
P2 x P3	-26.74*	-18.47**	38.45**	-25.00**	-16.67**	-23.08**	29.02**	-22.94**	-4.76	23.39**	136.36**
P4	30.63**	44.13**	42.87**	2.42	25.83**	-33.33**	29.27**	19.31**	0.01	-2.53**	-47.62**
P5	33.78**	30.58**	14.50**	11.57**	-27.27**	46.67**	-10.83**	14.08**	-21.74	79.10**	185.71**
P6	10.36	26.47**	-10.14**	-24.68**	-25.83**	7.89	-9.76**	1.20**	51.73**	272.58**	242.86**
P7	-22.58*	-5.46**	1.12	-28.31**	42.09**	153.85**	9.15**	-19.82**	-20.00	-51.31**	327.78**
P3 x P4	-1.16	1.52	13.44**	-15.60**	-22.69**	7.69	14.51**	18.78**	4.76	56.72**	184.85**
P5	-34.88**	-18.46**	-19.24**	-22.51**	-6.48*	0.00	29.56**	25.18**	-39.13**	27.99**	51.52**
P6	-20.00	-13.84**	-8.66**	-43.69**	-38.43**	-36.84**	18.13**	6.05**	23.81	0.18**	72.73**
P7	-38.71**	-20.03**	-21.16**	10.44**	-27.78**	-23.08**	14.51**	-29.82**	-12.00	-59.71**	-42.59**
P4 x P5	21.33*	-16.67**	8.04**	0.67	-7.44**	10.26*	-6.40**	4.88**	-26.09*	-3.13**	-23.81**
P6	-5.50	0.01	11.61**	-23.22**	130.95**	44.74**	77.34**	-0.73**	19.99	45.15**	45.83**
P7	-53.76**	-30.88**	-20.87**	8.87**	20.03**	33.33**	37.70**	-31.58**	-94.80**	-77.55**	-92.98**
P5 x P6	-44.00**	-25.00**	-17.39**	-24.11**	-21.48**	47.37**	7.39**	0.00	-21.74	40.68**	446.67**
P7	-54.41**	-41.79**	17.60**	30.47**	-4.95**	6.67*	24.14**	-35.67**	-20.00	-59.03**	-81.48**
P6 x P7	-73.55**	-45.44**	-45.60**	-28.52**	1.05	-13.16**	63.28**	-29.29**	-28.00*	-87.65**	-81.48**
L.S.D. at 0.05	20.18	2.52	5.96	2.50	5.21	0.19	0.36	0.19	24.78	0.73	0.17
L.S.D. at 0.01	26.89	3.36	7.94	3.33	6.94	0.25	0.47	0.25	33.02	0.97	0.23

*and ** significant at the $P < 0.05$ and the $P < 0.01$ levels of probability, respectively

Table (5): Estimates of the specific combining ability effects for *in vivo* and *in vitro traits.*

crosess	Plant height (cm)	No. of branches per plant	No. of clusters per plant	Earliness of flowering (day)	Fruit weight (gm)	No. of fruits per plant	Early yield (kg)	Total yield (kg)	T.S.S	Callus induction %	Callus fresh weight (gm)	Callus dry weight (gm)
P1 x P2	-79.64**	-3.47*	5.89	-2.69**	10.07**	35.36**	0.09	2.45**	-3.29**	-19.58	-2.28**	-0.48**
P3	55.69**	9.64**	14.33**	-8.69**	-5.69**	58.58**	0.06	0.79**	0.89**	-40.69**	-3.31**	-0.44**
P4	-13.42	2.86**	-20.00**	-0.58	-13.69**	4.14	-0.05	-0.40*	-0.28*	2.64	-1.15**	-0.22*
P5	48.81**	9.53**	14.22**	-3.25**	5.68**	-11.64**	-0.38**	-0.19**	3.00**	-61.81**	-0.43	0.64**
P6	125.92**	16.75**	59.78**	7.08**	-4.91**	28.69**	-0.94**	2.53**	0.04	-30.69*	1.02**	-0.24
P7	5.03	0.97	20.67**	-10.92**	-7.41**	-9.86**	0.15	-0.89**	0.34**	12.64	2.98**	0.04
P2 x P3	-50.75**	-2.69*	46.67**	7.08**	1.40	4.58	-0.01	0.71**	-2.24**	5.97	1.56**	0.15
P4	75.14**	0.53	-13.67**	-1.81*	12.40**	18.14**	-0.22*	1.39**	3.39**	29.31*	-0.64	-0.33**
P5	76.36**	2.19	-16.44**	-1.47	15.97**	-26.64**	0.08	-1.00**	2.47**	4.86	2.05**	0.01
P6	44.47**	-8.58**	-30.89**	2.86**	-6.82**	-18.31**	0.36**	-1.41**	1.60**	28.19*	3.60**	0.18
P7	48.58**	-0.36	4.00	-0.14	-31.32**	26.14**	0.39**	-0.07	-0.90**	19.31	-0.52	1.60**
P3 x P4	123.47**	20.64**	38.78**	-4.81**	5.14**	6.36*	0.13	0.88**	1.87**	36.97**	4.17**	0.65**
P5	-27.31*	11.31**	1.00	7.53**	-8.49**	20.58**	0.08	0.66**	2.05**	-56.25**	1.27**	0.04
P6	56.81**	7.53**	6.56*	2.86**	-15.08**	-18.08**	-0.25*	0.10	0.30**	54.86**	0.72	0.17
P7	-113.08**	2.75**	-1.56	-0.14	20.42**	-19.64**	-0.14	0.39	-0.92**	18.19	-2.22**	-0.26**
P4 x P5	25.58*	-4.47**	-2.33	-10.36**	-7.99**	12.14**	0.18	0.27	-0.62**	-2.92	-0.09	-0.11
P6	-33.31**	-11.25**	2.22	-3.03**	6.42**	27.47**	0.26*	1.88**	-0.29**	58.19**	0.91*	0.14
P7	-32.19**	-4.03**	2.11	-12.03**	12.42**	19.92**	0.44**	0.60**	-1.89**	-178.47**	-3.63**	-0.38**
P5 x P6	-58.08**	-10.58**	-21.56**	0.31	-8.21**	4.69	0.73**	0.16	-0.71**	-6.25	1.11**	0.45**
P7	-40.97**	-6.36**	33.33**	3.31**	44.29**	0.14	-0.21*	1.65**	-2.71**	17.08	-1.31**	-0.44**
P6 x p7	-109.86**	-15.14**	-30.11**	4.64**	-0.80	11.47**	0.03	0.86**	-0.57**	-11.81	-2.90**	-0.38**
L.S.D. at 0.05	22.19	2.72	6.68	1.73	2.75	5.73	0.20	0.39	0.21	27.11	0.80	0.19
L.S.D. at 0.01	29.61	3.62	8.91	2.31	3.66	7.64	0.27	0.52	0.28	36.18	1.07	0.25

*and ** significant at the $P < 0.05$ and the $P < 0.01$ levels of probability, respectively