

**STUDY OF GENOTYPE - ENVIRONMENT INTERACTION IN  
TOMATO TRIPLE TEST CROSS 3. GENETIC  
COMPONENTS AND PREDICTION OF  
RECOMBINANT INBRED LINES**

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**ABSTRACT :** The two  $F_1$ 's; of the two tomato crosses Money Maker x Castle Rock (MMxCR) and Carmeuco 200 x Peto 86 ( $C_{200}$  x Peto); and their parents were crossed with a group of 11 cultivars for each of the two crosses , to get 11 families for  $L_{11}$ ,  $L_{21}$  and  $L_{31}$  sets of triple test crosses. The produced 33 families for each cross were tested under three micro-environments (30, 45 and 60 cm, plant spacing).

Highly significant mean squares (M.S) for additive, dominance and epistasis and their interactions with the micro- environments were detected for final plant height, branch number, average early fruit weight, early fruit number, early yield, average fruit weight of total yield, total fruit number and total yield/plant; except those of the interactions additive, dominance and epistasis x environment for were fruit weight (in early yield) insignificant. Also, M.S. values for  $i$  type and  $i$  type x environments were highly significant, except those for early fruit weight and number in the two crosses, early yield in cross 2 and total fruit number and total yield in the two crosses. For  $j+1$  type and  $j+1$  type x environments, the M.S. values were all highly significant, except that for early fruit number in cross 1. The estimated values of D and H components (tested by  $\chi^2$ ) were found homogenous in the three environments in the two crosses, except those for H in cross 1 and D in cross 2 of plant height, D in cross 2 of average early fruit weight and early yield in the two crosses, H in cross 2 of average fruit weight in total yield, D and H in cross 1 of total fruit number and total yield, and D of total fruit number and H of total yield in cross 2. Estimates of  $\sqrt{H/D}$  reflected mostly partial dominance at all environments in the two crosses in the studied traits, but some few cases showed complete or overdominance. Results of the prediction indicated the presence of promising portions of elite pure breeding lines that could be extracted from the advanced generations of selfing the  $F_1$ 's in the two crosses, except for total yield in cross 2.

**Key wards:** Genotype - environment interaction (GxE), triple test cross (TTC), additive, dominance, epistasis ,recombinant.

## INTRODUCTION

Tomato (*Lycopersicon-esculentum* Mill.) is considered one of the most important vegetable crops in Egypt. For improving the yield and yield attributes, inbred families are often produced and evaluated as possible varieties or as parents of hybrids. The structure of genetic variability among inbred families at different generations of selfing depends on the way genes act and varies according to the trait selected. The knowledge of the relative proportions of genetic components of variance is necessary for choosing the effective breeding scheme.

The triple test cross method (TTC), which is an extension of the North Carolina Design-3 (NCD III) of Comstock and Robinson (1952), described by Kearsey and Jinks (1968), to detect and estimate additive, dominance and epistatic components of the genetic variation has been modified in various ways to make the method applicable to more complex types of materials and to obtain more informations about the material under investigation (Jinks et al., 1969; Perkins and Jinks, 1970; Perkins and Jinks, 1971; Ketata et al., 1976; Jinks and Virk, 1977; Chahal and Jinks, 1978; Katiyar and Ahmad, 1996; Tefera and Peat, 1997; Singh et al., 1997).

The modified design and analysis suggested by Perkins and Jinks (1971) and Jinks and Virk (1977) provides information about the interaction between environments and additive, dominance and epistatic effects of genes at the micro-and macro-environmental levels.

Previous works on tomato detected the additive, dominance and epistatic effects for number of branches, final plant height, fruit number / plant, fruit weight / fruit and yield / plant. Additive and dominance gene effects were almost equally sensitive to macro-and micro-environments. The j+l type epistasis was more sensitive to the environments than the i type epistasis (Singh and Singh, 1984). Moreover, genotype-environment interaction (GxE) of tomato was also detected by Poysa et al. (1986), Berry et al. (1988), Danne et al. (1991) and Ismail (1997).

Present work was undertaken to determine the relative sensitivity of different kinds of gene effects to different micro-environments (Plant spacings) for some metrical traits in two tomato triple test crosses. Predicting the range of inbred lines and the proportion of inbreds, expected to fall outside parental range, were also considered.

## MATERIALS AND METHODS

The present study was carried out at the Experimental Farm at El-Khattara, Faculty of Agriculture, Zagazig University on the two tomato crosses Money Maker (MM)xCastle Rock (CR) as cross 1, and Carneuco 200 ( $C_{200}$ ) x Peto 86 (Peto) as cross 2. The  $P_1$ ,  $P_2$  and  $F_1$  of each cross were crossed with 11 cultivars (Schedule 1), to get three family sets ( $L_{1i}$ ,  $L_{2i}$  and  $L_{3i}$ ; 11 family each); as the modified triple test cross mating system suggested by Perkins and Jinks (1971), and Jinks and Virk (1977).

The resultant 66 families were evaluated under three micro-environments (30, 45 and 60 cm, plant spacings), in split-plots in a randomized complete block design, with three replicates. The main-plots were devoted for plant spacings and the sub-plots were for the triple test cross families, in each cross.

This study was carried out during the seasons of 1997/998 to the summer season of 2001. Seeds of the four parental cultivars were sown on Oct. 28, 1997 in speedling trays and the raised seedlings were transplanted on Dec. 21, 1997 under a plastic house to produce

seeds of  $F_1$ 's for cross 1 (MM x CR) and cross 2 ( $C_{200}$ xPeto). Parents,  $F_1$ 's and the 11 Ni-cultivars seeds, for each cross, were sown on July 7, 1998, transplanted on Aug. 10, 1998 in 30 cm pots and kept under a lath house during summer season. At flowering, crosses started on Sept. 5, 1998 between each Ni-cultivars with  $P_1$ ,  $P_2$  and  $F_1$  of each cross to produce seeds of  $L_{1i}$ ,  $L_{2i}$  and  $L_{3i}$  families for each cross, respectively. Crosses continued until Jan. 25, 2001 to compensate the shortage of some genotypes seeds in TTC sets.

For the evaluation trail, seeds of the 11 TTC families in  $L_{1i}$ ,  $L_{2i}$  and  $L_{3i}$  sets for each cross (33 genotypes) were sown on Mar. 3, 2001 in a lath box for each genotype and the raised seedlings were distributed and transplanted in the field according to split-plot design with three replicates, on Apr. 18, 2001 at El-Kattara Farm. The sub-plot area was  $4.5m^2$  (3m long x 1.5m wide) with uncultured space (1.5m) between each two adjacent sub-plots. Fertigation and other cultural practices were done as recommended for commercial tomato production in sandy soil farms.

Schedule 1. Appriviation and source of the tomato Ni-cultivars.

Ni - cultivars		Appriv.	Source
Name	Group		
Super Marmande	1 and 2	SM	Daehnfeldt, Holland
Strain-B	1 and 2	SB	Sun Seeds, Parma, Idaho, USA
Carmeuco 201	1 and 2	C <sub>201</sub>	Inter. Agric., Res., Argentina
Aledo VF	1 and 2	Aledo	Clause, France
Sun Drop	1 and 2	SD	Bruinsma, Holland
Super Strain-B	1 and 2	SSB	Sun Seeds, Parma, Idaho, USA
Pearson Improved	1 and 2	PI	Noord Scharwoude, Holland
Beef Stick	1 and 2	BS	American Seed, USA
Carmeuco 200	1	C <sub>200</sub>	Inter. Agric., Res., Argentina
Peto 86	1	Peto	Peto Seed, USA
UC 97-3	1	UC	Peto seed, USA
Money Maker	2	MM	Yates, New Zealand Ltd.
Castle Rock	2	CR	Castle Seed, USA
Rutgers Select	2	RS	American Seed, USA

Observations were taken on four plants from each sub-plot at the end of the season to measure plant height and branch number/plant. Early yield traits; i.e., average early fruit weight, early fruits number/plant and early yield/ plant. The first three pickings were considered as early yield, starting from 72-85 days after transplanting. Total yield traits ;i.e., average fruit weight, fruits number/plant and total yield / plant were determined by the end of the harvesting season.

The obtained data were subjected to the analysis of

variance according to Cochran and Cox (1957), following the used experimental design .

Triple test cross (TTC) analysis for crosses 1 and 2 under 30, 45 and 60cm (env. 1, 2 and 3, respectively) was carried out separately, according to Kearsey and Jinks (1968), to detect additive, dominance and epistatic components of the variation. The analysis suggested by Perkins and Jinks (1971) and Jinks and Virk (1977) was followed to get informations about the interactions between environments and each of additive, dominance and epistatic effects

of genes at the micro-environmental levels. Before proceeding to the biometrical analysis, the analysis of variance for  $L_1$ ,  $L_2$  and  $L_3$  as well as  $L_1$  and  $L_2$  types of families were carried out separately to obtain the error variance for testing epistasis, additive and dominance gene effects.

#### **Biometrical Analysis :**

##### **1. Detecting additive genetic variance from North Carolina design III (NCD-3)**

The variance component of sums ( $L_{1i} + L_{2i}$ ) and its interaction with environments was employed to detect the additive genetic component according to Comstock and Robinson (1952).

##### **2. Detecting additive genetic variance from Triple test cross system (TTC)**

The variance component of sums ( $L_{1i} + L_{2i} + L_{3i}$ , additive) and additive x environment interaction were detected and estimated, according to Kearsey and Jinks (1968) and Perkins and Jinks (1971), respectively.

##### **3. Detecting dominance genetic variation**

The variance component of difference ( $L_{1i} - L_{2i}$ ) was used to test the presence of dominance variance.

#### **4. Testing of epistasis**

The variance component of epistasis ( $L_{1i} + L_{2i} - 2L_{3i}$ ) and epistasis x environment interaction of families of each cross was used for detecting and estimating the overall epistatic component of variation. Both the overall epistasis and its interaction with the environments were corresponding to 10 and 20 degrees of freedom, respectively, which could be further partitioned into two items; namely,  $i$  type (with 1 degree of freedom for both  $i$  epistasis and  $i$  epistasis x environment interaction) which detected the presence of additive x additive; and the item  $j+1$  (with 9 degrees of freedom for  $j+1$  epistasis and 19 degrees of freedom for  $j+1$  epistasis x environment interaction) which detected the presence of additive x dominance + dominance x dominance, respectively. The later item ( $j+1$ ) is the difference between the overall epistasis and  $i$  type of epistasis.

#### **5. Estimates of additive, dominance and genetic ratios under different environments**

The genetic components of variation can be estimated under the different environments, to show the effects of these environments on the estimates of

these measurements. The expected mean squares (EMS) for additive (sums) and dominance (differences) components of variation according to Perkins and Jinks (1971).

Estimation of Fr value, the covariance between sums and differences, has the expectation of :  $\text{cov}(L_{1i} + L_{2i} + L_{3i}) / (L_{1i} - L_{2i}) = -1/8 \text{ Fr}$ . Where Fr means the association dispersion of dominant alleles in the parental lines, having a minimum value of 1, if all dominant genes are associated in  $P_1$  and minimum value of -1, if all dominant genes are associated in  $P_2$ .

Correlation coefficient of sums and differences (r, sums/differ.) was used to compute the correlation coefficient between  $(L_{1i} + L_{2i} + L_{3i})$  and  $(L_{1i} - L_{2i})$  under different environments in this study.

#### 6. Predicting the properties of recombinant lines

The proportion of inbreds superior to its  $F_1$  or outperform parental range (m), is equal to the probability integral, corresponding to the value of  $[d] / D$ ; whilst, the range of inbreds is given by  $m \pm 2D$  (Jinks and Perkins 1972; Jinks and Pooni, 1976).

## RESULTS

Results of the present study for the detection of additive, dominance and epistasis genetic components of variation, and their predictions are presented under the following topics.

### 1. Detection of additive, dominance and epistasis

#### 1.1 Plant growth traits

Results in Table 1 showed highly significant mean squares for sums (additive; NCDIII and TTC) and their interactions with environment were detected for plant height and branch number. The differences (dominance) and their interactions with the environments gave also highly significant M.S. values. Moreover, the additive effects resulted from both the estimating methods were much higher than the dominance effects. The interaction of additive x environment and of dominance x environment were less than that for the main additive and dominance effects.

The results in Table 1, showed also highly significant mean squares for epistasis (overall) and its two types (i and j+1), and for their interactions with environment. Moreover, i type (additive x additive) and i type x environment gave higher M.S. values than the corresponding

Table 1. Mean squares (M.S) of the variance components, additive NCDIII ( $\bar{L}_{1i} + \bar{L}_{2i}$ ), additive TTC ( $\bar{L}_{1i} + \bar{L}_{2i} + \bar{L}_{3i}$ ), dominance ( $\bar{L}_{1i} - \bar{L}_{2i}$ ) and epistasis ( $\bar{L}_{1i} + \bar{L}_{2i} - 2\bar{L}_{3i}$ ), and their interaction with environments of the two triple test crosses sets for some plant growth traits

Items	d.f.	Cross 1 : (MM <sup>1</sup> x CR <sup>2</sup> )		Cross 2 : (C <sub>200</sub> <sup>3</sup> x Peto <sup>4</sup> )	
		Plant height (cm)	Branch No./plant	Plant height (cm)	Branch No./plant
$(\bar{L}_{1i} + \bar{L}_{2i})$					
Additive (NCDIII)	10	600.034**	205.347**	193.758**	180.659**
Add. NCDIII x Env.	20	58.060**	68.064**	12.782**	28.668**
$(\bar{L}_{1i} + \bar{L}_{2i} + \bar{L}_{3i})$					
Additive (TTC)	10	1019.926**	267.052**	434.837**	196.610**
Add. TTC x Env.	20	126.036**	94.359**	96.039**	55.389**
$(\bar{L}_{1i} - \bar{L}_{2i})$					
Dominance	10	265.806**	226.514**	134.078**	44.380**
Dominance x Env.	20	62.217**	52.016**	17.102**	37.800**
$(\bar{L}_{1i} + \bar{L}_{2i} - 2\bar{L}_{3i})$					
Overall epistasis	10	293.977**	352.891**	456.958**	271.727**
i type epistasis	1	733.366**	507.919**	1276.067**	616.216**
j+l type epistasis	9	245.156**	335.919**	365.946**	233.450**
Overall epi. x Env.	20	198.369**	124.617**	97.826**	59.386**
i type epi. x Env.	1	623.854**	441.462**	1156.476**	582.788**
j+l type epi. x Env.	19	175.975**	107.941**	42.107**	31.838**
Pooled error	196	3.520	8.107	3.393	6.838

\*\* ; Highly significant at 1% level of probability.

1: Money Maker cv. , 2: Castle Rock cv , 3: Carmeuco 200 cv, and 4: Peto 86.

values for j+l (additive x dominance + dominance x dominance), respectively in the two crosses.

## 1.2 Early yield and its components

Data in Table 2 illustrated

the presence of highly significant effects for, sums by both estimates, and for differences were detected on fruit weight and early yield in the two crosses; except those for fruit number in cross 1. On the other hand, the M.S. values of

Table 2. Mean squares (M.S) of the of variance components, additive NCDIII ( $\bar{L}_{1i} + \bar{L}_{2i}$ ), additive TTC ( $\bar{L}_{1i} + \bar{L}_{2i} + \bar{L}_{3i}$ ), dominance ( $\bar{L}_{1i} - \bar{L}_{2i}$ ) and epistasis ( $\bar{L}_{1i} + \bar{L}_{2i} - 2\bar{L}_{3i}$ ) and their interaction with environments of the two triple test crosses sets for early yield traits

Items	d.f.	Cross 1: (MM <sup>1</sup> x CR <sup>2</sup> )			Cross 2: (C <sub>200</sub> <sup>3</sup> x Peto <sup>4</sup> )		
		Avg. fruit weight (gm)	Fruit No. / plant	Early yield /plant (gm)	Avg. fruit weight (gm)	Fruit No. / plant	Early yield / plant (gm)
$(\bar{L}_{1i} + \bar{L}_{2i})$							
Additive (NCDIII)	10	539.646**	0.677 <sup>NS</sup>	9943.737**	698.367**	8.543**	60260.777**
Add. NCDIII x Env.	20	106.856 <sup>NS</sup>	1.143 <sup>NS</sup>	9108.928**	64.312 <sup>NS</sup>	1.085 <sup>NS</sup>	10312.741**
$(\bar{L}_{1i} + \bar{L}_{2i} + \bar{L}_{3i})$							
Additive (TTC)	10	812.006**	1.480 <sup>NS</sup>	14927.745**	1461.043**	20.337**	129992.688**
Add. TTC x Env.	20	186.619 <sup>NS</sup>	2.837 <sup>NS</sup>	18976.748**	114.437 <sup>NS</sup>	2.532 <sup>NS</sup>	26265.975**
$(\bar{L}_{1i} - \bar{L}_{2i})$							
Dominance	10	612.680**	1.844 <sup>NS</sup>	6913.699**	2187.125**	18.671**	96454.058**
Dominance x Env.	20	135.819 <sup>NS</sup>	1.982 <sup>NS</sup>	4261.653**	86.959 <sup>NS</sup>	0.929 <sup>NS</sup>	8421.650**
$(\bar{L}_{1i} + \bar{L}_{2i} - 2\bar{L}_{3i})$							
Overall epistasis	10	528.856**	14.835**	133965.215**	1526.051**	15.406**	108859.588**
i type epistasis	1	254.352 <sup>NS</sup>	0.979 <sup>NS</sup>	4707.614*	94.102 <sup>NS</sup>	0.255 <sup>NS</sup>	927.298 <sup>NS</sup>
j +1 type epistasis	9	559.356**	16.375**	148327.171**	1685.156**	15.381**	120852.065**
Overall epi. x Env.	20	639.501**	3.063 <sup>NS</sup>	58235.892**	285.042**	4.819 <sup>NS</sup>	28207.841**
i type epi. x Env.	1	749.744 <sup>NS</sup>	0.425 <sup>NS</sup>	3019.503*	163.584 <sup>NS</sup>	0.096 <sup>NS</sup>	1353.504 <sup>NS</sup>
j+1 type epi. x Env.	19	633.962	3.042 <sup>NS</sup>	2906.126**	263.013**	5.068 <sup>NS</sup>	29621.227**
Pooled error	196	195.346	4.493	717.502	78.783	3.472	559.052

NS, \*,\*\*, Insignificant, significant and highly significant at 5% and 1% levels of probability, respectively.

1: Money Maker cv., 2: Castle Rock cv., 3: Carneuco 200 cv, and 4: Peto 86.



the interaction effects of additive x environment and dominance x environment on fruit weight and fruit number were insignificant in the two crosses. The results illustrated also that highly significant additive, dominance and their interactions mean squares, for early yield, were detected. Moreover, the main effects of the two components of variance were found higher than their corresponding interactions with the environments.

Concerning epistasis (Table 2), the overall epistasis and its interaction x environment gave highly significant, except that of epistasis x environment for fruit number in the two crosses. The  $j+l$  type was found significant, but  $i$  type was insignificant for early yield and its components. The  $j+l$  type of spistasis x environment was also significant for fruit weight and early yield; but was not so for fruit number, in the two crosses. On the other hand,  $i$  type x environment was insignificant for all early yield traits; except that for early yield, in cross 1 only.

### 1.3 Yield and its components

Results in Table 3 revealed that mean squares values by both estimates for sums and es-

timate for differences and their interactions with the environments appeared highly significant for yield and its components in the two crosses. However, the main effects of additive and dominance were higher than those for the interactions of the two components with the environment.

The results of the detected epistasis (Table 3), show that overall epistasis and epistasis x environment mean squares were highly significant for all yield traits in the two crosses. Of the two interaction components,  $j+l$  type and  $j+l$  x environment mean squares were also highly significant for all yield traits in the two crosses. But,  $i$  type showed insignificant M.S. values for total yield / plant, in both crosses, and for fruit number /plant, in cross 2. Insignificant values also detected for  $i$  type x environment for total yield / plant in cross 1 and for all traits in cross 2.

## 2.Components of Genetic Variation

### 2.1 Plant growth traits

The results in Table 4 indicate that the estimates of D and H for plant height and branch number in the two crosses were relatively different at the different environments. Testing the

Table 3. Mean squares (M.S) of the of variance components, additive NCDIII ( $\bar{L}_{1i} + \bar{L}_{2i}$ ), additive TTC ( $\bar{L}_{1i} + \bar{L}_{2i} + \bar{L}_{3i}$ ), dominance ( $\bar{L}_{1i} - \bar{L}_{2i}$ ) and epistasis ( $\bar{L}_{1i} + \bar{L}_{2i} - 2\bar{L}_{3i}$ ) and their interaction with environments of the two triple test crosses sets for yield traits

Items	d.f.	Cross 1 : (MM <sup>1</sup> x CR <sup>2</sup> )			Cross 2 : (C <sub>200</sub> <sup>3</sup> x Peto <sup>4</sup> )		
		Avg. fruit weight (gm)	Fruit No. / plant	Yield /plant (gm)	Avg. fruit weight (gm)	Fruit No. / plant	Yield / plant (gm)
$(\bar{L}_{1i} + \bar{L}_{2i})$							
Additive (NCDIII)	10	1167.667**	365.836**	681071.260**	1031.934**	366.326**	1684200.493**
Add. NCDIII x Env.	20	51.867**	67.981**	228842.080**	31.379**	16.379**	138793.951**
$(\bar{L}_{1i} + \bar{L}_{2i} + \bar{L}_{3i})$							
Additive (TTC)	10	1708.444**	554.108**	991720.867**	1963.341**	991.925**	3591805.900**
Add. TTC x Env.	20	105.741**	117.711**	484911.547**	84.689**	173.899**	180458.651**
$(\bar{L}_{1i} - \bar{L}_{2i})$							
Dominance	10	885.833**	222.604**	1163537.150**	1458.194**	244.115**	2086143.614**
Dominance x Env.	20	20.897**	57.155**	266487.279**	15.611**	20.111**	84358.418**
$(\bar{L}_{1i} + \bar{L}_{2i} - 2\bar{L}_{3i})$							
Overall epistasis	10	1097.139**	1102.203**	4123721.717**	1064.983**	431.842**	3799348.621**
i type epistasis	1	271.559**	37.106**	91056.733NS	24.098**	6.213NS	30665.737NS
j +1 type epistasis	9	1188.870**	1220.547**	4571795.604**	1180.637**	479.134**	4218091.164**
Overall epi. x Env.	20	473.498**	118.915**	958301.234**	162.766**	80.520**	351330.759**
i type epi. x Env.	1	168.480**	34.105**	7970.918NS	11.424NS	0.102NS	19262.664NS
j +1 type epi. x Env.	19	489.552**	123.379**	1008318.619**	170.731**	84.753**	368808.027**
Pooled error	196	8.567	9.712	32009.727	5.540	10.415	47734.835

NS\*\*; Insignificant, and highly significant at and 1% level of probability, respectively.

1: Money Maker cv., 2 : Castle Rock cv , 3 : Carneuco 200 cv, and 4: Peto 86.

Table 4. Estimates of additive variation (D), dominance variation (H), degree of dominance ( $\sqrt{H/D}$ ), covariance sums / differences (Fr) and correlation (r) between sums and differences in the two tomato triple test crosses under different environments for some plant growth traits

Character Parameter	Plant height (cm)				Branch No. / plant			
	Env. 1	Env. 2	Env. 3	Overall	Env. 1	Env. 2	Env. 3	Overall
Cross 1 (MM <sup>1</sup> x CR <sup>2</sup> )								
D	531.024	505.755	235.320	264.856	233.704*	153.154	68.913	51.168
$\chi^2$				1.764				3.397
H	43.673	366.564*	284.260	90.488	129.326	125.572	75.649	77.555
$\chi^2$				9.638*				0.816
$\sqrt{H/D}$	0.29	0.85	1.11	0.58	0.73	0.91	1.05	1.23
Fr	-1277.72	-947.31	727.26		-657.72	547.49	426.55	
r	0.63	0.17	-0.21		0.28	-0.30	-0.44	
Cross 2 (C <sub>200</sub> <sup>3</sup> x Peto <sup>4</sup> )								
D	418.623	99.887	108.404	100.385	132.462	114.918	60.009	41.840
$\chi^2$				6.705*				1.588
H	50.648	42.781	74.853	51.992	64.747*	29.963*	25.042*	2.928
$\chi^2$				0.816				2.581
$\sqrt{H/D}$	0.35	0.65	0.83	0.72	0.70	0.51	0.65	0.26
Fr	-1234.33	-325.50	-439.26		-345.54	-381.15	-133.00	
r	0.64	0.37	0.37		0.64	0.37	0.37	

\*  $\chi^2$  significant at the 0.05 level of probability.

1: Money Maker cv., 2: Castle Rock cv., 3: Carmeuco 200 cv., and 4: Peto 86

heterogeneity of estimated D values for plant height, using  $\chi^2$ , illustrated that the three estimates for D were homogeneous in cross 1 and heterogeneous in cross 2. In the later one was highly affected by environment 1 and was also confirmed to be significant, when tested against overall, using F- test for equality test of variances; but the other D variances, in the two crosses, were homogeneous. H estimates for plant height were heterogeneous in cross 1 and homogeneous in cross 2, using the two tests of heterogeneity of variances. The gene expression of this trait, as shown by dominance ratio ( $\sqrt{H/D}$ ), reflected a partial dominance ( $\sqrt{H/D} < 1$ ) under all environments in the two crosses, except for cross 1 under environment 3 (60 cm) which showed a complete dominance. For assessing the gene expression using Fr, this covariance was negative at environments 1 and 2 in cross 1 and in the three environments, in cross 2; indicating that the recessive alleles were more frequent than the dominant alleles, irrespective of whether these are increasing or decreasing in their effects. Moreover, the respective r values having opposite signs (positive), indicated also

that the expression was mostly due to recessive alleles.

For branch number, Table 4 illustrated that D and H estimates, at the three environments in the two crosses, were homogeneous, using  $\chi^2$  - test, and did not generally differ from overall in each case. But, D in environment 1 in cross 1 was found significant when tested against overall and gave an increased value under this environment. H in cross 2 under all environments differed significantly from overall. The ratio ( $\sqrt{H/D}$ ) reflected a partial dominance on the inheritance of branch number at environment 1 in cross 1 and at the three environments in cross 2. But for environments 2 and 3 in cross 1, the expression was a complete dominance. Fr values were found negative and r values were positive at environment 1 in cross 1 and at the three environments in cross 2, indicating that the recessive alleles were more frequent than the dominant ones. But in cross 1 at environments 2 and 3, Fr was positive and r was negative showing dominant genes.

## 2.2 Early yield and its components

Results in Table 5 show that the estimates of D and H at the three environments did not

Table 5. Estimates of additive variation (D), dominance variation (H), degree of dominance ( $\sqrt{H/D}$ ), covariance sums / differences (Fr) and correlation (r) between sums and differences in two tomato triple test cross, under different environments, for early yield traits

Character Parameter	Cross 1 (MM <sup>1</sup> x CR <sup>2</sup> )				Cross 2 (C <sub>200</sub> <sup>3</sup> x Peto <sup>4</sup> )			
	Env. 1	Env. 2	Env. 3	Overall	Env. 1	Env. 2	Env. 3	Overall
Average fruit weight								
D	550.044	466.119	168.926	170.488	619.852	682.052	388.430	389.544
$\chi^2$				2.250				7.528*
H	407.526	239.661	237.130	189.720	647.094	841.296	872.704	919.231
$\chi^2$				1.456				0.706
$\sqrt{H/D}$	0.86	0.72	1.19	1.05	1.02	1.11	1.50	1.54
Fr	1414.48	6381.34	1740.21		2932.07	5423.57	1653.35	
r	-0.22	-0.87	-0.65		-0.35	-0.54	-0.21	
Early fruits number / plant								
D	1.647	1.718	3.802	-0.456	5.561	7.779	12.087	5.208
$\chi^2$				3.397				0.838
H	0.601*	0.446	2.243*	-0.144	6.654	5.073	8.798	7.784
$\chi^2$				0.926				0.243
$\sqrt{H/D}$	0.60	0.51	0.77	0.562	1.09	0.81	0.85	1.223
Fr	-6.10	-2.19	-4.39		-20.06	-8.76	-3.64	
r	0.46	0.19	0.11		0.25	0.11	0.03	
Early yield / plant								
D	13108.718*	15445.552*	24584.229*	-1469.196	2569313.750*	35874.490	122324.400*	30514.674
$\chi^2$				1.037				7.786*
H	2654.293	2125.099	10618.214	1582.924	21230.427	19248.517	72776.200	767560.759
$\chi^2$				40.251				5.690
$\sqrt{H/D}$	0.45	0.37	0.66		0.09	0.73	0.77	
Fr	-52599.95	43700.84	83716.27		-14395.42	17736.31	319144.58	
r	0.67	-0.57	-0.39		0.01	-0.05	0.25	

\*  $\chi^2$  significant at the 0.05 level of probability.

1: Money Maker cv., 2: Castle Rock cv., 3: Carneuco 200 cv., and 4: Peto 86.

significantly differ, and appeared homogeneous for average early fruit weight and number, using  $\chi^2$ -test, except D in cross 2 which reflected heterogeneity for average fruit weight. These values did not also differ from overall D and H in the two crosses, except H at environments 1 and 3 in cross 1 for number of fruits. The expression of fruit weight, as assessed by  $\sqrt{H/D}$ , was mostly a complete dominance for fruit weight at environment 3 in cross 1 and at all environments in cross 2. At environments 1 and 2 in cross 1, a partial dominance was detected. In this respect,  $Fr$  values was positive and  $r$  was negative, indicating the presence of more dominant genes and that the parents contained most of dominant genes. Fruit number, showed a partial dominance in the two crosses at all environments, except that at environment 1 in cross 2, which showed a complete dominance.  $Fr$  and  $r$  values for this trait were positive and negative, respectively. It indicates that the dominant alleles were more frequent than the recessive ones and the parent had most dominant alleles.

For early yield (Table 5), data reveal that values of D in cross 1 and H in the two crosses

had significant  $\chi^2$ , so they were heterogeneous under the three environments. But, those for D in cross 1 were homogeneous. However, the three values were significantly differed from their respective overall. The values of the degree of dominance ( $\sqrt{H/D}$ ) indicated the presence of a partial dominance of all cases, except that for environment 1 in cross 2 which showed an absence of dominances ( $r = 0$ ). Data for  $Fr$  and  $r$  values showed positive and negative signs, respectively, at environments 2 and 3 in the two crosses and negative and positive, respectively at environment 1 in the two crosses. These results indicated that, with wide plant spacing, the dominant alleles were prevailed.

### 2.3 Total yield and its components

Results in Table 6 show that, the estimates of D were homogeneous and heterogeneous in the two crosses for fruit weight and total number of fruits, respectively. Also, they did not differ significantly when tested against their respective overall. For H values, they had homogeneous and heterogeneous variances in crosses 1 and 2, respectively for fruit weight and vice versa for fruit number.

Table 6. Estimates of additive variation (D), dominance variation (H), degree of dominance ( $\sqrt{H/D}$ ), covariance sums / differences (Fr) and correlation (r) between sums and differences in two tomato triple test cross, under different environments, for total yield traits.

Character Parameter	Cross 1 (MM <sup>1</sup> x CR <sup>2</sup> )				Cross 2 (C <sub>200</sub> <sup>3</sup> x Peto <sup>4</sup> )			
	Env. 1	Env. 2	Env. 3	Overall	Env. 1	Env. 2	Env. 3	Overall
Average fruit weight								
D	951.883	499.239	468.803	473.491	691.841	746.224	694.654	555.691
$\chi^2$				1.544				0.022
H	558.567	266.239	287.898	382.340	565.355	468.967	455.094	641.152
$\chi^2$				1.654				8.271*
$\sqrt{H/D}$	0.77	0.73	0.77	0.90	0.90	0.79	0.81	1.07
Fr	6114.22	4140.96	3862.40		5997.02	4246.11	6262.71	
r	-0.63	-0.85	-0.79		-0.72	-0.54	-0.84	
Fruits number / plant								
D	63.440	137.221	588.839*	128.659	201.037	905.727	232.961	241.013
$\chi^2$				12.131*				7.102*
H	31.892	77.589	227.432	72.568	88.010	107.447	88.88	97.509
$\chi^2$				8.822*				0.132
$\sqrt{H/D}$	0.71	0.75	0.62	0.75	0.66	0.34	0.62	0.64
Fr	-115.99	-286.17	117.97		1175.07	1610.58	1327.49	
r	0.19	0.21	-0.24		-0.66	-0.39	-0.69	
Total yield / plant								
D	129163068.40*	474101.215	1299704.51	146545.638	737016.067	1235418.095	1980289.536	101584.321
$\chi^2$				66.586*				2.294
H	284858.121	882031.778	1966319.938*	398688.698.	653100.137	1027554.58	102755.58	881860.160
$\chi^2$				8.006*				8.006*
$\sqrt{H/D}$	0.05	1.36	1.23	1.65	0.94	0.91	0.73	0.93
Fr	24169049.68	-1175248.32	4097141.84		6343408.60	8467901.56	14614856.26	
r	-0.30	0.14	-0.19		-0.69	-0.56	-0.76	

\*  $\chi^2$  significant at the 0.05 level of probability.

1: Money Maker cv., 2: Castle Rock cv., 3: Carmeuco 200 cv, and 4: Peto 86.

However, all H values in the two crosses in both traits did not differ from their respective overall value. The degree of dominance estimates ( $\sqrt{H/D}$ ) for both traits indicated the presence of partial dominance in their inheritance. The values of Fr and r showed positive and negative signs, respectively, for fruit weight in the two crosses, indicating that the dominant alleles were more than the recessive alleles and the parents contained most dominant genes irrespective of their effects. Similar behaviour was observed for fruit number at environment 3 in cross 1 and at the three environments in cross 2, and opposite behaviour was detected at environments 1 and 2 in cross 1.

For total yield (Table 6), heterogeneity of D variances in cross 1 and H variances in the two crosses were observed. While, D variances in cross 2 were homogeneous, using  $\chi^2$ -test. The values of both estimates in the two crosses did not differ from their respective overall value, except that for D in environment 1 in cross 1. The dominance ratio ( $\sqrt{H/D}$ ) differed according to the environment and in the two crosses. It also showed an absence of dominance at environment 1 in cross

1, partial dominance at environment 3 in cross 2, a complete dominance at environments 1 and 2 in cross 2 and an over-dominance at environments 2 and 3 in cross 1. Moreover, Fr and r values showed that the dominant alleles were more frequent, and the parents contained most of the dominant genes, under the different environments; except at environment 1 in cross 1.

### 3. Predicting the Proportion of Superior Pure Breeding lines

Since the tomato is an autogamous crop, and selfing is prevailing for an infinite number of generations, the population derived from an  $F_1$  would be heterogeneous and had a large number of homozygous lines. Therefore, prediction of the inbreds expected to fall beyond the parental range and superior to it or to their  $F_1$  was computed.

#### 3.1 Plant growth traits

Results in Table 7 show that environment 1 in the two crosses reflected a wider expected range of inbreds that could be extracted from  $F_1$ , compared with that for environments 2 and 3, and that for environment 2 was a relatively higher than that for environment 3. The



Table 7. Predicted range of inbreds expected to fall outside the parental range, for tomato plant growth traits under the studied different environments

Character, cross and environment	Parameter Range of inbreds $m \pm 2 \sqrt{D}$	Probahility $h / \sqrt{D}$	Proportion of inbreds falling outside parental range (%)
<b>Plant height</b>			
Cross 1 ( Money Maker x Castle Rock; MM x CR)			
Env. 1	26.240 - 118.418	-0.034	48.64
Env. 2	44.212 - 134.168	-0.102	45.94
Env. 3	66.660 - 128.020	0.289	38.63
Cross 2 ( Carmeuco, 200 x Peto 86 ; C <sub>200</sub> x Peto )			
Env. 1	34.839 - 116.681	-0.015	45.42
Env. 2	72.551 - 112.529	0.035	48.60
Env. 3	81.517 - 123.163	0.832	20.28
<b>Branch No.</b>			
Cross 1 ( Money Maker x Castle Rock; MM x CR)			
Env. 1	6.415 - 67.565	-0.021	49.16
Env. 2	21.929 - 71.431	-0.558	28.84
Env. 3	34.167 - 67.373	-0.963	16.76
Cross 2 ( Carmeuco, 200 x Peto 86 ; C <sub>200</sub> x Peto )			
Env. 1	14.342 - 60.378	0.085	46.71
Env. 2	22.552 - 68.588	-0.465	32.10
Env. 3	33.947 - 64.923	-0.602	27.36

expected elite pure lines which may be superior to their parents and  $F_1$  were more than 46% of the extracted pure lines for plant height and branch number in the two crosses and more than 45% for environment 2 in the two crosses for plant height. Under other environments, there were considerable number of the superior inbreds that could be identified (more than 20%) for the two traits, but the lowest was found at environment 1 in cross 1 for branch number.

### 3.2 Early yield and its components

Data in Table 8 revealed a wider range, of the extracted inbreds, was predicted at environments 1 and 2 in the two crosses for average fruit weight (close and intermediate plant spacings). On the other hand, such a wider range was predicted with the wide plant spacing, relative to other plant spacings, for early fruit number and early yield. Moreover, the proportions of superior inbreds were higher (more than 41%) for environments 2 and 3, in cross 1, and environment 1, in cross 2, than the other comparable environment in the two crosses. On the other hand, it appeared rare to find inbreds of superior fruit size

at environment 3 in cross 2. Moreover, the expected proportion of the superior inbreds for fruit number and early yield was higher than 35% of all the cases and reached over 48% in particular cases.

### 3.3 Total yield and its components

Results in Table 9 reflected a relatively wider expected range for fruit weight with the decrease in plant spacing in cross 1. However, the expected range were also high and relatively alike in cross 2 at all environments. On the other hand, increasing plant spacing seemed to increase the range of inbreds for fruit number and yield in the two crosses.

The expected proportion of superior inbreds for fruit weight was high (more than 37%) in the two crosses at the three environments. The expected proportion for fruit number was considered high at environment 1 (31%) in cross 1 and at environment 2 (36%) in cross 2; moderate (more than 25%) at environments 2 and 3 in cross 1 and environment 1 in cross 2; and low at environment 3 in cross 2. For total yield, only one case was expected to have a high portion (48.6%) of elite inbreds which was observed at

Table 8. Predicted range of inbreds expected to fall outside the parental range, for tomato early yield traits under the studied different environments

Character, cross and environment	Parameter Range of inbreds $m \pm 2\sqrt{D}$	Probahility $h / \sqrt{D}$	Proportion of inbreds falling outside parental range (%)
<b>Average early fruit weigth</b>			
<b>Cross 1 ( Money Maker x Castle Rock; MM x CR)</b>			
Env. 1	8.464 - 102.276	0.330	37.07
Env. 2	20.710 - 107.070	-0.214	41.53
Env. 3	37.566 - 89.554	-0.222	41.22
<b>Cross 2 ( Carmeuco, 200 x Peto 86 ; C<sub>200</sub> x Peto )</b>			
Env. 1	12.076 - 111.664	-0.062	47.53
Env. 2	10.598 - 115.062	0.556	28.91
Env. 3	24.733 - 103.567	1.101	13.55
<b>Early fruits No.</b>			
<b>Cross 1 ( Money Maker x Castle Rock; MM x CR)</b>			
Env. 1	-0.249 - 4.887	-0.041	48.36
Env. 2	1.049 - 6.291	-0.231	40.86
Env. 3	1.110 - 8.910	0.097	46.14
<b>Cross 2 ( Carmeuco, 200 x Peto 86 ; C<sub>200</sub> x Peto )</b>			
Env. 1	-2.006 - 7.426	0.363	35.83
Env. 2	-2.746 - 8.408	0.143	44.31
Env. 3	-2.753 - 11.533	0.058	47.69
<b>Early yield / plant</b>			
<b>Cross 1 ( Money Maker x Castle Rock; MM x CR)</b>			
Env. 1	-102.855 - 355.149	0.315	37.64
Env. 2	-5.110 - 492.010	-0.365	35.75
Env. 3	67.811 - 564.931	0.001	49.60
<b>Cross 2 ( Carmeuco, 200 x Peto 86 ; C<sub>200</sub> x Peto )</b>			
Env. 1	-3079.596 - 3332.036	0.091	46.37
Env. 2	-196.850-560.772	0.362	35.37
Env. 3	-430.611-968.385	0.307	37.95

Table 9. Predicted range of inbreds expected to fall outside the parental range, for tomato yield traits under the studied different environments

Character, cross and environment	Parameter $m \pm 2\sqrt{D}$	Range of inbreds $h / \sqrt{D}$	Probability $h / \sqrt{D}$	Proportion of inbreds falling outside parental range (%)
Average fruit weight				
Cross 1 ( Money Maker x Castle Rock; MM x CR)				
Env. 1	-0.265 - 123.145	0.181	42.82	
Env. 2	20.143 - 104.517	0.089	46.55	
Env. 3	18.596 - 105.204	0.294	38.44	
Cross 2 ( Carneuco, 200 x Peto 86 ; C <sub>200</sub> x Peto )				
Env. 1	8.944 - 114.155	0.361	35.87	
Env. 2	9.706 - 118.974	0.289	38.63	
Env. 3	12.447 - 117.873	0.319	37.49	
Fruits No./plant				
Cross 1 ( Money Maker x Castle Rock; MM x CR)				
Env. 1	10.130 - 41.990	0.495	31.03	
Env. 2	15.072 - 61.928	0.888	28.72	
Env. 3	3.828 - 100.892	0.623	26.66	
Cross 2 ( Carneuco, 200 x Peto 86 ; C <sub>200</sub> x Peto )				
Env. 1	-1.448 - 55.268	0.671	25.11	
Env. 2	-26.371 - 94.011	0.357	36.05	
Env. 3	11.984 - 73.036	0.897	18.49	
Total yield / plant				
Cross 1 ( Money Maker x Castle Rock; MM x CR)				
Env. 1	-21132.036-24327.936	0.035	48.60	
Env. 2	1091.570 - 3845.770	1.160	12.30	
Env. 3	912.068 - 5472.266	1.243	10.16	
Cross 2 ( Carneuco, 200 x Peto 86 ; C <sub>200</sub> x Peto )				
Env. 1	-58.843 - 3375.143	1.079	14.03	
Env. 2	-114.287 - 4331.687	0.946	17.21	
Env. 3	-56.235 - 5572.675	1.022	15.34	

environment 1 in cross 1; but , all other cases had low expectations and appeared infrequently to find inbreds of superior yield to their parents.

### DISCUSSION

For detecting the relative contribution of additive, dominance and epistasis, triple test cross (TTC) proposed by Kearsey and Jinks (1968), was modified by Jinks *et al.* (1969). This design was considered the best mating design in this respect. The modified triple test cross detects epistasis and estimates additive (D) and dominance (H) components as well as the direction of dominance (Fr) with a high degree of precision (Singh *et al.*, 1997, on Pea). This test is an extension of North Carolina design-III, which was suggested by Comstock and Robinson (1948 and 1952), and had a third tester ( $F_1$ ). The estimations of the additive and dominance with environments were considered fairly good. That is due to that the pre-assumptions for other breeding designs are not needed for TTC. The estimates of D and H, depended on orthogonal comparisons provided a reliable estimates in comparison with the other designs, which gave highly negatively correlated estimates of these two

components and hence, the dominance ratio had a large sampling variance (Jinks, 1983). Also, with the presence of interaction, the inflation of D due to complementary action and the deflation due to duplicate action had similar effects on both the components, which did not affect the dominance ratio. Dominance ratio is very important in planning a breeding program; once, its estimation is reliable, the prediction of the derived superior lines at  $F_{\infty}$  selfed generation would be available, using the normal probability integral (Jinks and Pooni, 1976).

#### 1. Detecting additive, dominance and epistasis

There were highly significant additive and dominance variances for all studied traits; i.e. plant height, branch number, average early fruit weight, early yield, yield and its components in the two crosses (MM x CR) and ( $C_{200}$  x Peto 86). For early fruit number, both the variances were highly significant in cross 2 ( $C_{200}$  x peto 86), but not in cross 1 (MM x CR). Also, highly significant additive x environments and dominance x environments for all those traits, except those of average early fruit weight and early fruit number,

were detected in the two crosses. Similar results showing that the variances due to both sums and differences were highly significant for all the traits under different environments (Singh *et al.*, 1989 on spring wheat; Katiyar and Ahmad, 1996 on bread wheat, and Tefera and Peat, 1997 on t'ef).

Regarding the overall epistasis - environment interactions, highly significant variances were found due to those components for all studied traits, except those due to overall epistasis-environment for early fruit number, in the two crosses. On tomato, Singh and Singh (1984) found that epistasis was highly significant for all the eight studied characters in both studied crosses. On wheat, Sharma *et al.* (1995) estimated significant values for *i* type epistasis and *i* type x environment. In the present study, both the components of interaction (*i* type, additive x additive, and *i* type x environment) reflected highly significant mean squares for plant height and branch number in the two crosses. For early yield traits, both the components were found highly significant for early yield, but in cross 1 only. For total yield and its components, both the components were highly significant for average

fruit weight in cross 1 and for only *i* type in cross 2. With regard to *j+1* type and its interaction with the environment, all the studied traits showed highly significant mean squares for those components, except that for *j+1* type x env. for early fruit number, in the two crosses. Such a result was also demonstrated by Singh and Singh (1984) on tomato.

Moreover, additive effects for those traits were generally higher than those for dominance and epistasis. The interaction of those three parameters with the environments were less than that of their main effects. Also, the estimated values for *i* type and *i* type x environment were higher than their respective values for *j+1* type and *j+1* x environments in plant height and branch number in the two crosses and were less than those for *j+1* and *j+1* x environment in early and total yield. On two tomato crosses grown under two fertilizer levels, as micro-environments, Singh and Singh (1984) reported that the *i* type epistasis x environment was significant for final plant height in cross 1 and for branch number in both crosses. On the other hand, *j+1* type x environment was significant for final plant height, number of fruits/plant,

wieght/fruit and yield/plant in the two crosses.

## 2. Genetic components

Regarding to plant growth traits, results of this work indicate that the estimates of D for plant height under different plant spacings were homo- and heterogeneous in cross 1 and 2, respectively, using  $\chi^2$ -test. Those estimates did not also differ from their overall estimate, except that for environment 1 in cross 2, using F-test. The estimate values for H component, appeared hetero- and homogeneous in cross 1 and 2, respectively, and differ from overall value at environment 2 in cross 1, only. For branch number, the estimates of D and H under different plant spacings were all homogeneous; but, when tested against the respective overall estimate, D in environment 1 in cross 1 and all estimates of H in cross 2 appeared significantly higher than their respective overall values. Estimates of D and homogeneity were relatively higher than those of H. The heterogeneity of H in plant height of the two crosses, indicated the sensitivity of H to environments, and, so, branch number in cross 2, that is due to significant epistasis and epistasis x environment interaction.

Singh and Singh (1984) found that tomato plant height and branch number had highly significant epistasis values, indicating that D and H and their interactions with environments were confounded by epistatic gene effects. While, Singh (1979 and 1980) found that additive gene effects were sensitive to micro-environments than the dominance gene effects in barely and wheat, respectively. On rice, the estimates of additive (D) and dominance (H) components were highly significant for most of the traits, although, the D component was higher than H (Vijayakumar *et al.*, 1996). On pea triple-test cross, Singh *et al* (1997) reported that the estimates of both D and H components were highly significant for plant height, pod number/plant, seeds/pod, seed weight and seed yield/plant, but in pod length only dominant component was significant.

The estimates of the degree of dominance ( $\sqrt{H/D}$ ) for plant height and branch number revealed involving of partial dominance ( $<1$ ) in the inheritance of both traits under all the environments, except that under environment 3 in cross 1, which showed complete dominance ( $=1$ ). Moreover, the recessive genes were more frequent in the

parents in cross 2, and environments 1 and 2 in cross 1 and under environments 1 in cross 2 the expression was mostly due to recessive genes, as shown from  $Fr$  and  $r$  values. The other cases in cross 1 were vice versa. The dominance ratio under this design was not affected by epistasis (Jinks and Pooni, 1980; Jinks, 1983; Batta *et al.*, 1986 on pigeon pea ; Singh *et al.*, 1986, 1987 and 1988 on field peas). The degree of dominance ( $\sqrt{H/D}$ ) was in the range of partial dominance for most of the pea traits (Singh *et al.*, 1997). Similar results were reported by Vijayakumar *et al.* (1996) on rice, Dhindsa and Bains (1986), Singh *et al.* (1986 and 1995 and Sharma *et al.* (1995) on wheat. On tomato diallel analysis, the ratio  $(H_1/D)^{1/2}$  indicated the presence of over-dominance in all traits under different environments (Ismail, 1997), and Verma and Yunus (1986) on bread-wheat.

For early yield, the estimates of  $D$  and  $H$  were mostly homogeneous for average early fruit weight and early fruit number and did not differ from overall. But,  $D$  estimates were heterogeneous for average fruit weight in cross 1 and  $H$  differed from its overall in environments 1 and 3

for branch number in cross 1. Moreover, the estimates of  $\sqrt{H/D}$  reflected a partial dominance for both the traits in cross 1, except that at environment 3 in cross 1 for fruit weight, which suggested a complete dominance. But in cross 2, both the traits showed a complete dominance, except that for branch number at environments 2 and 3, which showed a partial dominance. Moreover, fruit weight reflected positive  $Fr$  and negative  $r$  values ; whereas , reversal trends were given by fruit number, both under all environments and in the two crosses.

For early yield, the estimates of  $D$  and  $H$  were heterogeneous in the two crosses under all environments, but  $D$  was homogeneous in cross 1. The values that differed from overall were those at all environments in cross 1 and at environments 1 and 3 in cross 2; and that for  $H$  was at env. 3 in cross 1. Moreover, the estimates of  $\sqrt{H/D}$  reflected the presence of a partial dominance in the inheritance of early yield.  $Fr$  and  $r$  values had positive and negative signs , respectively at environments 2 and 3 in the two crosses and vice versa at environment 1.

Average early fruit weight and fruit number were, mostly,



not affected by the change in environment, as shown from the detected homogeneity of D and H. But for early yield, D and H values were heterogeneous, indicating their sensitivity to environments. Therefore, environment (plant spacing) would be considered in improving early yield, indicating that breeding a tomato cultivar under a specific plant spacing may not be valid to other ones. Selection, also, should directly deal with early yield, but not to its components. Such a conclusion was also reported by Wells and Kofoid (1986) on wheat.

For total yield, estimates of D and H were homogeneous for fruit weight and heterogeneous for fruit number and total yield. But as exceptions, estimates of D for fruit weight in cross 2, and D and H in cross 1 were found hetero- and homogeneous, respectively.

The estimates of  $\sqrt{H/D}$  illustrated that a partial dominance was involved in the inheritance of those traits under all environments in the two crosses, but a complete dominance was noticed under environments 2 and 3 for fruit number in cross 1. Fr and r values were oftenly positive and negative, respectively for those traits under all environments in the two crosses, but they were vice versa under

environments 1 and 2 in cross 1 for fruit number, and under environment 1 for total yield.

Since all studied yield traits involved homogeneous D and H components, these traits, and even yield/plant, could be improved in breeding programs by selecting promising inbreds of high yield, or through selecting for its components.

### 3. Predicting the proportion of superior pure breeding lines

Present results of plant height and branch number indicated that the expected range of inbreds which may fall outside the range of parents were relatively high with the decrease in plant spacings. Also, the proportion of the superior inbreds that may be extracted from selfing were expected to be high, more than 45% in environments 1 and 2, for plant height, and more than 46% in environment 1 and 28% in environment 2, for branch number. While for environment 3, the expected elite portions of inbreds were low (around 16% in both traits).

For early and total yields, and their components; the ranges of inbreds increased with the decrease of plant spacing for fruit weight in the two crosses. However, for early and total yields and then fruit numbers

the ranges increased with increasing the plant spacing in the two crosses. The proportions of the inbreds that may have superior performances than their parents, or even  $F_1$ 's were relatively high (more than 28%) for early yield traits, except that at env. 3 in cross 2 for fruit weight (about 13%) in the two crosses. For total yield, the expected proportion of the superior inbreds for fruit weight was similar to those of average early fruit weight. But for fruit number and total yield, they were mostly 18% and 10%, respectively. However, there were some exceptional cases that had high proportions of good inbreds; those were in environment 1 in cross 1 for fruit number and total yield, and in environment 2 in cross 2, for fruit number.

Predictions, in the present study, of superior lines that could be extracted from  $F_1$ 's in advanced self generations showed considerable portion of elite inbreds for all studied traits; except for total yield in cross 2. Therefore, the two crosses ( $F_1$ 's) have considerable values in breeding program, when dealing with improvement of those traits. But, for total yield, cross 1, only, showed a considerable value to improve this trait.

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### دراسة التفاعل الوراثي البيئي في التلقيح الإختباري الثلاثي في الطماطم ٣-المكونات الوراثية وإمكانية التنبؤ بالسلالات النقية الجديدة

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تم تهجين اثنين من هجن الطماطم ، هما موني ميكر × كاسل روك (MMx CR) و كارميكو ٢٠٠ × بيتو ٨٦ (C200 x Peto) وأبائهم مع ١١ صنفاً للحصول على ١١ عائلة لكل مجموعة من  $L_{1i}$ ،  $L_{2i}$ ،  $L_{3i}$  باستخدام نظام التلقيح الإختباري الثلاثي ، وتم تقييم الثلاث وثلاثين عائلة الناتجة من كل هجين تحت ظروف ثلاث بيئات صغرى (٣٠ ، ٤٥ ، ٦٠ كمسافات زراعة) .

أظهرت التباينات الراجعة للإضافة والسيادة والتفوق وتفاعلاتها مع البيئات معنوية عالية لصفات إرتفاع النبات النهائى وعدد الأفرع ومتوسط وزن الثمرة المبكرة وعدد الثمار المبكرة والمحصول المبكر ومتوسط وزن الثمرة وعدد الثمار الكلى والمحصول الكلى ، بينما كانت الإضافة والسيادة وتفاعل التفوق  $\times$  البيئة لمتوسط وزن الثمرة ( للمحصول الكلى) غير معنوي ، وأيضاً كان طراز التفوق (i) وتفاعله مع البيئة عالى المعنوية فيما عداه فى صفتى وزن وعدد الثمار المبكرة ، فى كلا الهجينين وفى المحصول المبكر فى الهجين الثانى ، وعدد الثمار الكلى والمحصول الكلى فى كلا الهجينين . أما بالنسبة لطراز التفوق (j+1) وكذا تفاعله مع البيئة فكانت قيمة كل منهما عالية المعنوية ، عداها فى صفة عدد الثمار المبكرة فى الهجين الأول . أما مكوئى التباين H, D ( الذين أختبرا بمربع كاي) فكانت تقديرات كل منهما تحت الظروف البيئية المستخدمة متجانسة فى كلا الهجينين ماعدا قيمة H فى الهجين الأول وD فى الهجين الثانى لصفة إرتفاع النبات وقيم D فى صفتى متوسط وزن الثمرة المبكرة والمحصول المبكر فى كلا الهجينين وقيمة H فى الهجين الثانى لصفة متوسط وزن الثمرة وكلا من قيم H, D فى الهجين الأول لعدد الثمار الكلى والمحصول الكلى ، وفى الهجين الثانى لقيم D لعدد الثمار الكلى و H للمحصول الكلى . وأظهرت تقديرات درجة السيادة فى أغلب الحالات سيادة جزئية (غير تامة) عند كل البيئات المختبرة فى الهجينين لمعظم الصفات التى درست ، ولكن فى حالات قليلة شوهدت سيادة تامة أو سيادة فائقة . وأشارت نتائج التنبؤ إلى وجود نسب واعدة من السلالات النقية الجديدة التى يمكن الحصول عليها كنتيجة للتلقيح الذاتى للجيل الأول فى الأجيال المتقدمة فى كل من الهجينين ، عدا المحصول الكلى فى الهجين الثانى .