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INHERITANCE AND NATURE OF COLD TOLERANCE IN TOMATO

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ABSTRACT

Interspecific crosses were made between three cultivars, i.e. Edkawi, Floradade and UC. 97-3, which belong to *Lycopersicon esculentum,* and LA1383, which belongs to *Lycopersicon hirsutum,* to study the inheritance and nature of cold tolerance. All obtained populations, i.e. P_1, P_2, F_1, F_2, Bc_1 and Bc_2 for all possible interspecific crosses were evaluated in a field experiment as individual plants. Genetic differences were detected among the different parental genotypes concerning foliage cold tolerance, fruit set percentage and total yield/plant. The inheritance of cold tolerance, fruit set percentage and total yield/plant was in quantitative pattern. The high level of cold tolerance was partial dominant over the low level. The low percentage of fruit set under low temperature showed partial dominance over the high percentage of fruit set. Over dominance was observed for high yield/plant in the interspecific cross UC. 97-3 X LA1383. The broad sense heritability estimates for foliage cold tolerance were 98.73%, 87.19% and 60.91% while the estimates of the narrow sense heritability were 75.56%, 63.22% and 56.97% for the interspecific crosses Edkawi X LA1383, Floradade X LA1383 and UC. 97-3 X LA1383, respectively. The minimum number of effective gene pairs controlling foliage cold tolerance, percentage of fruit set and total yield/plant under low temperature were 1-4,2-3 and 1-4 gene pairs, respectively. Significant positive correlation was detected between foliage cold tolerance and total yield / plant. However, foliage cold tolerance was negatively correlated with each of Earliness, fruit weight and fruit length in the interspecific crosses Edkawi X LA1383 and Floradade X LA1383. Highly significant positive correlations between foliage cold tolerance and chemical composition of plant foliage, i.e. chlorophyll a and b and total carotenoides as well as reducing, non-reducing and total sugars were detected. The combined effect of fruit weight, number of fruit/plant, fruit length and diameter was found to have highly significant correlation with total yield/plant under low temperature conditions.

Key words: ***Interspecific, Broad and narrow heritability, Correlation, Tomato, Lycopersicon hybrids.***

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is one of the most popular vegetable crops in many parts of the world. However, there are serious problems associated with the winter season planting of tomato in Egypt including frost damage, and low percentage of fruit set (Hassan 1988). Cultivars of tomato recommended for the winter season should be tolerant to low temperature conditions to reduce as much as possible the damage associated with the low temperature during the winter season. The market in Egypt needs more adapted tomato genotypes, which are tolerant to cold conditions. In the open field, under environmental conditions of Kalubia Governorate Egypt, Radwan *et al* (1986) and Agwah and Mahmoud (1994) suggested that sowing seeds in October and transplanting in November was a good timing to evaluate *Lycopersicon esculentum* cultivars for tolerance to low temperature. In addition, EL-Saka (1997) mentioned that the frequency distribution for foliage cold tolerance in the F_2 of some crosses between *L. esculentum* genotypes indicated quantitative inheritance pattern for foliage cold tolerance.

The ability of tomato plants to fruits set under low temperature conditions was inherited quantitatively with partial dominance for high percentage of fruit set (Ibrahim 1984). In addition, he found that the heritability estimates for the high percentage of fruit set under low temperature conditions were very low indicating the high influence of the environmental effects on the expression of this character. On the other hand, Kalloo and Baberjee (1990) observed qualitative inheritance pattern for percentage of fruit set under low temperature in the segregating generation of crosses between *L. esculentum* and *L.pimpinellifolium*. Moreover, EL-Saka (1997) found that number of major effective genes controlling foliage cold tolerance, percentage of fruit set under low temperature conditions, and total yield/plant under low temperature were 1-3, 1, 3-39 gene pairs, respectively.

Maisonneuve *et al* (1986) mentioned that the foliage of the cold tolerant tomato genotypes, when exposed to low temperature conditions, it lost part of chlorophyll content at very low rate at night and then will compensated the lost chlorophyll at the day time. In addition, Kamps *et al* (1987) evaluated different tomato germplasm for resistance to chilling injury by subjecting the plants at the 4 to 11 leaf development stage to temperature of 2.5°C for 72 hours and found high correlation between the visual rating of plant damage and chlorophyll fluorescence which was found to be the most precise assay to quantify chilling. Byrd *et al* (1995) recorded decrease in leaf photosynthesis when tomato plants were exposed to low temperature of 4°C. Moreover, Keller and Steffen (1995) observed that during the chilling treatment, levels of soluble sugars per leaf dry weight increased. They pointed out the involvement of soluble sugar level in the acclimatization of tomato plants to chilling.

Furthermore, sugars have been reported to be highly correlated with freezing tolerance in many plants (Levitt 1980 and Gusta *et al* 1996). EL-Saka (1997) mentioned that significant positive correlations between cold tolerance of adult plant foliage and the studied chemical characteristics of fruits, *i.e.* vitamin C content, juice acidity, and total sugars content.

The objectives of this research were to study the inheritance of cold tolerance at adult plant stage and to develop a selection criteria for cold resistance. Such information will be of great importance to design a successful breeding program for cold tolerance in tomato.

MATERIALS AND METHODS

This research was conducted at the Agricultural Experimental Station of the Department of Horticulture, Faculty of Agriculture Moshtohor, Zagazig University, Benha Branch, during 2000 to 2002. Four parental genotypes of tomato, *i.e.* U.C. 97-3, Floradade, Edkawi, which belong to *Lycopersicon esculentum*, and LA1383, which belongs to *L. hirsutum*, were used in this study. The ***hirsutum*** line 1383 is known for its high foliage resistance to low temperature and its high capacity to set fruit under such cold condition. Seeds of the different cultivars were obtained from the section of self-pollinated vegetable crops breeding, Department of vegetable crops, Agricultural Research center, Dokki, Egypt. Seeds of hirsutum LA1383 were kindly provided by Dr. Rick Jones. Prof. of plant breeding, University of California, Davis, U.S.A. Plants of all parental genotype were selfed for two generations before starting the research and making the crosses.

Seeds of the different parental genotypes were planted in the nursery separately on February 15, 2000 Ten seedlings per parent were transplanted in the field on April 8, 2000. The following crosses were made between the parental genotypes:-

U.C. 97-3 X LA1383, Floradade X LA1383 and Edkawi X LA1383.

On February 24, 2001, seeds of the different parental genotypes and their F_1's were planted. On April 18, 2001, ten seedlings from each of the parents and F_1's were transplanted in the field separately. The F_1 plants of each cross were saved to obtain the F_2 seeds and backcrossed to each of the two involved parents to obtain seeds of backcross populations .

Seedlings of the different populations, i.e. P_1, P_2, F_1, F_2, Bc_1 and Bc_2 of all crosses were transplanted in the field on November 2, 2001 for evaluating the plants of each population individually .The experimental design used in conducting this experiment was randomized complete block design with three replicates. Each replicate contained one ridge for each of the parental genotypes and their F_1 plants, four ridges for F_2 plants and two ridges for each backcross plants. Ten seedlings were transplanted on one side of each ridge of 3.5 meters length and 90 cm wide, with one seedling per hill at 35 cm a part. All other agriculture practices, i.e. irrigation, fertilization, weed control,...etc., were followed as in the district. Minimum and maximum temperature degrees were recorded daily during the experimental period. The recorded temperature degrees are as follows:

Month	Average recorded temperature (°C)	
	Maximum	Minimum
November	27.00	12.90
December	20.20	11.60
January	19.80	9.90
February	19.70	10.10
March	22.40	10.60
April	35.70	8.80

Foliage cold tolerance

A scale from 1 to 9 was used in evaluating the tolerance level of the individual plants, 10 weeks after transplanting. The evaluation scale used by El-Saka (1997) was modified as follows:

1 = More than 50% of plant leaves were totally or partially burned .

2 = Less than 50% of plant leaves were totally or partially burned .
3 = More than 50% of plant leaves were curled but no sign for any burns .
4 = Less than 50% of plant leaves were curled but no sign for any burns .
5 = More than 50% of plant leaves showed visible anthocyanin pigment (purple colour).
6 = Less than 50% of plant leaves showed visible anthocyanin pigment (purple colour).
7 = Plant leaves showed pale anthocyanin pigment in the top of the plant only.
8 = Plant leaves showed dark green colour with no sign of anthocyanin formation .
9 = Plant leaves were totally healthy with normal colour.

Data recorded

The following characteristics were recorded for the individual plants of the different population:- earliness of flowering, fruit set percentage, number of branches, number of fruits/plant, fruit weight, total yield/ plant and fruit length and diameter .

Sugar content of leaves was determined using the method described by Flood and Priesty (1973).

Photosynthetic pigments and carotenoides were determined in fresh leaves as described in A.O.A.C. (1975).

Statistical Genetic analysis

Means, standard deviation, total variance and type of inheritance were calculated as described by Briggs and Knowles (1977).

The nature of dominance was determined by calculating the potence ratio (P) using the equation given by Smith (1952).

$$\text{Potence ratio (P)} = \frac{F_1 - M.P.}{1/2(P_2 - P_1)}$$

Where:

F_1 = F_1 mean, P_1 = The smaller parent mean, P_2 = The larger parent mean, and M. P. = Mid parent value = $\frac{1}{2}(P_2 + P_1)$

Broad sense heritability (BSH) was estimated by the following method which was described by Allard (1960).

$$BSH = \frac{VF_2 - (VF_1 + VP_1 + VP_2)/3}{VF_2} X100$$

Narrow sense heritability (NSH) was estimated after Mather and Jinkes (1971).

$$NSH = \frac{2VF_2 - (VBc_1 + VBc_2)}{VF_2} X100$$

Whereas:-

VF_1 = Variance of the first generation, VF_2 = variance of the second generation, VP_1 = variance of the first parent, VP_2 = variance of the second parent, VBc_1 = variance of the first backcross, and $V\ Bc_2$ = variance of the second backcross.

The minimum number of the gene pairs differentiating the two parents was estimated using the method given by Castle and Wright (1921).

$$N = \frac{D^2}{8(VF_2 - VF_1)}$$

Where : -

N = minimum number of gene pairs by which the parental differ, D = Mean of larger parent-Mean of smaller parent, VF_2 = variance of F_2 population, and VF_1 = variance of F_1 population.

Estimates of the mean and its standard deviation and total variance of the studied characters for all populations were calculated using the methods described by Briggs and Knowles (1977).

Coefficients of correlation between different characters in F_2 populations and multiple regression analyses were performed using the methods described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Foliage cold tolerance

The results presented in Table (1) indicated significant differences among the different parental germplasm concerning the degree of foliage cold tolerance. On a scale ranged from 1 (susceptibility) to 9 (tolerance), the parental LA1383 had the highest degree of foliage cold tolerance (8.23), followed by cv. Floradade (3.73), cv. Edkawi (3.03) and cv. UC.97-3 (2.23). Based on these results, the parental LA1383 can be considered as good source for the useful genes controlling foliage cold tolerance in tomato plants.

Table 1. Frequency distribution for foliage cold tolerance in the parents, F_1, F_2, Bc_1 and Bc_2 of some tomato interspecific crosses.

Population	Scale									Total No.of plants	Mean SE.	Variance
	1	2	3	4	5	6	7	8	9			
Edkawi(P1)	-	10	7	13	-	-	-	-	-	30	3.03 1.12	1.61
LA1383(P2)	-	-	-	-	-	-	5	10	15	30	8.23 1.12	0.81
F_1	-	-	-	-	5	10	14	1	-	30	6.37 1.12	0.66
F_2	10	11	15	12	15	17	23	13	4	120	6.59 o.56	80.60
Bc1(F1XP1)	5	10	23	19	3	-	-	-	-	60	3.08 0.79	50.02
Bc2(F1XP2)	-	-	-	1	4	10	18	22	5	60	7.18 0.79	50.28
L.S.D. 0.05 0.01											4.43 4.83	
Floradade(P1)	-	-	14	7	9	-	-	-	-	30	3.73 0.38	1.23
LA1383(P2)	-	-	-	-	-	-	5	10	15	30	8.23 0.38	0.81
F_1	-	-	-	-	10	10	9	1	-	30	6.03 0.38	0.79
F_2	10	12	11	11	13	24	16	15	8	120	4.64 0.19	7.34
Bc1(F1XP1)	1	3	6	9	10	10	9	8	4	60	5.57 0.27	5.04
Bc2(F1XP2)	-	3	9	5	9	10	11	9	4	60	5.72 0.27	5
L.S.D. 0.05 0.01											2.88 3.13	
U.C.97-3(P1)	10	11	3	6	-	-	-	-	-	30	2.23 0.35	1.56
LA1383(P2)	-	-	-	-	-	-	5	10	15	30	8.23 0.35	0.81
F_1	-	-	-	2	4	9	9	6	-	30	6.43 0.35	5.37
F_2	9	14	14	11	14	15	18	16	9	120	5.03 0.18	6.6
Bc1(F1XP1)	-	5	14	11	14	3	5	8	-	60	4.72 0.25	5.42
Bc2(F1XP2)	-	-	1	7	12	14	14	10	2	60	6.18 0.25	4.02
L.S.D. 0.05 0.01											2.19 2.88	

Differences among *L. esculentum* cultivars concerning foliage cold resistance have been reported (Radwan *et al* 1986, Kamps *et al* 1987 and Foolad and Lin 2001). The *L. esculentum* cultivars Super Marmande and Marmande were reported to be cold tolerant (Agwah and Mahmoud 1994 and Khan *et al* 1995). EL-Saka (1997) found that there were significant differences in the degree of foliage cold tolerance between cultivar Super Marmande and each of the tomato genotypes Castle Rock and UC. 97-3.

The relative potence ratio (P) values were 0.28 for the interspecific cross Edkawi X LA1383, 0.02 for the interspecific cross

Floradade X LA1383 and 0.40 for the interspecific cross UC. 97-3 X LA1383 (Table 2). This indicated that the high level of foliage cold tolerance was partially dominant over the low level of cold tolerance. This result can be supported by the result of Kamps *et al* (1987) who made intergeneric crosses between *L. esculentum* and *Solanum lycopersicoides* to study the inheritance of resistance to chilling injury and suggested dominant nuclear gene control for this character. Moreover, Foolad and Lin (2001) indicated that the variation among generations with regard to cold tolerance was genetically controlled, with additive effects.

Table 2. Potence ratio, broad and narrow sense heritability and minimum number of effective gene pairs estimates for some tomato interspecific crosses .

Characters / Crosses	Foliage cold tolerance				Fruit set percentage				Total yield / plant			
	P.ratio	B.S.H.	N.S.H.	No. of gene pairs	P.ratio	B.S.H.	N.S.H.	No. of gene pairs	P.ratio	B.S.H.	N.S.H.	No of gene pairs
Edkawi X LA1383	0.28	98.73	75.56	1	-0.64	78.18	48.49	2	0.56	60.40	15.63	4
Floradade X LA1383	0.02	87.19	63.22	1	-0.74	72.01	53.39	3	-1.08	97.02	51.32	1
U.C.97-3 X LA1383	0.49	60.91	56.97	4	-0.23	82.57	19.96	3	1.26	49.49	6.49	2

The F_1 hybrids of all crosses (Table 1) had intermediate degree of foliage cold tolerance between the two parents indicating that resistance to cold was dominant over the low level of cold tolerance. The frequency distribution of F_2, Bc_1 and Bc_2 of different interspecific crosses (Table 1) indicated a quantitative inheritance pattern for foliage cold tolerance. This result can be supported by Vallejos (1979) who mentioned that the physiological disorder caused by low temperature is complex phenomenon. In addition, Daubeny (1959) reported that the development of tomato plants at low temperature was not a simple character. EL-Saka (1997) showed that the frequency distribution for foliage cold tolerance in the F_2 of some crosses between *L. esculentum* genotypes indicated quantitative inheritance pattern for foliage cold tolerance.

The broad sense heritability estimates for foliage cold tolerance ranged from intermediate (60.91%) to high (98.73%) in the different interspecific crosses (Table 2). The same data in Table (2) revealed that all used interspecific crosses had values above 60.91% and 56.97% for broad and narrow sense heritability, respectively. Such results indicated that the greater part of phenotypic variance was due to genetic variance. These results indicated the possibility of achieving success in selecting for high foliage cold tolerance in the segregating generations of the crosses between *L. esculentum* and *L. hirsutum*. In addition, it may be suggested that selection would be effective for this character in all interspecific crosses under study. In this respect, EL-Saka (1997) mentioned that the broad sense heritability estimates ranged from 74.69% to 91.23% while the estimates of the narrow sense heritability ranged from 5.09% to 77.54% in some crosses between *L. esculentum* genotypes.

The minimum number of effective gene pairs controlling cold tolerance in tomato plants ranged from 1 to 4 (Table 2) Similar findings were obtained by EL-Saka (1997) who found that the number of the major effective genes controlling foliage cold tolerance ranged from 1 to 2 gene pairs.

Fruit set percentage

The parental LA1383 had the highest fruit set values (84.65%) followed by cv.Edkawi (43.78 %), cv. Floradade (31.44%) and cv. UC. 97-3 (26.90%) (Table 3). The differences between the parental genotypes were highly significant. This conclusion is supported by Robinson and Echim (1988) who found considerable variation among 200 cultivars and breeding lines of *L. esculentum*. In addition, the presence of *L esculentum* genotypes which show high fruit set under low temperature have been reported (Radwan *et al* 1986, Agwah and Mahmoud 1994 and Fernandez-Munoz *et al* 1995)

The potence ratio (P) values were – o.64 ,- 0.74 and – o.23 for the interspecific crosses Edkawi X LA1383, Floradade X LA1383 and UC. 97-3 X LA1383, respectively (Table 2). These results indicated partial dominance for the low fruit set percentage under low temperature conditions in the different interspecific crosses. These results agree with those of Kemp (1966) who found that the highest percentage of fruit set of *L. esculentum* genotypes at low night temperature (40 F) was recessive. On the other hand, Ibrahim (1984) found partial dominance for high percentage of fruit set under low temperature conditions.

Fruit set percentage under low temperature conditions was found to be inherited quantitatively, based on the frequency distribution of this character in the F_2, Bc_1 and Bc_2 populations of the studied interspecific crosses (Table 3). Similar quantitative inheritance pattern has been reported by Ibrahim (1984) who found that the ability of tomato plants to fruit set under low temperature conditions was inherited quantitatively. On the other hand, Kalloo and Baberjee (1990) observed quantitative inheritance pattern for percentage of fruit set under low temperature in the segregating generation of crosses between *L. esculentum* and *L. pimpinellifolium*.

Table 3. Frequency distribution for fruit set percentage under low temperature conditions in the parents, F_1, F_2, Bc_1 and Bc_2 populations of some tomato interspecific crosses.

Population	Upper class limits (%)									Total No. of plants	Mean SE	Variance
	10	20	30	40	50	60	70	80	90			
Edkawi(P1)	-	-	-	10	14	6	-	-	-	30	43.78 2.5	56.89
LA1383(P2)	-	-	-	-	-	-	-	7	23	30	84.65 2.5	28.84
F_1	-	-	-	-	23	7	-	-	-	30	51.05 2.5	13.99
F_2	-	2	7	24	40	16	14	8	9	120	57.18 1.25	152.31
Bc1(F1XP1)	-	6	14	22	14	4	-	-	-	60	35.87 1.77	164.35
Bc2(F1XP2)	-	-	-	-	6	6	20	28	-	60	66.93 1.77	66.42
L.S.D. 0.05 0.01											15.49 20.40	
Floradade(p1)	-	5	4	21	-	-	-	-	-	30	31.44 2.93	50.69
LA1383(p2)	-	-	-	-	-	-	-	7	23	30	84.65 2.93	28.84
F_1	-	-	-	15	9	6	-	-	-	30	38.33 2.93	226.20
F_2	-	17	22	29	25	10	7	7	3	120	38.75 1.47	364.05
Bc1(F1XP1)	-	14	2	18	10	16	-	-	-	60	40.30 2.07	319.69
Bc2(F1XP2)	-	-	-	29	17	4	6	4	-	60	42.76 2.07	214.04
L.S.D 0.05 0.01											18.18 23.93	
U.C.97-3(P1)	-	11	9	10	-	-	-	-	-	30	26.90 2.46	35.16
LA1383(P2)	-	-	-	-	-	-	-	7	23	30	84.65 2.46	28.84
F_1	-	-	-	11	8	11	-	-	-	30	49.02 2.46	67.40
F_2	2	15	15	42	31	6	4	2	3	120	39.47 1.23	243.67
Bc1(F1XP1)	-	4	8	18	12	4	14	-	-	60	46.22 1.74	345.59
Bc2(F1XP2)	**-**	**-**	**1**	**26**	**30**	**1**	**1**	**1**	**-**	**60**	**43.38 1.74**	**93.12**
L.S.D. 0.05 0.01											**15.24 20.06**	

The broad sense heritability estimates for fruit set percentage were 78.18, 72.01 and 82.57 and the narrow sense were 48.49, 53.39 and 19.96 for the interspecific crosses Edkawi X LA1383, Floradade X LA1383 and UC. 97-3 X LA1383, respectively (Table 2). Such estimates give an indication for the validity of selection to improve this character. These results corroborate those of EL-Saka (1997) who found that the broad sense heritability estimates ranged from 93.72% - 96.40% in some crosses between *L. esculentum* genotypes.

The minimum number of gene pairs controlling the fruit set percentage ranged from 2 to 3 gene pairs (Table 2). These result agreed with those reported by Kemp (1966) who reported that fruit set of *L.esculentum* genotypes at night temperature of 40 F was found to be controlled by one recessive gene pair. Also, EL-Saka (1997) showed that one gene pair was found to be controlling fruit set under low temperature.

Total yield per plant

Highly significant differences were observed between the parental genotypes LA1383, Edkawi, Floradade and UC. 97-3 concerning total yield/plant (Table 4) under low temperature conditions. Line 1383 gave the highest yield per plant (2315.5g). However, the other parental genotypes Edkawi, Floradade and UC. 97-3 gave 1212.67, 1676.33 and 849.5 g per plant, respectively. These results indicated that the parental LA1383 was the most tolerant genotype to low temperature as explained by its relatively high total yield per plant obtained under low temperature conditions. These findings corroborate that of EL-Saka (1997) who mentioned that highly significant differences were observed between the *Lycopersicon* parental genotypes, *i.e.*, Super Marmande, Castle Rock, UC. 97-3, Line 3 and Floradade concerning total yield/plant.

The potence ratio (P) calculated for the total yield/plant under low temperature conditions in the different interspecific crosses (Table 2) indicated partial dominance for high yield in the interspecific cross Edkawi X LA1383 and for low yield in the cross Floradade X LA1383 as well as over dominance in the cross UC. 97-3 X LA1383. These results are in accordance with those reported by EL-Saka (1997) who found partial dominance for both low and high yield under low temperature conditions, in some crosses between *L. esculentum* genotypes. Such differences in nature of dominance for total yield/plant under low temperature conditions are environmental effects on this characters.

The frequency distribution for total yield/plant in the F_2, Bc_1 and Bc_2 populations in the different interspecific crosses (Table 4) showed continuous variation in the expression of this character which indicates quantitative inheritance pattern for this character. Therefore, the obtained results are similar to those reported by EL-Saka (1997) who indicated that a quantitative inheritance pattern for total yield/plant under low temperature conditions was observed.

The broad sense heritability estimates for total yield/plant ranged from intermediates (49.49%) to high (97.02%) in the different interspecific crosses (Table 2). Narrow sense ranged from low (6.49%) to intermediates (51.32%). These results indicated the possibility of making progress through selection for this character. These results agree with those reported by EL-Saka (1997) who mentioned that the values of the broad sense heritability for total yield/plant ranged from 25.95% to 68.74% in some crosses between *L. esculentum* genotypes.

The minimum number of gene pairs controlling the total yield per plant of tomato ranged from 1 to 4 gene pairs (Table 2). Obtained results were supported by those of EL-Saka (1997) who mentioned that number of major genes controlling total yield per plant under cold conditions ranged from 3 to 39 gene pairs.

Simple correlation

Highly significant positive correlation was detected between foliage cold tolerance and each of chlorophyll-a and b, carotenoides, reducing sugars, non-reducing sugars and total sugars in the interspecific crosses Edkawi X LA1383 and Floradade X LA1383 (Table 5). This result agreed with those of Dolstra *et al* (2002) who found significant chloroplast – related differences in photosynthetic performance under low temperature. Moreover, significant positive correlation was found

Table 4. Frequency distribution of P_1, P_2, F_1, F_2, Bc_1 and Bc_2 populations for total yield/plant (g) under low temperature conditions for the different tomato interspecific crosses.

Population	Upper class limit (g.)												Total No of plants	Mean SE	Variance
	400	800	1200	1600	2000	2400	2800	3200	3600	4000	4400	4800			
Edkawi (P1)	-	8	3	19	-	-	-	-	-	-	-	-	30	1212.67 250.6	115504.8
LA:1383(P2)	-	-	-	-	-	-	14	9	7	-	-	-	30	2315.5 250.6	421863.2
F_1	-	-	-	4	13	3	10	-	-	-	-	-	30	2074.0 220.56	2551111.7
F_2	-	8	16	27	46	13	1	1	1	1	6	-	120	1833.9 125.3	2599735.4
Bc1(F1 X P1)	-	-	19	30	11	-	-	-	-	-	-	-	60	1626.0 177.2	4022752.3
Bc2(F1 X P2)	-	6	12	6	11	5	5	12	2	1	-	-	60	1938.1	770410.0
L.S.D. 0.05 0.01														517.67 681.42	
Floradade(P1)	-	-	9	4	7	10	-	-	-	-	-	-	30	1676.3 418.4	364948.9
LA:1383(p2)	-	-	-	-	-	-	14	9	7	-	-	-	30	2315.5 418.4	421863.2
F_1	-	-	-	17	4	9	-	-	-	-	-	-	30	1649.7 418.4	196328.8
F_2	-	1	13	21	21	6	14	14	10	4	4	12	120	3012.1 209.2	11004669.0
Bc1(F1 XP1)	-	5	9	12	9	11	8	1	1	4	-	-	60	2252.7 295.9	4067845.3
Bc2(F1XP2)	-	-	11	11	20	10	4	3	1	-	-	-	60	1937.6 295.9	1289473.8
L.S.D. 0.05 0.01														548.35 653.44	
UC.97-3(P1)	-	20	10	-	-	-	-	-	-	-	-	-	30	849.5 128.4	35713.4
LA:1383(p2)	-	-	-	-	-	-	14	9	7	-	-	-	30	2315.5 128.4	421863.2
F_1	-	-	-	-	8	3	6	13	-	-	-	-	30	2507.7 128.4	418311.4
F_2	-	16	17	32	29	15	7	1	3	-	-	-	120	1631.8 64.2	578040.9
Bc1(F1XP1)	-	4	13	17	15	6	1	1	3	-	-	-	60	1664.1 90.8	807679.7
Bc2(F1XP2)	2	3	4	24	24	1	1	1	-	-	-	-	60	1536.4 90.8	310873.2
L.S.D. 0.05 0.01														265.22 349.12	

between foliage cold tolerance and total yield/plant in the interspecific cross Floradade X LA1383. This relationship could be partially due to the relatively high biological efficiency, especially concerning photosynthesis, of the plants with high level of foliage tolerance to low temperature. However, foliage cold tolerance was negatively correlated with each of earliness, fruit weight and fruit length in the same interspecific crosses. The observed significant positive correlations between foliage cold tolerance and sugars percentage in the crosses is supported by the findings of Keller and Steffen (1995) who mentioned that during chilling treatments, levels of soluble sugars per leaf dry weight increased and suggested the involvement of soluble sugar levels in acclimatization to chilling. In addition, many investigators found that there were high relationship between foliage cold tolerance and each of chlorophyll and sugars content in plant leaves (Levitti 1980, Maisonneuve *et al* 1986, Kamps *et al* 1987, Byrd *et al* 1995, Gusta *et al*

1996 and EL-Saka 1997).

Fruit weight was negatively correlated with each of chlorophyll-a and b, carotenoides, reducing sugars, non-reducing sugars and total sugars. However, it was positively correlated with fruit length and diameter in the interspecific crosses Edkawi X LA1383 and Floradade X LA1383 (Table 5).

Highly significant positive correlation was observed in the F_2 population of the interspecific cross Edkawi X LA1383 between total yield/plant and each of chlorophyll-a and b, carotenoides, reducing sugars, non-reducing sugars and total sugars. This relationship seems to be logic because the relatively high tolerance of plant foliage under low temperature will result in high biological efficiency of the plant which will have positive effects on the total yield/plant and its components. In this regard, EL-Saka (1997) found that there were significant positive correlation between total yield/plant under low temperature conditions and foliage cold tolerance.

Multiple correlation

Concerning total yield per plant as the dependent variable in the cross Edkawi X LA1383, the combined effect of fruit weight, number of fruits/plant, fruit length and diameter was found to have highly significant relationship with total yield/plant under low temperature condition. In addition, significant relationship was found between total yield / plant and number of branches/plant (Table 6).

The value of R squared was 0.47 which indicates that 47% of the variation in total yield/plant observed in the F_2 plants was related to a relationship between total yield/plant and the combined effect of fruit weight, number of fruits/plant, fruit length and diameter and number of branches/plant. The value of multiple correlation coefficient was 0.68. The previously mentioned characters together will have a direct or indirect effect on total yield/plant under low temperature condition. These results were agree with those reported by EL-Saka (1997) who found that, concerning the cross Super Marmande X Floradade, significant correlation was observed between total yield/plant and the combined effect of number of branches/ plant, number of fruit/plant and fruit weight. Whereas, the multiple R was 0.87 and R squared was 0.76.

Table 5. Coefficient of correlation values (r) of different characters for some Interspecific crosses.

Crosses	Characters	Earliness	No of branches / plant	Fruit weight	Fruit length	Fruit diameter	Total yield / plant	Chlorophyll-a	Chlorophyll-b	Carotenoides	Reducing sugars	Non-reducing sugars	Total sugars
Edkawi X LA1383	Cold tolerance	** -0.265	0.038	** -0.325	** -0.313	-0.054	0.168	** 0.278	** 0.250	** 0.320	** 0.320	** 0.326	** 0.297
	Earliness		0.103	-0.150	0.098	* -0.191	0.095	** 0.529	** 0.490	** 0.491	** 0.463	** 0.413	** 0.466
	No of branches/plant			** -0.215	** -0.240	** -0.355	0.167	0.135	0.133	0.121	0.112	0.108	0.118
	Fruit weight				* 0.263	** 0.262	** 0.245	** -0.357	** -0.377	** 0.346	** 0.393	** -0.379	** -0.379
	Fruit length					** 0.635	-0.036	-0.074	-0.055	-0.104	-0.104	-0.022	-0.047
	Fruit diameter						* 0.179	-0.140	-0.113	-0.122	-0.000	* -0.186	* -0.173
	Total yield / plant							** 0.472	** 0.526	** 0.468	** 0.498	** 0.338	** 0.415
	Chlorophyll-a								** 0.949	** 0.968	** 0.923	** 0.776	** 0.980
	Chlorophyll-b									** 0.897	** 0.878	** 0.854	** 0.940
	Carotenoides										** 0.978	** 0.658	** 0.811
	Reducing sugars											** 0.584	** 0.758
	No-reducing sugars												** 0.972
Floradade X LA1383	Cold tolerance	** -0.317	0.108	** -0.503	** -0.261	-0.106	* 0.205	** 0.969	** 0.922	** 0.972	** 0.345	** 0.851	** 0.910
	Earliness		-0.028	0.098	0.149	-0.075	-0.032	** -0.302	** -0.327	** -0.277	-0.168	* -0.194	** -0.259
	No of branches			-0.050	-0.105	** -0.200	0.112	0.099	0.048	0.129	-0.138	** 0.208	0.108
	Fruit weight				** 0.282	* 0.195	0.090	** -0.436	** -0.454	** -0.450	** -0.246	** -0.417	** -0.486
	Fruit length					** 0.695	0.063	-0.167	** -0.221	-0.149	-0.168	-0.084	-0.156
	Fruit diameter						-0.022	-0.098	-0.135	-0.063	-0.022	-0.003	-0.014
	Total yield / plant							* 0.202	* 0.184	* 0.208	0.086	* 0.184	* 0.196
	Chlorophyll-a								** 0.942	** 0.986	** 0.276	** 0.835	** 0.861
	Chlorophyll-b									** 0.912	** 0.509	** 0.665	** 0.828
	Caroteneides										** 0.276	** 0.897	** 0.912
	Reducing sugars											-0.020	** 0.507
	Non-reducing sugars												** 0.870

Significant at 5% level of significance

Significant at 1% level of significance

Table 6. Multiple regression coefficients between foliage cold tolerance and other characters in the interspecific cross Edkawi X LA1383.

Involved dependent variables	R-square	Multiple reg.	Significance
Number of branches/plant	0.467	0.683	*
No. of fruits/plant			**
Fruit weight			**
Fruit length			**
Fruit diameter			**

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توريث و طبيعة توريث مقاومة البرودة في الطماطم

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تم إجراء تهجين نوعي بين ثلاث أصناف من الطماطم و هي الإدكاوى و الفلوريدات و اليوسى ٩٧-٣ (وهي تابعة للنوع *L. esculentum*) مع السلالة ١٣٨٣ (وهي تابعة للنوع *L. hirsutum*) و ذلك لدراسة توريث و طبيعة السيادة لصفة المقاومة للبرودة. كل العشائر المتحصل عليها و هي الأب الأول و الأب الثاني و نباتات الجيل الأول و نباتات الجيل الثاني و نباتات التهجين الرجعي الأول و نباتات التهجين الرجعي الثاني و ذلك لكل الهجن النوعية الممكن الحصول عليها من التهجين بين الأصناف و السلالة السابقة تم تقييمها في تجربة حقلية كنباتات فردية.

أوضحت النتائج انه توجد اختلافات وراثية بين الآباء المختلفة المستخدمة في التهجين في صفة مقاومة المجموع الخضري للبرودة و نسبة العقد و المحصول الكلي للنبات. وكان توريث صفة المقاومة للبرودة و نسبة عقد الثمار و المحصول الكلي للنبات توريثاً كمياً.

وجد أن المستوى العالي من المقاومة للبرودة سائد سيادة جزئية على المستوى المنخفض من المقاومة. ووجد أن نسبة عقد الثمار المنخفضة كانت سائدة سيادة جزئية على نسبة العقد العالية تحت ظروف الجو البارد. كما وجد أن المحصول الكلي العالي للنبات كان سائداً سيادة فائقة على المحصول المنخفض في الهجين النوعي يوسى٩٧-X٣ السلالة١٣٨٣. تم تقدير درجة التوريث بمعناها الواسع لصفة مقاومة المجموع الخضري للبرودة كانت ٩٨,٧٣% - ٨٧,١٩% - ٦٠,٩١% بينما درجة التوريث بمعناها الضيق كانت ٧٥,٥٦%-٦٣,٢٢% - ٥٦,٩٧% و ذلك للهجن النوعية إدكاوى X السلالة١٣٨٣ - فلوريدا X السلالة١٣٨٣- اليوسى٩٧-X٣ السلالة١٣٨٣ و ذلك بنفس الترتيب. وجد أن اقل عدد للجينات التي تتحكم في صفات مقاومة المجموع الخضري للبرودة و نسبة عقد الثمار

و المحصول الكلى للنبات تحت ظروف البرودة كانت ١ – ٤, ٢ – ٣, ١– ٤ أزواج من الجينات بنفس الترتيب٠

وجدت علاقة معنوية موجبة بين مقاومة المجموع الخضري للبرودة والمحصول الكلى للنبات. بالرغم من ذلك لقد وجدت علاقه معنوية سالبه بين مقاومة المجموع الخضري للبرودة وكل من التبكير في الأزهار – وزن الثمرة – طول الثمرة وذلك في الهجن النوعية ادكاوى X السلالة ١٣٨٣ و فلوريدات X السلالة ١٣٨٣. وجدت علاقة موجبة عالية المعنوية بين مقاومة المجموع الخضري للبرودة والمحتوى الكيماوي للمجموع الخضري من كلوروفيل أ و ب – الكاروتينات الكلية – السكريات المختزلة – السكريات الغير مختزله – السكريات الكلية. علاوة على ذلك هناك ارتباط موجب عالي المعنوية لتأثير كل من وزن الثمرة وعدد ثمار النبات وطول وقطر الثمرة على المحصول الكلى للنبات تحت ظروف البرودة.

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