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INHERITANCE OF SOME FRUIT CHARACTERS AND RESISTANCE TO ROOT-KNOT NEMATODE, *MELOIDOGYNE INCOGNITA*, IN TOMATO (*SOLANUM LYCOPERSICUM*, L.)

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ABSTRACT: *This study was carried out at the Experimental Farm, Faculty of Agriculture, Menoufia University, Shibin El-Kom during three summer seasons. The cultivar Super Beef Steak and the line Bl-15 were used as parents to produce the required populations, i.e., F_1, F_2 and Bcp_1 and Bcp_2. The six populations were evaluated for number of days to the first ripe fruit, average fruit weight, total soluble solids and ascorbic acid content, as well as, resistance to the root knot nematode, Meloidogyne incognita. A randomized complete blocks design was used. Data were recorded on an individual plant for each population. Regard to the resistance to root knot nematode, the experiment was carried out in pots. Data obtained suggested that the number of days to ripening showed over-dominance for the short period. Total soluble solids and ascorbic acid contents are controlled by additive gene with slight dominance for the low contents. Partial dominance for the small fruit was found. With regard to root knot nematode resistance, the character is controlled by single dominant gene for low number of galls and egg masses. Therefore, developing of tomato cultivars and F_1 hybrids for resistance could be achieved by breeding programs.*

Key words: *Dominance, partial dominance, additive, segregation, egg masses and gall number, genetic advance.*

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae, which is believed to consist of 96 genera and over 2800 species distributed in three subfamilies: Solanoideae (to which Solanum belongs), Cestroideae and Solanineae (Knopp *et al.,* 2004).

Today fruit quality and disease resistance are a major focus of most breeding programs. The major fruit quality traits of interest to both fresh market and processing tomato industries being fruit size, shape, total soluble solids (TSS %) and vitamin C contents, as well as, other characters such as lycopene, β-carotene, fruit firmness and flavor (Foolad, 2007).

The inheritance and type of gene actions of earliness were studied by several investigators. Nassar (1988) reported that about 86% of the variability in early yield among hybrids or cultivars of tomato was dependent on the genotype.

Number of days from transplanting to first ripe fruit was controlled by a single pair of genes with complete dominance of the short period to maturity and requires presence of many minor genes (Ahmed *et al.,* 2006), indicating importance of the additive gene action for controlling this trait and suggesting that selection may be beneficial for improvement the early maturity. The number of days to maturity was controlled by a single pair of genes with dominance to the short period to maturity and presence of some additive gene effects (Midan *et al.,* 2009).

Regarding average fruit weight, positive heterosis was found in some studied (Ahmed *et al.,* 2011). High BSH (96.5%) and genetic advance (52.44) values were observed by Rajesh *et al.* (2006). High heritability associated with high genetic advance were also observed for individual fruit weight by Ghosh *et al.* (2010) and Rajasekhar *et al.* (2013).

Regarding to TSS% content, Khalil *et al*. (1986) found that, the trait was quantitatively inherited with additive gene action and slight dominance of high content. Also, Shirin and Hazra (2013) reported that, additive and dominance components were highly significant and important for conditioning this trait. Heterosis relative to mid-parent (Megahed, 2002 and Masry, 2014) as well as better parent (Singh *et al.,* 2008) were reported for TSS% content. Meanwhile, negative MPH % and no-dominance for this trait were observed by Yashavantakumar (2008) and Mostafa (2015), respectively. The estimated narrow sense heritability (NSH) was moderate (57.43%) as reported by Shirin and Hazra (2013). Both heritability and genetic advance under selection were high (Rajasekhar *et al.,* 2013).

For vitamin C content, all degrees of dominance were observed in different tomato F_1 crosses by many workers. Significant positive MP-heterosis was found by Megahed (2002) and Mostafa (2015). While significant negative MP-heterosis was detected by Tendulkar (1994). Regarding to BP-heterosis, Kumar and Sharma (2011) found positive values. On the other hand, it was significantly negative (Mahendrakar, 2004). The study of Mostafa (2015) revealed partial , complete and over- dominance for the high vitamin C content. High BSH with high genetic advance as percent of mean (GAM) were recorded for vitamin C content, indicating predominance of additive gene action for this character. Simple selection based on phenotypic performance would be more effective (Rajasekhar *et al.,* 2013) for improving this trait.

Concerning the root-knot nematode disease according to Roberts and May (1986) susceptible cultivars loosed until 50% of yield due to infections *M. incognita* in tomato and the resistant cultivars were unaffected. Positive correlation between damage levels of roots, egg mass number and second stage larvae population in the root was significant (Rudi *et al.,* 2012).

Few studies have been conducted on the inheritance of resistance to root-knot nematode in tomato. Khalil and Salem (1983) found that this character was simply inherited with complete dominance of the resistance over susceptibility. They added that BSH was estimated as 62.4%, indicating that selection on the individual plant basis could be successfully to improve resistance level. Mark (1986) also reported that the resistance may be under control of a single gene locus in tomato.

Recently, El-Shennawy and Khalil (2014) stated that both additive and non-additive gene effects were involved in the inheritance of this trait. GCA: SCA ratio revealed that GCA effects were play the main role, indicating that the resistance degree could be improved by selection.

MATERIALS AND METHODS

This study was conducted at the Experimental Farm, Faculty of Agriculture, Menoufia University, Shibin El-Kom, Egypt during three summer seasons, (2014 - 2016). In the first season two parental genotypes, i.e., Super Beef Steak cultivar and Cherry line (BL- 15), which were widely differed in their traits and have high degree of homogeneity were used in the study. The seedlings were transplanted in the field and the crossing was made between the two parents to produce the F_1 seeds. The F_1 and the two parents were grown in the second season. The F_1 plants were selfed and backcrossed to both parents to develop the required F_2 and backcrosses seeds. In the third season (2016), the six populations, i.e., P_1, P_2, F_1, F_2, Bcp_1 and Bcp_2 were grown in a field experiment to evaluate some characters i.e., number of days from transplanting to fruit ripening, average fruit weight, total soluble solids (TSS%) and ascorbic acid contents (vitamin C).

A randomized complete blocks design with three replicates was used. Each replicate of the six populations was represented by 1-4 ridges, the ridge contains 10 plants. The number of ridges was, one for each of the non-segregating populations, three for each of Bcp_1 and Bcp_2 and four for the F_2 populations. The ridge was 4 meters long and 1 meter wide with spacing of 40 cm within plants. Fertilization, irrigation, disease and insect control programmes were carried out as usual in tomato.

Data were recorded on an individual plant of each population regarding the studied characters (number of days from transplanting) to the first ripe fruit, average fruit weight, total soluble solids (TSS) and ascorbic acid (vitamin C) contents. The latter three characters were determined at the third harvest for five fruits per plant.

In the same season (2016), pots experiment were carried out to test the degree of resistance to root-knot nematode disease for the six populations. Two seedlings (five weeks old) of each population were planted in plastic pots (25 cm diameter) filled with 4 kg of sterilized soil. A Randomized Complete Blocks Design with three replicate was used. Total number of plants for each population were 30 for the non-segregating populations, 90 for each backcross and 108 for F_2 populations.

Two-months-old night shade (*Solanum nigrum* L.) infected roots with *Meloidogyne incognita* was washed with tap water to remove adhering soil particles, cut into small pieces (approximately 1-2 cm) and vigorously shaken in a bottle containing 0.5% NaOCl for 3 min according to Hussey and Barker (1973). After that the eggs were collected on 38 µm sieve and washed in a beaker. The egg suspension was transferred to Baermann trays with soft tissue paper at room temperature to allow egg hatching. After 96 hours, the freshly hatched second stage juveniles were standardized and concentrated.

After one week, 1000 J_2 *M. incognita* were added by pipette around each seedling. Pots were irrigated as needed and fertilized every three weeks, Greinzet NPK solution (50 ml / 10 liters water) either added to the soil or sprayed on the leaves (50 ml/pot). The experiment was terminated eight weeks after planting. At the end of experiment, the response of genotypes to nematode infection was rating based on number of gall scale (Table 1), according to Taylor and Sasser (1978).

Statistical analysis:

Data were statistically analyzed using the standard method of a Randomized Complete Blocks Design (R.C.B.D), illustrated by Al-Rawi and Khalf-Allah (1980). The least significant difference (L.S.D) was used to test the significance of differences among the various means (Snedecor and Cochran, 1973).

Table (1). Modified rating scale for the assessment of level of resistance or susceptibility based on number of galls.

Number of galls	Galling index	Resistance rating
0	0	Immune (I)
1-2	1	Highly resistant (HR)
3-10	2	Resistant (R)
11-30	3	Moderately resistant (MR)
31-70	4	Moderately susceptible (MS)
71-100	5	Susceptible (S)
> 100	6	Highly susceptible (HS)

Heterosis percentages: Heterosis relative to mid- parents (MPH%) and better parent (BPH%) were estimated, according to Mather and Jinks (1971)

Potence ratio (P): This parameter which determine the nature of dominance and its direction was estimated according to Smith (1952).

The genetic parameters, coefficient of variance (C.V. %), Additive variance ($^1/_2$ D), dominance variance ($^1/_4$ H), broad and narrow sense heritability (BSH and NSH), predicted gain under selection (ΔG) and genetic advance under selection (ΔG%) were calculated according to Singh and Chaudhary (1995).

RESULTS AND DISCUSSION

The obtained results showed significant differences between the two parental genotypes in all studied characters. The analysis of variance of population means showed no significant differences at 5% level of significance among the replications for the studied traits. Therefore, data of the three replications of each population were pooled and handled for the genetic analysis. The estimated coefficient of variance (C.V.%) of the studied populations for all studied characters showed that the non- segregating populations, i.e., P_1, P_2 and F_1 were the least variable comparing with the segregating ones, i.e., F_2 , Bcp_1 and Bcp_2. This could be explained by the high homogeneity of the parents and F_1 plants, meanwhile, the segregating populations consist of homozygous and heterozygous plants.

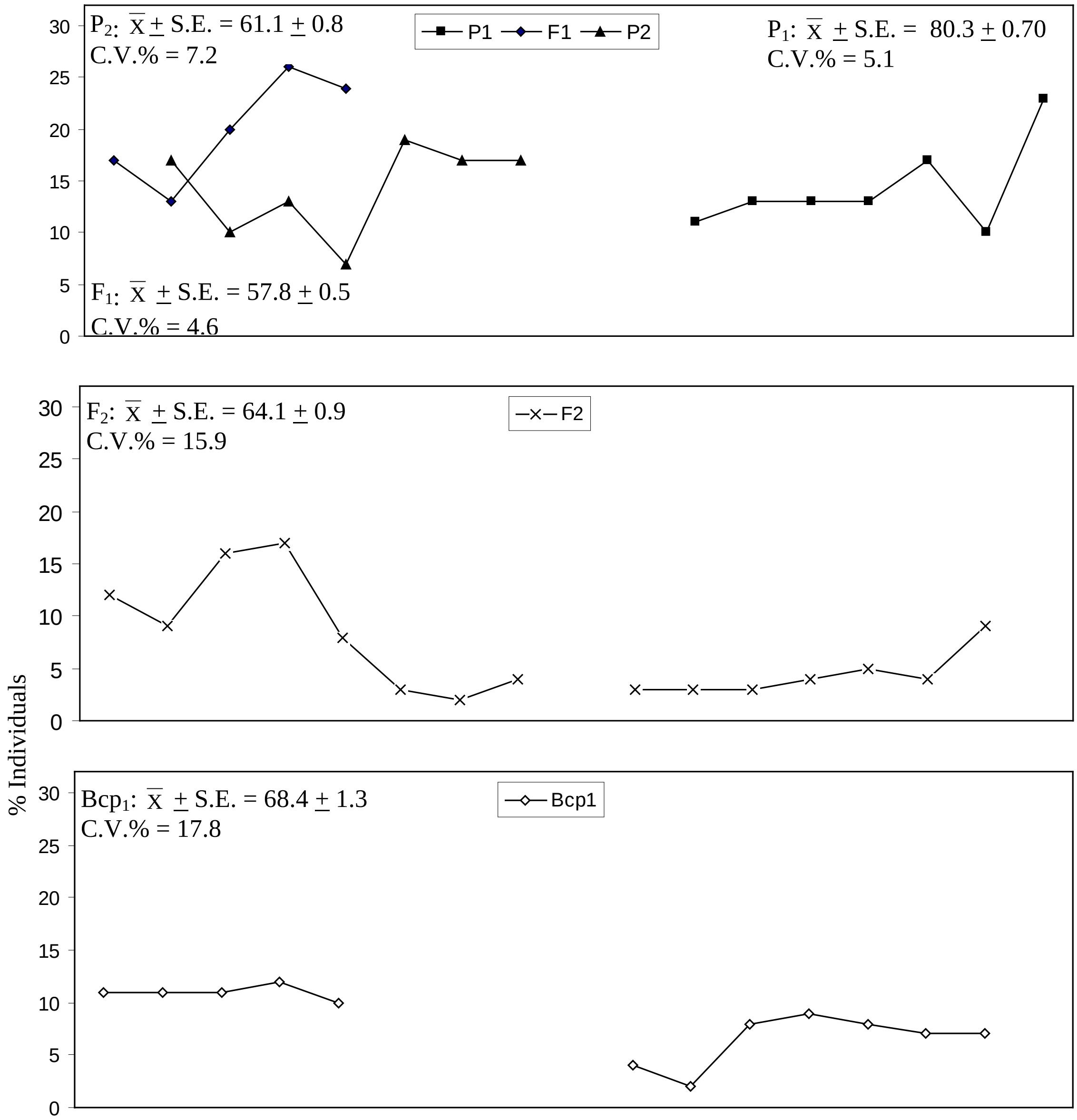
1. Number of days to fruit ripening:

Data of this trait are illustrated in Table (2) and Figure (1). The means of the two parents were 80.3 and 61.1 days for P_1 (Super beef Steak) and P_2 (Bl-15), respectively. This significant difference between the two parents is dependent on genotype as reported by Nassar (1988). The resulted cross (P_1 x P_2) showed mean value of 57.8 days, indicating dominance towards the short period to maturity. The estimated negative mid-parent heterosis (MPH) and better parent heterosis (BPH) (-18.2% and -5.4%, respectively) suggest over dominance for the short period to maturity which confirmed by potence ratio value (1.3). The dominance of the short period to maturity was also found in tomato by Midan *et al.* (2009).

Table (2). Means and coefficient of variance for number of days to fruit ripening and average fruit weight in the six tomato populations.

Character / Population	Number of days to fruit ripening			Average fruit weight (gm)		
	Obtained mean ± S.E.	Theoretical mean	c.v.%	Obtained mean + S.E.	Theoretical mean	c.v.%
P_1	80.3 ± 0.7	-	5.1	159.9 ± 0.6	-	2.1
P_2	61.1 ± 0.8	-	7.2	12.8 ± 0.4	-	9.6
F_1	57.8 ± 0.5	70.7	4.6	28.8 ± 0.6	86.4	12.3
F_2	64.1 ± 0.9	64.3	15.9	23.8 ± 0.9	72.1	42.7
Bcp_1	68.4 ± 1.3	69.0	17.8	35.1 ± 0.9	94.4	25.8
Bcp_2	58.3 ± 0.3	59.5	3.9	7.4 ± 0.7	20.8	40.5
L.S.D. at 0.05	2.40			3.40		

0.01	3.5			4.76		



P2: x̄ ± S.E. = 61.1 ± 0.8
C.V.% = 7.2
P1
F1
P2
P1: x̄ ± S.E. = 80.3 ± 0.70
C.V.% = 5.1
F1: x̄ ± S.E. = 57.8 ± 0.5
C.V.% = 4.6
F2: x̄ ± S.E. = 64.1 ± 0.9
C.V.% = 15.9
F2
% Individuals
Bcp1: x̄ ± S.E. = 68.4 ± 1.3
C.V.% = 17.8
Bcp1
0
5
10
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25
30

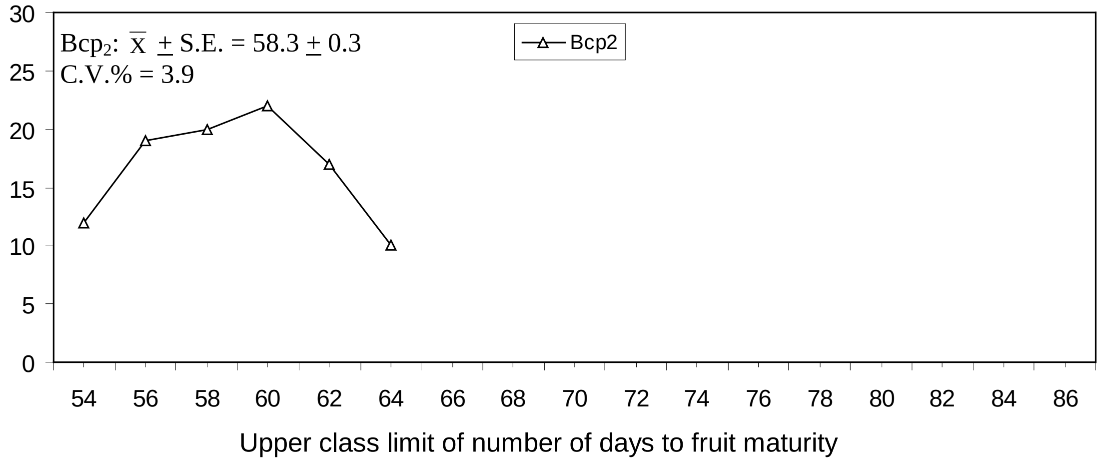


Figure (1). Distributions of number of days to fruit maturity in the six tomato populations.

The average number of days (64.1) of F_2 exceed that of F_1 population with an inbreeding depression (I.D) values -10.9%, this may be due to the over dominance of the short period to maturity which was observed in F_1.

The means of Bcp_1 and Bcp_2 were significantly differed, this could be also explained by the over-dominance of the short period to maturity. It is noticed that the obtained means of F_2, Bcp_1 and Bcp_2 were very close to the theoretical means, suggesting that this character might be simply inherited.

As shown in Figure (1), F_2 plants segregated into two classes with about 70: 30% ratio. The first class was similar to P_2 and F_1 populations and the second class was similar to the latter (recessive) parent in ripening. The ratio is fit a 3:1 using X^2 test with probability of 0.20 – 0.50 and support the mono-genic inheritance.

The Bcp_1 plants segregated into two classes with a ratio of 55: 45%. The first class was distributed within the range of F_1 and P_2, while the second class distributed within the range of P_1 populations. This ratio was fit a 1:1 using X^2 test with a probability of 0.20 – 0.50. On the other hand, the plants of Bcp_2 were distributed within the range of F_1 and P_2 without any segregation, as expected when the character is controlled by single pair of genes with dominance for the short period to maturity. This conclusion is in agreement with that of Midan *et al.* (2009).

Data of Table (3) show that the estimated significant negative MPH%, BPH% and potence ratio values were in accordance with the over-dominance hypothesis. The calculated BSH, NSH, $^1/_2$ D and $^1/_4$ H, indicated that both additive and dominance gene effects are involved in the inheritance of this trait. Furthermore, the estimated ΔG%, genetic advance under selection, showed that considerable progress for early fruit maturity could be achieved by heterosis breeding and selection. It could be concluded that the number of days from transplanting to fruit ripening, in this study, is controlled by single pair of genes with over-dominance of the short period and presence of some additive gene effects and heterosis breeding could be used. This conclusion was also reported by Ahmed *et al.* (2006).

Table (3). Genetic parameters estimated for the studied traits.

Population \ Character	Number of days to fruit maturity	Average fruit weight	TSS	Vitamin C	Number of gall	Number of egg masses
1. MP Heterosis	-18.2**	-66.65**	-11.0**	-0.17	-73.04**	-69.2**
2. BP Heterosis	-5.4**	-81.99**	-27.7**	-29.48	-8.33	-8.0
3. Potence ratio	1.3	-0.78	-0.47	-0.01	1.03	1.04
4. BSH	86.2	82.7	89.8	92.2	96.7	93.14
5. NSH	49.6	32.0	17.8	79.9	61.9	46.49
6. $^{1}/_{2}$ D	51.8	17.0	0.26	47.58	90.21	29.8
7. $^{1}/_{4}$ H	38.2	26.9	1.06	7.28	50.76	30.1
8. ΔG	10.44	4.8	0.55	12.7	15.42	7.59
9. ΔG%	16.29	13.5	8.32	44.6	129.9	75.9

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

2. Average fruit weight:

The two parents significantly differed in average fruit weight (159.9 and 12.8 gm) for the cultivar Super Beef Steak (P_1) and the line Bl-15 (P_2), respectively. The F_1 mean (28.8 gm) was very close to that of the small fruited parent with significant Mp-heterosis of -66.7%, indicating dominance towards the small fruited parent (Table 2). The estimated potence ratio (-0.78) indicated partial dominance. The F_2 mean was slightly lower than the F_1 mean, this may be due to the partial dominance of the small fruit. Regarding the two backcrosses, the fruit of Bcp_1 plants slightly exceeded that of F_1 by about 22%, while the average fruit weight of Bcp_2 was significantly lower than that of F_1 as shown in Table (2).

The Bcp_1 and Bcp_2 means (35.1 and 7.4) are different, supporting the dominance of small fruit weight. The obtained and theoretical means of all studied populations showed significant differences. This could be lead to suggest that the character is controlled by several genes. It is noticed that the actual means were always lesser than the expected means, supporting the dominance gene effects of the light fruit weight.

As shown in Figure (2) the plants of F_2 distributed over a wide range of fruit weight scale. All plants were similar to those of P_2 (small fruited parent) and F_1. None of plants were similar to P_1 (large fruited parent), due to the partial dominance of the light fruit. Also none of Bcp_1 plants had average fruit weight similar to P_1, all plants lied in the distance of F_1 with slight skewness towards P_2, supporting the dominance toward the small fruit. With regard to Bcp_2 (F_1 x Bl-15), the plants were similar to F_1 and P_2 with about 50% for each of them as expected when the small fruit is dominant.

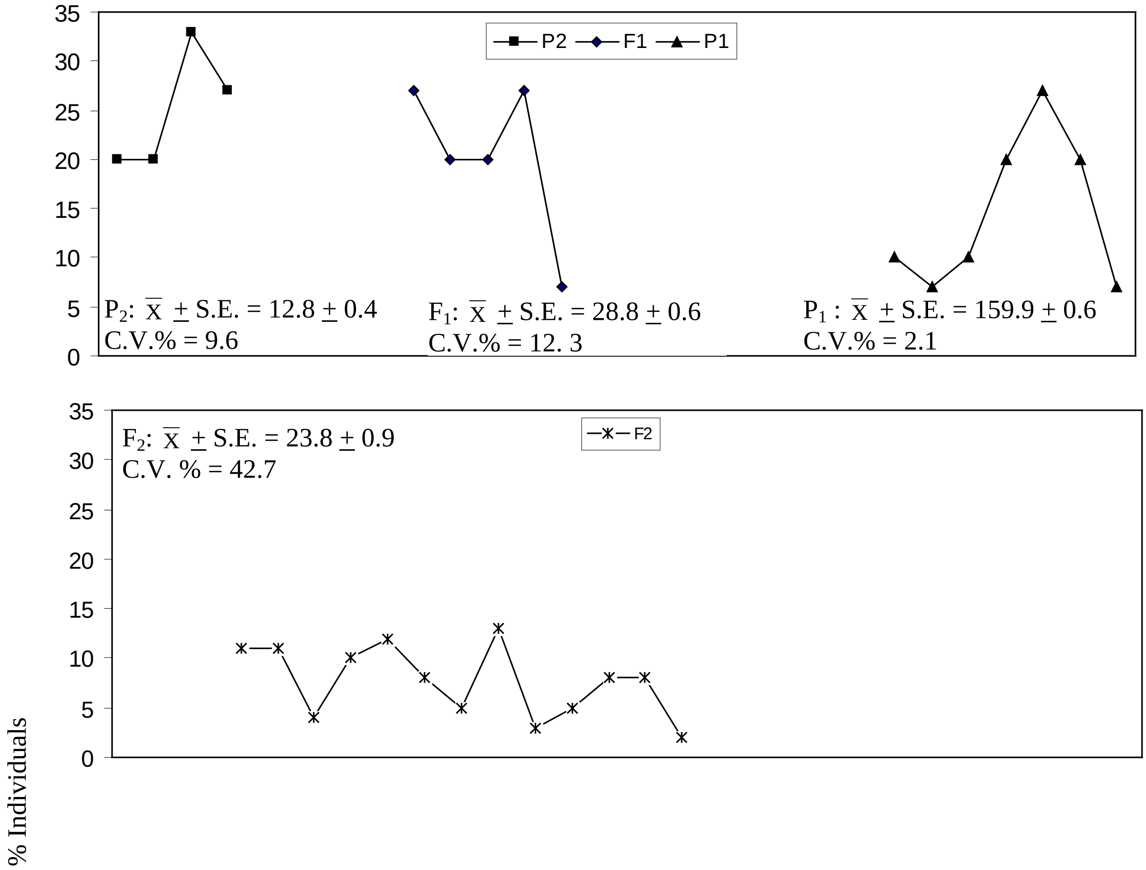
The obtained BSH (82.7%), NSH (32.0%), additive (17.0) and dominance (26.9) variance suggest that both additive and dominance gene effects are involved in the inheritance of average fruit weight in this cross. These findings are agreement with those of Ghosh *et al.* (2010) and Rajasekhar *et al.* (2013). All these findings lead to suggest that this character is controlled by several genes with partial dominance of the small fruit and presence of some additive gene effects.

3. Total soluble solids (TSS% content):

Data of TSS% are presented in Table (4) and illustrated in Figure (3). The means of the two parents showed significant difference in fruit TSS% content (5.59 and 8.95%). The obtained mean of F_1 population (6.47%) was between the mid-parents and the low parent (P_1), indicating partial dominance for the low TSS% content. The partial dominance was revealed by the estimated significant negative mid-parent heterosis (MPH), significant positive low-parent heterosis and potence ratio, values which were -11.0, 15.7% and 0.47, respectively.

The means of F_1 and F_2 were approximately similar, indicating the presence of additive gene effects. The means of the two backcrosses differed, indicating also the presence of additive gene effects. However, the additive gene effects were verified by the approximation of theoretical and actual means of Bcp_1 and Bcp_2. Hence, it could be concluded that both additive and dominance gene effects are involved in the inheritance of this trait. This results were also found by Shirin and Hazra (2013).

Plants of the parents distributed without over lapping, the range was 4.8 – 6.1 and 8.5 – 9.7% for P_1 and P_2, respectively. None of the F_1 plants were similar to the high parent (P_2) in TSS% content. While only five plants were similar to the low parent (P_1) and the remaining plants ranged between the parent, indicating the importance of additive effects.



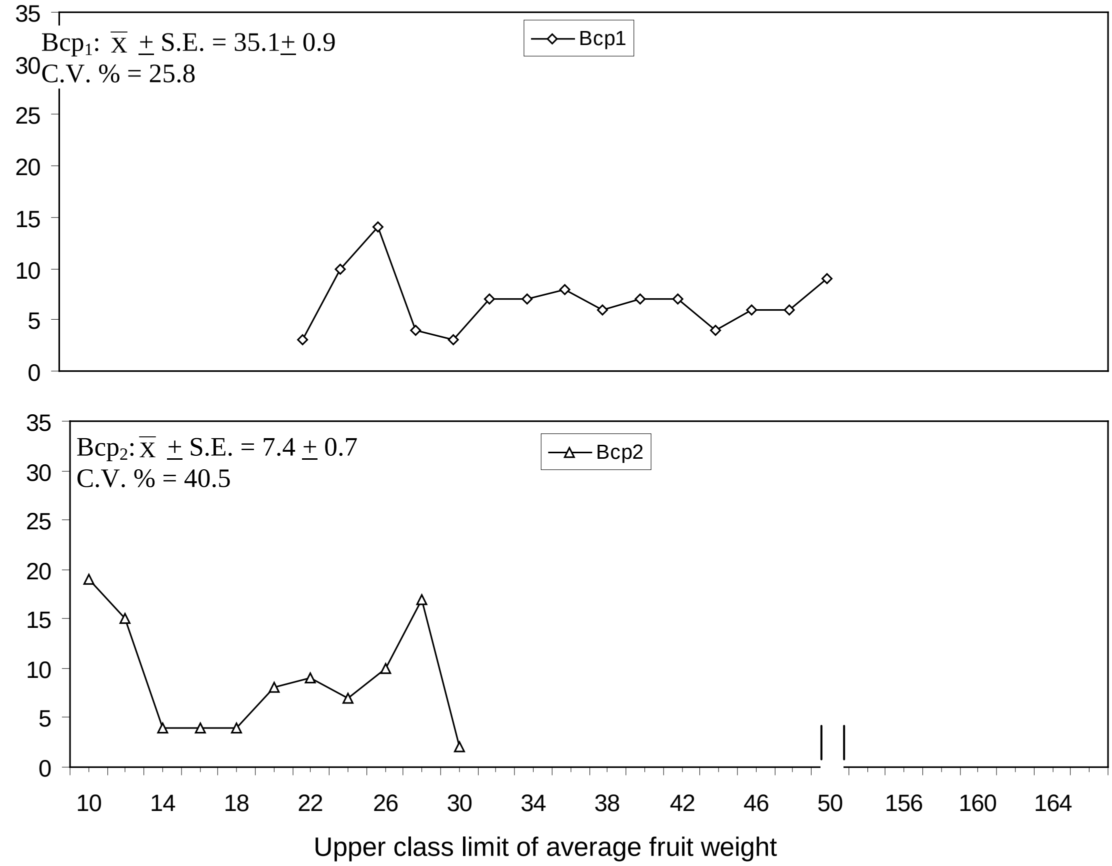
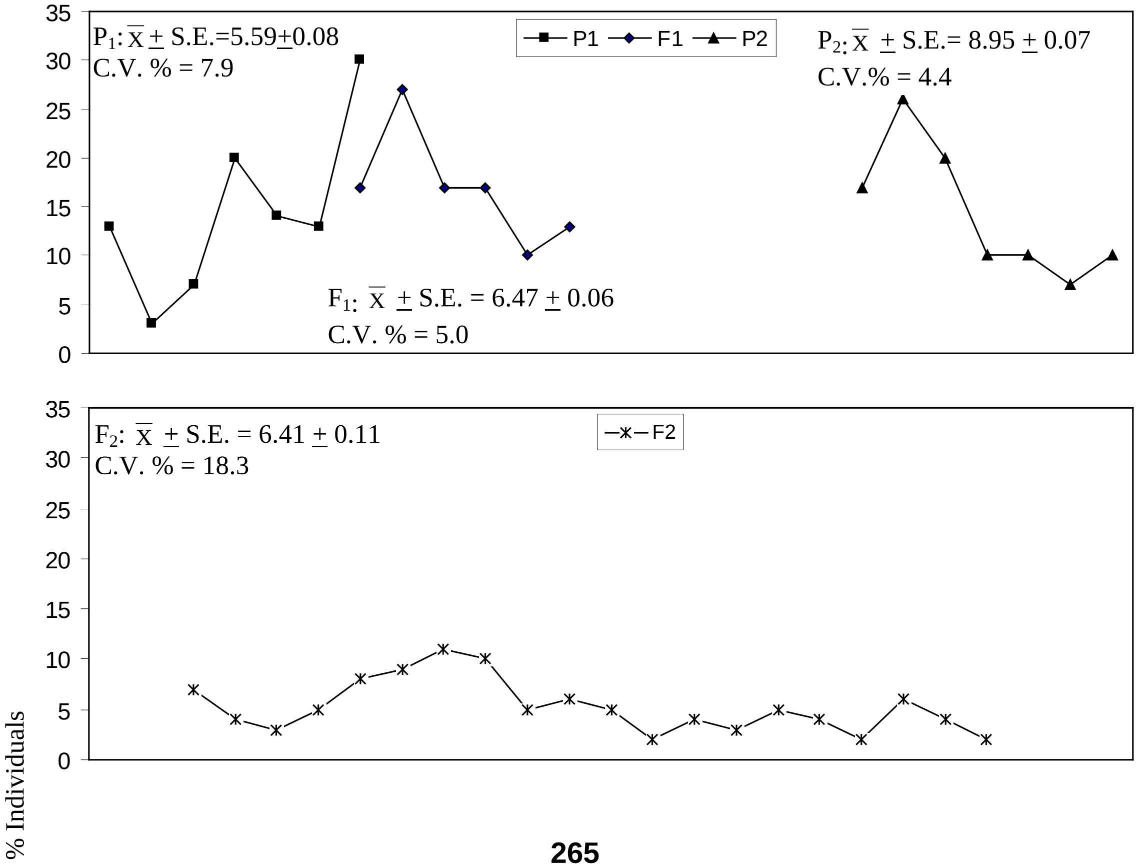


Figure (2). Distributions of average fruit weight in the six tomato populations.



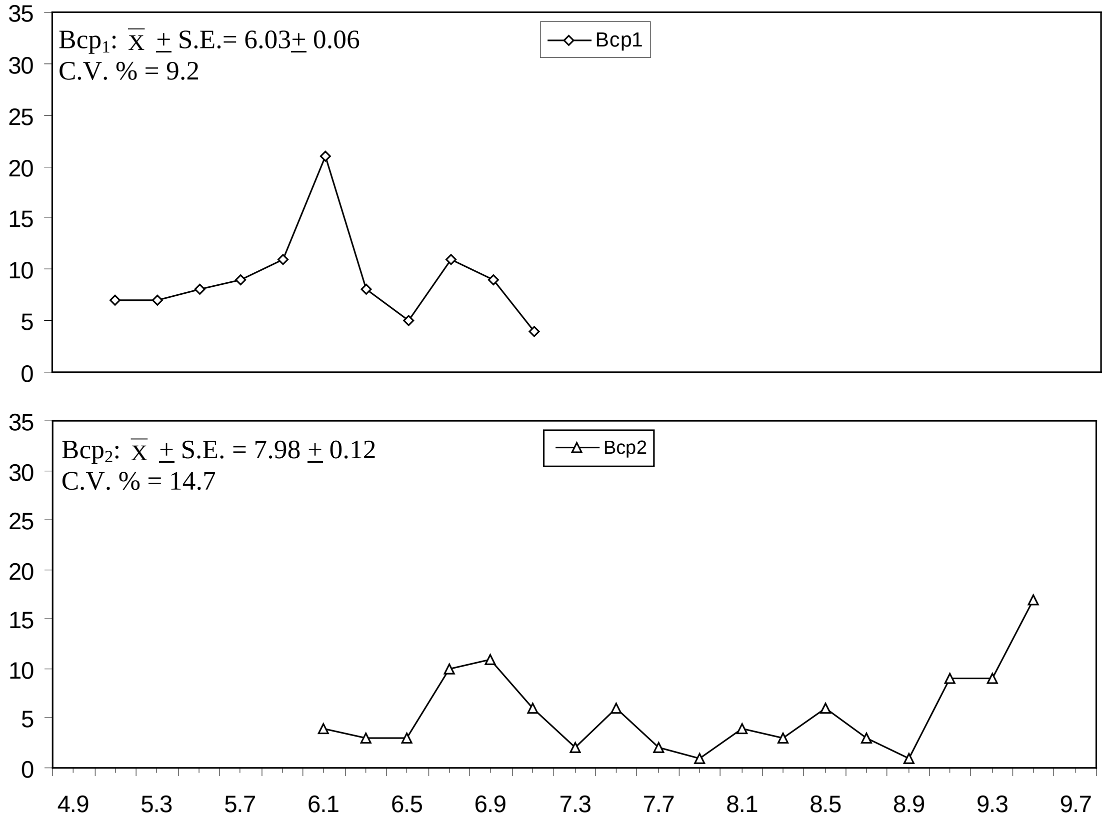


Figure (3). Distributions of TSS% in the six tomato populations.

Table (4). Means and coefficient of variance for total soluble solids (TSS %) and ascorbic acid (vitamin C) contents in the six tomato populations.

Character / Population	Total soluble solids (TSS)			Vitamin C		
	Obtained mean ± S.E.	Theoretical mean	c.v.%	Obtained mean + S.E.	Theoretical mean	c.v.%
P_1	5.59 ± 0.08	-	7.9	16.8 ± 0.33	-	10.90
P_2	8.95 ± 0.07	-	4.4	40.7 ± 0.45	-	6.00
F_1	6.47 ± 0.06	7.27	5.0	28.7 ± 0.39	28.75	7.70
F_2	6.41 ± 0.11	6.87	18.3	28.5 ± 0.70	26.20	29.10
Bcp_1	6.03 ± 0.06	6.03	9.2	24.2 ± 0.69	22.75	27.11
Bcp_2	7.98 ± 0.12	7.50	14.7	34.2 ± 0.56	34.70	15.60
L.S.D. at 0.05	0.14			2.1		
0.01	0.19			2.9		

Regarding the F_2 plants, they distributed on a wide range (5.3 – 9.1%). They covered the ranges of P_1, F_1 and P_2 populations suggest that the character is may be quantitatively inherited. The minimum number of gene pairs was estimated as three ones. The plants of Bcp_1 occupied the range of both P_1 and F_1 plants (4.9 – 7.3%)

as expected due to the partial dominance genes of the low content. On the other hand, plants of Bcp_2 (the recessive parent) stretched on a wide range (6.1 – 9.5%). About 31 and 43% were similar to F_1 and P_2 populations, respectively. The remaining plants were between the two populations (Figure 3).

The estimated additive ($^1/_2$ D) and dominance ($^1/_4$ H) effects support the importance of both additive and dominance gene effects in the inheritance of TSS% content in this study. The additive gene effect was also clear from the estimated broad sense (BSH) and narrow sense (NSH) heritabilities which were 89.8 and 17.8%, respectively. The presence of additive effect is useful and could be help in improvement TSS% content by selection. Also, the calculated ΔG% supported this suggestion.

All these findings lead to suggest that the total soluble solids content in tomato is controlled by several genes with additive gene effects and partial dominance of the low content. Accordingly, producing tomato lines or cultivars have high TSS% content could be able by breeding and selection. The partial dominance for low TSS% content, which reflected by the negative MP-heterosis, was also found by Yashavantakumar (2008).

4. Vitamin C:

The means of both parents (16.8 and 40.7 mg/100gm (P_1 and P_2, respectively) significantly differed in vitamin C content. The F_1 mean (28.7 mg/100 gm) is very close to the mid-parent value (28.8 mg/100gm). The low insignificant estimated MPH -0.17% and potence (0.01) values indicate no-dominance for the character. The mean of F_2 (28.5), as expected, was approximately similar to that of F_1 (28.7), since the character is controlled by additive genes. On the other hand, the obtained F_2 mean was slightly higher than the theoretical mean as shown in Table (4). The two means of Bcp_1 and Bcp_2 populations (24.2 and 34.2, respectively) showed significant difference due to the high difference between the two parents in vitamin C content. The theoretical and obtained means of the two Backcrosses were close, suggesting that ascorbic acid content may be controlled by one pair of genes.

The distribution of F_1 plants clearly reveals the no-dominance gene action. None of the F_1 plants had vitamin C content similar to either parent, all plants were in between the two parents with a range of 26 – 32 mg. The F_2 plants distributed in a wide range (16.0 – 44.0). About 22, 48 and 20% of the plants were similar to P_1, F_1 and P_2 populations, respectively, in vitamin C content. This ratio (1: 2: 1) is fit a X^2 test with a probability of 0.75- 0.90. This ratio suggest that the trait may be controlled by one pair of genes with mostly additive effects (Fig 4).

The monogenic inheritance was also revealed by the distribution of Bcp_1 and Bcp_2 plants. About 56 and 47% of their plants were similar to the F_1 population in two backcross, respectively. Meanwhile, 44 and 43% were similar to P_1 and P_2 in Bcp_1 and Bcp_2, respectively. The ratios 1: 1 are fit a X^2 test with a probability of 0.75-0.90 for Bcp_1 and 0.25-0.50 for Bcp_2 according to monogenic hypothesis. The additive gene effects were more importance in the inheritance of this trait as reported by Megahed (2002) and Mostafa (2015).

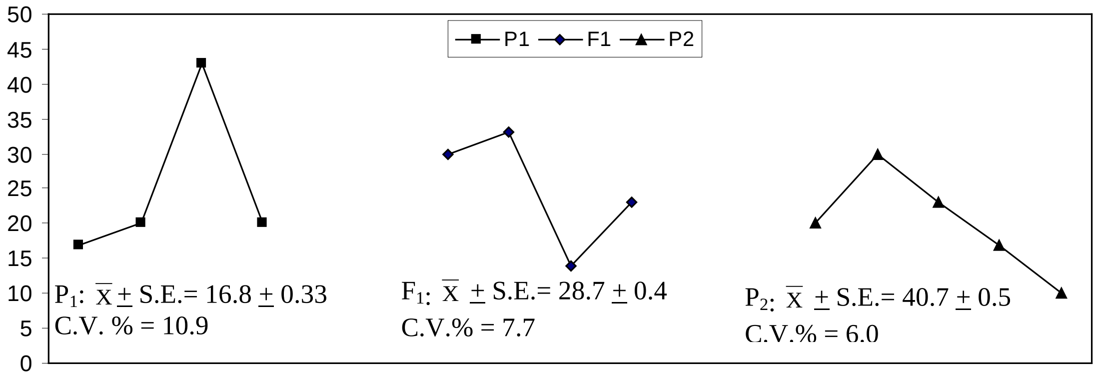
The calculated insignificant mid-parents heterosis (-0.17%), potence ratio (-0.01), $^1/_2$ D (47.58) and $^1/_4$ H (7.28) values support the postulated monogenic inheritance of vitamin C content with mostly additive gene effects and slight dominance of the low content. The high obtained BSH (92.2%) and NSH (79.9%) are in accordance with the qualitative character. Therefore, the vitamin C content could be improved by selection. Genetic advance under selection (ΔG %) was found as 44.6%. The high genetic advance under selection with high BSH were also reported by Rajasekhar (2013) and Mostafa (2015).

5. Resistance to root knot nematode disease:

The cross "Super Beef Steak × Bl-15" was used in studying the inheritance of tomato resistance to root-knot disease caused by *Meloidogene incognita*. The super Beef Steak (SBS) which is considered as moderately susceptible cv., as reported by El-Shennawy and Khalil (2014), was used as female parent, while the resistant line Bl-15 was used as male parent. Number of galls per root and egg masses were considered as indicator to degree of resistance for the studied populations (P_1, P_2, F_1, F_2, Bcp_1 and Bcp_2). Data obtained are illustrated in Tables (3 &5) and Figures (5 & 6).

Table (5). Means and coefficient of variance for root-knot nematode resistance as number of galls and egg masses in the six tomato populations.

Character / Population	Gall number			Egg masses		
	Obtained mean ± S.E.	Theoretical mean	c.v.%	Obtained mean + S.E.	Theoretical mean	c.v.%
P_1	34.8 ± 0.5	-	7.9	23.7 ± 0.55	-	12.9
P_2	6.0 ± 0.4	-	35.2	4.7 ± 0.25	-	28.9
F_1	5.5 ± 0. 3	20.4	28.5	4.8 ± 0.27	14.2	27.5
F_2	11.87 ± 0.9	13.1	101.7	10.1 ± 0.77	9.25	80.1
Bcp_1	18.1 ± 1.5	20.2	77.9	12.6 ± 1.03	14.0	77.6
Bcp_2	5.9 ± 0.2	5.7	26.6	5.7 ± 0.18	4.5	32.2
L.S.D. at 0.05	1.2			1.0		
0.01	1.7			1.4		



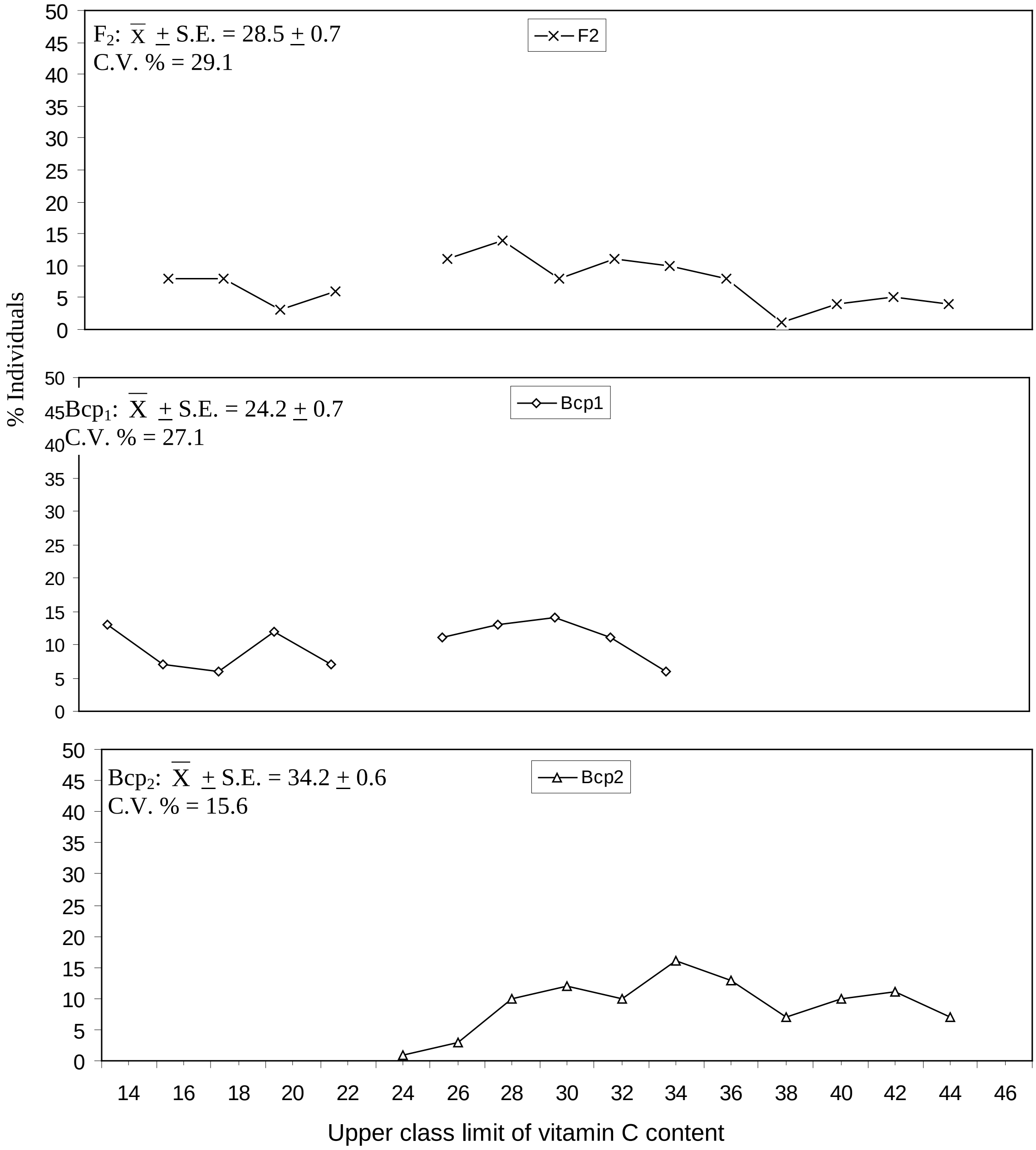
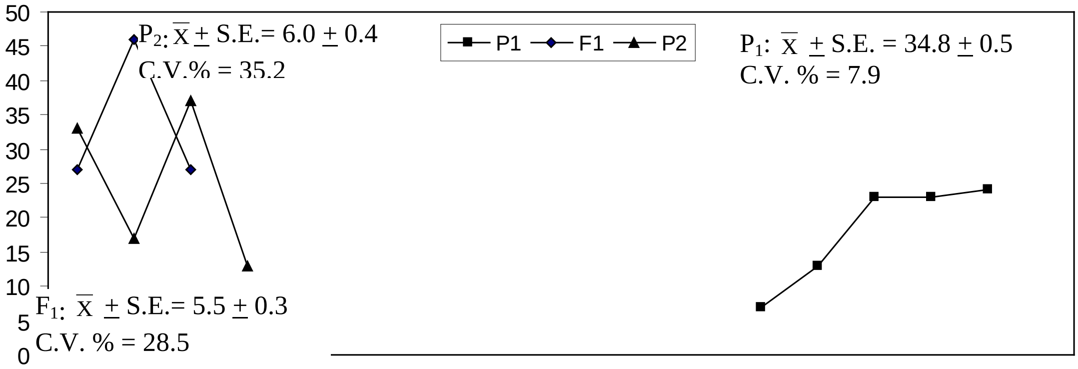


Figure (4). Distributions of vitamin C content in the six tomato populations.



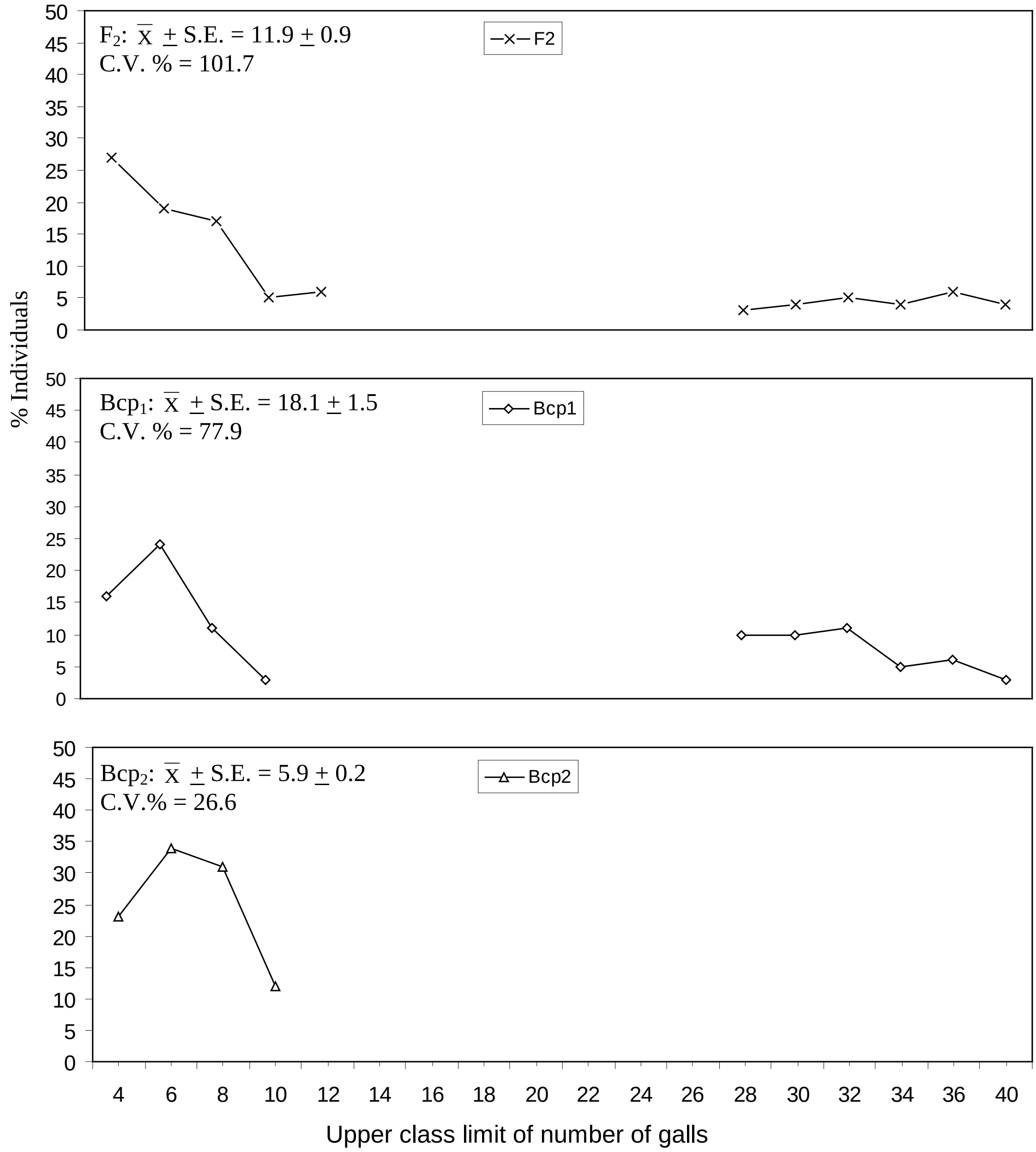
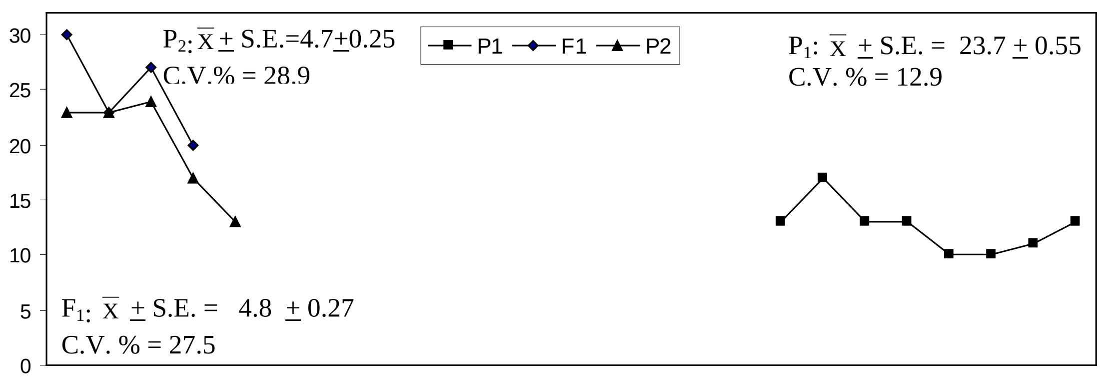


Figure (5). Distributions of number of galls / plant in the six tomato populations.



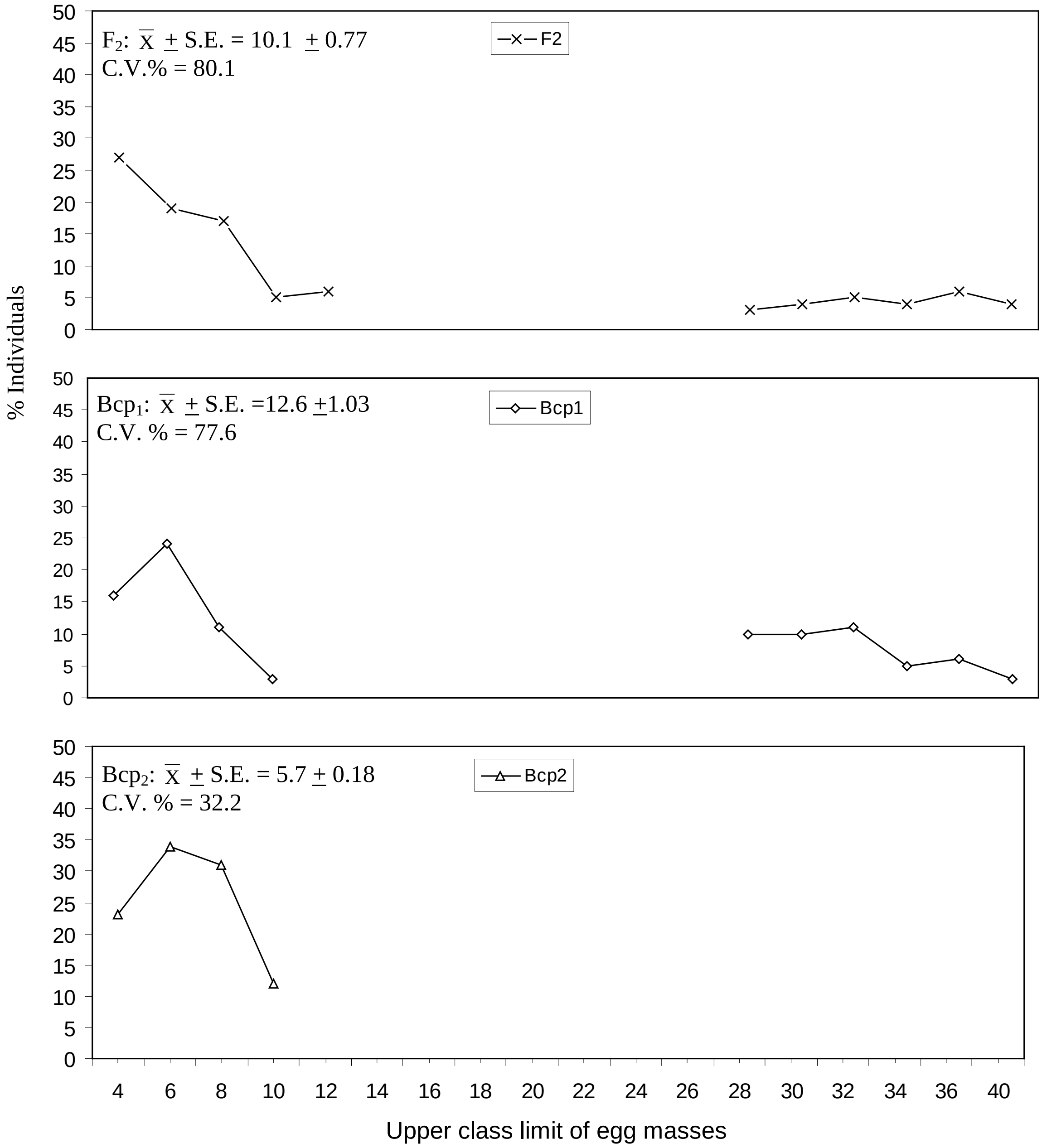


Figure (6). Distributions of egg masses in the six tomato populations.

5.1. Number of galls:

The parents significantly differed in gall number / root. It ranged from 29 – 38 with an average of 34.8 in P_1 [Moderately susceptible cv. (MS)], and from 3 – 9 with an average of 6.0 galls in P_2 [the resistant parent (R)]. The mean of F_1 population (5.5) was very close to that of P_2 (R.P.), indicating dominance for the resistant genes over the susceptible ones. The estimated significant negative MPH, insignificant negative BPH (-73.04 and -8.33%, respectively) and positive potence ratio (1.03) together support the dominance of the resistance genes. Similar results was also reported by Khalil and Salem (1983) and Mark (1986).

F_2 mean (11.87) was higher than F_1 and P_2 means as expected when the character is controlled by dominant genes. The obtained Bcp_1 and Bcp_2 means (18.1 and 5.9, respectively) were differed, due to the dominance gene effects. The actual means of F_2, Bcp_1 and Bcp_2 suggesting that resistance may be controlled by one pair of genes. According to rating scale (Table 1), the P_2, F_1 and Bcp_2 populations are resistant, meanwhile, F_2 and Bcp_1 populations are moderate resistant (MR). The monogenic inheritance was previously suggested by Khalil and Salem (1983) and Mark (1986) in tomato.

Distribution of the segregating populations support the postulated dominance hypothesis. Figure (5) show that F_2 plants distributed in two groups with a ratio of 3:1 with a probability of 0.05-0.10, the first is similar to both F_1 and P_2 (R.P), and the second group is similar to P_1 (S.P). The plants of Bcp_1 (F_1 × S.P) also distributed is two similar classes (1: 1) with a probability of 0.25-0.50. On the other hand, all plants of Bcp_2 (F_1 × R.P) were similar to F_1 and P_2 without distinct classes. The distribution of F_2, Bcp_1 and Bcp_2 is in accordance with the monogenic inheritance of this character.

The genetical parameters estimates (Table 3) are in agreement with the simply inherited characters. High BSH (96.7%), NSH (61.9%), $^1/_2$ D (90.27), $^1/_4$ H (50.8) and ΔG% (129.9%) indicate that both additive and dominance effects are involved in the inheritance of resistance to root-knot nematode disease. Therefore, it could be concluded that this trait may be controlled by one pair of genes with dominance to high degree of resistance and presence of some additive effects. Heterosis breeding could be used to produce tomato F_1 hybrids resistant to this disease. Also selection programme could be applied to develop new resistant lines or cultivars for commercial production. The F_2 population have high degree of resistance, hence it might be used in tomato production in the infected soil.

5.2. Egg masses:

Data of egg masses are presented in Tables (3 and 5), and Figure (6). A comparison between data presented on the inheritance of both gall number and egg masses reveal a striking similarity between the two characters in their modes of inheritance. Much similarity were observed between the two characters in respect to relative values of c.v.% (variances), distribution patterns of parents, F_1, F_2, Bcp_1 and Bcp_2 populations. The estimated parameters such as MP and BP-heterosis, potence ratio, BSH and NSH, additive and dominance gene effects and genetic advance under selection (ΔG %) also followed the same trend with very close values (Table 5). Consequently, it is clearly apparent that the mode of inheritance of gall number and egg masses is identical. Accordingly, it is concluded that the two characters are controlled by one pair of genes with dominance of resistance over susceptible genes and follow the same mechanism of inheritance. The high association between the two traits lead to suggest that the determine of degree of resistance to root-knot nematode disease in tomato could be done by number of galls only.

This was the first attempt to determine the relationship between the genetics resistance of tomato to root-knot nematode disease as gall number and egg masses. A critical review of the literature on the subject failed to reveal any report on this nature.

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وراثة بعض الصفات الثمرية وصفة المُقاومة لمرض تعقُّد الجذور النيماتودي في الطماطم

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الملخص العربى

أجريت هذة الدراسة بمزرعة التجارب بكلية الزراعة بشبين الكوم- جامعة المنوفية فى ثلاثة مواسم صيفية (2014 ، 2015 ، 2016). حيث استخدم الصنف سوبر بيف ستيك والسلالة BI-15 كآباء لإنتاج العشائر اللازمة للدراسة وهى الجيل الأول ، الجيل الثانى والهجين الرجعى لكلا الأبوين. وتم تقييم العشائر الستة لصفات عدد الأيام من الشتل لنضج أول ثمرة ، متوسط وزن الثمرة ، محتوى الثمرة من المواد الصلبة الكلية الذائبة وفيتامين ج بالإضافة إلى صفة المقاومة لمرض تعقد الجذور النيماتودى. وقد تم التقييم فى تجربة حقلية مصممة بطريقة القطاعات الكاملة العشوائية وثلاثة مكررات، وبالنسبة لتجربة النيماتودا فقد تم التقييم فى تجربة أصص بنفس التصميم وتم تسجيل البيانات لجميع الصفات على النباتات الفردية ثم اجراء التحليل الإحصائى والحسابات الوراثية بالطرق المناسبة لتحديد طبيعة وراثة هذة الصفات. وقد أوضحت النتائج المتحصل عليها وجود السيادة الفائقة لعدد الأيام القليل من الشتل للنضج ، ووجود سيادة جزئية للثمار الصغيرة وبالنسبة لصفتى محتوى الثمار من المادة الصلبة الكلية الذائبة وفيتامين ج وجد أنها محكومة بعوامل وراثية مضيفة مع وجود سيادة جزئية للمحتوى القليل. وبالنسبة لمرض تعقد الجذور النيماتودى فإن صفة المقاومة محكومة بزوج واحد من العوامل الوراثية وسيادة للعدد القليل من العقد النيماتودية وكتل البيض. وهذة النتائج تشير إلى إمكانية تحسين الطماطم لهذة الصفات عن طريق برامج التربية. كما يمكن استخدام عشائر الجيل الأول (الأصناف الهجين) فى الزراعة وذلك فى الصفات التى أظهرت سيادة فائقة مثل عدد الأيام للنضج وكذلك التى أظهرت سيادة تامة مثل المقاومة لمرض تعقد الجذور.