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EVALUATION OF SOME TOMATO GENOTYPES AGAINST THE ROOT KNOT NEMATODE, *Meloidogyne incognita*

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ABSTRACT

In the present investigation, 15 F_1 combinations and their parental cultivars or lines of tomato were tested for their response to *Meloidogyne incognita* by inoculation with 1000 2nd stage juveniles of nematode in pots experiment at the Experimental Farm, Faculty of Agriculture, Shebin El- Kom.. Population means, degree of heterosis and types of gene effects were estimated for the studied traits. Obtained results showed significant differences among the studied genotypes against nematode infection (formation of galls, egg masses and number of developmental stages) as well as their growth parameters (root weight, shoot weight, plant height and weight of fruits). None of the evaluated genotypes was immune. However, four resistance rates were found; *i.e.*, highly resistant by the two crosses Endless Summer × Bl.14 and Endless Summer × Roma hybrids, resistant by the cultivar Endless Summer and the cross Super Beef Steak × Endless Summer. The remaining genotypes were rated as moderately resistant, except the cultivar Super Beef Steak, which was scored as moderately susceptible. General and specific combining abilities (GCA: SCA) showed that both additive and non-additive gene actions were involved in the inheritance of resistance for root knot nematode. The ratio between GCA: SCA revealed that the GCA effects played the main role for inheritance of this trait. The two cultivars Endless Summer and Roma were the best combiners for breeding against resistance to root nematode disease, since they showed the highest GCA effects. Moreover, desirable significant heterosis values were observed related to the better parent concerning number of galls per root, number of developmental stages and number of egg masses in some F_1 combinations. Significant positive correlations were found between number of galls / root and number of egg masses, number of developmental stages and root weight. Meanwhile, significant negative correlations were found between number of galls and plant height, shoot weight and fruit weight.

Key words: Tomato genotypes, root- knot nematode, heterosis, combining ability, additive

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is the second most important vegetable crop next to potato. It has been estimated that more than 50% of the world's total crop production is lost every year through the activity of pests and diseases, in spite of many control measures that are employed (Russel, 1981). As reported by Sikora and Fernandez (2005), root- knot nematodes, *Meloidogyne* spp., are considered among the top five major plant pathogens of tomato, which limit the quantity and quality of fruit yield. According to Nirmaladevi and Tikoo (1992), the yield loss in tomato due to root-knot nematode has been estimated to be up to 61.0%, while it ranged from 32 to 40% according to Anwar and Mckenry (2012).

Root-knot nematodes caused major damage to plants. The infected plants develop galls with varying sizes and shapes on their roots. These galls reduced the efficacy of nutrient and water

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uptake in the host, which cause stunting, yellowing of the foliage and wilting in the presence of adequate soil moisture (Hafez and Sundararaj, 2003).

Chemical usage is a common and popular practice to manage nematodes, but it is expensive, may cause environmental pollution and possible health hazard problems. Therefore, search for better options has been emphasized. Molinari (2011) reported that the most effective and economical methods is the use of resistant cultivars or hybrids, which reduce the nematode population densities and minimize the application nematicides. According to Oostenbrink (1966), the nematode population may be suppresed to 10 – 50 percent of its harmful density by using the resistant cultivars or hybrids.

Farag (1994) found that tomato genotypes were varied in degree of resistance. He added that there were three rates of resistance; *i.e.,* resistant, moderate resistant and moderate susceptible. The varietal differences were also reported by Riyandari (2002).

Indu *et al.* (2009) stated that resistance to root-knot nematode in tomato was found sixty years ago in *Lycopersicen peruvianum* accession pl 128657 by Bailey (1941). They also reported that improvement of yield coupled with a considerable level of resistance can be achieved through the development of F_1 hybrids. High degree of resistance to this disease was also found in *L. pimpinellifolium* by Khalil and Salem (1983).

The resistant plants could be identified based on either number of females, or the egg mass score and gall index recorded in the infected root (Cousins and Walker, 2002). According to Indu *et al.* (2009) identification of nematode resistant donors and utilization in development of F_1 hybrids by hybridization with yielding lines will be a boon to tomato growers for maximum production of quality tomato without using much chemicals through the use of nematicides.

Few studies have been conducted on the inheritance of resistance to root knot nematodes on tomato. Indu *et al.* (2009) mentioned that heterosis in relation to mid-parents (MP-heterosis) was found in most studied crosses, but it was found in four crosses in relation to the better parent (BP-heterosis), indicating hybrid vigour. They suggested that these crosses can be selected for the exploitation of hybrid vigour and commercial utilization under root- knot nematode infested areas. The study of Khalil and Salem (1983) on the inheritance of root-knot nematode on tomato showed that the resistance was dominance and controlled by single dominant gene. The mongenic inheritance was also found by Gomez *et al.* (2000) and Murti *et al.* (2012),they found that the resistance was controlled by a dominant gene. Genetic analyses revealed a monogenic or polygenic determinism of the resistance identified in wild plants. It is noticed that the monogenic inheritance is desirable for breeding purpose, because of their simplicity in introgression into genotypes that is good quality and high production, but susceptible to nematode.

Root length and fresh weight are considered as an important root knot nematode resistant traits. According to Indu *et al.* (2009) the F_1 crosses showed significant positive heterosis over the better parent in root length. Regarding root weight, the galled roots recorded more weight than the resistant roots of tomato plants. All hybrids which involved less root weight parents also showed the lowest weight of roots. They added that most hybrids expressed negative heterosis over the better parent in root weight.

Correlations between some characters related to root- knot nematode resistance were studied by Murti *et al.* (2012). Significant positive correlation was found between root gall intensity, number of egg masses and J_2 larvae population. On the contrary, insignificant negative correlation between J_2 larvae population with others was exist, except with root gall intensity. Root gall intensity significantly correlated with number of eggs, in which the correlation coefficient was the high (r = 0.52**).

Knowledge about the genetics of resistance to particular disease is helpful in any programme of breeding for resistance. It is necessary to plant breeders to understand exactly how resistance is inherited before a successful breeding programme can be carried out. Hence, this is the aim of this investigation.

MATERIALS AND METHODS

This work was conducted in the Experimental Farm, Faculty of Agriculture, Minufiya University, Shebin El-Kom, Egypt during two successive summer seasons of 2012 and 2013. The study was started by three cultivars; *i.e.,* Super Beef Steak, Endless Summer, Roma and three lines; *i.e.,* Bl.5, Bl.14 and Bl.18. The cultivars were brought from USA and the lines were on hand from previous study of Khalil, Faculty of Agricultuer, Minufiya University. All genotypes were at a high degree of homozygosis.

In the first season, crossing was made among the six parents, without reciprocals, to produce the required F_1 combinations. In the second season (2013), all genotypes (six parents and 15 F_1's) were evaluated against the root-knot nematode *Meloidogyne incognita*, as well as, some other characters under artificial infection into green seral house in pots experiment.

Preparation of Nematodes Inoculum

The root-knot nematodes, *M. incognita*, used in the experiment was isolated from tomato roots. The nematodes isolate was multiplied from a single egg mass on night shade (*Solanum nigrum* L.) in pots in the faculty greenhouse and was confirmed by examining the perineal pattern (Taylor and Nestcher, 1974)

For collection of (J2) juveniles, infected roots of Two-months-old night shade (*Solanum nigrum* L.) infected roots were 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). 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. For soil preparation, clay-sandy mixed soil (1: 1, v/v) were sterilized by adding 5% formalin solution. Consecutively, soil was covered with polyethylene sheet for seven days to retain the gas then left for two weeks until all traces of formaldehyde disappeared according to Abdel-Monaim *et al.* (2011).

Evaluation of Studied Populations

Twenty-one tomato genotypes (15 F_1 crosses and 6 parents) were tested for their response to *M. incognita* infection. Three seedlings (five weeks old) of each population were planted in plastic pots (25 cm diameter) filled with 4 kg of sterilized soil. After one week, for seedlings adaptation, 1000 J_2 of *M. incognita* were added by pipette into three holes around each seedlings. A randomized complete blocks design with four replicates was used. Each replicate consisted of six plants, for each population arranged in three pots (two plants in pot). 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 per pot). The experiment was terminated eight weeks after planting.

At the end of the experiment, roots and shoots fresh weight, plant height and weight of fruits were recorded. The measurement of egg masses was taken by staining Root system of plants with a 0.15% phloxine B (Holbrook *et al.,* 1983).

The response of genotypes to nematodes infection was rating based on number of galls scale (Table 1) according to (Mukhtar *et al.,* 2013). Also number of developmental stage was recorded after staining the roots with sodium hypochlorite–acid fuchsin by transfers the roots into a boiling acid fuchsin for 30 seconds according to (Bybd *et al.*, 1983)

Statistical Analysis

Average data were subjected to analysis of variance (ANOVA) using Costat software. The mean differences were compared by Duncan's Multiple range test (DMRT). Average degree of heterosis was estimated as a percent of increase or decrease of F_1 from the mid parental (MP) and better parental (BP) values (Sinha and Khanna, 1975). Potence ratio (P) was estimated to determine the nature of dominance and its direction (Smith, 1952). Both (GCA) and (SCA) were estimated according to Griffing (1956) method (2) model (1).

Table 1. Modified raing 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)

RESULTS AND DISCUSSION

Significant differences were found among the studied genotypes in response to degree of root- knot nematode, *Meloidogyne incognita*, infection and other studied traits (Table 2). Most studied genotypes were moderately resistant. None of the tested populations were found immune based on the number of galls (Table 2). However, there were four rates of host suitability; *i.e.,* highly resistant (HR), resistant (R), moderate resistant (MR) and moderate susceptible (MS).

Parental Cultivars and Lines

The lowest number of galls (7.87) was reflected by the cultivar Endless Summer. The number of galls value lead to suggest that this cultivar could be considered as resistant to root knot nematode infection. The cultivar Roma and the breeding lines Bl.5 and Bl.18 could be considered as moderately resistant (MR), their number of galls / root system were 16.25, 22.37 and 24.37, respectively. On the other hand, the highest average number of galls (42.75 and 31.25) were shown by the Bl.14 and Super Beef Steak cv., respectively. They are considered as moderately susceptible to root- knot nematode disease.

With regard to egg masses and number of developmental stages, the parental genotypes significantly differed. Maximum number of egg masses (35.62 and 24.5) and developmental stages (23.0 and 20.12) were recorded with the line Bl.14 and the cultivar Super Beef Steak, which was classified as (MS) based on gall number / root. The resistant parent (Endless Summer) showed the lowest egg masses (5.5) as shown in Table 2.

Regarding plant growth parameters (root weight, shoot weight, plant height and fruit weight / plant), it was observed that the resistant cv. (Endless Summer) showed the lowest root weight, as expected when the number of galls was low, while it gave the highest values for plant height, shoot weight and fruit weight per plant. On the other hand, the highest values of root weight were found in the susceptible parents (Bl.14 and Super Beef Steak cv.). They also showed the lowest fruit weight.

F_1 Crosses

Data presented in Table 2 show that the two crosses (Endless Summer × Roma and Endless Summer × Bl.5) were highly resistant, followed by the cross Super Beef Steak × Endless Summer which was resistant. The number of galls / root for these crosses was 2.37, 2.50 and 8.87, respectively. Regarding number of egg masses, the lowest values (1.37 and 1.62) were given by the two HR crosses followed by the resistant cross (Super Beef Steak × Endless Summer). The obtained number of developmental stages was the lowest in the crosses Endless Summer × Roma and Endless Summer × Bl.5 with an average of 6.0 and 5.0, respectively. Therefore, according to data obtained, it could be suggested that the crosses Endless Summer × Roma, Endless Summer × Bl.5 were the best of all followed by the cross Super Beef Steak × Endless Summer, since they had high degree of resistance. It is noticed that, the resistant cultivar Endless Summer was involved in these resistant crosses. These results lead to suggest that, it is useful to use F_1 cross in tomato production in infected area.

Table 2. Estimated some nematode and plant growth parameters in the studied tomato genotypes

Genotypes•	Number of galls	Reaction	Egg masses	Developmental stages	Shoot weight (g)	Root weight (g)	Plant height (c)	Fruit weight (g)
1	31.25^{b}	MS	24.50^{b}	20.12^{f}	59.13^{j}	17.75^{a}	53.25^{ghij}	81.60^{fghi}
2	7.87^{j}	R	5.50^{i}	15.37^{h}	78.75^{b}	11.43^{ij}	61.62^{a}	89.60^{a}
3	16.25^{gh}	MR	11.37^{e}	12.00^{i}	76.00^{c}	14.78^{f}	56.75^{b}	83.95^{d}
4	22.37^{e}	MR	17.50^{c}	16.75^{g}	75.37^{c}	12.85^{h}	55.75^{bcde}	82.80^{e}
5	42.75^{a}	MS	35.62^{a}	23.00^{e}	59.56^{j}	16.99^{bc}	53.25^{ghij}	81.52^{fghi}
6	24.37^{de}	MR	18.00^{c}	13.00^{i}	72.98^{d}	13.86^{g}	54.25^{fghi}	84.38^{d}
1 × 2	8.87^{j}	R	6.87^{hi}	20.25^{f}	62.48^{h}	15.90^{de}	53.25^{ghij}	82.70^{e}
1 × 3	18.00^{fg}	MR	11.12^{e}	33.00^{b}	76.00^{c}	14.78^{f}	56.75^{b}	83.95^{d}
1 × 4	16.75^{gh}	MR	7.62^{gh}	22.12^{e}	71.54^{c}	14.83^{f}	55.25^{cdef}	85.38^{c}
1 × 5	27.62^{c}	MR	7.12^{hi}	19.87^{f}	61.49^{hi}	15.45^{ef}	53.00^{hij}	81.41^{ghij}
1 × 6	22.25^{e}	MR	16.50^{cd}	46.75^{a}	56.81^{k}	18.02^{a}	51.50^{k}	80.67^{ij}
2 × 3	2.37^{k}	HR	1.37^{j}	6.00^{j}	80.83^{a}	10.55^{j}	61.87^{a}	86.72^{b}
2 × 4	2.50^{k}	HR	1.62^{j}	5.00^{j}	71.63^{e}	12.17^{hi}	55.87^{bcd}	84.74^{cd}
2 × 5	14.75^{hi}	MR	6.00^{hi}	16.00^{gh}	58.86^{j}	16.16^{cde}	52.87^{ij}	82.11^{efg}
2 × 6	13.62^{i}	MR	6.12^{hi}	19.50^{f}	61.08^{i}	15.77^{ef}	52.87^{ij}	82.64^{ef}
3 × 4	18.37^{fg}	MR	9.25^{fg}	29.00^{c}	72.05^{de}	12.58^{h}	54.37^{efgh}	84.47^{d}
3 × 5	23.25^{e}	MR	7.00^{hi}	23.00^{e}	68.32^{g}	12.76^{h}	55.62^{bcdef}	84.13^{d}
3 × 6	15.12^{hi}	MR	6.12^{hi}	19.62^{f}	69.83^{f}	11.61^{i}	56.37^{bc}	83.91^{d}
4 × 5	26.37^{cd}	MR	12.37^{e}	26.00^{d}	62.13^{hi}	15.44^{ef}	54.62^{defg}	81.87^{efgh}
4 × 6	19.75^{f}	MR	10.87^{ef}	22.00^{e}	61.54^{hi}	16.79^{cd}	53.12^{hij}	80.53^{j}
5 × 6	25.75^{cd}	MR	15.37^{d}	34.00^{b}	62.46^{h}	16.24^{cde}	52.25^{jk}	81.03^{hij}

• 1 = Super Beef Steak, 2 = Endless Summer, 3 = Roma, 4 = Bl.5, 5 = Bl.14 and 6 = Bl.18 .

* Duncan's multiple range test was used-values followed by the same letters are not significantly differed ($p \leq 0.05$).

The remaining crosses were rated of moderate resistant (MR) to this nematode. The number of galls ranged from 13.62 (in the cross Endless Summer × Bl.18) to 27.62 / root (in the cross Super Beef Steak × Bl.14) and developmental stages from 19.5 (in Endless Summer × Bl.18) to 34.00 (in Bl.14 × Bl.18).

Regarding plant growth parameters, the resistant cross Endless Summer × Roma showed the highest shoot weight, fruit weight and plant height with Super Beef Steak × Bl.5 for fruit weight / plant. The lowest average root weight was reflected by the highly resistant crosses (Endless Summer × Roma and Endless Summer × Bl.5). Generally, the obtained means ranged between 56.81 to 80.83 g for shoot weight, 10.55 to 18.02 g for root weight, 51.5 to 61.87 cm for plant height and from 80.53 to 86.72 g for fruit weight / plant as shown in Table 2.

The observed differences among the studied genotypes may be due to genetic background of the genotypes (Jacquet *et al.,* 2005). The susceptible plants allowed the juveniles to penetrate the roots and completed their development to maturity as shown by high numbers of galls and egg masses number. On the other hand, the resistant plants produce some toxic in the root exudates, which reduce penetration of the hatching juveniles and development of nematode in plant tissues (Jaubert *et al.,* 2002; Kamran *et al.,* 2012).

According to Nelson *et al.* (1990), the juveniles can develop on susceptible host, whereas the development can be delayed in resistant host. Bala (1984) added that the efficiency of galled roots in absorption of water and nutrient was reduced. This modification leads to foliage chlorosis and stunting of vegetative growth.

Also, Esfahani *et al.* (2012) reported that biochemical changes were also occurred in resistant plants after inoculation, the root cells of resistant plants react against nematode via increase in NADPH oxidase activity.

Combining Ability

Estimates of mean squares for GCA and SCA showed highly significant differences for both GCA and SCA for the studied traits, indicating that genes with additive and non-additive effects are involved in the inheritance of these traits. However, the estimated GCA / SCA ratios revealed that GCA effects were more important than SCA ones (Table 3).

As shown in Table 4, estimates of GCA for each studied parental genotype concerning the studied traits exhibited that the two cultivars Endless Summer and Roma, as well as, the breeding line Bl.5 were the best combiners for breeding to resistance for root-knot nematode disease. The two cultivars, Endless Summer and Roma gave highly significant negative GCA values for number of galls per root, number of developmental stages and number of egg masses, while the line Bl.5 reflected negative GCA values for the three characters, but it was significant for number of developmental stages only. On the other hand, the cultivar Super Beef Steak and the lines Bl.14 and Bl.18 gave highly significant positive GCA values, indicating that they are poor combiners for breeding to root-knot nematode disease. However, Endless Summer cv. was the best of all, followed by Roma cv., with GCA values of -28.37 and -8.81 for gall number; -18.77 and -5.27 for developmental stage; and -16.81 and -8.06 for number of egg masses for the two cultivars, respectively.

Regarding SCA effects, the estimated values showed that 10, 6 and 12 crosses gave significant negative values for gall number / root, number of developmental stages and number of egg masses, respectively (Table 5). For number of galls, the negative values ranged from -2.92 to -14.28 / root, for developmental stage ranged between -2.71 to -26.58 and from -2.65 to -34.40 for number of egg masses. It could be suggested that most F_1 combinations exhibited high degree of resistance against root-knot nematode disease. It could be also concluded that the crosses Super Beef Steak× Bl.5, Super Beef Steak × Bl.14, Endless Summer × Roma, Endless Summer × Bl.5, Endless Summer × Bl.14 and Roma × Bl.18 showed highly significant SCA values in the above three traits. Added to that, most crosses, which had significant negative SCA values, had at least one parent with high significant GCA effect; *i.e.,* Endless Summer, Roma and Bl.5. Generally, these combinations could be considered the most desirable ones for resistance to root- knot nematodes. Also the best combiners (Endless Summer, Roma and Bl.5) could be used in breeding for resistant to root-knot nematode, *Meloidogyne incognita*.

Degree of Heterosis

Degree of heterosis was estimated based on mid parents (MP-heterosis) and better parent (BP-heterosis) for the number of galls, developmental stages and egg masses in the evaluated crosses. Data are presented in Table 6.

MP-Heterosis

All crosses, except the cross Roma × Bl.5, gave significant negative MP-heterosis values for number of galls/root, indicating dominance towards the better parent (few gall number). While the cross Roma × Bl.5, showed insignificant MP-heterosis values (-6.33), indicating no-dominance for the number of galls/root. Regarding number of developmental stages, only four crosses reflected dominance towards the lower number of developmental stages, since they gave highly significant negative MP-heterosis values. Meanwhile, the remaining crosses gave highly positive values. For number of egg masses, all crosses gave significant negative MP-heterosis values, suggesting dominance towards the lowest number of egg masses.

BP-Heterosis

Hybrid vigour for the lowest number of galls per root was observed in five crosses; *i.e.,* Super Beef Steak × Bl.5, Super Beef Steak × Bl.14, Endless Summer × Roma, Endless Summer × Bl.5 and Bl.5×Bl.18. They gave highly significant negative values from the lowest gall number parent. Four crosses; *i.e.,* Super Beef Steak × Endless Summer, Super Beef Steak × Roma, Super Beef Steak × Bl.18 and Roma × Bl.18 did not differ significantly from the lower gall number with insignificant BP-heterosis values, suggesting complete dominance for low egg number.Partial dominance for the better parent was also observed in some crosses, since their estimated heterosis values were significantly

Table 3. Mean squares for combining ability (GCA and SCA) for number of galls, egg masses and developmental stages

S.O.V. \ Character	No. of galls		No. of developmental stages		No. of egg masses	
	MS	F	MS	F	MS	F
GCA	853.93	491.47**	355.224	947.76**	328.32	320.68**
SCA	64.81	37.296**	238.242	635.65**	134.27	131.14**
GCA / SCA	1.49		13.18		2.45	

Table 4. Estimated GCA effects for the parental lines regarding number of galls, egg masses and developmental stages

Parents \ Character	No. of galls	No. of developmental stages	No. of egg masses
1	9.25**	12.917**	7.81**
2	-28.375**	-18.771**	-16.81**
3	-8.81**	-5.271**	-8.06**
4	-0.625	-3.458**	-0.56
5	24.88**	6.667**	13.88**
6	3.688**	7.917**	3.75**
L.S.D. at 0.05	0.872	0.4048	0.669
0.01	1.195	0.555	0.917

* Significant at 5% level, and **- significant at 1% level.

1= Super Beef Steak, 2 = Endless Summer, 3= Roma, 4= Bl.5, 5= Bl.14 and 6= Bl.18.

Table 5. Estimates of SCA effects of the studied crosses for the studied characters

Crosses	No. of galls	No. of developmental stages	No. of egg masses
1 × 2	-11.23**	4.55**	-4.21**
1 × 3	-4.30**	27.05**	-0.96
1 × 4	-14.48**	-7.27**	-17.96**
1 × 5	-8.98**	-22.89**	-34.40**
1 × 6	305.71**	401.86**	180.22**
2 × 3	-13.17**	-21.27**	-4.84**
2 × 4	-19.36**	-26.58**	-11.84**
2 × 5	-9.86**	-2.71**	-12.28**
2 × 6	7.83**	5.55**	-2.65**
3 × 4	8.08**	33.92**	1.91*
3 × 5	-2.92*	4.29**	-19.03**
3 × 6	-6.23**	-7.45**	-10.90**
4 × 5	-2.11	11.48**	-10.53**
4 × 6	-0.92	-0.77	-4.40**
5 × 6	-8.92**	24.11**	-5.84**
L.S.D. at 0.05	2.39	1.11	1.83
0.01	3.19	1.48	2.45

* Significant at 5% level, and **- significant at 1% level.

1= Super Beef Steak, 2 = Endless Summer, 3= Roma, 4= Bl.5, 5= Bl.14 and 6= Bl.18.

negative from MP, but significantly positive from the BP. These crosses were Endless Summer × Bl.14, Endless Summer × Bl.18, Roma × Bl.14, Bl.5 × Bl.14 and Bl.14 × Bl.18.

With regard to developmental stages, significant negative BP-heterosis values (-47.5 and -68.5) were given by the two crosses "Endless Summer × Roma and Endless Summer × Bl.5", respectively, suggesting hybrid vigour for low number. Complete dominance for the few number of developmental stages was also observed by the crosses "Super Beef Steak × Bl.14 and Endless Summer × Bl.14", which gave insignificant BP-heterosis values.

Regarding egg masses, of the studied 15 F_1 crosses 10 ones showed highly significant negative BP-heterosis values, suggesting hybrid vigour for low number. The remaining five crosses revealed dominance for low number of egg masses, insignificant BP-heterosis values were estimated for these crosses.

Potence Ratio (P)

The estimated potence ratio (Table 6) were in accordance with the postulated hypothesis. All the crosses which exhibited hybrid vigour for the studied characters gave P values more than -1.0 (-2.43, -2.09 and -2.29 for the crosses Super Beef Steak × Bl.5, Super Beef Steak × Bl.14 and Endless Summer × Roma, respectively) for number of galls. When the complete dominance was suggested, the P values were equal or near to -1.0 (-0.91 and -0.81 in the crosses Super Beef Steak × Endless Summer and Super Beef Steak × Roma, respectively) for number of galls. The cross Roma × Bl.5 which showed no-dominance for number of galls gave potence value of 0.35, near to zero.

The correlation coefficients between number of galls per root, number of egg masses, number of developmental stages, plant height, root weight, shoot weight and fruit weight were calculated. Data in Table 7 show that there was high or highly significant positive correlation between: number of galls and each of number of egg masses, number of developmental stages and Root weight; number of egg masses versus root weight; number of developmental stages versus root weight; plant height versus both shoot weight and fruit weight; and also between fruit weight and shoot weight.

On the other hand, significant negative correlation was found between number of galls versus plant height, fruit weight and shoot weight; number of egg masses and both plant height and fruit weight; developmental stages versus each of plant height, shoot weight and fruit weight. The significant negative correlation was also observed between plant height versus root weight and between fruit weight and root weight as well as between root weight and shoot weight.

Table 6. Estimates of mid parent (MP), better parent (BP) heterosis and potence ratio (P) for number of galls, developmental stages and egg masses

Hybrids	No. of galls			No. of developmental stages			No. of egg masses		
	Heterosis (%)		P	Heterosis (%)		P	Heterosis (%)		P
	MP	BP		MP	BP		MP	BP	
1 × 2	-55.65**	15.22	-0.91	16.43**	34.78**	1.21	-55.56**	13.51	-0.91
1 × 3	-26.89**	9.28	-0.81	106.32**	184.06**	3.89	-40.54**	-5.71	-1.09
1 × 4	-38.74**	-27.14**	-2.43	17.49**	28.43**	2.05	-63.98**	-56.88**	-3.88
1 × 5	-25.28**	-15.03**	-2.09	-7.69**	-0.83	-1.11	-75.98**	-71.71**	-5.04
1 × 6	-20.12**	-5.00	-1.26	177.23**	245.68**	8.95	-19.69**	0.0	-1.0
2 × 3	-81.82**	-71.74**	-2.29	-55.28**	-47.83**	-3.87	-83.18**	-75.68**	-2.69
2 × 4	-81.72**	-63.04**	-1.62	-70.10**	-68.48**	-13.6	-86.30**	-72.97**	-1.75
2 × 5	-40.41**	89.13**	-0.59	-16.02**	5.44	-0.79	-68.72**	2.70	-0.99
2 × 6	-13.97*	73.91**	-0.28	34.10**	43.21**	5.36	-46.76**	0.0	-1.0
3 × 4	-6.33	14.43*	-0.35	107.2**	156.52**	5.55	-38.55**	-21.43**	-1.77
3 × 5	-18.37**	44.33**	-0.42	32.69**	100.00**	0.97	-69.57**	-40.0**	-1.41
3 × 6	-23.21**	-6.19	-1.27	56.00**	69.57**	7.00	-55.81**	-45.71*	-3.0
4 × 5	-18.13**	12.86**	-0.66	29.46**	52.94**	1.92	-53.02**	-32.11**	-1.72
4 × 6	-15.71**	-15.71**		46.45**	65.43**	4.05	-37.44**	-35.29**	-11.29
5 × 6	-20.73**	9.29*	$-0.\bar{7}55$	85.46**	151.85**	3.24	-40.26*	-9.80**	-0.30
L.S.D. at 0.05		1.81			0.84			1.39	
0.01		2.61			1.21			2.00	

* Significant at 5% level, and **- significant at 1% level.

1= Super Beef Steak, 2 = Endless Summer, 3= Roma, 4= Bl.5, 5= Bl.14 and 6= Bl.18.

Table 7.Correlation coefficients between some pairs of traits in the studied tomato genotypes infected by *Meloidogyne incognita*

Characters	No. of egg masses	No. of developmental stages	Plant height	Fruit weight	Root weight	Shoot weight
No. of galls	0.853**	0.461*	-0.582**	-0.599*	0.609**	-0.529*
No. of egg masses		0.347	-0.444*	-0.452*	0.573**	-0.380
No. of develop. stages			-0.555**	-0.485*	0.538*	-0.460
Plant height				0.870**	-0.778**	0.850**
Fruit weight					-0.768**	0.845**
Root weight						-0.790**

* Significant at 5% level, and **- significant at 1% level.

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تقييم بعض التراكيب الوراثية فى الطماطم لمقاومة نيماتودا تعقد الجذور

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أجريت التجارب الخاصة بهذه الدراسة بمزرعة التجارب بكلية الزراعة بشبين الكوم بهدف تقييم ٢١ تركيباً وراثياً (ثلاثة أصناف وثلاث سلالات من الطماطم ، بالإضافة إلى الهجن الفردية الناتجة من التهجين بينهم فى اتجاه واحد) للمقاومة لمرض تعقد الجذور النيماتودى فى الطماطم ، وذلك لتحديد درجة المقاومة والتوصية ببعض الأصناف والهجن التى تحمل صفة المقاومة بدرجة تؤهلها للزراعة فى المناطق الموبوءة بهذه الآفة، حيث أن استخدام الأصناف المقاومة هى الوسيلة الأفضل للحد من المرض وتقليل استخدام المبيدات الملوثة للبيئة، تم التقييم تحت ظروف العدوى الصناعية بالمسبب المرضى *Meloidogyne incognita* فى تجربة أصص، وسجلت القياسات على عدد من الصفات (عدد العقد على الجذور، طول النبات ، وزن الجذور، وزن المجموع الخضرى، وزن ثمار النبات) وتم حساب المتوسطات وإجراء التحليل الإحصائى وتقدير بعض الحسابات الوراثية، أظهرت الدراسة وجود اختلافات معنوية بين العشائر المدروسة فى معظم الصفات المدروسة- خاصة فى درجة المقاومة لمرض تعقد الجذور؛ حيث ظهرت أربع درجات من المقاومة وهى مقاوم بدرجة عالية ، ومقاوم، ومتوسط المقاومة، متوسط الحساسية، وبصفة عامة ظهرت المقاومة العالية فى الهجينين Endless Summer × Roma and Endless Summer × Bl.5. وكان الصنف Endless Summer مقاوماً للمرض، كما اتضح من قياس القدرة على التآلف لصفات المقاومة أهمية كلٍ من الفعل المضيف والغير مضيف فى وراثة صفة عدد العقد على الجذور، وعدد الاطوار اليرقية ، وكتل البيض، ولكن كان التأثير المضيف هو الأهم، وبتقدير القدرة العامة على التآلف للآباء أمكن اعتبار الصنفين Endless Summer و Roma هما الأفضل للاستخدام فى برامج التربية، حيث أظهرا التأثيرات الأعلى فى قيمة القدرة العامة المحسوبة، وظهرت قوة الهجين لصفة المقاومة للصفات المدروسة فى عدد من الهجن – مما يشجع على استخدام الهجن فى الزراعة على نطاق تجارى للتغلب على مشكلة الإصابة بمرض تعقد الجذور النيماتودى، كما لوحظ ارتباط موجب بين عدد العقد على الجذور وعدد كتل البيض ومتوسط وزن الجذور ، وارتباط سالب بين عدد العقد وارتفاع النبات، ووزن المجموع الخضرى ووزن الثمار.

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