# Results and Discussion

## I. Greenhouse experiment:

### a)*Number of galls:*

The mean square values associated with parents, hybrids , and parents Vs hybrids showed high significance (Table 1) indicating that the different genotypes showed different levels of resistance to root-knot nematode measured by number of galls.

The parental cultivars Ronita, Nemared and Anahu were the most resistant, while Edkawi, Super Marmand and PI 376072 showed high susceptibility, using number of galls as a criteria to evaluate the resistance of the different genotypes to the root-knot nematode (Table 2). Cultivar Ronita was previously found to be resistant (Freeaz and Churota-Masca, 1985). On the other hand, the $F_1$ Hybrids Ronita x Nemared, Ronita x Anahu, PI 376072 x Nemared and Nemared x Anahu were the most Resistant, followed by Super Marmand x Nemared, Super Marmand x Anahu, Edkawi x Anahu, Ronita x PI 376072, Super Marmand x Ronita, PI 376072 x Anahu and Edkawi x Nemared. The other crosses i.e. Edkawi x PI 376072, Super Marmand x PI 376072 and Edkawi x Super Marmand showed high susceptibility. Differences among *L. esculeantum* germplasm concerning their resistance to the root knot nematode have been reported (Riggs and Winstead 19959; Harrison, 1960; Dropkin and Webb, 1967; Tanveer and Saad, 1971; Sikora et al., 1973; Singh and

**Table 1: Mean square values of the different characters for the different sources of variance in the greenhouse experiment:**

| Source of variance | df | No. of galls | No. of eggs | R. factor |
|---|---|---|---|---|
| **Genotypes** | 20 | 10838.6** | 130526384** | 5.1** |
| **Parents** | 5 | 15301.5** | 164533344** | 6.6** |
| **Hybrids** | 14 | 8652.9** | 115966912** | 4.5** |
| **Parents Vs Hybrids** | 1 | 19123.2** | 164324288** | 6.7** |
| **General combining ability GCA** | 5 | 6120.7 | 70964232 | 2.8 |
| **Specific combining ability SCA** | 15 | 850 | 11152292 | 0.4 |
| **GCA/SCA** | | 7.20 | 6.36 | 7 |

**: Significant at 1%, level of significance

**Table 2:Means of number of galls, number of egges and R.factor for the inoculated plants of the different parental genotypes and its $F_1$ hybrids evaluated in the greenhouse experiments:**

| Genotypes | Measurements | | | |
|---|---|---|---|---|
| | No.of galls | No. of egges | R. factor | plant reaction |
| Edkawi | 101 | 11200 | 2.2 | Susceptible |
| Edkawi X Super Marmand | 101 | 9000 | 1.8 | Susceptible |
| Edkawi X Ronita | 1.6 | 202 | 0.04 | Resistance |
| Edkawi X PI 376072 | 101 | 14500 | 2.82 | Susceptible |
| Edkawi X Nemared | 1.4 | 300 | 0.06 | Resistance |
| Edkawi X Anahu | 0.6 | 120 | 0.02 | Resistance |
| Super Marmand | 101 | 11400 | 2.3 | Susceptible |
| Super Marmand X Ronita | 0.8 | 132 | 0.03 | Resistance |
| Super Marmand X PI 376072 | 101 | 10820 | 2.16 | Susceptible |
| Super Marmand X Nemared | 0.2 | 40 | 0.01 | Resistance |
| Super Marmand X Anahu | 0.2 | 42 | 0.01 | Resistance |
| Ronita | 0 | 0 | 0 | H.Resistance |
| Ronita X PI 376072 | 0.6 | 86 | 0.02 | Resistance |
| Ronita X Nemared | 0 | 0 | 0 | H.Resistance |
| Ronita X Anahu | 0 | 0 | 0 | H.Resistance |
| PI 376072 | 101 | 8200 | 1.6 | Susceptible |
| PI 376072 X Nemared | 0 | 0 | 0 | H.Resistance |
| PI 376072 X Anahu | 1.0 | 220 | 0.04 | Resistance |
| Nemared | 0 | 0 | 0 | H.Resistance |
| Nemared X Anahu | 0 | 0 | 0 | H.Resistance |
| Anahu | 0 | 0 | 0 | H.Resistance |
| L.S.D. 5% | 0.92 | 1457.62 | 0.29 | |
| L.S.D. 1% | 1.23 | 1933.24 | 0.39 | |

Choudhury, 1973; Taylor, 1975; Hashem, 1977; Kandakova et al., 1979; Pchelintseva, 1979; Hassan et al., 1980; Desouki et al., 1982; Vito et al., 1986; Castagnone et al., 1994). The source of this resistance found in *L.esculentum* germplasm is from *L. peruvianum* (Bailey, 1941; McFarlane et al., 1946; Watts, 1947; Thomason and Smith, 1957; Fassuliotis and Bhatt, 1982; Williamson et al., 1993; Kaloshian et al., 1998)

The mean square values associated with general (gca) and specific (sca) combining ability were highly significant (Table 1) indicating the involvement of both additive and non- additiv effects in the inheritance of resistance to root-knot nematode. However, the ratio of gca/sca, exceeded unity (7.2) indicating that the additive effects were more important than the non-additive effects in the inheritance of resistance to root-knot nematode. These results agreed with those of Walters et al., (1995) who was studying the inheritance of resistance to root knot nematode (*Meloidogyne arnaria)* in cucumber and found that the resistance was inherited quantitatively using gall index data. In addition, they observed in the same study the importance of additive genetic variance component in the inheritance of this character. Furthermore, Sikora et al., (1973), proposed one or more genes other than the Mi gene that might directly or indirectly affect root knot nematode resistance in tomato which in turn might result in quantitative inheritance pattern for resistance to root knot nematode in tomato.

Using number of galls as criteria for resistance to root-knot nematode, the parental cultivars, Ronita, Nemared and Anahu showed highly significant desirable general combining abiltity effect $\hat{(gi)}$ (Table 3) indicating that these parental genotypes can be considered as good combiners in breeding programs for resistance to root-knot nematode in tomato.

The results presented in (Table 4) indicated that the $F_1$ hybrids PI 376072 x Nemared showed the highest desirable significant negative specific combining ability effect $\hat{(sij)}$ concerning resistance to root-knot nematode measured by number of galls, followed by the $F_1$ hybrids Super Marmand x Anahu, Super Marmand x Nemared, Edkawi x Anahu, Ronita x PI 376072, Super Marmand x Ronita, PI 376072 x Anahu and Edkawi x Nemared .

The broad and narrow sense heritability estimates were 62.19% and 37.81% (Table 5), respectively, which indicated the influence of the environmental effects on the expression of this character. Theses results are close to those of Walters et al., (1995) who studied the inheritance of resistance to root knot nematode (*M. arnaria)* in cucumber, and found that the broad sense heritability ranged from 57% to 81%, and the narrow sense heritability ranged from 50 % to 85 % .

**B)Number of Eggs:**

The mean square values associated with parents, hybrids, and parents vs hybrids showed high significance (Table 1) indicating that the different genotypes showed different levels of resistance to

**Table (3):General combining ability effects $\hat{gi}$ for the different studied measurements of root knot nematode resistance for the different genotypes in the greenhouse experiment:**

| Genotypes | Measurements | | |
|---|---|---|---|
| | No. of galls | No. of egges | R. factor |
| **Edkawi** | 25.43 | 3054.33 | 0.60 |
| **Super Marmand** | 25.13 | 2593.33 | 0.52 |
| **Ronita** | -25.14 | -2708.42 | -0.54 |
| **PI 376072** | 25.18 | 2492.33 | 0.49 |
| **Nemared** | -25.32 | -2718.42 | -0.54 |
| **Anahu** | -25.29 | -2713.17 | -0.54 |
| **L.S.D. 5%** | 0.211 | 332.656 | 6.673 |
| **L.S.D. 1%** | 0.280 | 441.200 | 8.851 |

**Table (4): Specific combining ability effects $\hat{Sij}$ for the different measurements of root knot nematode resistance in the greenhouse experiment:**

| Genotypes | Measurements | | |
|---|---|---|---|
| | No.of galls | No. of egges | R. factor |
| Edkawi X Super Marmand | 21.27 | 197 | 0.05 |
| Edkawi X Ronita | -27.85 | -3299.25 | -0.65 |
| Edkawi X PI 376072 | 21.22 | 5798 | 1.10 |
| Edkawi X Nemared | -27.82 | -3191.25 | -0.63 |
| Edkawi X Anahu | -28.70 | -3376.50 | -0.67 |
| Super Marmand X Ronita | -28.35 | -2908.25 | -0.58 |
| Super Marmand X PI 376072 | 21.52 | 2579 | 0.52 |
| Super Marmand X Nemared | -28.78 | -2990.25 | -0.60 |
| Super Marmand X Anahu | -28.80 | -2993.50 | -0.60 |
| Ronita X PI 376072 | -28.60 | -2853.25 | -0.56 |
| Ronita X Nemared | 21.30 | 2271.50 | 0.45 |
| Ronita X Anahu | 21.27 | 2266.20 | 0.45 |
| PI 376072 X Nemared | -29.03 | -2929.25 | -0.58 |
| PI 376072 X Anahu | -28.05 | -2714.50 | -0.54 |
| Nemared X Anahu | 21.45 | 2276.25 | 0.45 |
| L.S.D. 5% (Sij - Sij) | 0.653 | 1030.696 | 0.207 |
| L.S.D. 1% (Sij - Sij) | 0.869 | 1367.007 | 0.274 |
| L.S.D. 5% (Sij - Sik) | 0.864 | 1363.483 | 0.274 |
| L.S.D. 1% (Sij - Sik) | 1.149 | 1808.38 | 0.363 |

**Table (5): The broad ($h^2_{bs}$) and narrow ($h^2_{ns}$) sense heritability estimates for the different measurements of root knot nematode resistance in the greenhouse experiment:**

| Charaters | Heritebility % | |
|---|---|---|
| | Broad sense $h^2_{bs}$ | Narrow sense $h^2_{ns}$ |
| Number of galls | 62.19 | 37.81 |
| Number of Egges | 62.93 | 36.42 |
| R. factor | 62.91 | 36.65 |

root-knot nematode measured by number of eggs.

Parental cultivars Ronita, Nemared, and Anahu were the most Resistant, while Edkawi, PI 376072,. and Super Marmand showed high susceplibilty, using number of eggs as a criteria to evaluate the resistance of the different genotypes to root knot nematode (Table 2). On the other hand, the $F_1$ hybrids Ronita x Nemared, Ronita x Anahu, PI 376072 x Nemared, and Nemared x Anahu were the most Resistant and followed by Super Marmand x Nemared, Super Marmand x Anahu, Ronita x PI 376072, Edkawi x Anahu, Super Marmand x Ronita Edkawi x Ronita, PI 376072 x Anahu, and Edkawi x Nemared. Such $F_1$ hybrids could perform well in areas with possible soil contamination with root knot nematode. However Edkawi x Super Marmand, Super Marmand x PI 376072, and Edkawi x PI 376072 showed high susceptibility.

The mean square values associated with general (gca) and spicific (sca) combining ability were highly significant (Table 1) indicating the involvement of both additive and non-additive effects in the inheritance of resistance to root-knot nematode in tomato, However, the ratio of gca/sca, presented in the same Table, exceeded unity indicating that the additive effects were more important than the non-additive effects in the inheritance of resistance to root-knot nematode. These results agreed with those of Walters et al., (1995) who found that resistance to root knot nematode in cucumber was inherited quantitatively, using egg mass data.

Using number of eggs as a criteria for measuring resistance of tomato to root-knot nematode, the parental cultivars Ronita, Nemared and Anahu showed higly significant desirable general combining ability effects ($\hat{gi}$) (Table 3). Indicating that these parenal genotypes can be considered as a good combiners in breeding programs for resistance to root-knot nematode in tomato.

The results presented in (Table 4) indicated that $F_1$ hybrid Edkawi x Anahu showed the highest desirable, significant negative specific combining ability ($\hat{Sij}$) effects concerning resistance to root-knot nematode measured by number of eggs, followed, in descending, order, by the $F_1$ hybrids Edkawi x Ronita, Edkawi x Nemared, Super Marmand x Anahu, Super Marmand x Nemared, PI 376072 x Nemared, Super Marmand x Ronita, Ronita x PI 376072 and PI 376072 x Anahu

The broad and narrow sense heritability estimates were 62. 93%, and 36.42% (Table 5), respectively. Results indicated the influence of the environmental effects on the expression of this character. These estimater were close to those of Walters et al., (1995) who was studying the inheritance of resistance to root knot nematode in cucumber and found that the broad sense heritability ranged from 57% to 81%, and the narrow sense heritability ranged from 50% to 85%.

**C)Reproduction (R)factor:**

The mean square values associated with parents, hybrids , and parents vs hybrids showed high significance (Table 1) indicating that

the different genotypes showed different levels of resistance to root-knot nematode measured by root-knot nematode R. factor.

The parental cultivars Ronita, Nemared and Anahu were the most resistant, while Edkawi, Super Marmand, and PI 376072 showed high susceptibility, using root-knot nematode reproduction (R) factor as a criteria to evaluate the resistance of the different genotypes to root-knot nematode (Table 2). On the other hand, the $F_1$ hybrids Ronita x Nemared , Ronita x Anahu , PI 376072 x Nemared and Nemared x Anahu were the most resistant followed, in descending order, by Super Marmand x Nemared, Super Marmand x Anahu, Ronita x PI 376072, Edkawi x Anahu, Super Marmand x Ronita, Edkawi x Ronita, PI 376072 x Anahu, and Edkawi x Nemared. On the other hand, the F1 hybrids Edkawi x PI 376072, Super Marmand x PI 376072 and Edkawi x Super Marmand showed high susceptibility.

The mean square values associated with general (gca) and specific (sca) combining ability were highly significant (Table 1) indicating the involvement of both additive and non-additive effects on the inheritance of resistance to root-knot nematode. However, the ratio of gca/sca, presented in the same table, exceeded unity (Table 1), indicating that the additive effcts were more important than than the non-additive effects in the inheritance of resistance to root-knot nematode .

Using R.factor as a criteria for resistance to root-knot nematode, the parental cultivars Ronita, Nemared and Anahu showed highly

significant disirable general combining ability effect $\hat{(gi)}$ (Table 3) indicating that these parental genotypes can be considered as good combiners in breeding programs for resistance to root-knot nematode in tomato.

The results presented in (Table 4) indicated that $F_1$ hybrid Edkawi x Anahu showed the highest desirable significant negative specific combining ability $\hat{(sij)}$ effects concerning resistance to root-knot nematode measured by R.factor, followed by the $F_1$ hybrids Edkawi x Ronita , Edkawi x Nemared, Super Marmand x Nemared, Super Marmand x Anahu, Super Marmand x Ronita PI 376072 Nemared, Ronita x PI 376072 and PI 376072 x Anahu.

The broad and narrow sense heritability estimates were 62.91%, and 36.35% (Table 5), respectively. These results indicated the influence of the environmental effects in the expression of this character. Rohini et al., (1984) and Zacheo et al., (1988) reported the influence of day and night temperatures on the expression of resistance to the root knot nematode in tomato.

**II. Field Experiment.**

**Number of days from transplanting to first flower:**

Under the condition of the artificial inoculation with root knot nematode, number of days from transplanting to first flower was less than that recorded for the uninoculated plants, for the cultivars Edkawi, Super Marmand, Ronita, PI 376072; however, the difference was not significant except in case of the cultivars Edkawi and

Nemared where the differences were significant at the 5% level of significance (Table 6). These results can be explained by the fact that tomato plants usually flower earlier under stress comparing to its flowering under normal conditions. In addition, the non-significant difference observed in this study between the inoculated and uninocualted plants of the cultivars Super Marmand, Ronita and PI 376072 concerning number of days from transplanting to frist flower can be expected, because the effect of the artificial inoculation with the root-knot nematode on the tomato plants usually appears after 60 days from the artificial inoculation. This means that in the cases where the difference was not significant, the root-knot nematode in the roots of the inoculated plants may not severely affect the number of days from transplanting to first flower. Based on this discussion it can be concluded that both the significant and non-significant difference observed between the uninoculated and inoculated tomato plant concerning number of days from transplanting to first flower should not be neglected during selection for root-knot nematode resistance in tmomato. Furthermore, the $F_1$ hybrids between the different parental genotypes had lower number of days from transplanting to first flower under the condition of artificial inoculation with the root-knot nematode comparing to the number of days associated with the uninoculated plants, except the $F_1$ hybrids Edkawi x PI 376072, Super Marmand x Ronita, Super Marmand x PI 376072 and Super Marmand x Nemared, (Table 6). As mentioned before, the earliness of flowering sometimes occurs when the tomato

**Table (6) :Means of fruit set, number of days to first flower anthesis, number of fruit per plant, fruit weight, plant yield, for the inoculated and uninoculated plants of the different parental genotypes and its $F_1$ hybrids, evaluated in the field:**

| Genotypes | Characters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of days to first flower anthesis | | Fruit set percentage | | Number of fruits per plant | | Fruit weight (gm) | | Plant yield (gm) | |
| | inoculated | uninoculated | inoculated | uninoculated | inoculated | uninoculated | inoculated | uninoculated | inoculated | uninoculated |
| Edkawi | 30.40 | 33.40 | 65.20 | 78.80 | 54.80 | 86.80 | 65.40 | 73.40 | 3546.20 | 5785.00 |
| Edkawi X Super Marmand | 23.60 | 33.80 | 77.00 | 82.00 | 146.00 | 152.20 | 61.00 | 66.60 | 8587.60 | 10062.40 |
| Edkawi X Ronita | 26.60 | 28.60 | 82.20 | 82.40 | 136.40 | 133.20 | 67.60 | 75.80 | 9290.00 | 9940.00 |
| Edkawi X PI 376072 | 30.80 | 29.20 | 74.20 | 77.80 | 248.80 | 300.60 | 31.20 | 31.80 | 7737.60 | 9520.00 |
| Edkawi X Nemared | 30.60 | 32.40 | 83.80 | 86.60 | 86.60 | 95.80 | 65.00 | 55.40 | 5593.80 | 5826.60 |
| Edkawi X Anahu | 30.40 | 33.40 | 78.80 | 82.20 | 93.40 | 93.60 | 87.00 | 90.60 | 8140.00 | 8516.80 |
| Super Marmand | 34.40 | 34.8 | 70.00 | 74.60 | 63.20 | 63.00 | 56.80 | 87.00 | 3650.00 | 5790.00 |
| Super Marmand X Ronita | 33.20 | 30.40 | 74.20 | 74.20 | 88.40 | 101.40 | 52.20 | 47.00 | 4606.60 | 4750.00 |
| Super Marmand X PI 376072 | 38.60 | 32.20 | 52.40 | 55.20 | 96.20 | 94.00 | 29.20 | 55.60 | 2800.00 | 5120.00 |
| Super Marmand X Nemared | 35.20 | 28.80 | 61.80 | 67.60 | 115.60 | 116.20 | 46.00 | 53.80 | 5410.00 | 6040.00 |
| Super Marmand X Anahu | 31.60 | 33.80 | 74.00 | 75.00 | 114.60 | 135.00 | 46.20 | 40.80 | 5150.00 | 5270.00 |
| Ronita | 31.40 | 32.80 | 80.80 | 83.00 | 56.60 | 61.00 | 54.60 | 52.20 | 3083.40 | 3137.40 |
| Ronita X PI 376072 | 24.40 | 34.60 | 72.20 | 74.00 | 167.40 | 172.20 | 23.20 | 23.80 | 3900.00 | 4075.00 |
| Ronita X Nemared | 29.80 | 34.40 | 64.40 | 71.80 | 69.00 | 69.60 | 69.40 | 68.60 | 4800.00 | 4670.00 |
| Ronita X Anahu | 29.20 | 33.60 | 64.20 | 66.60 | 120.80 | 119.20 | 52.60 | 56.00 | 6383.20 | 6624.00 |
| PI376072 | 31.00 | 32.80 | 41.60 | 53.20 | 39.80 | 97.41 | 17.60 | 24.20 | 687.60 | 2290.00 |
| PI376072 X Nemared | 28.80 | 33.20 | 64.50 | 65.80 | 119.20 | 120.80 | 27.40 | 31.00 | 3220.00 | 3730.00 |
| PI376072 X Anahu | 32.00 | 34.00 | 69.80 | 81.20 | 152.40 | 131.60 | 27.60 | 32.40 | 4110.00 | 3180.00 |
| Nemared | 32.00 | 37.60 | 65.80 | 64.60 | 44.00 | 46.60 | 105.40 | 104.20 | 4600.00 | 4820.00 |
| Nemared X Anahu | 33.60 | 38.60 | 57.00 | 58.60 | 48.20 | 48.60 | 71.00 | 72.80 | 3416.60 | 3515.00 |
| Anahu | 34.00 | 33.60 | 62.00 | 64.20 | 37.60 | 47.80 | 86.60 | 88.20 | 3250.00 | 3333.20 |
| L.S.D 5% | 2.68 | | 3.66 | | 16.10 | | 7.03 | | 451.83 | |
| L.S.D 1% | 4.10 | | 5.60 | | 24.63 | | 10.75 | | 691.03 | |

plants expose to stress, like the stress caused by the infection with the root-knot nematode. On the other hand, in the few cases where the inoculated plants flowered later than the uninoculated plants, the delay in the flowering could be due to the relative toleranc of these $F_1$ hybrids to stress caused by the infection with the root-knot nematode. The unsignificant difference between the number of days from transplanting to first flower associated with inoculated plants of the cross Edkawi x PI 376072 and that associated with its uninoculated plants can be considered as a support for the previous explaination.

The mean square values for parents, hybrids, and parents vs hybrids showed high significance (Table 7) which indicated the differences, previously mentioned, between the different genotypes involved in the present study concerning number of days from trnsplanting to first flower anthesis.

The mean square values for general (gca) and specific (sca) combining ability were significant (Table 7) indicating the involvement of both the additive and non-additive types of gene interaction in the inheritance of earliness of flowering under the condition of artificial inoculation with the root-knot nematode in tomato. However, the ratio gca/sca exceeded 1 (Table 7) which indicated that the additive type of gene interaction was more important than non-additive type of gene interaction.

Results preseted in (Table 8) show that cultivars Edkawi, Ronita, and PI 376072 had negative general combining effects for

**Table (7): Mean squares of number of days to first flower, number of fruits/plant, fruit weight, plant yield, for the inoculated and uninoculated plants of the different parental genotypes and its $F_1$ hybrids, evaluated in the field:**

| Sources | df | Number of days to first flower | Fruit set % | Fruit number/plant | Fruit weight | Plant yield |
|---|---|---|---|---|---|---|
| **Genotypes** | 20 | 56.10** | 588.50** | 13519.90** | 2688.00** | 2319682.60** |
| **parents** | 5 | 13.40 | 826.00** | 532.00** | 4518.90** | 8586170.00** |
| **Hybrids** | 14 | 71.50** | 502.60** | 11437.30** | 1927.90** | 21205266.00** |
| **Parents vs Hybrids** | 1 | 53.00* | 603.50** | 107616.10** | 4176** | 124131936.00** |
| **General combining ability GCA** | 5 | 15.10 | 222.30 | 2017.80 | 1637.80 | 6991526.50 |
| **Specific combining ability SCA** | 15 | 9.95 | 82.80 | 2932.70 | 170.90 | 3855311.50 |
| **GCA/SCA** | | 1.53 | 2.68 | 0.69 | 9.58 | 1.81 |

**: Significant at 1%, level of significance

* : Significant at 5%, level of significance

**Table (8): General combinin ability effects $\hat{gi}$ for the different studied characters for the different genotypes in the field experiment under the condition of the aritificial inoculation with the root-knot nematode:**

| Genotypes | Characters | | | | |
|---|---|---|---|---|---|
| | number of days to first flower | first set % | fruits number/plant | fruit weight | plant yeild |
| Edkawi | -1.72 | 6.19 | 15.14 | 7.70 | 1556.73 |
| Super Marmand | 1.81 | 0.43 | -1.56 | -4.10 | -16.67 |
| Ronita | -1.44 | 5.24 | -0.56 | -0.85 | 144.88 |
| PI 376072 | -0.12 | -8.31 | 20.49 | -25.90 | -1355.59 |
| Nemared | 0.56 | -1.71 | -21.63 | 13.58 | -293.39 |
| Anahu | 0.91 | -0.98 | -11.88 | 9.58 | -35.97 |
| L.S.D. 5% | 0.741 | 0.695 | 4.316 | 1.812 | 125.503 |
| L.S.D. 1% | 0.982 | 0.918 | 5.724 | 2.395 | 166.455 |

number of days to first flower, under the condition of artificial inoculation with the root-knot nematode, while cultivars Super Marmand , Nemared and Anahu, under same conditions, had positive general combining effects. Since earliness of flowering is a desirable character, it can be concluded that cultivars Edkawi, Ronita and PI 376072 can be considered as good combiners for earliness of flowering. However, other charactersitcs of these combiners such as resistance to the root-knot nematode, and high yield under the condition of artificial inoculation with the nematode, should be considered at the same time, before deciding to select a certain cultivar/line to be used as a combiner in any breeding program for resistance of tomato to root-knot nematode .

The $F_1$ hybrids which had negative specific combining ability were Edkawi x Super Marmand (-6.56), Ronita x PI 376072 (-5.12), PI 376072 x Nemared (-2.72), Super Marmand x Anahu (-2.19), Ronita x Anahu (-1.34), Edkawi x Ronita (-1.32), and Ronita x Nemared (-0.39) (Table 9). As mentioned before, the other characteristics of these $F_1$ hybrids in addition to earlinenss of flowering, should be considered before deciding the value of these $F_1$ hybrids .

Results presented in (Table 10) show that the percentages of better parent heterosis expressed by the $F_1$ hybrids under the condition of artificial inoculation with the root-knot nematode were not the same as that expressed by the uninoculated plants of these $F_1$

Table (9): Specific combining ability effects Sij for the different characters in the field experiment:

| Genotypes | Characters | | | | |
|---|---|---|---|---|---|
| | Number of doys to first flower | Fruit set% | Number of fruits | Fruit weight | plant yield |
| Edkawi X Super Marmand | -6.56 | 3.12 | 32.46 | 2.97 | 2192.17 |
| Edkawi X Ronita | -1.82 | 2.67 | 21.86 | 6.32 | 2733.02 |
| Edkawi X PI 376072 | 1.56 | 8.19 | 113.21 | -5.03 | 2681.10 |
| Edkawi X Nemared | 0.68 | 11.19 | -6.86 | -10.70 | -524.90 |
| Edkawi X Anahu | 0.13 | 5.47 | -9.81 | 15.30 | 1763.87 |
| Super Marmand X Ronita | 1.76 | 1.27 | -9.44 | 2.72 | -376.98 |
| Super Marmand X PI 376072 | 5.83 | -12.98 | -22.69 | 4.77 | -683.10 |
| Super Marmand X Nemared | 1.76 | -4.18 | 38.84 | -17.90 | 864.70 |
| Super Marmand X Anahu | -2.19 | 7.29 | 28.09 | -13.70 | 347.27 |
| Ronita X PI 376072 | -5.12 | -7.14 | 47.51 | -4.48 | 255.35 |
| Ronita X Nemared | -0.39 | -7.26 | -8.76 | 2.25 | 93.15 |
| Ronita X Anahu | -1.34 | -8.18 | 33.29 | -10.55 | 1418.92 |
| PI376072 X Nemared | -2.72 | 6.49 | 20.39 | -14.70 | 13.62 |
| PI376072 X Anahu | 0.13 | 10.97 | 43.84 | -10.50 | 646.20 |
| Nemared X Anahu | 1.06 | -8.34 | -18.24 | -6.58 | -1109.40 |
| L.S.D 5% (Sij – Sij) | 2.295 | 2.153 | 13.373 | 5.615 | 388.859 |
| L.S.D 1% (Sij – Sij) | 3.043 | 2.845 | 17.736 | 7.421 | 515.741 |
| L.S.D 5% (Sij - Sik) | 3.036 | 2.848 | 17.691 | 7.428 | 514.412 |
| L.S.D 1% (Sij - Sik) | 4.026 | 3.763 | 23.463 | 9.817 | 682.262 |

**Table (10) :Percentage of heterosis in the $F_1$ generation over better parent for number of days to first flower, percentage of fruit set, fruit number per plant, fruit weight, and plant yeild:**

| Genotypes | Heterosis % | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of days to first flower | | Fruit set% | | Number of fruits per plant | | Fruit weight | | Plant yield | |
| | inoculated | uninoculated | inoculated | uninoculated | inoculated | uninoculated | inoculated | uninoculated | inoculated | uninoculated |
| Edkawi X Super Marmand | -28.49 | -2.87 | 10.00 | 4.06 | 131.01 | 75.35 | -6.73 | -23.45 | 135.82 | 73.79 |
| Edkawi X Ronita | -15.29 | -14.37 | 1.73 | -0.72 | 140.99 | 53.46 | 3.36 | 3.27 | 161.97 | 71.42 |
| Edkawi X PI 376072 | -0.65 | -12.58 | 13.80 | -1.27 | 354.01 | 209.26 | -52.29 | -56.68 | 118.19 | 64.56 |
| Edkawi X Nemared | -4.38 | -13.83 | 27.36 | 9.90 | 58.03 | 10.37 | -38.33 | -41.07 | 21.60 | 0.72 |
| Edkawi X Anahu | -10.59 | -0.60 | 20.86 | -0.76 | 70.44 | 7.83 | 0.46 | 2.72 | 129.54 | 47.22 |
| Super Marmand X Ronita | -4.49 | -12.64 | -8.17 | -10.60 | 39.87 | 51.34 | -8.10 | -45.98 | 26.21 | -17.96 |
| Super Marmand X PI 376072 | -12.21 | -7.47 | -33.71 | -26.01 | 52.22 | -3.29 | -48.59 | -36.09 | -23.29 | -11.57 |
| Super Marmand X Nemared | 2.33 | -23.40 | -11.71 | -9.38 | 82.91 | 73.43 | -56.36 | -50.29 | 17.61 | 4.32 |
| Super Marmand X Anahu | -8.14 | -2.87 | 5.71 | 0.54 | 81.33 | 94.03 | -46.64 | -73.74 | 41.10 | -1.99 |
| Ronita X PI 376072 | -22.29 | 5.49 | -10.64 | -10.84 | 195.76 | 77.16 | -57.51 | -54.41 | 26.48 | 29.88 |
| Ronita X Nemared | -6.88 | -8.51 | -20.30 | -13.49 | 21.91 | 14.10 | -34.16 | -33.97 | 4.35 | -3.11 |
| Ronita X Anahu | -14.12 | 0.00 | -20.55 | -19.76 | 113.43 | 95.41 | -39.26 | -36.51 | 96.41 | 98.73 |
| PI376072 X Nemared | -10.00 | -11.70 | -1.82 | 1.86 | 170.91 | 24.28 | -74.01 | -70.25 | -30.00 | -22.61 |
| PI376072 X Anahu | -5.88 | 1.19 | 11.50 | 26.48 | 282.91 | 35.39 | 68.13 | -63.27 | 26.46 | 25.41 |
| Nemared X Anahu | -1.18 | 2.66 | -13.37 | -9.29 | 9.55 | 4.29 | 32.64 | -30.13 | -25.73 | -27.07 |
| L.S.D 5% | 2.81 | 2.58 | 2.64 | 2.67 | 16.38 | 16.25 | 6.88 | 7.31 | 476.25 | 484.03 |
| L.S.D 1% | 3.73 | 3.41 | 3.48 | 3.52 | 21.72 | 21.47 | 9.09 | 9.70 | 631.65 | 641.96 |

hybrids. For example, the $F_1$ hybrids Edkawi x Super Marmand had the highest percentage of better parent heterosis under the condition of nematode infection (-28.49), while the percentage associated with its uninoculated plants was -2.87 (Table 10). On the other hand, the $F_1$ hybrid Super Marmand x Nemared had highest percentage of better parent heterosis with the uninoculated plants which was-23.40, while in case of the inoculated plants of the same $F_1$ hybrids showed a value of 2.33. These results indicated significant interaction between genotype and the condition under which the plants grew i.e with or without nematode inoculation. In addition, the chracteristics other than number of days from transplanting to first flower should be considered, especially under the condition of artificial inoculation with the root-knot nematode before deciding which $F_1$ hybrids is the best.

An intermediate estimate of the broad sense heritability (78.98%) was found for number of days from transplanting to first flower anthesis under the condition of artificial inoculation with the root-knot nematode (Table 11). This value indicates that the environmental effect had an effect on the experession of this charcter. On the other hand, the narrow sense heritability estimate for this character was 10.34% which indicated the importance of selecting the plants in the segregating generations for this charachter based on family mean instead of individual plant basis.

**Table (11): Broad ($h^2_{bs}$) and narrow ($h^2_{ns}$) sense hertability estimates for the different studied characters in the field experiment under the condition of the aritificial inoculation with the root-knot nematode:**

| Charcters | Heritability % | |
|---|---|---|
| | Broad sense $h^2_{bs}$ | Narrow sense $h^2_{ns}$ |
| Number of days to first flower | 78.98 | 10.39 |
| Fruit set % | 76.38 | 22.85 |
| Number of fruits/plant | 107.42 | -9.24 |
| Fruit weight/plant | 58.57 | 40.55 |
| Plant yield | 84.84 | 14.46 |

**2- Fruit set percentage:**

The fruit set percentages of the inoculated plants of cultivars Edkawi, Super Marmand, Ronita and PI 376072 were significantly lower than that of their uninoculated plants (Table 6). These results could be due to blocking the vascular system in the roots of the inoculated plants by the nematode. On the other hand, the fruit set percentage of the inoculaed and uninoculated plants of the cultivars Nemared and Anahu were not significantly different from each other (Table 6). This could be due to the high level of resistance to nematode showed by the cultivars Nemared and Anahu. The cultivar Ronita showed the highest percentage of fruit set whether the plants were inoculated (80.8%) or not (83.0%). This indicated that this cultivar could be a good source for high percentage of fruit set under the condition of artificial infestation with the root-knot nematode . On the other hand, the parental genotype PI 376072 had the lowest percentage of fruit set, whether the plants were inoculated (41.6%) or not (53.2%). The $F_1$ hybrids Edkawi x Nemared and Edkawi x Ronita had the highest percentages of fruit set whether under the condition of the arificial infestation with the nematode or not (Table 6). The percentages of fruit set associated with plants artificially inoculated with the root-knot nematode were 83.8%, and 82.2%, and that associated with plants which were not artificially inoculated were 86.6%, and 82.4%, for the $F_1$ hybrids Edkawi x Nemared, and Edkawi x Ronita, respectively. There results indicated that such $F_1$ hybrids could be recomended in the areas which may have possible soil,

infestation with the root-knot nematode.

The results presented in (Table 7) indicated significant general and specific combining ability indicating the involvement of both additive and non-additive effects on the inheritance of high fruit set percentage under the condition of artificial infestation with the root-knot nematode. In addition the GCA/SCA role exceeded the unity which indicated that the additive genetic variance played an important role in the inheritance of high percentage of fruit set under the conditon of infestation with the root-knot nematode .

The cultivars Edkawi and Ronita showed significant positive desirable general combining ability effects ($\hat{gi}$) (Table 8), which indicated that these two cultivars were good combiners to make $F_1$ hybrids with high percentage of fruit set under the condition of infestation with the root-knot nematode. This cnclusion was supported by the results presented in (Table 6), where the $F_1$ hybrids Edkawi x Nemared and Edkawi x Ronita had the highest percentages of fruit set under the condition of infertation with root-knot nematode.

The results presented in (Table 9), showed that the $F_1$ hybrids Edkawi x Nemared had the highest significant positive specific combining ability ($\hat{Sij}$) for high percentage of fruit set under condition of infestation with the root-knot nematode, followed, in descending order, by the $F_1$ hybrids PI 376072 x Anahu, Edkawi x PI 376072, Super Marmand x Anahu, Ronita x PI 376072 and PI 376072 x Nemared. The results indicated that the above mentioned

$F_1$ hybrids had the potential of performing well in areas with posible soil infestation with root-knot nematode .

The percentage of better parent heterosis associated with the $F_1$ hybrids, under the condition of the artificial infestation, was higher in case of the $F_1$ hybrid Edkawi x Nemared (27.36%) followed, in descending order, by the $F_1$, hybrids Edkawi x Anahu (20.86%), Edkawi x PI 376072 (13.80%), PI 376072 x Anahu (11.50%), Edkawi x Super Marmand (10.0%), Super Marmand x Anahu (5.71%), and Edkawi x Ronita (1.73%) (Table 10). The better parent heterosis experssed by some $F_1$ hybrids concerning fruit set percentag under the condittion of infestation with root-knot nematode, could be due to the positive interaction between the additive genes controlling this character in the two involved parents. The $F_1$ hybrids with relatively high better parent hetrosis can be recomended in areas with possible soil infection with root-knot nematode

The broad sense heritability estimate for fruit set percentage under the condition of artificial infestation with the root-knot nematode was 76.38%., (Table 11). This result indicates that the environmental effects had an influence on the expresion of this character. On the other hand, the narrow sense heritability estimate was 22.85%, (Table 11), which indicates the importance of selection for this character through replicated experiments to reduce, as much as posible, the environmental effects on the expresion of this character.

**Number of fruits/plant:**

Only two parental genotypes i,e. Edkawi and PI 376072 showed significant differences between number of fruits obtained from the plants inoculated with root-knot nematode and that obtained from the uninoculated plants of the same genotype (Table 6) Numbers of fruits of the inoculated plants were 54.8 and 39.8, and those of the uninoculated plants were 86.8 and 97.4, for the parental genotypes Edkawi and PI 376072, respectively. On the other hand, the other parental genotypes showed no significant differences between number of fruits obtained from the inoculated plants and that obtained from the uninoculated plants (Table 6). In the case of the susceptible cultivar Super Marmand, number of fruits of the inoculated plant (63.2) was almost the same as that of the uninoculated plant (63.0), which was anexpected perfomance from a susceptible cultivar. It is worth mentioning here that number of fruits per plant should be considered along with fruit weight and/or total fruit yield/ plant Roijadhav et al., (1997).

The results presented in (Table 7), indicated significant mean squares for both the general and specific combining ability, indicating the involvement of both the additive and non additive effects on the inheritance of number of fruits/plant (Table 7). However, the GCA/SCA ratio was less than one indicating that the dominance component of the gentic variance was more important in the inheritance of number of fruits /plant under the condition of artificial

infestation with root-knot nematode than the role of the additive component.

Two parental genotypes showed desirable general combining effects ($\hat{gi}$)(Table 8), which were 14.14, and 20.49 for the cultivar Edkawi and line PI 376072 respectively. These results indicated that these parental cultivars are good combiner in making hybrids with high number of fruits/plant under the condition of infection with root-knot nematode .

The highest desirable specific combining effects ($\hat{Sij}$) were showed by the $F_1$ hybrids Edkawi x PI 376072 (113.21), Ronita x PI 376072 (47.51), PI 376072 x Anahu (43.84), Super Marmand x Nemared (38.84), Ronita x Anahu (33.29) and Edkawi x Super Marmand (32.46), (Table 9). These results indicated that the previously mentioned $F_1$ hybrids can be recommended in the locations which may have soil contamination with root-knot nematode. The means of fruits number/plant presented in (Table 6) support this conclusion, whereas the highest number of fruits/plant under the condition of artifical infestation with root-knot nematode were 248.8, 167.4, 152.4, 146.0, and 136.4 for the $F_1$ hybrids Edkawi x PI 376072, Ronita x PI 376072, PI 376072 x Anahu, Edkawi x Super Marmand, and Edkawi x Ronita, respectively .

The hybrid Edkawi x PI 376072 showed the highest percentage of better parent heterosis for number of fruits/plant whether under the condition of artificial infestion (354.01%) or not (209.26%),

(Table10). On the other hand, the $F_1$ hybrids PI 376072 x Anahu and Ronita x PI 376072 showed high percentage of better parent heterosis for number of fruits /plant only under the condition of the artificial infestation with root-knot nematode where the estimated heterosis were 282.9% and 195.76%, respectively (Table 10). The high percentage of better parent hetrosis expressed by the previously mentioned $F_1$ hybrids for number of fruits/plant under the condition of artificial infestation with root-knot nematode indicated the value of planting such $F_1$ hybrids in the arears with high risk of tomato infection with root-knot nematode. Uppal et al., (1997) reported hterosis for number of fruits/plant in tomato.

The negative value estimated for the narrow sense heritability (Table 11) was considered to be zero. Such value indicated that slection for high number of fruits/plant under the condition of artificial infestatin with root-knot nematode in the segregating generations of tomato crosses should be based on means of families evaluated in replicated experiments. On the othe hand, Pujari et al., (1995), reported high heritability for number of fruits per plant in tomato.

**Fruit weight**

Fruit weight of the inoculated plants of parental genotypes Edkawi, and Super Marmand were significantly lower then that of their uninoculated plants (Table 6). This results could be due to blocking the vascular system in the roots of the inoculated plants by

the nematode. On the other hand, the fruit weight of the inoculated and uninoculated plants of the parental genotypes Ronita, PI 376072 Nemared and Anahu were not significantly different from each other (Table 6). This result could be due to the high level of resistance to nematode showed by these tomato germplasm. The cultivars Edkawi, and Super Marmaand, Nemared, and Anahu showed the highest fruit weight whether under in inoculation or uninoculation condition (Table 6). However, the cultivars Nemared showed the nighest fruit weight under the condition of artificial infestation with Root Knot nematode (105.4 gm) while the average fruit weight of uninoculated plants was (104.2gm). On the other hand, the parental genotype PI 376072 had the lowest fruit weight whether the plants were inoculated (17.60gm) or uninoculated (24.2gm) (Table 6). The $F_1$ hybrids Edkawi x Nemared, Edkawi x Ronita, Nemared x Anahu, and Ronito x Nemared showed the highest fruit weight, whether under the condition of the artificail infestation with nematode or not (Table 6). The fruit weight associated with plants artificailly inoculated with root-knot nematode were 87gm, 67.6 gm, 71gm, and 69.4 gm, and that associated with plants which were not artificially inoculated were, 90.6 gm 75.8 gm, 72.8 gm and 68.8 gm, for the $F_1$ hybrids, Edkawi x Anahu, Edkawi x Ronita, Nemardx Anahu, and Ronita x Nemared, respectivelly. These results indicated that such $F_1$ hybrids could be recommended in the areas which might have possible soil infestation with the root knot nematode, especially when considering that fruit weight had the greatest direct effect on yield (Ghosh and Syamal, 1994).

The results presented in (Table 7) indicated significant general and specific combining ability indicating the involvement of both additive and non-additive effects on the inheritance of high fruit weight under the condition of artificial infestation with root knot nematode. In addition, the GCA/SCA ratio exceeded the unity which indicated that the additive gentic variance played an important role in the inheritance of high fruit weight under the condition of infestation with root-knot nematode

The cultivars, Nemared, Anohu, and Edkawi showed significant postive desirable general combining ability effects ($\hat{gi}$) (Table 8), which indicated that these cultivars can be considered as good combiners to make $F_1$ hybrids with high fruit weight under the condition of infestation with root knot nematode. This conclusion was supported by the results presented in (Table 6), where the $F_1$ hybrids Edkawi x Anahu, Edkawii x Ronita Nemared x Anahu, and Ronata x Nemared, had the highest fruit weight under the condition of infestation with root knot nematode .

The results presented in (Table 9) showed that the $F_1$ hybrids Edkawi x Anahu had the highest signifcant positive specific combining ability ($\hat{Sij}$) for the high fruit weight under the condition of infestation with root knot nematode, followed, in descending order, by the $F_1$ hybrids Edkawi x Ronita, Super Marmand x PI 376072, Edkawii x Super Marmand, super Marmandx Ronita, and Ronita x Nemared. These results indicated that the above mentioned

$F_1$ hybrids had the potential of preforming well in areas with possible soil infestation with root knot nematode .

The $F_1$ hybird Edkawi x Ronita showed almost similar positive percentage of better parent heterosis under the condition of artificial inoculation with root-knot nematode (3.36%) and in case of uninoculation conditions (3.27%) (Table 10). However, the hybrids PI 376072 x Anahu, and Nemared x Anahu had better parent heterosis percentages of 68.13%, 32.64%, respectivelly, under the artificial condition. These results indicated that such hybrids could perform well under the condition of soil infestations with the root knot nematode

The broad sense heritability estimated was (58.57%)(Table 11). On the other hand the narrow sense heritability estimate was low (40.55%), indicating the importance of selecting for high fruit weight in the segregating generations, under the condition of artificial inoculation with root knot nematode, based on family mean basis in replicated experiments to reduce the non-additive effects on the expression of this character. On the other hand, Kumari et al., (1994), and Pujari et al., (1995) reported high heritability for fruit weight in tomato.

**Plant Yield**

The plant yield of the inoculated plants of cultivars Edkawi , Super Marmand and PI 376072 were significantly lower than that of

their uninoculated plants (Table 6). These results could be due to blocking the vascular system in the roots of the inoculated plants by the nematode. On the other hand, the yield of the inoculated and uninoculated plants of the cultivars Ronita, Nemared and Anahu were not significantly different from each other (Table 6). This could be due to the high level of resistance to nematode showed by the cultivars Ronita, Nemared and Anahu. The cultivars Edkawi and Super Marmand showed the highest plant yield under uninoculated plants condition. However, these cultivars along with cultivar Anahu showed the lowest plant yield when their plants were inoculated. The cultivar Nemared showed the highest plant yield under the condition of artificial infestation with root-knot nematode. On the other hand, the parental genotype PI 376072 had lowest plant yield whether the plants were inoculated or uninoculated (Table 6).

The $F_1$ hybrids Edkawi x Ronita, Edkawi x Super Marmand and Edkawi x Anahu showed the highest plant yield whether under the condition of the artificial infestation with nematode or not (Table 6). The plant yield associated with plants artificially inoculated with the root-knot nematode were 9290.01 gm, 8587.6gm and 8140.0gm and that the associated with plants which were not artificially inoculated were 9940gm, 10062.4gm 8516.8gm, for the $F_1$ hybrids Edkawi x Ronita, Edkawi x Super Marmand, Edkawi x Anahu, respectively. The results indicated that such $F_1$ hybrids should be recommended in the areas which might have possible soil infestation with the root-knot nematode to reduce the damage caused by this nematode which was

reported in many parts of world (Dropkin, 1954 and 1972; Houssny and Oteifa, 1956; Oteifa and El-Gindi, 1957; Oteifa, 1964; Ibrahim et al., 1976; El-Gindi and Moussa, 1979; Eisenback et al, 1981; CORR, 1983; MAFF, 1983; Johnson and Fassuliotis, 1984; Hartman and Sasser, 1985; Hirshmann, 1985).

The results presented in (Table 7) indicated significant general and specific combining ability indicating the involvement of both additive and non-additive effects on the inheritance of high plant yield under the condition of artificial infestation with the root-knot nematode. In addition, the GCA/SCA ratio exceeded the unity which indicated that the additive genetic variance played an important role in the inheritance of high plant yield under the condition of infestation with root-knot nematode. Rai et al., (1997) reported that both the additive and non-aditive components played major role in the control of yield and yield components.

The cultivars Edkawi and Ronita showed significant positive desirable general combining ability effect ($\hat{gi}$) (Table 8), which indicated that these tow cultivars are good combiners to make $F_1$ hybrids with high plant yield under the condition of infestation with root-knot nematode. This conclusion was supported by the results presented in (Table 6), where the $F_1$ hybrids Edkawi x Ronita, Edkawi x Super Marmand and Edkawi x Nemared had the highest plant yield under the condition of infestation with root-knot nematode

The results presented in (Table 9) showed that the $F_1$ hybrids

Edkawi x Ronita had the highest significant positive specific combining ability ($\hat{Sij}$) effects for high plant yield under the condition of infestation with root-knot nematode followed, in descending order, by the $F_1$ hybrids Edkawi x PI 376072, Edkawi x Super Marmand, Edkawi x Anahu, and Ronita x Anahu. These results indicated that the above mentioned $F_1$ hybrids had the potential of performing well in areas with possible soil infestation with root-knot nematode.

The $F_1$ hybrids Edkawi x Super Marmand, Edkawi x Ronita, and Edkawi x PI 376072 showed the highest percentage of better parent heterosis whether under the condition of artificial inoculation with root-knot nematode or not (Table 10). However, the hybrid Edkawi x Anahu had a percentage of 129.54% better parent heterosis under the artificial inoculation condition, while the percentage was 47.22% in case of the uninoculation. On the other hand, the $F_1$ hybrid Ronita x Anahu had relatively high percentages of better parent heterosis at both cases of inoculation and uninoculation which were 96.41% and 98.73%, respectively (Table 10). It is worth mentioning here that, in general, the $F_1$ hybrids which perform well under wide range of conditions will be prefered than that which perform well only under certain conditions. Based on this fact, the $F_1$ hybrids which had the highest percentages of better parent hetrosis under both conditions of inoculation and uninoculation, i.e Edkawi x Super Marmand, Edkawi x Ronita, and Edkawi x PI 376072 (Table 10) can be considered the best $F_1$ hybrids. The results presented in (Table 6) support this conclusion since these $F_1$ hybrids had the highest plant

yield at both the conditions of inoculation and uninoculation. Raijadhav and Kale (1986), who made crosses between resistance and susceptible tomato cultivars, observed hetrosis in all studied characters including yield. In addition, Singh et al., (1995), and Uppal et al., (1997) reported high better parent heterosis for plant yield in tomato.

The brood sense heritabiltiy estimate was 84.84% (Table 11). On the other hand the narrow sense heritabibity estimate was low (14.46%), indicating the importance of selecting for high yield in the segregating generations under the condition of artificial inoculation with root-knot nematode, based on family mean basis in replicated experiment to reduce the non additive effects on the expresion of this charcater

**Detached leaves fresh weight**

The highest fresh weight of the detached leavs of the uninoculated plants was associated with the parental genotype PI 376072 (1065 gm) followed by, in descending order, cultivars Nemared (860 gm) Ronita (851.2 gm), Super Marmand (802.6 gm), Anahu (700.0 gm), nad Edkawi (616.6 gm), (Table 12). The high weight of the fresh leaves could increase the efficiency of photosynthesis which in return may have positive effects on the yield and its quality of the tomato plant, assuming presence of balance between roots and leaves. On the other hand, data presented in the same table show that the fresh weight of the leaves detached from the inoculated plants of the parental cultivars Edkawi, Super Marmand

**Table (12): Means of detached leaves fresh weight, Number of branchs, Plant height, and Roots fresh weight for the inoculated and uninoculated plant of the different parental genotypes and its $F_1$ hybrids, evaluated in the field:**

| Genotypes | Characters | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Leaves fresh weight/plant | | No. of branchs/plant | | Plant height (cm) | | Roots fresh weight/plant | |
| | inoculated | uninoculated | inoculated | uninoculated | inoculated | uninoculated | inoculated | uninoculated |
| Edkawi | 410 | 616.6 | 9.6 | 12.4 | 74.6 | 98.6 | 350 | 375 |
| Edkawi X Super Marmand | 600 | 1075 | 11.2 | 16.6 | 155.4 | 177.2 | 244 | 321 |
| Edkawi X Ronita | 1955 | 1985 | 17.2 | 17.8 | 114.2 | 117.6 | 386 | 388 |
| Edkawi X PI 376072 | 985 | 1050 | 17.4 | 21.2 | 172.2 | 219.6 | 345 | 459 |
| Edkawi X Nemared | 862.6 | 880 | 14.8 | 14.8 | 155 | 127.2 | 231.2 | 236.6 |
| Edkawi X Anahu | 760 | 800 | 14.8 | 13.8 | 88 | 95.6 | 217 | 222 |
| Super Marmand | 606.2 | 802.6 | 7.0 | 30.4 | 100.8 | 118.8 | 172.6 | 225 |
| Super Marmand X Ronita | 993.4 | 1055 | 16 | 17.8 | 199.2 | 199.8 | 318.4 | 345 |
| Super Marmand X PI 376072 | 948 | 1215 | 14.6 | 17.2 | 165 | 206.4 | 358.2 | 356 |
| Super Marmand X Nemared | 920 | 930 | 16.2 | 17 | 156.6 | 188.2 | 266 | 300 |
| Super Marmand X Anahu | 825 | 835 | 16.4 | 17 | 133.2 | 138.6 | 211 | 212 |
| Ronita | 808.2 | 851.2 | 14 | 15.8 | 116.4 | 119 | 301.8 | 306 |
| Ronita X PI 376072 | 2098 | 2235 | 12.8 | 19.2 | 226.8 | 232.6 | 547 | 599 |
| Ronita X Nemared | 916.6 | 965.2 | 13.6 | 14 | 131.6 | 135.2 | 515 | 529 |
| Ronita X Anahu | 819.4 | 855 | 13 | 14.2 | 118.2 | 135.2 | 288 | 302 |
| PI 376072 | 780 | 1065 | 13 | 18 | 189.2 | 221 | 601.2 | 495 |
| PI376072 X Nemared | 1215 | 1240 | 17.8 | 20 | 159.8 | 173.6 | 378 | 424 |
| PI376072 X Anahu | 2337.6 | 2351 | 21.8 | 20.4 | 232.4 | 236.6 | 366.2 | 371 |
| Nemared | 812.6 | 860 | 15 | 15.2 | 125.6 | 125.8 | 565 | 565 |
| Nemared X Anahu | 675 | 815 | 14.2 | 15.2 | 115 | 119.2 | 347.6 | 359 |
| Anahu | 665 | 700 | 11 | 12.4 | 92 | 99.8 | 267 | 265 |
| L.S.D 5% | 114.94 | | 2.31 | | 17.23 | | 27.37 | |
| L.S.D 1% | 175.77 | | 3.53 | | 26.36 | | 41.87 | |

and PI 376072 were significantly less than the fresh weight of the leaves detached from the uninoculated plants of the same genotypes (Table 12). Such differences can be attributed to the effect of inoculation with root-knot nematode. On the other hand, the differences between the inoculated and uninoculated plants of the resistant cultivars Ronita, Nemared and Anahu in this respect were not significantly different, which are expected results for the previously mentioned resistant cultivars

The results presented in (Table 13) indicated significant mean squares for the general and specific combining ability. In addition, the general to specific combining ability ratio was 1.04 (Table 13). These results indicated the equal importance of the role of both the additive and non-additive gene interacion types in the inheritance of detached leaves fresh weight of tomato plants under the condition of artificial infestation with root-knot nematode .

Putting in consideration the positive effects of high fresh weight of leaves on the biological efficiency of tomato plants under the condition of artificial infestation with root-knot nematode, the parental cultivars Ronita and PI 376072 can be considered the best combiners to form tomato hybrids with high biological effeiciency under such conditions, because both cultivars showed positive and significant general combining ability effects (Table 14). The results presented in (Table 15) show that the highest positive specific

**Table (13): Mean squeres of detached leaves weight, number of branchs, plant height, and roots fresh weight for the inoculated plants of the different parental cultivars and its $F_1$ hybrids under the condition of artificial inoculation with the root-knot nematode:**

| Sources | df | Characters | | | |
|---|---|---|---|---|---|
| | | Leaves fresh weight | No. of branchs | Plant height | Roots fresh weight |
| Genotypes | 20 | 1277601.3** | 62.5** | 9485.9** | 73096.9** |
| Parents | 5 | 122588.8** | 44.8** | 7970.4** | 145739** |
| Hybrids | 14 | 1475479.4** | 43.00** | 8447** | 49701** |
| Parents Vs Hybrids | 1 | 4282368.0** | 422.4** | 31608.9** | 37429** |
| General combining ability (GCA) | 5 | 263037.6 | 15.3 | 3937.4 | 40352.8 |
| Specific combining ability (SCA) | 15 | 253014.5 | 11.6 | 1217.1 | 6041.6 |
| GCA/SCA | | 1.04 | 1.32 | 3.24 | 6.68 |

**: Significant at 1%, level of significance

**Table 14: General combining ability effects $\hat{gi}$ for the different studied characters for the different genotypes in the field experiment under the condition of the aritificial inoculation with the root-knot nematode:**

| Genotypes | Characters | | | |
|---|---|---|---|---|
| | leaves fresh weight | No. of branchs | Plant height | Roots fresh weight |
| Edkawi | -126.87 | -1.13 | -21.63 | -37.80 |
| Super Marmand | -187.34 | -1.88 | -0.49 | -85.35 |
| Ronita | 175.16 | 0.73 | 1.97 | 29.05 |
| PI 376072 | 268.26 | 2.00 | 4.94 | 96.40 |
| Nemared | -97.87 | 0.40 | -4.73 | 55.28 |
| Anahu | -31.32 | -0.18 | -17.03 | -57.58 |
| L.S.D. 5% | 27.80 | 0.50 | 3.24 | 8.47 |
| L.S.D. 1% | 36.74 | 0.66 | 4.30 | 11.19 |

**Table (15): Specific combining ability effects $\hat{S}ij$ for the different character in the field experiment:**

| Genotypes | Characters | | | |
|---|---|---|---|---|
| | Leaves fresh weight | No. of branchs | Plant height | Roots fresh weight |
| Edkawi X Super Marmand | -84.44 | -0.57 | 32.68 | 20.64 |
| Edkawi X Ronita | 907.09 | 2.78 | -10.00 | 48.24 |
| Edkawi X PI 376072 | -156.04 | 1.75 | 9.03 | -60.11 |
| Edkawi X Nemared | 87.71 | 0.75 | 37.50 | -132.79 |
| Edkawi X Anahu | -81.46 | 1.13 | -17.20 | -34.14 |
| Super Marmand X Ronita | 5.94 | 2.33 | 52.88 | 28.19 |
| Super Marmand X PI 376072 | -132.56 | -0.30 | -20.30 | 0.64 |
| Super Marmand X Nemared | 205.59 | 2.90 | 19.98 | -50.44 |
| Super Marmand X Anahu | 44.01 | 3.68 | 5.88 | 7.41 |
| Ronita X PI 376072 | 654.94 | 4.25 | 40.03 | 75.04 |
| Ronita X Nemared | -160.31 | -2.35 | -9.50 | 84.16 |
| Ronita X Anahu | -324.09 | -2.37 | -10.60 | -29.99 |
| PI 376072 X Nemared | 44.99 | 0.63 | -20.28 | -120.19 |
| PI 376072 X Anahu | 1101.01 | 5.20 | 64.63 | -19.14 |
| Nemared X Anahu | -195.44 | -0.80 | -7.10 | 3.39 |
| L.S.D 5% (Sij - Sij) | 86.13 | 1.54 | 10.05 | 26.23 |
| L.S.D 1% (Sij - Sij) | 113.83 | 2.04 | 13.33 | 34.67 |
| L.S.D 5% (Sij - Sik) | 113.94 | 2.04 | 13.29 | 35.00 |
| L.S.D 1% (Sij - Sik) | 150.49 | 2.69 | 17.63 | 45.86 |

combinig ability effects ($\hat{Sij}$) was associated with the $F_1$ hybrid PI 376072 x Anahu (1101.01) followed by, in descending order, Edkawi x Ronita (907.09) and Ronita x PI 376072 (654.94). The previously mentioned $F_1$ hybrids were obtained from crosses made between the best two combiners respecting high detached leaves fresh weight of plants inoculated with root-knot nematode i.e PI 376072 and Ronita. Furthermore, the results presented in (Table 12), support the previously mentioned results because the $F_1$ hybrids PI 376072 x Anahu, Ronita x PI 376072 and Edkawi x Ronita had the highest percentages of better parent hetrosis i.e. 199.69%, 159.60% and 144.90, respectively (Table 16).

The broad sense heritability estimate for detached leaver fresh weight under the condition of artificial infestation with root-knot nematode was 98.30%, while the narrow sense heritability estimate was 0.97%, (Table 17). These results indicated that the expression of this character was influenced, for a great deal, by the environmental conditions. Such environmental effects can be removed by evaluating the plants of the segregating generations in replicated experiment when selecting for tomato plants with large number and/or weight of leaves under the condition of artificial infestation with root-knot nematode.

**Number of branchs /plant:**

Significant differences among the different parental genotypes concerning number of branchs/plant whether the plants were planted

**Table (16): Percentage of heterosis in the $F_1$ generation over better parent for detached leaves fresh weight, number of branchs, plant height, and roots fresh weight:**

| Genotypes | Heterosis | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | leaves fresh weight | | No. of branchs | | Plant height | | Roots fresh weight | |
| | inoculated | uninoculated | inoculated | uninoculated | inoculated | uninoculated | inoculated | uninoculated |
| Edkawi X Super Marmand | -1.02 | 33.94 | 16.67 | -45.40 | 54.17 | 49.16 | -30.29 | -14.40 |
| Edkawi X Ronita | 141.90 | 133.20 | 22.86 | 12.66 | -1.89 | -1.18 | 10.29 | 3.47 |
| Edkawi X PI 376072 | 26.28 | -1.41 | 33.85 | 17.78 | -8.99 | -0.63 | -42.61 | -7.27 |
| Edkawi X Nemared | 6.15 | 2.33 | -1.33 | -2.63 | 23.41 | 1.11 | -59.08 | -58.12 |
| Edkawi X Anahu | 14.29 | 14.29 | 32.73 | 11.29 | -4.35 | -4.21 | -38.00 | -40.80 |
| Super Marmand X Ronita | 22.92 | 23.94 | 14.29 | -14.45 | 71.13 | 67.90 | 5.50 | 12.67 |
| Super Marmand X PI 376072 | 21.54 | 14.09 | 12.31 | -43.42 | -12.79 | -6.61 | -40.42 | -28.08 |
| Super Marmand X Nemared | 13.22 | 8.14 | 8.00 | -44.08 | 24.68 | 49.60 | -52.92 | -46.90 |
| Super Marmand X Anahu | 24.09 | 4.04 | 49.59 | -44.08 | 32.14 | 16.67 | -21.15 | -20.00 |
| Ronita X PI 376072 | 159.60 | 109.86 | 55.71 | 6.67 | 19.87 | 5.25 | -9.02 | 21.01 |
| Ronita X Nemared | 12.80 | 11.19 | -9.33 | -11.39 | 4.78 | 7.47 | -8.85 | -6.37 |
| Ronita X Anahu | 1.39 | 0.45 | -7.14 | -10.13 | 1.55 | 13.61 | -4.27 | -1.37 |
| PI376072 X Nemared | 49.52 | 16.43 | 18.67 | 11.11 | -15.54 | -21.45 | -37.13 | -24.96 |
| PI376072 X Anahu | 199.69 | 120.75 | 67.69 | 13.33 | 22.83 | 7.06 | -39.09 | -25.05 |
| Nemared X Anahu | -16.93 | -5.53 | -5.33 | 0.00 | -8.44 | -5.25 | -38.48 | -36.46 |
| L.S.D 5% | 105.49 | 129.29 | 1.89 | 9.68 | 12.31 | 21.60 | 32.12 | 19.31 |
| L.S.D 1% | 139.41 | 170.87 | 2.49 | 12.84 | 16.32 | 28.64 | 42.46 | 25.52 |

**Table (17) Broad ($h^2_{bs}$) and narrow ($h^2_{ns}$) sense heritability estimates for different studied characters in the field experiment under the condition of inoculation with root-knot nematode:**

| Characters | Heritability % | |
|---|---|---|
| | Brood sense $h^2_{bs}$ | Narrow sense $h^2_{ns}$ |
| Leaves fresh weight | 98.30 | 0.97 |
| No. of branchs | 88.53 | 7.00 |
| Plant height | 72.62 | 26.39 |
| Roots fresh weight | 62.27 | 36.98 |

in soil artificially infested with the root-knot nematode or in soil free from that nematode (Table 12). Under the condition of the artificial infestation with root-knot nematode, the plants of the parental cultivars Nemared had the highest number of branchs/plant (15.0), followed by Ronita (14.0), PI 376072 (13.0), Anahu (11.0), Edkawi (9.6) and Super Marmand(7.0). On the other hand, under the condition of nematode free-soil, plants of the parental genotype PI 376072 had the highest number of branchs/plant (18.0) followed by Ronita (15.8), Nemared (15.2), Anahu (12.4) Edkawi (12.4), and Super Marmand (12.4). The parental genotypes previously recorded as resistant to the root-knot nematode showed no significant differences between the number of branchs/plant under the condition of planting in soil infected with the root-knot nematode and the number recorded for the plants planted in soil free of root-knot nematode, except the parental line PI 376072 which showed slight significant difference between the number recorded in both cases. On the other hand, the cultivars Edkawi and Super Marmand showed significant differences between the numbers recorded in both cases. The large number of branchs/plant especially under the condition of artificial infestation with the root-knot nematode reflects the high yielding atility of plants under such conditions. Based on this point of view, the parental genotypes Ronita, PI 376072, Nemared and Anahu have the potential of high yielding ability under the condition of infestation with root-knot nematode (Table 12).

The results presented in (Table 13) showed significant general

and spesific combining ability for number of branchs under the conditions of artificial infestation with root-knot nematode. The GCA/SCA ratio exceeded unity (2.06), (Table 13), indicating the important role of the additive gene action in the inheritance of this charachter.

The parental genotypes PI 376072 Ronita and Nemared showed significant positive general combining ability effects ($\hat{gi}$) which were 2.00, 0.78 and 0.40 respectively, while the other parental genotypes showed negative general combining ability effects, (Table 14). These results indicated that the parental genotypes which showed significant positive general combining ability effects could be good combiners to form hybrids with high number of branchs/plant in fields having posible soil contamination with root-knot nematode, like the fields in the new reclaimed soil.

The $F_1$ hybrids obtained from the crosses involving one of the best combiners, which had the highest positive general combining ability effects, i.e. PI 376072 and Ronita, had the highest specific combining ability effects, (Table 15). The $F_1$ hybrids PI 376072 x Anahu and Ronita x PI 376072 had the higest positive specific combining ability effects, which were 5.20 and 4.25, respectively.

The $F_1$ hybrids with the highest positive specific combining ability effects i.e., PI 376072 x Anahu and Ronita x PI 376072 showed the highest percentages of better parent heterosis under the conditions of arificial infestation with root-knot nematode, which was

67.59% and 55.71%, respectively (Table 16). These results reflects the value of such hybrids to be planted under such conditions.

The broad-sense heritability estimate for number of branchs/plant under the condition of artificial infestation with root-knot nematode was 88.53%, while the narrow sense heritability estimate was 7.00%, (Table 17). These results indicated the high effects of the environmental conditions on the expression of this character. Based on thes results, selection for this character should be based on family means in the segregating generations of the crosess between tomato genotypes.

**Plant height**

With all parental genotypes, the healthy plants were higher than the inoculated ones within the same genotype (Table 12). However,the difference in plant height between the healthy and inoculated plants was only significant in case of the parental genotypes Edkawi, Super Marmand, and PI 376072. On the other hand, in case of the cultivars Ronita, Nemared, and Anahu, which showed the highest degree of resistance to root-knot nematode in the greenhouse experiment (Table2), the differences were not significant (Table 12). The significant reduction in plant height of the inoculated plants of the susceptible genotypes could be due to the effect of inoculation with root-knot nematode .

The $F_1$ hybrids which showed the highest plant height were PI 376072 x Anahu, Ronita x PI 376072, Edkawi x PI 376072, and

Super Marmand x PI 376072 (Table 12). The differences between the healthy and inoculated plants concerning plant height for the $F_1$ hybrids Edkawi x PI 376072 and Super Marmand x PI 376072 were significant but the differences were not significant in case of the $F_1$ hybrids Ronita x PI 376072 and PI 376072 x Anahu. Such differences could be due to the gentic variation in resistance to root-knot nematode among the previously mentioned $F_1$ hybrids .

The mean square values for general and specific combining ability were significant (Table 13). In addition, the GCA/SCA ratio was 3.24. These results indicated that the additive gene action was more important than the dominance gene action, in the inheritance of plant height under the conditions of artificial infestion with the root-knot nematode .

Among the parental genotypes, only Ronita and PI 376072 showed significant positive general combining ability effects indicating the suitability of these two genotypes as combiners to form $F_1$ hybrids with high plant height under the condition of plant infesation with root-knot nematode (Table 14).

The $F_1$ hybrids PI 376072 x Anahu and Super Marmand x Ronita which both contained one of the best combiners, had the highest specific combining ability effects, (Table 15). In addition, the $F_1$ hybrid Super Marmand x Ronita had the highest percentage of better parent hetrosis whether the plants were planted in soil, artificially infested with root-knot nematode or nematode free-soil

(Table 16). It is worth mentioning here that the high plant height of tomato plants artificially infected with root-knot nematode, can be considered as a tolerance for that infection; however, the other characteristics such as yield and its quality under such conditions should be considered .

An intermediate estimate of broad sense heritability equal to 72.62% and low narrow sense heritability estimate equal to 26.39% were calculated (Table 17). Such results indicate that evaluation and selction for taller plants under the condition of plant infection with root-knot nematode should be performed through replicated experiments to reduce on much as possible, the environmental effects on the inheritance of this character. On the other hand, Kumari and Supramanian, (1994) and Pujari et al., (1995) reported high heritability for plant height in tomato.

**Root fresh weight:**

The highest root fresh weight of the parental genotypes was that associated with the cultivar which had an average of 565 gm for the inoculated and uninoculated plants, (Table 12). In addition, the parental genotypes Edkawi, Ronita, and Anahu showed no significant difference between the fresh root weight of the inoculated plants and that of the uninoculated plants. On the other hand, the susceptible cultivar Super Marmand showed significant difference between the root fresh weight of the inoculated plants (172.6 gm) and that of the uninoculated plants (225 gm), (Table 12). Such differentiations observed in the present study could be due to the differences between

the different genotypes respecting resistance to root-knot nematode. However, further studies are needed to study the rate of root development of these tomato genotypes especially under the condition of infection with the root-knot nematode.

The results presented in (Table 13) show significant mean squares for general and specific combining ability which indicated the involvement of both the additive and dominance gene action in the inheritance of root fresh weight under the condition of nematode infection. The GCA/SCA ratio exceeded unity (6.68) which indicated that the additive gene action was more important than the dominance gene action in the inheritance of this character.

The parental genotypes PI 376072, Nemared, and Ronita gave significant positive general combinig ability effects which were 96.40, 55.28 and 29.05, respectively (Table 14). Based on these results, the previously mentioned parental genotypes can be considered as good combines to form $F_1$ hybrids with large root system under nematode infection conditions which may give strength to the plants under such conditions.

The $F_1$ hybrids which had the highest specific combining ability effects were Ronita x Nemared (84.16), Ronita x PI 376072 (75.04), and Edkawi x Ronita (48.24), (Table 15). Only, the $F_1$ hybrids Edkawi x PI 376072 and Super Marmand x Ronita had small percentages of better parent hetrosis i.e 10.29% and 5.50%, respectively under the condition of nematode infection. On the other hand, the $F_1$ hybrids Ronita x PI 376072 , Super Marmand x Ronita, and Edkawi x Ronita

showed small percentages of better parent hetrosis under the condition of planting in nematode free soil (Table 16).

An intermediate broad sense heritability (62.27%) and below intermediate narrow sense heritbility (36.48%) were estimated for root fresh weight under the condition of infection with root-knot nematode (Table 17). These results indicated the posibility of improving this character; however, the environmental effects on the expression of this character should be considered .

**Root Phenols Content**

Significant differences in root phenols contents between the plants of the different parental genotpys, whether the healthy or the inoculated, were detected (Table 18). Both the healthy and. infected plants of the parental cultivars which previously reported as resistant to the root knot rematode, i.e Ronita, PI 376072, Nemared, and Anahu had higher root phenols contents than that of the other cultivars, i.e Super Marmand which was previously reported as susceptible cultivar, and cultivar Edkawi (no reports have been published on its resistance to the root knot nematode), (Table 18). The root phenols contents of the healthy and inoculated plants of the cultivar Edkawi were higher than that of the cultivar Super Marmard (Table 18). The root phenols contents of the healthy plants of the different genotypes in descending order were 185.8, 173.0, 160.8, 152.2, 136.2, and 91.0 mg/100gm (f.w) for the parental genotypes Anahu, Ronita, PI 37602, Nemared, EdKawi, and Super Marmand,

**Table (18):Means of root phenols content, and leaf chlorophyll content, for the inoculated and uninoculated plants of the different genotypes and its $F_1$ hybrids, evaluated in the field:**

| Genotypes | Characters | | | |
|---|---|---|---|---|
| | Root phenols content (mg/100g.f.w) | | Leaf chlorophyll content(mg/100g.f.w) | |
| | inoculated | uninoculated | inoculated | uninoculated |
| Edkawi | 192.4 | 136.2 | 139.48 | 139.24 |
| Edkawi X Super Marmand | 166.8 | 101 | 133.04 | 133.44 |
| Edkawi X Ronita | 223.8 | 153.4 | 103.6 | 107.72 |
| Edkawi X PI 376072 | 212 | 195.2 | 88.92 | 126.04 |
| Edkawi X Nemared | 204 | 73 | 100.4 | 101.92 |
| Edkawi X Anahu | 215.8 | 79 | 106.92 | 107.04 |
| Super Marmand | 113.8 | 91.0 | 89.32 | 100.92 |
| Super Marmand X Ronita | 229 | 174.8 | 137.76 | 138 |
| Super Marmand X PI 376072 | 190 | 76.2 | 125.36 | 144.44 |
| Super Marmand X Nemared | 202.2 | 84.8 | 117.64 | 120.08 |
| Super Marmand X Anahu | 225.8 | 85.8 | 145.96 | 151.16 |
| Ronita | 268.8 | 173 | 149.56 | 149.72 |
| Ronita X PI 376072 | 160.8 | 76.8 | 128.36 | 129.24 |
| Ronita X Nemared | 203.8 | 146.8 | 126.84 | 132.44 |
| Ronita X Anahu | 217 | 75.8 | 111.64 | 138.76 |
| PI 376072 | 203.8 | 160.8 | 141.76 | 154.6 |
| PI376072 X Nemared | 198 | 74 | 156.68 | 153.84 |
| PI376072 X Anahu | 195.8 | 162.2 | 151.76 | 154.48 |
| Nemared | 197.2 | 152.2 | 151.16 | 154.28 |
| Nemared X Anahu | 213.8 | 84.4 | 133.12 | 152.4 |
| Anahu | 235.8 | 185.8 | 132.60 | 152.92 |
| L.S.D 5% | 18.83 | | 9.96 | |
| L.S.D 1% | 28.79 | | 15.34 | |

respectively. On the other had, the root phenols contents of the infected plants of th different parental genotypes in descending order were 268.8, 235.8, 203.8, 197.2, 192.4 and 113.8 mg/100gm (f.w) for the parental genotypes Ronita, Anahu, PI 376072, Nemared, Edkawi, and Super Marmand, respectevely. Similar trend of results was observed on the $F_1$ hybrids obtained from crosses between the different parental genotypes (Table 18). The association of the high root phenols content with the resistant genotypes indicated the importance of root phenols content as a defense mechanism against the root knot nematode. In addittion, the increase in root phenolse content of the inoculated plants of the different parental genotypes and $F_1$ hybrids comparing to the root phenols content of the uninoculated plants within the same parental genotype or $F_1$ hybrid showed that the infection of the tomato plants with the root knot nematode might have activated the phenols defense mechanism of the plants. Furthermore, the obtained results in the present study indicated that root phenols content can be used as a criterion in selection for resistance to the root knot nematode in tomato breeding programs. The involvement of root phenols content as a resistance mechanism against the root knot nematode have been reported (Wilski et al., 1971; Haung and Rohde, 1973; Bajaj and Mahajan, 1977; Hassan and Saxina, 1977; Masood and Hussain, 1979; Okophyi and Sadykin, 1978; Narayana, 1979; El-Sherif et al., 1980; Naryana and Reddly,1980; Ganguly and Dasgupta, 1982; Bajaj et al., 1983 and 1986; Okophyi, 1983; Sadykin and Okophyi, 1985; Okopyi et al.,

1987; Zacheo et al., 1988; Hassan, 1990). On the other hand substances, other than phenolic substances, could be involved in the resistance of tomato to the root knot nematode (Barrons, 1939; Giebal, 1974).

The results presented in (Table 19) show significant mean squares for both general and specific combining ability, which indicated the involvement of both the additive and dominances type of gene interactions in the inheritance of root phenols content (Table 19). In addition, the GCA/SCA ratio was 2.73, which indicated that the additive types of gene interaction was more important than the dominance type in the inheritance of this character.

Among the involved parental genotypes, only cultivars Ronita and Anahu had desirable significant positive general combining effects $(\hat{gi})$ which were 18.57 and 14.54, respectively (Table 20). These results indicated that cultivars Ronita and Anahu can be considered the best combiners to from tomato $F_1$ hybrids with high level of root phenols content which, as previously mentiod, is a defense mechanism against the root knot nematode.

The highest desirable positive specific combining ability effects $(\hat{Sij})$ were associated with the two $F_1$ hybrids Super Marmand x Anahu (30.66) and Super Marmard x Ronita (29.84), (Table 21). These results support the results presented in (Table 18) which showed that the inoculated plants of the pereviously mentioned $F_1$ hybrids, i.e Super Marmand x Anahu, had the highest root phenols

**Table (19): Mean squeres of root phenols content and, leaf chlorophyll content, for the inoculated plants of the different parental cultivars and its $F_1$ hybrids under the condition of the artificial inoculation with the root-knot nematode:**

| Sources | df | Root Phenols Content | Leaf Chlorophyll Content |
|---|---|---|---|
| **Genotypes** | 20 | 4757.9** | 2115.1** |
| **Parents** | 5 | 13502.4** | 2625.9** |
| **Hybrids** | 14 | 1986.6** | 1953.8** |
| **Parents Vs Hybrids** | 1 | 80.3 | 1818.3** |
| **General commbining ability (GCA)** | 5 | 1814.4 | 361.8 |
| **Specific commbining ability (SCA)** | 15 | 664 | 443.4 |
| **GCA/SCA** | | 2.73 | 0.82 |

**: Significant at 1%, level of significance

**Table (20): General combining ability effects ($\hat{gi}$) for root phenols content and leaf chlorophyll, for the different parental genotypes under the condition of the artificial inoculation with the root-knot nematode:**

| Genotypes | Characters | |
|---|---|---|
| | Root phenols content | Leaf chlorophyll content |
| Edkawi | -2.03 | -10.02 |
| Super Marmand | -22.76 | -6.71 |
| Ronita | 18.57 | 1.92 |
| PI 376072 | -7.41 | 5.32 |
| Nemared | -0.91 | 6.12 |
| Anahu | 14.54 | 3.37 |
| L.S.D. 5% | 4.83 | 3.88 |
| L.S.D. 1% | 6.39 | 5.13 |

Table (21): Specific combining ability effects ($\hat{Sij}$) for root phenols content and leaf chlorophyll, for the different $F_1$ hybrids under the condition of artificial infestation with root knot nematode:

| Genotypes | Characters | |
|---|---|---|
| | Root phenols content | Leaf chlorphyll content |
| Edkawi X Super Marmand | -11.76 | 22.33 |
| Edkawi X Ronita | 3.91 | -15.73 |
| Edkawi X PI 376072 | 18.09 | -33.81 |
| Edkawi X Nemared | 3.59 | -23.13 |
| Edkawi X Anahu | -0.06 | -13.82 |
| Super Marmand X Ronita | 29.84 | 15.11 |
| Super Marmand X PI 376072 | 1.681 | -0.69 |
| Super Marmand X Nemared | 22.51 | -9.21 |
| Super Marmand X Anahu | 30.66 | 21.78 |
| Ronita X PI 376072 | -53.71 | -6.31 |
| Ronita X Nemared | -17.21 | -8.63 |
| Ronita X Anahu | -19.64 | -21.08 |
| PI 376072 X Nemared | 2.96 | 17.81 |
| PI 376072 X Anahu | -14.69 | 15.64 |
| Nemared X Anahu | -3.19 | 0.20 |
| L.S.D 5% (Sij - Sij) | 15.00 | 4.38 |
| L.S.D 1% (Sij - Sij) | 19.79 | 5.79 |
| L.S.D 5% (Sij - Sik) | 19.81 | 5.80 |
| L.S.D 1% (Sij - Sik) | 26.18 | 7.66 |

contents. The inoculated plants of the $F_1$ hybrids Super Marmand x Rointa and Super Marmand x Anahu had average root phenols contents equal to 229.0 and 225.8 mg/100gm (f.w) (Table 18). Based on these results, the $F_1$ hybrids Super Marmand x Ronita and Super Marmand x Anahu can be recommended in areas with possible soil infection with the root knot nematode, because these two $F_1$ hybrids are carrying the defense mechanism of root phenols content which is activated upon infection with the root knot nematode. However, other characteristics of these $F_1$ hybrids such as yield and its quality should be considered before making such recommendation. Among the $F_1$ hybrids which had relatively high amount of root phenols content (Table 18), the $F_1$ hybird Edkawi x PI 376072 was the only one which showed small percentage of better parent heterosis for root phenols content associated with the plants grown in nematode free soil (21.39%) (Table 22). The broad sense heritability for root phenols content of the plants inoculated with root knot nematode was72.22% while the narrow sense heritability for this character was 23.20%, (Table 23). The low narrow sense heritability observed for this character in the present study indicated the importance of evaluating tomato plants for this character in the segregating generations of tomato crosses in replicated experiment to reduce as much as possible the environement effects on the expression of this character.

**Leaf Chlorophyll Contents:**

The leaf chlorophyll content of the uninoculated plants of the different parental genotypes and $F_1$ hybrids were either significantly

**Table (22):Percentage of heterosis in the $F_1$ generation over better parent for the root phenol content and, leaf chlorophyll content, for the different $F_1$ hybrids:**

| Genotypes | Heterosis (%) | | | |
|---|---|---|---|---|
| | Root phenols content | | Leaf chlorophyll content | |
| | inoculated | uninoculated | inoculated | uninoculated |
| Edkawi X Super Marmand | -13.31 | -25.84 | -4.62 | -4.17 |
| Edkawi X Ronita | -16.74 | 8.21 | -30.75 | -28.05 |
| Edkawi X PI 376072 | 4.02 | 21.39 | -37.27 | -42.28 |
| Edkawi X Nemared | 3.45 | -52.04 | -33.58 | -33.94 |
| Edkawi X Anahu | -4.48 | -57.48 | -24.52 | -30.01 |
| Super Marmand X Ronita | -14.81 | 1.04 | -7.14 | -7.83 |
| Super Marmand X PI 376072 | -6.77 | -52.61 | -11.57 | -6.57 |
| Super Marmand X Nemared | 2.54 | -44.28 | -22.16 | -22.19 |
| Super Marmand X Anahu | -4.24 | -53.82 | 9.94 | -1.15 |
| Ronita X PI 376072 | -40.18 | -55.61 | -41.20 | -16.40 |
| Ronita X Nemared | -24.18 | -15.15 | -16.09 | -14.16 |
| Ronita X Anahu | -19.27 | -59.20 | -25 37 | -9.29 |
| PI 376072 X Nemared | -2.85 | -53.98 | 3.65 | -0.49 |
| PI 376072 X Anahu | -16.96 | -17.70 | 7.05 | -7.76 |
| Nemared X Anahu | 9.33 | -54.58 | -9.29 | -1.22 |
| L.S.D 5% | 18.34 | 7.42 | 5.37 | 5.81 |
| L.S.D 1% | 24.24 | 9.84 | 7.09 | 7.68 |

**Table (23) Broad ($h^2_{bs}$) and narrow ($h^2_{ns}$) sense heritability estimates for root phenols content and leaf chlorophyll, for the different $F_1$ hybrids under the condition of artificial infestation with root knot nematode:**

| Charaters | Heritability % | |
|---|---|---|
| | Brood sense $h^2_{bs}$ | Narrow sense $h^2_{ns}$ |
| Roots phenols content | 72.22 | 23.20 |
| Leaf chlorophyll content | 103.84 | -5.07 |

or not significantly higher than the chlorophyll content of the inoculated plants (Table 18). The reduction in the chlorophyll leaf contents of the inoculated plants could be due to the effect of the infection with the root-knot nematode. In addition, the uninoculated and inoculated plants of the parental genotypes which were previosly recorded as resistant genotypes i.e Ronita, PI 376072, Nemared, and Anahu had higher amount of chlorophyll leaf content than that of the cultivar Super Marmand which was previously reported as susceptible to the root-knot nematode (Table 18). Logically, the plants with high level of leaf chlorophyll contents under the condition of infection with root-knot nematode, will be biologically efficient than the plants with less level of leaf chlorophyll content.

Significant mean squares for general and specific combining ability were observed indicating the involvement of both the additive and dominance type of gene interaction in the inheritance of leaf chlorophyll content amount in the plants inoculated with root-knot nematode (Table 19). However, the dominance type of gene interaction is more important than the additive type because the GCA/SCA ratio was less than unity (0.82), (Table 19).

The parental cultivars which were previously recorded as resistant to the root-knot nematode, i.e., Ronita, PI 376072, Nemared, and Anahu had desirable positive general combining ability effects $(\hat{gi})$ equal to 1.92, 5.32, 6.12 and 3.37, respectively, (Table 20). However, the other cultivars Edkawi and Super Marmand showed

undesirable negative general combining ability effects equal to -10.02 and -6.71 respectively, (Table 20). The parental genotypes which had desirable positive gi, i.e. Ronita, PI 376072, Nemared, and Anahu can be considered as good combiners to form $F_1$ hybrids with plants having high level of leaf chlorophyll content especially under the condition of infection with the root-knot nematode. Such hybrids suppose to have more biological efficiency under the condition of infection with the root-knot nematode.

The $F_1$ hybrids Edkawi x Super Marmand, Super Marmand x Ronita, Super Marmand x Anahu and PI 376072 x Anahu had desirable positive specific combining ability effects ($\hat{S}ij$) (Table 21). Such $F_1$ hybrids, as mentioned before, will have relatively high biological efficiency under the condition of infection with the root-knot nematode. In addition, the only three $F_1$ hybrids which showed better parent heterosis under the condition of planting in nematode inoculated-soil were Super Marmand x Anahu (9.94%), PI 376072 x Nemared (3.65%) and PI 376072 x Anahu (7.05%), (Table 22). On the other hand, non of the $F_1$ hybrids showed better parent heterosis under the condition of planting in nematode free-soil (Table 22).

The broad sense heritability for the leaf chlorophyll content under the condition of artificial infestation with the root-knot nematode was considered to be 100% while the narrow sense heritability was considered to be zero (Table 23). These results indicated non significant role of the additive type of gene interaction

in the inheritance of the amount of leaf chlorophyll content under the condition of infection with root nematode. Based on these result the progress in improving this character in tomato breeding programs will be very slow.

**III Penetration Bioassay Experiment :**

The different parental genotypes showed differentiation concerninig number of larvae penetrated the root tips within ten days, (Table 24). No larvae were detected inside the root tips of the cultivars Ronita, Nemared, and Anahu, while the average number of larvae detected in the root tips of the parental genotypes Edkawi, Super Marmand, and PI 376072 were 90.00, 81.67, and 53.33, respectively (Table 24). No significant differences were observed between the parental genotypes Edkawi and Super Marmand. However, the average number of larvae detected in the root tips of the parental genotype PI 376072 (53.33) was significantly less than that of the cultivars Edkawi (90.00) and Super Marmand (81.67). The susceptibility showed by the parental genotype PI 376072 in the present study, eventhough it was recorded as a resistant genotype to the root-knot nematode, could be due to using different root-knot nematode race in inoculating this genotype to evaluate its resistance. Differences in the virulence of root knot nematode isolates were reported by Rajkumar and Krishnoppa (1986), Roberts and Thomason (1987), and Castagnone-Sereno et al., (1996). Based on these results, the cultivars Ronita, Nemared ,and Anahu can be considered as good sources for resistance to the penetration of the root-knot

Table(24):Means, general $(\hat{gi})$ and specific $(\hat{sij})$ combining ability effects, genral (gca) and specific (sca) combining ability maen squares, gca/sca ratio, and broad ($h^2_{bs}$) and narrow ($h^2_{ns}$) heritability estimates, for number of larvae penetrated the root tips of the different parental genotypes and $F_1$ hybrids in the penetration bioassay:

| Genotypes | Parents | | | | | | Hybrids | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Edkawi | Super Marmand | Ronita | PI376072 | Nemared | Anahu | Edkawi x Super Marmand | Edkawi x Ronita | Edkawi x PI376072 | Edkawi x Nemared | Edkawi x Anahu | Super Marmand x Ronita | Super Marmand x PI376072 | Super Marmand x Nemared | Super Marmand x Anahu | Ronita x PI376072 | Ronita x Nemared | Ronita x Anahu | PI376072 x Nemared | PI376072 x Anahu | Nemared x Anahu |
| Means | 90 | 81.67 | 0.00 | 53.33 | 0.00 | 0.00 | 77 | 0.00 | 1.67 | 0.00 | 0.00 | 0.00 | 41.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| L.S.D 5% | 9.85 | | | | | | | | | | | | | | | | | | | | |
| L.S.D 1% | 13.17 | | | | | | | | | | | | | | | | | | | | |
| Genotypes | G.C.A effects | | | | | | S.C.A effects | | | | | | | | | | | | | | |
| | Edkawi | Super Marmand | Ronita | PI376072 | Nemared | Anahu | Edkawi x Super Marmand | Edkawi x Ronita | Edkawi x PI376072 | Edkawi x Nemared | Edkawi x Anahu | Super Marmand x Ronita | Super Marmand x PI376072 | Super Marmand x Nemared | Super Marmand x Anahu | Ronita x PI376072 | Ronita x Nemared | Ronita x Anahu | PI376072 x Nemared | PI376072 x Anahu | Nemared x Anahu |
| | 17.94 | 20.86 | -14.39 | 4.36 | -14.39 | -14.39 | 21.45 | -20.00 | -37.08 | -20.00 | -20.00 | -22.92 | 0.00 | -22.92 | -22.92 | -6.42 | 12.33 | 12.33 | -6.42 | -6.42 | 12.33 |
| L.S.D 5% | 2.25 | | | | | | 6.17 | | | | | | | | | | | | | | |
| L.S.D 1% | 3.01 | | | | | | 8.24 | | | | | | | | | | | | | | |
| | G.C.A | | | | | | S.C.A | | | | | | G.C.A/S.C.A | | | | | | | | |
| | 223573 | | | | | | 561.62 | | | | | | 3.98 | | | | | | | | |
| Heritability % | | | | | | | | | | | | | | | | | | | | | |
| $h^2_{bs}$ | | | | | | | | | | | | | $h^2_{ns}$ | | | | | | | | |
| 63.72 | | | | | | | | | | | | | 35.68 | | | | | | | | |

nematode larvae into the roots of tomato. The results obtained from this *in vitro* bioassay (Table 24) agreed with that obtained from the greenhouse experiment (Table 2) in which the whole roots of the tomato plants were examined 60 days after inoculation. These results indicated the efficiency of the *in vitro* bioassay used in the present study in detecting the resistance of tomato germplasm to the root-knot nematode. In addition, The tomato breeder will save time and efforts by using this bioassay. These results agreed with those of Dropkin and Webb (1967), who found that resistant plants of tomatoes were characterized by decrease in larvae penetration. In addition, Pontenza et al., (1996) reported differences in the penetration rate of root knot nematode larvae into roots of susceptible and resistant alfaalfa cultivars. However, these result disagreed with those of Riggs and Winstead, (1959), who mentioned that larvae of root knot nematode penetrated the root of resistant tomato plants as rapidly as they penetrated roots of susceptible plants. The $F_1$ hybrids resulted from crosses between the parents which had been penetrated by the root knot nematode larvae, i.e, Edkawi x Super Marmand, Edkawi x PI 376072, and Super Marmand x PI 376072 showed susceptibility measured by number of larvae penetrated the root tips within ten days (Table 24). However, the susceptibility showed by the $F_1$ hybrids Edkawi x PI 376072 was very slight. On the other hand, the $F_1$ hybrids obtained from crosses involved one or two resistant parents showed resistance to the root-knot nematode. These results indicated the complete dominance of resistance over susceptibility to the root-

knot nematode. The resistance of tomato to the root knot nematode have been reported to be dominant over susceptibility (McFarlans et al., 1946; Watts, 1947; Barham and Sasser, 1956; Gilbert and McGuier, 1956; Thomason and Smith, 1957; Riggs, 1960; Hernandez et al., 1965; Ohekar, 1965; Kumar, 1967; Sidhu and Webster, 1973; Singh et al., 1974; Fatunlo and Salu, 1977; Kalloo and Bhatti, 1979; Medina-Filho and Stevens, 1980; Rajadhav and Kale, 1986).

The parental cultivars Ronita, Nemared, and Anahu had significant desirable negative general combining ability effects ($\hat{gi}$) (Table 24) which indicated that these cultivars can be considered as good combiners to from hybrids with high resistance to the penetration of the root-knot nematode into the roots.

The $F_1$ hybrids which showed desirable negative specific combining ability were Edkawi x PI 376072 (-37.08), Super Marmand x Ronita (-22.92), Super Marmand x Nemared (-22.92), Super Marmand x Anahu (-22.92), Edkawi x Ronita (-20.00), Edkawi x Nemared (-20.00), Edkawi x Anahu (-20.00), Ronita x PI 376072 (-6.42), PI 376072 x Nemared (-6.42), and PI 376072 x Anahu (-6.42). Such $F_1$ hybrids will perform well under the condition of infection with root-knot nematode.

Significant general (GCA) and specific (SCA) combining ability were detected (Table 24) indicating the involvement of both the additive and dominance types of gene interaction in the inheritance of resistance to penetration of root-knot nematode into roots of tomato