# INFLUENCE OF TRANSPLANT SPACING AND PLANTING DATE ON FRUIT YIELD, PLANT STATUS OF TOMATO AND POPULATION DEVELOPMENT OF *MELOIDOGYNE INCOGNITA*

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**Summary.** Field studies were conducted to evaluate the most suitable tomato transplant spacing and planting date at a field site infested with *Meloidogyne incognita.* Tomatoes were transplanted the 20th of each month from March through July and, on each date, transplants were spaced 35, 45 and 55 cm apart in 60-cm-wide rows. Initial population densities of *M. incognita* were determined prior to transplanting each month and populations per 200 $cm^3$ soils were: 212, 246, 321, 790, and 410 in March, April, May, June and July, respectively. Tomato plant growth and yield was greatest in the April and May plantings. Tomatoes transplanted in March were stunted due to high nematode multiplication on their roots. The tomatoes transplanted in July suffered nematode damage in the vegetative phase and the cool temperatures at fruiting reduced ripening. Highest yield and largest fruit size were attained at the in-row plant spacing of 45 cm.

**Key words:** *Lycopersicon esculentum*, root-knot nematode, control, transplant spacing, planting date, yield.

Tomato (*Lycopersicon esculentum* Mill.) is cultivated as an important summer vegetable crop in the mid hills (1300 m above mean sea level) of Himachal Pradesh, North India. Tomatoes are generally transplanted from 15th March to 15th April in this region of the country. The most important pests are *Meloidogyne incognita* (Kofoid *et* White) Chitw., *Helicoverpa armigera* (Hubner) and *Spodoptera litura* Fabr. Of the biotic factors responsible for losses to the tomato crop, the most significant are plant-parasitic nematodes, having been reported to cause 33.3% yield loss of tomato in the Solan district of Himachal Pradesh. In this region, farmers rotate peas (*Pisum sativum* L.) with tomato, and both plants are good hosts of root knot nematode in India (Anonymous, 1998). Of the over 62 species belonging to 20 genera of nematodes associated with tomato worldwide, the most important is the root-knot nematode, *M. incognita* (Dasgupta, 1997). Samples taken from tomato in 75 countries showed that *M. incognita* is the most widespread of the root-knot nematodes on tomatoes, occurring on 53% of crops; *M. javanica* (Treub) Chitw. has been recorded on 50% of crops, *M. arenaria* (Neal) Chitw. on 8%, *M. hapla* Chitw. on 8%, and *M. exigua* Goeldi or other species on 2% (Dasgupta, 1997). Conventional nematicides have a dramatic initial impact on plant-parasitic nematodes but high costs hinder their wide application (Farahat *et al.*, 1993). The repeated application of these synthetic nematicides has several detrimental effects, such as development of pesticide resistance, pest resurgence, pesticide residues and environmental pollution (Gnanapragasam *et al.*, 1993). These limitations in the use of nematicides encourage the investigation of eco-friendly approaches to nematode management. Among these approaches is crop management through changes in planting date and plant spacings. Masuda (1976) found significant improvement in the growth of kidney bean plants when they were sown early in *M. incognita*-infested soil. There was greater build-up of *Hirschmanniella oryzae* Luc *et* Goodey in basmati rice transplanted in mid June or late July as compared to early transplanting (Randhawa *et al.*, 1992). In The Netherlands, good quality carrots could be produced in a field infested with *Meloidogyne fallax* Karssen when sowing was postponed until the start of June (Molendijk and Brommer, 1998). Therefore, we conducted investigations to observe the effect of plant spacing and transplanting time on population densities of *M. incognita* and tomato growth and yield.

## MATERIALS AND METHODS

The investigation was carried out at the experimental farm of the Department of Entomology and Apiculture, University of Horticulture and Forestry, Nauni, Solan (H.P.) in the mid hills of Himachal Pradesh, India.

Tomato seeds (cv. Manisha) were treated with Bavistin (0.1%) + Indofil M-45 (0.25%) prior to sowing to reduce fungal seedling disease. Seedlings were produced in formalin-treated (formaldehyde:water in the ratio of 1:1) nursery soil on different dates, so that transplants were available on the 20th of every month from March to July.

The test field was infested with root-knot nematode (*Meloidogyne incognita*), and had previously been cropped with peas (*Pisum sativum* L.). To assess the initial nematode population (Pi), soil samples (five sub samples per plot to make a composite sample) were collected randomly at a depth of 10-20 cm from each plot before transplanting tomatoes on the 20th of each month from March to July. Sub-samples of 200 $cm^3$ of soil from each plot were processed using Cobb's decanting and sieving technique to extract the nematodes.

Fifteen beds, 3 m long and 2 m wide, were prepared at monthly intervals. Seedlings were transplanted at in-row plant spacing of 35, 45 (recommended space) and 55 cm apart in the 60-cm-wide rows. Five replicate plots for each plant spacing were prepared on each of the five planting dates, according to a 3 × 5 factorial randomized block design (three spacings and five planting dates). Standard cultural practices, such as weeding, hoeing, irrigation, and staking were followed throughout the experiment.

Observations were made of fruit yield (harvested on different dates according to their maturity) and fruit count (number of fruits per kg). Crops were harvested on 17th July, 21st August, 11th September, 28th September and 20th November for the March, April, May, June and July transplanted crops, respectively. At harvest, plant growth measurements were made on five plants per plot, viz., shoot length (from the tip of longest shoot to collar region, in cm), shoot weight (fresh weight with leaves but without roots in g), root weight (fresh weight in g), and root galling index. Final nematode population densities were also recorded at harvest

Root gall index, of five plants per plot selected randomly, was assessed according to a 1-5 scale (1 = no gall, 2 = 1-10 galls, 3 = 11-30 galls, 4 = 31-100 galls and 5 = 100 galls and above). To estimate the final nematode soil population density, composite soil samples (five sub samples per replicate to make a composite soil) were collected from the rhizosphere of tomatoes at 15-20 cm deep. Sub-samples of 200 $cm^3$ soil were processed as described above.

The plots of different transplanting dates were run for different durations according to the crop cycle. Average air temperatures and rainfall were also recorded during the study period.

Data were analysed, compared by critical difference (CD) at the 5% level of significance, and the effect of planting time, planting distance and their interactions calculated.

## RESULTS AND DISCUSSION

*Effects on* M. incognita. Average populations of *M. incognita* juveniles (J2) before each transplanting date were 212, 246, 321, 790 and 410 per 200 $cm^3$ for March, April, May, June and July, respectively (Table I). The highest final nematode population density (Pf) among planting dates was from the crop transplanted in March and terminated on 17th July (4890 J2/200 $cm^3$ soil). The next highest was in June-transplanted tomatoes harvested on 28th September (4858 J2/200 $cm^3$ soil). The nematode reproduction rate (Pf/Pi) was 23.1 in former as compared to 6.1 in the later. The lowest nematode population densities (1599 J2/200 $cm^3$ soil) and reproduction rate (3.9) were observed on 20th November in the plots transplanted in July. From September to November temperatures declined, reaching a minimum of 15.5 °C in November (Fig. 1), which did not favour nematode reproduction.

A maximum mean nematode population density of 3436 J2/200 $cm^3$ was recorded at the 35 cm in-row plant spacing, which was significantly higher than the 3148 and 3132 J2/200 $cm^3$ soil recorded at planting distances of 45 and 55 cm apart, respectively. The highest nematode density of all, of 5280 J2/200 $cm^3$ soil, was recorded at the 35 cm planting distance in plots transplanted in March, and the lowest density of all, of 1448 J2/200 $cm^3$ soil, was in the crop transplanted in July at the 35 cm plant spacing (Table II).

Mean root gall index was maximum (3.8) at the 35 cm plant spacing, significantly smaller (3.4) at the 45 cm planting distance, and least (2.9) at the 55 cm plant spacing (Table III). Tomatoes transplanted in March and June (mean gall indices of 3.9 and 3.8, respectively) exhibited more severe root galling than that observed in the crops transplanted in April and May (mean gall in-

**Table I.** Initial and final populations of *Meloidogyne incognita* juveniles (per 200 $cm^3$ of soil) in the field at different times.

| Initial population | | Final population | | Multiplication rate (×) |
|---|---|---|---|---|
| Date | Population | Date | Population | |
| 20th March | 212 | 17th July | 4890 | 23.1 |
| 20th April | 246 | 21st August | 2558 | 10.0 |
| 20th May | 321 | 11th September | 2290 | 7.1 |
| 20th June | 790 | 28th October | 4858 | 6.2 |
| 20th July | 410 | 20th November | 1599 | 3.9 |

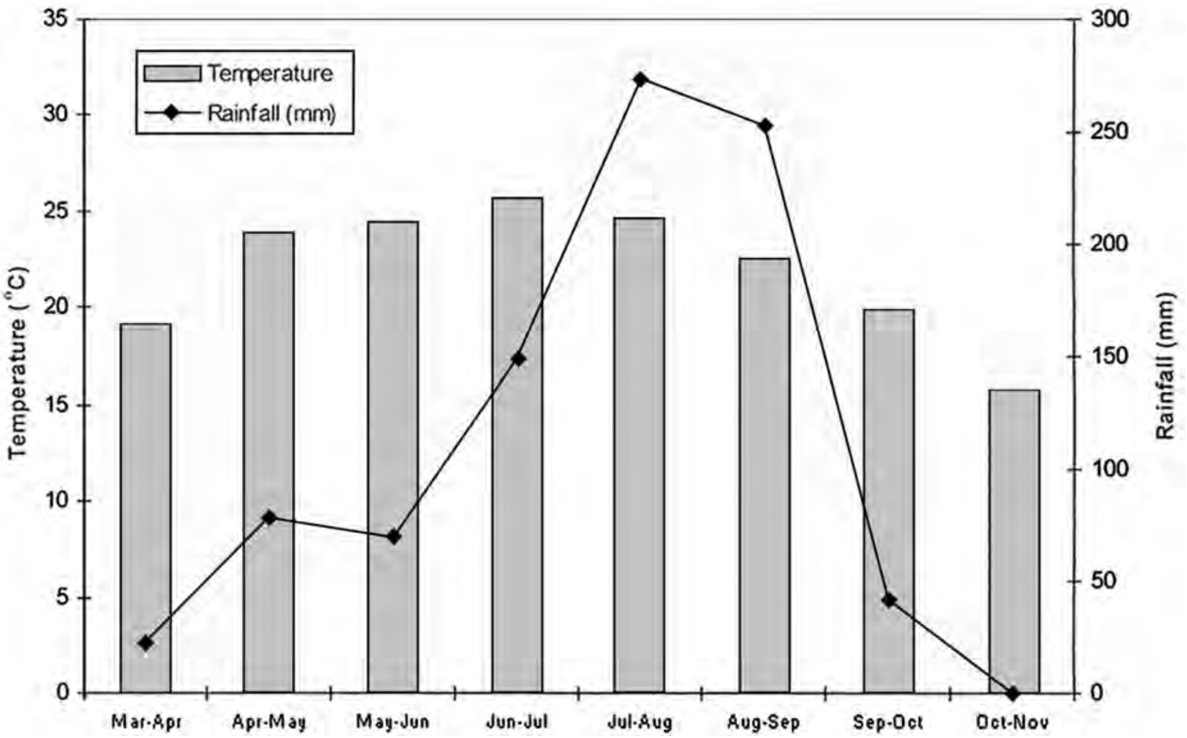


**Fig. 1.** Average temperature and rainfall from 20th March to 20th November 2002.

**Table II.** Effect of planting dates and in-row plant spacings on final nematode population of *M. incognita* on tomato.

| Month | Final nematode population (per 200 cm$^3$ soil) at plant spacing (cm) | | | Mean |
|---|---|---|---|---|
| | 35 | 45 | 55 | |
| March | 5280 | 4720 | 4670 | 4890 |
| | (3.72) | (3.67) | (3.67) | (3.68) |
| April | 2884 | 2600 | 2191 | 2558 |
| | (3.45) | (3.41) | (3.34) | (3.40) |
| May | 2317 | 2188 | 2366 | 2290 |
| | (3.36) | (3.33) | (3.37) | (3.35) |
| June | 5251 | 4750 | 4573 | 4858 |
| | (3.72) | (3.67) | (3.66) | (3.68) |
| July | 1448 | 1485 | 1863 | 1599 |
| | (3.15) | (3.17) | (3.26) | (3.20) |
| Mean | 3436 | 3148 | 3132 | |
| | (3.54) | (3.50) | (3.50) | |
| $CD_{0.05}$ | | | | |
| Planting date (T) | | 0.03 | | |
| Plant spacing (S) | | 0.02 | | |
| T × S | | 0.04 | | |

CDs were calculated on log transformed values, whose averages are in parentheses.

dices of 3.2 and 2.7, respectively). The minimum gall index of 2.0 was recorded in the crop transplanted in May at the 55 cm in-row spacing, followed by the crops transplanted in April and May at plant spacings of 55 and 45 cm (gall indices of 2.4 and 2.7, respectively). The highest mean gall index for planting dates was 3.9 and occurred in the crop transplanted in March.

*Effects on yield.* The highest fruit yield of 21.3 kg per plot was obtained from tomatoes transplanted in May at the 45 cm plant spacing (Table IV), and was similar to yields of the crops transplanted in April at the same spacing (20.6 kg per plot) and in May at the 35 cm plant spacing (19.6 kg per plot). Overall, the in-row plant spacing of 45 cm gave the highest mean fruit yield of 14.3 kg per plot, followed by the 35 cm plant spacing with 12.1 kg per plot; a significantly lower mean yield of 7.4 kg/plot was obtained at the 55 cm plant spacing. Tomatoes transplanted in April and May yielded more (16.7 and 18.1 kg, respectively) than those transplanted in March, June and July (6.7-8.2 kg per plot).

**Table III.** Root galling index* caused by *M. incognita* on tomato when transplanted at different dates and plant spacings.

| Planting date (month) | Plant spacing (cm) | | | Mean |
|---|---|---|---|---|
| | 35 | 45 | 55 | |
| March | 4.3 (2.05) | 4.0 (1.98) | 3.5 (1.87) | 3.9 (1.97) |
| April | 3.8 (1.94) | 3.2 (1.80) | 2.4 (1.53) | 3.2 (1.75) |
| May | 3.3 (1.81) | 2.7 (1.63) | 2.0 (1.34) | 2.7 (1.61) |
| June | 4.2 (2.05) | 3.7 (1.93) | 3.5 (1.86) | 3.8 (1.95) |
| July | 3.6 (1.87) | 3.4 (1.85) | 3.2 (1.78) | 3.4 (1.84) |
| Mean | 3.8 (1.95) | 3.4 (1.84) | 2.9 (1.69) | |
| $CD_{0.05}$ | | | | |
| Planting date (T) | | 0.12 | | |
| Plant spacing (S) | | 0.09 | | |
| T × S | | 0.15 | | |

CDs were calculated on log transformed values whose averages are in parentheses.
* Root gall index on 1-5 scale: 1 = no gall, 2 = 1-10 galls, 3 = 11-30 galls, 4 = 31-100 galls and 5 = 100

**Table IV.** Effect of different planting dates and in-row plant spacings on the fruit yield of tomato in a field infested with *M. incognita*.

| Planting date (month) | Yield (kg/plot) at different plant spacing (cm) | | | Mean |
|---|---|---|---|---|
| | 35 | 45 | 55 | |
| March | 7.7 | 9.6 | 4.3 | 7.2 |
| April | 18.1 | 20.6 | 10.7 | 16.7 |
| May | 19.6 | 21.3 | 13.3 | 18.1 |
| June | 6.2 | 9.6 | 4.5 | 6.7 |
| July | 9.2 | 10.3 | 5.3 | 8.2 |
| Mean | 12.1 | 14.3 | 7.6 | |
| $CD_{0.05}$ | | | | |
| Planting date (T) | | 1.63 | | |
| Plant spacing (S) | | 1.26 | | |
| T × S | | 1.99 | | |

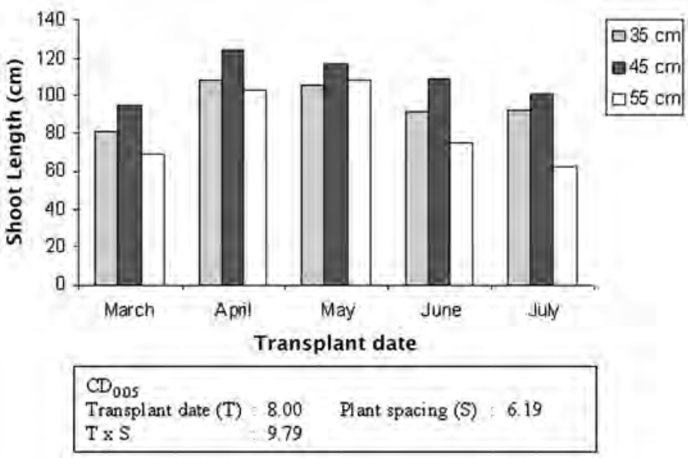


**Fig. 2.** Effects of different transplant dates and plant spacings on shoot length of tomato plants in a field infested with *Meloidogyne incognita*.

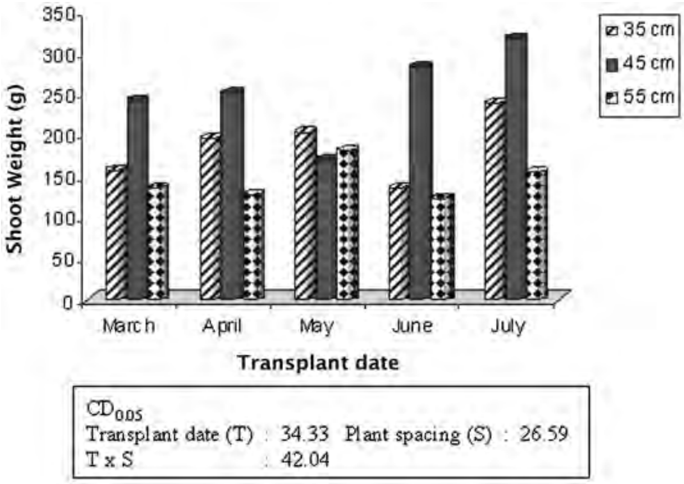


**Fig. 3.** Effects of different transplant dates and plant spacings on shoot weight of tomato plants in a field infested with *M. incognita*.

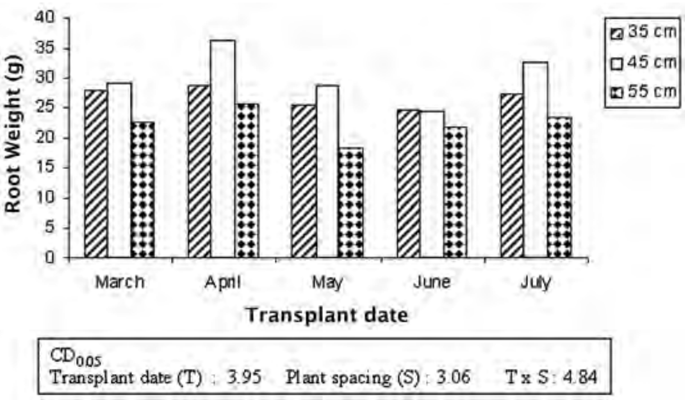


**Fig. 4.** Effects of different transplant dates and plant spacings on root weight of tomato plants in a field infested with *M. incognita*.

*Effect on plant status*. Tomatoes transplanted in April, May and July at the 45 cm spacing were significantly taller (mean shoot length 109.5 cm) than at the other planting distances (Fig. 2). Mean plant height was significantly greater in plots transplanted in April and May (112.1 cm and 110.3 cm, respectively) than in those transplanted in March, June and July. The shortest plants (62.4 cm) were in the plots transplanted in July at an in-row spacing of 55 cm. Tomatoes transplanted in April and May at 35 or 55 cm attained similar heights (103.4 cm to 108.5 cm).

The trends in shoot weight (Fig. 3) differed from those for shoot length. The average shoot weight was greatest for the planting distance of 45 cm (253.2 g) and for the July planting (237.2 g). Shoot weights in the crops transplanted on other dates at 45 cm spacing were significantly heavier than those for tomatoes planted 35 cm apart in March, April, June and July.

Tomatoes transplanted in May at the 55 cm plant spacing had the lowest mean root weight (18.4 g) and those transplanted in April at 45 cm the greatest (36.4 g) (Fig. 4). Mean root weights differed significantly at the three planting distances: the 45 cm plant spacing gave the heaviest roots (30.3 g) and the 55 cm spacing the lightest (22.4 g). The greatest root weights were recorded in tomatoes transplanted in April, March and July (30.3-26.6 g).

The growth parameters observed suggested that, overall, the best plant status was achieved with transplanting in April and May at a spacing of 45 cm.

*Correlation studies*. Analysis of correlation confirmed the significant ($P \leq 0.05$) negative correlation between root gall index and yield ($r = -0.69$) and number of fruits ($r = -0.59$), and between nematode population and yield ($r = -0.35$) and number of fruits ($r = -0.41$). A positive significant ($P \leq 0.05$) correlation was also recorded between nematode population and root gall index ($r = 0.28$).

Plant growth and development was affected more by plant spacing rather than by planting date. However, planting dates did have an impact on nematode pathogenic potential that eventually affected the fruit yield. Vawdrey and Stirling (1996) reported higher yield losses due to root-knot nematode in summer-maturing tomatoes as compared to winter-maturing crops. Trutmann *et al.* (1993) also used variation of sowing time and sowing density as a tool for management of nematodes on French bean. In The Netherlands, good quality carrots could be produced in a field infested with *Meloidogyne fallax* when sowing was postponed until the start of June (Molendijk and Brommer, 1998).

Our field studies revealed that, in the mid hills of North India, the period between April and May and not the commonly used March-April period was the best for transplanting. The reason is that climatic conditions from April to September were the most conducive for young seedlings to develop into a crop stand able to tolerate infestation of *M. incognita*, largely because seedlings transplanted during April and May experience favourable conditions of temperature and humidity, which allows them to escape nematode damage. Seedlings transplanted in March remained weak due to high nematode multiplication on their roots, while July-transplanted crops suffered from nematode attack in the early vegetative phase and from low temperatures during the fruiting stage, thus retarding fruit development. The highest tomato yields were attained at the 45 cm plant spacing. Our findings confirm results of Sharma and Bhatia (2002), who reported that sowing time had significant effects both on nematode population and crop yield in French beans. In Japan, early planting of rice was suggested to reduce the population of *Hirschmanniella mucronata* (Das) Luc *et* Goodey (Sato *et al.*, 1970). Randhawa *et al.* (1991) found that the population of *H. oryzae* was least when rice was transplanted on 15th July compared to early June transplanted crop; spacing had no effect upon *H. oryzae*. Our investigations demonstrated that the recommended spacing (60 × 45 cm) and the transplant dates of April and May are the best for the cultivation of tomato in the studied region. All this would suggest that planting date and spacing must be selected according to crop, nematode to be managed and the geographical area of cultivation.

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Accepted for publication on 22 August 2006.