Journal of Entomology and Zoology Studies
Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(5): 448-451

Received: 01-07-2018
Accepted: 03-08-2018

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Yield loss assessment of tomato through *Meloidogyne incognita* (kofoid and white) chitwood, in Himachal Pradesh, India

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Abstract
An experiment was conducted during 2016 and 2017, to estimate the severity of damage in terms of yield losses by root knot nematode (*Meloidogyne incognita*), a dangerous and devastating pest, on tomato (*Solanum lycopersicum* L.), which is the prime cash crop of mid hill region of Himachal Pradesh, India. In this study, a field experiment was conducted under which half of the alternate plots were treated with Carbofuran, remaining were kept untreated and paired t-test was applied. Results revealed 35.2 and 37.4 per cent avoidable yield losses during the years 2016 and 2017. Significant differences were also observed in plant heights, fresh and dry weights of plants between Carbofuran treated and untreated plants. The treatment with Carbofuran resulted in 77.7, 79.7 percent reduction in final nematode population (soil), 40.0 and 36.8 percent (root), 37.5, and 29.1 percent in root knot index during both the years.

Keywords: *Meloidogyne incognita*, *Solanum lycopersicum* L., yield losses, Carbofuran

1. Introduction
Tomato (*Solanum lycopersicum* L.), a widely grown vegetable of family solanaceae, due to its culinary variability, is considered most popular vegetable after potato. The continents of Asia and Africa account for more than 80 per cent of the global area under tomato production, yielding about 70 per cent of the world output (FAO, 2012[1]). In the year 2016-17, it is estimated to be about 809 thousand hectare area of the country that was under tomato cultivation, producing 20708 thousand MT of fruits (NHB, 2016[2]). The state of Himachal Pradesh, endured with various climatic zones, is suitable for tomato production, where it is extensively grown in the mid hills as a summer season vegetable crop. Considered a super food, tomato is a rich source of micronutrients viz. minerals, vitamins and anti-oxidants essentially required for a well-balanced human diet. High levels of lycopene, an anti-oxidant that reduces the risk of cancer, cardiovascular disorder and cellular aging, make tomato a wonder vegetable (Gerster, 1997[3]; Giovannucci, 1999[4]; De Cesare *et al.*, 2012[5]; Abdel-Monaim, 2012[6]).
Tomato suffers huge qualitative and quantitative losses due to biological stresses present in the ecosystem. Among the various pests and diseases affecting tomato, plant parasitic nematodes pose a major threat, incurring an estimate monitory loss of USD 80 billion per year (Nicol *et al*, 2011[7]). The most prevalent and destructive among the nematode pests of tomato is *Meloidogyne* species, causing high levels of economic losses on vegetables, especially in tropical and sub-tropical agriculture (Saxena & Singh, 1997[8]; Trudgill and Blok, 2001[9]; Castagnone-Sereno *et al.*, 2013[10]; Anes & Gupta, 2014[11]; Ngele & Kalu, 2015[12]). In this genus, *Meloidogyne incognita* is the most dominant species, inhibiting subtropical and tropical climatic zones, accounting for about 64 per cent of infestation, and inflicting serious loss to tomato fruit yield (Sasser, 1980[13]).
Hence, the present study was undertaken to assess the prevalence of *M. incognita* in the fields of Solan area and the yield losses it cause to the prime cash crop of the region.

2. Materials and Methods
The experiment was laid for 2 consecutive years, 2016 and 2017, in a field having *Meloidogyne incognita* population above economic threshold level in the farm of department

of Entomology, YSP UHF, Nauni, Solan, at geographic location of 30.51°N 77.10°E and elevation of 1240.63 meters. The field was thoroughly ploughed, and soil samples 250ml (200cc) were drawn from the depth of 15 cm with the help of an auger and processed for initial nematode population. The whole field was divided into 30 plots with requisite buffer area of 1x1m dimensions and each alternate plot was treated with Carbofuran @ 3 kg a.i./ha and other fifteen plots were kept untreated for appraisal of losses and layout of the experiment in accordance with the paired plot technique. The seeds of susceptible variety of tomato (*Solanum lycopersicum* L.) i.e., hybrid NS816 were sown in a nematode free nursery. Thus, raised seedlings were further transplanted in the main field during the month of April, at a plant-to-plant distance of 45 cm and row-to-row distance of 60 cm, enabling the growth of four plants per plot. Both the treatments were properly labeled. Standard cultural practices like staking, weeding, hoeing, irrigation etc. were followed in the crop throughout the experiments. The experiments were terminated when the plants stopped yielding the fruits and started wilting i.e. in the last week of September, 2016 and second week of September, 2017. Observations were recorded on initial nematode population in the field, yield per plot and root-knot index at harvest. The avoidable loss was worked out in these two treatments as per the formula given by Pradhan (1964[14]) as follows:

$$\text{Avoidable loss (\%)} = \frac{\text{Yield in treated plots - yield in untreated plots}}{\text{Yield in treated plots}} \times 100$$

$$\text{Increase in yield (\%)} = \frac{\text{Yield in treated plots - yield in untreated plots}}{\text{Yield in untreated plots}} \times 100$$

3. Results and Discussions

Initial nematode population

When the data was scrutinized, the *M. incognita* population was found above economic threshold level (289 and 236 juveniles/ 200 cc of soil in both the years, respectively) in the soil, and thus, field was approved for the experiment. The population of other nematode genera (16 and 21 nematodes/ 200 cc of soil in two consecutive years, respectively) was also recorded from the samples, however, it was considered too low to have any impact on plant status and yield parameters of the test crop.

At the termination of experiment, the observations regarding plant growth parameters, root knot popu.9 and 127.7 cm, in 2016 and 2017, respectively, which was significantly higher than the mean height of 89..47 and 94.67 cm attained in the plants growing in untreated nematode infested soil. The data also indicated about the efficacy of Carbofuran against the test nematode as the plant height increased by 41 and 35 per cent in comparison to untreated plots and yield losses were recorded and the results obtained are presented hereunder:

Plant growth parameters

Shoot length: It is evident from the data presented in table 1, pertaining to plant growth parameters of tomato that *M. incognita* infestation adversely affected the aerial growth of the host plants, as a result of which, the nematode infected plants remained stunted during both the years. The average shoot length of the plants grown in Carbofuran treated soil was recorded to be 125, during 2016 and 2017, respectively, in the plants grown in Carbofuran treated soil.

Root length: The average root length, at 20.2 and 25.2 cm in the plants grown in untreated nematode infected soil was recorded to be significantly lesser than that of plants grown on nematicide treated soil, which attained the root length of 15.9 and 18.7 cm, resultantly, the root growth remains stunted. The average increase in root lengths of Carbofuran treated plants in comparison to untreated plants was 27.2 and 40.0 per cent, indicating the devastating effect of nematodes to the root growth of the plants.

Root weight: As the root knot nematode affected the root length, the decline in the root weight (table 1) was also evident. The roots of tomato plants growing in Carbofuran treated soil, on an average weighed 35.1 and 38.1 g as compared to significantly lower weights of 22.4 and 27.6 g, recorded in plants grown in untreated nematode infected soil, during 2016 and 2017, respectively. These weights were 36.0 and 27.5 per cent lower in comparison to the weights of treated roots.

Table 1: Effect of Carbofuran on plant growth parameters of tomato in the presence of *Meloidogyne incognita*

Parameters	Years	Treatments		Percent increase over untreated	T(cal)
		Soil application of Carbofuran @ 2kg a.i/ha	Untreated control		
Shoot length* (cm)	2016	125.9	89.5	41.0	7.5
	2017	127.7	94.7	35.0	7.5
Root length* (cm)	2016	20.2	15.9	27.2	6.1
	2017	25.2	18.1	40.0	6.4
Root weight* (g)	2016	35.1	22.4	56.0	6.9
	2017	38.1	27.6	38.0	7.3

*****Average of fifteen replications

Avoidable yield losses

The mean yield of 36.4 and 34.8 tonnes/ ha, as presented in table 2, was recorded in the plants grown in soil treated with Carbofuran as compared to 23.6 and 22.4 tonnes/ ha, in the untreated plots. The average yield loss was incurred to be 35.2 and 37.4 per cent in 2016 and 2017, respectively, which signifies the potential of test nematode and the extent of damage to the farmer's pocket.

Table 2: Effect of Carbofuran on the yield of tomato in the presence of *M. incognita*

Parameters	Years	Treatments		Percent avoidable losses	Percent increase in yield over untreated plants	T(cal)
		Soil application of Carbofuran @ 2kg a.i/ha	Untreated control			
Yield* (t/ha)	2016	36.4	23.6	35.2	54.2	5.1
	2017	35.8	22.4	37.4	59.8	5.5
T_{table} = 1.7						

*****Average of fifteen replications

Status of Root knot nematode infestation in plant and soil

Root gall index: Mean root gall index (on 1-5 scale) in treated plots was 41.1 percent lower than that attained from untreated roots. It meant that plants growing in nematode infected soil suffered significantly more root infection and that Carbofuran adversely affected the root penetration of *M. incognita* J_2s, which eventually led to significantly reduced galling. Per cent decline in nematode population over untreated control at termination was to the tune of 77.7 and 79.7 in Carbofuran treated plots, during both the years. The root population also decreased to the tune of 40.0 (in 2016) and 36.8 (in 2017) percent. The figures signified the susceptibility of tomato var. NS816 to *M .incognita* and efficacy of Carbofuran at recommended dose against the test nematode.

Table 3: Effect of Carbofuran on the root gall index and *M. incognita* soil and root population

Parameters	Years	Treatments		Per cent decrease over untreated	T (cal)
		Soil application of Carbofuran @ 2kg a.i/ha	Untreated control		
Root gall index*(on 1-5 scale)**	2016	2.7	4.3	37.5	5.9
	2017	3.0	4.2	29.1	6.1
Final nematode population* (soil)	2016	95.8	429.7	77.7	7.5
	2017	88.7	438.0	79.7	7.5
Final nematode population* (Root)	2016	22.8	38.1	40.0	6.4
	2017	22.7	35.9	36.8	7.2

*****Average of fifteen replications

** Root gall index on 1-5 scale (1= no gall, 2= 1 to 10 galls, 3= 11 to 30 galls, 4= 31 to 100 galls and 5= above 100 galls)

The test nematode is a serious pest of tomato and its damage potential in terms of yield losses on tomato cv. NS816 ranged between 35.2 to 37.4 percent in the mid hill region of Himachal Pradesh. The study is in accordance with the yield losses of 22-30 per cent (Sasser & Carter, 1985[15]) and 25-100 percent (Seid *et al.*, 2015[16]) that have been reported on tomato due to *M. incognita*. In Western Anatolia (Turkey) *Meloidogyne* spp. caused up to 80 per cent yield losses in processing tomato-growing areas (Kas¸ kavalci, 2007[17]). In northeastern Spain, an initial population density in soil of 4750 juveniles/250 cm^3 of *M. javanica* caused about 61 percent yield reduction in tomato cropped in summer plastic houses (Verdejo-Lucas *et al.*, 1994[18]). Singh and Kumar (2010[19]) also reported 38 per cent losses in tomato due to root knot nematodes. The yield losses incurred from the AICRP centres across the country are about 13-99 per cent in vegetables. In reference to polyhouse grown tomato and cucumber, these losses are estimated to be 28-29 percent, but in disease complex situation the losses increase from 40-70 percent (Sabir and Walia, 2017[20]). These losses manifold in the situations when the farmers are unaware of the existence of these tiny creatures and do not implement management practices on their crops. Therefore, necessary steps should be taken in the field of awareness as well as management of these nematodes to minimise economical losses to the farmer.

4. Conclusion

The results revealed the economic severity of infestation by root knot nematode, and the need of management practices to be carried out in the infested field. During 2016 and 2017, the economic damage was assessed to the tune of 35.2 and 37.4 per cent, respectively. The study also indicated the nematicidal efficacy of Carbofuran @ 2kg a.i/ha, and hence, can be considered an effective chemical control against this annihilative species.

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