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Management of Root-knot Nematode (*Meloidogyne incognita*) in Tomato (*Solanum lycopersicum* L.) by Trap crop, Bio-pesticides and Chemical Approaches

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Abstract
The research trial experiment was carried out for two years during Kharif Season-2018 & 2019 at Agricultural Research Station (ARS) Navgaon-Alwar, Rajasthan on Tomato. In this research trial applied two fungal bio-agents and one chemical as nursery treatment. Okra (Abelmoschus esculentus) was used as trap crop except untreated check for the nematode trapped at initial stage and okra plants were uprooted after 18 days from date of germination. Fungal bio-agents viz. Paecilomyces lilacinus and Trichoderma harzianum @ 5.0 and 10 g /m2 doses were applied of each respectively and one chemical Carbofuran 3G @ 2.5 and 5.0 g /m2 were applied untreated check (control) was maintained. Research findings of the research trial was Paecilomyces lilacinus @ 10g/ m2 area in nursery treatment was found best fungal bio-agent for the management of root-knot nematode, M. incognita. P. lilacinus @ 10g/ m2 area plant parameters recorded highest shoot length 2018 (75.60 cm) 2019 (66.66) and pooled of both the years (71.13), root length 2018 (30.50 cm) 2019 (27.20) and pooled of both the years (28.85), highest shoot weight 2018 (731.83 g) 2019 (391.66) and pooled of both the years (561.75), root weight 2018 (53.06 g) 2019 (45.00) and pooled of both the years (49.03) and highest tomato yield were recorded 2018 (254.16 q/ha)2019 (243.38) and pooled of both the years (248.77). Nematode reproductive parameters were recorded, number of females (galls) / plant 2018 (4.66) 2019 (4.00) pooled of both the years (4.33), number of egg masses / plant 2018 (2.33) 2019 (1.66) and pooled of both the years (2.00), number of eggs and larvae / egg mass 2018 (206.67), 2019 (143.33) and pooled of both the years (175.00) nematode population J2 / 200 cc soil 2018 (153.33) 2019 (153.33) and pooled of both the years (153.33) and final nematode population 2018 (634.00) 2019 (390.66) and pooled of both the years (512.66). Tomato growth and yield was improved and nematode population was decreased.

Key Words: *Bio-agents, Chemicals, Meloidogyne incognita, Okra, Trap crop and Tomato.*

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I. Introduction:

Tomato (*Solanum lycopersicum* L.) is an important crop grown throughout the world. Fruits and vegetables constitute an important part of our dietary menu providing minerals and vitamins for necessary growth and development of the body. India is the second largest producer of vegetable in the world next to China. The tomato is an important vegetable crop which is cultivated throughout the year in the country. In India, tomato is cultivated in 778 thousand ha with a total production of 19397 thousand tonnes with the productivity 24.93 tonnes /ha (NHB, 2018-19). The total area under tomato cultivation in Rajasthan is 18.03 thousand ha with a total production of 90.32 thousand tonnes and the productivity is 5.00 tonnes /ha (Commissionerate of Horticulture, DOA, GOR, 2019-20).

The ability of this crop to grow throughout the year, except in extreme climatic conditions, makes it a very valuable to the growers and is an additional source of earning profit even during off season and tomatoes are being cultivated as food (Boswell, 1949). Tomatoes are used as a vegetable as well as an addition in almost all vegetable preparation and used for soup, salad, pickles, ketchup, sauce and in many other ways. It is the most important “Protective food” because of its special nutritive value and also of its widespread production.

Genus *Lycopersicon* has several species, but only two of them are edible i.e. *S. lycopersicum* L. the cultivated tomato and *L. pimpinellifolium* Muller, small fruited tomato. A large number of tomato (*S. lycopersicum* L.) varieties are available in India and most of them have gained popularity and comes under commercial cultivation.

In spite of development of various plant protection measures, the crop of such an economic importance, unfortunately suffers severely from several diseases caused by bacteria, fungi, viruses, nematodes or by adverse environmental conditions. Among nematodes, root-knot nematode, *Meloidogyne incognita* (Alam *et al*., 1975; Khan *et al*., 1978) *M. Javanica* (Rao and Prasad, 1969), reniform nematode, *Rotylenchulus reniformis* (Rao and

Prasad, 1969; Kheir and Osman, 1977), lesion nematode, *Pratylenchus penetrans* (Estores, 1971) stunt nematode, *Tylenchorhynchus brassicae* (Alam *et al*., 1975) attack on tomato crop but the root-knot nematode is the most common.

It has received a greater attention in India and other countries though their first record seems to be in the last century (Barber, 1901). However, in Rajasthan, it was first noticed by Arya (1957) found its infestation on tomato and later Yadav and Naik (1966) found *Meloidogyne* spp. widely distributed in the soils of Rajasthan, infecting vegetables and many other economically important crops.

During the last decade, incidence of root-knot nematode has been reported to be increasing in the various part of world including India. This increase may be due to intensive agriculture to maximize the production of field as well as vegetable crops. The success in increasing their population and survival may also probably due to their polyphagous nature, enabling them to survive and remain active throughout the year.

Root-knot nematode cause severe losses in the tomato. Bhatti and Jain (1977) estimated the crop losses up to 46 per cent in Haryana state. Reddy (1985) estimated per cent loss of (39.77) at 20 larvae/g soil in tomato field of Karnataka. Sharma and Baheti (1992) estimated losses up to 46 per cent against *M. incognita* on tomato. Sen (1960) had reported a loss of about 70 per cent to tomato, chilli, brinjal and okra from Bihar, due to this nematode.

Among various pest and diseases, which damage crops, plant parasitic nematodes, present a formidable pest problem for different crops. Most species attack and feed on plant roots and underground plant parts. Vegetable crops are excellent host for a wide range of plant parasitic nematodes different groups of vegetables are prone to several species of nematodes which are causing losses to the crops. Estimated overall average annual yield losses of the world major vegetable crops by nematodes are 12.3 per cent an average loss for the 40 crops in developed countries were estimated to be 8.8 per cent compared with 14.6 per cent for developing countries (Ravichandra, 2008).

II. Material And Methods:

Estimation of Soil Population:

Initially 200 cc soil of each sample was processed using Cobb's sieving and decanting technique (Cobb's 1918), followed by Baermann's funnel technique (Cristie and Perry, 1951). After 24 hours, suspension was drawn in a beaker from funnel and kept for some time to allow the nematode to settle down at the bottom. Upper water layer from the beaker was gently removed in order to have a concentrated nematode population. The volume of the suspension was maintained to 100 ml, from this maintained suspension 10 ml nematode suspension was drawn with the help of a pipette and poured over a counting dish. The root-knot nematode larvae were identified and counted under stereoscopic binocular microscope. Dilution count method was used for estimation of number of *Meloidogyne* juveniles.

Identification of Root-knot Nematode:

Root-knot nematode infested roots were washed thoroughly and stained with 0.1 per cent acid fuchsin lacto phenol at 80 ^{o}C for 2-3 minutes (Mc Beth *et al.* 1941). After a gentle wash in tap water, roots were kept in clear lacto phenol for at least 24 hours and then examined under stereoscopic binocular microscope. After staining the females were teased out from the roots and perineal pattern were prepared (Tylor and Netscher, 1974), compared with the 'key' given by Tayler *et al.* (1955) and identified as *M. incognita.*

Raising of Nursery:

Tomato variety Satyam was used in this experiment and seedlings were raised in the 1m x 1m size plots and seeds were sown in line sowing method. Forty five days old seedlings thus grown were transplanted in main field for various plots.

Staining of Root Material for Root Population:

To estimate the root population (eggs per egg mass and immature females) the roots of tomato plants were stained in 0.1 per cent acid fuchsin in lactophenol at 80 ^{o}C for 2-3 minutes and kept in clear lactophenol until they were observed.

After Care:

Care was taken right from sowing till harvest of the experiments. The seeds before sowing were treated with carbendazim at the rate of 2 g / kg seed to protect against fungal attack. Drenching of Blitox (0.1 per cent) and to avoid insect damage was given as and when required. Weeding and hoeing was done timely to avoid weeds and to maintain proper aeration in soil in all experimental plots regularly. The recommended doses of nitrogen and phosphorus @ 12 and 6 g / m^2 area were applied for proper growth of plants. Irrigation was given as and when required during the experimentation.

Objective of this research trial was to know the effect of trap crop, bioagents and chemicals against root-knot nematode management in tomato. First of all highly susceptible okra variety were sown in the main field except control treatment. After 18 days from date of germination okra plants were uprooted carefully. Tomato seedlings obtained from the nursery remain free from nematode. Tomato seedlings transplanted at particular place where okra plants were uprooted. The susceptible plants were trap the nematode population because nematodes penetrate the okra plants and completely associated with the rhizosphere of okra plants. The trapped populations of root-knot nematode completely exit out with the roots of okra plants. Root-knot nematode is sedentary endoparasites in nature of parasitism. The zone of rhizosphere contains less population of nematodes. For the protection of seedlings against nematode infection in nursery applied bioagents and chemical in nursery as soil treatment. The tomato seedlings become healthy enough to sustain nematode attack and are able to give good yield. The following treatments viz., T_{1-} *Paecilomyces lilacinus* (*Purpureocillium lilacinum*) @ 5g/ m^2, T_{2-} *Paecilomyces lilacinus* (*Purpureocillium lilacinum*) @ 10g/ m^2, T_{3-} *Trichoderma harzianum* @ 5g/m^2, T_{4-} *Trichoderma harzianum* @ 10g/m^2, T_{5-} Carbofuran 3G @ 2.5g/m2 , T_{6-} Carbofuran 3G @ 5.0g/m2, T_{7-} Untreated Check, were taken. Day to day care was taken and crop was harvested at maturity. Observations were recorded from each treatment replication wise, observations at the time of sowing *viz.*, 1. Initial Nematode Population (INP) of nursery field. 2. Initial Nematode Population (INP) of main field. Observations recorded on plant growth parameters *viz.*, 1. Shoot Length (cm) 2. Root Length (cm) 3. Shoot Weight (g) 4. Root Weight (g) 5. Yield Q / Ha. and observations recorded on nematode reproduction parameters *viz*., 6. Number of Galls (Females) / Plant 7. Number of Egg Massase/ Plant 8. Number of Eggs & Larvae / Egg mass 9. Nematode Population/ 200 CC Soil 10. Final Nematode Population (FNP) in Soil + Roots. Total numbers of treatments were seven and all treatments were replicated three times. Data statistically analysed with statistical design, RBD.

III. Results:

Research findings and results of two years studies were conducted for the management of nematode in tomato nursery with trap crop okra, two different doses of two fungal bioagents *viz. P. lilacinus* (new name *P. lilacinum*) and *T. harzianum* @ 5.0g / m^2 and 10 g / m^2 and one chemical with two different doses @ 2.5 g and 5.0 g / m^2 nursery area in soil with line application method. *P. lilacinus* (new name *P. lilacinum*) @ 10 g / m^2 dose was found significantly superior over untreated control plant parameters recorded highest shoot length (75.60 cm) 2018 (66.66 cm) 2019 and pooled of both the years (71.13 cm), root length (30.50 cm) 2018 (27.20 cm) 2019 and pooled of both the years (28.85 cm), highest shoot weight (731.83 g) 2018 (391.66 g) 2019 and pooled of both the years (561.75 g), root weight (53.06 g) 2018 (45.00 g) 2019 and pooled of both the years (49.03 g) and highest tomato yield were recorded (254.16 q/ha) 2018 (243.38 q/ha) 2019 and pooled of both the years (248.77 q/ha) (Table & Fig. 1). Nematode reproductive parameters were recorded, number of females (galls) / plant (4.66) 2018 (4.00) 2019 and pooled of both the years (4.33), number of egg masses / plant (2.33) 2018 (1.66) 2019 and pooled of both the years (2.00), number of eggs and larvae / egg mass (206.67) 2018 (143.33) 2019 and pooled of both the years (175.00) nematode population J2 / 200 cc soil (153.33) 2018 (153.33) 2019 and pooled of both the years (153.33) and final nematode population (634.00) 2018 (390.66) 2019 and pooled of both the years (512.66) (Table & Fig. 2). Tomato yield was increased and nematode population was decreased significantly.

IV. Discussion:

The fungal bioagents *viz. P. lilacinus* (new name *P. lilacinum*) and *T. harzianum* @ 5.0g / m^2 and 10 g / m^2 and one chemical with two different doses @ 2.5 g and 5.0 g / m^2 nursery area in soil with line application method. *P. lilacinus* (new name *P. lilacinum*) @ 10 g / m^2 dose was found significantly superior over untreated for the management of root-knot nematode on tomato. The okra susceptible variety was used as trap crop for trape the initial nematode population from main field except control plots. Data revealed that different fungal bio-agents were significantly effective in improving the plant growth characters to a varied degree and in reducing the nematode reproduction over the untreated check. Improvement in plant growth characters and reduction of nematode reproduction were directly proportionate to applied doses of fungal bio-agents. However, among these fungal bio-agents, *P. lilacinus* was found the most effective as compared to *T. harzianum* and chemical in improving plant growth characters and reduction of nematode reproduction. Among doses, *P. lilacinus* @ 10 g/ m2 area was found superior over *P. lilacinus* @ 5g/ m2 area, *T. harzizanum* @ 5.0 & 10g/ m2 area and chemical.

These findings are in agreement with the results of Ashraf *et al.* (2005) who reported *P. lilacinus* as an effective and important fungal bio-agent in controlling reniform nematode in different agronomic crops. De Leij and Kerry (1991) reported the potential of *P. chlamydosporium* as a biological control agent against *M. arenaria* on tomato plants. Significant reduction in the population more than 80 per cent after the first nematode generation was achieved. Similarly Vyas *et al.* (1997) also reported that the *P. lilacinus* gave better control *of M.*

javanica race 2 over *Metarhizium anisopliae*. Some reports also confirmed that *P. lilacinus* colonized root tissues in its interaction with nematode (Cabanillas *et al*. 1998). Similarly Cayrol and Gomes (1991) reported that *P. lilacinus* propagules in the soil were correlated to the initial dose applied and decreased progressively through time with increased doses.

In the present investigation among doses 10g / m2 area for fungal bio-agent i.e. of *P. lilacinus* was found to be the best in reducing nematode reproduction over *T. harzianum* and chemicals. These finding are in agreement with Khan (1986) who also reported that when 2g *P. lilacinus* was added / pot gave better results against pathogens. The reduction in the nematode populations resulted by a way of fungal attack on larvae or death of females before egg laying thus reducing their fecundity and if eggs are produced, these are colonized and destroyed. *P. lilacinus* was found to be more effective against root knot and reniform nematode (Khan and Saxena, 1996). In other way Khan and Goswami (2000) reported that the gall development and final nematode population of *M. incognita* decreased with the increasing dose of fungus *P. lilacinus* and 8g fungus infested rice/ kg soil was the optimum dose for suppression of *M. incognita* in tomato. As far as the doses of bioagent are concerned Olia and Goswami (2000) reported that 9g fungal culture of *Aspergillus niger* was the best dose in reducing root-knot nematode, *M .incognita* population. Dhawan *et al*. (2005) reported that the highest reduction in number of galls, egg mass/ plant and eggs/ egg mass of *M. incognita* with soil application of the fungus *Arthrobotrys oligospora* @ 3 per cent w/w and soil application of the fungus was superior in reducing nematode population compared to seed treatment.

This study revealed that *P. lilacinus* (New name *Purpureocillium lilacinum*), @ 10g / m2 area was found most effective over *P. lilacinus*, @ 05g / m2 area, *T. harzianum* @ 5 & 10g / m2 area and chemical @ 2.5 & 5.0 g/m2 area in reducing population of *M. incognita* on tomato and enhancing plant growth characters.

Table:1 Management of root-knot nematode (*Meloidogyne incognita*) through trap crop, bio-agents and chemicals in Tomato (*Solanum lycopersicum* L.) (2 Years Result, *Kharif* Season-2018 & 2019)
(TABLE ON PLANT PARAMETERS)

Treatment Details		Plant Growth Characters														
		Shoot Length (cm)			Root Length (cm)			Shoot Weight (g)			Root Weight (g)			Yield Q / Ha.		
		2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
P. lilacinus @ 5g/ m2	T_1	70.80	63.40	67.10	25.26	25.16	25.21	653.53	372.66	513.10	47.43	42.33	44.88	237.49	246.94	242.22
***P. lilacinus* @ 10g/ m2**	T_2	**75.60**	**66.66**	**71.13**	**30.50**	**27.20**	**28.85**	**731.83**	**391.66**	**561.75**	**53.06**	**45.00**	**49.03**	**254.16**	**243.38**	**248.77**
T. harzianum @ 5g/m2	T_3	60.40	57.00	58.70	18.53	21.26	19.90	453.63	263.33	358.48	32.23	32.40	32.31	143.05	175.05	159.05
T. harzianum @ 10g/m2	T_4	68.26	62.66	65.47	22.40	23.33	22.86	613.66	325.00	469.33	41.36	37.66	39.51	196.24	218.33	207.29
Carbofuran 3G @ 2.5g/m2	T_5	57.08	53.33	55.20	16.53	18.26	17.40	402.03	248.33	325.18	28.40	28.16	28.28	128.33	157.33	142.83
Carbofuran 3G @ 5.0g/m2	T_6	65.25	60.23	62.74	20.26	21.91	21.09	503.70	283.33	393.51	35.06	34.33	34.70	171.66	182.00	176.83
Untreated Check	T_7	**53.40**	**48.66**	**51.03**	**15.10**	**16.23**	**15.66**	**385.33**	**211.66**	**298.50**	**25.16**	**24.66**	**24.91**	**85.00**	**75.66**	**80.33**
	CD Years	3.240			2.443			23.511			5.634			10.315		
	CD Treat ments	3.919			3.861			136.258			6.159			33.916		
	CD Y X T	7.767			3.656			35.998			4.939			27.189		

Note: (i) INP in Nursery 427 L/200 CC Soil (ii) INP in Main Field 359 L/200 CC Soil
Okra used as trap crop
Okra plants uprooted after 18 Days from date of sowing except untreated check

Table:2 Management of root-knot nematode (*Meloidogyne incognita*) through trap crop, bio-agents and chemicals in Tomato (*Solanum lycopersicum* L.) (2 Years Result, *Kharif* Season-2018 & 2019) (TABLE ON NEMATODE PARAMETERS)

Treatment Details		Nematode Reproduction Parameters														
		No. of Females (Galls) / Plant			No. of Egg Masses / Plant			No. of Eggs and Larvae / Egg Mass			Nematode Population / 200 CC Soil			Final Nematode Population Root + Soil		
		2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
P. lilacinus @ 5g/ m2	T_1	6.66	6.33	6.50	3.00	2.66	2.83	211.66	150.00	180.83	200.00	171.66	185.83	850.00	581.33	715.66
***P. lilacinus* @ 10g/ m2**	T_2	**4.66**	**4.00**	**4.33**	**2.33**	**1.66**	**2.00**	**206.66**	**143.33**	**175.00**	**153.33**	**153.33**	**153.33**	**634.66**	**390.66**	**512.66**
T. harzianum @ 5g/m2	T_3	16.66	10.00	13.33	9.66	5.66	7.66	232.66	203.33	218.00	398.33	233.33	315.83	2,662.33	1,390.00	2,026.16
T. harzianum @ 10g/m2	T_4	9.33	7.00	8.16	4.33	3.33	3.83	216.66	155.00	185.83	300.00	205.00	252.50	1,252.66	727.00	989.83
Carbofuran3G @ 2.5g/m2	T_5	20.33	12.00	16.16	12.00	7.00	9.50	243.33	221.66	232.50	418.33	251.66	335.00	3,357.00	1,810.33	2,583.66
Carbofuran3G @ 5.0g/m2	T_6	16.00	8.33	12.16	7.66	5.00	6.33	221.66	191.66	206.66	325.00	228.33	276.66	2,042.66	1,203.33	1,623.00
Untreated Check	T_7	**30.33**	**32.67**	**31.50**	**18.33**	**20.33**	**19.33**	**263.33**	**275.00**	**269.16**	**505.00**	**420.00**	**462.50**	**5,355.33**	**6,042.66**	**5,699.00**
	CD Years	2.101			0.994			4.870			20.169			220.459		
	CD Treat ments	8.217			4.711			54.742			123.441			1,462.888		
	CD Y X T	3.091			1.936			30.952			47.390			464.653		

Note: (i) INP in Nursery 427 Larvae / 200 CC Soil (ii) INP in Main Field 359 Larvae / 200 CC Soil

Okra used as trap crop

Okra plants uprooted after 18 Days from date of sowing except untreated check

Fig.1 Plant Parameters

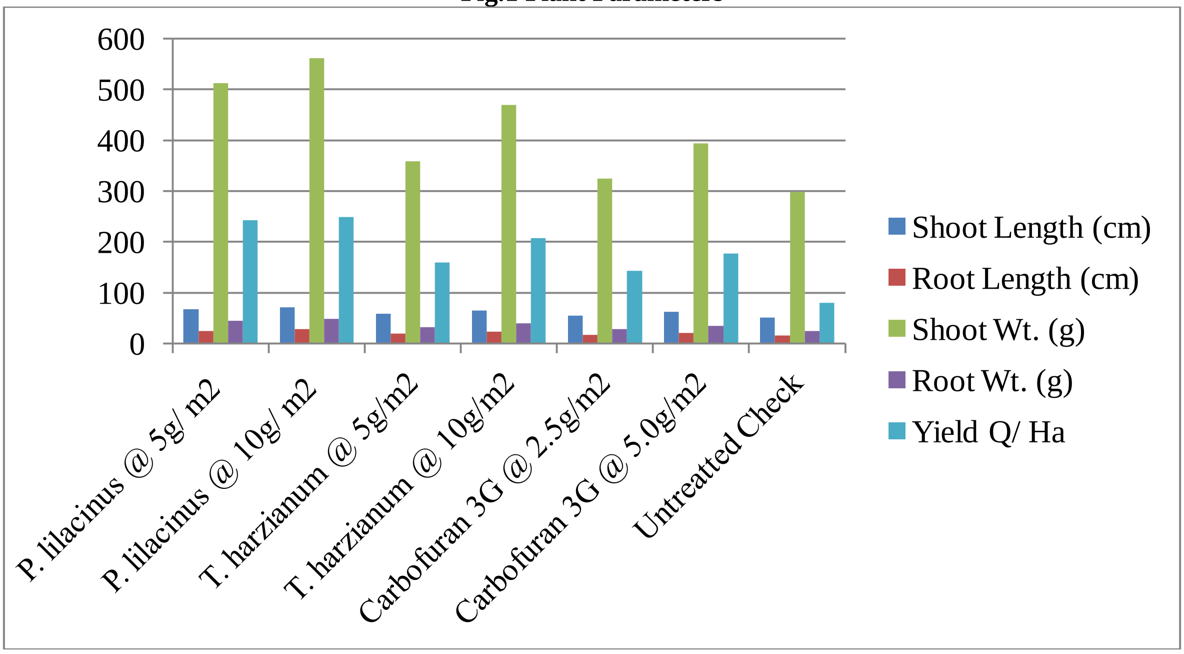

Fig. 1 Effect of trap crop, bio-agents and chemicals on Tomato (*Solanum lycopersicum* L.) yield & plant growth parameters against root-knot nematode (*Meloidogyne incognita*)

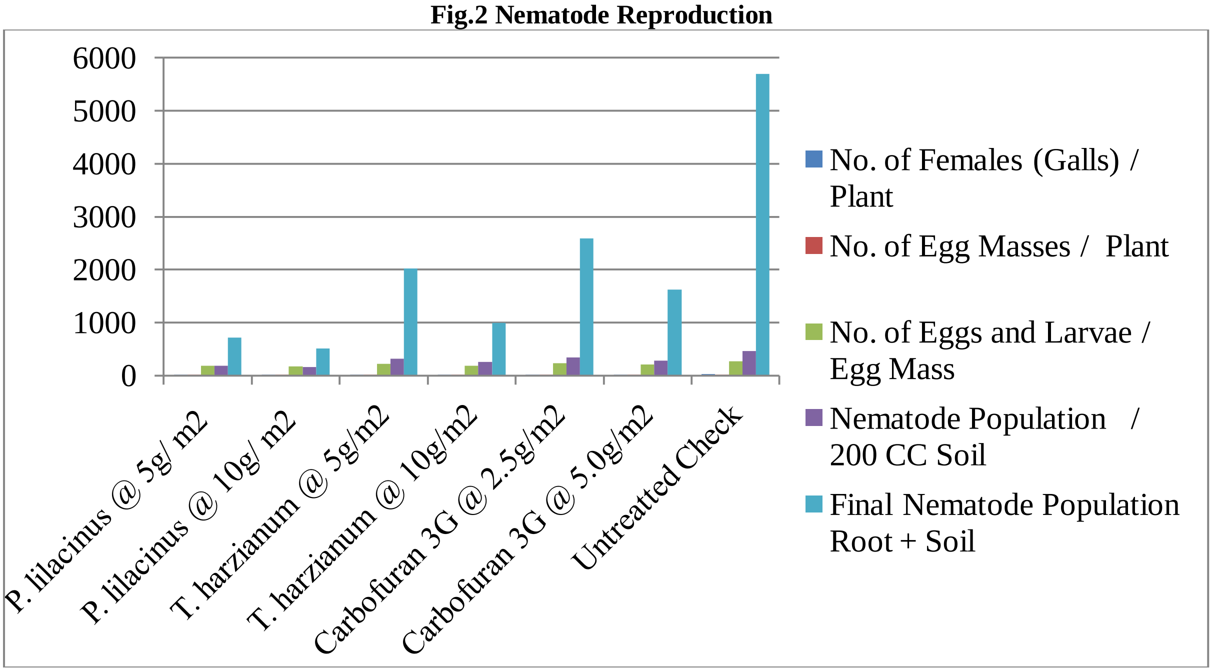

Fig. 2 Effect of trap crop, bio-agents and chemicals on root-knot nematode (*Meloidogyne incognita*) reproduction in Tomato (*Solanum lycopersicum* L.) crop.

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