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Management of tomato wilt complex caused by *Meloidogyne incognita* and *Fusarium oxysporum* f. sp. *lycopersici* through organic amendments

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Abstract
Tomato (*Solanum lycopersicon* Mill.) is the second most important vegetable crop. It suffers from various phytopathogenic diseases. Among the fungal diseases, wilt disease caused by *Fusarium oxysporum* f. sp. *lycopersici* is most important disease and is limiting factor in its production. The fungus also develops synergistic relationship with *Meloidogyne* spp. leading to root-knot wilt disease complex. This complex is highly destructive to tomato plants and is characterized by enhanced wilt symptoms. Efficacy of different organic amendments (@5g / kg soil) were evaluated against root-knot wilt disease complex developed by *Meloidogyne incognita* and *Fusarium oxysporum* f. sp. *lycopersici.* Observations were made on plant growth parameters, nematode reproduction and wilt disease incidence in tomato. The experimental results showed that among organic amendments, neem cake was found significantly superior to increase plant growth parameter, reduce nematode population and wilt disease incidence followed by castor cake.

Keywords: tomato, wilt, *Meloidogyne incognita, Fusarium oxysporum*, organic amendments

Introduction
Tomato (*Solanum lycopersicon* Mill.) is the second most important vegetable crop next to potato, belong to the family *Solanaceae*. Tomato crop suffers from various phytopathogenic diseases (*i. e*. fungal, bacterial, viral and nematode *etc*.). Among the fungal diseases, wilt disease caused by *Fusarium oxysporum* f. sp. *lycopersici* is most important disease and is limiting factor in its production. This pathogen infects the tomato plant through mycelium or spores penetrating tip of the roots or root laterals and wounds from roots. Browning of the vascular tissue is strong evidence of fusarium wilt [1]. Among the nematode diseases root-knot is a severe problem for vegetable production. Reddy, 1985 [2] estimated 39.77 per cent loss in tomato field. The tomato yield losses ranging from 32 to 40% due to root knot nematode has been reported [3]. Arya, 1957 [4] found its infestation on tomato in Rajasthan.The nematode not only causes direct damage to plants at their own, but generally helps fungi, bacteria and plant viruses to invade host plant. Plant parasitic nematodes could interact with other plant-pathogens to increase damage to the plant or to break plant resistance (i.e., vascular fungal diseases; 5). The fungus also develops synergistic relationship with root-knot nematode, *Meloidogyne* spp. leading to root-knot wilt disease complex [6]. This complex is highly destructive to tomato plants and is characterized by enhanced wilt symptoms on the infected plants with suppressed growth and yield [7]. Chemical methods have been mostly used to control the diseases and are effective in the management of diseases but these are not eco-friendly. Most of the chemicals are hazardous to environment and not safer in use. Therefore, non-chemical methods (*i.e.,* organic amendments, bio-agents, botanicals *etc*.) are gaining importance in the disease management. In view of this the present investigation was carried out to manage of tomato wilt complex caused by *Meloidogyne incognita* and *Fusarium oxysporum* f. sp. *lycopersici* through organic amendments

Materials and Methods
The experiment was carried out in pots filled with infested soil having *Fusarium oxysporum* f. sp. *lycopersici* and 2 J_2/g of soil of root-knot nematode, *M. incognita* castor cake, mahua cake, karanj cake, mustard cake, neem cake and vermicompost were added to soil each @ 5g/kg soil

before 20 days of transplanting for proper decomposition. Nematode at the time of sowing and fungus one week after (N1+F2) was also maintained for comparison. Hence, there were 7 treatments with 5 replications arranged in completely randomized design. Observations were recorded after 45 days of transplanting or at the time of harvesting. Observation on PDI, shoot length (cm), root length (cm), fresh shoot weight, and fresh root weight (g) were taken at the time of harvesting. The root were washed carefully under tap water and stained with 0.1 per cent acid fuchsin lacto-phenol at boiling temperature and after wash kept in clear lacto-phenol for 24 hrs. Thereafter the roots were examined thoroughly under a stereoscopic binocular microscope for counting number of gall per plant and number of egg masses per plant. The data were subjected to statistical analysis.

I Preparation and maintenance of pure culture of fungus

The fungus was multiplied on pre-soaked sterilized sorghum grain in flask by inoculating with 7 days old culture of *Fusarium oxysporum* f. sp. *lycopersici* and incubated at 25±1°C temperature for 7 days.

II Preparation and maintenance of pure culture of *M. incognita*

Root knot nematode infested tomato plants were collected from the fields of nearby vegetable growing villages and brought to the laboratory. Egg masses were carefully detached from roots and were kept in distilled water in watch glasses at laboratory temperature for hatching. Freshly hatched 2nd stage juveniles were then inoculated on one month old tomato plants already grown and maintained in 6" sized earthen clay pots filled with steam sterilized soil to obtained adequate pure population of *M. incognita* on the plants and in soil to carry out further experiments.

III Pots Filling

The earthen pots of 6" size were filled with 1 kg infested soil. The fungus *Fusarium oxysporum* f. sp. *lycopersici* and root-knot nematode (2 J_2 /g soil) mix in the soil. castor cake, mahua cake, karanj cake, mustard cake, neem cake and vermicompost were added to soil each 5g/kg soil before 20 days of transplanting for proper decomposition. Each treatment was replicated five times and seven plants maintained in each pot. Nematode at the time of sowing and fungus one week after (N1+F2) was also maintained for comparison.

IV Transplanting and After care

Tomato seedling was raised in nursery. Uniform size seedlings were transplanted in pots, one healthy plant in each pot was maintained and others were uprooted carefully without disturbing the one to be maintained.

Care was taken right from sowing till harvest of experiments. To avoid insect damage spray of Malathion (0.05%) were given as and when required. Weeds were uprooted from experimental pots. The pots were randomly rotated to eliminate the effect of sun and shade. The appropriate amount of water was provided throughout the course of experimentation.

V Harvest

The experiment was completed 45 days after transplanting, while harvesting of plants, the care was taken to avoid losses of both roots and nematodes in adhering soil. Observation on plant growth {shoot length (cm), root length (cm), fresh shoot weight, and fresh root weight (g)}, nematode reproduction and wilt PDI on tomato were recorded. The root was washed carefully under tap water and stained with 0.1 per cent acid fuchsin lacto phenol at 80 ºC for 2-3 minutes [8] and after wash kept in clear lacto phenol for 24 hrs. Thereafter the roots were examined thoroughly under a stereoscopic binocular microscope for counting number of galls per plant and number of egg masses per plant. The data were subjected to statistical analysis.

Results and Discussion

Data presented in table-1 showed that all the organic amendments (castor cake, mahua cake, karanj cake, mustard cake, neem cake and vermicompost) significantly increase the plant growth and decrease nematode reproduction as well as wilt disease incidence in tomato over control. Among the organic amendment, neem cake was found most effective followed by castor cake and mahua cake to manage the nematode population and fungus growth, resulted increase in plant growth parameters (shoot length, root length, shoot weight and root weight) and reduction in number of galls per plant, number of egg masses per plant and per cent disease incidence. The result of our findings indicated that application of organic amendments as soil treatment significantly reduced the fungus, *Fusarium* oxysporum and root-knot nematode, *Meloidogyne incognita* in tomato roots. Root galling due to *M. incognita* infection was less in tomato plant roots treated with organic amendments as compared to untreated inoculated control. This result corroborates with the findings of Rathar and Siddiqui, 2007 [9], Kalaiarasan *et al*., 2007 [10] and Chandrawat *et al.*, 2020 [11] that proved the effectiveness of oilcakes improving plant growth and reducing nematode population in tomato. Oil cakes were also responsible for increase the level of defence enzymes in the tomato plant [11]. Singh *et al*., 2009 [12] and Sreenivasan, 2010 [13] applied neem oilcakes and found significant increase in the plant growth and decrease in root knot nematode population in green gram and medicinal coleus respectively. Similar observation was also reported by Srivastava, 2002 [14] in papaya. Similar findings were reported by Dhivya *et al*., 2017 [15]. Neem cake extract recorded the maximum reduction of mycelial growth over control by Mahua cake. Similar results were showed by Padmodaya *et al*. 1999 [16] in *Fusarium solani* on tomato. Tiyagi and Alam, 1995 [17] supported the earlier report that application of neem cake followed by castor cake and mustard cake in the soil, significant improvement was observed in plant growth parameters and great reduction in the number of root galls caused by *M. incognita* in green gram and next crop chickpea. Meena *et al*., 2014 [18] revealed that plant products significantly enhanced growth of maize and reduced nematode infection over check. However, neem leaves powders at 4 q/ha were found to be the most effective in improving growth of maize and reducing infection of *Heterodera zeae*.

Hence, the study concluded that organic amendments are effective option for management of wilt complex disease of tomato caused by *Fusarium* and *Meloidogyne*. It is clearly indicating that organic amendments are most effective in increase the plant growth and decrease the nematode population and wilt incidence compare over control.

Table 1: Efficacy of various organic amendments on wilt (*Fusarium oxysporum* f. sp. *lycopersici*) incidence and *Meloidogyne incognita* in tomato under pot condition

Treatments	Shoot length (cm)	Root Length (cm)	Shoot weight (g)		Root weight (g)		No of Galls/ plant	No of egg Masses/ plant	PDI
			Fresh	Dry	Fresh	Dry			
Castor cake	47.33	16.67	26.72	6.22	6.39	1.88	24.11	17.68	24.61 (29.73)
Mahua cake	45.67	15.27	26.20	5.35	5.60	1.81	25.37	15.01	26.23 (30.81)
Karanj cake	38.83	14.17	19.34	4.06	4.78	1.35	29.12	21.34	33.43 (35.32)
Mustard cake	33.28	12.53	16.63	3.35	4.57	1.19	31.28	32.67	38.97 (38.62)
Neem cake	51.75	18.27	28.64	6.97	7.31	2.48	22.14	14.69	22.58 (28.36)
Vermicompost	41.17	14.50	23.49	4.67	5.18	1.51	27.07	21.68	30.37 (33.43)
Control (N1+F2)	19.85	6.90	3.69	0.54	0.73	0.47	39.35	26.69	59.03 (50.21)
SEm%	0.773	0.615	0.730	0.402	0.360	0.289	0.184	0.157	0.979
CD at 5%	2.318	1.843	2.188	1.204	1.079	0.868	0.551	0.470	2.936

*****Average of five replications
Figures given in parenthesis are angular transformed values

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