Chapter

The Emerging Nematode Problems in Horticultural Crops and Their Management

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Abstract

Plant-parasitic nematodes (PPNs) are responsible for significant monetary losses to horticultural crops. They are unseen foes of crops and devitalize plants by causing injury to plant roots or aboveground parts. From last few decades, increased attention has been paid to nematode problems in horticultural crops in open as well as under protected cultivation. PPNs are obligate parasites, mostly have wide host range and are widespread pathogens of horticultural crops. The dimension of damage is density dependent and their management options vary with type of crop, nematode species and other factors. Recent approaches to combat losses caused by nematodes are the use of nematicides, cultural practices and resistant cultivars that may be used singly or in an integrated manner. This book chapter gives an overview of the emerging nematode problems in horticultural crops and their management strategies.

Keywords: nematode, horticultural crops, disease complex, management

1. Introduction

Horticulture has emerged as an important and viable diversification option in agriculture which transformed the subsistence farming system into a high value commercial enterprise [1]. It has led to the revolutionary changes in the socio-economic status of farmers in various parts of the country. Due to the rich diversity of agro-climatic conditions prevailing in the country, India is regarded as a horticultural paradise. Estimated 234.2 tonnes of horticultural produce are being produced from about 20.66 million hectares [2]. The horticulture has proven its credibility as a potential sector to enhance agricultural production, improve household nutritional security and income generation through diversification and employment, value addition and export [3]. Innovative technologies and their execution coupled with supporting infrastructure has brought India at the door-step of golden revolution, which has enabled India the global leader in production of many horticultural crops [4]. In spite of the enormous success achieved in the horticulture sector, several constraints still exist. Besides new emerging challenges, poor productivity per unit area continues to be a concern in most of the horticultural crops with climate change impacting productivity further. Phyto-nematodes are among the important biotic stresses in the horticultural sector cause severe losses in these crops (**Table 1**). The introduction of new species, new

S. No.	crops	Nematode affecting the crop	Per cent yield losses	Monetary losses (Rs. in millon)
1.	Banana	*Meloidogyne incognita*	15	9710.46
2.	Guava	*Meloidogyne* spp.	28	2350.88
3.	Citrus	*Tylenchulus semipenetrans*	27	9828.22
4.	Pomegranate	*Meloidogyne* spp.	23	3023.44
5.	Brinjal	*M. incognita*	21	3499.12
6.	Chili	*M. incognita*	15	744.90
7.	Cucumber	*Meloidogyne* spp.	12	110.46
8.	Okra	*Meloidogyne* spp.	19.5	2480.86
9.	Tomato	*Meloidogyne* spp.	23	6035.20
10.	Capsicum	*Meloidogyne* spp.	10	52.92

Kumar et al. [5].

Table 1.
The losses caused by plant parasitic nematodes to economically important crops in India.

mutant of the species and resistance among the present species to various environmental conditions are emerging threats to all horticultural crops.

2. Emerging nematode problems

2.1 Nematode as emerging threat to protected cultivation

In the present era protected cultivation is an emerging technology adopted by farmers on a large scale, for growing seasonal as well as off-season crops. Under protected conditions farmers' taken several high economic value crops such as vegetables and ornamentals. Growers can noticeably increase their income by cultivation of vegetables in off-season as the vegetables produced during their normal season generally do not fetch good returns due to glut in the markets. Polyhouse crops attacked by a number of insects, pests and diseases including plant parasitic nematodes, they are interfering with the successful cultivation of vegetables and ornamentals under protected structures. Favorable conditions such as moisture, temperature and continuous availability of host in polyhouses favor the multiplication of phyto-nematodes. Among plant parasitic nematodes, root-knot nematode, *Meloidogyne* spp. are the most overwhelming pest in protected structures. Root-knot nematodes have wide host range attacking on almost all the crops grown under polyhouses and causes significant damage. Many a times complete crop failure due to association of nematode and soil borne fungi (disease-complexes) have been reported (**Figure 1**). In Haryana, 63.15% polyhouses were found infested with root-knot nematodes [6].

Capsicum (bell pepper), cucumber, chillies, tomato, muskmelon, gerkins and ornamentals like chrysanthemum are very common crops in protected cultivation. These crops are grown throughout India and are seriously infested with *Meloidogyne incognita*, *Meloidogyne javanica* (Root-knot nematodes) and *Rotylenchus reniformis* (Reniform nematode). Other nematodes such as lesion nematode (*Pratylenchus* spp.), foliar nematode (*Aphelenchoides* spp.) and burrowing nematode (*Radopholus similis*) which may develop in vegetable and ornamental crops grown under polyhouses. The overall annual yield losses due to nematodes goes up to 60% under

Figure 1.
Nematode infestation under polyhouses a. root-knot nematode infested root B. crop failure (source: Original photos).

protected structures and also reduced the quality of the produce of crops in the market due to unthrifty growth.

2.2 The emerging threat of nematodes in orchards and plantation crops

Nematodes are serious menace in fruit orchards and plantation crops in the country. Recently, the threat has been increased due to the introduction of new nematode species such as *Meloidogyne enterolobii* is an emerging threat to guava [7]. Growers of fruits such as guava, pomegranate, citrus, banana are facing the nematode problems in their orchards such as root-knot nematodes, citrus nematode, reniform nematode, burrowing nematode and lesion nematode etc. Farmers are not aware to this menace due to hidden nature and non-diagnostic symptoms which is of major concern in their multiplications in the orchards. Recently, pomegranate and guava growers are encountering the problems of yellowing of leaves, stunting and less productivity of trees (**Figure 2**). Such trees were found to be severely infested with root-knot nematodes on the basis of soil and root samples. Crop losses caused by phyto nematodes to fruit crops are very high, with an average annual yield losses estimated at about 20–40% worldwide [5]. The losses have increased tremendously when two or more species occurs simultaneously or mainly with secondary pathogens like fungi and bacteria forming disease-complexes.

2.3 Potato cyst nematodes, *Globodera* species on potato

Outbreaks of potato cyst nematodes are reported in most of the potato growing temperate areas of the world and declared as a quarantine pest throughout the world. In India, it was reported from the Nilgiri hills during 1961and triggered the implementation of domestic quarantine in 1971 under the Destructive Insect Pest Act 1914. Under this act movement of potato for seed purposes was restricted realizing the potential threat to potato production and trade [8, 9]. However, recent reports on the presence of potato cyst nematode in some of the potato growing areas in our country have implications of the movement and production of potato. Recently it has been reported from Himachal Pradesh, Uttarakhand and Jammu and Kashmir [10].

Figure 2.
Guava orchard infested with root knot nematode (source: Original photos).

2.4 The emerging nematode problem in mushroom cultivation

Several biotic factors such as fungi, bacteria, nematodes, insects and mites have challenged mushroom cultivation. Among these, mushroom nematodes are the most dreaded ones. Once they get entry into the mushroom houses, it becomes almost impossible to get rid of these worms. Their multiplication is very fast because of very short life cycle (8–10 days). They attack on a variety of fungi, including plant pathogenic ones. They are stylet bearing like other plant parasitic nematodes and have the same feeding mechanism. Nematodes affected mushroom hyphae produced less yield by sucking cell sap. Their presence in mushroom beds is associated with severe losses, often leading to crop failure [11]. Unlike the management practices commonly used for plant parasitic nematodes like crop rotation, summer plowing, use of chemicals' etc., are not applicable here due to the different nature of the crop.

2.5 Nematodes in flowers

Apart from root-knot nematodes and lesion nematodes on various crops, *Aphelenchoides besseyi* has raised as new peril in floriculture. Interestingly, in recent years, as a single flower, tuberose, *Polianthes tuberosa* L. occupies the lion share in the global publications on the nematode problems in flowers. Phenological factors influenced nematode population towards consistent variation with several ups and downs synchronizing with that of the flower production. Heavy infestation at early stages of the plants resulted stunting, hardening of the stalks and spikes and development of the prickle like structures on them.

2.6 Nematode problems in the nursery of horticultural crops

Nematode infested nursery is the important threat in horticultural crops, and most of these crops are raised in the nursery. Infested nursery is the source of dissemination of nematode in the horticultural field. Once the nematodes have introduced in the main field it is impossible to get rid from these worms. Seedling raised in nursery are infested by several nematodes produced in Haryana and other part of the country. Nematodes attack on seedlings form galls and stunted growth are the indicators of nematode damage in nursery (**Figure 3**). *Meloidogyne* spp. (root-knot nematodes) and *Rotylenchulus reniformis* (reniform nematode) are the most damaging nematode among the plant parasitic nematodes in nursery.

2.7 Nematode-pathogen interaction: a real threat

Nematodes associated with other secondary micro-organism increased the losses' manifolds. Phyto parasitic nematodes provide avenues for secondary pathogens viz., fungi, bacteria, viruses, etc. and favor the establishment on host. Nematode alter the host physiology for colonization of secondary microbes. However, nematode

Figure 3.
A. Nematode infestation in the nursery B. guava nursery infested with root knot nematode (source: Original photos).

Figure 4.
Root infested with Meloidogyne *spp. and wilt fungus (source: Original photos).*

themselves are capable of causing significant losses in the crops, their connotation with secondary microbes preponed the disease and compound the damage. The rotting fungi (*Rhizoctonia bataticola*, *R. solani*) and wilt fungus, *Fusarium oxysporum* has been reported in compounding the disease severity by nematode [12]. Combined infection of nematode and fungal pathogens leads to sever rotting and death of plants (**Figure 4**). Sometimes, presence of both pathogens, nematode and secondary pathogens breaks the resistance in resistant cultivars of plants [13].

3. Nematode management in horticultural crops

Aim of nematode management is to reduced crop losses in yield and quality of crops and manage the nematode population below economic threshold level.

4. Preventive measures

4.1 Soil testing for nematode mandatory before establishing polyhouses/net-houses

Soil testing is mandatory for the farmers before erection of the polyhouses, green house, net houses and orchards.

4.2 Nematode-free planting materials

Infested planting material is the foremost important means of spreading of nematodes in horticultural crops. At present, there is no chemical or non-chemical methods are available that resolve the nematode problem in protected cultivation once introduced into the crops. Nematode-free planting material that produced on soilless substrates are increasingly used to exclude soil borne species of nematodes, but also to promote the plant establishment and crop production.

4.3 Hot-water treatment

Hot water treatments was successfully used to manage plant parasitic nematodes spread through planting material in some crops like strawberry, citrus. In this technique temperature and time combination is very important otherwise the planting material may become unfit for transplanting.

5. Curative measures

5.1 Sanitation

Rapid destruction of infested planting material and weeds from the field that can help in minimizing the nematode population and prevent further spread of nematodes. Entry points and equipment used in protected structures should be sanitized. Using clean water also helps in minimizing the further spread of pest.

5.2 Tillage and soil solarization

Soil solarization in the hottest part of the year by using transparent polyethylene plastic (LLDP 25 μm) 6–8-week period after harvesting of the crop are very helpful in reducing nematode population in the soil. A plowed field with moist soil covered with polyethylene sheet help in raising the soil temperature and is lethal for the soil borne pests.

Soil tillage in the months of May–June in northern Indian conditions for two to three times also helps in reducing the nematode populations. Soil solarization or tillage is dependent on hot weather and fallow soil with the crop-free period of 4–6 weeks is necessary which may not be economically feasible to the growers.

5.3 Crop rotation

Continuous monoculture of the susceptible crop has tremendously increased the pest problem including plant parasitic nematodes. In such circumstances, crop rotation with the non-host crop is one of the good options to reduce nematode build up. Popularity of this method depends upon the availability of suitable non-host crop. The length of rotation is however related to the magnitude of the initial nematode population and the rate of population decline during rotation. In protected structures, rotating susceptible crops with poor or non-hosts, trap crops, antagonistic crops or biofumigants such as brassicas, that fetch profit to grower, can be an alternative.

5.4 Resistant variety or grafting on resistant rootstock

Resistant variety or grafted resistant root-stock is one of the convenient methods of nematode management in horticultural crops. In India, still there is no released resistant variety to nematodes in protected conditions. However, in India work is restricted to evaluation of germplasm against plant parasitic nematodes. Grafting of commercially important crop genotypes on nematode resistant rootstocks (eg. scion of commercial tomatoes on wild eggplants root stocks, *Solanum toxicarium*, *S. sisymbriifolium* and *S. torvum*) is an efficient choice for management of *Meloidogyne* spp. in vegetables under protected cultivation system [14]. Susceptible but agronomically desired arabica scion on resistant Robusta root stock of coffee have been effective against *Pratylenchus coffee*.

5.5 Organic amendments

Use of organic amendments is a good option to reduce nematode build up as well increase plant tolerance by raising nutrient status. Both edible and non-edible oil cakes are used for suppressing nematode population in soil. Organic amendments manage the nematode population by release of toxic compounds during decomposition, improve soil fertility increased the plant vigor, tolerance and promoting antagonistic microbial activity.

5.6 Biological control

Recently, bio-agents has paid much attention due to popularity in suppression of nematode population as well as environmentally sound option for management. Bio-agents such as egg parasitic fungi – *Purpureocillium lilacinum*, *Pochonia chlamydosporia*, antagonistic fungus – *Trichoderma viride*, *Trichoderma harzianum*, bacterial parasites – *Pseudomonas fluorescence*, *Pasteuria penetrans* and Mycorrhizal fungus, *Glomus fasciculatum* has to be used in nematode management. Amendments (neem cake, vermicompost or FYM) enriched with bio-agents was found potential for management of plant parasitic nematodes in polyhouses [15].

5.7 Chemical nematicides

New nematicides such as 3-F nematicides that all having Trifluoro group in their molecular structure (fluensulfone, fluopyram, and fluazindolizine) are very effective against plant parasitic nematodes but till now they are not registered for use in many crops in India.

At present, there are no conventional fumigant or non-fumigant nematicides registered for greenhouse use in India. Thus, protected cultivation growers are dependent on other IPM practices such as exclusion, sanitation, nematode resistant plant varieties when available, and other cultural and biological means of nematode management.

6. Integrated nematode management

Pre-plant application of fumigants followed by neem cake fortified with bio-agents suppressed the plant parasitic nematode populations under polyhouses. Nonetheless, integrated nematode management in protected structures have certain limitations such as non-host availability, crop preference, plant parasitic nematode incidence at different geographical locations. Keeping in view of this, suitability of integrated management practices with general farming practices has to be remolded according to local conditions.

7. Conclusions

Farmers/growers neglect the nematode diseases in the crops because of hidden nature and non-diagnostic symptoms produced by nematodes on crops. Plant parasitic nematodes associated with secondary microbes present in the rhizosphere form disease-complexes and increase crop damage. Changes in the cropping system, also changes the nematode community structure and there by nematode problem. A menace of plant parasitic nematodes is increasing day by day under protected conditions, orchards, plantation crops, mushroom houses and field crops.

Clearly, recent research on nematode management in polyhouses has focused primarily on plant parasitic nematode and soil borne fungal pathogens. Nematodes are extremely diverse habitats, ubiquitous and vary enormously in their lifestyles, we shall gain knowledge of nematode behavior and biology of nematode taxa for the comparative approach under more realistic environmental conditions. Thorough knowledge of tolerance, behavioral and sensitivities of nematodes to various environmental extremes is an important for fundamental science and management.

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Conflict of interest

The authors declare no conflict of interest.

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