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Nematode Management in Polyhouse Cultivation

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ABSTRACT: Globally, the area under protected cultivation is 4.05 lakh hectares, while in India it is close to 110,000 hectares after the National Horticulture Mission enacted the promotion of polyhouses and greenhouses. Though the cultivation of crops in polyhouses enhances the yield per unit area, there is a build-up of soil-borne pests and pathogens, especially nematodes. The plant parasitic root-knot (*Meloidogyne incognita*) and reniform (*Rotylenchulus reniformis*) nematodes, once introduced in a polyhouse, multiply to high densities due to the availability of optimum moisture around the root zone, favourable temperatures and uninterrupted food from long duration varieties, enabling the completion of several life cycles. The number of infective juveniles in the soil increases tremendously, from 1–3 J2/cc soil at pre-plant to up to 80 J2/cc soil at crop maturity. Multiple root galls that gradually increase in number and size are predisposed to fungal pathogens like *Rhizoctonia solani*, *Fusarium oxysporum, Macrophomina etc.*; sometimes followed by mortality of plants. *M. incognita* and *M. javanica* are serious constraints to polyhouse vegetables, especially tomato and cucumber causing yield losses of 25–100 per cent. Chemical nematicides like metham sodium and Velum prime (fluopyram) are effective in nematode management. However, they result in an initial decline in nematode densities for 3–4 months and later the residual nematode population in the soil builds-up exponentially. With an increasing awareness of environmental protection and food safety, there is a need to exploit environment-friendly methods of nematode management. Besides the phytosanitary measures which are most important, deep tillage of the soil, use of soil solarization, biocontrol agents, trap crops, organic amendments and grafted cultivars can reduce the pest population below economic threshold levels. The various options have their merits and demerits and therefore managing the nematode pests in polyhouses is challenging and requires awareness, monitoring and regulation.

Keywords: Cultural practices, grafting, *Meloidogyne incognita*, prophylactic and therapeutic measures

Globally, the area under protected cultivation is 5.63 million ha, with China leading, followed by Spain, South Korea and Turkey (Hickman, 2019). In India, the area under polyhouse cultivation has been increasing since 2005 after the National Horticulture Mission enacted the promotion of polyhouses and greenhouses in the country and is presently close to 110,000 ha (Table 1).

The most common crops cultivated in polyhouses include vegetables; mainly, tomato, cucumber, capsicums, green beans, beetroot, eggplant, lettuce, sweet peas, chilli, okra, spinach, spring onion, cabbage and Chinese leek. Among fruits strawberries, muskmelon, watermelon and grapes; and among ornamentals anthuriums, carnations, gerberas, gladioli, roses, chrysanthemums and orchids are common (Singh, 2016). In terms of fruit and vegetable crops under protected cultivation, India ranks seventh in the world with 25,000 hectares while

Table 1. Area under polyhouse cultivation in India

Year	Area (ha)
2005–06	451.82
2006–07	440.47
2007–08	4796.55
2008–09	7086.81
2009–10	–
2010–11	5536.47
2011–12	30,000
2013–23	110,000

Support from NHB, NHM & RKVY

China ranks first with 2,76,000 hectares (Patnaik and Mohanty, 2021).

Cultivation in polyhouses reduces the abiotic stress of temperature and moisture fluctuations seen in open fields and optimises profits. It enhances the yield and profit per unit area substantially (Table 2). However, there is a build-up of soil-borne pests and pathogens, especially nematodes due to - a) continuous availability of food, b) favourable temperature and moisture, c)

Table 2. Cost-benefit ratio of vegetable crops under polyhouse cultivation

Crop	Variety	Spacing (cm)	Crop duration (months)	Total Production (kg/1000 m²)	Estimated Sale Price (Rs/kg) Farmer	Market	Cost of cultivation (Rs)*	Total income (Rs)*	Net profit (Rs)*
Gherkin	DG-6	50 × 50	4	2300	30	50-60	25500	69000	43500
Cherry tomato	Cherry Red Cherry Yellow	60×50	4	2000	30	80-100	26250	60000	33750
Bitter gourd	Gynoecious	60 × 50	4	2000	25	50-60	26250	50000	23750
Cucumber	Parthenocarpic	50 × 50	4	2000	25	40-50	25500	62500	37000

*Second year onwards profit: Gherkin: Rs.59,000; Cherry tomato: Rs.50,000; Bitter gourd: Rs.40,000; Cucumber: Rs.52,500. The crops were raised for 4–5 months duration under polyhouses. However, with the same structure other crops can also be grown by utilizing different types of cladding material like shade net *etc.* (**Source:** Division of Vegetable Science, IARI, New Delhi, India)

Fig. 1. ***Meloidogyne incognita*** **infestation in different crops in polyhouse**
Top left: Symptomless plants in September, Top middle: Galling observed in March, Top right: Roots of muskmelon, Bottom left: Adult females in 1 cm tomato roots, Bottom middle: Predisposition to *Fusarium* in tomato, Bottom right: Nematode problem in gerbera

narrow genetic diversity with little or no crop rotation, d) optimum growth inputs, and e) little or no natural enemies. Among the nematode pests, the root-knot nematode (*Meloidogyne incognita* and *M. javanica*), reniform (*Rotylenchulus reniformis*) and *Pratylenchus* spp. are the most common (Fig. 1). These nematodes once introduced, multiply to densities much above the economic threshold levels due to completion of several life cycles in a crop season. The number of infective juveniles of *M. incognita* and *M. javanica* in the soil may range from 1–3 J2/cc soil at pre-plant to up to 80 J2/cc soil at crop maturity (Kamra *et al.*, unpublished). Root galls gradually increase in numbers and size and are predisposed to fungal pathogens like *Rhizoctonia solani*, *Fusarium oxysporum, Macrophomina*, *Thielaviopsis etc*.; and bacterial wilt pathogen, *Ralstonia solanacearum*. The yield losses in tomato and cucumber range from 25–100 per cent.

The various management options include prophylactic and therapeutic.

PROPHYLACTIC MEASURES

It is essential to examine the soil and nursery before planting for the presence of the nematodes and adopt therapeutic measures if required. The seedlings should be carefully examined by a nematologist; as once seedlings from infected nursery are transplanted in the main field, it becomes difficult to manage. In Haryana, a certification for nematode-free soil is essential before constructing a new polyhouse (Sabir and Walia, 2017).

Secondly, periodic dehumidification by venting or the use of fine meshes on the side walls of constructed structures reduces the relative humidity inside a polyhouse and abates the risk of foliar pathogens. The poorly drained zones if prevalent inside a polyhouse can be treated using straw mulches near the root zone (Bruce *et al*., 2019).

Thirdly, periodic removal of weeds (either mechanically or by herbicide spraying) is essential because several weeds, belonging to families Amaranthaceae, Chenopodiaceae, Asteraceae, Malvaceae, Poaceae, and Polygonaceae, act as excellent hosts for nematode perpetuation in polyhouses.

THERAPEUTIC MEASURES

A list of various chemical and non-chemical methods adopted in polyhouse crops in different countries is available in Phani *et al.* (2021).

Chemical nematicides

Various chemical fumigant nematicides like methyl bromide, metham sodium, 1,3 dichloropropene and chloropicrin, and non fumigants like carbofuran, cadusafos, dazomet, fenamiphos and oxamyl have been used to manage nematodes in polyhouses (Sorribas *et al*., 2020). New nematicides like fluensulfone (Nimitz 2% GR®), fluopyram (Velum Prime® 34.48% SC) and fluazaindolizine (Salibro®) have come in the market recently. The chemical nematicides are effective in nematode management, but they are biocidal in action; kill the target nematodes and also cause significant changes in soil microbiome (Lloyd *et al*. 2023). Besides, after an initial decline in nematode densities for 3–4 months, the residual nematode population in the soil

Fig. 2. Pre-treatment of polyhouse with metham sodium

builds-up exponentially. All precautionary measures like wearing gloves and masks by the applicators and covering the soil with polythene for at least two weeks after application of fumigant nematicides like metham sodium should be adopted (Fig. 2).

Use of biological agents

Several biocontrol fungi like *Purpureocillium lilacinum, Pochonia chlamydosporia, Trichoderma* spp., *Streptomyces griseoviridis etc.*, and bacteria like *Pseudomonas fluorescens*, *P. putida, Serratia marcescens, Bacillus amyloliquifasciens, B. subtilis* and *B. cereus* have been used in polyhouse cultivation. However, there is a need to exploit the local soil microbiome for nematode suppression (Zhou *et al.*, 2019; Kumar and Dubey, 2020). Polyhouse tomato plants that showed significantly reduced nematode infection in a root-knot infested soil were used for isolation of rhizobacteria (*Bacillus* spp.), which when multiplied and used for pre-plant application reduced gall index and reproduction factor of the nematode besides activating the defence response by enhancing the expression of genes and enzymes governing resistance (Devindrappa *et al.*, 2022, 2023).

Though several biocontrol agents are recommended for root-knot management in polyhouses, the time and frequency of their application are not always mentioned. As most varieties cultivated in polyhouses are long duration (4–6 months) and indeterminate type, the application of biocontrol agents can be repeated at about 45 days in the presence of high nematode densities to achieve the desired results. Also, the quality of the biopesticide if purchased from the market should be tested in the lab, before recommending its application.

Use of grafting

Commercially important genotypes with nematode resistant rootstocks have been developed for managing root-knot nematode in polyhouses (Phani *et al.*, 2024). In tomato, the rootstocks of *Solanum torvum, S. sisymbrifolium, S. toxicarium, S. macrocarpon,* and *S. aethiopicum* have been used; in watermelon, the rootstocks of bottle gourd, interspecific hybrids of *Cucurbita maxima* and *C. moschata*, and wild watermelon (*Citrullus amarus*); for cucumber, a variety of genetic bases like *Cucumis* spp., *Cucurbita* spp., *Cucurbita* interspecific hybrids, bottle gourd, wax gourd, Luffa, and figleaf gourd (*Cucurbita facifolia*) have been used. *Cucumis pustulatus* and *Cucumis metuliferus* rootstocks for watermelon, melon, and cucumber scions provide promising protection against *M. incognita*. In India, vegetable grafting at ICAR Indian Institute of Vegetable Research, Varanasi is being conducted since 2013 to select the best rootstocks for root-knot nematode resistance, soil-borne diseases, and waterlogging tolerance. Successful field trials of Pomato (tomato scion grafted on potato rootstock) and Brimato (both eggplant and tomato grafted on an eggplant rootstock) during 2020–2021 resulted in the initiation of their commercial production (ICAR newsletter; https://icar.org.in/).The International Crops Research Institute for the Semi Arid Tropics (ICRISAT, Hyderabad) assisted more than 400 farmers and stakeholders in Andhra Pradesh to obtain 30–50 per cent higher yields in grafted vegetables, compared to the non-grafted traditional varieties (ICRISAT happenings newsletter; https://www.icrisat.org/). However, the grafted vegetables if introduced frequently may alter the nematode and soil microbiome community leading to the evolution of new nematode biotypes and emergence of certain other pests and pathogens affecting the scion, in response to selective pressures. As a precautionary measure, rotation of rootstocks among different species should be introduced. Grafting is effective for nematode pest management; however, it needs expertise and unless done mechanically, is not cost-effective.

Use of cultural practices

Deep tillage disturbs the established nematode community, but may not eradicate the surviving population (Lenz and Eisenbeis, 2000). Solarizing the soil after light irrigation using thin transparent sheets of 25–30 μm thickness for at least four weeks prior to planting increases the soil temperature by 5–10°C. This technique is highly effective in hot summer months. However, the disposal of the polythene sheets is challenging problem. Use of organic amendments like green manure, poultry and cattle manure, and oilseed cakes cause a suppressive effect on nematodes at the rate of 20 tons per ha, however, sometimes it is not easily available in the market.

The use of trap plants reduces the population densities of *Meloidogyne* spp. in rotation systems. Keeping a crop that is highly susceptible to *Meloidogyne* species in the soil for a short period, from which a large number of larvae are extracted together with the entire root system of the plants, can help reduce populations of these nematodes before they begin to transform into adult and reproductive females (Samara, 2022). For example, the use of lettuce and radish as trap plants, manage to reduce the populations of *M. incognita*. However, this management tactic is to be used with caution, so that the infected roots are extracted in their entirety and incinerated outside the cultivation area.

Even though most of the measures mentioned above have demonstrated their effectiveness in reducing nematode densities, to achieve populations of gall forming nematodes below the damage threshold in a sustainable manner over time, it is important to integrate the possible options intelligently, bearing in mind the factors like economic value of the crop, abiotic factors and acceptability to the producer.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Bruce, A.B., Maynard, E.T. & Farmer, J.R. (2019). Farmers perspectives on challenges and opportunities associated with using high tunnels for specialty crops. *Horticultural Technology* **29:** 290–299.

Devindrappa, M., Kamra, A., Grover, M. & Gawade, B. (2022). Nematicidal rhizobacteria with plant growth-promoting traits associated with tomato in root-knot infested polyhouses. *Egyptian Journal of Biological Pest Control* **32:** 51. https://doi.org/10.1186/s41938-022-00539-1

Devindrappa, M., Kamra, A., Singh, D., Gawade, B. & Sirohi, A. (2023). Plant growth promoting *Bacillus* species elicit defense against infecting tomato in polyhouse. *Journal of Basic Microbiology*. https://doi.org/10.1002/jobm.202300146

Hickman (2019). *World greenhouse vegetable statistics - 2019 Updates*. Cuesta Roble Consulting Press, Mariposa, CA. www.cuestaroble.com

Kumar, A. & Dubey, A. (2020). Rhizosphere microbiome: Engineering bacterial competitiveness for enhancing crop production. *Journal of Advanced Research* **24:** 337–352.

Lenz, R. & Eisenbeis, G. (2000). Short-term effects of different tillage in a sustainable farming system on nematode community structure. *Biology and Fertility of Soils* **31:** 237–244.

Lloyd A.W., Percival, D., Morgan, G.I., Langille & Svetland N.Y. (2023). Changes to soil microbiome resulting from synergetic effects of fungistatic compounds pyrimethanil and fluopyram in lowbush blueberry agriculture, with nine fungicide products tested. *Microorganisms* **11:** 410. https://doi.org/10.3390/microorganisms11020410

Patnaik, R.K. & Mohanty, S. (2021). Protected cultivation**:** importance, scope and status. *Food and Scientific Reports* **2:** 19–21.

Phani, V., Gowda, M.T. & Dutta, T.K. (2024). Grafting vegetable crops to manage plant-parasitic nematodes: A review. *Journal of Pest Science* **97:** 539–560.

Phani, V., Khan, M.R. & Dutta, T.K. (2021). Plant-parasitic nematodes as a potential threat to protected agriculture: Current status and management options. *Crop Protection* **144:** 105573.

Sabir, N. & Walia, R.K. (2017). *Management of nematodes in protected cultivation with short notes on key pests*. Project Coordinating Cell, All India Coordinated Research Project on Nematodes in Cropping Systems, 24 pp.

Samara, R. (2022). Evaluation of eleven potential trap crops for root-knot nematode (RKN) control under glasshouse conditions. *Journal Open Agriculture*. https://doi.org/10.1515/opag-2022-0074

Singh, B. (2016). *New age protected cultivation* (E-magazine). Indian Society of Protected Cultivation, New Delhi publication, **2:** 57.

Sorribas, F.J., Djian-Caporalino, C. & Mateille, T. (2020). Nematodes. In: Gullino, M.L., Albajes, R. & Nicot, P.C. (eds.), *Integrated pest and disease management in greenhouse crops*. Springer International Publishing, pp. 147–174. https://doi.org/10.1007/978-3-030-22304-5_5

Zhou, D., Feng, H., Schuelke, T., De Santiago, A., Zhang, Q., Zhang, J., Luo, C. & Wei, L. (2019). Rhizosphere microbiomes from root knot nematode non infested plants suppress nematode infection. *Microbial Ecology* **78:** 470–481.