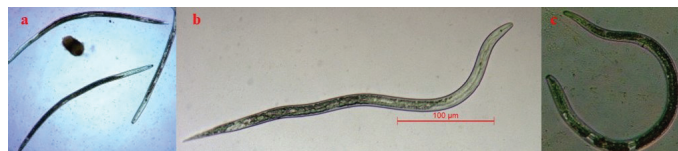


Management of plant-parasitic nematodes in spice crops

India's spice sector, spread over 4.31 million ha, faces significant yield losses due to plant-parasitic nematodes (PPNs) such as *Radopholus similis*, *Meloidogyne* spp., *Pratylenchus* spp., and *Rotylenchulus reniformis*. These nematodes impair root systems, reduce nutrient uptake, and promote secondary infections, causing yield losses of 29–64% in key crops like black pepper, turmeric, ginger, and cardamom. This Paper highlights the major nematode pests affecting spice crops, their damage symptoms, and the resulting disease complexes. Effective management of PPNs requires an integrated approach combining preventive, cultural, biological, physical, and chemical strategies. Adoption of Integrated Nematode Management (INM) practices is essential to ensure sustainable production, export quality, and long-term resilience in India's spice cultivation systems.

INDIA, known as the 'Land of spices', cultivates spices across 4.31 million ha with a production of 11.83 million tonnes (2022–23). Key spice crops—black pepper, turmeric, ginger, and cardamom—account for a significant share of this, both in area (8.81 lakh ha) and export value (USD 4.41 billion). However, production is severely affected by plant-parasitic nematodes (PPNs), especially *Radopholus similis* (burrowing), *Meloidogyne* spp. (root-knot), *Pratylenchus* spp. (lesion), and *Rotylenchulus reniformis* (reniform), which collectively cause yield losses ranging from 29 to 64% depending on the crop. These nematodes damage root systems, impair nutrient uptake, promote secondary infections, and lead to complex disease syndromes, necessitating comprehensive management for sustainable spice cultivation.

Major nematode parasites in spice crops



Major plant-parasitic nematodes associated with spice crops

- Burrowing nematode (*Radopholus similis*),
- Root-knot nematode (*Meloidogyne incognita*), and
- Lesion nematode (*Pratylenchus coffeae*)

Radopholus similis (Burrowing nematode)

Black pepper: *R. similis* is the primary agent of 'slow wilt' or 'yellows disease', first identified in Indonesia and later in Indian pepper plantations. It causes progressive yellowing, leaf shedding, dieback, and eventually death of the vine. Root lesions and rotting feeder roots are characteristic. The disease may mimic water stress but

leads to complete vine loss in 3–5 years.

Ginger and turmeric: In ginger, *R. similis* causes small brown lesions and rhizome rot, leading to chlorosis and plant stunting. In turmeric, it contributes to poor rhizome formation and secondary infections.



Damage symptom of *Radopholus similis* in black and pepper, a) Pepper vines expressing 'slow wilt' symptom, and b) Roots with lesions

Meloidogyne spp. (Root-knot nematodes)

Black Pepper: *M. incognita* and *M. javanica* induce galling on roots, resulting in yellowing, stunted growth, and reduced yield. These nematodes are active year-round, with population peaks in April–May and build-up during September–October.

Turmeric: Root galling, chlorosis, desiccated leaves, and poor rhizome development are common. Infected plants often show patchy wilting and reduced pigmentation in rhizomes, lowering market quality.

Ginger: Leads to galling and decay of root systems. Infected rhizomes show internal browning, water-soaking, and rot, with foliar yellowing and early drying.

Cardamom: Causes stunted growth, poor tillering, and marginal leaf necrosis. While mature plants may not show root galls, young seedlings are highly susceptible.

In nurseries, *M. incognita* hampers seedling emergence and establishment, resulting in up to 40–50% seedling mortality.



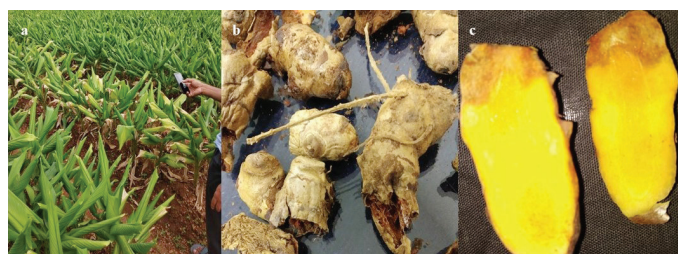
Root-knot nematode damage symptom in the roots of, a) Black pepper, b) Ginger, and c) Turmeric

Pratylenchus spp. (Lesion Nematodes)

Ginger: Causes ‘ginger yellows’, with yellowing leaves, necrotic lesions on rhizomes, and stunted plants. *P. coffeae* also facilitates fungal infections, such as *Pythium* and *Fusarium*.

Turmeric: *Pratylenchus coffeae* is a growing concern in major turmeric-producing states. It produces brown lesions and rhizome rot, often misdiagnosed as nutrient deficiency. Infected rhizomes are dry, wrinkled, and discolored internally.

Cardamom: Contributes to root rot and poor plant health, especially in conjunction with *Meloidogyne* spp.



Damage symptom caused by lesion nematode *Pratylenchus coffeae* in turmeric,

a) Foliar symptom under field condition,
b) Severely infected rhizomes, and

c) Cross-section of damaged rhizomes with brown lesions

Disease complexes and secondary infections

PPN infestations frequently lead to disease complexes with soil-borne pathogens. For instance:

Black pepper: Co-infections with *Phytophthora capsici* or other fungal pathogens exacerbate symptoms and increase vine or plant mortality.

Ginger: *Meloidogyne* spp. predispose plants to bacterial wilt (*Ralstonia solanacearum*) and fungal infections, intensifying rot and collapse.

Turmeric: *Pratylenchus* spp. associated with *Pythium aphanidermatum* causes rhizome rot.

Remedies and management strategies

Spices are valuable export potential crops, and keeping them free of nematodes is essential, not only for a

healthy harvest but also for eco-friendly farming practices. Since people often eat spices like ginger in a raw form, managing these pests with minimal chemical use is very important. Managing nematodes in spice crops requires an integrated approach combining cultural, biological, and chemical control methods.

Preventive measures

Prevention is better than cure, the nematode infestation can be prevented by adopting following practices such as:

- Soil testing at regular intervals to determine the presence of nematodes in the soil
- Planting nematode-free rhizomes
- Adopting crop rotation for 3-4 seasons with non-host crops
- Wash off soil from farm tools and disinfect.
- Solarize the soil by ploughing field, moisten soil and cover using plastic sheet for 4-6 weeks during summer

Cultural practices

- **Crop rotation:** Avoid planting spices like ginger, turmeric in the same field consecutively; rotate with non-host crops like maize or sorghum.
- **Soil solarization:** Covering soil with transparent plastic sheets during peak summer kills nematodes and soil-borne pathogens.
- **Use of healthy seed rhizomes:** Always plant certified, disease-free rhizomes to prevent nematode introduction.
- **Mulching:** Applying green leaves or organic matter improves soil health and reduces nematode populations.

Physical control

- **Hot water treatment:** It provide an eco-friendly solution. Studies have shown that dipping seed rhizomes of ginger, turmeric in water heated to about 51°C for around 10 minutes can significantly reduce nematode populations. Other approaches have involved longer treatments at slightly lower temperatures to disinfect the rhizomes. These methods help to kill the nematodes without relying on harsh chemicals.

Biological control

- Beneficial microbes like *Trichoderma* and *Pseudomonas* spp., can suppress nematode populations.
- Nematode-trapping fungi such as *Paecilomyces lilacinus* have shown effectiveness in reducing *Meloidogyne* infections.
- Use of *P. chlamydosporia* (@20 g/bed with 10⁶ cfu/g) suppresses root-knot nematodes
- Neem cake and other organic amendments enhance soil microbial activity and reduce nematode impact.

Exploring host plant resistance

- **Use of resistant or tolerant varieties:** Exploring the host plant resistance is a conventional eco-friendly approach where resistant/tolerant varieties or cultivars can be used as an option to overcome plant-parasitic

nematode problem. Few of the released varieties released by ICAR-IISR found to have resistant/tolerant to PPN. For example, in black pepper (*IISR Pournami* tolerant to tolerant to *Meloidogyne incognita*), in ginger (*IISR Mahima* – resistant to *Meloidogyne incognita*), in turmeric (*IISR Pragati* is moderately resistant to *Meloidogyne incognita*). Further screening of accessions in NAGS may provide promising results on HPR exploration.

Chemical control

- Nematicides like carbofuran and carbosulfan can help control severe infestations but should be used cautiously due to environmental concerns
- Experimental evidences proves that newer molecules such as Nimitz® (fluensulfone), Velum® Prime (fluopyram) are showing promising results
- Application of fluopyram 34.48 SC (Velum® Prime) @ 500 g a.i. /ha or application of carbofuran 3 CG @1 kg a.i. /ha or fluensulfone 2% GR @ 512 g a.i. /ha can effectively control nematodes

CONCLUSION

Plant-parasitic nematodes, especially *Meloidogyne incognita*, *Radopholus similis*, and *Pratylenchus coffeae*, significantly undermine the productivity and quality of major spice crops. Their direct damage and synergistic interactions with other pathogens contribute to major crop losses and economic setbacks in spice export. Early diagnosis, awareness of symptomatology, and adoption of Integrated Nematode Management (INM) practices are vital which include, use of nematode-free planting material, crop rotation and soil solarization, biological control agents, and resistant varieties. A holistic, region-specific approach is essential for safeguarding India's spice sector and sustaining its global leadership in spice exports.

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SUSTAINABLE DEVELOPMENT GOALS RELATED TO FRUITS AND VEGETABLES



SDGs 2 3

Health benefits of fruit and vegetables
Harness the goodness

Fruit and vegetables have multiple health benefits. They strengthen the immune system, combat malnutrition and help prevent non-communicable diseases.



SDGs 2 3

Diversified diet and a healthy lifestyle
Live by it, a diverse diet

Adequate amounts of fruit and vegetables should be consumed daily as part of a diversified and healthy diet.



SDGs 2 3

Food loss and waste
Respect food from farm to table

Fruit and vegetables are worth more than their price. Maintaining their quality and assuring their safety across the supply chain, from production to consumption, reduces losses and waste and increases their availability for consumption.



SDGs 2 3

Innovate, cultivate, reduce food loss and waste

Innovation, improved technologies and infrastructure are critical to increase the



SDGs 2 8 12 13 14 15

Highlighting the role of family farmers
Growing prosperity

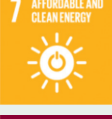
Cultivating fruit and vegetables contributes to a better quality of life for family farmers and their communities. It generates income, creates livelihoods, improves food security and nutrition, and enhances resilience through sustainably managed local resources and increased agrobiodiversity.



SDGs 1 2 3 4 5 8 11 12 15

Sustainable value chains
Foster sustainability

Sustainable and inclusive value chains can help increase production, and help to enhance the availability, safety, affordability and equitable access to fruit and vegetables to foster economic, social, and environmental sustainability.



SDGs 1 2 3 4 5 8 11 12 15

Efficiency and productivity within fruit and vegetable supply chains to reduce loss and waste.



SDGs 1 2 3 4 5 8 11 12 15

Source: Fruit and vegetables – your dietary essentials, FAO background paper, FAO, Rome



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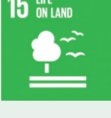
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