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Integrated Approaches for Management of Root-Knot Nematode (*Meloidogyne* Spp.) in Vegetable Production

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Abstract: -

Root-Knot Nematodes (RKNs), belonging to the genus *Meloidogyne*, represent one of the most pervasive and destructive pathogens affecting vegetable production across India. These microscopic, soil-borne worms attack the root systems of a wide range of crops, including tomato, brinjal, okra, cucumber and chilli, leading to significant yield losses often underestimated or misdiagnosed by farmers. This article provides a comprehensive overview of the problem, its symptoms, Economic impact and a holistic Integrated Nematode Management (INM) strategy tailored for the diverse agro-climatic regions in India.

Keywords: *Meloidogyne*, Symptoms, Life-cycle and INM.

Introduction:

In India, vegetable cultivation is a vital component of agriculture, contributing significantly to nutrition security and farmers' income. However, this intensive cultivation, often with mono-cropping and under protected environments, has exacerbated pest and disease issues. Among these, RKN (*Meloidogyne* spp.) infestation is a prime concern. It is estimated that nematodes cause annual crop losses of approximately 10-15% and if in severe infestation of nematode, it goes upto 30-60% crop loss, translating to billions of rupees in lost revenue.

The Pathogen (Nematode-*Meloidogyne* spp.) RKNs are microscopic, soil-dwelling roundworms that infect plant roots, causing the formation of characteristic swellings called galls or "root knots." They are among the most destructive plant parasites worldwide, especially in vegetable crops,

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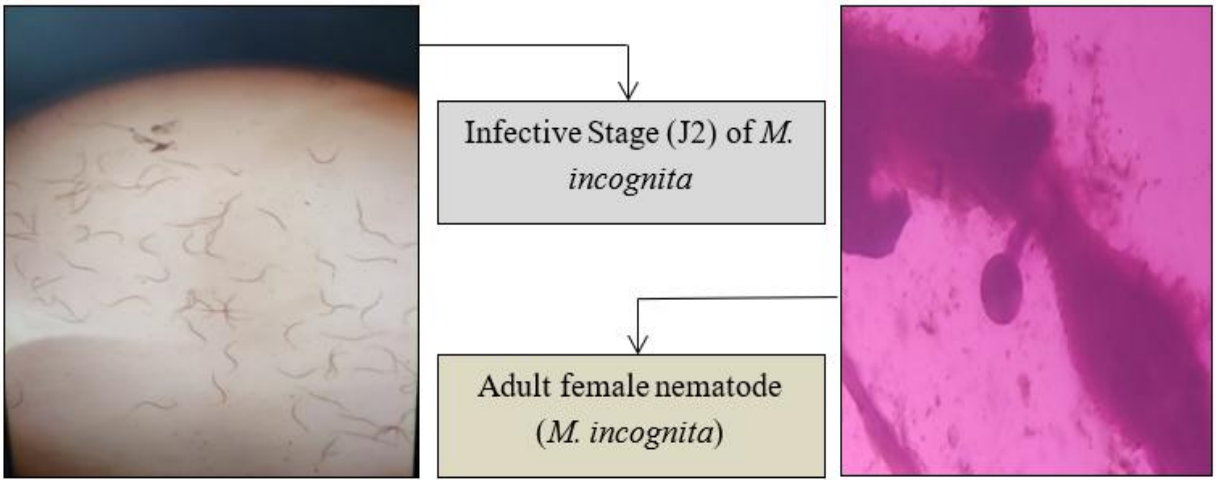
reducing plant growth and yield by disrupting water and nutrient uptake. Their wide host range and rapid life cycle make them a significant challenge for farmers and gardeners. The most common species devastating Indian vegetables are *M. incognita* (the Southern root-knot nematode), *M. javanica* and *M. arenaria*. The life cycle, completed in about 3-4 weeks under optimal conditions (25-30°C), is key to its success as a pest.



Economic impact - A perusal of data presents in table reveals that economic loss in vegetable crops

Root-knot nematodes	Host vegetables	Loss
M. incognita	Ivy gourd	35.09 %
***M.* spp.**	Radish	8-20 %
***M.* spp.**	Chilli	8-23%
M. incognita	Pointed gourd	44%
***M.* spp.**	Okra	480 million/annually
M. incognita	Cucumber	66.84%
***M.* spp.**	Sponge gourd	547.5 billion/annually

Jain *et al.*, 2007 and Gowda *et al.*, 2017

Symptoms of Damage

- **Below Ground (Root Symptoms)**
  - Galls/Knots- The most characteristic symptom, these are swollen, tumour-like growths on the roots of varying sizes.
  - Root Rot- Severe infestation (Bacteria, Fungus and Virus) leads to decay and rotting of the galled roots.
- Above Ground (Plant Symptoms)
  - Stunting- Patches of stunted, slow-growing plants in the field
  - Yellowing (Chlorosis)- Yellowing of leaves, resembling nutrient deficiency

- Wilting- Plants wilt easily during hot days despite sufficient soil moisture
- Yield Loss- Reduced fruit size, number and quality, often leading to premature plant death.

Healthy root system of Tomato

Infected root system of Tomato

Integrated nematode management (INM) strategies

A combination of cultural, biological, resistant varieties and chemical tactics is essential (Khan and Siddiqui *et al.*, 2020).

Cultural and physical control

- **Crop rotation:** Rotate non-host or poor-host crops (Marigold- *Tagetes* spp., mustard, sesame, maize, sorghum) with susceptible vegetables. Marigold roots release alpha-terthienyl, which is nematotoxic.
- **Soil solarization:** A highly effective method for warmer regions. During the hottest months (April-June), moist soil is covered with transparent polyethylene sheets (100-200 gauge) for 4-6 weeks. This uses solar energy to heat the soil, killing nematodes and other pests.
- **Sanitation:** Remove and destroy infected plant roots after harvest to reduce inoculum levels.
- **Organic amendments:** Application of organic matter like compost, neem cake, mustard cake, poultry manure and green manure (*Sesbania*) improves soil health and encourages antagonistic microorganisms. Their decomposition releases compounds like ammonia that are toxic to nematodes.
- **Fallowing and flooding:** Where feasible, leaving land fallow or flooding it for an extended period can reduce nematode populations.

Biological control (commercial bio-agents)

- **Fungi:** *Purpureocillium lilacinus*, *Pochonia chlamydosporia* – parasitize nematode eggs and females.

- **Bacteria:** *Pasteuria penetrans* – a parasitic bacterium that attaches and kills J2s.
- **Predatory fungi:** *Arthrobotrys* spp. – trap and consume nematodes.
- **Application:** Products based on these agents (eg. *P. lilacinus* formulations) are available in the market and should be applied to the soil at the time of sowing or planting as per label instructions.

Chemical control (Nematicides)- Chemical control should be a last resort due to high cost, environmental concerns and residue issues, especially in vegetables.

- **Soil application** – Carbofuran (Furadon 3G) @0.3 gm a.i./m^2 and with carbosulfan 25EC @500 ppm.
- **Nursery bed treatment at the time of sowing** - Sebuphos (Rugby 20WP) or carbofuran (Furadon 3G) or benfurocarb (Oncol 50WP) @ 0.3 or 0.6 gm a.i./m^2 .
- **Bare-root dip treatment**- Oxamyl, prophos and dinematize @ 500-1000 ppm for 6 hrs, Zolone (Phosalone 35EC) or monocrotophos (Monocil 36SL) or carbosulfan (Marshal 25ST or DS) @ 0.05%.

Use of resistant/tolerant varieties- This is one of the most economical and effective strategies. Plant breeders have developed varieties with resistance to specific RKN species.

Sr. No.	Vegetable	Resistance Variety
1	Tomato	SL-120, Hisar Lalit
2	Brinjal	Black Beauty
3	Chilli	Pusa Jwala, Mohini, Red Wonder
4	Cowpea	Barasati Mutant, IHR- 29-5
5	Pea	B-58, C-50
6	Potato	Kufri Dewa
7	Okra	Harichickni, Vaishali Badher
8	Pumpkin	Dasta, Jaipuri
9	Watermelon	Shahjapuri
10	Ridge gourd	Panipati, Merrut special

Khan *et al.*, (2015)

Conclusion

The management of root-knot nematodes in Indian vegetable crops does not rely on a single solution but requires the adoption of a consistent and integrated approach. By combining cultural practices like solarization and crop rotation with the bolstering of soil organic matter, the introduction of bio-agents and the adoption of resistant varieties, farmers can effectively manage this hidden enemy (Nematodes). This shift from reactive chemical use to proactive INM is crucial for ensuring the sustainability, productivity and profitability of India's vital vegetable sector.

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