

4. Understanding the Role of Nematodes in Plant Health

Ektedar^{1*}, Chaudhry Shadan², Prakriti shree³, Ayush kumar³

¹M. Sc (Ag) Plant Pathology, Department of Plant Protection, Ch. Charan Singh University, Meerut- 250 004 Uttar Pradesh,

²M. Sc Agricultural Entomology Department of Plant Protection, Ch. Charan Singh University, Meerut- 250 004 Uttar Pradesh,

³B. Sc (Agriculture) Hons, Vishveshwarya Group of Institutions, Gautam Budh Nagar - 201314 Uttar Pradesh.

Introduction

Nematodes are microscopic, worm-like organisms that inhabit a wide range of ecosystems, including agricultural soils. They are among the most abundant multicellular organisms on Earth, with an estimated one million individuals per square meter of soil in fertile fields. In agriculture, nematodes are often viewed negatively due to their destructive impact as plant parasites. However, nematodes also include numerous beneficial species that contribute to nutrient cycling, microbial regulation, and biological pest control.

For farmers, agronomists, and agricultural students, understanding the dual role of nematodes—as both plant pathogens and essential soil ecosystem regulators—is crucial. Such knowledge allows for the development of integrated soil and crop management strategies that suppress harmful species while promoting beneficial ones.

Classification of Nematodes in Agriculture

Nematodes affecting plant health can be broadly categorised based on their feeding habits and ecological roles:

1. **Plant-parasitic nematodes (PPNs):** These directly attack plant roots or above-ground tissues.
2. **Free-living nematodes:** Non-parasitic nematodes that feed on bacteria, fungi, and other soil organisms, contributing to soil fertility.
3. **Predatory nematodes:** Feed on other nematodes and small invertebrates, regulating soil populations.
4. **Entomopathogenic nematodes (EPNs):** Attack and kill insect pests, making them valuable biological control agents.

Table 1. Major groups of nematodes and their functions

Nematode Group	Feeding Mode	Role in Agriculture
Plant-parasitic nematodes	Plant roots/shoots	Cause crop damage, yield loss

Free-living nematodes	Bacteria, fungi	Nutrient cycling, soil fertility
Predatory nematodes	Other nematodes	Biological regulation of nematode populations
Entomopathogenic nematodes	Insects	Biocontrol of insect pests

Plant-Parasitic Nematodes: Threats to Crops

Plant-parasitic nematodes (PPNs) are responsible for significant yield losses globally, estimated at \$80–100 billion annually. They damage plants by piercing root or shoot cells with a stylet (spear-like mouthpart) and extracting nutrients.

Major types of PPNs:

- **Root-knot nematodes (*Meloidogyne* spp.):** Induce galls on roots, interfering with water and nutrient uptake. They affect vegetables, cereals, and fruit crops.
- **Cyst nematodes (*Heterodera* and *Globodera* spp.):** Form cysts containing eggs, which persist in soil for years, posing long-term management challenges.
- **Lesion nematodes (*Pratylenchus* spp.):** Cause necrotic lesions in roots, predisposing plants to fungal and bacterial infections.
- **Stem and bulb nematodes (*Ditylenchus* spp.):** Attack above-

ground plant parts such as onion bulbs and garlic stems.

Symptoms in crops:

- Stunted growth and chlorosis due to impaired nutrient uptake.
- Root galling, necrosis, or rotting.
- Increased susceptibility to secondary pathogens.
- Uneven patches of poor growth in fields.

Table 2. Examples of important plant-parasitic nematodes

Nematode Species	Host Crops	Symptoms/Impact
<i>Meloidogyne incognita</i>	Tomato, cotton, soybean	Root galls, reduced yield
<i>Heterodera glycines</i>	Soybean	Yellowing, stunting, cysts
<i>Globodera rostochiensis</i>	Potato	Root damage, severe yield loss
<i>Pratylenchus penetrans</i>	Carrot, corn, wheat	Root lesions, predisposition to rot
<i>Ditylenchus dipsaci</i>	Onion, garlic	Bulb swelling, tissue softening

Beneficial Nematodes and Soil Health

Not all nematodes are harmful. Many contribute to soil fertility and plant health through indirect mechanisms:

1. **Free-living nematodes** decompose organic matter by feeding on bacteria and fungi. This releases nutrients in plant-available forms, enhancing crop growth.

2. **Predatory nematodes** regulate populations of plant-parasitic nematodes, reducing crop damage.
3. **Entomopathogenic nematodes (EPNs)** such as *Steinernema* and *Heterorhabditis* species are valuable in biological control. They release symbiotic bacteria (*Xenorhabdus* and *Photorhabdus*) into insect hosts, killing pests like cutworms, grubs, and borers within 48 hours.

Table 3. Beneficial nematodes and their contributions

Beneficial Nematode Type	Contribution to Agriculture
Free-living (bacterivores, fungivores)	Enhance soil nutrient cycling and structure
Predatory nematodes	Reduce harmful nematode populations.
Entomopathogenic nematodes	Biological control of soil-dwelling insects

Case Studies in Nematode-Plant Interactions

1. Root-Knot Nematodes in Vegetable Production

In tropical vegetable farms, *Meloidogyne incognita* has been shown to reduce tomato yields by up to 50%. Farmers traditionally relied on nematicides, but integrated methods (crop rotation with non-hosts, soil solarisation, resistant varieties, and biocontrol agents such as *Paecilomyces lilacinus*) have proven effective in reducing nematode pressure.

2. Soybean Cyst Nematode (*Heterodera glycines*)

This nematode is the most damaging pest of soybeans worldwide. Resistant cultivars and crop rotation with non-host crops (maize, wheat) are the main management practices. Molecular diagnostics have improved early detection, helping prevent severe infections.

3. Entomopathogenic Nematodes in Pest Control

Steinernema carpocapsae has been successfully applied in citrus orchards to control citrus root weevil. Similarly, *Heterorhabditis bacteriophora* is used against white grubs in turfgrass and maize. These examples highlight the potential of nematodes as commercial biopesticides.

Table 4. Case studies of nematode interactions

Case Study	Nematode Species	Host Crop/Pest	Management/Outcome
Vegetable production	<i>M. incognita</i>	Tomato	Rotation + resistant varieties improved yields
Soybean production	<i>H. glycines</i>	Soybean	Resistant cultivars + rotation
Citrus orchards	<i>S. carpocapsae</i>	Citrus root weevil	Biological control success
Turfgrass /maize	<i>H. bacteriophora</i>	White grubs	Effective pest suppression

Management Strategies for Farmers

Managing nematodes requires integrated approaches that combine cultural, biological, and chemical methods:

- **Crop rotation:** Planting non-host crops to break nematode life cycles.
- **Resistant varieties:** Breeding and deploying cultivars resistant to cyst and root-knot nematodes.
- **Organic amendments:** Compost, manure, and biofumigant crops (e.g., mustard, marigold) can suppress nematode populations.
- **Biological control:** Application of nematophagous fungi (*Paecilomyces*, *Trichoderma*) and EPNs.
- **Chemical nematicides:** Still used in high-value crops but increasingly restricted due to environmental concerns.

Future Directions and Research

Research is advancing towards more sustainable and precise nematode management:

- **Molecular diagnostics:** Early detection of nematodes using qPCR and DNA barcoding.
- **RNA interference (RNAi):** Gene silencing approaches to disrupt nematode pathogenicity.
- **Genome editing of crops:** Using CRISPR-Cas to engineer nematode-resistant plants.
- **Soil microbiome manipulation:** Enhancing microbial antagonists of PPNs through soil inoculants.

- **Commercialisation of biocontrol nematodes:** Expanding EPN formulations for broader pest control.

Conclusion

Nematodes represent a paradox in agriculture: while some are among the most destructive crop pathogens, others provide vital ecosystem services and act as natural allies in pest control. Understanding their biology, ecological roles, and management strategies allows farmers to harness the beneficial while suppressing the harmful. For agronomists and students, nematodes exemplify the complexity of soil ecosystems and the need for integrated, science-based approaches to crop protection. Effective nematode management lies in balance—minimising plant-parasitic damage while promoting beneficial nematode activity for healthier soils and crops.