



Neem: Nature's Medicine Against Plant Parasitic Nematodes

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Neem demonstrates effectiveness against microorganisms and ectoparasites, including nematode, bacteria, fungi, viruses, ticks, and mites. To develop remedies to mitigate the adverse impacts of plant parasitic nematodes embraced by sustainability, it is crucial to understand the role of neem as organic amendments. Neem products possess multiple mechanisms and bioactive compounds, including azadirachtin, salannin, nimbin, and meliantriol, that exhibit nematocidal properties alongside insecticidal, fungicidal, and bactericidal effects. Neem beyond medicinal benefits also act as fertilizer in agriculture, and provides nutritional benefits.

Introduction

Nematodes are multicellular ubiquitous organisms that survive from snowy mountain peaks to deep hot springs. Plant parasitic nematodes, a subset of nematodes, threatens crops productivity and impart enormous loss ranging from 12% to 14.6% annually worldwide (Koul, 2004). Sustainability threatening nematodes are microscopic that rely entirely on plants for survival, often causing significant damage to their hosts. Nematodes damage goes unnoticed as its expression is mainly targeted to roots and above ground symptoms are generic that include yellowing, stunting, wilting and reduced crop production. Delay in detection leads to secondary pathogens attack like bacteria, virus and fungi, that acquires center stage, due to visible symptoms and economic loss. In India average annual estimated crop and yield loss is approximately 21.3% that encompasses 19% of horticultural crops and 11% of the field crops due to nematode attack (Reddy, 2021). Major nematode groups that cause severe damage worldwide are root-knot nematodes (*Meloidogyne* spp), cyst nematodes (*Globodera*/ *Heterodera* spp), lesion nematodes (*Pratylenchus* spp) and several others (Khan, 2023). Nematode cause adverse effect on plant growth, yield and quality harvest impacting farmers income leading to food availability for future generation that becomes one of the greatest challenges in nematode as they are microscopic in nature due to which management of nematode is crucial.

Synthetic Nematicides and its future

Nematodes are silent killers of the plant with symptoms appearing late when management seems out of hand. Farmers tend to incline towards synthetic compounds for hurried management. Examples of leading synthetic nematicides formulated to reduce plant parasitic nematodes includes fumigants such as Carbofuran, Fluensulphone, Fluopyram, fluazaindolizine and spirotetramat that helps in suppressing nematodes population however the injudicious use of chemicals leads to residue accumulation in soil contaminating water leading to harmful effect on soil health, human health, and the environment. Additional

addons such as biodiversity loss, release of harmful gases such as ammonia, nitrous oxide and greenhouse gases are some hidden factors contributing to negative sustainability. Instead of relying on synthetic nematicides, botanical treatment offers sustainable and eco-friendly solution which not only reduce their population but also control crop loss, improve soil health and increase overall crop productivity without causing any harm to the ecosystem (Taye *et.al.*, 2013). Botanical treatment includes plant extract such as neem, marigold, castor, garlic, plant leaves & oils that contains natural nematicidal, antifeedant and anti-repellent properties that helps in reducing nematode population in the soil.

Neem as an alternative solution for controlling nematodes

Neem also known as “Natures drugstore” in India is considered as pure and protective that has cleansing powers. Neem is also seen as a sustainable and culturally rooted solution to crop protection. Numerous studies have shown that different neem products have strong nematicidal effect on species like *Pratylenchus spp.* and *Meloidogyne spp* particularly azadirachtin compound, that target hormonal system of insect rather than it's nervous or digestive systems due to which nematode becomes non-resistant (Adusei & Azupio, 2022). According to studies, neem products suppress nematode reproduction, limit larval mobility, and decrease egg hatching, which leads to a noticeable population decline and less damage to the roots ultimately reducing crop loss. Neem (*Azadirachta indica*) contains over 100 biologically active compounds, mainly belonging to the limonoid and terpenoid groups. The most important compounds include azadirachtin, nimbin, nimbidin, salannin, and gedunin, which provide strong insecticidal, antimicrobial, and medicinal properties. Other compounds such as quercetin, β -sitosterol, and various fatty acids and tannins also contribute to neem's antioxidant and therapeutic effects (Agbo *et.al.*, 2019). Neem has a safety profile that minimizes the environmental impact, making it perfect for incorporating with integrated pest management (IPM) strategies and sustainable agricultural practices.

Effects Of Neem Based Product on Plant- Parasitic Nematodes:

Nematode Name	Neem Form Used	Dosages & Applications	Crop Treated	Country	References
<i>Meloidogyne incognita</i> (Root-knot nematode)	Neem cake (organic amendment)	400 kg/ha mixed in soil before planting	Tomato	India	(Jeevan <i>et.al.</i> , (2025) & (Jhamta <i>et.al.</i> , 2025))
<i>Meloidogyne javanica</i>	Neem oil (soil drench)	5 ml/L of water applied around root zone	Cucumber	Egypt	(Reddy, (2025))
<i>Heterodera glycines</i> (Soybean cyst nematode)	Neem seed extract (aq. Solution)	10% applied weekly	Soybean	USA	(Akhtar & Hakeem, (2025))
<i>Rotylenchulus reniformis</i> (Reniform nematode)	Neem leaf powder	200 kg/ha mixed with soil	Cotton	Brazil	(Luneja & Mkindi, (2025))
<i>Pratylenchus penetrans</i> (Root lesion nematode)	Neem oil emulsion	3 ml/L of water (soil drench)	Potato	Netherland	(Ibrahim <i>et.al.</i> , (2025))
<i>Radopholus similis</i> (Burrowing nematode)	Neem cake + Urea mix	500 kg/ha + Neem cake + 50 kg/ha + urea	Banana	India	(Rao <i>et.al.</i> , (2016) & Daneel, (2017))

<i>Tylenchulus semipenetrans</i> (Citrus nematode)	Neem leaf extract	8% foliar & soil treatment	Citrus	Spain	(Kumar & Pervez, 2023)
<i>Meloidogyne spp.</i>	Neem Cake + FYM	250g/ pit (Mixed with Trichoderma Spp.)	Banana	India	(Rao et.al., 2016)
<i>Meloidogyne graminicola</i> (Rice root-knot nematode)	Neem cake	500 kg/ha incorporated before sowing	Rice	India	(Haque & Khan, 2022)
<i>Hirschmanniella oryzae</i> (Rice root nematode)	Neem cake (emulsion)	4 ml/L as soil drench at early tillering stage	Rice	Philippines	(Ahmad et.al., 2022)
<i>Aphelenchoides besseyi</i> (White tip nematode)	Neem seed extract (aq. Solution)	10% seed soak for 12 hours before sowing	Rice	China	(Ni, 2019)

Future scope and management of nematodes by neem

Despite all of its benefits, maximizing neem's nematicidal potential requires proper application including dosage, formulation, and timing. Ongoing research is focused on developing advance formulation, like nano-emulsions that increases neem's stability, bioavailability, and nematode control (Tiwari, 2024). Research on production of bio compounds resembling neem can be formulated that may have direct nematicidal effects which effects decomposition and stimulate root and shoot development. Neem can be interogressed with various chemicals and formulation can be prepared for its additive effects. Alongside research may be taken up for combining biological agents such as *Pseudomonas* spp. and efficient biological agents for making it more effective against nematodes.

Conclusion

One of the most difficult hidden threats to crop productivity is plant-parasitic nematodes which frequently result in significant losses. Despite of their effectiveness conventional chemicals nematicides are hazardous to human health, soil health, beneficial organisms and to the environment. For controlling these nematodes, an alternative solution is neem (*Azadirachta indica*) that provides ecofriendly management and efficient substitute from chemical products especially in systems like Direct Seeded Rice (DSR). In addition to directly suppressing nematode populations different formulations include neem cake, leaf powder, seed kernels, oils which helps in encouraging beneficial microbes, plant growth and crop resilience to nematode populations. So adding neem with soil or combining with beneficial microbes results in improving plant growth, reduces nematode damage and lowers dependence on synthetic nematicides which will eventually lead up to sustainability.

References

1. Koul, O. (2004). Neem: a global perspective. In *Neem: today and in the new millennium* (pp. 1-19). Dordrecht: Springer Netherlands.
2. Wondimeneh Taye, W. T., Sakhuja, P. K., & Tadele Tefera, T. T. (2013). Root-knot nematode (*Meloidogyne incognita*) management using botanicals in tomato (*Lycopersicon esculentum*).
3. Kumar, V., Khan, M. R., & Walia, R. K. (2020). Crop loss estimations due to plant-parasitic nematodes in major crops in India. *National Academy Science Letters*, 43(5), 409-412.
4. Adusei, S., & Azupio, S. (2022). Neem: A novel biocide for pest and disease control of plants. *Journal of chemistry*, 2022(1), 6778554.

5. Tiwari, S. (2024). Impact of nematicides on plant-parasitic nematodes: Challenges and environmental safety. *Tunisian Journal of Plant Protection*, 19(2).
6. Rao, M. S., Umamaheswari, R., Priti, K., Rajinikanth, R., Grace, G. N., Kamalnath, M., ... & Vidyashree. (2016). Role of biopesticides in the management of nematodes and associated diseases in horticultural crops. In *Plant, Soil and Microbes: Volume 1: Implications in Crop Science* (pp. 117-148). Cham: Springer International Publishing.
7. Daneel, M. S. (2017). Nematode pests of minor tropical and subtropical crops. In *Nematology in South Africa: a view from the 21st century* (pp. 373-393). Cham: Springer International Publishing.
8. Agbo, B. E., Nta, A. I., & Ajaba, M. O. (2019). Bio-pesticidal properties of Neem (*Azadirachta indica*). *Adv. Trends Agric. Sci*, 1, 17-26.
9. Ni, L. Z. (2019). *Occurrence of Aphelenchoides besseyi (Christie, 1942) in Different Rice Growing Regions and Management of White Tip Disease* (Doctoral dissertation, MERAL Portal).
10. Reddy, P. P. (2021). Nematode diseases of crops and their management. Springer Singapore.
11. Haque, Z., & Khan, M. R. (2022). Organic management of rice root-knot nematode, *Meloidogyne graminicola*. In *Sustainable Management of Nematodes in Agriculture, Vol. 1: Organic Management* (pp. 247-267). Cham: Springer International Publishing.
12. Ahmad, S., ur Rehman, F., Adnan, M., Ahmad, I., Ahmad, S., Ghazanfar, M. U., ... & Kalsoom, M. (2022). Botanical extracts for rice fungal diseases. In *Modern techniques of rice crop production* (pp. 471-492). Singapore: Springer Singapore.
13. Kumar, K. K., & Pervez, R. (2023). Citrus Nematode in Fruit Crops and Their Management by Biological and Biotechnological Interventions. In *Novel Biological and Biotechnological Applications in Plant Nematode Management* (pp. 453-466). Singapore: Springer Nature Singapore.
14. Khan, M. R. (2023). Nematode pests of agricultural crops, a global overview. *Novel biological and biotechnological applications in plant nematode management*, 3-45.
15. Tiwari, S. (2024). Impact of nematicides on plant-parasitic nematodes: Challenges and environmental safety. *Tunisian Journal of Plant Protection*, 19(2).
16. Jeevan, H., Patidar, R. K., Kadam, V., Dutta, P., Nongbri, E., Gouda, M. R., ... & Nysanth, N. S. (2025). Implementing sustainable practices to combat root knot nematode infestation in tomato farming from Meghalaya. *Scientific Reports*, 15(1), 602.
17. Jhamta, S., Thakur, N., Singh, S., Yadav, N., Kumar Rai, A., & Yadav, A. N. (2025). Enhancing tomato crop protection: Utilizing microbial and botanical bioproducts to control *Meloidogyne incognita* population. *Plant Science Today*, 12, 5106.
18. Reddy, P. P. (2025). *Nematode Diseases of Vegetable Crops and their Management*. CRC Press.
19. Akhtar, M. S., & Hakeem, K. R. (Eds.). (2025). *Plant-Nematode Interactions and Their Management Strategies*. CRC Press.
20. Luneja, R. L., & Mkindi, A. G. (2025). Advances in botanical-based nano formulations for sustainable cotton insect pest management in developing countries. *Frontiers in Agronomy*, 7, 1558395.