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Entomopathogenic Nematodes: An Overview

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Entomopathogenic nematodes (EPNs) are a group of nematodes that specifically target insects, making them valuable biological control agents in integrated pest management (IPM) programs. These nematodes are particularly effective due to their ability to parasitize and kill a wide range of insect pests. Important EPN genera include *Steinernema* and *Heterorhabditis* belonging to family Steinernematidae and Heterorhabditidae respectively. *Steinernema* and *Heterorhabditis* nematodes have mutualistic associations with bacteria of the genera *Xenorhabdus* and *Photorhabdus*, respectively. EPNs release the bacteria into the insect haemolymph and the insect gets killed due to the toxins produced by the bacteria.

Life Cycle

Third stage juveniles are infective (IJs) and they are the only free-living stage of entomopathogenic nematodes present in soil. The IJs of entomopathogenic nematodes penetrate the host insect through natural openings like spiracles, mouth, anus (*Steinernema* spp.) and through the inter segmental membranes of the cuticle (*Heterorhabditis* spp.). After entering the insect body, they release bacteria from their intestines into the insect haemolymph and bacteria multiply quickly and produce insecticidal toxins. Infected insect typically dies within 24 to 48 hours due to septicemia. After the host death, nematodes continue to feed on the developing bacterial and host tissue until the food resources in the host cadaver are depleted. They reproduce for several generations inside the cadaver. Within few days of an insect's death, large number of IJs will emerge from the cadaver and begin searching for new hosts in the soil (Kaya and Gaugler, 1993). Insects killed by

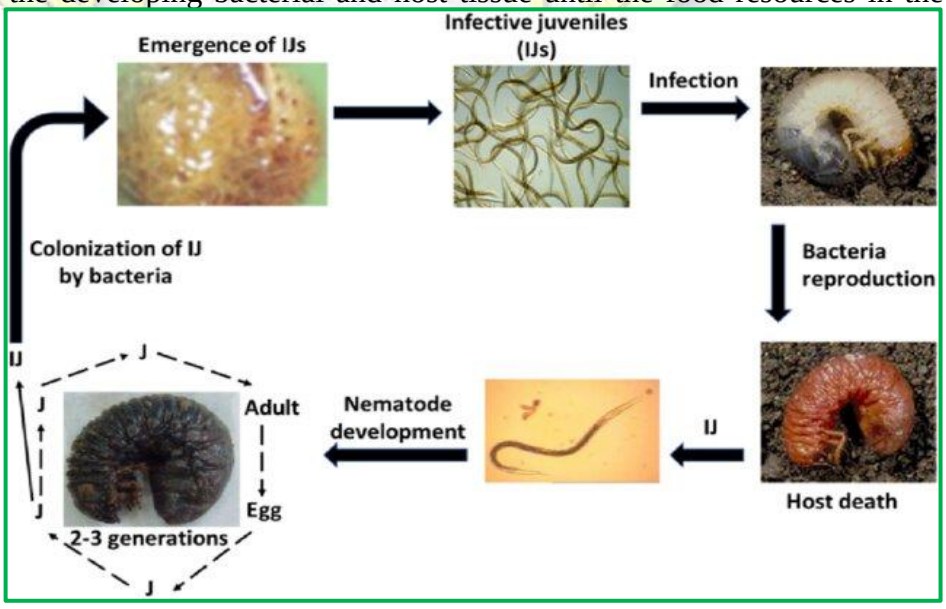

Fig 1: Life cycle of entomopathogenic nematodes (Sabbahi *et al.*, 2022)

Heterorhabditis spp. turn red and insects killed by *Steinernema* become brown or tan. The colour of the host body indicates the pigments produced by the mutualistic bacteria growing within the host insects (Kaya and Gaugler, 1993).

Host range

Steinernema and *Heterorhabditis* are genera of entomopathogenic nematodes, which are known for their ability to parasitize and kill a variety of insect hosts. According to Shapiro-Ilan et al. (2017), over 100 species of *Steinernema* and 16 species of *Heterorhabditis* have been documented. In laboratory conditions, *Steinernema carpocapsae* alone infected more than 250 species of insects from over 75 families in 11 orders (Poinar, 1975). In research conducted by Sharmila et al. (2018), *Heterorhabditis indica* and *Steinernema glaseri* were found to be effective against a diverse range of insect species under laboratory conditions. Specifically, 17 insect species from the orders Lepidoptera, Coleoptera, and Hemiptera, as well as one species of slug, were identified as hosts for *H. indica* and *S. glaseri.*

Benefits and Applications

1. **Broad Host Range**: EPNs target a wide range of soil-dwelling insect pests, including beetle larvae, caterpillars, and grubs, which are often resistant to chemical pesticides
2. **Environmental Safety**: They are safe for non-target organisms, including humans, animals, and plants, making them an environmentally friendly pest control option.
3. **Ease of Application**: EPNs can be applied using standard agricultural equipment, such as sprayers and irrigation systems.
4. **Compatibility**: They can be integrated with other pest management strategies, including chemical pesticides and other biological control agents.

Challenges

1. **Environmental Sensitivity**: EPNs can be sensitive to environmental conditions such as temperature, humidity, and UV radiation.
2. **Storage and Shelf Life**: Maintaining the viability of EPNs during storage and transportation can be challenging.
3. **Cost**: The production and application of EPNs can be more expensive compared to chemical pesticides. Initially, the cost of EPNs might be higher compared to chemical pesticides, though the long-term benefits and sustainability often outweigh the initial expense

Formulation of EPNs

Developing formulation is an important aspect for successful application of bio-agents in field. There are different EPN formulations available *viz*., talc-based formulations, alginate beads/capsules, hydrogels, clay pellets, application of infected galleria larvae directly to soil etc. In alginate capsules and hydrogels, infective juveniles are present in active state and in talc-based formulations and clay formulations infective juveniles are in inactive state. Shelf life of nematodes varies in each of the formulations and depends on various factors like storage, temperature and moisture.

Heterorhabditis indica, EPN formulation is suitable for soil application to combat soil-dwelling insect pests like root grubs, root weevils etc. effectively. On the other hand, *Steinernema carpocapsae*, is intended for foliar application and target borers infecting fruits, pods, and stems (Lacey and Georgis, 2012). These EPN-based products offer an eco-friendly alternative to chemical pesticides, fitting well into integrated pest management (IPM) strategies.

List of EPN Bioformulations from India (Singh *et al*., 2022;)

Species	Trade name	Formulation Type and manufacturer	Target Insect species
S. carpocapsae	Bouncer	Wettable powder Multiplex pvt.ltd	Foliar pests like diamond back moth of cabbage, gram pod borer, rice leaf folder, mustard saw fly, aphids, mealy bugs, tea loopers etc and also kills soil borne pests like root grubs, cutworms and root weevil
H. indica	Nema power	Wettable powder KN Biosciences	White grubs, termites
	Aarmour	Wettable powder Ponalab	White grubs, termites
	Soldier	Wettable powder Multiplex pvt.ltd	White grubs, borers, root grubs, weevils and cutworms
	Grub Nash	Wettable powder Khandelwal biofertilizer	White grubs

Conclusion

Entomopathogenic nematodes offer a promising, environmentally friendly alternative to chemical insecticides. Their ability to target a broad range of insect pests, coupled with ongoing advancements in research and technology, continues to enhance their effectiveness and commercial appeal. However, challenges related to environmental sensitivity, storage, and cost need to be addressed to fully realize their potential in integrated pest management (IPM) programs. Overcoming these challenges will enable wider adoption and maximize the benefits of EPNs in sustainable agriculture.

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