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7. Management of Insects by Entomopathogenic Nematodes

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Abstract:

Entomopathogenic nematodes are tiny, underground worms that have the power to penetrate and get rid of a wide variety of insect pests. They are effective biological control agents for insect pests and can be used in pest management plans to reduce the need for chemical pesticides. Using entomopathogenic nematodes to manage insects can be done in a number of ways, including the following: planting in the soil. The soil can be injected with these microscopic worms, which can then hunt for and infect soil-dwelling insects including grubs, root maggots, and cutworms.

The nematodes enter the insect's body and release germs that multiply and cause septicemia, which finally kills the insect. Application to foliage: Some types of entomopathogenic nematodes, such as Steinernema feltiae, can be applied as a foliage spray, directly attacking pests like aphids and thrips that feed on leaves. Utilisation in conjunction with other management strategies: To effectively control insect pests, entomopathogenic nematodes can be used in combination with a variety of control strategies, such as agronomic practises (crop rotation, cultivation of resistant types), physical impediments (plant coverings), and chemical insecticides. Production: Entomopathogenic nematodes can be produced in large quantities in laboratories for use as commercial biopesticides. These nematodes are grown in artificial growth conditions and can be applied to the field in a number of ways. Entomopathogenic nematodes have the potential to provide efficient, long-lasting, and environmentally responsible management of insect pests in agricultural and horticulture contexts.

Keywords:

Entomopathogenic nematodes, Insect pest management, biological control, Integrated pest management, Sustainable agriculture.

7.1 Introduction:

Nematodes are round, non-segmented worms that are typically tiny in size and have colourless appendages. Nematodes come in both undesirable and useful varieties. Alternative names for undesirable nematodes include "plant parasitic nematodes." Despite being viewed as a threat to agriculture, some nematodes have beneficial roles (Labaude and Griffin 2018). Entomopathogenic nematodes kill pests of agricultural crops by infecting them, demonstrating the effectiveness of these organisms as biological control agents (Baiocchi *et al*., 2017). Beneficial nematodes attack pest insects that live in the soil, but they don't harm people, animals, plants, or earthworms. Since they don't damage anyone, they can act as organisms for biological control (Denno *et al*., 2008; Mc Donnell *et al*., 2020).

Due to the inclusion of helpful bacteria from the *Enterobacteriaceae* families like *Xenorhabdus* and *Photorhabdus*, linked with the *Steinernema* and *Heterorhabditis* genera, respectively, EPNs (*Entomopathogenic* Nematodes) offer significant potential for eliminating a wide range of insect pests (Boemare, 2002; Adeolu *et al*., 2016). The EPNs' contagious juveniles live in the soil and are constantly looking for weak insect victims to infect. The infectious juveniles immediately infiltrate these host insects upon contact, either through naturally occurring holes or by directly penetrating the exoskeleton (Miles *et al*., 2012).

The infectious juveniles release bacterial symbionts into the insect host's internal milieu (haemocoel), where they quickly multiply and create a variety of exoenzymes, metabolites, poisons, and virulence factors. The insect host dies as a result within 24 to 48 hours (Ciche and Ensign, 2003). The EPN finishes its life cycle inside the host, eating the symbionts before moving on to a next host (Bal *et al*., 2014; Pant *et al*., 2023). A way to manage a variety of insect pests, such as caterpillars, cutworms, crown borers, grubs, craneflies, thrips, and beetles, is made possible by entomopathogenic nematodes. Entomopathogenic nematodes have been widely introduced into agricultural fields and have shown to have minimal effects on unintended insects, reaffirming their standing as exceptionally eco-friendly agents. Using entomopathogenic nematodes successfully requires:

a. Grasping their life cycles and functions;
b. Ensuring the proper alignment of nematode species with the targeted pests;
c. Administering them under favourable environmental conditions, considering factors like soil temperature, moisture, and sunlight;
d. Employing them exclusively alongside compatible pesticides.

Entomopathogenic nematodes must be handled carefully during storage and transit because they are living creatures. Additionally, they depend on particular environmental elements to flourish in the soil after application. Due to a variety of qualities, these nematodes show promise as excellent candidates for integrated pest management and sustainable agriculture (Bender *et al*., 2014). Some of these species have the capacity to recycle and endure in the environment, which may have an indirect or direct impact on populations of plant diseases and parasitic nematodes. Additionally, they are compatible with a wide range of chemical and biological insecticides frequently used in IPM programmes and can indirectly improve soil quality (Campos-Herrera, 2015a).

7.2 Biology and Life cycle of EPNs:

Nematodes typically go through five stages in their life cycle, starting with the egg stage and ending with the adult stage. The third juvenile stage in entomopathogenic nematodes (EPNs) is also referred to as the "infective juvenile" or "dauer" stage and is the only free-living stage (as seen in Figure 6.1). According to Poinar's research from 1990, the infectious juvenile has the capacity to flourish in the soil environment, aggressively seeking out and infecting nuisance insects (Pant *et al*., 2023; Maurya *et al*., 2023 a). When conditions are ideal, the entire life cycle of *Steinernematids* and heterorhabditids within a host, from egg to egg, takes from 3 to 7 days. According to information provided by Kaya and Koppenhofer in 1999, the emergence of infectious juveniles from the host takes place between 6 and 11 days for *Steinernematids* and between 12 and 14 days for heterorhabditids. Figure 6.2 shows a graphic illustration of the entomopathogenic nematode life cycle, from host infection to emergence.

Figure 6.1: An Infective Juvenile of Entomopatho¬Genic Nematode

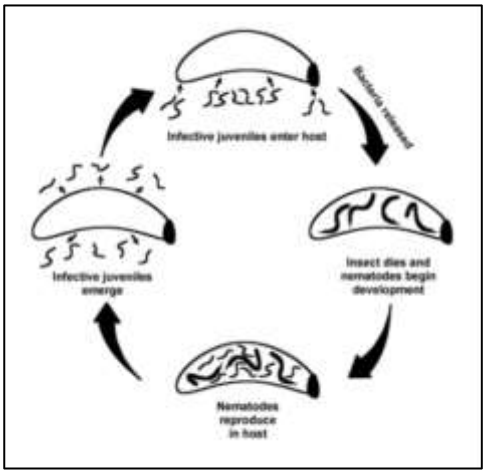

Figure 6.2: General Life Cycle of Entomopathogenic Nematode

7.3 Management of Insect Pests:

7.3.1 Mechanisms of Controlling Insect Pests with EPNs:

Understanding their host-finding strategies is essential for efficiently matching entomopathogenic nematode species with nuisance insects for infection and control, as described by Gaugler in 1999. The only nematodes that can survive in soil, find, and pierce insect pests are entomopathogenic nematodes in the infectious juvenile stage (Campos-Herrera, 2015b). Ambush and cruising are the two main tactics used by infectious juvenile entomopathogenic nematodes to locate hosts in the soil, as Gaugler and colleagues described in 1989. *Steinernema carpocapsae* and *S. scapterisici* are examples of ambusher species, whereas *Heterorhabditis bacteriophora* and *S. glaseri* are examples of cruiser species. According to Campbell and Gaugler in 1997, species like *S. riobrave* and *S. feltiae* demonstrate a combination of cruising and ambushing behaviours (Chiriboga *et al*., 2017; Pandey *et al*., 2022).

7.3.2 Ambushing:

Entomopathogenic nematodes that use the ambushing tactic frequently remain still, mostly close to the soil surface. Through direct touch, or "nictation," in which the nematode stands on its tail with the majority of its body in the air, they identify host insects. Cutworms, armyworms, and mole crickets are just a few examples of the extremely mobile insect pests that these nictating nematodes effectively suppress at the soil surface by attaching to and eating their passing insect hosts (Dara, 2017).

7.3.3 Cruising:

The cruising technique is used by entomopathogenic nematodes, which are much more mobile and able to move through different soil depths. By detecting carbon dioxide or other volatiles emitted by the host, they locate their hosts. At various soil levels, cruiser entomopathogenic nematodes are most effective against immobile and slowly moving insect pests like white grubs and root weevils (Gassman and Clifton 2017).

7.3.4 Infection:

Usually, a single insect host becomes infected by numerous entomopathogenic nematodes. Through natural apertures like the mouth, anus, genital hole, or breathing pore (as shown in Figure 4) or by rupturing the insect's exterior cuticle, infectious juvenile nematodes enter the insect's body cavity. *Heterorhabditids* accomplish this via a dorsal "tooth" or hook.

When the infectious juveniles enter the host's body cavity, they release bacteria that coexist in the nematode's stomach in a healthy symbiotic relationship. Only *Xenorhabdus* spp. bacteria and *Photorhabdus* bacteria live with *Steinernematids* and *Heterorhabditids*, respectively, in this very specialised nematode-bacterium association. When the bacteria are discharged into the host, they quickly grow and, in ideal circumstances, cause the host to pass away within 24 to 48 hours (Pant *et al*., 2023).

Entomopathogenic nematodes consume both the host insect tissue and the bacteria they discharge. Entomopathogenic nematodes reach their adult stage in a matter of days after they are within the host. As seen in Figure 5, these adult nematodes generate hundreds of thousands of new juveniles, frequently finishing many life cycles within a single host. After the host has been eaten, the infectious juveniles break through the host's empty shell, travel into the soil, and start looking for a new host while armed with a fresh supply of bacteria (Pant *et al*., 2023).

The infectious juvenile is shielded from its surroundings and predators by an external cuticle. According to ideal circumstances, *Steinernematids* appear 6–11 days after the initial infection, whereas *Heterorhabditids* appear 12–14 days later (Kaya and Koppenhofer, 1999). Since infective juveniles can become prey to invertebrates and bacteria, it is yet unknown how long they will survive in the soil (John *et al*., 2019b).

7.4 Application Methods of EPNs:

Standard application techniques include the use of pressurised sprayers, mist blowers, electrostatic sprayers, and even aerial sprays to apply entomopathogenic nematodes to horticultural or agricultural crops (Georgis, 1990; Wright *et al*., 2005; Shapiro-Ilan *et al*., 2006a). Depending on the cropping system, the appropriate application equipment must be chosen. Each scenario necessitates different handling considerations, including volume, agitation, nozzle type, pressure, recycle time, environmental factors, and spray dispersion pattern (Grewal, 2002; Fife *et al*., 2003, 2005; Entomopathogenic Nematodes: Shapiro-Ilan *et al*., 2009, Wright *et al*., 2005; Shapiro-Ilan *et al*., 2006a; Lara *et al*., 2008). It's crucial to make sure there is enough agitation while applying. Larger plots might need the use of effective spraying equipment like boom sprayers, while smaller plots might be suited for handheld tools like water cans or backpack sprayers (John *et al*., 2019a). As an alternative, applicators can look into subsurface injection, microjet irrigation systems, or baits (Wright *et al*., 2005; Lara *et al*., 2008). When administering entomo-pathogenic nematodes in aqueous suspension, a variety of formulations can be used, such as activated charcoal, alginate and polyacrylamide gels, clay, peat, polyurethane sponge, vermiculite, and water dispersible granules (WDG) (Georgis, 1990; Georgis *et al*., 1995).

7.5 Advantages of EPNs:

These nematodes have many benefits. Warm-blooded animals, including humans, have been shown to be unaffected by EPNs and the bacterial symbionts that they are linked with (Pionar *et al*., 1982; Boemar *et al*., 1996). While cold-blooded animals have demonstrated sensitivity to EPNs at very high dosages in experimental settings (Pionar and Thomas 1988; Kermarrec *et al*; 1991), field settings have not consistently reproduced these unfavourable findings (Georges *et al*; 1991; Bathon 1996). Nematodes often kill insects within 24-48 hours, as opposed to other biological agents, which typically take days or weeks to kill the host. They are naturally present in soil and have been found on all continents with the exception of Antarctica (Kaya and Gaugles 1993; Gryphon *et al*. 1990). They are simple and relatively cheap to culture, have an infective stage lifespan of a few weeks to months, exhibit the ability to infect numerous insect species (Maurya *et al*., 2023 b). Nematode foliar sprays have successfully managed quarantine leaf-eating caterpillars like *Tuta absoluta*, *Spodoptera littoralis*, *Helicoverpa armigera*, and *Pieris brassicae* on a variety of crops. These applications also show potential for managing a wide variety of other insect pests. It's important to note that applying EPNs doesn't require the use of masks or any other safety gear like chemical substitutes (Maurya *et al*., 2020). According to Pionar *et al*. (1982), Boemar *et al*. (1996), Akhurust and Smith (2002), neither mammals nor plants are harmed by EPNs or the bacteria that they are linked with.

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