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Entomopathogenic Nematodes

Warriors of Sustainable Agriculture

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Introduction

Nematodes are multicellular microscopic metazoans that dwell in the topsoil of the earth's surface. One handful of soil contains thousands of nematodes both good and bad. Only plant parasitic nematodes are detrimental to plants while other groups of nematodes including free living and predatory nematodes helps in nourishment of soil, nutrient recycling and control of bacterial and fungal antagonists. EPN, a group under free living nematodes are explored and is in exponential growth as a biological control in many European, Australian and Asian nations. Entomopathogenic nematodes (EPN) belonging to order Rhabditida are a group of free-living nematodes that are extraordinarily lethal to many important insect pests of various crops. The groups of nematodes are ubiquitous in nature and inhabitants of ecologically diverse habitats like cultivated fields, forests, grasslands, deserts and beaches. The major genera of EPN inducted in management strategies are *Steinernema* spp., *Heterorhabditids* spp. and *Oscheius* spp.

These nematodes are identified as lethal adversaries against caterpillars, worms, grubs, borers, thrips and beetles of Lepidopteron, Dipterans and Coleopterans insect orders. The nematodes explore penetrate and kill the host within 24-48 hours of infection and its tendency to multiply exponentially on its host and again move back into the soil waiting for next host makes it a suitable candidate for sustainable agriculture. Besides benefitting sustainability, the associated safety like non requirement of registration, no special spraying nozzles, neutral impact on groundwater contamination and pollinators adds to its cause for environmental stability. Dozens of different insect pests are susceptible to infection, yet no adverse effects have been shown against beneficial insects or other non-targets in field studies. The importance of the EPN is also enhanced due to its compatibility with various reported agrochemicals. EPN's are unique because they combine with bacteria to control insect's pests which makes in more interesting.

Life cycle of Entomopathogenic nematode (EPN)

The Entomopathogenic nematodes undergo an egg stage, four juvenile phases and an adult stage, in their life cycle and the third juvenile stage (J_3) is known as the "infective juvenile" or "dauer" stage that infects the insect pest. At room temperature the life cycle is completed

within 15-18 days. The nematodes are generally ambushing type (*Steinernema* spp.) where they wait for their host nictating on their tail or cruising type (*Heterorhabditids* spp.) where the nematode move in soil to find their host following cues. After finding the host the nematodes enter the body through their natural openings. Once the juveniles (J_3) enter the body of the insect through natural openings like spiracles, anus etc. a symbiotic bacterium (*Xenorhabdus* for *Steinernematid* and *Photorhabdus* for *Heterorhabditids*), are released from the nematode gut, which then multiplies rapidly and causes rapid insect death due to septicemia within 24 to 48 hrs. The colour of the dead insect changes to brick red and yellow when infected by *Heterorhabditids* spp. and *Steinernema* spp. juveniles respectively.

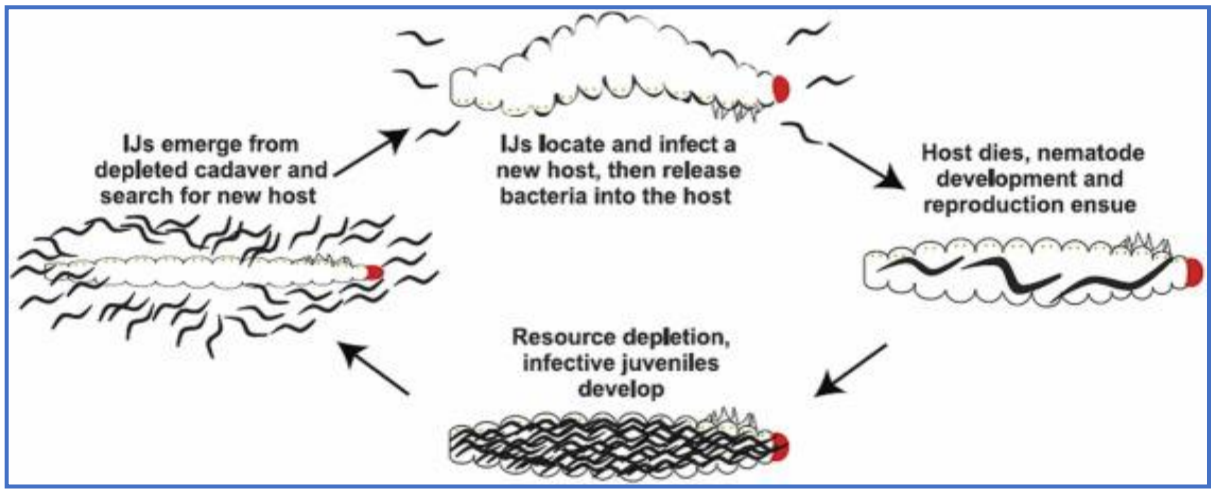

Fig 1: Pictorial representation of the EPN life cycle and its various infective stages inside the host

The nematodes feed upon the bacteria and liquefying host and mature into adults. *Steinernematid* infective juveniles may become males or females, whereas *Heterorhabditids* develop into self-fertilizing hermaphrodites although subsequent generations within a host produce males and females as well. The life cycle is completed in a few days under congenial conditions, and hundreds and thousands of new infective juveniles emerge in search of fresh hosts.

Table 1: Entomopathogenic nematodes infecting various insect pests in diversified crops.

Order	Scientific and/or common name	Crop	Country	Nematode sp.
Gelechiidae	*Phthorimaea operculella (Zeller)*	Potato	India	Sc, Hi
Carposinidae	*Carposina niponensis* (Walsingham)	Apple	China	Sc
Pyralidae	*Chilo suppressalis* (Walker)	Rice	Korea	Sc, Sg, Hb
	C. zonellus (Swinhoe)	Maize	India	Sc
Noctuidae	*Tryporyza incertulas*	Rice	India	Sc
	Spodoptera littoralis	Cabbage	Egypt	Hb, Hi, Sc, Sa, Sr
	Spodoptera litura (F.)	Foliar crops	India	Hi, Sg
		Glasshouse and nursery crops	India	Hi
		Crucifers	Korea	Sc, Hb, Sm, Sl, Sg
	Spodoptera furgiperda	Corn	USA	S sp.

Lepidoptera	*Helicoverpa armigera*	Foliar crops	India	Hi, Sg
	Helicoverpa zeae	Corn	USA	Sr
	Pieris brassicae (Linnaeus)	Crucifers	India	Hi, Sc, St
	Palpita indica (Saunder)	Vegetables	Korea	Sc, Sg, Sl, Hb
	Banana moth (*Opogona sachari)*	Ornamental		Hb, Sc
	Army worm	Vegetables		Sc, Sf, Sr
	Banana root borer (*Cosmopolites sordidus*)	Banana		Sc, Sf, Sg
	Black cut worm (*Agrotis ipsilon*)	Turf, Vegetable		Sc
	Borers (*Synanthedon* spp.)	Fruits trees and Ornamentals		Hb, Sc, Sf
	Codling moth (*Cydia pomonella*)	Pome fruit		Sc, Sf
	Corn earworm (*Helicoverpa zeae*)	Vegetables		Sc, Sf ,Sr
	Corn rootworm (*Diabrotica* spp.)	Vegetables		Sc, Hb
	Carne fly	Turf		Sc
	Fungus gnats	Mushroom, greenhouse		Sf, Hb
	Grape root borer (*Vitacea polistiformis*)	Grapes		Hz, Hb
	Artichoke plume moth (*Platyptilia carduidactyla*)	Artichoke		Sc
	Billbug (*Sphenophorus* spp.)	Turf		Hb, Sc
	Plum curculio (*Conotrachelus nenuphar*)	Fruit trees		Sr
	Cat flies (*Ctenocephalides felis*)	Home yard, Turf		Sc
	Cranberry girdler (*Chrysoteuchis topiaria*)	Cran barriers		Sc
	Navel orange worm (*Amyelois transitella*)	Nut and fruit trees		Sc
	Lris borer (*Macronoctus onusta*)	Lris		Hb, Sc
	Shore flies (*Scatella* spp.)	Ornamental		Sc, Sf
	Leaf miners (*Liriomyza* spp.)	Vegetables, Ornamentals		Sc, Sf
Coleoptera	Strawberry root weevil (*Otiorhynchus ovatus*)	Berries		Hm
	Black vein weevil (*Ortiorhynchus sulcatus*)	Ornamental, berries		Hb, Hm, Hd
	Scarab grubs	Turf		Hb, Sc, Sg
	Large pine weevil (*Hylobius albietis*)	Forest plantings		Hd, Sc
	Sweet potato weevil (*Cylas formicarius*)	Sweet potato		Hb, Sc, Sf
	Small hive beetle (*Aethina tumida*)	Bee hives		Hi, Sr
	Citrus root weevil (*Pachnaeu* spp.*)*	Citrus, Ornamental		Sr, Hb

Note: Sc- *Steinernema carpocapsae*, Hi- *Heterorhabditids indica*, Sg- *Steinernema glasseri*, Hb- *Heterorhabditids bacteriophora*, Sr- *Steinernema riobrave*, Sa-*Steinernema abassi*, Sl- *Steinernema longicaudatum*, Sm- *Steinernema masoodi*, Sf- *Steinernema feltiae,* Hd -*Heterorhabditids downesi,* Hz- *Heterorhabditids zealandica*

Factors affecting entomopathogenic nematodes in soil

Primarily there are two factors that affect EPN i.e. biotic factors and abiotic factors. In biotic factors the major concern is for habitats, plants, hosts, competition with various other microbes, displacement, inter and intraspecific competition among various EPN, competition with various non-EPN. Among abiotic factors the major concerns that affect the nematode survivality and successful niche formation depends on soil texture and structure, soil moisture, soil temperature, time of application and rainfall. The EPN have a major share in the biopesticide market as the formulations carry the nematodes in metabolically arrested state. The EPN are also tested to be compatible with various marketable pesticides and insecticides. Similarly, the nematodes are also reported to be compatible with various bio-control agents like *Bacillus thuringiensis*. Some chemicals like Aldicarb, Carbofuran and Diazinon should be avoided while spraying together. EPN are generally found in undisturbed soil due to less human footprints and insignificant chemical molecules application.

Advantages

- Broader insect pest host range.
- Hostiling the host within 24-48 hrs. of impact
- No registration required.
- Successful mass production through *in-vivo* and *in-vitro* production.
- No specialized application equipment required.
- Safety towards all no target pests and vertebrates.
- Provides healthy soil conditions.

Disadvantages

- Limited shelf life and storage facility required.
- Requires adequate moisture capacity or field capacity.
- Native strains required for successful management.
- Sensitive to high temperature and rainfall.

Conclusion and Future thrusts

The need of the hour is sustainability as chemical molecules in agriculture have left a lot to deal with. The entomopathogenic nematodes in particular have emerged as an excellent bio-control agent of soil-dwelling insect pests as they parasite and cause mortality of the insect pest within 24-48 hrs. Their indigenous availability, easy isolation and economical mass production units tag them as handy and beneficial nematodes. Due diligence, they hence have attracted widespread commercial interest but the reason of lack of success against insect pests of different orders in field studies remains puzzled. Understanding these behavioral patterns and their genetics will enhance the use and production of the most adapted species for insect control. Moreover, basic information on the biology, behavioral ecology and genetics of these nematodes are lacking that requires further elucidation. Nematodes are ubiquitous in nature and abundant in soil so research is needed to better understand the factors that regulate their population and on how their population can be enhanced to initiate epizootic in insect-pest populations. There is also an urgent requirement of spreading awareness about this beneficial nematode to the farmers and stakeholders for adaptation and parallelly smoothened mass production units should be set up to meet the needs of the growing demand so that agriculture moves in a direction towards achieving a safer environment for the future generation.

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Fig 2: *Corcyra* larvae infected by unidentified EPN species

Fig 3: Adult grub of rice roots killed by EPN