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Entomopathogenic Nematodes: Tools in Biocontrol of Insect Pests in Vegetable Crops

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Abstract

The entomopathogenic nematodes of the genera *Steinernema* and *Heterorhabditis* have capacity to manage insect pests mutually and interact with bacteria of the genera *Xenorhabdus* and *Photorhabdus*. These nematodes kill insects within 24 to 28 hours by interacting with their symbiotic bacteria in contrary to other biological control agents that take days or weeks to do so. Entomopathogenic nematodes know to have great insect management potentially and also known safer to non targeted organism and effectively work with their symbiotic bacteria. The biological control agents like fungal bacteria and other micro-organisms require longer time for insect killing. The infective juveniles (IJs) are known to tolerate short-term exposure of various chemical compounds like insecticide, fungicides, herbicides, fertilizers including nematodes and growth regulators and provide opportunity of mass application. They are also known to be compatible with other biocontrol agents under various agro-climatic conditions. The use EPNs can also offer a cost-effective alternative to insect-pest control.

Introduction

Pest insects are prone to harming vegetable crops. Vegetables are directly harmed by insect pest attacks, and many of them serve as carriers of a variety of viral diseases. (Rai. et al., 2014). The nematology literature initially used the word "entomopathogenic" in reference to the bacterial symbionts of Steinernema and Heterorhabditis (Thomas, 1979). Entomopathogenic nematodes (EPNs) differ from other insect-parasitic nematodes in that they can kill insect hosts by working with insect-pathogenic bacteria. Small, non-segmented, elongated, appendage-free roundworms called entomopathogenic nematodes are found in soil. Steinernematidae and Heterorhabditidae are two nematode families that infest insects. EPNs have developed particular strategies that enable them to connect with and spread

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diseases to insect hosts. Due to advancements in application techniques and the capacity to produce them in vast quantities in laboratory settings, entomopathogenic nematodes are now recognized as effective biological control agents (Grifin *et al.*, 2005). It has been noted that insect infestations in vegetables, such as gall midges, Mealy bugs, Hadda beetles, serpentine leaf miners, and spiraling whiteflies, diminish production by 24 to 100%. In various areas, the cabbage butterfly, stem fly, red spider mite, leafhopper, and plume moth are gradually rising to the position of the nation's top pests (Anonymous, 2014). Only these insect-parasitic nematodes possess the perfect combination of biological control traits (Cranshaw and Zimmerman, 2013). Steiner identified Aplectana kraussei as the first entomopathogenic nematode in 1923. Cutworms are widespread, polyphagous, and devour many different types of fruit and vegetable crops. All of India potato-growing regions contained *A. ipsilon*, but the region from Punjab to Bengal and Madhya Pradesh in Central India garnered the most attention (Lal and Rohilla, 2007). It is crucial to anticipate when and how these nematodes will be efficient and practical biological controllers. Different EPNs have been employed to control soil insects, with varying degrees of success. Scapteriscus spp. in Florida grasslands (Parkman *et al.*, 1996) used Steinernema scapterisci, an imported species, as a conventional biological control agent to show how mole cricket invasions can be successfully managed.

Distribution of EPNs:

EPNs are found in practically all soils, but are restricted by host availability, environmental factors, soil temperature, and moisture state. From various nations throughout the world, 21 species of Heterorhabditis and about 100 genuine species of Steinernema have been identified (Bhatt et al. 2020). Because the survival and contagiousness of these nematodes depend on the same parameters, the effects of environmental and biotic factors have a significant impact on the dissemination of EPNs in soil.

Classification of Systematic Position

Phylum	Nematoda	Chitwood,1950
Class	Secernentea	Van Linstow, 1905
Order	Rhabditida	Chitwood, 1933
Sub order	Rhabditina	Chitwood, 1933
Super family	Rhabditoidea	Travassos, 1920

Family	Steinernematidae	Philipjev, 1934
	Hetrorhabditidae	Poinar, 1976
	Neosteinernematidae	Nguyen &Smart, 1994
Genus	Steinernema	Steiner, 1927
	Hetrorhabditis	Poinar, 1976
	Neosteinernema	Nguyen &Smart,1994

In all the classes, Adenophorea and Secernentea, there are a total of 24 families of insect parasitic nematodes that belong to the phylum Nematoda. The significant insect parasites that can kill host insects are the families Steinernematidae and Heterorhabditidae of the order Rhabditida, classes Secernentea. Steinernema and Neosteinernema are the only two genera of the Steinernematidae currently recognized, with the former having 85 species and the latter having just one. There are only 16 species in the sole genus Heterorhabditis, which belongs to the family Heterorhabditidae (Hunt and Subbotin, 2016). Only two of these species *Steinernema thermophilum* by (Ganguly and Singh, 2000) and *Heterorhabditis indica* by (Poinar *et al.*, 1992) have been identified in India

Life Cycle

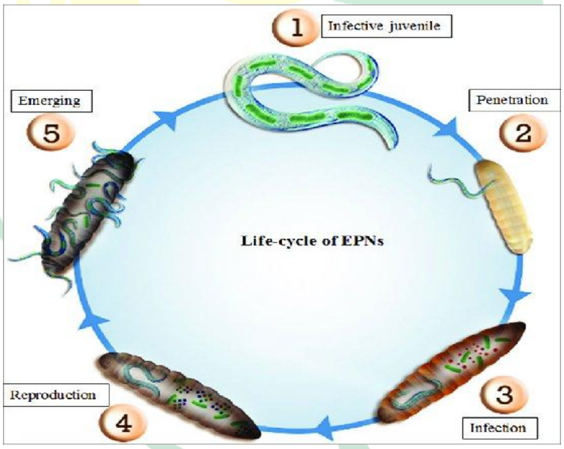

Fig 1. The General life cycle of entomopathogenic nematodes. The numbers on the figure show the order of stages in the life cycle of entomopathogenic nematodes. (Figure was modified from http://www. nosopharm.com).

The majority of nematodes have an egg stage, four juvenile phases, and an adult stage in their life cycle. The sole free-living stage is the third juvenile stage of EPNs, often known as the "infective juvenile" or "dauer" stage. The infectious juvenile can survive in the soil, where it finds a pest insect to attack and infect (Poinar, 1990). Steinernematids and Heterorhabditids can go from egg to egg inside of a host in 3–7 days under ideal circumstances. It takes between 6 and 11 days for Steinernematids and 12 to 14 days for Heterorhabditids for infectious juveniles to emerge from the host (Kaya and Koppenhöfer, 1999). Nematodes that kill insects are known as entomopathogenic nematodes. EPNs have been discovered in many biologically different areas and all around the world. They are incredibly intricate, specialized, and diverse. The nematode/bacterium complex that functions as a biological control unit to kill an insect host is thus the key feature of biopesticides (Sujatha *et al.,* 2016) the life cycles of the entomopathogenic nematodes Steinernema and Heterorhabditis. Infectious juveniles (IJs) that are out foraging can engage in a variety of activities, from the active hunt for a host (cruiser) to the passive technique of nictation (ambusher). Infection can happen through natural holes or by piercing thin areas of the cuticle once a host has been found and accepted. IJs discharge their symbiotic bacteria into the hemolymph, and the host succumbs to toxemia and septicemia within 24 to 48 hours. Up to three generations of EPNs can exist inside the host cadaver. Adults in the majority of Steinernema species are always both males and females; however, in Heterorhabditis species, the first generation's adults are hermaphrodites, and the generations after them contain hermaphrodites, females, and males. A new cohort of IJs departs the host cadaver and begins searching for a new host when available space and food become scarce.

Economic importance of Entomopathogenic Nematode

EPNs are incredibly destructive to large insect pests, but they pose little damage to unintended organisms or the environment (Georgis and Hague, 1991). Unlike dangerous substances and other microbes.

Table-1. List of Steinernema and Heterorhabditis species recorded from different parts of India.

Sr. No.	Species identifed	References
1.	S. thermophilum	Ganguly and Singh (2000)
2.	S. carpocapsae	Hussaini *et al.* (2001)
3.	S. tami	Hussaini *et al.* (2001)
4.	S. bicornutum	Hussaini *et al.* (2001)
5.	S. siamkayai	Ganguly *et al.* (2002)

6.	S. dharanai	Kulkarni *et al.* (2012)
7.	S. glaseri	Kadav and Lalramliana (2012)
8.	S. surkhetense	Bhat *et al.* (2017)
9.	S. sangi	Lalramnghaki *et al.* (2017)
10.	S. pakistanense	Bhat *et al.* (2018)
11	S. cholashanense	Mhatre *et al.* (2017)
12.	S. hermaphroditum	Bhat *et al.* (2019)
13.	H. indica	Poinar Jr *et al.* (1992)
14.	H. baujardi	Vanlalhlimpuia and Lalramnghaki (2018)
15.	H. bacteriophora	Bhat *et al.* (2020)

EPNs are quite safe and don't need any specialized applications. Due to their relationships with harmful symbiotic bacteria, EPNs produce efficient outcomes within 24 to 48 hours, whereas the majority of bio-products take days or weeks to kill (Akhurst and Smith 2002). Nematodes may be mass produced in a short amount of time, and when used in the field, they are discovered to be compatible with the majority of common agro-chemicals and other biopesticides.

Table1.Commercial use of entomopathogenic nematodes (EPN) *Steinernema* and *Heterorhabditis* as bionematicides.

S. No.	Entomopathogenic nematode species	Major Pest Targeted-recommendation by various commercial companies
1	*Steinernema glaseri*	White grubs (scarabs, especially Japanese beetle, *Popillia* sp.), banana root borers
2	*Steinernema carpocapsae*	Turf grass pests- billbugs, cutworms, armyworms, sod webworms, chinch bugs, crane flies. Orchard, ornamental and vegetable pests - banana moths, codling moths, cranberry girdlers, dogwood borers and other clearwing borer species, black vine weevils, Peachtree borers, shore flies (*Scatella* spp.
3	*Steinernema feltiae*	Fungus gnats (*Bradysia* spp.), shore flies, western flower thrips, leaf miners
4	*Steinernema*	Mole crickets (*Scapteriscus* spp.)

	scapterisci	
5	*Steinernema riobrave*	Citrus root weevils (*Diaprepes* spp.), mole crickets
6.	*H. bacteriophora*	White grubs (scarabs), cutworms, black vine weevils, flea beetles, corn root worms, citrus root weevils
7.	*Heterorhabditis megidis*	Weevils
8.	*Heterorhabditis indica*	Fungus gnats, root mealy bugs, grubs
9.	*Heterorhabditis marelatus*	White grubs (scarabs), cutworms, black vine weevils
10.	*Heterorhabditis zealandica*	Scarab grubs

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