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Sustainable bio-control strategies for managing root grub, *Basilepta fulvicorne jacobus* (Coleoptera: chrysomelidae) in small-cardamom

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Abstract

The current investigation examined the pathogenicity of three indigenous entomopathogenic nematodes (EPNs) - *Heterorhabditis indica* (ICAR-NBAIR strain), *Heterorhabditis bacteriophora* and *Steinernema carpocapsae* supplied as a powder formulation against the root grub of cardamom. In addition to assessing mortality, the study monitored the attachment and penetration rates of the infective juveniles (IJs) into the target insect. *H. indica* exhibited the highest penetration efficiency, outperforming *H. bacteriophora*, while *S. carpocapsae* showed the lowest entry rate; penetration ability was found to depend on the specific infection strategy of each EPN species.

Application of the EPNs involved placing the novel powder at the base of the plant, a method that is rapid, simple and reduces labour requirements. The wettable-powder (WP) formulation proved highly effective in controlling root grub, lowering production costs and decreasing reliance on chemical insecticides such as fipronil, chlorpyrifos and phorate in small-scale cardamom systems. The results indicate that cardamom root grub is susceptible to all three tested EPNs, though their insect-killing capacities differ. *H. indica* (ICAR-NBAIR) and *H. bacteriophora* (ICAR-NBAIR) emerged as the most promising candidates for grub management. These nematodes represent ecologically safe, efficient, sustainable and on-farm recyclable “green” technologies for cardamom cultivation, offering a cost-effective, value-added approach to support sustainable agriculture in small-holder cardamom plantations.

Keywords: Pest management, entomopathogenic nematodes, cardamom, root grub

Introduction

Spices add flavors, aromas, and diversity to cuisines all over the world, making them an integral element of culinary traditions. These aromatic plant compounds not only enhance the taste of our food but also have significant historical and economic value. A range of many areas cultivate spice crops, which boost regional and international economies. However, these valuable goods are still at risk from plant parasitic nematodes, which can have a big impact on the spice industry's profitability (Pervez, 2018) ^[11]. In addition to being valued for their ability to enhance flavor, spices like pepper, ginger, turmeric, cloves, cardamom, and cinnamon are often recognized for their medicinal properties. Many nations and cultures have a long history of using spices to give local cuisine distinctive and delectable flavors. Spice crops have a significant economic impact. For millions of people, they are an essential source of income, especially in tropical and subtropical areas. The production and export of spices is a major industry in nations like Vietnam, Indonesia, India, and Sri Lanka, supporting both their total economic growth and agricultural development. Due to the growing interest in herbal medicines and traditional medicine, as well as the growing desire for unique and exotic flavors in the food and beverage business, this economic sector has been steadily rising.

Cardamom, often called the “Queen of spices,” is the small-seeded variety *Elettaria cardamomum* L. Maton. It ranks among the world's oldest and third-most valuable spices, after saffron and vanilla, and belongs to the Zingiberaceae family.

Indigenous to the evergreen forests of India's Western Ghats, the plant thrives with 1 300-4 000 mm of annual rainfall and temperatures of 10-31.5 °C in cool, shaded sites at 600-1 400 m elevation (Murugan *et al.*, 2024) ^[12]. In the hilly districts of Kerala, Karnataka and Tamil Nadu it is typically cultivated as an under-storey crop beneath forest canopy.

The long-term sustainability of India's cardamom sector depends on tackling issues such as drought, deforestation, pest outbreaks, chemical residues, irrigation management and market competition, while improving traceability and adopting innovative agronomic technologies. Recent yield gains must be converted into economic benefits for growers through effective market exploitation. Low productivity is often linked to biotic stresses, the most important being insect pests. Major pests include thrips (*Sciothrips cardamomi* Ramk.), shoot, panicle and capsule borer (*Dichocrocis punctiferalis* Guen.), shoot fly (*Formosina flavipes* Mall.), red spider mite (*Tetranychus urticae* Koch), coconut scale (*Aspidiotus destructor* Sign.), aphid (*Pentalonia nigronervosa* Coquerel), lacewing bug (*Stephanitis typicus* Dist.) and whitefly (*Dialeurodes cardamomi* David & Subr.). Among these, cardamom thrips and root grub cause the greatest damage, with uncontrolled infestations capable of reducing yields by up to 60%.

Cardamom root grub (*Basilepta fulvicorne*, Chrysomelidae) is a serious threat to small-cardamom roots, typically causing 29-66% yield loss, with individual cases ranging from 10% to 70% depending on infestation intensity (Varadarasan, 1993) ^[4]. The larvae tunnel into roots, causing leaf yellowing and progressive shoot die-back. Although chemicals such as chlorpyrifos and phorate can reduce grub numbers, repeated use harms soil microbes that underpin soil health and disrupts the Western Ghats agroforestry systems where cardamom and other spices are cultivated. Consequently, these insecticides are now banned for cardamom production. Nematodes are widespread, unsegmented roundworms, and more than 30 families contain species that associate with insects and other invertebrates (Lacey *et al.*). These associations range from incidental (phoretic or commensal) to obligate parasitism and pathogenicity (Stock & Hunt, 2012) ^[3].

Entomopathogenic nematodes (EPNs) belonging to the genera *Steinernema* and *Heterorhabditis* are the most promising insect-associated biocontrol agents. These soil-dwelling worms combine traits of parasitoids and pathogens: they locate hosts using chemoreceptors, much like parasitoids, and they carry symbiotic bacteria that kill and digest the insect, acting as pathogens (Lacey *et al.*). EPNs can effectively suppress several lepidopteran, dipteran and coleopteran pests of commercial crops and can be mass-produced in liquid fermenters. Their life cycle relies on a mutualistic relationship with an enteric bacterium that is essential for killing the host insect and converting its tissues into nutrients required for nematode growth and development.

Natural damage and symptoms of attack of root grub

Soil-dwelling insects such as white grubs, cutworms, termites and root grubs are responsible for 24-40% yield reductions in a range of crops including sugarcane, maize, arecanut, cardamom, groundnut, potato, banana, guava, turmeric, pulses, vegetables and grasses with overall direct losses ranging from 20% to 60%. The larvae of these root-feeding pests live in the rhizosphere, where they consume roots, leading to leaf yellowing, wilting and eventual plant death. Ongoing deforestation, depletion of soil organic carbon, suppression of microbial activity and loss of natural antagonists driven by human activity and geological

changes have weakened the ecological balance, allowing these subterranean insects to spread more widely and pose a growing threat to agricultural production.

Root grub is a serious threat to cardamom because its feeding on roots limits nutrient uptake, leading to leaf yellowing; the damage is especially severe in poorly shaded areas. The adult beetle is a small (4-6 mm) shiny insect that may be metallic blue, green or brown, with females larger than males. They are active on cardamom leaves in the early morning and late evening but do not feed on the crop; instead they graze on leaves of jackfruit, mango, guava and similar trees. Adult populations peak in March-April and again in August-September. Females lay 124-393 eggs in batches of 12-63 on dry cardamom leaves or mulch. The creamy-white larvae hatch, drop to the ground, locate the root zone and begin feeding. There are two larval periods: April-July and September-January. The larvae are short, stout, C-shaped and become mature in 45-60 days. Pupation occurs inside an earthen cocoon. The first generation (March-August) lasts 65-102 days, while the second generation (September-February) takes 73-111 days.

Material and Methods

Nematodes can be produced on a large scale and applied with ordinary farm equipment such as sprayers and drip-irrigation systems. For in-vivo multiplication, wax-moth (*Galleria mellonella*) larvae are inoculated with infective juveniles (IJs) of the chosen entomopathogenic nematode (EPN); after the larvae die, the IJs are recovered from the cadavers. Field trials were conducted from 2021 to 2023 in Santhanpara and Vandanmedu villages of Idukki district, Kerala. Two small-cardamom cultivars, 'Njallani' and 'Bhoomi', were planted in 3 m × 3 m plots at the end of June 2021, and all standard agronomic practices were followed except for root-grub control. Five treatments plus an untreated control (see Table 1) were arranged in a randomized block design with three replications. The EPN powder was mixed with water (5 g L⁻¹) and drenched at the base of each plant (≈5 L per plant, delivering 2 × 10⁵ - 4 × 10⁵ IJs). The nematodes emerge from the cadavers in the soil, locate root grubs, and kill them, with applications timed for May-June and September-October. Root-grub counts were recorded from 25 plants per treatment one day before treatment and at 15, 30, and 45 days after application. Data were analyzed using the method of Gomez and Gomez (1998) ^[8].

Results and Discussion:

The data in Tables 1 and 2 show that *Heterorhabditis indica* gave the greatest reduction in root-grub numbers, cutting the population by 12.05% (2022) and 20% (2023) at 15 days after treatment, followed by *H. bacteriophora* (5.65% and 15%) and *Steinernema carpocapsae* (4.15% and 6.75%) relative to the untreated control. At 30 days, the reductions were 35% for *H. indica*, 25% for *H. bacteriophora* and 10% for *S. carpocapsae*. By 45 days the figures rose to 65%, 36% and 32% respectively, and after 60 days the corresponding decreases were 95%, 65.75% and 45.70% compared with the untreated plots. All differences were statistically significant.

Our results align with Menti *et al.* (2000) ^[14], who noted that the pathogenicity of entomopathogenic nematodes can vary markedly between and within species because infective juveniles (IJs) differ in their ability to locate and invade hosts. In our trials, *Heterorhabditis indica* IJs penetrated root-grub larvae more efficiently than *H. bacteriophora* or *Steinernema carpocapsae*, and the penetration rate reflected each isolate's infection strategy. This variation may stem from intrinsic

heterogeneity among root-grub individuals or from the use of distinct nematode isolates. Likewise, Tomalak (2004) ^[15] reported differences in IJ penetration among native EPN isolates

collected from nearby sites, confirming that infection efficiency can differ both between strains of the same species and between different species (Mwaitulo, 2011) ^[16].

Table 1: Effect of entomopathogenic nematodes (EPNs) on root grub population (2021-22)

Treatments	Dose/ha	Percentage of reduction over pre-treatment				Percentage of reduction over untreated control			
		15 DAT	30 DAT	45 DAT	60 DAT	15 DAT	30 DAT	45 DAT	60 DAT
T1:ICAR-NBAIR EPN (<i>Heterorhabditis indica</i>)	8×10 ⁹ nematodes/ha	12.05	20.68	39.40	65.65	8.10	29.00	50.00	67.80
T2:ICAR-NBAIR EPN (<i>Heterorhabditis bacteriophora</i>)	8×10 ⁹ nematodes/ha	5.65	14.25	26.70	45.25	7.90	32.50	61.00	64.00
T3:ICAR-NBAIR EPN (<i>Steinernema carpocapsae</i>)	8×10 ⁹ nematodes/ha	4.15	20.10	24.00	31.50	9.00	30.10	60.00	67.00
Untreated control	-	-	-	-	-	-	-	-	-

Table 2: Effect of entomopathogenic nematodes (EPNs) on root grub population (2022-23)

Treatments	Dose/ha	Percentage of reduction over pre-treatment				Percentage of reduction over untreated control			
		15 DAT	30 DAT	45 DAT	60 DAT	15 DAT	30 DAT	45 DAT	60 DAT
T1:ICAR-NBAIR EPN (<i>Heterorhabditis indica</i>)	8×10 ⁹ nematodes/ha	20.00	30.00	65.00	95.00	10.00	40.00	60.00	87.00
T2:ICAR-NBAIR EPN (<i>Heterorhabditis bacteriophora</i>)	8×10 ⁹ nematodes/ha	15.00	25.00	36.00	65.75	15.00	38.00	75.00	79.00
T3:ICAR-NBAIR EPN (<i>Steinernema carpocapsae</i>)	8×10 ⁹ nematodes/ha	6.75	10.20	32.00	45.70	20.00	32.00	65.00	70.00
Untreated control	-	-	-	-	-	-	-	-	-

Table 3: Effect of various eco-friendly treatments on growth and yield attributes of small cardamom

Treatments	No. of panicle increased per plant	Percentage increase over control	Production (Kg/ha)	Productivity (quintal/ha)
T1:ICAR-NBAIR EPN (<i>Heterorhabditis indica</i>)	65-70	65.25	1502	6.20
T2:ICAR-NBAIR EPN (<i>Heterorhabditis bacteriophora</i>)	41-52	40.01	912	4.68
T3:ICAR-NBAIR EPN (<i>Steinernema carpocapsae</i>)	38-46	30.23	824	3.94
Untreated control	-	-	-	-

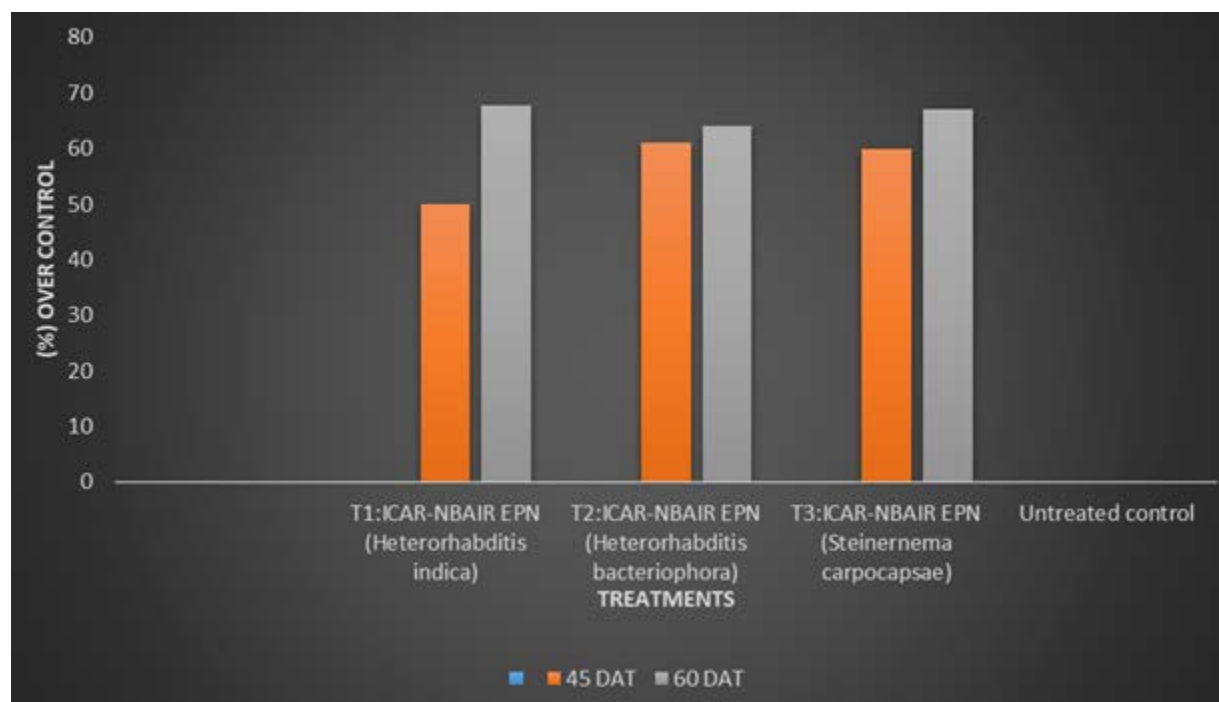


Fig 1: Percentage Control Achieved by Different Entomopathogenic Nematode Treatments at 45 and 60 Days after Treatment (DAT)

Conclusion

In conclusion the soil application of *Heterorhabditis indica* in May and September would significantly effective in reducing root grub population (more than 87%) within 60 days of application and recorded highest yield of 6.20 t/ha with

accounted for 37.28% higher yield than untreated control. Biological control of root grub is a suitable alternative; Entomopathogenic fungi such as *Beauveria bassiana* (on beetles of root grub) and *Metarhizium anisopliae* (on grubs) are pathogenic to the pest, but controlling under field condition is

not highly effective. Entomopathogenic nematode (EPN), a native isolate *Heterorhabditis indica* (ICAR-NBAIR EPN) is highly effective in controlling the pest under field conditions. The technology of mass production and application of EPN, which are user-friendly, in the field, has been standardized. Several farmer groups, NGOs, a commercial firm, and KVK were trained on the technology; more than 500 farmers used EPN in their fields, and root grub problem were effectively controlled in Kerala.

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