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Entomopathogenic Nematodes as Biocontrol Agents in Plant Pathology and Sustainable Crop Health

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Abstract: Entomopathogenic nematodes (EPNs), particularly species of the genera Steinernema and Heterorhabditis, are increasingly recognized as effective biological control agents in modern agriculture. While traditionally applied for insect pest suppression, growing evidence suggests that EPNs play a broader role in plant pathology through indirect and direct mechanisms. This study examines the impact of EPN application on plant disease suppression, soil microbial dynamics, and plant growth enhancement. Laboratory-based experiments demonstrated significant reductions in disease severity and improvements in plant growth parameters following EPN treatments compared to untreated controls ($p < 0.05$). The findings highlight the multifunctional role of EPNs within integrated pest and disease management frameworks and their potential contribution to sustainable crop production.

Keywords: *Entomopathogenic Nematodes; Biological Control; Plant Pathology; Soil Microbiota; Integrated Pest Management; Sustainable Agriculture.*

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I. INTRODUCTION

The increasing demand for sustainable agricultural practices has intensified interest in biological alternatives to chemical pesticides. Entomopathogenic nematodes (EPNs) are microscopic roundworms that parasitize a wide range of insect pests and have been successfully integrated into pest management programs worldwide. Species such as local strain for Georgia *Steinernema carpocapsae* and *Steinernema germanica* sp. from Germany exhibit high virulence against soil-dwelling insect stages and are compatible with environmentally friendly farming systems.Beyond their role in insect control, EPNs may influence plant health and disease dynamics. Insect pests often serve as vectors for plant pathogens or create wounds that facilitate secondary infections. By reducing pest populations, EPNs indirectly limit pathogen transmission. Moreover, interactions between EPNs, their symbiotic bacteria, and soil microorganisms may directly affect plant defense mechanisms and pathogen suppression. This article explores these interactions and evaluates the role of EPNs in plant pathology and sustainable crop health.

➢ *Biology of Entomopathogenic Nematodes*

EPNs belong primarily to the families *Steinernematidae* and *Heterorhabditidae*. Their life cycle involves a symbiotic relationship with bacteria of the genera *Xenorhabdus* and *Photorhabdus*, respectively. Infective juveniles enter insect hosts through natural openings or the cuticle and release their symbiotic bacteria into the host hemocoel. The bacteria rapidly multiply, causing septicemia and host death within 24–72 hours.Following host mortality, nematodes reproduce within the cadaver and eventually release new infective juveniles into the soil. This efficient biological system enables EPNs to persist in agroecosystems under favorable environmental conditions and contributes to their effectiveness as biocontrol agents.

➢ *Role of EPNs in Plant Pathology*

EPNs contribute to plant pathology primarily through indirect mechanisms associated with insect pest suppression. Root-feeding insects frequently facilitate pathogen invasion by damaging plant tissues. The reduction of these pests decreases opportunities for fungal and bacterial infections.Recent studies suggest that EPNs may also exert direct effects on plant health. EPN applications can stimulate systemic resistance responses in plants, enhancing tolerance to pathogens. Additionally, antimicrobial compounds produced by EPN-associated bacteria may suppress soil-borne pathogens within the rhizosphere.

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➢ *Influence on Soil Microbial Communities*

Soil microbial diversity plays a critical role in plant health and disease resistance. EPN introduction alters microbial community structure through the release of symbiotic bacteria and organic substrates derived from insect cadavers. These changes may favor beneficial microorganisms such as nitrogen- fixing bacteria and mycorrhizal fungi. Experimental observations indicate that soils treated with EPNs exhibit increased microbial activity and improved nutrient cycling. Such changes enhance root development and overall plant vigor, indirectly contributing to disease suppression.

II. MATERIALS AND METHODS

Controlled laboratory experiments we were conducted to evaluate the effects of EPN application on plant health and disease severity. *Steinernema carpocapsae* and *Steinernema germanica* we used to soil containing insect pests associated with pathogen transmission. Plant growth parameters, disease incidence, and soil microbial composition were monitored under standardized environmental conditions.

➢ *Statistical Analysis*

Data were analyzed using one-way analysis of variance (ANOVA) to compare nematode-treated plants with untreated controls. Disease severity, plant height, leaf area, and microbial abundance were included as variables. Differences were considered statistically significant at $p < 0.05$.

III. RESULTS AND DISCUSSION

EPN-treated plants exhibited significantly reduced disease severity compared to controls. Both nematode species enhanced plant growth parameters, indicating improved plant health. The observed effects support the hypothesis that EPNs contribute to disease management through both pest suppression and soil health improvement. These findings align with previous research emphasizing the multifunctional nature of EPNs. Their integration into sustainable agricultural systems may reduce reliance on chemical pesticides while maintaining crop productivity.

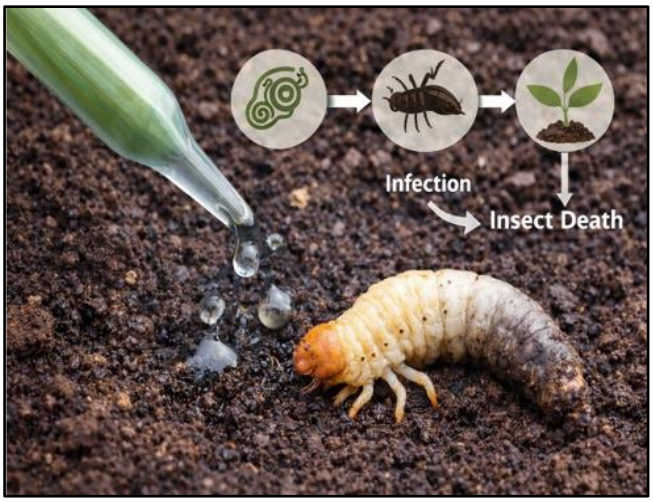

Fig 1 Soil Application of Entomopathogenic

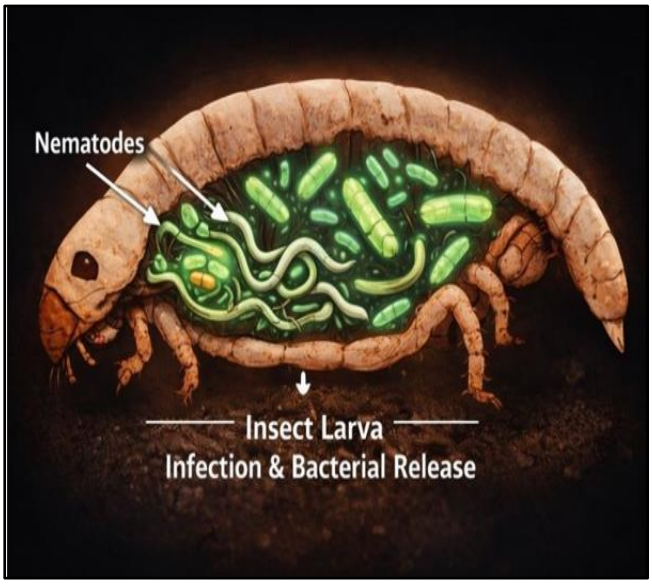

Fig 2 Insect Larva Infection and Bacterial Nematodes Release

Fig 3 Healthy vs Damaged Crops

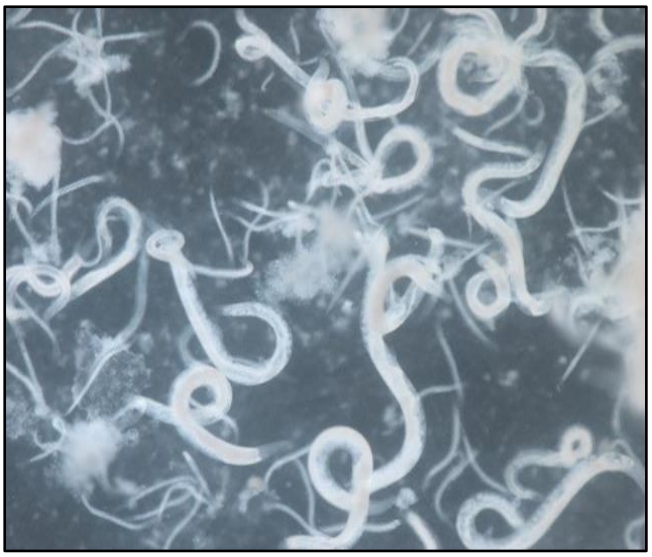
Fig 4 Microscopic View of Entomopathogenic Nematodes *Steinernema Carpocapsae* and *Steinernema Germanica*

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Fig 5 Microscopic View of Entomopathogenic Nematodes *Steinernema Carpocapsae* and *Steinernema Germanica*

IV. CONCLUSION

Entomopathogenic nematodes represent valuable tools in sustainable plant disease management. Their ability to suppress insect pests, influence soil microbial communities, and enhance plant resistance underscores their importance in integrated pest and disease management strategies. Future research should focus on long-term field evaluations and interactions with other biological control agents.

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