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Guava Root-Knot Nematode (*Meloidogyne enterolobii*): A Disease of Quarantine Importance in India

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Guava (Psidium guajava), often referred to as the "poor man's apple," is a significant fruit crop in India due to its nutritional value, affordability, and adaptability to various agro-climatic conditions. India is one of the largest producers of guava, with the fruit being cultivated extensively across tropical and subtropical regions. However, guava production faces numerous challenges, one of the most severe being the threat posed by the root-knot nematode Meloidogyne enterolobii .It is a highly virulent nematode species known for causing significant damage to a wide range of host plants, including guava. This nematode species is of particular quarantine importance in India due to its ability to spread rapidly, its resistance to conventional control measures, and its substantial economic impact on guava production.

Meloidogyne enterolobii as a Quarantine Pest

Meloidogyne enterolobii, commonly known as the guava root-knot nematode, is one of the most aggressive root-knot nematodes. It is a major threat to guava production in India and other guava-growing regions worldwide. The nematode was first described in China in 1983 and has since spread to various countries, including India, where it poses a significant risk to agriculture.This nematode is classified as a quarantine pest due to its ability to cause extensive damage to crops and its potential to spread rapidly across regions. The classification as a quarantine pest implies that Meloidogyne enterolobii is subject to strict phytosanitary measures to prevent its introduction and spread in non-infested areas.

Biology, Life Cycle and Symptoms of *Meloidogyne enterolobii*

Meloidogyne enterolobii is a sedentary endoparasitic nematode, meaning it remains in a fixed location within the host plant's roots throughout its life cycle. The life cycle of M. enterolobii comprises several stages:

Egg Stage: The female nematode lays eggs in a gelatinous matrix on or near the root surface. A single female can lay hundreds of eggs.

Juvenile Stage: The eggs hatch into second-stage juveniles (J2), which are the infective stage. These juveniles penetrate the roots of the host plant and establish feeding sites within the vascular tissue.

Adult Stage: As the juveniles feed, they develop into adult females. The feeding activity of the nematodes induces the formation of root galls, which disrupt the plant's nutrient and water uptake.

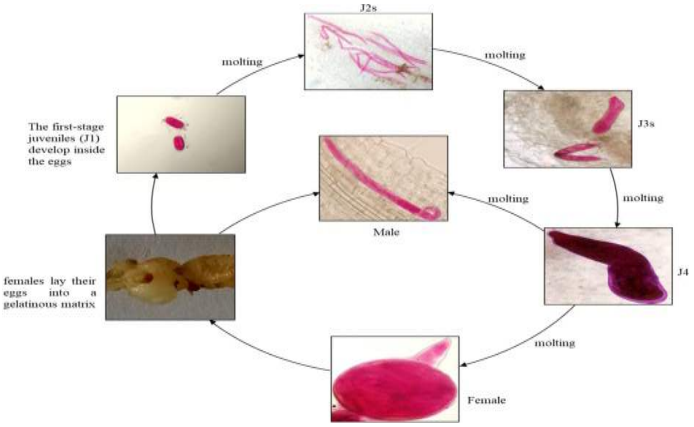
The entire life cycle can be completed in as little as 25 days under favourable conditions, leading to multiple generations per year. This rapid reproduction rate, combined with its ability to infect a wide range of host plants, makes Meloidogyne enterolobii particularly challenging to manage. The root-knot disease caused by Meloidogyne enterolobii manifests in several distinct symptoms, which can be detrimental to the affected plants:

Root Galls: The formation of galls or knots on the roots is the most characteristic symptom of infection. These galls disrupt the normal functioning of the root system, impairing the plant's ability to absorb water and nutrients.

Stunted Growth: Plants infected with M. enterolobii often exhibit stunted growth, reduced vigor, and chlorosis (yellowing of leaves). In severe cases, plants may wilt and die, particularly under stress conditions such as drought.

Reduced Yield: The infection leads to significant reductions in fruit yield and quality, making the fruits less marketable and reducing the overall profitability of guava orchards.

The economic impact of Meloidogyne enterolobii in India is substantial. The nematode not only affects guava production but also poses a threat to other crops, including vegetables and fruit trees. Infestations can lead to the imposition of trade restrictions, as infested



areas may be subject to quarantine regulations that prevent the export of guava and other affected crops. This can result in significant financial losses for farmers and the agricultural sector as a whole.

Geographical Distribution and Spread in India

Meloidogyne enterolobii has been reported in several states across India, particularly in areas where guava is extensively cultivated. The nematode is capable of surviving in a wide range of environmental conditions, which has facilitated its spread across different agro-climatic zones in the country.

Uttar Pradesh

Uttar Pradesh is one of the largest guava-producing states in India, particularly in regions such as Allahabad (Prayagraj), Lucknow, and Gorakhpur. The state has reported several cases of *Meloidogyne enterolobii* infestations, leading to the implementation of quarantine measures. Farmers in these regions are advised to follow strict phytosanitary protocols to prevent the spread of the nematode to other areas.

Maharashtra

In Maharashtra, particularly in regions like Nashik, Pune, and Ahmednagar, guava cultivation is an important agricultural activity. The presence of *Meloidogyne enterolobii* has been confirmed in some of these regions, prompting the state government to enforce quarantine measures. The movement of guava plants and soil from these areas is regulated to prevent the nematode's spread to other parts of the state.

Tamil Nadu

Tamil Nadu, with its extensive guava orchards in districts such as Coimbatore, Salem, and Dindigul, has also reported the presence of *Meloidogyne enterolobii*. Quarantine regulations have been implemented in affected areas, with a focus on controlling the spread of the nematode through soil and plant material. The state agricultural department conducts regular inspections and awareness programs to educate farmers about the risks of *Meloidogyne enterolobii*.

Karnataka

Karnataka, particularly in regions like Bengaluru Rural, Kolar, and Chikkaballapur, is another major guava-producing state where *Meloidogyne enterolobii* has been detected. The state's quarantine measures include restrictions on the movement of guava plants and the implementation of cultural and biological control strategies to manage nematode populations.

West Bengal

In West Bengal, districts such as Nadia, Murshidabad, and Malda are known for guava cultivation. The detection of *Meloidogyne enterolobii* in these areas has led to the enforcement of quarantine protocols to prevent the spread of the nematode to other guava-growing regions. The state's agricultural department is actively involved in monitoring and controlling nematode infestations.

The primary means of spread for *M. enterolobii* include:

- **Contaminated Soil**: The movement of soil containing nematode eggs or juveniles can lead to the spread of the pest to new areas.
- **Infected Plant Material**: The transportation of infected guava plants or other host plants can introduce the nematode into non-infested regions.
- **Irrigation Water**: Water used for irrigation can carry nematode larvae from infested areas to healthy plants, furthering the spread of the pest.

The widespread distribution of *Meloidogyne enterolobii* in India poses a significant challenge for managing the pest and preventing its further spread.

Quarantine Measures and Regulations in India

In response to the threat posed by Meloidogyne enterolobii, the Indian government has implemented several quarantine measures aimed at preventing the introduction and spread of this nematode. These measures include:

Phytosanitary Inspections: Regular inspections of guava plants and other host crops are conducted to detect the presence of *M. enterolobii.* Inspections are particularly stringent for plants and soil intended for export or interstate transport.

Certification Requirements: Before being transported or exported, guava plants and soil must be certified as free from Meloidogyne enterolobii. Certification ensures that the material meets the phytosanitary standards set by importing countries or regions.

Movement Restrictions: The movement of plant material, soil, and equipment from infested areas to non-infested areas is strictly regulated. These restrictions help to contain the pest within already affected regions and prevent its spread to new areas.

Awareness Programs: The government and agricultural extension services conduct awareness programs to educate farmers and agricultural workers about the risks posed by Meloidogyne enterolobii and the importance of adhering to quarantine regulations.

These quarantine measures are crucial for protecting India's guava industry and preventing the spread of Meloidogyne enterolobii to new regions.

Integrated Pest Management (IPM) Strategies

Integrated Pest Management (IPM) is a holistic approach to managing pests, including Meloidogyne enterolobii, by combining multiple control strategies in a coordinated manner. The key components of an IPM strategy for managing *M. enterolobii* in guava include:

Cultural Control

Crop Rotation: Rotating guava with non-host crops can help reduce nematode populations in the soil. However, the selection of rotation crops must be done carefully, as M. enterolobii has a wide host range.

Sanitation: Cleaning equipment and tools used in infested fields before moving to non-infested areas can prevent the spread of the nematode. This includes removing soil from machinery and washing roots of planting material.

Organic Amendments: Incorporating organic matter, such as compost or green manure, into the soil can improve soil health and reduce nematode populations by promoting the growth of beneficial microorganisms that antagonize nematodes.

Biological Control

Nematode-Trapping Fungi: Certain fungi, such as Paecilomyces lilacinus and Purpureocillium lilacinum, can trap and kill nematode juveniles, reducing their population in the soil.

Nematode-Antagonistic Bacteria: Bacteria like Bacillus subtilis and Pseudomonas fluorescens produce substances that are toxic to nematodes or enhance plant resistance to nematode infection.

Biological Soil Treatments: Application of biological control agents, such as nematode-trapping fungi and beneficial bacteria, can reduce nematode populations in the soil.

Breeding for Resistance: Developing guava varieties that are resistant to Meloidogyne enterolobii is an important long-term strategy for managing the nematode. Research is ongoing to identify and develop guava cultivars with enhanced resistance to nematodes.

Chemical Control

Nematicides: The use of chemical nematicides, such as carbofuran and fenamiphos, can be effective in reducing nematode populations in heavily infested soils. However, the use of chemical nematicides should be carefully managed to avoid environmental contamination and the development of nematode resistance.

Soil Fumigation: Soil fumigants, such as 1,3-dichloropropene, can be used to treat infested soils before planting. However, soil fumigation is costly and may not be suitable for all production systems

Molecular diagnostics, gene editing, biopesticides, and biological soil amendments are among the latest advancements being explored. Despite these efforts, challenges remain in managing Meloidogyne

enterolobii effectively. The nematode's wide host range, potential for resistance development, and the complexity of breeding durable resistance in guava are

significant hurdles. Future research should focus on understanding nematode-plant interactions, developing sustainable management strategies, and fostering international collaboration to accelerate the development of effective control measures.

Molecular characteristics *of Meloidogyne enterolobii*

Conclusion

Meloidogyne enterolobii poses a significant threat to guava production in India, particularly in states where the nematode has been reported as a quarantine pest. The classification of M. enterolobii as a quarantine pest underscores the importance of implementing strict phytosanitary measures to prevent its introduction and spread in non-infested areas. Integrated Pest Management (IPM) strategies, combining cultural, biological, and chemical control methods, offer the most effective approach to managing this nematode. Ongoing research and the development of new control measures are essential for ensuring the long-term sustainability of guava production in the face of this formidable pest.

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