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Biology and Management of Potato Nematodes

[1]Supriya Kumari* and [2]Dr. Vijay Kumar

Author's Affiliation
[1]Research Scholar PG. Dept. of Zoology R.N College Hajipur (BRABU Muzaffarpur) Applied for life membership
[2]Associate Professor, PG. Dept. of Zoology R.N College Hajipur (BRABU Muzaffarpur) L17608

***Corresponding Author:**
Supriya Kumari
Research scholar, PG. Dept. of Zoology, R.N College Hajipur, (BRABU Muzaffarpur), Bihar 844101, India.
E-mail: sup698607@gmail.com

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Abstract
Potato cyst nematodes (PCNs), specifically Globodera rostochiensis and Globodera pallida, are significant pests affecting potato crops globally. These nematodes cause considerable yield losses and are difficult to manage due to their resilient cysts that persist in soil for many years. This review examines the biology of PCNs, including their life cycle, host range, and the symptoms and damage they cause. Management strategies discussed include cultural practices (crop rotation, resistant varieties, sanitation, trap crops), biological control (natural enemies, biopesticides, nematophagous fungi), and chemical control (nematicides, fumigants). An integrated pest management (IPM) approach, combining multiple tactics, is emphasized. Regulatory measures like quarantine and certification programs are also addressed. Advances in genetic research, diagnostics, and field trials are highlighted as promising developments for enhancing nematode control. The review underscores the need for a multifaceted strategy to mitigate the impact of PCNs on potato production.

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INTRODUCTION

Potato nematodes, particularly the potato cyst nematodes (PCNs) Globodera rostochiensis and Globodera pallida, pose a significant threat to potato crops worldwide. These nematodes cause substantial yield losses and are notoriously difficult to manage due to their resilient cysts, which can persist in soil for many years (Davies & Elling, 2015). To effectively combat these pests, it is essential to have a thorough understanding of their biology and to implement integrated management strategies (Trudgill, 2014). This comprehensive overview covers the biology of potato nematodes, their impact on crops, and various management approaches.

BIOLOGY OF POTATO NEMATODES

Classification and Morphology

Potato cyst nematodes belong to the family Heteroderidae. They are microscopic, obligate parasites of potato and other solanaceous plants. The two primary species, Globodera rostochiensis and Globodera pallida, are distinguished based on morphological and molecular characteristics (Castillo & Vovlas, 2007; Singh, 2010).

Morphology

- Egg: The eggs are oval-shaped and contained within a cyst. Each cyst can hold several hundred eggs.
- **Juveniles:** The infective second-stage juveniles (J2) are slender, with a spear-like stylet used for penetrating plant roots.
- **Adults:** Adult females are spherical, turning into cysts after fertilization. Males are vermiform (worm-like) and are primarily involved in fertilization.

Life Cycle

The life cycle of potato cyst nematodes includes the following stages: egg, juvenile, adult, and cyst.

1. **Egg:** Female nematodes lay eggs inside their bodies, forming protective cysts. Each cyst contains hundreds of eggs that can survive in the soil for up to 30 years, enduring harsh conditions.

2. **Juvenile:** The infective second-stage juveniles (J2) hatch from eggs in response to host plant root exudates. They migrate through the soil to find and invade potato roots.

3. **Adult:** Inside the roots, J2 nematodes develop into third and fourth-stage juveniles, eventually becoming adults. Male nematodes leave the roots to fertilize females, while females remain inside the roots.

4. **Cyst:** After fertilization, females swell and burst through the root surface, forming cysts that contain eggs. These cysts fall into the soil and protect the eggs until suitable conditions trigger hatching.

Host Range

Potatoes are the primary host for PCNs, but these nematodes can also infect other solanaceous crops, such as tomatoes and eggplants. Additionally, certain weed species like black nightshade (Solanum nigrum) can serve as alternate hosts, complicating control efforts by maintaining nematode populations in the absence of cultivated hosts (Sharma, 2013).

Symptoms and Damage

Infestation by potato cyst nematodes results in several symptoms and types of damage to potato crops:

- **Stunted Growth:** Nematode feeding on roots disrupts nutrient and water uptake, leading to stunted plant growth.

- **Yellowing:** Affected plants often exhibit yellowing leaves, which can be mistaken for nutrient deficiencies.

- **Wilting:** Infested plants may wilt, particularly under water stress conditions, due to impaired root function.

- **Yield Reduction:** Severe infestations can cause significant yield losses, with some fields experiencing total crop failure.

- **Poor Tuber Quality:** Infested plants produce smaller and fewer tubers, reducing the market value of the crop.

Economic Impact

The economic impact of potato cyst nematodes is substantial. Yield losses can reach up to 80% in heavily infested fields. The costsassociated with managing these pests, including soil fumigation, nematicide applications, and the use of resistant varieties, add to the financial burden on farmers. Additionally, infested fields may face quarantine restrictions, limiting market access and causing further economic losses.

MANAGEMENT OF POTATO NEMATODES

Cultural Practices

1. **Crop Rotation:** Crop rotation is a fundamental strategy for managing potato cyst nematodes. Rotating potatoes with non-host crops such as cereals (wheat, barley) and legumes (peas, beans) can significantly reduce nematode populations. However,

effective rotation requires long periods (4-6 years) due to the longevity of cysts in the soil (Kumar et al., 2020).

2. **Resistant Varieties:** The development and use of potato varieties resistant to specific nematode species can effectively reduce nematode populations. Resistance is often based on genetic traits that prevent nematode development or reproduction. However, resistance-breaking nematode populations can evolve, making it essential to use resistant varieties judiciously and combine them with other management practices.

3. **Sanitation:** Preventing the spread of nematodes to uninfested fields is critical. Sanitation measures include cleaning equipment and machinery to remove soil and plant debris that may harbor cysts. This practice is particularly important when moving equipment between fields.

4. **Trap Crops:** Trap crops are plants that stimulate nematode hatching but do not support their development, thereby reducing nematode populations in the soil. For example, certain varieties of Solanum sisymbriifolium can act as trap crops for PCNs.

5. **Fallowing:** Leaving fields fallow (without crops) can help reduce nematode populations. However, this practice may not be economically viable for many farmers.

6. **Green Manures and Cover Crops:** Planting green manures and cover crops like mustard or radish can improve soil health and reduce nematode populations through biofumigation and soil microbial activity

Biological Control

1. **Natural Enemies:** Several natural enemies, including predatory fungi and bacteria, can suppress nematode populations. For instance, the fungus Pochonia chlamydosporia parasitizes nematode eggs and cysts, reducing their viability. Similarly, bacteria such as Pasteuria penetrans can infect and kill nematodes.

2. **Biopesticides:** Commercial products containing nematode-parasitic fungi and bacteria are available for use in infested fields. These biopesticides provide environmentally friendly control options and can be integrated into broader management programs.

3. **Nematophagous Fungi:** Certain fungi, such as Hirsutella rhossiliensis, are known to parasitze and kill nematodes. These fungi can be applied to soil to reduce nematode populations.

Chemical Control

1. **Nematicides:** Nematicides are chemicals specifically designed to kill nematodes. They can be applied as soil drenches, granules, or fumigants. While nematicides can effectively reduce nematode populations, they are often expensive and pose risks to human health and the environment. Common nematicides include organophosphates (e.g., fenamiphos) and carbamates (e.g., oxamyl).

2. **Fumigants:** Soil fumigants, such as methyl bromide and 1,3- dichloropropene, are highly effective against nematodes. However, their use is restricted in many regions due to environmental concerns and potential health hazards.

3. **New Chemical Alternatives:** Research is ongoing to develop safer and more effective chemical alternatives for nematode control. These include bio-based nematicides and novel chemical compounds with reduced environmental impact.

Integrated Pest Management (IPM)

An integrated pest management (IPM) approach combines multiple strategies to manage nematode populations sustainably. Key components of an IPM program for potato cyst nematodes include:

1. **Monitoring and Sampling:** Regular soil sampling to assess nematode population levels is crucial for making informed management decisions. Various techniques, such as soil assays and molecular diagnostics, can be used to detect and quantify nematodes (Jones et al., 2013).

2. **Threshold Levels:** Establishing economic thresholds for nematode populations helps determine when control measures are necessary. Thresholds are based on the relationship between nematode density and crop yield loss.

3. **Combination of Tactics:** Utilizing a combination of cultural, biological, and chemical control methods reduces reliance on any single strategy and mitigates resistance development. For example, crop rotation can be combined with the use of resistant varieties and biopesticides.

4. **Preventive Measures:** Implementing preventive measures, such as quarantine and sanitation, helps prevent the introduction and spread of nematodes to uninfested areas.

REGULATORY AND QUARANTINE MEASURES

1. **Quarantine:** Preventing the introduction and spread of nematodes to non-infested areas through strict quarantine measures is essential. This includes regulating the movement of soil, plants, and equipment from infested to non-infested regions.

2. **Certification Programs:** Ensuring planting materials are free from nematode contamination through certification schemes helps prevent the spread of nematodes. Certified seed potatoes, for example, are produced under stringent conditions to minimize the risk of nematode infestation.

3. **Phytosanitary Measures:** Implementing phytosanitary measures, such as soil testing and treatment, before planting can help reduce the risk of nematode infestations.

RESEARCH AND ADVANCES

1. **Genetic Research:** Identifying and developing new sources of resistance through genetic studies and biotechnological approaches is a priority. Marker-assisted selection and genetic engineering can accelerate the development of resistant potato varieties.

2. **Advanced Diagnostics:** Utilizing molecular techniques, such as polymerase chain reaction (PCR) and loop-mediated isothermal amplification (LAMP), for rapid and accurate detection of nematodes helps inform management practices.

3. **Field Trials:** Conducting field trials to test the efficacy of new control methods and integrated strategies is essential for validating and optimizing management approaches.

4. **Microbiome Research:** Understanding the soil microbiome and its interactions with nematodes can lead to novel biocontrol

CONCLUSION

Effective management of potato cyst nematodes requires a comprehensive understanding of their biology and the implementation of integrated pest management strategies. Combining cultural practices, biological control, chemical applications, and regulatory measures can sustainably reduce nematode populations and mitigate their impact on potato production. Continued research and advancements in genetic and molecular techniques hold promise for developing more effective and environmentally friendly control methods.

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