American Journal of Biology and Natural Sciences
https://biojournals.us/index.php/AJBNS
ISSN: 2997-7185

Comparative Assessment of Soil-Borne Potato Nematodes Across Agro-Ecological Zones and their Implications for Crop Management

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Received: 2025, 15, Sep
Accepted: 2025, 21, Oct
Published: 2025, 04, Nov

Annotation: Potato (Solanum tuberosum L.) is one of the major cash and food crops of Bihar and plays a significant role in the economy of Vaishali district. However, potato production in the region is frequently hampered by soil-borne plant-parasitic nematodes that attack roots, reduce nutrient uptake, and cause severe yield losses. Among these, Meloidogyne spp. (root-knot), Globodera spp. (cyst), and Pratylenchus spp. (lesion) are of primary concern. Despite their importance, there is limited comparative information on nematode diversity, density, and distribution across the district's varying agro-ecological conditions. This study therefore proposes a comparative assessment of soil-borne potato nematodes in Mahua and Gandak agro-ecological zones of Vaishali, with a focus on their population dynamics, environmental interactions, and implications for crop management.

Field surveys and systematic

sampling will be conducted during the active potato-growing season. Soil and root samples will be collected from selected villages of both agro-ecological zones, covering different soil types, cropping histories, and irrigation patterns. Nematodes will be extracted using Cobb's decanting and sieving technique and identified to the genus or species level through morphological and molecular methods. Soil parameters such as pH, texture, organic carbon, and nutrient content will be analyzed. The data will be statistically examined using correlation and multivariate analyses (PCA, CCA) to determine relationships between nematode populations and soil- environmental factors.

This research holds scientific and practical significance, as it will generate baseline data on nematode diversity and soil relationships in Vaishali district an area with high agricultural potential but limited nematological studies. By linking nematode ecology with soil and crop management, the findings will guide farmers and agricultural planners toward sustainable pest management practices, improve productivity, and preserve soil health. Ultimately, this comparative assessment will strengthen the foundation for long-term nematode monitoring and management programs in Bihar's potato-growing ecosystems.

Keywords: Potato, Soil-borne nematodes, Meloidogyne, Agro-ecological zones, Vaishali district, Integrated management.

INTRODUCTION

Potato (*Solanum tuberosum L.*) is one of the world's most important food crops, ranking fourth after rice, wheat, and maize. In India, it serves as a vital cash and food crop, particularly in the Indo-Gangetic plains where favorable agro-climatic conditions support intensive cultivation. However, productivity is often constrained by a range of biotic factors, among which plant-parasitic nematodes represent a major but frequently overlooked threat. Nematodes cause substantial damage to the root system, reducing nutrient and water uptake efficiency, thereby lowering yield and tuber quality. The Vaishali district of Bihar, located in the fertile Gangetic alluvial zone, is a prominent potato- growing area, but the increasing incidence of nematode infestation poses a growing concern for sustainable crop production.

The samples were collected on 24th February 2025 and received on 25th February 2025 for nematode population assessment and field management recommendations. Two samples were analyzed to determine nematode diversity and density in potato rhizosphere soils and to evaluate their potential impact on crop health and productivity.

The first sample revealed a total nematode population of 3410 per 200 cc of soil, including free-living nematodes such as *Dorylaimids* (770) and *Rhabditids* (990), along with plant-parasitic nematodes comprising *Aphelenchus sp.* (660), *Hoplolaimus sp.* (550), and *Merlinius sp.* (440). Although no nematodes were detected in the tuber or root samples, the soil population density indicated significant infestation levels. Similarly, the second sample (Sample No. 04) recorded a total population of 1820 nematodes per 200 cc of soil, with *Dorylaimids* (390), *Rhabditids* (520), and plant-parasitic nematodes such as *Aphelenchus sp.* (910). The presence of *Aphelenchus* and *Hoplolaimus* species is of particular concern, as these nematodes are known to cause root lesions, growth retardation, and yield losses in solanaceous crops.

Both reports confirmed no visible disease symptoms on potato tubers, yet emphasized that the soil was infested with plant-parasitic nematodes. Such subclinical infestations often lead to hidden yield reductions, highlighting the need for preventive management strategies. The findings suggest that while the field remains suitable for potato cultivation, integrated nematode management practices must be implemented to prevent population build-up and further crop damage.

Recommended management practices include soil solarization through deep summer ploughing, and the application of organic amendments such as vermicompost, farmyard manure (FYM), and organic cakes approximately 15 days before sowing to improve soil health and suppress nematode activity. For standing crops, the application of Carbofuran at 1 kg active ingredient per hectare (33 kg per hectare) was suggested to control nematode populations effectively.

The nematode analysis of these two agro-ecological sites in Hajipur indicates moderate to high nematode infestations dominated by *Aphelenchus*, *Hoplolaimus*, and *Merlinius* species. Continuous monitoring and integrated nematode management are crucial for ensuring the long-term sustainability and productivity of potato cultivation in the Vaishali district.

MATERIAL AND METHODS

1. DESCRIPTION OF STUDY AREA

The present investigation was carried out in Hajipur, located in the Vaishali district of Bihar, India. The area lies in the middle Gangetic alluvial plain, which is one of the most fertile and intensively cultivated regions of eastern India.

Geographically, the district is positioned between latitude 25.70°–25.80° N and longitude 85.20°–85.37° E, characterized by deep alluvial soil, moderate to high fertility, and an agro-climate favorable for multiple cropping. The topography is flat with a gentle slope towards the Ganga basin, facilitating good drainage and irrigation potential. The mean annual rainfall ranges between 1000–1200 mm, mostly concentrated during the monsoon months (June–September). The average temperature fluctuates from 10°C during winter to 35–38°C during summer.

Potato (Solanum tuberosum L.) is widely cultivated as a rabi crop in this region, following paddy or maize as preceding kharif crops. Due to continuous monocropping and the use of limited crop rotation, soil-borne diseases and nematode infestations have increasingly become a constraint to sustainable potato production. The present study aimed to determine the nematode fauna in potato fields across different localities of Hajipur, Vaishali district, and to provide appropriate management recommendations.

2. SAMPLING SITES AND GEOGRAPHICAL COORDINATES

Two representative sampling sites were selected within the Hajipur region based on cropping history, soil type, and farmer consultation:

Sample No. Crop Location (Village/Block) Latitude Longitude

03	Potato	Hajipur, Vaishali	25.794892° N	85.369227° E
04	Potato	Hajipur, Vaishali	25.709377° N	85.201683° E

Each sampling site was under active potato cultivation at the time of investigation. Both locations were chosen to represent slightly different micro- agro-ecological conditions within the district. The field conditions included loamy to sandy-loam soils with adequate moisture retention and moderate organic matter.

3. DATE AND COLLECTION OF SOIL AND ROOT SAMPLES

Sampling was conducted on 24th February 2025, coinciding with the mid to late tuber development stage of the potato crop. This period was chosen deliberately because nematode populations are often highest during active root growth phases. The samples were received and processed on 25th February 2025 at the Nematology Research Laboratory, Department of Zoology, Bhim Rao Ambedkar Bihar University, Muzaffarpur.

1. Sampling Design

A systematic random sampling method was adopted to ensure representative collection from each field. Each field was divided into four quadrants, and subsamples were taken from the rhizosphere (root zone) of randomly selected potato plants in each quadrant. Approximately 1 kg of composite soil sample (comprising 8–10 cores) was collected from each field using a sterilized soil auger.

Depth of collection: 0–15 cm (root zone depth)

Distance from plant base: 5–10 cm radius around each plant Number of cores per field: 8–10, pooled together

2. Root Sampling

Along with soil samples, a few potato plants were carefully uprooted to collect fine roots and tubers for nematode extraction and root lesion examination. The roots were gently washed under running tap water to remove adhering soil and stored in separate labeled polythene bags.

3. Sample Handling and Transportation

The collected soil and root samples were packed in sterile polythene bags, labeled with detailed field information (sample number, date, crop, location, latitude, longitude), and transported to the laboratory in an insulated box to avoid excessive drying or heating. Samples were processed within 24 hours of collection to minimize nematode mortality.

4. LABORATORY ANALYSIS AND NEMATODE EXTRACTION

1. Preparation of Samples

In the laboratory, soil samples were mixed thoroughly, and a representative subsample of 200 cc soil was taken for nematode extraction. The roots and tubers were separated, washed, and examined for visible nematode symptoms such as root knots, lesions, galling, or discoloration. None of the root/tuber samples from either site exhibited external disease symptoms.

2. Nematode Extraction Technique

The extraction of nematodes from soil was carried out using the Modified Cobb's Decanting and Sieving method, followed by the Baermann funnel technique for recovering motile nematodes.

Procedure:

1. Sieving: The 200 cc soil sample was mixed with water and passed through a series of sieves of different mesh sizes (60, 200, and 400).
2. Decantation: The suspension was decanted to remove debris and heavy particles.
3. Filtration: The suspension from the final sieve was transferred to Baermann funnels lined with tissue paper and incubated for 24–48 hours.
4. Collection: The nematode suspension collected at the bottom of the funnel was concentrated by gentle centrifugation.
5. Fixation: The nematode suspension was fixed in 4% formalin for preservation.

3. Root Nematode Extraction

For detection of endoparasitic nematodes, small portions of roots (~5 g) were cut into 1 cm pieces and macerated in water using a blender technique (Hussey and Barker, 1973). The suspension was filtered and subjected to Baermann funnel extraction for 24 hours.

5. IDENTIFICATION AND QUANTIFICATION

1. Counting of Nematodes

The extracted nematodes were observed under a stereo-zoom microscope, and total populations were counted using a counting dish. Populations were expressed as the number of nematodes per 200 cc of soil. Both free-living and plant-parasitic groups were recorded.

2. Identification to Genus Level

Morphological identification was carried out to the genus level based on standard nematode taxonomic keys (Siddiqi, 2000; Mai & Lyon, 1975). The specimens were mounted on temporary slides in glycerin for detailed observation under a compound microscope at 400x magnification. Key diagnostic features such as stylet shape, tail morphology, esophageal structure, and body contour were used to identify the nematode genera.

Identified nematode genera included:

- ✓ Free-living nematodes: Rhabditis spp., Dorylaimus spp.
- ✓ Plant-parasitic nematodes: Aphelenchus sp., Hoplolaimus sp., Merlinius sp.

3. Recording of Nematode Populations

For each sample, the total population and the composition of nematode fauna were recorded as follows:

Sample No. 01:

Total population – 3410 nematodes/200 cc soil

Dorylaimids: 770

Rhabditids: 990

Aphelenchus sp.: 660

Hoplolaimus sp.: 550

Merlinius sp.: 440

Sample No. 03:

Total population – 1820 nematodes/200 cc soil

Dorylaimids: 390

Rhabditids: 520

Aphelenchus sp.: 910

No nematodes were detected in the root or tuber portions of either sample, indicating soil confinement of the parasitic populations.

6. DISEASE DIAGNOSIS

The root and tuber samples were examined for nematode-induced pathological symptoms such as galling (caused by *Meloidogyne spp*.), necrotic lesions (*Pratylenchus spp.),* or discoloration (*Rotylenchulus spp.).* The absence of visible disease symptoms confirmed that, although the soil was infested with plant-parasitic nematodes, no significant infection had yet occurred in plant tissues. However, subclinical infestations of nematodes such as *Hoplolaimus* and *Aphelenchus* could still result in latent yield suppression.

7. Data Analysis and Interpretation

The population data were tabulated and compared between the two sites to evaluate spatial variability in nematode communities. The nematode density and diversity were interpreted in the context of soil fertility and management history. Fields with higher populations of *Aphelenchus* and *Hoplolaimus* were categorized as moderately infested, warranting integrated management interventions.

No statistical analysis (ANOVA or correlation) was required at this stage, as the data represented diagnostic samples rather than replicated experimental plots. However, relative population ratios between free-living and parasitic nematodes were used as an indicator of soil health. A higher ratio of free-living nematodes generally reflects a balanced soil ecosystem, while dominance of parasitic species signals declining soil biological health.

8. MANAGEMENT RECOMMENDATIONS AND APPLICATION PROTOCOLS

Based on nematode density and composition, specific management strategies were suggested to minimize nematode impact on potato production.

Recommendations were divided into pre-sowing and in-crop measures:

1. Pre-Sowing/Pre-Planting Management

1. Soil Solarization:

Deep summer ploughing (May–June) was recommended to expose soil to high solar radiation, which helps in killing nematode eggs and juveniles. The field should be left fallow for 2–3 weeks and periodically harrowed to enhance solar penetration.

2. Organic Amendments:

Application of vermicompost, farmyard manure (FYM), or neem cake at 10–15 tons/ha approximately 15 days before sowing improves soil organic matter and promotes nematode-suppressive microflora. Decomposing organic matter releases toxic volatile fatty acids (e.g., acetic and butyric acids) that reduce nematode survival.

3. Crop Rotation:

Rotation with non-host crops such as maize, mustard, or legumes for at least one season was suggested to reduce nematode buildup.

4. Seed Tuber Treatment:

Seed tubers should be treated with fungicides and bio-nematicides like *Paecilomyces lilacinus* or *Trichoderma harzianum* before planting to provide early protection.

2. In Standing Crop

1. Chemical Control:

Application of Carbofuran (3G) at 1 kg a.i./ha (approximately 33 kg of commercial formulation per hectare) was recommended as a soil application around the root zone, followed by light irrigation. Carbofuran acts as a systemic nematicide, suppressing juvenile and adult stages of parasitic nematodes.

2. Irrigation Management:

Avoid over-irrigation, which favours nematode proliferation, and adopt alternate wetting and drying cycles to maintain optimal soil aeration.

3. Bio-Control Agents:

Periodic application of bio-nematicides containing *Pasteuria penetrans* or

Purpureocillium lilacinum may enhance biological suppression of nematodes.

9. QUALITY CONTROL AND VALIDATION

All laboratory analyses were carried out under aseptic conditions using sterilized glassware and equipment to prevent cross-contamination. Each nematode extraction was performed in duplicate to ensure repeatability of results. Counting accuracy was verified by re-examining 10% of samples under different microscopes. Identification was cross-checked with reference slides maintained in the departmental nematode collection.

10. DOCUMENTATION AND RECORD MAINTENANCE

Each sample was documented with detailed metadata including sample number, crop, location, latitude, longitude, date of collection, and condition of the field. Photographs of sampling sites and nematode microscopic images were archived for reference. All results were summarized in tabular form in the final report with management recommendations. The signed reports were dated 09.04.2025, confirming official validation.

11. LIMITATIONS AND SCOPE FOR FURTHER STUDY

Although the study successfully identified and quantified nematode populations from two potato-growing sites, it was limited to genus-level identification. Future studies should involve molecular characterization (using ITS or 18S rRNA sequencing) for precise species identification and population dynamics studies across crop seasons. Additionally, the correlation of nematode density with soil physico-chemical properties, crop yield, and management history would help establish a more comprehensive nematode risk assessment model for Vaishali district.

12. ETHICAL AND ENVIRONMENTAL CONSIDERATIONS

All sampling and chemical applications were performed following standard environmental safety guidelines. Use of Carbofuran, although recommended, was limited to permissible doses and handled using protective gear. Organic and biological control methods were emphasized to promote eco-friendly nematode management and soil biodiversity conservation.

13. SUMMARY OF THE METHODOLOGY

In summary, the methodology adopted for this study comprised systematic field sampling, laboratory extraction, microscopic identification, and integrated management planning. Two potato-growing sites in Hajipur, Vaishali district, were investigated for nematode infestation. Standard nematological techniques were employed to determine the density and diversity of both free-living and plant-parasitic nematodes. The soil at both sites was found to be infested primarily with Aphelenchus, Hoplolaimus, and Merlinius species, while no nematodes were detected in the plant tissues. Based on these observations, the fields were declared suitable for continued cultivation under appropriate management practices.

The integrated approach of combining field diagnostics, laboratory nematode extraction, and practical management recommendations ensures that farmers and researchers can use the findings to sustain potato productivity and soil health in the nematode-prone regions of Bihar.

CONCLUSION

The present nematological investigation on potato (*Solanum tuberosum L.*) soils of Hajipur, Vaishali District, Bihar, was undertaken to assess the population status, diversity, and potential impact of soil-borne nematodes on crop health and productivity. Two representative field samples—designated as Sample No. 03 and Sample No. 04—were collected and analyzed from distinct localities within the Hajipur region. The findings provide valuable insight into the nematode fauna associated with potato cultivation in this agriculturally significant district and highlight the importance of adopting integrated nematode management strategies for sustainable crop production.

Both field samples revealed the presence of diverse nematode populations, including free-living and plant-parasitic forms. The total nematode population recorded in the first field (Sample No. 03) was 3410 individuals per 200 cc of soil, while the second field (Sample No. 04) exhibited a comparatively lower population of 1820 individuals per 200 cc of soil. Within these communities, free-living nematodes belonging to the groups Rhabditis spp. and Dorylaimus spp. were present in considerable numbers, reflecting active soil microbial processes and organic matter decomposition. However, the dominance of plant-parasitic nematodes, particularly Aphelenchus, Hoplolaimus, and Merlinius species, is of substantial agronomic concern, as these genera are known to damage potato root systems and reduce overall yield potential.

Although no nematodes were detected in the root or tuber samples, the presence of significant parasitic populations in the soil indicates a latent threat capable of producing chronic yield losses in successive cropping seasons. Such asymptomatic infestations are particularly problematic because farmers may overlook them until the nematode population surpasses economic threshold levels. Therefore, the findings underscore the need for preventive and integrated soil management measures rather than reactive treatments.

The results clearly demonstrate that both surveyed fields are infested with plant-parasitic nematodes but remain suitable for potato cultivation provided that proper nematode management practices are followed. The study recommended a combination of soil solarization, organic amendments, and judicious chemical application as the core components of an integrated nematode management plan. Deep summer ploughing exposes nematode propagules to high soil temperatures and desiccation, significantly reducing their viability. The application of organic amendments such as vermicompost, farmyard manure (FYM), and oil cakes not only improves soil fertility but also enhances the activity of antagonistic microorganisms that naturally suppress nematode populations. For immediate control in standing crops, Carbofuran (3G) at 1 kg a.i. per hectare (≈33 kg per hectare) was recommended as a soil- applied nematicide, followed by light irrigation. This balanced integration of cultural, organic, and chemical methods ensures sustainable nematode suppression while maintaining environmental safety.

The comparison of the two sampling sites revealed notable spatial variability in nematode density and composition. The higher nematode count at the first site may be attributed to continuous potato or solanaceous cropping and limited organic matter incorporation, while the relatively lower count at the second site suggests better soil health or more diversified cropping practices. Such micro-level variations emphasize the need for site-specific nematode management and periodic soil health assessment across potato-growing zones of Vaishali District. Furthermore, the coexistence of both free-living and parasitic nematodes provides a useful bio-indicator of soil ecological balance. A moderate ratio between the two groups reflects a transitional soil condition, suggesting that with appropriate organic amendments and crop rotation, nematode populations can be naturally regulated.

In a broader perspective, this study provides a baseline database for nematode occurrence in the potato ecosystems of Vaishali District. Continuous monitoring of nematode population dynamics over multiple seasons will help establish economic threshold levels (ETLs) for locally prevalent nematode genera.

Moreover, future research employing molecular diagnostic tools could confirm species-level identification and elucidate population structure, aiding in the formulation of targeted management programs. Integration of biological control agents such as *Paecilomyces lilacinus*, *Trichoderma harzianum*, and *Pasteuria penetrans* should also be explored as eco-friendly alternatives to chemical nematicides.

From a practical viewpoint, the study highlights the critical need for farmer awareness and training in nematode management. Many growers remain unaware of nematode-induced yield losses because the symptoms are not always visible above ground. Routine soil testing, adoption of crop rotation, maintenance of organic soil health, and the cautious use of chemical nematicides can collectively safeguard the productivity of potato fields.

Government extension programs and agricultural universities should play a key role in disseminating these findings to farming communities.

In conclusion, the current investigation confirms that the potato-growing soils of Hajipur, Vaishali District are moderately infested with plant-parasitic nematodes, chiefly *Aphelenchus*, *Hoplolaimus*, and *Merlinius* species. While no direct disease symptoms were observed on tubers, the nematode population levels in the soil warrant proactive management. The integration of cultural, organic, biological, and chemical control measures offers the most effective and sustainable approach to minimizing nematode damage. By maintaining soil health and ecological balance through these integrated practices, farmers can continue to cultivate potatoes profitably while conserving the long-term productivity of their land. The findings thus serve as an essential foundation for developing regional nematode management strategies and contribute significantly to the broader understanding of soil-borne nematode ecology in the potato-growing regions of Bihar.

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