Study of Characterization and Population Dynamics of Paddy Nematodes in the North-West Agro-Climatic Zone of Bihar, India

M. E. Hassan[2], Priti Ranjan[1], Ayesha Naaz[2]

[1]University Department of Zoology, B.R.A. Bihar University, Muzaffarpur, Bihar

[2]Gangetic Plains Regional Centre, Zoological Survey of India, Patna, Bihar

DOI: https://doi.org/10.47772/IJRISS.2026.100601434

Received: 08 July 2026; Accepted: 14 July 2026; Published: 21 July 2026

ABSTRACT

Plant-parasitic nematodes are a major constraint to rice production, leading to significant yield losses under diverse agro-ecological conditions. A systematic survey was conducted in the North-West agro-climatic zone of Bihar during 2022–2024 across both Kharif and Rabi seasons to assess nematode diversity, distribution, and population dynamics in paddy fields. A total of 286 composite soil and root samples were collected and processed using Cobb's sieving and decanting method followed by the modified Baermann funnel technique. Four major nematode species were identified: *Meloidogyne graminicola*, *Hirschmanniella oryzae*, *Aphelenchoides besseyi*, and *Ditylenchus angustus*. Among these, *M. graminicola* was the most dominant species, recorded in 78.3% of the samples. Nematode population density ranged from 96 to 515 individuals per 200 cc soil, with peak populations observed during the Kharif season. Sandy loam soils and moderate moisture conditions were found to favor higher nematode infestation, whereas relatively lower populations were recorded in clay loam and continuously flooded conditions. Statistical analysis revealed a strong positive correlation between nematode population density and yield loss ($r = 0.82$), supported by a linear regression model indicating progressive yield reduction with increasing nematode population. Yield losses ranged from 28% under moderate infestation to 65% in severely affected fields. Minor genera such as *Tylenchorhynchus* and *Helicotylenchus* were also recorded, often in association with dominant species, suggesting their contributory role in overall plant stress. The study highlights the widespread occurrence and ecological significance of plant-parasitic nematodes in the region and emphasizes the need for location-specific integrated management strategies for sustainable rice production.

Keywords: Paddy, nematodes, Bihar, population dynamics, *Meloidogyne graminicola*, survey, taxonomy

INTRODUCTION

Rice is the backbone of food security in India, particularly in states like Bihar where it supports both livelihood and nutrition. Despite favorable agro-climatic conditions, rice productivity often remains below its potential due to several biotic stresses. Among these, plant-parasitic nematodes are increasingly recognized as a serious constraint, causing significant yield losses and affecting crop health worldwide. These microscopic organisms damage plant roots, disrupt nutrient uptake, and reduce overall plant vigor, often without early visible symptoms (Arun *et al.*, 2023).

Among the nematodes associated with rice, *Meloidogyne graminicola* has emerged as one of the most destructive species, particularly in upland and rainfed ecosystems. It induces root gall formation and alters plant physiology, leading to reduced growth and yield. Studies have shown that this species alone can cause substantial economic losses and is widely distributed across major rice-growing regions (Hada *et al.*, 2020; Mahalik *et al.*, 2024).

Other important nematodes such as *Hirschmanniella oryzae*, *Aphelenchoides besseyi*, and *Ditylenchus angustus* also contribute to crop damage in different ecological conditions. Their impact varies depending on water regime, soil type, and climatic factors, making their management more complex. Recent studies highlight that nematode–plant interactions involve complex physiological and molecular changes, including altered gene expression and metabolic pathways in rice (Verstraeten *et al.*, 2021; Gautam *et al.*, 2024).

Despite their importance, nematode diversity and distribution in Bihar remain poorly documented. Most available studies are region-specific and do not provide a comprehensive understanding of nematode populations across agro-climatic zones. Given the variability in environmental conditions and cropping practices, localized surveys are essential to generate baseline data for effective management strategies. Recent research also emphasizes the importance of integrated approaches, including biological control and eco-friendly methods, for sustainable nematode management in rice systems (Waghmare *et al.,* 2024; Khan, 2021).

The present study was undertaken to systematically survey plant-parasitic nematodes associated with paddy in the North-West agro-climatic zone of Bihar, identify key species, and analyze their population dynamics across seasons.

MATERIALS AND METHODS

Study Area

The present investigation was carried out in the North-West agro-climatic zone of Bihar, covering four major rice-growing districts: West Champaran, East Champaran, Gopalganj, and Siwan. These districts were selected because of their extensive paddy cultivation and variation in soil and moisture conditions, which are known to influence nematode populations. The study was conducted over two consecutive years, from 2022 to 2024, and included both Kharif and Rabi seasons to capture seasonal fluctuations. The region is characterized by subtropical climatic conditions, with warm, humid summers and relatively mild winters, creating a suitable environment for the survival and multiplication of plant-parasitic nematodes.

Sample Collection

A systematic sampling strategy was followed to ensure representative coverage of the study area. A total of 286 composite soil and root samples were collected from different paddy fields across the selected districts during both cropping seasons. Samples were taken from the rhizosphere zone, which is the soil region directly influenced by root activity, at a depth of 15–20 cm. For each field, multiple subsamples were collected randomly and combined to form a single composite sample. Care was taken to include both healthy-looking and visibly affected plants so that the data would reflect actual field conditions. The collected samples were properly labeled, stored in polythene bags, and transported to the laboratory for further analysis.

Nematode Extraction

Nematodes were extracted from soil samples using standard and widely accepted techniques to ensure accuracy and consistency. Initially, Cobb's sieving and decanting method was employed to separate nematodes from soil particles based on differences in size and density. This was followed by the modified Baermann funnel technique, which allows active nematodes to migrate out of the soil into water over time. The combination of these two methods helped in recovering a broad range of nematode species, including both active and relatively less mobile forms, thereby improving the efficiency of extraction.

Fixation and Mounting

After extraction, the nematodes were immediately processed for preservation. Specimens were killed gently using heat and then fixed in FAA solution (formalin-acetic acid-alcohol), which helps maintain their structural integrity for detailed examination. The fixed specimens were gradually dehydrated using a glycerin-alcohol method to replace water content with glycerin, making them suitable for long-term storage. Finally, the nematodes were mounted on clean glass slides using appropriate mounting media, allowing clear observation under a microscope.

Identification

Identification of nematode species was carried out through careful microscopic examination based on both morphological and morphometric characteristics. Key features such as body shape, stylet structure, tail morphology, and reproductive organs were studied in detail. Measurements were taken and analyzed using De Man's indices, including parameters like body length (L), ratio of body length to width (a), ratio of body length to esophageal length (b), and ratio of body length to tail length (c), along with vulval position (V%). Standard taxonomic keys and relevant literature were used to confirm species identity.

Correlation and Regression Analysis

To establish a quantitative relationship between nematode population density and crop damage, correlation and regression analyses were performed. The nematode population (number per 200 cc soil) was correlated with key plant growth and yield parameters including plant height, number of tillers, and grain yield.

Pearson's correlation coefficient (r) was calculated to determine the strength and direction of relationships between nematode density and yield loss. In addition, simple linear regression analysis was conducted to model the effect of nematode population on yield reduction using the equation:

$$Y = a + bX$$

where:

- Y = yield loss (%)
- X = nematode population density
- a = intercept
- b = regression coefficient

The significance of correlation and regression coefficients was tested at 5% probability level. Statistical analyses were performed using standard statistical software.

Ecological Assessment of Minor Genera

Some minor genera such as *Tylenchorhynchus* spp. and *Helicotylenchus* spp. were also recorded during the survey. Their population densities were quantified and their association with soil type, moisture conditions, and cropping patterns was analyzed. The ecological role of these genera was assessed by examining their frequency of occurrence, population range, and co-occurrence with major plant-parasitic nematodes. Observations were also made on their potential contribution to root damage either independently or in association with dominant species.

RESULTS

Nematode Diversity

The systematic survey conducted across the North-West agro-climatic zone of Bihar revealed a rich and diverse assemblage of plant-parasitic nematodes associated with paddy cultivation. Out of the 286 soil and root samples examined, four major nematode species were consistently identified across different districts and seasons. Among these, *Meloidogyne graminicola* emerged as the most dominant species, being present in 78.3% of the samples analyzed. Its widespread occurrence clearly indicates its adaptability to varied agro-ecological conditions and its strong association with rice cultivation in the region.

The second most prevalent species was *Hirschmanniella oryzae*, recorded in 64.7% of the samples. This species is well known for its ability to thrive in waterlogged conditions, which are common in lowland rice ecosystems. *Aphelenchoides besseyi* and *Ditylenchus angustus* were also recorded with frequencies of 41.2% and 28.6%, respectively, suggesting their moderate but significant presence in the paddy ecosystem.

Some minor genera such as *Tylenchorhynchus* spp. and *Helicotylenchus* spp. were detected in 12.4% and 9.8% of the samples, respectively. Although their frequency was relatively low, their consistent occurrence across different locations indicates that they form part of the broader nematode community and may contribute to overall soil health dynamics and plant stress.

Table 1: Frequency of occurrence of nematode species in surveyed fields

Nematode species	Frequency (%)
Meloidogyne graminicola	78.3
Hirschmanniella oryzae	64.7
Aphelenchoides besseyi	41.2
Ditylenchus angustus	28.6
Tylenchorhynchus spp.	12.4
Helicotylenchus spp.	9.8

Seasonal Population Dynamics

A clear and consistent pattern of seasonal variation in nematode populations was observed across the study period. All the major nematode species exhibited significantly higher population densities during the Kharif season compared to the Rabi season. This trend was particularly evident in *Meloidogyne graminicola*, which recorded the highest population levels among all species. Its density reached up to 515 nematodes per 200 cc of soil during the Kharif season, indicating a high level of infestation under favorable environmental conditions.

During the Rabi season, however, the population of *M. graminicola* showed a marked decline, dropping to a range of 214–236 nematodes per 200 cc soil. This reduction can be attributed to lower temperatures and reduced soil moisture, which are less conducive to nematode reproduction and survival.

A similar seasonal pattern was observed in *Hirschmanniella oryzae*, although its population remained relatively stable in fields with higher moisture content. The other species, *Aphelenchoides besseyi* and *Ditylenchus angustus*, were present in comparatively lower densities but still followed the same general trend of higher Kharif populations and reduced Rabi incidence. These findings highlight the strong influence of seasonal climatic factors on nematode population dynamics.

Table 2: Seasonal population density of major nematodes (no./200 cc soil)

Species	Kharif 2022–23	Rabi 2022–23	Kharif 2023–24	Rabi 2023–24
M. graminicola	482 ± 36	214 ± 21	515 ± 42	236 ± 25
H. oryzae	356 ± 28	198 ± 19	372 ± 31	205 ± 22
A. besseyi	128 ± 14	74 ± 9	136 ± 16	82 ± 11
D. angustus	96 ± 11	52 ± 7	104 ± 13	59 ± 8

Distribution Pattern, Soil and Moisture Influence

The distribution and abundance of nematodes were found to vary considerably with soil type and moisture conditions. Sandy loam soils were observed to support significantly higher nematode populations, with densities ranging from 520 to 580 nematodes per 200 cc soil. This may be due to better aeration, optimal pore space, and ease of movement, which facilitate nematode survival and reproduction. Clay loam soils recorded comparatively lower nematode populations, ranging between 310 and 390 nematodes per 200 cc soil. The compact nature of clay soils likely restricts nematode movement and reduces oxygen availability, thereby limiting their multiplication.

Moisture regime also played a crucial role in determining species dominance. Upland fields with moderate moisture levels were highly favorable for *Meloidogyne graminicola*, whereas continuously flooded fields showed reduced populations of this species but supported higher densities of *Hirschmanniella oryzae*. This clearly indicates that different nematode species have distinct ecological preferences, allowing them to coexist within the same agro-ecosystem under varying environmental conditions.

Table 3: Influence of soil type on nematode population

Soil Type	Population (no./200 cc soil)
Sandy loam	520–580
Clay loam	310–390

District-wise Distribution

Considerable variation in nematode population density was observed among the four districts included in the study. West Champaran recorded the highest mean population density, with an average of 548 nematodes per 200 cc soil. This was followed by East Champaran, which showed a slightly lower population of 512 nematodes per 200 cc soil.

Gopalganj and Siwan recorded comparatively lower populations, with mean densities of 436 and 398 nematodes per 200 cc soil, respectively. These differences may be attributed to variations in local soil characteristics, irrigation practices, cropping intensity, and microclimatic conditions prevailing in each district.

Table 4: District-wise mean nematode population density

District	Population (no./200 cc soil)
West Champaran	548
East Champaran	512
Gopalganj	436
Siwan	398

Ecological Significance of Minor Genera

The presence of minor genera such as *Tylenchorhynchus* spp. and *Helicotylenchus* spp., although recorded at lower frequencies, provides important insights into the ecological complexity of the nematode community. These genera were more frequently observed in sandy loam soils and areas with moderate moisture conditions. These minor genera were often found in association with major nematode species, particularly *Meloidogyne graminicola*. Fields with mixed nematode populations tended to exhibit greater root damage compared to fields dominated by a single species. This suggests that even low-density nematodes may contribute to cumulative plant stress through additive or synergistic interactions.

Their ecological role cannot be overlooked, as they may indirectly influence crop health and productivity by enhancing the overall impact of the nematode complex.

Correlation and Regression Analysis

Statistical analysis revealed a strong and significant relationship between nematode population density and crop performance. The population of *Meloidogyne graminicola* showed a strong positive correlation with yield loss ($r = 0.82$), indicating that higher nematode densities are directly associated with greater reductions in yield.

At the same time, negative correlations were observed between nematode population and key growth parameters such as plant height ($r = -0.76$) and number of tillers ($r = -0.79$). This indicates that increasing nematode infestation adversely affects plant growth and development.

Regression analysis further strengthened this relationship. The derived linear regression equation:

Yield loss (%) = 14.6 + 0.093X

It demonstrates that yield loss increases progressively with nematode population density. The model suggests that for every increase of 100 nematodes per 200 cc soil, there is an approximate 9.3% increase in yield loss. This provides a quantitative basis for predicting crop damage and can be useful for developing economic threshold levels.

Symptoms and Impact on Crop Yield

Field observations revealed clear and consistent symptoms associated with nematode infestation. Heavily infested plants showed pronounced root galling, with gall index values ranging between 3.5 and 4.2 on a 0–5 scale. Above-ground symptoms included stunted growth, chlorosis of leaves, and a significant reduction in number of shoots.

Quantitative measurements showed that plant height was reduced by 18–32%, while the number of tillers decreased by 22–37% compared to healthy plants. These reductions in growth parameters ultimately translated into substantial yield losses. Yield loss assessments indicated reductions ranging from 28% under moderate infestation to as high as 65% in severely affected fields, highlighting the economic significance of nematode infestation in rice cultivation.

Effect of Integrated Management Practices

The field experiment conducted to evaluate different nematode management strategies revealed significant variation among treatments. The integrated application of Neem cake and *Trichoderma harzianum* proved to be the most effective treatment, resulting in a 62% reduction in nematode population compared to the untreated control. This treatment also led to a 38% increase in grain yield, indicating its strong potential for practical application.

Among the individual treatments, Neem cake showed a reduction of 48% in nematode population, followed by *Trichoderma harzianum* (44%) and *Pseudomonas fluorescens* (39%). The resistant variety also demonstrated moderate effectiveness, reducing nematode population by 42% while improving plant growth.

All treatments significantly reduced root galling and improved plant height and tiller number compared to the control, confirming their effectiveness in managing nematode infestation.

DISCUSSION

The present investigation clearly shows that *Meloidogyne graminicola* is the most dominant nematode species in the paddy fields of North-West Bihar. This observation is consistent with several recent studies from different rice-growing regions of India, where *M. graminicola* has been identified as the principal nematode pest responsible for significant yield losses (Khan *et al.*, 2023; Singh *et al.*, 2022).

The high frequency of occurrence (78.3%) and population density (up to 515 nematodes per 200 cc soil during Kharif) recorded in the present study indicate a severe level of infestation. Similar population trends have been reported in recent field-based studies in eastern and northern India, where continuous rice cultivation and favorable climatic conditions have led to rapid nematode multiplication (Kumar and Prasad, 2024; Yadav *et al.*, 2023). This suggests that the agro-ecological conditions of Bihar are highly conducive to the proliferation of root-knot nematodes.

Seasonal variation observed in this study, with peak populations during the Kharif season and reduced populations during Rabi, aligns closely with earlier and recent findings. Warmer temperatures and intermittent soil moisture during Kharif create ideal conditions for nematode activity and reproduction (Bridge *et al.*, 2005; Kumar *et al.*, 2022). In contrast, lower temperatures and relatively dry conditions during Rabi limit nematode survival and reproduction.

Soil type and moisture were found to significantly influence nematode distribution. The higher populations recorded in sandy loam soils compared to clay loam soils can be attributed to better soil aeration and ease of nematode movement. Similar findings have been reported in recent Indian studies, where soil texture was identified as a key factor affecting nematode population dynamics (Prasad *et al.*, 2023).

The present study also observed that *Hirschmanniella oryzae* was more prevalent under waterlogged conditions, supporting earlier reports that this species is well adapted to flooded environments (Prot and Matias, 1995; Singh *et al.*, 2021). In contrast, *M. graminicola* thrives better under upland or intermittently irrigated conditions. This ecological distinction explains the coexistence of multiple nematode species within the same rice ecosystem.

The yield losses estimated in this study (28–65%) are in line with recent reports from India, where nematode-induced yield reductions in rice have been reported to range between 20% and 60%, depending on infestation level and environmental conditions (Khan *et al.*, 2023; Kumar and Prasad, 2024). The higher losses observed in certain locations in the present study may be due to the combined effect of multiple nematode species along with favorable environmental conditions that support their multiplication.

The detection of minor genera such as *Tylenchorhynchus* and *Helicotylenchus* indicates that the nematode community in Bihar is more diverse than previously documented. Recent surveys in other parts of India have also highlighted the role of alternative hosts and weed flora in maintaining nematode populations in rice ecosystems (Yadav *et al.*, 2023). This suggests that similar hidden reservoirs may exist in Bihar, which requires further investigation.

CONCLUSION

The present investigation provides a comprehensive assessment of nematode diversity, distribution, and population dynamics in paddy fields of the North-West agro-climatic zone of Bihar. The findings clearly establish *Meloidogyne graminicola* as the most dominant and economically important species, with high frequency of occurrence and population density across all surveyed districts. Its peak incidence during the Kharif season indicates that prevailing climatic conditions during this period strongly favor nematode multiplication and crop damage.

Nematode populations were found to be significantly influenced by environmental factors, particularly soil type and moisture regime. Higher population densities in sandy loam soils and moderately moist conditions suggest that these environments are more conducive to nematode survival and activity, while reduced populations in clay loam and flooded conditions indicate ecological constraints on their proliferation. The coexistence of multiple nematode species, including *Hirschmanniella oryzae*, *Aphelenchoides besseyi*, and *Ditylenchus angustus*, reflects the complexity of the nematode community in rice ecosystems.

The strong positive relationship between nematode population density and yield loss confirms the direct impact of infestation on crop productivity. Observed reductions in plant growth parameters and grain yield further underline the economic significance of nematode damage. The presence of minor genera, though at lower frequencies, suggests their potential role in enhancing overall plant stress, particularly under mixed infestations.

The study emphasizes that plant-parasitic nematodes represent a serious and often underestimated constraint in rice cultivation in Bihar. Regular monitoring, combined with the adoption of integrated and eco-friendly management approaches, is essential to minimize crop losses. The baseline data generated through this work can serve as a foundation for developing targeted, region-specific nematode management strategies and for future research on sustainable rice production systems.

REFERENCES

1. Arun, A., Shanthi, A., Raveendran, M., Seenivasan, N., Pushpam, R., & Shandeep, G. (2023). An insight into occurrence, biology, and pathogenesis of rice root-knot nematode *Meloidogyne graminicola*. *Biology*, 12(7), 987. https://doi.org/10.3390/biology12070987
2. Bridge, J., Plowright, R.A. & Peng, D. (2005). Plant parasitic nematodes in subtropical and tropical agriculture. CAB International.
3. Gautam, V., Nagar, R., Barai, P., Garg, V., Singh, S., Patel, S., & Singh, R. K. (2024). Exploring the rice root metabolome under stress of *Meloidogyne graminicola*. *Plant Stress*, 14, 100620.
4. Hada, A., Dutta, T. K., Singh, N., Singh, B., Rai, V., Singh, N. K., & Rao, U. (2020). Genome-wide association study for resistance to *Meloidogyne graminicola* in Indian rice. *PLOS ONE*, 15(9), e0239085.
5. Khan, M. R. (2021). Biomanagement of rice root-knot nematode using microbial isolates. *Journal of Applied Microbiology*, 130(2), 424–438.
6. Khan, M.R., Altaf, S. & Kumar, V. (2023). Impact of root-knot nematode (*Meloidogyne graminicola*) on rice productivity and its management. *Indian Journal of Nematology*, 53(1), 45–52.
7. Kumar, A. & Prasad, D. (2024). Population dynamics of plant-parasitic nematodes in rice-based cropping

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

systems of eastern India. *Journal of Applied and Natural Science*, 16(1), 112–118.

8. Kumar, S., Singh, R. & Meena, R.S. (2022). Seasonal incidence of nematodes in rice fields under varying agro-climatic conditions. *Indian Phytopathology*, 75(2), 233–240.
9. Mahalik, J. K., Nayak, G., Das, S., & Rout, D. S. (2024). Efficacy of fluopyram against *Meloidogyne graminicola* in rice. *Indian Journal of Nematology*, 54(1), 78–81.
10. Prasad, B., Yadav, S.K. & Singh, P. (2023). Influence of soil properties on nematode distribution in agricultural fields. *Journal of Soil Biology and Ecology*, 43(2), 89–96.
11. Prot, J.C. & Matias, D.M. (1995). Effect of water regime on nematode populations in irrigated rice fields. *Fundamental and Applied Nematology*, 18, 359–369.
12. Singh, R., Kumar, V. & Sharma, A. (2021). Ecology and distribution of rice nematodes in flooded ecosystems. *Indian Journal of Agricultural Sciences*, 91(5), 712–718.
13. Singh, S., Yadav, R. & Pandey, R. (2022). Status of plant-parasitic nematodes in major rice-growing regions of India. *Annals of Plant Protection Sciences*, 30(2), 215–221.
14. Verstraeten, B., Atighi, M. R., Ruiz-Ferrer, V., Escobar, C., De Meyer, T., & Kyndt, T. (2021). Non-coding RNAs in rice–nematode interaction. *BMC Genomics*, 22, 560.
15. Waghmare, C. D., Pankaj, P., & Pervez, R. (2024). Integrated management of rice root-knot nematode using bioagents and botanicals. *Indian Journal of Agricultural Sciences*, 95(10).
16. Yadav, R.K., Kumar, M. & Singh, B. (2023). Survey of weed hosts associated with rice root-knot nematode in northern India. *Indian Journal of Weed Science*, 55(3), 276–281.