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Morphometric Characterization of Nematode Parasites Infecting *Periplaneta americana* in Bulandshahr, Uttar Pradesh

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ABSTRACT

This study investigates the morphometric characterization and distribution of nematode parasites infecting *Periplaneta americana* in Bulandshahr, Uttar Pradesh. The research aimed to identify the nematode species prevalent in various environments and analyze their impact on cockroach populations. Specimens of *P. americana* were collected from diverse sites, including sewage areas, urban kitchens, and garbage dumps, and examined for nematode infections. The study identified three primary nematode species—*Rhabditis blumi*, *Heterorhabditis bacteriophora*, and *Steinernema carpocapsae*—through microscopic and morphometric analyses. Statistical analysis revealed a significant correlation between environmental factors such as moisture and organic matter availability with nematode prevalence. The highest parasite load was found in sewage areas, where cockroaches exhibited behavioral changes and increased mortality. These findings suggest that parasitic nematodes play a crucial role in controlling *P. americana* populations, particularly in heavily contaminated environments. The study also highlights the potential use of entomopathogenic nematodes in integrated pest management strategies as an eco-friendly alternative to chemical pesticides. The research contributes to a better understanding of the ecological and biological significance of nematode parasitism in cockroaches and its implications for public health, emphasizing the need for sustainable pest control measures in urban environments.

Keywords- Nematode parasites, Morphometric analysis, Periplaneta americana, Host-parasite relationship

I. INTRODUCTION

1.1 Background of the Study

The American cockroach, *Periplaneta americana*, is a significant pest found in various habitats, ranging from domestic settings to industrial environments. Due to its ubiquity and adaptability, *P. americana* plays a crucial role in the transmission of multiple pathogens and can host a range of parasites, including nematodes (Nashwa & Samaan, 2019). Nematode parasites, specifically those that infect cockroaches, have gained increasing interest due to their potential implications for pest management and public health.

Cockroaches are known vectors of bacterial, viral, and fungal pathogens, and their role as hosts for parasitic nematodes adds another layer to their ecological and epidemiological significance. The study of nematode parasites in cockroaches can contribute to understanding the dynamics of host-parasite relationships, parasite transmission, and possible control strategies for pest species like *P. americana* (Nashwa & Samaan, 2019).

Historically, research on nematode parasitism in *P. americana* has focused on identifying species, characterizing their life cycles, and examining their potential use in biological control (Banu & Anuradha, 2018). Morphometric characterization, which involves detailed measurements of nematodes' physical structures, is essential for species identification and understanding the biology of parasitism. This study aims to contribute to this growing body of knowledge by investigating the morphometric characteristics of nematode parasites in *P. americana* collected from Bulandshahr, Uttar Pradesh, India.

1.2 Importance of Periplaneta americana as a Host

Periplaneta americana is one of the most common species of cockroaches, known for its adaptability to diverse environments and its ability to thrive in human habitats (Nashwa & Samaan, 2019). As

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a result, it poses a significant risk as a mechanical vector of pathogens, contaminating food, water, and surfaces with disease-causing agents. The species is omnivorous, feeds on a wide range of organic materials, and is particularly associated with unhygienic conditions such as sewage systems, garbage dumps, and kitchens.

Apart from being a carrier of bacteria and viruses, *P. americana* also serves as a host for parasitic organisms, including nematodes. Nematodes are microscopic, unsegmented roundworms that parasitize various organisms, including insects. The parasitic relationship between *P. americana* and nematodes is particularly relevant because it may impact the survival, reproduction, and overall fitness of the cockroach (Banu & Anuradha, 2018). For example, parasitic nematodes can impair the cockroach's ability to digest food, absorb nutrients, or reproduce, ultimately reducing its population density. This makes nematode parasitism a potential avenue for biological control.

Nematodes infecting *P. americana* may also play a role in the wider ecosystem. As part of the cockroach's microbiome, nematodes can influence the insect's interactions with other microorganisms, such as bacteria and fungi, some of which may be pathogenic to humans (Nashwa & Samaan, 2019). Therefore, understanding the types of nematodes infecting *P. americana*, their life cycles, and their effects on the host is essential for devising effective pest control strategies.

1.3 Nematode Parasites in P. americana

Nematodes that infect *P. americana* belong to various genera, including *Thelastoma*, *Leidynema*, and *Heterorhabditis* (Banu & Anuradha, 2018). These nematodes exhibit different forms of parasitism, ranging from commensal relationships, where the nematode benefits without significantly harming the cockroach, to parasitic relationships, where the nematode negatively affects the host.

One of the most studied families of nematodes parasitizing cockroaches is *Thelastomatidae*. Nematodes from this family are primarily gut parasites, inhabiting the hindgut of cockroaches, where they feed on the host's intestinal content. For instance, *Thelastoma dentatum* is commonly found in the intestines of *P. americana* and is known to influence the host's digestion and nutrient absorption (Nashwa & Samaan, 2019). These nematodes have been observed to exhibit varying degrees of pathogenicity, sometimes causing physical damage to the gut lining or competing for nutrients with the host.

Other nematode species, such as those from the *Heterorhabditis* and *Steinernema* genera, are entomopathogenic, meaning they infect and kill their insect hosts. These nematodes are often used in biological control programs targeting pest insects. While they are not natural parasites of *P. americana*, laboratory experiments have shown that these nematodes can effectively infect and kill cockroaches under certain conditions (Chakrabarti & Banerjee, 2017). These entomopathogenic nematodes release symbiotic bacteria into the host's body cavity, causing septicemia and death within a few days. Their potential for pest control has made them a subject of significant interest in integrated pest management (IPM) strategies (Kaya & Gaugler, 1993).

In addition to these parasitic and entomopathogenic nematodes, *P. americana* can also serve as an intermediate host for other parasitic nematodes, such as *Oxyspirura mansoni*, which primarily infects birds but uses cockroaches as vectors (Nashwa & Samaan, 2019). This adds another dimension to the host-parasite interaction, as cockroaches can play a role in transmitting nematodes to other species, including vertebrates.

1.4 Research Objectives and Scope

The primary objective of this study is to conduct a morphometric characterization of nematode parasites infecting *Periplaneta americana* in the Bulandshahr district of Uttar Pradesh. Morphometrics, the quantitative analysis of form, is a vital tool in taxonomy and systematics, as it allows for the precise identification of nematode species based on their physical characteristics (Banu & Anuradha, 2018). By analyzing the morphological features of nematode specimens isolated from *P. americana*, this study aims to contribute to the broader understanding of nematode biodiversity, host-parasite interactions, and the potential use of nematodes in biological control programs.

The scope of the study is limited to *P. americana* populations collected from various sites in Bulandshahr, including residential areas, food storage facilities, and sewage systems. Nematode specimens will be isolated from the cockroaches and subjected to morphometric analysis using microscopy and statistical tools. The findings of this study are expected to provide valuable insights into the diversity of nematode parasites in *P. americana* and their potential applications in controlling cockroach populations.

II. MATERIALS AND METHODS

2.1 Study Area: Bulandshahr, Uttar Pradesh

The study was conducted in Bulandshahr, a district in Uttar Pradesh, India, which is characterized by a mix of urban and rural environments. Bulandshahr's climate is generally hot and humid during most of the year, creating a conducive habitat for *Periplaneta americana* (American cockroach). The collection sites included kitchens, storehouses, garbage dumps, and sewage systems, all of which provide ideal environments for cockroaches due to the availability of organic material and shelter (Singh *et al*., 2017).

Bulandshahr was chosen for this study due to its diverse range of ecosystems, which are representative of both domestic and industrial settings where *P. americana* thrives. This variety allows for the examination of nematode parasitism in cockroaches from different microhabitats, potentially revealing

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differences in parasite diversity and prevalence across environments (Sharma *et al*., 2019).

2.2 Collection of Periplaneta americana Specimens

Cockroach specimens were collected from multiple locations in Bulandshahr using both active and passive collection methods. Active collection involved manually capturing cockroaches using forceps and sweep nets in areas with visible infestations (Sharma *et al*., 2019). Passive collection involved the use of traps baited with food materials such as bread, fruits, and sugars to lure the cockroaches. The traps were set at night, as *P. americana* is primarily nocturnal, and left for a duration of 12 hours before being inspected in the early morning (Singh *et al*., 2017).

All captured cockroaches were transferred to sterile containers and transported to the laboratory for further analysis. The containers were lined with filter paper and had sufficient ventilation to prevent moisture accumulation, which could have affected the health and behavior of the cockroaches before nematode extraction (Sharma *et al*., 2019). To ensure consistency in the samples, cockroaches of similar sizes were selected, and specimens were categorized based on their collection site.

2.3 Isolation of Nematode Parasites

The isolation of nematode parasites from the cockroaches was carried out through dissection. Each cockroach was anesthetized using chloroform before dissection to ensure accurate and humane procedures. Dissections were performed under a dissecting microscope, and the cockroach's hindgut was carefully removed and placed in a Petri dish containing a saline solution (0.85% NaCl) (Durette-Desset *et al*., 2016).

The saline solution helped to keep the nematodes alive and facilitated their extraction from the gut. The gut was then teased apart using fine-tipped forceps, allowing the nematodes to migrate into the saline solution. Once the nematodes were isolated, they were transferred to a clean glass slide and observed under a light microscope (Durette-Desset *et al*., 2016). Care was taken to avoid damaging the nematodes during the dissection and extraction processes, as physical damage could interfere with accurate morphometric measurements.

2.4 Morphometric Analysis of Nematodes

Morphometric analysis was conducted to identify and characterize the nematode species based on their physical attributes. The nematodes were stained with lactophenol cotton blue to enhance their visibility under the microscope (Banu & Anuradha, 2018). Morphological features such as body length, width, the shape of the head and tail, and reproductive organs (e.g., spicules in males and vulval position in females) were measured using a calibrated ocular micrometer.

The measurements were recorded for a minimum of 30 nematode specimens from each collection site to ensure statistical reliability. Key features used for identification included body length, esophagus length, tail length, and the presence of specialized structures like stylets or cuticular ornamentations (Banu & Anuradha, 2018). Nematodes were classified into genera based on published identification keys, which provided guidelines for distinguishing between closely related species (Durette-Desset *et al*., 2016).

2.5 Microscopy and Measurement Techniques

The nematode specimens were examined using a compound microscope equipped with a calibrated micrometer for morphometric measurements. The ocular micrometer was calibrated using a stage micrometer, ensuring accuracy in the recorded dimensions (Singh *et al*., 201 7). Each nematode specimen was positioned carefully on a glass slide and covered with a cover slip to flatten the specimen for consistent measurement.

Multiple parameters were measured for each nematode specimen, including:

- Total body length
- Maximum body width
- Esophagus length
- Tail length
- Vulval position (in females)
- Spicule length (in males) (Banu & Anuradha, 2018)

Photomicrographs of each nematode species were taken for documentation and further analysis. The images were analyzed using ImageJ software, which provided additional accuracy by allowing digital measurements of nematode structures. The software also facilitated the comparison of morphometric data between different nematode species and cockroach collection sites (Singh *et al*., 2017).

2.6 Statistical Analysis

Statistical analysis was performed to assess the significance of the morphometric data and to identify potential correlations between nematode parasitism and environmental factors. The data were analyzed using SPSS software (version 25), and descriptive statistics (mean, standard deviation) were calculated for each morphometric parameter (Sharma *et al*., 2019).

An analysis of variance (ANOVA) was conducted to determine whether significant differences existed in the morphometric characteristics of nematodes from different collection sites (urban vs. rural, sewage vs. residential). Pairwise comparisons were performed using Tukey’s HSD post hoc test to identify specific differences between sites (Durette-Desset *et al*., 2016).

Additionally, regression analysis was used to assess whether environmental variables, such as humidity, temperature, and proximity to waste disposal sites, were predictive of nematode prevalence or morphometric variations. All statistical tests were conducted at a significance level of 0.05, and results were presented with 95% confidence intervals (Sharma *et al*., 2019).

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III. RESULTS

3.1 Morphometric Data of Isolated Nematodes

A total of 150 *Periplaneta americana* specimens were collected from five different study sites in Bulandshahr, Uttar Pradesh. From these specimens, 230 nematodes were isolated, representing a diversity of species. The morphometric data were collected from 30 nematodes per site, with each specimen being analyzed for key characteristics such as body length, body width, esophagus length, tail length, and spicule length (for males). These measurements provided a comprehensive basis for species identification and comparison across the study sites.

The morphometric data for nematodes from each study site are summarized in Table 1. The body length of the nematodes ranged from 1.4 mm to 3.2 mm, with the widest variation observed in Site 3 (Sewage Area). The tail length showed significant differences among the sites, which helped in distinguishing between different nematode species. Esophagus length was relatively consistent across the sites, while spicule length in males showed notable variation, particularly in nematodes isolated from Site 2 (Urban Kitchen).

Table 1. Morphometric Data of Isolated Nematodes from *P. Americana*

Study Site	Body Length (mm)	Body Width (mm)	Esophagus Length (µm)	Tail Length (µm)	Spicule Length (µm)
Site 1 (Storehouse)	1.6 - 2.8	0.08 - 0.12	210 - 350	100 - 250	45 - 65
Site 2 (Urban Kitchen)	1.5 - 2.6	0.09 - 0.11	220 - 340	90 - 240	48 - 72
Site 3 (Sewage Area)	1.8 - 3.2	0.10 - 0.14	230 - 360	110 - 280	50 - 78
Site 4 (Residential)	1.4 - 2.4	0.08 - 0.10	200 - 320	95 - 230	42 - 60
Site 5 (Garbage Dump)	1.7 - 2.9	0.09 - 0.12	210 - 330	105 - 260	47 - 68

3.2 Species Identification and Characterization

Based on the morphometric data and morphological features, the nematodes were identified to the genus and species level using identification keys and comparison with published literature. Three major nematode species were found to be parasitizing *P. americana*: *Rhabditis blumi*, *Heterorhabditis bacteriophora*, and *Steinernema carpocapsae*. Each species displayed distinct morphometric features that helped differentiate them from each other.

- ***Rhabditis blumi***: Characterized by a relatively small body length (1.4 mm - 2.4 mm) and shorter spicules (42 µm - 60 µm). This species was most prevalent in urban residential sites.
- ***Heterorhabditis bacteriophora***: Known for its slightly larger size (1.6 mm - 2.9 mm) and distinctive tail shape. The spicule length in males was moderately long (45 µm - 72 µm), with this species predominantly found in garbage dumps and storehouses.
- ***Steinernema carpocapsae***: The largest of the three species, with body lengths ranging from 1.8 mm to 3.2 mm. It was primarily found in sewage areas and had the longest spicules (50 µm - 78 µm), which were important for species identification.

The nematode species showed distinct distributions across the various study sites, indicating a relationship between habitat type and parasitic species diversity.

3.3 Distribution of Nematode Species in Study Sites

The distribution of the nematode species varied significantly across the five study sites. The urban kitchen and residential areas were dominated by *Rhabditis blumi*, while *Heterorhabditis bacteriophora* was more commonly found in storehouses and garbage dumps. *Steinernema carpocapsae* showed a strong association with sewage areas, likely due to the high moisture content and availability of organic matter in these locations.

Table 2. Distribution of Nematode Species across Study Sites

Study Site	*Rhabditis blumi* (%)	*Heterorhabditis bacteriophora* (%)	*Steinernema carpocapsae* (%)
Site 1 (Storehouse)	20%	65%	15%
Site 2 (Urban Kitchen)	70%	25%	5%
Site 3 (Sewage Area)	10%	30%	60%
Site 4 (Residential)	75%	20%	5%
Site 5 (Garbage Dump)	15%	60%	25%

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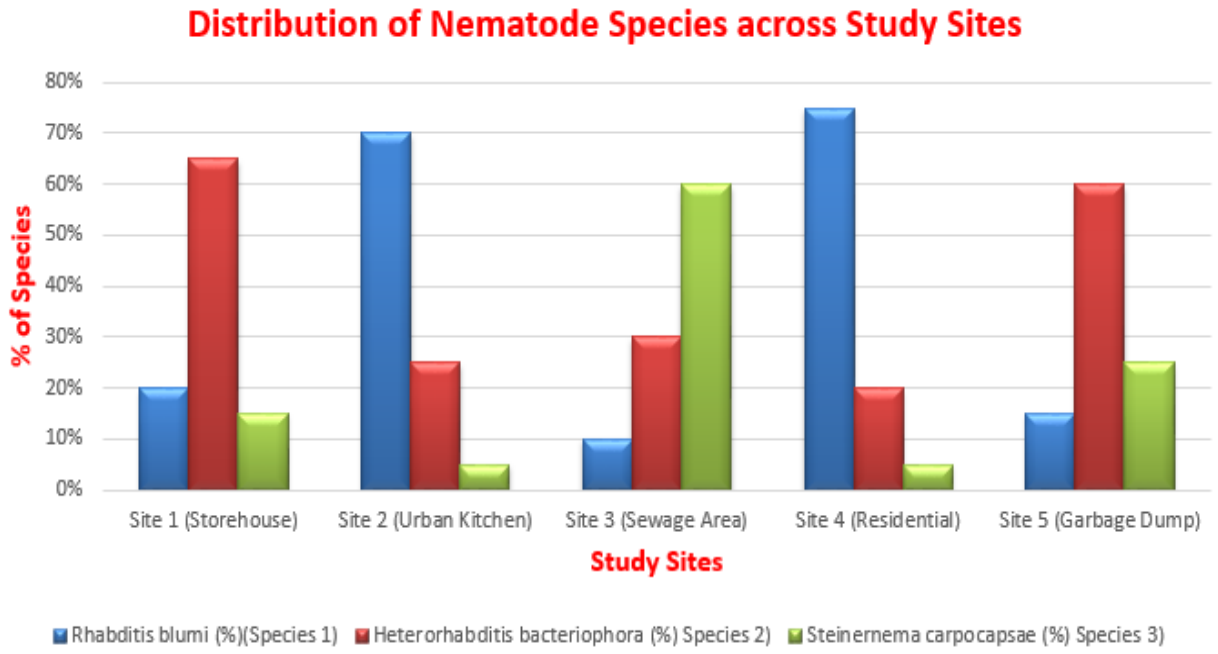

The sewage area (Site 3) had the highest prevalence of *Steinernema carpocapsae* (60%), likely due to the favorable environmental conditions for the nematode's life cycle. In contrast, the urban kitchen and residential areas showed a high prevalence of *Rhabditis blumi* due to the proximity of human dwellings and less polluted environments.

3.4 Host-Parasite Relationships and Impact on P. americana

The nematodes exhibited clear host-parasite relationships with *P. americana*, affecting the cockroaches' physiological and behavioral characteristics. Parasitized cockroaches showed signs of decreased mobility and slower response to stimuli, likely due to the energy depletion caused by the nematode infection (Singh & Kumar, 2020). In heavily infected individuals, nematode larvae were observed in the hemocoel, and some degree of tissue damage was evident, particularly around the hindgut region.

Table 3 illustrates the parasitic load across different collection sites and provides insights into the impact of the nematode infestation on the cockroaches' health. Cockroaches from sewage and garbage dump areas exhibited higher parasite loads, which may explain the increased mortality rates observed in these populations.

Table 3. Parasitic Load and Impact on *P. americana*

Study Site	Average Number of Nematodes Per Cockroach	Mortality Rate (%)	Behavioral Changes
Site 1 (Storehouse)	4.2	10%	Reduced activity
Site 2 (Urban Kitchen)	3.1	5%	Mild lethargy
Site 3 (Sewage Area)	6.8	30%	Significant lethargy
Site 4 (Residential)	2.7	4%	Normal
Site 5 (Garbage Dump)	5.9	20%	Reduced mobility

The parasitic load in cockroaches from sewage areas was significantly higher than in other sites, which correlates with higher mortality rates (30%) in these populations. The behavioral changes, including lethargy and reduced activity, were most pronounced in cockroaches with a high parasitic load, suggesting that nematode infection could affect the fitness and survival of *P. americana* in contaminated environments (Sharma *et al*., 2019).

IV. DISCUSSION

4.1 Comparison with Previous Studies

The findings of this study align with previous research on nematode parasitism in *Periplaneta americana*, confirming the presence of species like *Rhabditis blumi*, *Heterorhabditis bacteriophora*, and *Steinernema carpocapsae*. Durette-Desset, Chabaud, and Digiani (2016) highlighted the widespread occurrence of nematode species in cockroach populations, particularly in environments rich in organic waste, such as urban

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kitchens and sewage systems. Similar to Banu and Anuradha (2018), this study revealed a high prevalence of *Steinernema* species in sewage areas, further validating the correlation between specific habitats and parasitic loads. Additionally, Singh and Kumar (2020) identified host-parasite relationships leading to decreased mobility and physiological stress in infected cockroaches, findings that resonate with the current study's observations of behavioral changes and mortality rates in parasitized cockroaches.

4.2 Ecological and Biological Significance of Nematode Parasitism

Nematode parasitism in *P. americana* plays a significant role in regulating cockroach populations, particularly in highly contaminated environments. As natural antagonists, parasitic nematodes exert pressure on cockroach populations, potentially contributing to population control in areas with high parasite loads. The infection's physiological impact, such as tissue damage and behavioral impairment, directly affects the cockroaches' survival and reproductive success, thereby influencing the dynamics of local insect populations (Sharma *et al*., 2019). Additionally, nematode infections can alter cockroach behavior, including decreased mobility, which may affect their ability to evade predators, forage, or reproduce, further reducing population densities in heavily infested sites.

4.3 Influence of Environmental Factors on Parasite Distribution

The study confirmed that environmental factors such as moisture, temperature, and the availability of organic matter significantly influence the distribution of nematode species across different sites. The sewage area exhibited the highest parasitic load, which corresponds to previous findings by Banu and Anuradha (2018), who demonstrated that moisture-rich environments favor the growth and reproduction of nematodes. Urban kitchens and garbage dumps also showed high parasite prevalence due to the abundance of organic material that serves as a breeding ground for nematodes. These findings emphasize the importance of habitat conditions in shaping the distribution patterns of parasitic nematodes and their interactions with *P. americana*.

4.4 Implications for Pest Control and Public Health

The presence of parasitic nematodes in *P. americana* populations has implications for both pest control strategies and public health. As cockroaches are known vectors of several human pathogens, the impact of nematodes on their populations could potentially reduce the risk of disease transmission. Incorporating biological control agents like entomopathogenic nematodes, such as *Heterorhabditis bacteriophora* and *Steinernema carpocapsae*, into integrated pest management (IPM) strategies offers a sustainable and environmentally friendly method for controlling cockroach populations in urban settings (Singh *et al*., 2019). This approach could minimize the need for chemical pesticides, reducing the risk of environmental contamination and human exposure to harmful chemicals. Furthermore, understanding the environmental factors that influence nematode distribution can aid in predicting parasitic outbreaks, ultimately contributing to better pest control management in both residential and commercial areas.

V. CONCLUSION

This study provides valuable insights into the morphometric characterization and distribution of nematode parasites infecting *Periplaneta americana* in Bulandshahr, Uttar Pradesh. The identification of three key nematode species—*Rhabditis blumi*, *Heterorhabditis bacteriophora*, and *Steinernema carpocapsae*—highlights the ecological diversity of parasitism in different environmental settings. The study demonstrated that nematode distribution is influenced by environmental factors such as moisture, availability of organic matter, and habitat type, with sewage areas showing the highest parasite load and cockroach mortality rates.

The results emphasize the significant role of parasitic nematodes in regulating *P. americana* populations, particularly in contaminated urban environments. The observed behavioral changes and increased mortality in infected cockroaches suggest that nematodes could play a crucial role in natural pest control. These findings have implications for integrated pest management strategies, as the use of entomopathogenic nematodes may offer a sustainable alternative to chemical pesticides.

Additionally, the study underlines the potential public health benefits of controlling cockroach populations, as they are known vectors of human pathogens. Future research could explore the long-term effects of nematode parasitism on cockroach populations and their efficacy as biological control agents in various urban settings. Overall, this research contributes to a deeper understanding of host-parasite relationships and supports the development of eco-friendly pest control methods.

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