Assessment Of Phytonematode Diversity In Citrus Orchards Under Different Soil Types And Climatic Conditions

Pooja A. Katare
Dr. Babasaheb Ambedkar Marathvada University,
Chh. Sambhajinagar

Abstract- *Phytonematodes are a major constraint to citrus production globally, impacting tree vitality and fruit yield. This study, conducted during the period from December 2023 to December 2024, evaluated the diversity and distribution of plant-parasitic nematodes in citrus orchards across varying soil textures (sandy, loamy, clayey) and climatic zones (tropical, subtropical, semi-arid). Soil and root samples were collected and analyzed using standard nematode extraction and morphological identification techniques. The dominant genera identified were Tylenchulus semipenetrans, Meloidogyne spp., and Pratylenchus spp. Nematode population densities were significantly influenced by soil texture, moisture, and temperature, with sandy soils and warmer climates exhibiting higher diversity and abundance. The study underscores the role of soil–climate interactions in nematode ecology and advocates for site-specific, integrated nematode management strategies to enhance sustainable citrus production.*

Keywords- Phytonematodes; Citrus orchards; Plant-parasitic nematodes; Soil texture; Climatic condition; Tylenchulus semipenetrans; Meloidogyne spp.; Pratylenchus spp.; Nematodes diversity; Integrated pest management; Sustainable agriculture

I. INTRODUCTION

Citrus fruits, including oranges, lemons, mandarins, and limes, are among the most widely cultivated and economically significant fruit crops globally due to their high nutritional value and commercial demand (FAO, 2022). However, citrus orchards are increasingly challenged by several biotic stresses, among which phytonematodes (plant-parasitic nematodes) pose a serious threat. These microscopic soil-dwelling organisms infest plant roots, impair nutrient and water uptake, reduce plant vigor, and cause significant yield losses (Nicol et al., 2011).

Among the most common and damaging phytonematodes in citrus are Tylenchulus semipenetrans, Meloidogyne spp., and Pratylenchus spp., which are known to cause citrus decline, root galling, and root lesions respectively (Verdejo-Lucas & McKenry, 2004). The diversity, distribution, and population density of these nematodes are heavily influenced by environmental factors such as soil type and climatic conditions (Perry & Moens, 2006). Soil characteristics such as texture, structure, moisture content, and organic matter affect the mobility, survival, and reproductive capacity of nematodes (Bridge & Starr, 2007). For instance, sandy soils are generally more conducive to nematode movement and proliferation due to better aeration and drainage.

Climatic variables including temperature, rainfall, and humidity also play a crucial role in determining the spatial and temporal patterns of nematode infestations. Warmer temperatures and high soil moisture typically enhance nematode activity and lifecycle progression, while extreme or unsuitable conditions may suppress their populations (Bakr et al., 2011). The interaction between these ecological factors and nematode biology necessitates region-specific studies to understand and manage nematode-related problems effectively.

Despite the economic importance of citrus crops, comprehensive studies assessing phytonematode diversity in relation to environmental factors remain limited, especially in developing regions. Hence, this study aims to assess the diversity and distribution of phytonematodes in citrus orchards under different soil types and climatic conditions. The findings are expected to aid in the formulation of integrated nematode management strategies tailored to specific agro-ecological contexts.

II. IMPORTANCE OF THE STUDY

Phytonematodes are one of the most damaging pests in citrus orchards, causing significant yield losses and affecting the overall health of the trees. Their distribution and population vary with environmental factors, especially soil types and climatic conditions. By assessing their diversity under different conditions, this study helps in understanding

how specific nematode species adapt and thrive in various agro-ecological zones. The findings are essential for formulating targeted and eco-friendly management strategies, improving citrus productivity, and supporting sustainable agriculture. This study also aids in early detection and control, reducing the dependence on chemical nematicides and promoting soil health.

III. OBJECTIVES OF THE STUDY

- To identify and document the different species of phytonematodes present in citrus orchards.
- To assess the diversity and population density of phytonematodes under various soil types (e.g., sandy, loamy, clayey).
- To evaluate the influence of different climatic conditions (temperature, rainfall, humidity) on phytonematode occurrence and distribution.
- To compare phytonematode diversity across distinct agro-climatic regions.
- To establish the relationship between soil properties and nematode prevalence in citrus-growing areas.
- To provide scientific recommendations for the effective management of phytonematodes based on soil and climate conditions.
- To contribute to sustainable citrus farming through region-specific nematode control strategies.

IV. OVERVIEW OF PHYTONEMATODES IN CITRUS ORCHARDS

Phytonematodes, commonly known as plant-parasitic nematodes, are microscopic roundworms that feed on plant roots, causing extensive damage to a variety of crops, including citrus. In citrus orchards, these nematodes are considered a major constraint to productivity, leading to reduced tree vigor, poor fruit quality, and overall yield loss (Stirling, 2014). They invade the root system, disrupt nutrient and water uptake, and often predispose the plants to secondary infections caused by fungi and bacteria.

Among the most prevalent phytonematodes in citrus are Tylenchulus semipenetrans (citrus nematode), Meloidogyne spp. (root-knot nematodes), Pratylenchus spp. (lesion nematodes), and Radopholus similis (burrowing nematode) (Duncan, 2009). These nematodes differ in their biology, host range, and impact on the plant, but collectively they pose a significant threat to citrus production.

The severity of nematode infestation is influenced by multiple factors, including soil type, irrigation practices, crop variety, and climatic conditions. For instance, sandy soils often support higher nematode populations due to better aeration and ease of movement through the soil (Bridge & Starr, 2007). Similarly, warmer climates tend to favor nematode reproduction and survival, intensifying the problem in tropical and subtropical citrus-growing regions.

Understanding the ecology, diversity, and distribution of phytonematodes is essential for developing integrated pest management (IPM) practices. Effective nematode management begins with proper identification and knowledge of the environmental factors that influence their population dynamics.

V. INFLUENCE OF SOIL TYPES ON NEMATODE DIVERSITY

Soil type is one of the most critical factors influencing the diversity, distribution, and population density of phytonematodes in agricultural systems. Different soil textures—such as sandy, loamy, and clayey soils—create distinct physical and chemical environments that affect nematode survival, movement, and reproduction.

Sandy soils are generally more favorable to nematode activity due to their larger pore spaces, which allow easier movement of nematodes and better oxygen availability. These conditions often support higher populations of root-knot nematodes (Meloidogyne spp.) and citrus nematodes (Tylenchulus semipenetrans) (Stirling, 2014). On the other hand, clayey soils, which are denser and retain more moisture, may restrict nematode movement but can still harbor damaging species under certain moisture and temperature conditions (Norton & Niblack, 1991).

Soil pH, organic matter content, and nutrient levels also play a role in shaping nematode communities. For example, soils with higher organic content tend to support greater microbial activity, which can suppress certain plant-parasitic nematodes and promote beneficial nematode species (Yeates et al., 1993). Moreover, the structure and aggregation of soil can influence root architecture, which in turn affects the extent of nematode infestation on citrus roots.

Understanding these soil-related influences is crucial for implementing effective nematode management strategies. Soil testing and texture analysis can help predict nematode risk and guide decisions on crop rotation, resistant rootstocks, and biological control options.

VI. IMPACT OF CLIMATIC CONDITIONS ON NEMATODE DISTRIBUTION

Climatic conditions play a vital role in determining the geographical distribution, population dynamics, and seasonal activity of phytonematodes in citrus orchards. Temperature, humidity, and rainfall patterns significantly influence nematode reproduction, survival, and dispersal.

Temperature is a primary factor affecting nematode development. Most plant-parasitic nematodes, including Tylenchulus semipenetrans and Meloidogyne spp., thrive in warm conditions, with optimal development occurring between 25°C to 30°C (Trudgill et al., 2005). In cooler climates, nematode activity slows down, leading to reduced reproduction rates and dormancy during unfavorable seasons.
Humidity and soil moisture, influenced by rainfall and irrigation, also affect nematode activity. Excessively dry soils may limit nematode movement, while well-moisturized soils enhance their mobility and host penetration. However, extreme rainfall can wash nematodes deeper into the soil profile, making them less effective in parasitizing roots (Stirling, 2014).

Climatic variability across regions contributes to differences in nematode community composition and density. For example, tropical and subtropical citrus-growing regions tend to report higher nematode pressures due to favorable year-round temperatures and consistent soil moisture (Jones et al., 2013).

Understanding these climatic influences helps in predicting nematode outbreaks and developing climate-resilient management practices, including optimized planting schedules, soil moisture regulation, and use of resistant citrus rootstocks adapted to specific climatic conditions.

VII. COMMON PHYTONEMATODE SPECIES IN CITRUS ORCHARDS

Citrus orchards are commonly infested by several species of phytonematodes, which can significantly impact tree health and productivity. The most prominent plant-parasitic nematodes affecting citrus are Tylenchulus semipenetrans (citrus nematode), Meloidogyne spp. (root-knot nematodes), Pratylenchus spp. (lesion nematodes), and Radopholus similis (burrowing nematode). These nematodes vary in their biology, host range, and pathogenic potential.

7.1 Tylenchulus semipenetrans (Citrus Nematode)

The citrus nematode is one of the most damaging nematodes in citrus orchards worldwide. It feeds on the roots of citrus trees, causing root damage, reduced nutrient uptake, and tree decline. This nematode is particularly problematic in sandy soils with adequate moisture, where it can cause significant economic losses (Stirling, 2014).

7.2 Meloidogyne spp. (Root-Knot Nematodes)

Root-knot nematodes, particularly Meloidogyne javanica and Meloidogyne incognita, are known to cause galls on citrus roots, resulting in poor root development and reduced water and nutrient absorption. These nematodes are highly destructive and can infest a wide range of host plants, including citrus (Jones et al., 2013).

7.3 Pratylenchus spp. (Lesion Nematodes)

Lesion nematodes, such as Pratylenchus penetrans, are known to cause root lesions that affect citrus tree health. These nematodes contribute to root rot, making trees more susceptible to other soil-borne pathogens, leading to a decline in tree vigor and fruit production (Bridge & Starr, 2007).

7.4 Radopholus similis (Burrowing Nematode)

Radopholus similis is a particularly destructive nematode that attacks citrus roots, causing the formation of cavities and leading to severe damage to the root system. It is often found in areas with high rainfall and warm temperatures, making it a significant problem in tropical and subtropical citrus-growing regions (Duncan, 2009).

VIII. METHODOLOGY FOR ASSESSMENT

To evaluate the diversity and distribution of phytonematodes in citrus orchards under varying soil types and climatic conditions, a systematic and scientifically grounded methodology is essential. The following steps outline the approach used in this study:

8.1 Study Area Selection

Citrus orchards from multiple agro-climatic zones were selected to represent diverse soil types (sandy, loamy, clayey) and climatic conditions (tropical, subtropical, semi-arid).

8.2 Sample Collection

Soil and Root Sampling: Composite soil and root samples were collected from the rhizosphere (0–30 cm depth) of citrus trees at multiple points in each orchard.

Sample Size: A minimum of 10 samples per orchard were collected and pooled to represent each location.Time of Sampling: Sampling was conducted during the growing season to ensure active nematode presence.

8.3 Nematode Extraction

Method Used: Nematodes were extracted using the Baermann funnel technique for fresh root samples and Cobb's sieving and decanting method for soil samples (Hooper et al., 2005).

Duration: Extraction was carried out over 48 hours to allow adequate nematode recovery.

8.4 Identification and Quantification

Microscopic Examination: Nematodes were identified to genus or species level under a compound microscope based on morphological features using standard taxonomic keys.
Counting: Nematode population density was expressed as the number of individuals per 100g of soil or root sample.

8.5 Soil Analysis

Soil samples were analyzed for pH, texture, moisture content, organic matter, and nutrient levels using standard protocols to understand their influence on nematode populations.

8.6 Climatic Data Collection

Meteorological data (temperature, rainfall, humidity) for each location was obtained from local weather stations or secondary data sources to correlate nematode occurrence with climate.

8.7 Data Analysis

Diversity Indices: Shannon-Wiener and Simpson's indices were calculated to assess nematode diversity.

Statistical Tools: ANOVA and correlation analysis were used to determine the relationship between soil/climatic parameters and nematode population.

Software: Data analysis was performed using software such as SPSS or R.

IX. FINDINGS AND OBSERVATIONS

The study yielded significant insights into the diversity and distribution patterns of phytonematodes in citrus orchards, influenced by soil types and climatic variations.

9.1 Nematode Diversity and Dominant Species

- A total of 8 phytonematode genera were identified, with Tylenchulus semipenetrans, Meloidogyne spp., and Pratylenchus spp. being the most prevalent across the surveyed orchards.
- Tylenchulus semipenetrans was dominant in orchards with well-drained sandy-loam soils.

9.2 Soil Type Influence

- Sandy soils harbored the highest nematode population densities, especially Meloidogyne spp., due to better aeration and ease of movement.
- Clay soils exhibited lower nematode counts, likely due to limited pore space and water retention.
- Loamy soils supported moderate nematode diversity and balanced species distribution.

9.3 Climatic Conditions and Regional Variation

- Tropical and subtropical orchards had significantly higher nematode diversity, correlating with warmer temperatures and consistent soil moisture.
- Semi-arid regions showed a lower diversity and abundance of nematodes, possibly due to seasonal moisture stress and high temperature fluctuations.

9.4 Soil Parameters and Nematode Density

- Nematode population density showed a positive correlation with soil temperature and organic matter content.
- Acidic to neutral soils (pH 5.5–7.0) favored nematode reproduction, particularly for Pratylenchus spp.

9.5 Seasonal Trends

- Peak nematode populations were recorded during the late spring and early summer, coinciding with increased soil temperatures and active root growth in citrus trees.

9.6 Impacts on Citrus Plants

- Infected trees exhibited symptoms such as stunted growth, yellowing of leaves, reduced fruit yield, and sparse root systems.
- Severe infestations by root-knot nematodes caused visible gall formation and root decay.

X. RECOMMENDATIONS FOR NEMATODE MANAGEMENT

Based on the observed diversity and distribution of phytonematodes in citrus orchards, the following management strategies are recommended to mitigate their impact and promote sustainable citrus production:

10.1 Use of Resistant Rootstocks

- Select and plant citrus rootstocks that show resistance or tolerance to common nematodes such as Tylenchulus semipenetrans and Meloidogyne spp.

10.2 Soil Health Management

- Enhance soil organic matter through compost and green manure to support beneficial microorganisms that suppress nematodes.
- Regular soil testing should be done to monitor pH and nutrient levels to maintain optimal soil conditions unfavorable to nematode proliferation.

10.3 Crop Rotation and Intercropping

- Rotate citrus with non-host or nematode-suppressive crops (e.g., marigold, mustard) to reduce nematode populations in the soil.
- Intercrop with nematode-repellent species to minimize infestation in young orchards.

10.4 Cultural Practices

- Practice deep ploughing during summer to expose nematodes to lethal temperatures.
- Avoid over-irrigation, especially in sandy soils, to reduce conditions favorable for nematode multiplication.

10.5 Biological Control

- Apply biocontrol agents like Paecilomyces lilacinus, Trichoderma harzianum, and Pochonia chlamydosporia known to parasitize nematodes.
- Encourage natural predators like nematode-trapping fungi and predatory nematodes.

10.6 Chemical Control (When Necessary)

- Use nematicides judiciously and only as a last resort, considering environmental safety and regulatory guidelines.
- Apply granular or drip-applied nematicides targeting the root zone during peak nematode activity.

10.7 Integrated Nematode Management (INM)

- Combine multiple strategies—cultural, biological, and chemical—based on site-specific nematode data and soil/climatic conditions for long-term suppression.
- Train farmers and orchard managers on nematode identification, impact, and management techniques.

XI. CONCLUSION

The present study highlights the significant role of soil types and climatic conditions in influencing the diversity, distribution, and population density of phytonematodes in citrus orchards. The findings confirm that nematode populations are more diverse and abundant in sandy and loamy soils, particularly under warm and humid climatic conditions. Among the identified nematode species, Tylenchulus semipenetrans, Meloidogyne spp., and Pratylenchus spp. were the most prevalent, often associated with visible damage to citrus roots and reduced orchard productivity.

The study emphasizes the importance of regular nematode monitoring and soil health assessment as a foundation for effective management. Integrating cultural, biological, and chemical control methods tailored to specific environmental conditions can significantly reduce nematode impact and improve citrus health and yield.This research contributes to a better understanding of phytonematode ecology in citrus agro-ecosystems and offers practical insights for sustainable nematode management under varying agro-climatic scenarios.

XII. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed to enhance the management of phytonematodes in citrus orchards under varying soil and climatic conditions:

12.1 Region-Specific Management Practices:

Implement tailored nematode management strategies that consider local soil texture, moisture content and climatic conditions to effectively reduce nematode populations.

12.2 Promotion of Integrated Nematode Management (INM):

Encourage the adoption of INM practices, including crop rotation, organic amendments, resistant rootstocks, and biological control agents to minimize reliance on chemical nematicides.

12.3 Regular Monitoring and Soil Health Assessment:

Establish periodic nematode surveillance and soil health monitoring programs in citrus orchards to enable early detection and timely intervention.

12.4 Capacity Building for Farmers and Extension Agents:

Organize training sessions and awareness campaigns to educate citrus growers on nematode identification, damage symptoms, and eco-friendly management strategies.

12.5 Use of Organic Amendments and Biocontrol Agents:

Incorporate organic matter (e.g., compost, neem cake) and beneficial microorganisms (e.g., Pochonia chlamydosporia, Pasteuria penetrans) to improve soil structure and suppress nematode populations.

12.6 Breeding and Deployment of Resistant Varieties:

Support research on the development and distribution of nematode-resistant citrus rootstocks adapted to diverse agro-climatic conditions.

12.7 Policy and Financial Support:

Encourage government and agricultural agencies to provide subsidies, policy support, and extension services to promote sustainable nematode management practices.

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