International Journal of Botany

ISSN: 1811-9700

OPEN ACCESS International Journal of Botany

ISSN 1811-9700
DOI: 10.3923/ijb.2024.26.33

Research Article
Seasonal Fluctuation in Nematode Population Associated with Soil Moisture in *Mangifera indica* and *Psidium guajava*

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Abstract

Background and Objective: Mango (*Mangifera indica*) and Guava (*Psidium guajava*), an economically significant fruit tree, were chosen to explore the influence of seasonal variations on the population of plant parasitic nematodes i.e., *Hoplolaimus indicus*, *Tylenchorhynchus brevilineatus* and *Helicotylenchus indicus* around the roots. This study related the seasonal fluctuation of phytonematode population of *Mangifera indica* and *Psidium guajava* associated with soil moisture (soil edaphic factor). **Materials and Methods:** In the present work the author has attempted to analyse population dynamics of plant parasitic nematodes infestation *Mangifera indica* (mango) and *Psidium guajava* (guava) under field conditions at Meerut (Western Uttar Pradesh). Soil samples were collected from three vertical depths (0.0-20.0; 20.01-40.0 and 40.01-60.0 cm) and three horizontal distances (30, 60 and 90 cm) from the stem of the host i.e., mango and guava from September, 2021 to February, 2022. Identification of phytonematodes was confirmed by the Indian Agricultural Research Institute in New Delhi. **Results:** Nematode distribution (both vertical and horizontal) in cultivated soil is frequently linked to that of plant roots and rhizosphere. Plant parasitic nematodes were found to be most abundant in the top layer (0.0-20 cm) of soil. The middle layer was 20.01-40 cm in depth, while the lowest stratum measured 40.01-60 cm. The findings also reveal that the multiplication of *Hoplolaimus indicus* was greater. Soil moisture exhibited a positive connection with total nemic population. When the percentage of soil moisture was high, the nematode population was at its peak. **Conclusion:** The ecological research of plant parasitic nematodes is vital in reducing infestations of practically all phytonematode parasites. Mango and guava are suitable hosts for *Helicotylenchus indicus*, *Tylenchorhynchus* and *Tylenchorhynchus brevilineatus*.

Key words: Phytonematodes, soil moisture, *Mangifera indica*, *Psidium guajava*, seasonal fluctuation

Citation: Kumkum, 2024. Seasonal fluctuation in nematode population associated with soil moisture in *Mangifera indica* and *Psidium guajava*. Int. J. Bot., 20: 26-33.

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Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Meerut District is located in Western Uttar Pradesh, India. Ecto- or endo-parasitic phytonematodes cause harm to crops. Aside from grain and vegetable crops, nematodes harm fruit trees, decorative flowers, shrubs and home garden plants. Nematodes cause plant damage is frequently missed due to the lack of identifiable symptoms. Plant parasitic forms produce not only mechanical harm to the roots, stems, leaves and flower structures of many plants, but also other non-specific symptoms such as sluggish growth, stunting and yellowing, which can also be linked to two nutritional and water-related illnesses. Mango (*Mangifera indica*) and guava (*Psidium guajava*) are among India's most significant fruit crops. The geographical pattern of related plant parasitic nematodes has received little consideration. The author sought to analyze the population dynamics of plant parasitic nematode infestations of *M. indica* (mango) and *Psidium guajava* (guava) under field circumstances in Meerut (Western Uttar Pradesh). The degree of harm done is determined by the pathogenic potential and population expansion of nematodes, which are heavily impacted by their starting population densities[1,2]. The quantity and spread of plant parasitic nematodes are controlled by soil texture, crop cycle and human activities[3]. As a result, the study of soil moisture in ecological studies is critical anytime the research is concerned with population densities at different soil layers and distances from the host plants. Thus, analyzing the distribution of plant parasitic nematodes around mango and guava roots is crucial not only for determining the pathogenic potential of the nematodes in a given location, but also for detecting nematode infection hotspots. A grove of mangoes (*Mangifera indica*) and guavas (*Psidium guajava*) was highly infested with three significant plant parasitic nematodes: *Hoplolaimus indicus*, *Helicotylenchus indicus* and *Tylenchorhynchus brevilineatus* around the roots. Vertical movement has been studied more extensively than horizontal movement. It has also been shown that the distribution of nematodes is typically associated with the dispersion of roots. It has also been shown that the distribution of nematodes is typically associated with the dispersion of roots.

As a result, the current study sought to examine the distribution of plant parasitic nematodes around mango roots at three vertical depths (0.0-20.0, 20.01-40.0 and 40.01-60.0 cm) and (30, 60 and 90 cm) three horizontal distances from the host's stem. The nematode population will be determined by a number of elements, the most significant of which is the environment, including the host. In India, several studies have been conducted on plant parasitic nematodes connected with various crops[4] (leguminous vegetable crops in West Bengal)[5] (agricultural crops, Gujarat and Diu union territory)[6] (pineapple ecosystem, Meghalaya)[7] (Pine trees, Himachal Pradesh)[8] (litchi plantations, Tripura)[9] and (banana, Thanjavur, Tamil Nadu). Almost all edaphic parameters[10], including soil temperature, moisture, pH, organic matter, soil humus, amino acids, nitrogen, phosphorus, calcium, potash and other plant micro and macro nutrients, have a major impact on nematode population variations. Soil moisture refers to the presence of water in soil, which affects nematode life cycles. It is also a crucial medium for active migration in soil. As a result, the study of soil moisture in ecological studies is critical anytime the research is concerned with population densities at different soil layers and distances from the host plants.

As a result, the objective of this study on the population fluctuations of phytonematodes connected with fruit plants (mango and guava) in the District Meerut of Western Uttar Pradesh associated with soil moisture (soil edaphic factor) was studied.

MATERIALS AND METHODS

Soil sampling: The observation period was from September, 2021 to February, 2022. Soil samples were taken at random from a mango (*Mangifera indica*) and guava (*Psidium guajava*) orchard located 20 km from Meerut City. Two 3-hectare plots were chosen to ensure ectoparasite consistency around mango and guava root zones. The plants were five years old and the plots were divided into micro-plots to decrease sampling errors sampling was done bimonthly using an auger at three vertical depths (0.0-20.0, 20.01-40.0 and 40.01-60.0 cm) and three horizontal distances (30, 60 and 90 cm) from the plant stem. The 216 soil samples were taken between September, 2021 and February, 2022. Five samples of each were merged to form a single sample.

Storage: Soil samples were maintained in polythene bags to avoid moisture loss and appropriately labelled. Soil samples were collected and analyzed within a day or two, as far as practicable. The additional soil samples were maintained at 15°C for further edaphic factor investigation.

Extraction of nematodes: Cobbs[11] shifting and gravity technique is used to process soil samples (250 mL each) for nematodes. For this, the dirt was placed in a bucket, filled with water and stirred to ensure a uniform suspension. The suspension was allowed to calm down. The nematodes float above the suspension. The suspension was passed through a succession of sieves, including 60, 100, 200 and 350 meshes. The residue from each sieve was condensed and put into a 250 mL beaker via a cotton sieve lined with tissue paper. The bottom of the cotton sieve stayed in contact with water overnight. To measure the population density of different nematodes, the contents of the beaker were passed through 350 meshes to lower the amount (up to 10 mL), placed into a counting plate and the nematodes were counted under a binocular microscope (Olympus Microscope-MLX-B Plus, Germany). Total numbers of nematodes were counted by genera. Genera-specific nematodes were then collected using a tiny wire needle attached to a small, thin wooden holder. The many types of nematodes isolated from soil samples were mounted and classified into genera and species.

Soil moisture: Soil moisture was assessed in the laboratory using the dry and wet weight technique. The obtained soil samples from various depths and distances were packed in polythene bags and sent to the laboratory to calculate the percentage of soil moisture. A certain quantity of soil samples was weighed (for fresh weight) and then dried in the oven at 105°C (for dry weight) using the approach suggested by Mishra[12].

Calculation:

$$\text{Moisture (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

The recorded data are presented as:

- ***Mangifera indica*:** Vertical depth 0.0-20.0 cm (Table 1), 20.01-40.0 cm (Table 2) and 40.01-60.0 cm (Table 3) up to 90 cm horizontal distances
- ***Psidium guajava*:** Vertical depth 0.0-20.0 cm (Table 4), 20.01-40.0 cm (Table 5) and 40.01-60.0 cm (Table 6) up to 90 cm horizontal distances

Statistical analysis: The relationship was analyzed with Excel software (Microsoft Office Professional Plus 2019, version 2208) and analyzed with SPSS 7.5 by One-way Analysis of Variance (ANOVA) followed by the LSD multiple range test. Significance among factors was considered at the level of $p<0.05$. Also using Pearson's correlation coefficient (R) and linear regression analysis.

Identification: Phytonematodes were identified using keys and validated by the Indian Agricultural Research Institute in New Delhi. The following worms were collected and recognized as having ecologically significant distributions: *Hoplolaimus indicus*, *Helicotylenchus indicus* and *Tylenchorhynchus brevilineatus*.

RESULTS

Soil moisture: Nematode distribution (both vertical and horizontal) in cultivated soil is often connected to that of plant roots and the rhizosphere. All plant nematodes spend varied amounts of time in soil during their life cycles. The effect of soil edaphic elements induces nematode population growth. It was discovered that seasonal changes had a direct impact on nematode populations. The population was concentrated at 20 cm deep, followed by 40 and 60 cm depths.

Fluctuating soil moisture can also increase or decrease the population of phytonematodes. The control of plant parasitic nematodes surrounding perennial crops is difficult because population behavior has a direct impact on management measures. During the six-month investigation, it was discovered that the total number of nemic populations was connected with soil moisture and that soil moisture exhibited a strong positive association surrounding both plants. Guava plantation roots showed a significant adverse association at 40.01-60.0 cm vertical depth, 30 cm ($p<0.10$) and 60 cm horizontal distance ($p<0.40$). Table 7 shows a functional linear regression that depicts the link between edaphic parameters and the total nemic population versus both plants. The data demonstrated that seasonal factors have a direct influence on the nematode population densities (Table 1).

The soil population of plant parasitic nematodes was largest in the top layer (0-20 cm). The intermediate layer was 20.01-40 cm deep, with the lowest stratum being 40.01-60 cm. The data also show that the multiplication of *Hoplolaimus indicus* was higher. It shows that mango and guava are excellent hosts for *Hoplolaimus indicus* and moderate hosts for *Tylenchorhynchus brevilineatus* and *Helicotylenchus indicus* (Table 1 and 6).

Soil moisture changes significantly as a result of biological and physical processes. It may be a significant medium for the active movement and passive dispersal of phytonematodes in soil. The retentive capacity of moisture in soil is highly reliant on soil texture and other elements that define soil phase (soil particles). Clays, which are made up of incredibly minute particles, have a large surface area, small holes and consequently excellent water retention properties.

In the current investigation, a strong positive association was found with soil moisture around both plants. Functional linear regression trend confirmed a positive relationship with the total nemic population under *M. indica* and *P. guajava*.

Table 1: Mean monthly data of population and edaphic factors at 0.0-20.0 cm vertical depth around root zones at *M. indica* at Meerut

Year	Month	Population (×100)	Moisture (%)
2021	September	9.3±0.03 (2-19)	1.62±0.01 (0.8-2.04)
	October	57.67±0.06 (9-79)	23.0±1.03 (19.4-25)
	November	11.2+1.04 (8-15)	55.6±2.08 (33-66)
	December	19.3±1.01 (13-27)	24.4±0.04 (23-25)
2022	January	29.6±1.01 (5-49)	25±0.06 (24-26)
	February	24.3±1.01 (24-29)	16.3±1.01 (14-25)

Table 2: Mean monthly data of population and edaphic factors at 20.01-40.0 cm vertical depth around root zones at *M. indica* at Meerut

Year	Month	Population (×100)	Moisture (%)
2021	September	9.33±1.01 (2-13)	1.62±0.04 (0.8-2.04)
	October	29.33±1.05 (4-60)	20.5±1.04 (11.1-31.5)
	November	6.33±0.05 (3-8)	41.7±2.07 (25-66.6)
	December	16.67±1.07 (15-17)	29.8±0.06 (23.4-42.8)
2022	January	28.67±1.32 (5-51)	11.4±0.09 (0.8-31.5)
	February	17±2.39 (7-32)	9.51±1.01 (2.04-23.4)

Table 3: Mean monthly data of population and edaphic factors at 40.01-60.0 cm vertical depth around root zones at *M. indica* at Meerut

Year	Month	Population (×100)	Moisture (%)
2021	September	15.33±1.01 (5-27)	2.04±0.05 (2.02-2.06)
	October	18.67±1.00 (3-39)	28.9±0.68 (19.4-42.8)
	November	5.33±0.05 (2-9)	36.8±0.03 (19.0-42.8)
	December	13.33±1.01 (6-24)	24.7±1.01 (24.1-25.0)
2022	January	13.6±1.04 (5-26)	15.4±1.02 (2.04-25)
	February	20.3±1.00 (18-40)	15.0±0.69 (1.0-42)

Table 4: Mean monthly data of population and edaphic factors at 0.0-20.0 cm vertical depth around root zones at *P. guajava* at Meerut

Year	Month	Population (×100)	Moisture (%)
2021	September	6.33±1.16 (1-12)	2.03±0.06 (2.02-2.04)
	October	20.67±1.01 (3-33)	3.59±1.02 (0.80-11.1)
	November	18±1.02 (4-26)	42.8±0.05 (19.0-66.6)
	December	36.3±1.05 (18-67)	25.1±0.06 (23-27)
2022	January	14.33±0.69 (11-21)	8.86±0.05 (0.80-2.04)
	February	24.67±1.02 (12-34)	1.67±0.05 (1.0-2.04)

Table 5: Mean monthly data of population and edaphic factors at 20.01-40.0 cm vertical depth around root zones at *P. guajava* at Meerut

Year	Month	Population (×100)	Moisture (%)
2021	September	13.3±1.01 (8-31)	2.03±0.05 (2.02-2.04)
	October	20.6±0.06 (3-33)	3±1.05 (0.80-11.1)
	November	22.67±1.02 (4-35)	50.7±0.03 (19.04-66.6)
	December	16±1.04 (12-20)	23.9±2.01 (23.4-25)
2022	January	21±1.04 (6-41)	8.86±1.18 (7.7-7.9)
	February	21±1.13 (17-28)	3.73±0.08 (3.68-3.76)

Table 6: Mean monthly data of population and edaphic factors at 40.01-60.0 cm vertical depth around root zones at *P. guajava* at Meerut

Year	Month	Population (×100)	Moisture (%)
2021	September	6.33±0.02 (4-9)	2.04±0.01 (2.04-2.04)
	October	6.33±0.03 (5-7)	2.3±0.05 (0.80-25)
	November	14.67±1.02 (2-33)	58.6±1.75 (42.8-66.6)
	December	17.3±0.58 (15-27)	23.9±1.26 (24.3-25)
2022	January	36.3±1.05 (24-49)	17.1±0.05 (0.8-31.5)
	February	22±0.50 (15-35)	9.34±0.05 (1.0-25)

A substantial negative association was observed between 40.01-60.0 cm vertical depth and 30 cm horizontal distance ($r = -0.30$; $p<0.40$; Table 7) and 60 cm horizontal distance ($r = -0.30$; $p<0.40$) at the same depth surrounding the guava plantation. A similar finding was made at 0.0-20.0 cm vertical depth and 30 cm horizontal distance ($r = -0.54$; $p<0.01$; Table 7) and at 20.01-40.0 cm depth and 60 cm horizontal distance ($r = -0.32$; $p<0.40$) surrounding the root zones of guava plants. The positive correlation was observed (Table 7) at 00.00-20.0 cm vertical depths, as well as at 30 cm ($p<0.40$) and ($p<0.10$), 60 cm ($p<0.10$) and ($p<0.40$), 90 cm ($p<0.40$) and ($p<0.20$) horizontal distances around root zones of mango

Table 7: Functional linear regression depicting correlation of soil moisture with total nemic population under *M. indica* and *P. guajava*

Distance/depth	*Mangifera indica*	*Psidium guajava*
H = 30 cm		
V = 0.0-20.0 cm	Y = -20.5969+2.2883X	Y = 16.9930-1.0426
	r = 0.36 and p<0.40	r = -0.54 and p<0.01
V = 20.01-40.0 cm	Y = -75.7193+4.7741X	Y = -0.5973+0.5175X
	r = 0.61 and p<0.05	r = 0.30 and p<0.40
V = 40.01-60.0 cm	Y = 126.0976-1.5438X	Y = -3.8943+0.4519X
	r = -0.30 and p<0.40	r = 0.50 and p<0.10
H = 60 cm		
V = 0.0-20.0 cm	Y = -69.3175+2.6041X	Y = -1.6029+0.4281X
	r = 0.54 and p<0.10	r = 0.30 and p<0.40
V = 20.01-40.0 cm	Y = -33.3941+1.7597X	Y = -10.1742+0.8985X
	r = 0.36 and p<0.40	r = 0.32 and p<0.40
V = 40.01-60.0 cm	Y = 133.6407-1.6596X	Y = -6.5961+0.7761X
	r = 0.30 and p<0.40	r = 0.32 and p<0.40
H = 90 cm		
V = 0.0-20.0 cm	Y = -11.2384+0.5374	Y = -19.1713+1.6271X
	r = 0.40 and p<0.40	r = 0.42 and p<0.20
V = 20.01-40.0 cm	Y = -26.4884+1.4829X	Y = -28.3189+1.9712X
	r = 0.62 and p<0.05	r = 0.45 and p<0.20
V = 40.01-60.0 cm	Y = -15.4529+0.9840X	Y = -28.3189+1.9712X
	r = 0.70 and p<0.025	r = 0.56 and p<0.10

H: Horizontal distance from host plants and V: Vertical depths

plants and guava plants. Positive correlation was observed at 20.01-40.0 cm vertical depth (30 cm horizontal distance, ($p<0.05$) (mango plant) and ($p<0.40$, guava plant) at 60 cm ($p<0.40$) (mango plant) and ($p<0.40$, guava plant) and 90 cm ($p<0.05$) (mango plant) and ($p<0.20$, guava plant). At 40.01-60.0 cm vertical depth (60 cm horizontal distance, ($p<0.40$) (mango plant) and at 90 cm ($p<0.025$) (mango plant) and ($p<0.40$, guava plant) and 90 cm ($p<0.05$) (mango plant) and ($p<0.10$, guava plant).

The data provided and summarized in Table 1-7, clearly showed that the population of plant parasitic nematodes was at its peak in that month when the soil moisture content was higher. The nematode population decreased in dry soil conditions. It multiplied again when the mango and guava plants were irrigated. Nematode population numbers vary with soil moisture and temperature. The number of several nematode species grew with rising moisture levels, but it decreased during dry circumstances. The soil pH was shown to have minimal effect on the nematode population. Nematode populations drop when soil moisture levels fall and temperatures rise.

DISCUSSION

Nematodes have a sluggish metabolism when exposed to cold temperatures and high moisture tension, causing them to consume food more slowly. Although the pre-adult stage is resistant to desiccation, data suggests that the nematode is heavily influenced by moisture. Temperature and moisture interactions have an impact on survival as well. The positive link with soil moisture was consistent with Wallace *et al.*[13] findings, which show that population density correlated with edaphic factors and discovered that *P. penetrans* is more likely to thrive in soils with high moisture tensions than slow moisture tensions. Wallace[14] suggested that immobilization in thin moisture films, as well as adequate aeration, contribute to higher survival in dry soil. Seinhorst[15] claims that all Dutch rivers and coastal clay soils appear to be contaminated with stem nematodes and that the illness on onions persists in heavy clay soil but not in sandy soil. In the current study, the soil of both orchards (mango and guava) was clay, which led to a substantial infestation of ectoparasitic phytonematodes. This might possibly be due to the increased growth of secondary roots during and after rain, which provides a suitable platform for nutrients. The addition of moisture, whether from rainfall or irrigation, typically has a significant impact on nematode behaviour. The nature of these alterations is, of course, determined by the amount of moisture provided as well as the edaphic and climatic conditions in place at the time.

The regulatory parameters impacting the ecology of these nematodes included in the study include soil moisture and their correlation. Rani and Resha[16] investigated the effects of soil temperature and moisture on the population dynamics of ectoparasitic nematodes that infest sugarcane. Siddiqui[17] investigated the seasonal fluctuations in nematode populations related to mango and guava. Maximum nematode populations were observed at high moisture and low soil temperature (July), whereas minimal nematode populations were detected throughout the pre- and post-monsoon seasons, with soil temperature and moisture ranging from high to low. Sen *et al.*[18], Bakonyi *et al.*[19] investigated how temperature and moisture impact soil nematode population structure in semiarid shrubland.

This nematode was discovered predominantly in sandy soils and its population density was found to be positively associated with soil moisture[20]. The population complex and measures of nematode community structure and sources of variability among and within fields[21]. Soil nematodes rely on soil moisture to protect their soft bodies and to provide nutrients for free-living worms[22]. Studies have demonstrated that soil moisture and soil patches have a key role in nematode survival under dry conditions[23-25].

According to several research, soil moisture and temperature have an influence on nematode populations such as *Helicotylenchus* in guava orchards[26] and increasing soil water has a favorable connection[27]. Yeates *et al.*[28] observed that nematodes are highly impacted by soil moisture content. According to Radová and Trnková[29], soil dryness must be avoided or soil moisture should be kept at a level suitable for the lowest nematode activity. Bakonyi and Nagy[30] proposed that temperature is more relevant than soil moisture content in modifying the nematode community.

Drought conditions may have induced a change in plant parasitic nematode populations. Drought conditions during the summer months (April, May and June) are produced by regularly high soil temperatures (30-39°C) and low soil moisture content, which has a detrimental influence on the nematode population. Nematode population declines in dry conditions may be induced by desiccation or nematode migration deep into the soil. Plant nitrogen content is affected by physiological stress produced by soil moisture deficiency.

In the winter (December and January), low soil temperatures (22 and 17°C) may have a negative impact on nematode population numbers. These soil temperatures, together with soil moisture content, can reduce nematode populations. Aside from these concerns, seasonal changes linked with the host plant's development[31], i.e., a transitory increase during each phase of active growth followed by a fall to a host-specific level, are likely to have occurred in our work. The soil population of nematodes was highest in the higher soil layer (10 cm), possibly due to the presence of more feeder roots at this level. However, soil pH has little effect on nematode populations.

As a result, it is possible that the change in nematode population densities was caused by either soil moisture, soil temperature, or a combination of the two. The results were consistent with Dao[32] and Saeed and Ghaffar[33]. The present observations place a high value on data on the distribution and variation of nematode population densities around mango and guava roots over different seasons. The ecological research of plant parasitic nematodes can help to reduce infestations of practically all phytonematode parasites. When beginning disease control programs, it is critical to understand the average density of nematode species that live in plant rhizospheres. These data suggest that plant parasitic nematodes linked with guava and mango have different population fluctuations throughout the year. This research has the potential to greatly benefit the Nematode Pest Management Programme.

CONCLUSION

The examination of the links between variations in soil parameters and irregular patterns should lead to a better understanding of how these organisms interact with the soil environment. The population density of nematodes is a reaction to the soil environment. Soil microsites with varying physical and chemical qualities have a variety of effects on the nematode and host plant. Thus, based on the foregoing findings, seasonal fluctuations in nematode populations inhabiting the rhizospheres of guava and papaya might be attributed to the direct influence of soil temperature, moisture or their combination on the activity and pace of growth of nematode pests.

SIGNIFICANCE STATEMENT

The soil is the core of life and any change (such as moisture, pH, organic matter, etc.) in the soil will undoubtedly impact the health of plants, other creatures and the delicate wave of the terrestrial ecosystem, both directly and indirectly. The relationships between soil edaphic factors, phytonematodes and plant hosts have been identified. When the soil moisture content is low, nematode infections on plants can be controlled to complete their life cycle. This will assist to prevent pests on the plant. Thus, ecological considerations can be critical when using components such as chemicals on a restricted scale and biocontrol agents.

ACKNOWLEDGMENT

I am immensely grateful to the principal and head of the Zoology Department of CCS University, Meerut, for providing required facilities and field investigations. The authors would like to thank Dr. A.K. Choubey for informative conversations about this study.

REFERENCES

1. Chandra, P., R. Sao, S.K. Gautam and A.N. Poddar, 2010. Initial population density and its effect on the pathogenic potential and population growth of the root knot nematode *Meloidogyne incognita* in four species of cucurbits. Asian J. Plant Pathol., 4: 1-15.
2. Udo, I.A. and K.I. Ugwuoke, 2010. Pathogenicity of *Meloidogyne incognita* race 1 on turmeric (*Curcuma longa* L.) as influenced by inoculum density and poultry manure amendment. Plant Pathol. J., 9: 162-168.
3. Chirchir, A.K., J.W. Kimenju, F.M. Olubayo and G.K. Mutua, 2008. Abundance and distribution of plant parasitic nematodes associated with sugarcane in Western Kenya. Asian J. Plant Pathol., 2: 48-53.
4. Roy, K., A.K. Mukhopadhyay and A. Pramanik, 2007. Occurrence, distribution and community analysis of plant parasitic nematodes associated with leguminous vegetable crops in West Bengal. Indian J. Nematol., 37: 58-62.
5. Patel, A.D., B.K. Panickar, B.A. Patel and D.J. Patel, 2007. Community analysis of plant parasitic nematodes associated with agricultural crops in Junagadh district of Gujarat and Diu-union territory. Indian J. Nematol., 37: 68-71.
6. Devi, G., 2007. Community analysis of plant-parasitic nematodes in pineapple ecosystem in Meghalaya. Indian J. Nematol., 37: 106-107.
7. Sapna, N., C.K. Deepak, W.K. Kum, K.W. Raman and K.B. Harish, 2009. Community analysis of plant parasitic nematodes associated with rhizosphere of chir pine nurseries and pine trees in natural forests of Himachal Pradesh, India. Indian J. Nematol., 39: 182-187.
8. Nath, R.C., B.C. Sinha, B. Mukherjee and M.K. Dasgupta, 2009. Community analysis and diversity of plant parasitic nematodes associated with litchi plantations in North Tripura District. Pest Manage. Hortic. Ecosyst., 15: 51-59.
9. Srinivasan, R., S. Kulothungan, P. Sundararaju and C. Govindasamy, 2011. Biodiversity of plant parasitic nematodes associated with banana in Thanjavur District of Tamil Nadu. Int. J. Plant Anim. Environ. Sci., 1: 63-69.
10. Trevathan, L.E., J.A. Cuarezma-Teran and L.M. Gourley, 1985. Relationship of plant-nematodes and edaphic factors in Colombian grain sorghum production. Nematropica, 15: 145-153.
11. Cobb, N.A., 1918. Estimating the Nema Population of Soil, with Special Reference to the Sugar-Beet and Root-Gall Nemas, Heterodera Schachtii Schmidt and Heterodera Radicicola (Greef) Müller: And with a Description of *Tylencholaimus aequalis* N. Sp. U.S. Government Printing Office, Washington, DC, United State, Pages: 48.
12. Mishra, R., 1968. Ecology Workbook. Oxford & IBH Publishing Company, Calcutta, India, Pages: 242.
13. Wallace, M.K., R.H. Rust, D.M. Hawkins and D.H. Macdonald, 1993. Correlation of edaphic factors with plant-parasitic nematode population densities in a forage field. J. Nematol., 25: 642-653.
14. Wallace, H.R., 1962. Observations on the behaviour of *Ditylenchus dipsaci* in soil. Nematologica, 7: 91-101.
15. Seinhorst, J.W., 1956. Population studies on stem eelworms. Nematologica, 1: 159-164.
16. Rani, S. and K. Resha, 2018. Effect of soil temperature and moisture on population dynamics of phytonematodes infesting sugarcane. Environ. Conserv. J., 19: 155-159.
17. Siddiqui, M.A., 2007. Seasonal fluctuation in nematode population associated with mango, *Mangifera indica* L. Arch. Phytopathol. Plant Protect., 40: 389-394.
18. Sen, D., 2017. Population fluctuation of soil inhabiting nematodes in relation to soil temperature and moisture at guava orchard in West Bengal, India. Rec. Zool. Surv. India, 117: 376-382.
19. Bakonyi, G., P. Nagy, E. Kovács-Láng, E. Kovács, S. Barabás, V. Répási and A. Seres, 2007. Soil nematode community structure as affected by temperature and moisture in a temperate semiarid shrubland. Appl. Soil Ecol., 37: 31-40.
20. Ashokkumar, P., S. Vadivelu, U.K. Mehta, R. Jeyarajan and A. Regupathy, 1991. Occurrence and seasonal variation of *Hemicriconemoides mangiferae* from tropical and subtropical orchards in Peninsular India. Nematropica, 21: 167-176.
21. Neher, D.A., S.L. Peck, J.O. Rawlings and C.L. Campbell, 1995. Measures of nematode community structure and sources of variability among and within agricultural fields. Plant Soil, 170: 167-181.
22. Liu, W., Z. Zhang and S. Wan, 2009. Predominant role of water in regulating soil and microbial respiration and their responses to climate change in a semiarid grassland. Global Change Biol., 15: 184-195.
23. Liang, W. and Y. Steinberger, 2001. Temporal changes in nematode community structure in a desert ecosystem. J. Arid Environ., 48: 267-280.
24. Joa, J.H., D.G. Moon, S.J. Chun, C.H. Kim, K.S. Choi, H.N. Hyun and U.G. Kang, 2009. Effect of temperature on soil microbial biomass, enzyme activities, and PLFA content during incubation period of soil treated with organic materials. Korean J. Soil Sci. Fert., 42: 500-512.
25. Song, M., X. Li, S. Jing, L. Lei, J. Wang and S. Wan, 2016. Responses of soil nematodes to water and nitrogen additions in an old-field grassland. Appl. Soil Ecol., 102: 53-60.
26. Sen, D., A. Chatterjee and B. Manna, 2008. Population fluctuation of *Helicotylenchus* Steiner, 1945 in relation to soil temperature, moisture and pH in guava orchard at South 24 Parganas, West Bengal, India. Rec. Zool. Surv. India, 108: 75-81.

27. Todd, T.C., J.M. Blair and G.A. Milliken, 1999. Effects of altered soil-water availability on a tallgrass prairie nematode community. Appl. Soil Ecol., 13: 45-55.
28. Yeates, G.W., J.L. Dando and T.G. Shepherd, 2002. Pressure plate studies to determine how moisture affects access of bacterial-feeding nematodes to food in soil. Eur. J. Soil Sci., 53: 355-365.
29. Radová, Š. and Z. Trnková, 2010. Effect of soil temperature and moisture on the pathogenicity of two species of entomopathogenic nematodes (Rhabditida: Steinernematidae). J. Agrobiology, 27: 1-7.
30. Bakonyi, G. and P. Nagy, 2000. Temperature-and moisture induced changes in the structure of the nematode fauna of a semiarid grassland-patterns and mechanisms. Global Change Biol., 6: 697-707.
31. Oostenbrink, M., 1966. Major Characteristics of the Relation Between Nematodes and Plants. H. Veenman and Zonen, Wageningen, Netherlands, Pages: 48.
32. Dao, D.F., 1970. Climatic Influence on the Distribution Pattern of Plant Parasitic and Soil Inhabiting Nematodes. Veenman, Utrecht, Netherlands, Pages: 185.
33. Saeed, M. and A. Ghaffar, 1986. Seasonal population fluctuations of *Hemicriconemoides mangiferae* and other nematodes associated with sapodilla (*Achras zapota*) in Karachi. Pak. J. Nematol., 4: 67-74.