Plant parasitic nematodes associated with banana (*Musa* spp. var. 'Nendran' AAB) – a diversity analysis at banana fields in Ottappalam Taluk of Kerala, India

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ABSTRACT

Plant parasitic nematodes were documented as one of the major constraints in world food production. Efforts to understand the relations of the hosts and parasites will help to develop viable management strategies. In this aspect, a research survey was conducted during the post-monsoon season of 2017 in Ottappalam Taluk of Kerala, India to investigate the occurrence and population abundance of plant parasitic nematodes associated with an important crop banana (*Musa* var. 'Nendran' AAB). An extensive and in-deep survey for banana nematodes for this agricultural region of Kerala is not yet done. A total of 21 rhizosphere soil samples and root samples each were collected and processed for this study. Analysis for the plant parasitic nematode community showed variable degree of occurrence of viz. *Aphelenchus* spp., *Dorylaimoides* spp., *Helicotylenchus* spp., *Hoplolaimus* spp., *Meloidogyne* spp., *Pratylenchus* spp., *Radopholus* spp., *Rotylenchulus* spp., *Rotylenchus* spp., and *Tylenchus* spp. in both soil and root samples. Random surveys and their data analysis were done with absolute frequency distribution (%), absolute density (%), prominence value, and ANOVA (P = 0.05). The values for absolute frequency distribution (%), absolute density (%), and prominence value of the genus *Meloidogyne* spp. were 85.71%, 1,128.57%, and 10,448.54 respectively for rhizosphere soil samples and were 71.43%, 985.71%, and 8,330.85 respectively for root samples in banana fields of Ottappalam Taluk, revealed the more widespread occurrence of this genus in banana fields of Ottappalam Taluk. At the same time, maximum diverse numbers of nematodes were reported from Sreekrishnapuram panchayath and Kadambazhipuram panchayath for soil and root samples respectively. These findings were very much informative for the data addition about nematode fauna diversity studies of the agriculture sector, especially for the crop banana.

Keywords: Survey, density, plant parasitic nematodes, banana, Ottappalam Taluk

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INTRODUCTION

Human populations are increasing drastically, and it became a major global challenge in the coming years to ensure food security. Dealing with bananas as a crop harbors a major part of our agricultural land, and it has been grown in India for over 4,000 years. According to The FAO estimates, the worlds' largest area of banana cultivation occupies in India. For banana production also India ranks first with a contribution of about 23% in the world pool of banana production (Biswas and Kumar, 2010).

To attain sustainability in agricultural productivity in a resource-poor area, significant improvements are necessary in terms of resource use efficiency (Keating *et al*., 2010). On considering crop yields, pest and disease management is essential. With this in mind, in dealing with each and all factors of banana production, nematodes are often-overlooked constraints. They affect crops through feeding plant roots and also lead to an infestation of secondary pathogens such as fungi and bacteria (Powell, 1971). Burrowing and spiral nematodes alone have caused banana crop losses of 30–60% around the world (Lambert and Bekal, 2002). While most of the fields use environmentally hazardous inorganic pesticides as the primary source of disease management over the past decades (UNEP, 2000), the need to consider nematode pests in an eco-friendly way is more acutely brought into focus. Another issue is the changing of non-damaging one to damaging one as cropping patterns change (Nicol, 2002). So, clear-cut identification of individual nematodes and characterization of communities is a challenging problem, emerging the importance of studies in diversity analysis, nematode population densities, and associated damage of plant parasitic nematodes on the banana.

The identification and characterization of nematode fauna in an area is the first step for disease management to ensure efficacy in crop production. Efforts are being made to improve their yield as well as quality by some techniques such as hybrid production. But for a permanent and feasible method of ensuring efficacy, it should be done by some managing practices for plant parasitic nematodes also. Region vise studies have more importance with respect to nematode diversity analysis. The land area of Ottappalam Taluk of India is undulating with plain and hilly areas and occurs in the central midlands Agro-Ecological Zone (AEZ). Major regions of Ottappalam Taluk prefer agriculture due to the presence of the widest river of Kerala state namely Bharathapuzha and its tributaries. Banana is a major crop in Kerala and is vastly observed in this area also. Hence the present study focused on determining the diversity, occurrence, and population abundance of nematodes at Ottappalam Taluk of India.

MATERIALS AND METHODS

The banana cultivated areas of Ottappalam Taluk in Kerala, India was selected for this study to check the distribution and density of plant parasitic nematodes associated with banana (*Musa* spp. var. 'Nendran' AAB).

Survey and Sample Collection

The identification of nematode fauna in an area was done by the following methods. Samples were collected from seven collection sites with a minimum of 100 banana plants. The sample collection site was demarcated based on panchayath/ municipality (area marked for local self-government bodies) for easy data documentation. Soil samples collected from a plot in a zig-zag manner, summed up and considered as one sample. In this, 250 g soil and 10 g root were used for nematode extraction. A total number of 21 samples with three samples from each collection site were collected for both soil and root samples from different banana growing fields in Ottappalam Taluk during August to December of 2017 as an intensive survey for plant parasitic nematodes. The details on collection sites were given in Table 1. At each place, samples were collected from banana plants at 25–30 cm away from the bole of the plant and to a depth of 10–30 cm. The collected samples were packed in polythene bags, properly labeled, and stored at room temperature until processed for nematode extraction.

Table 1 GPS co-ordinates of three sample collection sites per panchayath/municipality in Ottappalam Taluk

Panchayath/municipality	GPS co-ordinates of collection site
Ambalapara	10.8369 N; 76.4104 E, 10.8238 N; 76.4122 E, 10.8094 N; 76.4059 E
Cherpulassery	10.9055 N; 76.3077 E, 10.8954 N; 76.3195 E, 10.8684 N; 76.3246 E
Kadambazhipuram	10.8737 N; 76.4582 E, 10.8965 N; 76.5034 E, 10.8960 N; 76.4421 E
Kongad	10.8883 N; 76.5282 E, 10.8631 N; 76.5243 E, 10.8773 N; 76.5255 E
Pukotukavu	10.8608 N; 76.3918 E, 10.8588 N; 76.3902 E, 10.8597 N; 76.3976 E
Shornur	10.7805 N: 76.2824 E, 10.7784 N; 76.2843 E, 10.7877 N; 76.2734 E
Sreekrishnapuram	10.8790 N; 76.4258 E, 10.8789 N; 76.4047 E, 10.8996 N; 76.4004 E

Extraction of Nematodes from Soil Samples

A standard method of Cobb's decanting and sieving practices were done for the extraction of nematodes (Cobb, 1918) followed by the modified Baermann technique (Southey, 1986). All collected samples were taken in uniform quantity using a 500 mL capacity container. Then it was transferred to a plastic container and mixed well with tap water. After the settlement of large soil particles, it was poured into meshes having different mesh sizes arranged one above the other. The nematodes trapped in the lowermost mesh having a mesh size of 400 BSS were sieved and decanted to clear water. Then it was poured onto tissue paper over layered on a wire gauge mesh which was placed in a plastic petri dish with clear water. This setup was maintained for 12 hours to come out nematodes.

Extraction of Nematodes from Root Samples

The infected root bits were taken from a semi-hard portion of the main roots and 10 g (fresh weight) were taken for nematode extraction. Roots were washed thoroughly to remove adhered soil particles, cut into 4 cm sized pieces, and macerated gently using a kitchen mixer grinder (Panasonic, Japan). Then it was poured onto a wire gauge mesh which was placed in a plastic petri dish with clear water and over layered with tissue paper. This setup was maintained for 12 hours to come out nematodes.

Identification and Analysis of Samples for Nematodes

For the estimation of nematode population, nematodes present in the suspension were identified at 40X using stereomicroscope (Magnus) up to generic level using nematode identification key of Tarjan *et al*. (1977). The nematodes which were difficult to identify were picked and mounted on a glass slide for identification and images were also taken at higher magnification by camera attached compound microscope (Olympus). While the number of nematodes per sample was very low, counted directly by dividing samples into subsamples without using counting dish and then extrapolated with dilution factor. Morphometric parameters of each genus were done with the help of Magnus software. Occurrences of the population of each nematode in each sample were recorded. Absolute frequency (AF), absolute density (AD), and prominence value (PV) were calculated by using the formula proposed by Norton (1978) in which:

$$\text{Absolute frequency (\%)} = \frac{\text{Number of samples containing nematodes} \times 100}{\text{Number of samples collected}} \quad \text{------- (1)}$$

$$\text{Absolute density (\%)} = \frac{\text{Number of nematodes in all samples} \times 100}{\text{Number of samples collected}} \quad \text{------- (2)}$$

$$\text{Prominence value} = \text{Absolute density} \times \sqrt{\text{Absolute frequency}} \quad \text{------- (3)}$$

$$\text{Occurrence (\%)} = \frac{\text{Total number of a genus}}{\text{Total number of nematodes present in a study area}} \times 100 \quad \text{------- (4)}$$

Data were analyzed with statistical means to make a conclusion on population abundance on each nematode genus found in each collection site in the studied area. Means were computed based on linear model one-way analysis of variance (ANOVA) using SPSS 16.0 and if significant differences were detected, Duncan's new multiple range test was employed for means comparison (P = 0.05).

RESULTS AND DISCUSSION

Field Observation

In this study area, bananas were found as a crop after rice and vegetables. Most of the farmers neither rotated bananas with other crops nor practiced nematode disease control measures. Ottappalam Taluk ranks second in the Palakkad district for banana cultivation and the northern region showed a maximum in the Taluk.

Analysis of Soil and Root Samples

After completion of the nematode extraction and observation of twenty-one soil and root samples, ten different plant parasitic nematodes were observed in the banana (*Musa* var. 'Nendran AAB') crop at Ottappalam Taluk. Plant parasitic nematodes were found in all banana fields, and they were found below an economic threshold level (ETL) only. The different plant parasitic nematodes observed were *Aphelenchus* spp., *Dorylaimoides* spp., *Helicotylenchus* spp., *Hoplolaimus* spp., *Meloidogyne* spp., *Pratylenchus* spp., *Radopholus* spp., *Rotylenchulus* spp., *Rotylenchus* spp., and *Tylenchus* spp. (Figure 1). None of the genera was found in cent percentage in both soil and root samples collected from the study area. The species *Aphelenchus* spp. was observed only in analyzed root samples collected from Cherpulassery municipality and Kadambazhipuram panchayath. All ten genera were not observed in a single panchayath under study and the maximum number of genus observed per panchayath was seven at Kadambazhipuram panchayath. At Ambalapara panchayath only the single genus *Meloidogyne* spp. was observed in root sample analysis. The root analysis also showed that Kongad panchayath and Sreekrishnapuram panchayath were represented by only two genera. They are *Pratylenchus* spp. and *Radopholus* spp. from the Kongad panchayath and *Rotylenchulus* spp. and *Rotylenchus* spp. from the Sreekrishnapuram panchayath. For understanding the distribution patterns of nematodes population, absolute frequency, and absolute density of each nematode genus in each panchayath are given in Tables 2–4.

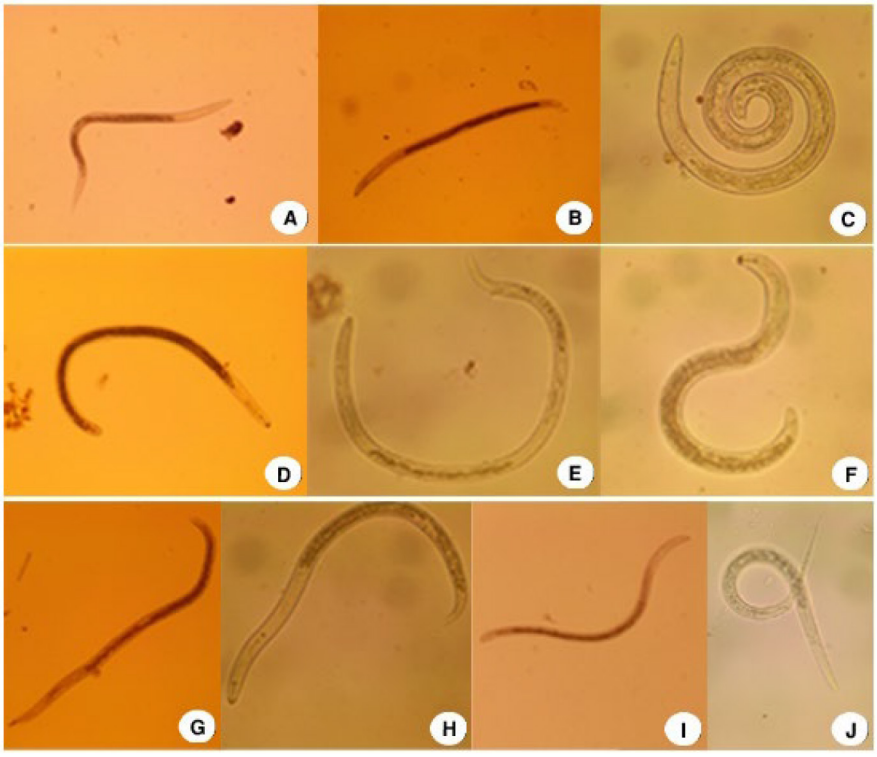

Figure 1 Different plant parasitic nematode species observed in banana var. 'Nendran' (AAB) in Ottappalam Taluk, India: (A) *Aphelenchus* spp., (B) *Dorylaimodes* spp., (C) *Helicotylenchus* spp., (D) *Hoplolaimus* spp., (E) *Meloidogyne* spp., (F) *Pratylenchus* spp., (G) *Radopholus* spp., (H) *Rotylenchulus* spp., (I) *Rotylenchus* spp., and (J) *Tylenchus* spp.

Table 2 Distribution of plant parasitic nematodes in the rhizosphere soil and root of banana grown in different panchayath/municipality of Ottappalam Taluk

Panchayath	Source	*Aph*	*Dor*	*Hel*	*Hop*	*Mel*	*Pra*	*Rad*	*Rot*	*Roc*	*Tyl*
Ambalapara	Soil	– – –	– – –	– – –	– – –	+++	+++	+++	– – –	+ – –	– – –
	Root	– – –	– – –	– – –	– – –	+++	– – –	– – –	– – –	– – –	– – –
Cherpulassery	Soil	– – –	– + –	– – –	– – –	+++	+++	– – –	+++	– – –	– – –
	Root	– – +	+++	– – –	– – –	+++	+++	– – –	– – –	– – –	– – –
Kadambazhipuram	Soil	– – –	– – –	– – –	– – –	+++	++ –	+++	– – –	– – –	– – –
	Root	– + –	+ – –	– – –	++ –	+++	+++	+++	– – –	– – –	+++
Kongad	Soil	– – –	+++	+ – +	– – –	– – –	+++	+++	+++	– – –	– – –
	Root	– – –	– – –	– – –	– – –	– – –	+++	+++	– – –	– – –	– – –
Pukotukavu	Soil	– – –	– – +	+ – +	+ – –	+++	– – –	– – –	+++	– – –	– – –
	Root	– – –	– – +	– – –	– – –	+++	– – –	– – –	+++	– – –	– – –
Shornur	Soil	– – –	++ –	– – –	– – –	+++	– – –	– – –	– – –	– – –	– – +
	Root	– – –	+++	++ –	– – –	+++	– – –	– – –	– – –	– – –	– – –
Sreekrishnapuram	Soil	– – –	+ – –	– – –	+++	+++	– – –	+++	+++	+ – +	– – –
	Root	– – –	– – –	– – –	– – –	– – –	– – –	– – –	+++	+ – +	– – –

Note: *Aph* = *Aphelenchus* spp., Dor = *Dorylaimoides* spp., *Hel* = *Helicotylenchus* spp., *Hop* = *Hoplolaimus* spp., *Mel* = *Meloidogyne* spp., *Pra* = *Pratylenchus* spp., *Rad* = *Radopholus* spp., *Rot* = *Rotylenchulus* spp., *Roc* = *Rotylenchus* spp., *Tyl* = *Tylenchus* spp. '+' plotted for the presence of respective nematode genus in the order of all three sampling from a collection site. Number of symbols indicate the degree of observation: '+' = present in a survey (present only in one observation), '++' = common (present only in two observations), '+++' = widespread (occurred in all three observations), '–' plotted for the absence of respective nematode genus in the order of all three sampling from a collection site (not recorded).

While comparing the nematode diversity in studied panchayaths, Sreekrishnapuram panchayath showed maximum diversity for soil samples and Kadambazhipuram panchayath showed maximum diversity for root samples. Here, the nematodes found in the soil samples collected from Sreekrishnapuram panchayath were *Dorylaimoides* spp., *Hoplolaimus* spp., *Meloidogyne* spp., *Radopholus* spp., *Rotylenchulus* spp., and *Rotylenchus* spp. and the root analysis revealed the information that *Aphelenchus* spp., *Dorylaimoides* spp., *Hoplolaimus* spp., *Meloidogyne* spp., *Pratylenchus* spp., *Radopholus* spp., and *Tylenchus* spp were the nematodes found at Kadambazhipuram panchayath. On analyzing the soil samples, a major contribution of 31.13% nematodes was found in Kongad panchayath followed by Pukotukavu panchayath, Sreekrishnapuram panchayath, Cherpulassery municipality, Kadambazhipuram panchayath, and Ambalapara panchayath with a share of 18.93%, 16.26%, 13.98%, 8.51%, and 7.88% respectively and Shornur municipality panchayath with the least share of 3.04%. Root samples showed the result as maximum diversity of 24.05% of nematodes were found at Pukotukavu panchayath and least was observed at Sreekrishnapuram panchayath (4.45%) and others are observed in the order of Kadambazhipuram panchayath (22.72%), Kongad panchayath (18.71%), Cherpulassery municipality (17.32%), Shornur municipality (8.02%) and Ambalapara panchayath (4.68%). An almost equal distribution showed at Ambalapara panchayath and Sreekrishnapuram panchayath.

Table 3 Nematode density in rhizosphere soil of banana var. 'Nendran' (AAB) in different panchayath/municipality of Ottappalam Taluk

Panchayath	Nematode genera	Total nematodes	Occurrence (%)	AF (%)	AD (%)	PV	Nematodes in a panchayath (%)
Ambalapara (62)	*Meloidogyne* spp.	13	20.97	100.00	433.33	4,333.33	7.88
	Pratylenchus spp.	44	70.97	100.00	1,466.67	14,667.67	
	Radopholus spp.	4	6.45	100.00	133.33	1,333.33	
	Rotylenchus spp.	1	1.61	33.33	33.33	192.42	
Cherpulassery (110)	*Dorylaimoides* spp.	3	2.73	33.33	100.00	577.32	13.98
	Meloidogyne spp.	19	17.27	100.00	633.33	6,333.30	
	Pratylenchus spp.	75	68.18	100.00	2,500.00	25,000.00	
	Rotylenchulus spp.	13	11.82	100.00	433.33	4,333.33	
Kadambazhipuram (67)	*Meloidogyne* spp.	46	68.66	100.00	1,533.33	15,333.33	8.51
	Pratylenchus spp.	3	4.48	66.67	100.00	816.52	
	Radopholus spp.	18	26.87	100.00	600.00	6,000.00	
Kongad (245)	*Dorylaimoides* spp.	11	4.49	100.00	366.67	3,666.67	31.13
	Helicotylenchus spp.	8	3.27	66.67	266.67	2,177.41	
	Pratylenchus spp.	44	17.96	100.00	1,466.67	14,667.67	
	Radopholus spp.	133	54.29	100.00	4,433.33	44,333.33	
	Rotylenchulus spp.	49	20.00	100.00	1,633.33	16,333.33	
Pukotukavu (149)	*Dorylaimoides* spp.	1	0.67	33.33	33.33	192.42	18.93
	Helicotylenchus spp.	11	7.38	66.67	366.67	2,993.92	
	Hoplolaimus spp.	6	4.03	33.33	200.00	1,154.64	
	Meloidogyne spp.	103	69.13	100.00	3,433.33	34,333.33	
	Rotylenchulus spp.	28	18.79	100.00	933.33	9,333.33	
Shornur (24)	*Dorylaimoides* spp.	2	7.69	66.67	66.67	544.37	3.04
	Meloidogyne spp.	20	76.92	100.00	666.67	6,666.67	
	Tylenchus spp.	2	7.69	33.33	66.67	384.90	
Sreekrishnapuram (128)	*Dorylaimoides* spp.	6	4.69	33.33	200.00	1,154.64	16.26
	Hoplolaimus spp.	11	8.59	100.00	366.67	3,666.70	
	Meloidogyne spp.	36	28.13	100.00	1,200.00	12,000.00	
	Radopholus spp.	31	24.22	100.00	1,033.33	10,333.30	
	Rotylenchulus spp.	40	31.25	100.00	1,333.33	13,333.30	
	Rotylenchus spp.	4	3.13	66.67	133.33	1,088.66	

Note: Numbers in parenthesis are total number of nematodes present. Occurrence = occurrence (%) of each genus in a panchayath, AF = absolute frequency distribution, AD = absolute density, PV = prominence value

Table 4 Nematode density in root of banana var. 'Nendran' (AAB) in different panchayath/municipality of Ottappalam Taluk

Panchayath	Nematode genera	Total nematodes	Occurrence (%)	AF (%)	AD (%)	PV	Nematodes in a panchayath (%)
Ambalapara (21)	*Meloidogyne* spp.	21	100.00	100.00	700.00	7,000.00	4.68
Cherpulassery (78)	*Aphelenchus* spp.	3	3.85	33.33	100.00	577.32	17.32
	Dorylaimoides spp.	3	3.85	100.00	100.00	1,000.00	
	Meloidogyne spp.	31	39.74	100.00	1,033.33	10,333.33	
	Pratylenchus spp.	41	52.56	100.00	1,366.67	13,666.67	
Kadambazhipuram (102)	*Aphelenchus* spp.	2	1.96	33.33	66.67	384.88	22.72
	Dorylaimoides spp.	3	2.94	33.33	100.00	577.32	
	Hoplolaimus spp.	5	4.90	66.67	166.67	1,360.86	
	Meloidogyne spp.	60	58.82	100.00	2,000.00	20,000.00	
	Pratylenchus spp.	11	10.78	100.00	366.67	3,666.67	
	Radopholus spp.	17	16.67	100.00	566.67	5,666.67	
	Tylenchus spp.	4	3.92	100.00	133.33	1,333.33	
Kongad (84)	*Pratylenchus* spp.	21	25.00	100.00	700.00	7,000.00	18.71
	Radopholus spp.	63	75.00	100.00	2,100.00	21,000.00	
Pukotukavu (108)	*Dorylaimoides* spp.	3	2.78	33.33	100.00	577.32	
	Meloidogyne spp.	71	65.74	100.00	2,366.67	23,666.67	24.05
	Rotylenchulus spp.	34	31.48	100.00	1,133.33	11,333.33	
Shornur (36)	*Dorylaimoides* spp.	3	8.33	100.00	100.00	1,000.00	8.02
	Helicotylenchus spp.	9	25.00	66.67	300.00	2,449.55	
	Meloidogyne spp.	24	66.67	100.00	800.00	8,000.00	
Sreekrishnapuram (20)	*Rotylenchulus* spp.	15	75.00	100.00	500.00	5,000.00	4.45
	Rotylenchus spp.	5	25.00	66.67	166.67	1,360.86	

Note: Numbers in parenthesis are total number of nematodes present. Occurrence = occurrence (%) of each genus in a panchayath, AF = absolute frequency distribution, AD = absolute density, PV = prominence value

With respect to the prominence value of rhizosphere soil sample data analysis, the highest value (44,333.33) was observed for the genus *Radopholus* spp. in Kongad panchayath and the least value (192.42) was observed by *Dorylaimoides* spp. at Pukotukavu panchayath and *Rotylenchus* spp. at Ambalapara panchayath. Dealing with the root samples, the highest prominence value (23,666.67) bearing genus was *Meloidogyne* spp. at Pukotukavu panchayath and the lowest value (384.88) was seen for *Aphelenchus* spp. at Kadambazhipuram panchayath.

The figure on nematode diversity of Ottappalam Taluk showed that the most observed genus in soil samples was *Meloidogyne* spp. with a share of 30.11% and the least observed genus was *Tylenchus* spp. (0.25%). In root samples also the most observed genus was *Meloidogyne* spp. with a share of 46.10% and the least observed one was *Tylenchus* spp. at 0.89%. The absolute frequency distribution and absolute density of *Meloidogyne* spp. were notably higher than those of other genera. The most frequently observed genus *Meloidogyne* spp. had occurred with an absolute frequency of 85.71% and prominence value of 10,448.54 in rhizosphere soil samples. These values in root samples for *Meloidogyne* spp. were 71.43% for absolute frequency and 8,330.85 for prominence value. The different types of nematodes observed in soil and root samples and their frequency of distribution and density were given in Tables 5–6. The nematode population abundance of each genus was given in Tables 7–8.

Table 5 Percentages of occurrence, frequency of distribution and density of different nematodes in rhizosphere soil of banana var. 'Nendran' (AAB) in Ottappalam Taluk

Nematode genera	Occurrence (%)	AF (%)	AD (%)	PV
Dorylaimoides spp.	2.92	38.09	109.52	675.99
Helicotylenchus spp.	2.41	19.05	90.48	394.87
Hoplolaimus spp.	2.16	19.05	80.95	353.31
Meloidogyne spp.	30.11	85.71	1,128.57	10,448.54
Pratylenchus spp.	21.09	52.38	790.48	5,721.05
Radopholus spp.	23.63	57.14	885.71	6,695.37
Rotylenchulus spp.	16.52	57.14	619.05	4,679.56
Rotylenchus spp.	0.64	14.29	23.81	89.99
Tylenchus spp.	0.25	4.76	9.52	2,078.00

Note: AF = absolute frequency distribution obtained by taking percentage of samples containing plant parasitic nematodes per number of samples collected, AD = absolute density obtained by taking percentage of number of nematodes in all samples per number of samples collected, PV = prominence value which is product of absolute density and square root of absolute frequency

Table 6 Percentages of occurrence, frequency of distribution and density of different nematodes in roots of banana var. 'Nendran' (AAB) in Ottappalam Taluk

Nematode genera	Occurrence (%)	AF (%)	AD (%)	PV
Aphelenchus spp.	1.11	9.52	23.81	73.45
Dorylaimoides spp.	2.67	38.10	57.14	352.70
Helicotylenchus spp.	2.00	9.52	42.86	132.24
Hoplolaimus spp.	1.11	9.52	23.81	73.46
Meloidogyne spp.	46.10	71.43	985.71	8,330.85
Pratylenchus spp.	16.26	42.86	347.62	2,275.78
Radopholus spp.	17.82	28.57	380.95	2,036.21
Rotylenchulus spp.	10.91	28.57	233.33	1,247.17
Rotylenchus spp.	1.11	9.52	23.81	73.46
Tylenchus spp.	0.89	14.29	19.05	72.01

Note: AF = absolute frequency distribution obtained by taking percentage of samples containing plant parasitic nematodes per number of samples collected, AD = absolute density obtained by taking percentage of number of nematodes in all samples per number of samples collected, PV = prominence value which is product of absolute density and square root of absolute frequency

The survey for plant parasitic nematodes in banana var. 'Nendran' (AAB) showed that four genera are prevalent in Ottappalam Taluk, Kerala on rhizosphere soil and root. The plant parasitic nematodes such as *Meloidogyne* spp., *Pratylenchus* spp., *Radopholus* spp., and *Rotylenchulus* spp. were those genera with respect to absolute frequency and density. On considering the species diversity and more number of nematodes per panchayath, the Kongad panchayath had more diversity showing a region in Ottappalam Taluk for soil samples. An interesting result showed that the mostly found genus *Meloidogyne* spp. was not observed in both rhizosphere soil samples and root samples at Kongad panchayath. This situation of the absence of the most prevalent genera was very common in most of the surveys (Khan and Hasan, 2010). With respect to the root samples, Kadambazhipuram panchayath was found as a more diverse region in Ottappalam Taluk by considering the species diversity and more number of nematodes per panchayath. The genus *Meloidogyne* observed in five panchayaths was the maximum occurrence of a nematode genus in these studied samples.

Table 7 Population abundance of each plant parasitic nematode species in different rhizosphere soil samples of banana var. 'Nendran' (AAB) in Ottappalam Taluk

Nematode genera	Sample collection site	Population abundance
Dorylaimoides spp.	Cherpulassery	1.00 ± 1.00^{ab}
	Kongad	3.67 ± 2.19^{a}
	Pukotukavu	0.58 ± 0.33^{b}
	Shornur	0.67 ± 0.33^{b}
Helicotylenchus spp.	Kongad	2.67 ± 1.76
	Pukotukavu	3.67 ± 2.33
Hoplolaimus spp.	Pukotukavu	2.00 ± 2.00
	Sreekrishnapuram	3.67 ± 1.20
Meloidogyne spp.	Abmbalapara	4.33 ± 2.03^{cd}
	Cherpulassery	6.33 ± 2.96^{cd}
	Kadambazhipuram	15.33 ± 2.84^{b}
	Pukotukavu	34.33 ± 3.38^{a}
	Shornur	6.67 ± 1.76^{cd}
	Sreekrishnapuram	12.00 ± 2.08^{bc}
Pratylenchus spp.	Ambalapara	14.67 ± 3.48^{b}
	Cherpulassery	25.00 ± 5.20^{a}
	Kadambazhipuram	1.00 ± 0.57^{c}
	Kongad	14.67 ± 2.91^{b}
Radopholus spp.	Ambalapara	1.33 ± 0.33^{c}
	Kadambazhipuram	6.00 ± 1.53^{bc}
	Kongad	44.33 ± 5.37^{a}
	Sreekrishnapuram	10.33 ± 2.40^{b}
Rotylenchulus spp.	Cherpulassery	4.33 ± 2.03^{bc}
	Kongad	16.33 ± 6.12^{a}
	Pukotukavu	9.33 ± 3.84^{abc}
	Sreekrishnapuram	13.33 ± 2.40^{ab}
Rotylenchus spp.	Ambalapara	0.33 ± 0.33
	Sreekrishnapuram	1.33 ± 0.88
Tylenchus spp.	Shornur	0.67 ± 0.67

Note: Different letters in the same column indicate significant differences according to Duncan's new multiple range test at $P < 0.05$

Table 8 Population abundance of plant parasitic nematode species in different root samples of banana var. 'Nendran' (AAB) in Ottappalam Taluk

Nematode genera	Sample collection site	Population abundance
Aphelenchus spp.	Cherpulassery	1.00 ± 1.00
	Kadambazhipuram	1.66 ± 0.88
Dorylaimoides spp.	Cherpulassery	1.00 ± 0.00
	Kadambazhipuram	1.00 ± 1.00
	Pukotukavu	1.00 ± 1.00
	Shornur	1.00 ± 0.00
Helicotylenchus spp.	Shornur	3.00 ± 2.08
Hoplolaimus spp.	Kadambazhipuram	1.67 ± 1.20
Meloidogyne spp.	Abmbalapara	7.00 ± 2.65^{bc}
	Cherpulassery	10.33 ± 2.60^{abc}
	Kadambazhipuram	20.00 ± 9.50^{ab}
	Pukotukavu	23.67 ± 6.69^{a}
	Shornur	8.00 ± 3.06^{bc}
Pratylenchus spp.	Cherpulassery	13.67 ± 3.84^{a}
	Kadambazhipuram	3.67 ± 1.20^{bc}
	Kongad	7.00 ± 2.52^{c}
Radopholus spp.	Kadambazhipuram	5.67 ± 2.60^{b}
	Kongad	21.00 ± 2.65^{a}
Rotylenchulus spp.	Kongad	11.33 ± 2.40^{a}
	Sreekrishnapuram	5.00 ± 1.73^{b}
Rotylenchus spp.	Sreekrishnapuram	1.67 ± 1.20
Tylenchus spp.	Kadambazhipuram	1.33 ± 0.33

Note: Different letters in the same column indicate significant differences according to Duncan's new multiple range test at $P < 0.05$

After a nationwide survey in Palakkad district, Khan *et al*. (2010) reported the widespread occurrence of *Radopholus similis, Meloidogyne incognita, Helicotylenchus multicinctus, Heterodera oryzicola,* and *Pratylenchus coffeae* in banana. In this study, these results were also in accordance with the results except none of the surveyed banana growing areas of Ottappalam showed the presence of *Heterodera oryzicola*. The presence of *Meloidogyne* spp. in Kerala as a plant parasite is reported by Nadakal (1964). Roy *et al*. (2014) documented the banana nematodes of a small area at vellayani, Kerala. It was found that seven phytonematodes were associated with the banana crop, of which *R. similis, H. multicinctus,* and *P. coffeae* were recorded as abundant nematode endoparasites. This result was in confirmation with the findings of the present study. *Pratylenchus, Meloidogyne, Helicotylenchus, Tylenchorhynchus, Hoplolaimus, Rotylenchulus, Hirschmanniella, Criconemoides* were observed in bananas in West Bengal (Khan and Hasan, 2010). In all soil samples analyzed, *M. incognita* was found to occur at the highest frequency in banana fields of Malaysia (Sayed Abdul Rahman *et al.*, 2014). The present study also revealed the same result. While many of the results for nematodes associated with banana showed the widespread presence of *R. similis,* but the present study report contradicted that mainstream view (Speijer and De Waele, 1997; Araya *et al*., 2002). But the *Radopholus* spp. was found next to *Meloidogyne* spp. in soil samples and third position in root samples at Ottappalam Taluk. The number of *M. incognita* was high in both soil and root samples. But it was very much higher in root samples than soil samples and it was expected as the natural behavior as upon reaching the infective J2 stage to stay immobile at the feeding sites (Williamson and Kumar, 2006). Both *Pratylenchus* spp. and *Radopholus* spp. were co-existed with *Meloidogyne* spp. in both types of samples. Almost all nematodes showed in Ottappalam Taluk were also reported from the Tanjavur district of Tamilnadu, India (Srinivasan *et al*., 2011). The presence of an identified population of nematodes was seemed to be important and to be under management. These demonstrate the importance of these three nematode genera in banana production as an inverse relationship occurred between the nematodes and the growth of bananas.

CONCLUSIONS

From this study, it is clear that there are several species of plant parasitic nematodes were presented in the Ottappalam Taluk of India. With respect to the soil and root samples, Sreekrishnapuram and Kadambazhipuram panchayaths respectively were found as the most extensive in nematode diversity showing region in Ottappalam Taluk. By considering the values of absolute frequency distribution (%) and absolute density (%), the genus *Meloidogyne* spp. was presented as the most abundant and highest frequency of distribution in this studied area. The studies on constraints affecting banana production are to be addressed for farmers and global food security.

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