Diversity of phyto-parasitic nematodes in the on-farm cocoa (*Theobroma cacao* L.) plantations of south western Nigeria

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Parasitic nematodes have evident contribution to the yield loss of cocoa in south western Nigeria, a region which accounts for the highest cocoa production of Nigeria. Research to identify types, population and frequency of occurrence of different nematode genera around the rhizosphere of cocoa in Nigeria has been poorly attempted. However, information on the biodiversity of each significant nematode species is critical for initiation of an efficient control programme. Therefore, to ascertain this critical information, soil samples were collected from 45 farms in three south western states of Nigeria. With the modified Baerman Funnel method, a total of 12 phyto-parasitic nematode taxa were extracted from the soil samples. Seventy-five percent of the extracted nematodes belong to the migratory class. *Meloidogyne* spp occurred in the highest abundance (79.83) and frequency (97.7%). Other genera with higher population densities were: *Tylenchus, Helicotylenchus, Pratylenchus* and *Rotylenchus* in the respective abundances of 35.2, 31.7, 30.3 and 23.9, with frequencies ranging between 65 - 77%. Cocoa trees host large populations of phyto-parasitic nematodes, the proportion of each genera is highly diverse; varying between farms, locations and states. A thorough investigation of individual nematode pathogenicity is necessary. Furthermore, their interactions within the rhizosphere and their contributory role to lowering cocoa productivity in farmer fields in Nigeria would be an informative guide to controlling them.

Keywords: abundance, cacao, diversity, farmers fields, frequency, nematodes, south western Nigeria

Cocoa (*Theobroma cacao* L.) is a major commercial crop of the equatorial region. It is extensively cultivated for the beans, the export of which provides foreign exchange to many West African countries (Opeke 2003; FAO 2005). Nigeria comes behind Cote d'Ivoire, Ghana and Indonesia in cocoa production and taking the third place behind Cote d'Ivoire and Ghana in export of cocoa bean (Verter and Bečvářová 2014). Cocoa is the leading agricultural export crop of Nigeria, producing over 250,000 metric tonnes of dried beans annually (Ibiremo et al. 2014).

Cocoa is mostly grown in 14 Nigerian states which fall in the high rainfall belt, including south west, south east and the south south regions of the country. Eight other states were recently identified as marginal cocoa growing states in Nigeria. Cadoni (2013) reported that the main producing states are located in the south west of the country, identifying Edo, Ekiti, Ogun, Ondo, Osun and Oyo states as high production areas.

Afolami et al. (2013) historically remarked that cocoa farming in Nigeria reached its peak in the early 1970s and has since then been on a steady decline. The factors mostly implicated for decline have been old age of most cocoa trees and plantations, declining soil fertility, pest and disease incidence, use of poor (unselected) planting material for plantation establishment etc. Afolami et al. (2013), who hinted that nematodes cannot be ignored in the search for improved and sustainable cocoa productivity in Nigeria, further suggested that the problem of nematodes on young cacao seedlings and the effect of years of uncontrolled multiplication of nematode populations on adult trees are worthwhile research investigations.

More than 14,000 Nematoda species have been described (Kergunteuil et al. 2016). The described genera are well distributed in almost every habitat on earth representing more than 80% of the metazoan taxonomic and functional diversity in soils (De Ley 2006; Kergunteuil et al. 2016). These biologically specialized

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metazoans are so significant among the multicellular organisms, combining large variation with deceptively simple underlying anatomical patterns and are highly diverse in almost every respect (De Ley 2006). They have remained key components of soil biodiversity and represent valuable bio-indicators of soil food webs (Kergunteuil et al. 2016). More diversity promises to be unveiled in the class as biological exploration continues into the yet- to be known species (De Ley 2006).

An IITA (1984) report indicated that nematodes are a subtle and insidious crop pest whose infestation can cause yield reduction in the range of 20 - 30%. The knowledge of the biodiversity of nematodes in cocoa fields/plantations is necessary for the formulation of control strategies for the pest, most often called "hidden enemies". Research to understand the diversity of nematode species in Nigerian cocoa soil have been less attempted compared to other crops, such as: pineapple (Daramola et al. 2013), sugarcane (Afolami et al. 2014) and tea (Orisajo 2012).

Except for the report of Afolami et al. (2013) in two cocoa on-station research testing locations (Ibadan and Owena) of the Cocoa Research Institute of Nigeria (CRIN) which revealed the presence of 10 nematode species in the studied cocoa plantations, there is a paucity of information regarding the biodiversity, quantity and distribution of plant-parasitic nematode species associated with cocoa in Nigeria. The availability of a more comprehensive report on the diversity of this organism in the cocoa-growing soils under farming conditions within the region would be an asset. Hence, the present research was proposed to verify the presence of economically important plant-parasitic nematodes species associated with cocoa, their abundance and distribution in farmer fields/plantations in south western Nigeria.

Materials and methods

Soil sample collection

A survey was carried out to investigate the distribution and frequency of nematode species in Ekiti, Ondo and Oyo states in Southwestern Nigeria from June 2013 to January 2014. With respect to the initial zoning system by the Agricultural Development Program (ADP) of each state, three cocoa growing zones (local governments) were sampled from the three states (Figure 1). Soil samples around the roots of cocoa trees were collected using a soil auger to a depth of 20 cm at the four cardinal directions around each plant to access a higher quantity of nematodes at the rhizosphere. Using the on-site terrain variability, each plantation or farm was divided into five groups. Soil samples were collected from five nearest cocoa tree stands within a group. The five soil samples were thereafter bulked in a polythene bag to make a composite sample for a replicate in a plantation/farm. Five replicate soil samples were collected in each of the five farms in three locations/zones in each of the three states, amounting to a total of 225 soil samples. The experiment was a nested design with zones nested within states and farms nested within zones. Collected soil samples were properly stored in an insulated cool box to prevent desiccation. Analysis of the sample was done in the Nematology Laboratory, Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria.

Extraction, identification of nematode species and data collection

Plant parasitic nematodes were extracted from the soil using the pie-pan modification of the Baerman Funnel method (Whitehead and Hemming 1965). With the aid of a counting slide (2 ml counting capacity), the number of nematodes in each suspension was estimated. The counting slide (4 × 8 cm) was made of Perspex with a well 0.5cm deep and horizontal grid lines. Counting and identification were done under a compound microscope at an objective magnification of ×10 ×40 and ×100. Identification was done to genus level using taxonomic keys (Hunt et al. 2005). A hand tally counter was used for counting and the mean of three counts was taken in each case. The mean number of nematodes calculated from the aliquot was multiplied by the total volume of the suspension to arrive at the total number in the soil. Percentage frequency was determined using the formula: n/N x 100, where n = the number of times an individual nematode occurred in all the samples and N is the sample size, i.e. 75 for each state.

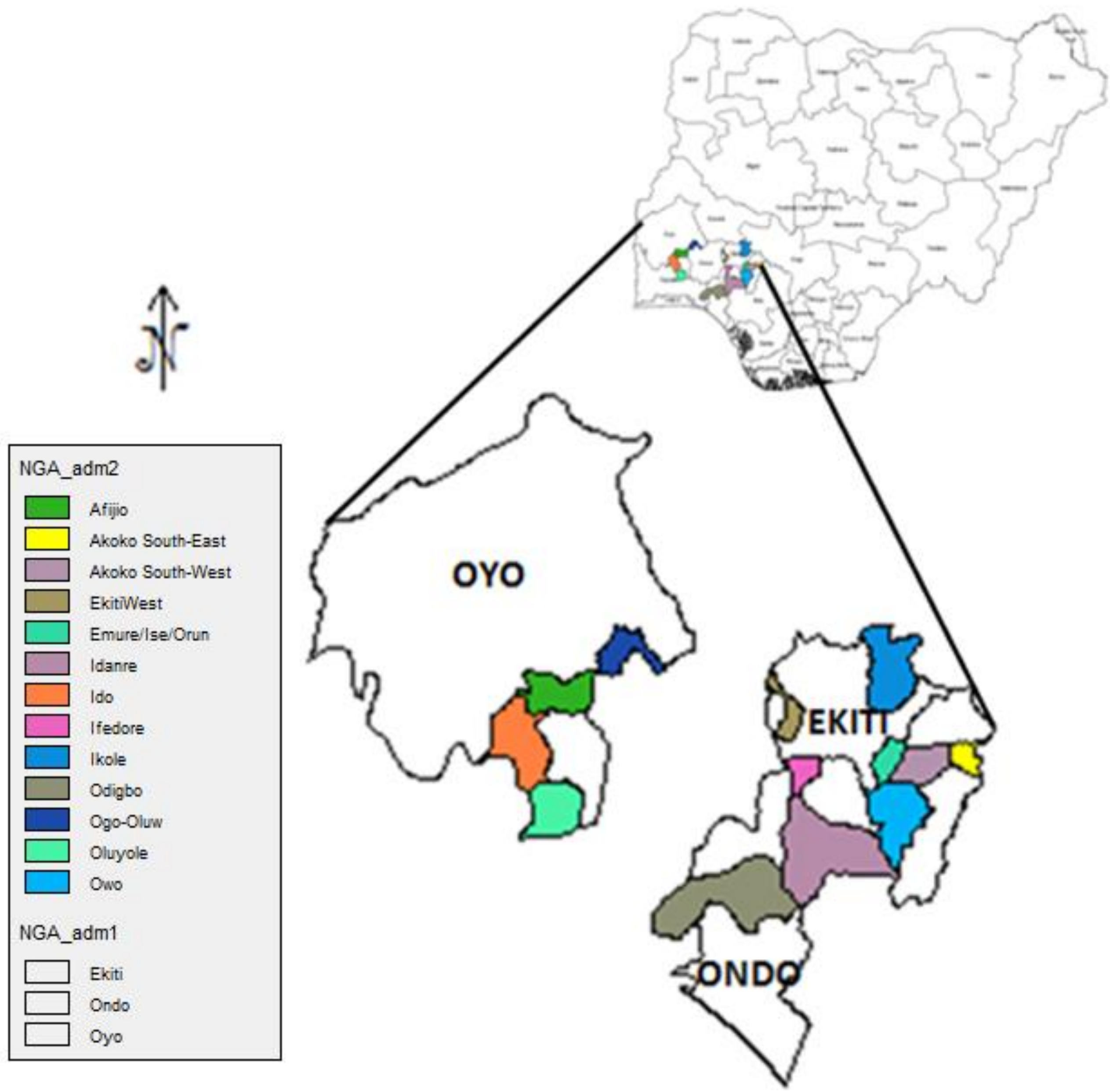

Figure 1: Map showing the three states and local government areas in south western Nigeria in which the 45 farms were located

Data analysis

To attain normality the counted data was transformed using the square root method; following the procedure in Gomez and Gomez (1984), 0.5 (a constant) was added to each count before the square root value was calculated. To adequately utilize all useful information within the experiment, variables (different nematodes types) were treated as class and the classes (different zones/locations) were treated as variables and vice versa. Analysis of variance (ANOVA) was employed to understand variability between and within factors. The data matrix containing the mean values for each nematode species across the 45 farms was subjected to Gower genetic distance (Gower 1971), then principal component analysis to understand the diversity of the twelve nematodes within a two-dimensional planes of principal component axes 1 and 2, then 1 and 3. Similarity among the 45 farms (with respect to the quantity of each of the twelve nematodes in them) using the transposed mean matrix data of farms and nematodes, was detected by clustering analysis. All analyses were performed using SAS software version 9.3 (SAS 2011).

Results

Twelve nematode species were identified as resident nematodes in the rhizosphere of cocoa trees in the three states surveyed in south western Nigeria (Table 1). The classifications were: sedentary endoparasitic (1), migratory endoparasitic (3), migratory ectoparasitic (6) and semi-sedentary endoparasitic (2). The most abundant and highest occurring genus was *Meloigdogyne* with the highest mean abundance (79.8) and frequency (97.7). *Tylenchus Helicotylenchus*, *Pratylenchus* and *Rotylenchus* were variously next to *Meloidogyne* in mean abundance (35.2, 31.7, 30.3 and 23.9) and mean frequency of 69%, 65%, 77% and 70% respectively in the three states (Table 1). *Radopholus* and *Aphelenchoides* were absent in the soil samples from Ondo and Ekiti states respectively. The average abundance of the twelve nematodes in the three states ranged between 20.9 (Ekiti state) and 29.8 (Oyo state). Soil samples from Oyo state had the highest number of nematode species (Table 1). The frequency of occurrence of eight out of 12 nematode genera in the 45 soil samples was greater than 50%.

The quantity of *Aphelenchoides*, *Pratylenchus*, *Helicotylenchus*, *Xiphinema*, *Rotylenchus*, *Tylenchus*, *Radopholus* and *Paralongidorus* in the soil around cocoa root significantly ($P \leq 0.05$) differed in the three states (Table 2). Significant variation ($P \leq 0.05$) in the quantity of *Meloidogyne* spp occurred only at farm level. Moreover, significant ($P \leq 0.05$) variation equally occurred among each of the three locations within each state with respect to the quantity of *Pratylenchus*, *Helicotylenchus*, *Tylenchus*, and *Radopholus* hosted in the rhizosphere (Table 2). Significant ($P \leq 0.05$) state by location interaction was observed for five out of the 12 nematodes genera. In this study, only the population of *Xiphinema* displayed significant ($P \leq 0.05$) state by location by farm interaction. *Meloidogyne* had the highest population mean of 80.2; this was distantly far from 34.4 from *Tylenchus* (the second population mean); the least population (5.6) was from *Radopholus* (Table 2). For each of the 12 nematode genera, the coefficients of variation across states, location and farms was very high ranging from 28.76 - 86.59%. However, the coefficients of variation within farms was somewhat lower ranging between 16.46 - 41.35% (Table 2).

The relative mean proportion of each of the 12 nematodes across the nine locations is presented in Table 3. Within each of the nine locations, the differences in the population of the twelve nematodes varied significantly ($P \leq 0.001$), with a consistent lead by *Meloidogyne spp*. The population of the nematodes (except *Meloidogyne*, *Rotylenchus* and *Mesocriconemoides*) varied significantly ($P \leq 0.05$) in each location. The highest population for *Pratylenchus*, *Xiphinema*, *Tylenchus, Trichodorus, Paralongidorus* and *Aphelenchoides* was recorded in the soil samples from Oyo area in Oyo state. Significantly (P≤0.05) higher population of *Tylenchus* was also recorded at Ikole, Ikere, Aramoko and Ibarapa. There were no significant differences between the populations of *Paralongidorus* and *Aphelenchoides* at Ibarapa and Oyo. The highest abundance of *Helicotylenchus, Hemicyclophora* and *Radopholus* occurred at Ikare, Akure and Ibarapa, respectively (Table 3).

Table 1: List, abundance and frequency of nematode species identified in the cocoa rhizosphere surveyed in 45 farms within the three south western states in Nigeria

Nematode species	Class of nematode	Ondo		Ekiti		Oyo		Mean	Mean
		Abund.	Freq.	Abund.	Freq.	Abund.	Freq.	Abund.	Freq.
Meloidogyne spp	Sedentary endoparasitic	84.0	99.0	74.6	96.0	80.9	98.0	79.8	97.7
Pratylenchus coffeae	Migratory endoparasitic	20.6	59.0	24.0	92.0	46.2	80.0	30.3	77.0
Xiphinema spp	Migratory ectoparasitic	17.5	51.0	8.0	40.0	32.0	69.3	19.2	53.4
Helicotylenchus spp	Migratory ectoparasitic	36.3	60.0	20.0	61.3	38.8	74.6	31.7	65.3
Hemicyclophora spp	Migratory ectoparasitic	8.3	20.0	10.6	48.0	10.5	48.0	9.8	38.7
Radopholous similis	Migratory endoparasitic	0.0	-	5.0	25.3	13.8	52.0	6.3	38.7
Trichodorous spp	Migratory ectoparasitic	16.1	55.0	21.0	70.6	22.2	65.3	19.8	63.6
Rotylenchulus reniformis	Semi-sedentary endoparasitic	18.9	64.0	26.2	80.0	26.6	65.3	23.9	69.8
Mesocriconemoides xenoplax	Migratory ectoparasitic	7.9	43.0	10.8	50.6	9.6	41.3	9.4	45.0
Aphelenchoides spp	Migratory endoparasitic	10.9	53.0	0.0	-	23.6	70.6	11.5	61.8
Tylenchus spp	Semi-sedentary endoparasitic	27.0	50.0	43.9	89.3	34.8	68.0	35.2	69.1
Paralongidorous Sali	Migratory ectoparasitic	6.3	42.6	7.2	42.6	18.7	52.0	10.7	45.7
Average		21.1		20.9		29.8			

Abund. = abundance, Freq. = frequency

Table 2: Variance component of the transformed population data of each of the 12 nematode species in a nested design

Sources of Variation	**DF**	**Mean Squares**											
		APHE	**MELO**	**PRAT**	**HELI**	**XIPH**	**ROTY**	**TYLE**	**TRIC**	**HEMI**	**RADO**	**PARA**	**CRIC**
Rep	4	14.31	19.89	10.79	36.00	9.23	66.51	22.28	28.66	5.05	8.28	2.51	19.92
State	2	220.83***	11.45	108.84***	91.24***	128.74***	23.30*	51.73***	11.55	0.71	96.92***	80.38***	4.59
Error(a)	8	4.45	8.74	12.32	9.03	9.30	14.99	15.56	7.22	2.31	4.17	4.91	5.16
Location	2	3.46	2.51	51.49***	41.00***	0.99	9.13	26.85*	11.82	7.52	19.35***	1.00	3.62
State*location	4	1.93	5.12	5.69	44.43***	10.81	5.35	33.81***	16.29*	15.21**	5.97*	7.24	4.05
Error(b)	24	3.38	10.40	5.01	7.38	5.87	6.75	3.67	6.01	3.67	2.19	3.98	4.65
Farm	4	1.10	15.68*	3.15	6.81	9.19	5.96	5.24	1.34	1.62	1.52	1.17	4.28
State*farm	8	2.19	8.68	2.42	10.44	5.42	9.40	6.91	3.87	5.08	1.42	2.64	4.38
Location*farm	8	2.37	2.18	4.58	3.54	4.14	1.89	7.48	4.53	3.22	2.95	1.39	2.11
State*location*farm	16	4.10	5.51	5.31	4.63	12.33**	7.69	4.07	5.11	3.31	3.54	0.83	4.47
Error(c)	144	3.84	6.09	9.25	7.38	5.65	6.29	7.44	5.99	3.90	2.36	3.86	3.44
Mean	-	11.43	80.24	29.28	32.14	18.98	23.40	34.42	19.38	9.64	5.64	10.30	9.30
CV (State/loc/farm)	-	78.94	28.76	65.07	55.56	67.37	62.85	52.39	65.41	74.44	86.59	75.00	77.31
CV (loc/farm)	-	34.42	16.46	25.01	25.53	32.88	33.27	22.14	30.03	30.78	41.35	35.04	40.76

APHE – *Aphelenchoides,* MELO – *Meloidogyne,* PRAT – *Pratylenchus,* HELI – *Helicotylenchus,* XIPH – *Xiphinema,* ROTY – *Rotylenchus,* TYLE – *Tylenchus,* TRIC – *Trichodorus,* HEMI – *Hemicycliophora,* RADO – *Radopholus*, PARA – *Paralongidorus* and CRIC – *Mesocriconemoides*

*, **, *** - significance at P ≤ 5%, 1% and 0.1% respectively

Table 3: Mean proportion of the 12 nematode genera in the nine locations

Nematode species	**MS**	Akure	Ikare	Owo	Ikole	Ikere	Aramoko	Ogbomoso	Ibarapa	Oyo
Meloidogyne	1.21	95.4	81.6	78	70.2	73.2	80.4	87.24	80.4	75
Pratylenchus	8.58***	22.2cde	11.4e	31.8bcd	22.2cde	18de	31.8bc	41.4ab	45.6ab	51.6a
Helicotylenchus	11.05***	30.6cd	60a	28.2cd	13.2d	15d	31.8bc	30.84cd	38.8bc	46.8ab
Xiphinema	7.56***	26.4abc	15abc	13.4bcd	6.6d	6d	11.4cd	22.8ab	34.8a	38.4a
Rotylenchus	2.15	19.2	15	17.4	19.2	29.4	30	21	31.2	27.56
Tylenchus	7.31***	24c	30ab	24bc	49.2a	38.16a	44.4a	16.2c	46.8a	41.4a
Trichodorus	2.79*	24.6ab	12c	13.2bc	22.2ab	16.8bc	24ab	15bc	21abc	30.6a
Hemicycliophora	1.93*	15a	7.2bc	9bc	11.4bc	7.2bc	13.2abc	6.6c	10.8bc	14.2ab
Radopholus	6.41***	0e	0e	0e	1.8e	10.2bc	3de	7.2cd	19.2a	15ab
Paralongidorus	4.79***	8.4bc	3.6c	5.4c	9bc	7.2bc	5.4c	15.6ab	22.2a	18.36a
Mesocriconemoides	0.82	8.4	6.6	7.2	8.4	11.4	12.6	10.8	5.4	12.6
Aphelenchoides	11.40***	11.4b	9.6b	11.1b	0c	0c	0c	18.6ab	23.4a	28.8a
Location MS		22.92***	25.36***	15.50***	31.56***	19.44***	22.51***	16.86***	20.16***	12.98***

*, **, *** - significance at P ≤ 5%, 1% and 0.1% respectively, MS = mean square

† Mean comparison of the proportion of each of the nematode genera in the nine locations is along the rows (Duncans Multiple Range Test – means with the same letter are not significantly different from each other).

† Mean comparison of the proportion of each of the nematode genera in each of the nine locations is along the columns

Similarity and diversity among the 45 farms with respect to the quantity of each nematode genera is presented in Figure 2. Three distinct clusters evolved from the dendrogram, each cluster grouped the farms based on the different population of nematodes. Number of farms grouped within each cluster were 17 (cluster I), 15 (cluster II) and 13 (cluster III). In the grouping structure (Figure 2), the mean proportion of each nematode genera in each farm within each state was highly similar. Each state captured the diversity of the 15 farms within it, although two farms: farms B (Ajagba farm) and E (Bolorunduro farm) from Ogbomoso zone, Oyo state merged with all the farms in Ondo State in cluster I. All farms in cluster II and III were distinctly from Ekiti and Oyo states respectively.

Cluster I had the highest population for *Meloidogyne* spp., however the same cluster had the lowest population of eight other nematode species, i.e. *Pratylenchus, Rotylenchus, Tylenchus, Trichodorus, Hemicyclophora, Radopholus, Paralongidorus* and *Mesocriconemoides*. Cluster II aggregated farms with the highest quantity of *Tylenchus* and *Criconemoides.* The same cluster recorded the least mean quantity for *Meloidogyne, Helicotylenchus, Xiphinema* and *Aphelenchus*. The abundance of *Pratylenchus, Helicotylenchus, Xiphinema, Rotylenchus, Trichodorus, Hemicyclophora, Radopholus, Paralongidorus* and *Aphelenchoides* was highest in cluster III (Figure 2).

Furthermore from Figure 2, the most similar farms in each of the three clusters were: Ondo State, Akure, Farm A (ODAKRA) and Ondo State, Owo, Farm E (ODOWE) (Cluster I), (Ekiti State, Ikole Farm C (EKIKLC) and Ekiti State, Ikole Farm D (EKIKLD) in Cluster II. Within Oyo State in cluster III Ogbomoso, Farm D (OYOGBD) and Oyo State, Oyo, Farm D (OYOYD) were most similar. Similarities within each of the three clusters in respective sequence as measured by Gower 1971 genetic distance (Table not shown) were 0.81, 0.83 and 0.78, judging cluster III (samples from Oyo state) to be the most diverse.

The figurative display of each nematode genera in Figures 3 and 4 was based on the respective populations of each nematode in the 45 soil samples across the three states in south western Nigeria. The two principal components (1 and 2) in Figure 3 and components 1 and 3 in Figure 4 explained 81.36% and 76.15% of the total variation in the abundance of each of the 12 nematode genera respectively. Range in abundance among the 12 nematode species was between *Radophilus* (least) and *Meloidogyne* (highest) in Figures 3 and 4. In the two figures, point 0.0 on the principal component axis 1 divided the 12 nematodes species into two groups (left and right), thus the 12 species were partitioned to five and seven members respectively in each of Figures 3 and 4.

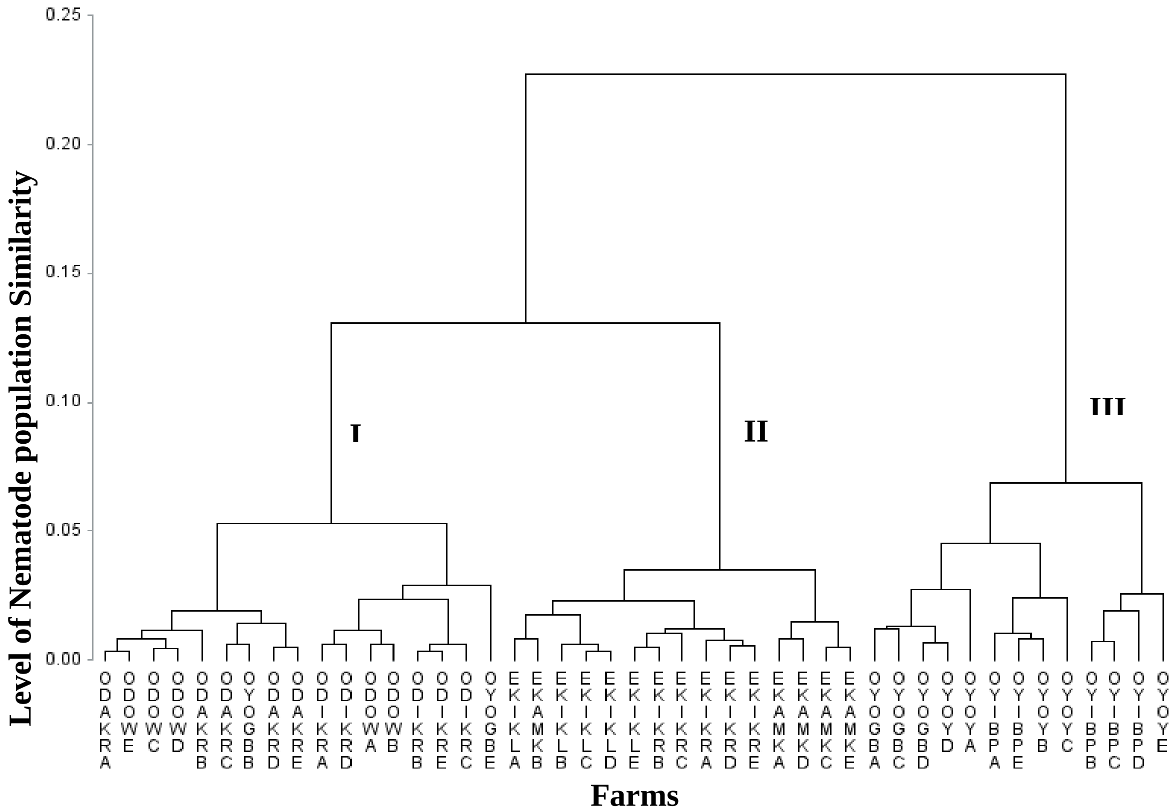

Figure 2: Diversity in the grouping of the 45 farms based on the proportion of the twelve nematode genera identified in the soil sample from each of the farms

* State and Location codes: OD – Ondo (AKR - Akure , OW - Owo , IKR - Ikare), EK – Ekiti (AM - Aramoko, IKR – Ikere and IKL - Ikole) and OY –Oyo (OY- Oyo, OGB – Ogbomoso and IBP – Ibadan/Ibarapa). The five farms in each location were named Farms A, B, C, D and E.

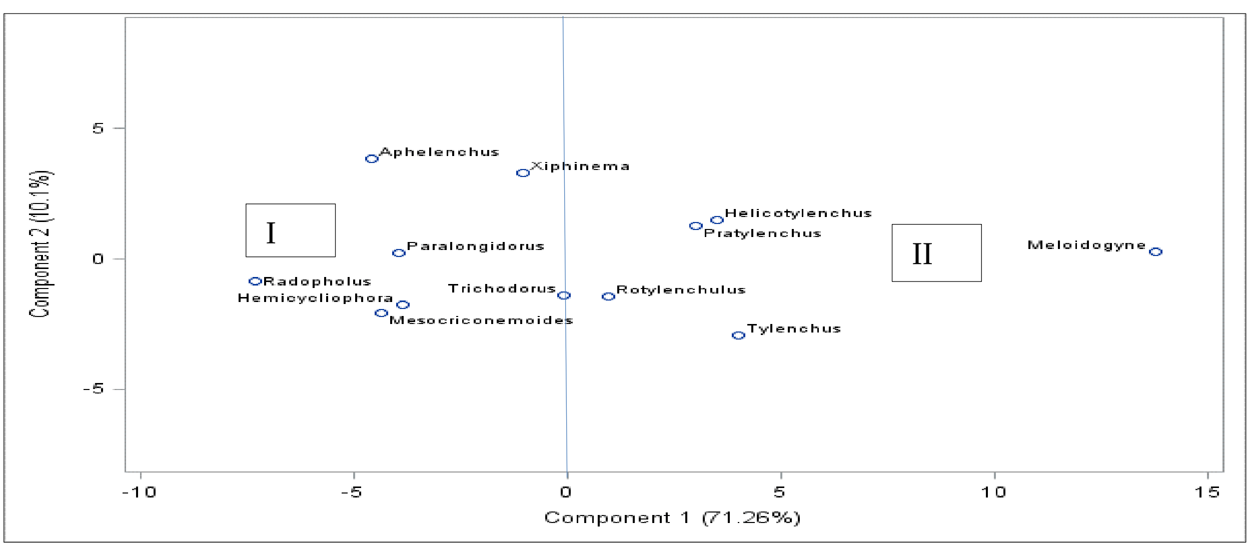

Figure 3: Two-dimensional display by principal components 1 and 2 of the 12 nematode genera based on their proportion in the 45 cocoa farms sampled across three states in south western Nigeria

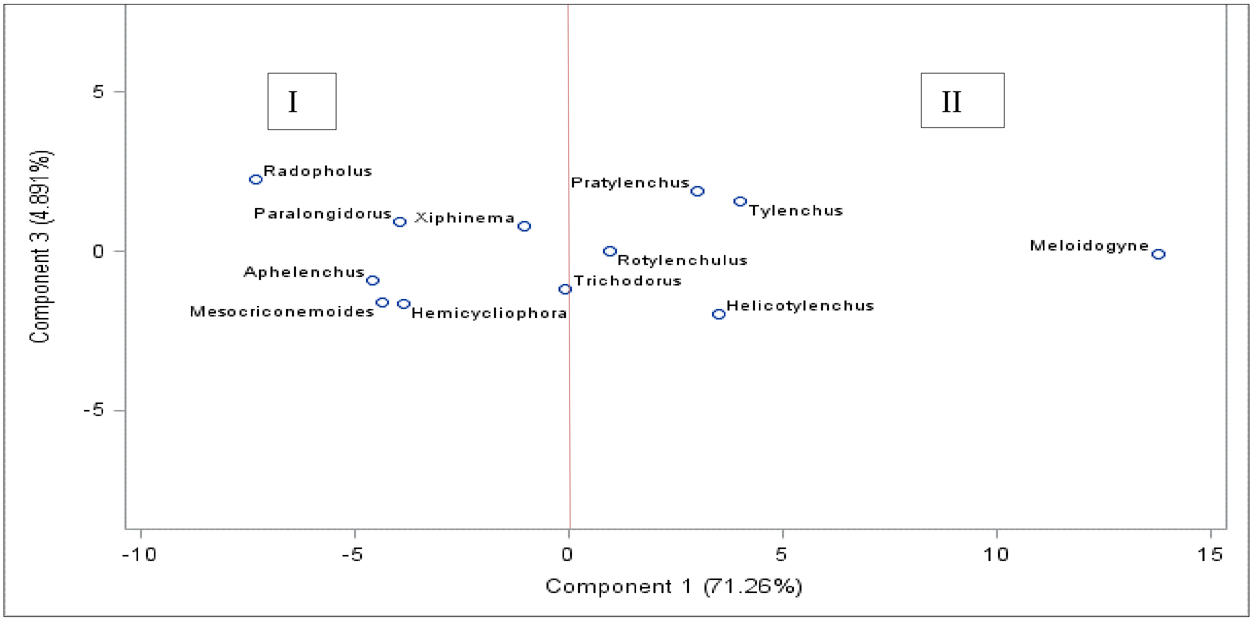

Figure 4: Two-dimensional display by principal components 1 and 3 of the 12 nematode genera based on their proportion in the 45 cocoa farms sampled across three states in south western Nigeria.

Discussion

Functional diversity in nematodes communities is habitat-specific dependent (Kergunteuil et al., 2016). Vegetation and organic soil layers are most determinants, so poor availability of these components could induce reduction of nematode quantity and diversity, but not availability. The unique property of exhibiting wide nutritional adaptations such as: herbivore, fungivore, bacterivore, substrate ingester, predator of animals, unicellular eukaryote feeder, parasites, and omnivore (Yeates et al., 1993) may have greatly supported their continuous survival in the most incredible habitat. Within the basic functional trophic guilds, Bongers (1990) identified the ranges of ecological adapters among nematodes to be within: “the colonizer” and “the persister”.

Forest ecology plays host to a wide distribution of differing taxa and populations of nematodes (Yeates 2007). This, in part, seems to justify the identified large number of nematode species in the root ecosystem of cocoa observed in this study. Moreover, the suitability of cocoa root in hosting 12 phyto-parasitic nematodes species seems to infer that cocoa root may be providing adequate food resource and suitable environmental conditions for their survival. Nwangi et al. (2014) noted that the extraction of diverse nematode genera from the soil and root samples of a crop is an indication that the crop is a potential host to phyto-parasitic nematodes.

Cocoa cultivation in farmers’ fields in south western Nigeria is never a sole cropping system; other crops such as: African walnut (*Coula edulis*), kolanut (*Cola acuminata* or *Cola nitida*), cocoyam (*Xanthosoma sagitifolium*), oranges (*Citrus sinensis*), cashew (*Anacardium occidentale*), pineapple (*Ananas comosus*), worowo (*Senecio biafrae*) etc are usually hosted in the plantation for the farmers’ food and cash security. Nwangi et al.

(2014) noted that high density of phyto-parasitic nematodes has been attributed to the extensive farming system including intercropping. The condition of multiple crop mixture may have accounted for many nematode genera isolated in our survey. The majority (75%) of the resident nematodes around the rhizosphere of cocoa tree root (from this study) were the migratory nematodes. The multiplicity of favourable hosts for this group of nematodes may have been responsible for their higher percentage compared to the sedentary ones.

Our observation of variability in nematode types and population in this study is consistent with some earlier reports (Chirchir et al. 2008; Zhang et al. 2012). In the study by Afolami et al. (2013) on cocoa in two locations (Ibadan and Owena in south western Nigeria), 10 and 12 different genera of nematodes were respectively identified. The coverage areas of the present study extends from forest, forest-savanna transition to the guinea savanna of Nigeria. A state in Nigeria is like a province comprising many diverse agro-ecologies. The proportion of the coefficients of variation for the states as a source of variation was huge compared to those for locations and farms. The high between-state, within-state and within-location variation identified in this study could be due to the inherent heterogeneity of the agricultural pattern and practices, biotic, climatic and edaphic characteristics in the 45 farms, which according to some workers (Sawadogo et al. 2009; Nwangi et al. 2014) have been identified to be responsible for inconsistent nematode distribution across agricultural ecologies. The large coefficient of variation observed in the population of the twelve nematode genera depicted wide variability in their distribution and abundance in the 45 highly diverse cocoa plantations. However, uniformity of nematode type and population existed for locations and farms within each state. The localized climatic, edaphic, cultural and cultivation pattern common to the different farms and locations within the states could be implicated for this similarity.

Several plant-parasitic nematodes species are associated with cocoa cultivation. The major species affecting cocoa based on the report of Barbosa et al. (2004) are *Meloidogyne* spp. and *Pratylenchus* spp. Our work identified more than these two, with *Tylenchus* and *Helicotylenchus* showing higher abundance and relatively the same frequency as *Pratylenchus*. The result of this survey for the abundance of plant-parasitic nematodes of cocoa revealed the prevalence of five nematode genera in the order of: *Meloidogyne* > *Tylenchus* > *Helicotylenchus* > *Pratylenchus* > *Rotylenchulus*. This concurs with the findings of many authors including Caveness (1965), Egunjobi et al. (1986) and Lamberti et al. (1992) that *Rotylenchus, Pratylenchus, Helicotylenchus, Tylenchus* and *Meloidogyne* species are among the notable plant-parasitic nematode genera which have been implicated world-wide as important nematode pests. Moreover, they have been reported to have wide host ranges.

The genus *Meloidogyne* (Root-knot nematodes) was most frequent and widely distributed in the surveyed exercise in the three states of Nigeria. Different species of *Meloidogyne* have been reported for leading economic significance in the cocoa field in Malaysia (Razak 1981), Bolivia (Bridge and Page 1982) etc. Over 2000 plant species are susceptible to one or more species of *Meloidogyne* (Horst 1990), this study idenfied Cocoa as one of such crop species.

Tylenchus spp occurred at high frequency and abundance in all the soil samples examined from the cocoa plots surveyed in the three states. This nematode species has also been found to exhibit mycophagy in soil (Magnusson 1986), therefore their relative abundance in the soil could not have been as a result of their direct feeding relationship with the cocoa roots but could be correlated to the composition of mycoflora in the soils as indicated by Walter (1987). Litter falls and their mineralization in cocoa plantations may be providing a good habitat for this species, noting that the soil samples were collected within a depth of 0 – 20 cm, the horizon with the highest rate of organic decomposition.

Helicotylenchus, the spiral nematodes found in large frequency in the cocoa soils from the present investigation was reported by Lamberti et al. (1992) to be a nematode of economic importance in cocoa plots. It was second to *Meloidogyne* in cabbage fields in Kenya (Nwangi et al. 2014) but its rank in abundance in the present study was third. The reasons for its high frequency and abundance are explained by wide host range and cropping history such as mixed cropping.

The report of the abundance of various species of *Pratylenchus* spp in cocoa plantations is quite significant. Regions where its economic importance as a cocoa pest has been recorded include Bahia region, Brazil (Sharma and Sher 1973), Western Africa (Luc and Guiran 1960) and Java (Fluitter and Mulholland 1941). In the present study, *Pratylenchus coffea* was the second to *Meloidogyne* in frequency but fourth to the same in abundance. Most striking about this migratory endoparasite is that it affects the root efficiency functions and exposes the plants to other infections through the root.

Other nematodes were encountered at relatively lower frequency and density in various states. The low occurrences of other nematodes may indicate their low frequency owing to the presence of major, indigenous and specific host-crop nematodes. Moreover, their low population may be attributed to the probable ability of cocoa to resist or tolerate them. Though most of these nematodes (*Mesocriconemoides xenoplax*, *Hemicycliophora* spp, *Aphelenchoides* spp, *Xiphinema* spp. etc.) are noted to have limited pathogenicity (Bridge 1988), their presence in cocoa plots could form an additional parasitic load and their subsequent increase in population may pose threat to cocoa production. The absence of *Radophilus* and *Aphelenchoides* species in the surveyed soil in Ondo and Ekiti state respectively could be explained by the remark of Gomes et al. (2003) that nematodes can survive within many small patches in the soil environment, but their life processes are very sensitive to climatic variations.

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