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PARASITIC NEMATODE POPULATIONS ASSOCIATED WITH DEVELOPMENTAL STAGES OF MANGO IN PRODUCTION REGIONS OF GHANA

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ABSTRACT

Nematode (*Phylum nematoda*) infestation is a major set back in mango (*Mangifera indica*) production world-wide. Control of nematodes requires understanding of their diversity, distribution and population densities. The objective of this study was to identify plant-parasitic nematodes associated with mangoes and their population densities at seedling and maturity stages in production regions of Ghana. The study was conducted in Greater Accra (Manya and Klagon) and the Eastern region (Somanya) during December 2016 to January 2018. Mango farmlands were surveyed for soil and root samples, from which nematodes were extracted, identified and quantified. Twenty-four nematode genera were identified in mango seedlings and matured trees from Somanya; and 14 genera dentified in seedlings and 22 in matured trees from Manya; while at Klagon, 15 nematode genera were identified in matured trees. *Helicotylenchus* spp. were the most populated in seedlings obtained from Somanya and Manya, with relative abundance of 23.29%. *Tylenchus* spp. had the highest population in mature trees, with relative abundance of 24.49% at Somanya and 38.86% at Manya; while *Helicotylenchus* spp. had the highest relative abundance of 43.96% at Klagon. Mature trees had higher nematode population densities, compared to seedlings. There were significant variation in nematode populations between seedlings and matured stages of mango.

Key Words: *Helicotylenchus* spp., *Mangifera indica*, *Tylenchus* spp.

RÉSUMÉ

L'infestation de nématodes (*Phylum nematoda*) constitue un problème majeur dans la production mondiale de mangue (*Mangifera indica*). La lutte contre les nématodes nécessite une compréhension de leur diversité, de leur répartition et de leur densité de population. L'objectif de cette étude était d'identifier les nématodes phytoparasites associés aux mangues et leurs densités de population aux stades de semis et de maturité dans les régions de production du Ghana. L'étude a été menée dans le Greater Accra (Manya et Klagon) et dans la région orientale (Somanya) de Décembre 2016 à Janvier 2018. Les terres agricoles de mangues ont été étudiées à la recherche d'échantillons de sol et de racines, à partir desquels les nématodes ont été extraits, identifiés et quantifiés. Vingt-quatre genres de nématodes ont été identifiés dans des plants de manguiers et des arbres matures de Somanya ; et 14 genres identifiés dans des semis et 22 dans des arbres matures de Manya ; tandis qu'à Klagon, 15 genres de nématodes ont été identifiés dans les arbres matures. *Helicotylenchus* spp. étaient les plus peuplés de plantes obtenus de Somanya et Manya, avec une abondance relative de 23,29 %. *Tylenchus* spp. avait la population la plus élevée d'arbres matures, avec une abondance relative de 24,49 % à Somanya et de 38,86 % à Manya; tandis que *Helicotylenchus* spp. avait l'abondance relative la plus élevée de 43,96% à Klagon. Les arbres matures présentaient des densités de population de nématodes plus élevées que les semis. Il y avait une variation significative des populations de nématodes entre les semis et les stades de maturité du manguier.

Mots Clés : *Helicotylenchus* spp., *Mangifera indica*, *Tylenchus* spp.

INTRODUCTION

Mango (*Mangifera indica*) is a stony fruit that belongs to the Anacardiaceae family; and serves as a rich source of dietary fiber, proteins, carbs, lipids, and other phytochemical elements. Major amino acids within this fruit include leucine, valine, lysine, cysteine, methionine, arginine, and phenylalanine (Maldonado-Celis *et al.*, 2019). However, infestations due to nematodes have constrained mango production and export. These organisms attack all parts of the plant, including the flowers, leaves, stems, seeds and roots; causing tremendous crop damage and yield losses (Agrios, 2005). Symptoms associated with root infestation include gall formation, foliar wilting, stunting and leaf chlorosis.

Nematode infestation in mango has had world-wide negative physiological and economic dimensions. A survey conducted in India revealed that eight nematode genera were associated with mango; with *Hemicricomoides mangiferae* being the most populated; while *Meloidogyne incognita* had the lowest counts (Kumar and Khan, 2015). McSorley *et al.* (1981) identified nine nematode genera in mangoes collected from South Florida, with *Rotylenchulus reniformis* showing the highest population density, and *Paratylenchus* spp. the lowest. However, there is limited research on nematode genera and infestation levels associated with mango plants in sub-Saharan Africa. Knowledge of the incidence and management of plant-parasitic nematodes is essential for achieving sustainable levels of mango production in the region. The objective of this study was to identify plant-parasitic nematodes and their population densities associated with mango production regions of Ghana.

MATERIALS AND METHODS

Study area. This study was conducted in two major mango production areas of Ghana; namely, Greater Accra and Eastern Region. In Greater Accra, the study was conducted in Manya and Klagon towns. Manya is located in Doryumu, and at longitude and latitude 6 ° 3' 0" N, 0° 24' 0" E; and altitude of 266 meters above sea level. The mean annual temperature is 29 °C, ranging from 32°C in the dry season to 26 °C during the rainy season. The soil complexes are predominantly Yaya-Pimpimso Bejna Association and Dewasi-Wayo Association (https://mofa.gov.gh/site/index.php/sports/district-directorates/eastern-region/238-upper-manya-krobo).

Klagon is also a town found in the Tema Metropolis District, at 5° 45' 0.832" N 0° 5' 36.499" E.; and altitude of 27 meters above sea level. The mean annual temperature is 26.9 °C ranging from 28.6 °C in the dry season to 24.6 °C during the rainy season. The soils are predominantly sand, clay, humus, gravel and stone. The Metropolis is underlain by the

Precambrian rocks of the Dahomeyan formation: metamorphic rocks made up of granite, gneiss and schist (https://www2.statsghana.gov.gh/docfiles/2010_District_Report/Greater%20Accra/Tema%20Metro.pdf).

In the Eastern region, the study was conducted at Somanya, at 6° 6' 14" N 0° 0' 54" W; and altitude of 82.36 meters above sea level. The mean annual temperature is 27.18 °C, and ranges from 34.55 °C in the dry season to 20.34 °C. The soil complexes in this district are in three major groups. (a). Soils developed over sand stone (Yaya-Pimpimso-bejua Association), (b). Soils developed over Buem (Dewasi-Wayo Association), and (c). Soils developed over Togo rocks (Menfe-Fete-Salom complex and the Oyarifa-Krobo-Memfe-Nyire complex). (https://mofa.gov.gh/site/directorates/district-directorates/eastern-region/240-yilo-krobo).

Soil and root sample collection

Somanya site. A hundred soil and fifty root samples were randomly collected from ten different farmlands at Somanya site. For each farm, soil and root samples were obtained from five different mature trees, and the soils were collected at two depths (0-15 and 15-30 cm). Five seedlings were purchased from five seedling stores that originally sold to the ten farms.

During soil sampling, an auger was used to bore a hole into the soil in close proximity to mango plants in order to obtain 0-15 cm depth of soil. The auger was then washed using clean water and placed back into the same hole to obtain the second sample at 15-30 cm depth. Soil samples from different depths were bagged and labeled separately.

With the aid of a cutlass, root samples from mango trees were excised from the base of the tree trunk, close to where soil samples were taken. Soil and root samples from seedlings were also collected and bagged separately.

Greater Accra. A total of eighteen soil and nine root samples were collected from six farms in Manya and three farms in Klagon. Twelve soil and six root samples were obtained from Manya; whereas six soil and three root samples were obtained from Klagon. Five seedlings were also purchased from Manya. Soil and root samples from mango trees were also randomly obtained from both farms using the same procedure described above for Somanya site. Soils and roots from seedlings were also collected and bagged separately.

Nematode extraction. Nematodes were extracted from soil samples using the sucrose centrifugation method (Jenkins, 1964). By this procedure, 200 g of soil was sieved and transferred into a beaker. Water of twice the volume of the soil sample, was added into the beaker and stirred manually. The suspension was left to settle for five minutes and the supernatant poured through nested sieves (36, 71, 91 μm and 1 mm).

With the help of a wash bottle, the nematodes were washed to one side of the 36 μm sieve and collected into labelled falcon tubes. The Falcon tubes containing nematodes were centrifuged at 1700 rpm, for five minutes. Following centrifugation, the supernatant was drained out, until it was about 1 cm above the pellet.

Sucrose solution was prepared by dissolving 454 g of sugar in 1 liter of distilled water, and this was transferred onto the pellets. The samples were centrifuged again at 1000 rpm for one minute. After centrifugation, the supernatant was poured through the 36 μm sieve and washed thoroughly, to rid it of any excess sucrose. The wash bottle was then used to collect nematodes carefully into well labeled falcon tubes.

Extraction of nematodes from all root samples was done using the Baermann funnel method (Van Bezooijen, 2006). Root samples were cut into pieces of 10 g each. The cut sample pieces were each blended for 3 seconds and transferred into a funnel lined with tissue paper and wire mesh. Distilled water was then filled into the funnel, until it touched the base of the wire mesh.

The setups were labeled according to replicates and source of roots; and left for 48 hours with the bottom tube of the funnel blocked using a stopper. After 48 hours, the funnel tube was unblocked in order to release and collect the excessive water containing nematodes. The water collected was run through the 71 and 36 µm sieves. A wash bottle was then used to collect the nematode sample from the 36 µm sieve into falcon tubes. The tubes were then labeled according to labels on funnels.

Identification and estimation of nematodes. For each samples extracted, nematodes were observed under a compound light microscope, and a tally counter was used to enumerate them. Additionally, a stereo-microscope was used to provide a detailed view of the nematodes. Nematodes were heat-fixed to the slides, to keep them in place. Morphological features including stylet, tail, labial framework and esophagus were used as the criteria for nematode identification (Luc *et al.,* 1990).

Population density (PD) of nematodes per 200 cm^3 of soil and 10 g root samples, and relative abundance (RA %) were calculated according to Norton (1978) as follows:

(i) PD = average number of nematodes per 200 cm^3 of soil, and 10 g root samples

(ii) RA% = the number of individuals of a nematode genus or species per total number of nematodes identiûed and counted from a 200 cm^3 soil sample.

Data analysis. Data collected on nematode populations were subjected to Analysis of Variance (ANOVA) using GenStat Statistical Package Edition 12, and means were separated using Duncan Multiple Range Test, at 5% significance level.

RESULTS

There were significant nematode genera site differences in the study area (Tables 1 and 2). In Somanya site, a total of 24 nematode genera were identified in soil from mango seedlings samples (Table 3). *Helicotylenchus* spp. were the most abundant (23.29%) in soil; while *Pratylenchus* spp., *Meloidogyne* spp. and *Tylenchus* spp. were the only genera identified in seedling roots with a mean relative abundance of 33.33%. For this site,

TABLE 1. Population densities of nematode genera among 10 sites at Somanya

Nematode genera	Mean
Helicotylenchus spp.	53.7e
Tylenchus spp.	59.1e
Aphelenchus spp.	15.7bcd
Tylenchulus spp.	14.4abcd
Aphelenchoides spp.	4.2abc
Ditylenchus spp.	2.6abc
Rotylenchus spp.	4.9abc
Pratylenchus spp.	10.2abcd
Paratylenchus spp.	14.5abcd
Scutellonema spp.	4.9abc
Hirshmeniella spp.	1.0ab
Enophida spp.	2.0ab
Rodopholus spp.	1.4ab
Heterodera spp.	7.6abc
Xiphinema spp.	1.5ab
Meloidogyne spp.	17.3cd
Longidorus spp.	23.2d
Belonolaimus spp.	1.8ab
Trichodorus spp.	3.2abc
Tylenchida spp.	0.1a
Rotylenchulus spp.	2.1ab
Hemicycliophora spp.	0.6ab
Dolichodorus spp.	1.9ab
Hemicricomoides spp.	0.3ab

TABLE 2. Population densities of nematode genera among seedling transplanting and matured mango trees from soil samples at Somanya

Nematode genera	Mean
Rhabditida spp.	1.3a
Hemicricomoides spp.	2.3a
Tylenchorhynchus spp.	1.3a
Tylenchida spp.	0.3a
Belonolaimus spp.	9.3ab
Xiphinema spp.	7.3ab
Hemicycliophora spp.	3.3ab
Ditylenchus spp.	12.3ab
Dolichodorus spp.	10.3ab
Rotylenchus spp.	9.0ab
Enophida spp.	10.7ab
Hirshmaniella spp.	3.3ab
Rodopholus spp.	4.7ab
Aphelenchoides spp.	17.3abc
Trichodorus spp.	14.3abc
Mesocriconema spp.	20.0abc
Rotylenchus spp.	18.7abc
Heterodera spp.	43.7abcd
Pratylenchus spp.	43.7abcd
Paratylenchus spp.	57.3abcd
Scutellonema spp.	41.0abcd
Tylenchulus spp.	71.0bcde
Meloidogyne spp.	80.3cde
Aphelenchus spp.	92.3de
Longidorus spp.	122.7e
Helicotylenchus spp.	256.3f
Tylenchus spp.	214.3f

Means followed by the same letters in a column are not significantly different at ($P< 0.05$) using Duncan test

Hemicricomoides spp., *Tylenchorhynchus* spp., *Hemicycliophora* spp., and *Rhabditis* spp. had the least relative abundance of up to 0.40% in soil.

At mature mango tree stages. There were significant differences among the nematodes for the ten sites (Table 2). Within the Somanya site, a total of 25 nematode genera were identified in soil taken from mature mango trees (Table 4). *Tylenchus* spp. had the highest relative abundance (24.49%) for root and soil samples. Out of the 10 nematode genera identified in root samples, *Tylenchus* spp. (41.18%) and *Tylenchulus* spp. (20.59%) had the highest relative abundance; while *Dolichodorus* spp., *Pratylenchus* spp., *Rotylenchulus* spp. and *Meloidogyne* spp. had the lowest relative abundance (2.94%) soil under mature trees and at this stage. *Hermicrycomoides* spp. appeared to be the least abundant in soil and roots of mango trees and so recorded the lowest relative abundance of 0.13%.

Manya site. Significant differences existed among the populations of nematodes from soil samples at the various stages of maturity of the mango (Table 5). A total of 14 nematode genera were associated with soil under mango seedlings obtained from the Manya site (Table 6). On the other hand, only four nematode genera were associated with roots of mango seedlings at this site (Table 6). *Helicotylenchus* spp. had the highest relative abundance (38.87%) in soil samples; whereas *Meloidogyne* spp. recorded the highest relative abundance (55.55%) in root samples. *Bursaphelenchus* spp. appeared the least in soil and roots at both seedling and mature mango tree stage; and had the lowest relative abundance (0.34%). At Manya site, 22 nematode genera were identified in soil samples collected from matured mango tree; while *Helicotylenchus* spp. was predominant at seedling stage (Table 7). *Tylenchus* spp. had the highest relative abundance of 38.86% in the soil; while *Radophulus* spp., *Anguina* spp., *Hoplolaimus* spp. and *Mesocriconema* spp. had the least relative abundance of 0.12%. No nematodes were identified in the root samples at this site.

Klagon site. At Klagon site, 15 nematode genera were identified in soil collected from mature mango trees (Table 8). *Helicotylenchus* spp. had the highest relative abundance (43.96%) in both soil and roots combined. Only three nematode genera were identified in root samples, out of which *Tylenchus* spp. had

TABLE 3. Population density and relative abundance of nematode genera identified in soil and root samples obtained from Somanya at seedling stage

Nematode genera	Population/ 200 g soil	Relative abundance (%) soil	Population/ 10 g roots	Relative abundance (%) Roots	Relative abundance (%) Root + soil
Pratylenchus spp.	29.00	2.92	1.00	33.33	3.01
Meloidogyne spp.	68.00	6.85	1.00	33.33	6.92
Tylenchus spp.	52.00	5.24	1.00	33.33	5.32
Helicotylenchus spp.	232.00	23.36	0.00	0.00	23.29
Tylenchulus spp.	69.00	6.95	0.00	0.00	6.93
Heterodera spp.	55.00	5.54	0.00	0.00	5.52
Paratylenchus spp.	27.00	2.72	0.00	0.00	2.71
Aphelenchoides spp.	10.00	1.01	0.00	0.00	1.00
Trichodorus spp.	11.00	1.11	0.00	0.00	1.10
Scutellonema spp.	43.00	4.33	0.00	0.00	4.32
Hemicricomoides spp.	4.00	0.40	0.00	0.00	0.40
Tylenchorhynchus spp.	4.00	0.40	0.00	0.00	0.40
Rhabditis spp.	4.00	0.40	0.00	0.00	0.40
Longidorus spp.	136.00	13.70	0.00	0.00	13.65
Aphelenchus spp.	12.00	12.08	0.00	0.00	1.20
Belonolaimus spp.	10.00	1.01	0.00	0.00	1.00
Xiphinema spp.	7.00	0.70	0.00	0.00	0.70
Hemicycliophora spp.	4.00	0.40	0.00	0.00	0.40
Ditylenchus spp.	11.00	1.11	0.00	0.00	1.10
Mesocricomoides spp.	60.00	6.04	0.00	0.00	6.02
Dolichodorus spp.	12.00	1.21	0.00	0.00	1.20
Rotylenchulus spp.	6.00	0.60	0.00	0.00	0.60
Enoplus spp.	12.00	1.21	0.00	0.00	1.20
Rotylenchus spp.	7.00	0.70	0.00	0.00	0.70
Total	993.00		3.00		
Grand total	996.00				

the highest relative abundance (50%). On the other hand, *Pratylenchus* spp. had the least population density in roots and soil, hence recorded the least relative abundance (0.05%).

DISCUSSION

The presence of significant differences in nematode population density and genera distribution between the various sites in Somanya, Klagon and Manya in Ghana (Tables 1,2,5), could be attributed to soil types and management practices utilised in these environments. Plant-parasitic nematode populations in soil may not always result in economic yield loss, this is because of densities being below damage thresholds (Khan, 2008). There are specific factors that can influence crop damage and yield losses e.g., soil types, prevailing nematode distribution pattern, plant cultivar, and nematode multiplication rates in these soils (Schomaker and Been, 2006; Khan, 2008).

In Somanya site, a total of 24 nematode genera were identified in soil from mango seedlings samples (Table 3). *Helicotylenchus*

TABLE 4. Population density and relative abundance of nematode genera in soil and root samples (soil 200 g, collected at 0-15 cm and 15-30 cm depth and 10 g of mango tree roots) obtained from Somanya at matured stage

Nematode genera	Population/ 200 g soil		Relative abundance (%) soil		Population/ 10 g roots	Relative abundance (%) roots	Relative abundance (%) roots + soil
	0-15 cm depth	15-30 cm depth	0-15 cm depth	15-30 cm depth			
Tylenchus spp.	369.00	222.00	25.05	23.05	14.00	41.18	24.49
Dolichodorus spp.	3.00	16.00	0.20	1.66	1.00	2.94	0.81
Tylenchulus spp.	85.00	59.00	5.77	6.13	7.00	20.59	6.11
Helicotylenchus spp.	377.00	161.0	25.53	16.72	2.00	5.88	21.86
Aphelenchoides spp.	21.00	21.00	1.43	2.18	2.00	5.88	1.78
Pratylenchus spp.	52.00	50.00	3.53	5.19	1.00	2.94	4.17
Scutellonema spp.	25.00	24.00	1.70	2.49	2.00	5.88	2.06
Rotylenchulus spp.	21.00	0.00	1.43	0.00	1.00	2.94	0.89
Meloidogyne spp.	105.00	68.00	7.13	7.06	1.00	2.94	7.04
Mesocricomoides spp.	0.00	0.00	0.00	0.00	3.00	8.82	0.12
Aphelenchus spp.	44.00	57.00	2.99	5.92	0.00	0.00	4.09
Rotylenchus spp.	33.00	16.00	2.24	1.66	0.00	0.00	1.98
Paratylenchus spp.	77.00	68.00	5.23	7.06	0.00	0.00	5.87
Scutellonema spp.	25.00	24.00	1.70	2.49	0.00	0.00	1.98
Hirshmeniella spp.	4.00	6.00	0.27	0.62	0.00	0.00	0.40
Enoplus spp.	14.00	6.00	0.95	0.62	0.00	0.00	0.81
Rodopholus spp.	14.00	0.00	0.95	0.00	0.00	0.00	0.57
Heterodera spp.	33.00	43.00	2.24	4.47	0.00	0.00	3.08
Xiphinema spp.	10.00	5.00	0.68	0.52	0.00	0.00	0.61
Longidorus spp.	140.00	102.00	9.50	10.59	0.00	0.00	9.80
Belonolaimus spp.	5.00	13.00	0.34	1.35	0.00	0.00	0.73
Ditylenchus spp.	17.00	9.00	1.15	0.93	0.00	0.00	1.05
Hemicrycomoides spp.	0.00	3.00	0.00	0.31	0.00	0.00	0.13
Trichodorus spp.	20.00	12.00	1.36	1.25	0.00	0.00	1.30
Hemicycliophora spp.	4.00	2.00	0.27	0.21	0.00	0.00	0.24
Total	1473.00	963.00			34.00		
Grand total	2470.00						

TABLE 5. Population densities of nematode genera among seedling transplanting and matured mango trees from soil samples for Klagon and Manya

Nematode genera	Mean	
Radophulus spp.	0.3	(0.3) a
Mesocriconema spp.	0.3	(0.3) a
Ditylenchus spp.	0.3	(0.3) a
Bursaphelenchus spp.	1.0	(0.6) a
Tylenchorhynchus spp.	1.0	(0.8) a
Criconemella spp.	1.7	(0.9) a
Scutellonema spp.	2.3	(1.0) a
Trichodorus spp.	2.7	(1.4) a
Anguina spp.	3.3	(1.5) a
Hoplolaimus spp.	8.3	(2.2) a
Heterodera spp.	10.3	(3.1) a
Hemicycliophora spp.	11.7	(3.3) a
Aphelenchoides spp.	16.0	(3.4) a
Longidorus spp.	18.0	(3.9) ab
Pratylenchus spp.	18.7	(4.2) ab
Hemicriconemoides spp.	27.3	(4.5) ab
Rotylenchus spp.	31.0	(5.1) ab
Meloidogyne spp.	42.7	(5.5) ab
Xiphinema spp.	64.7	(6.7) ab
Aphelenchus spp.	96.0	(8.1) ab
Tylenchulus spp.	99.7	(9.0) abc
Paratylenchus spp.	244.3	(12.5) bcd
Helicotylenchus spp.	356.3	(16.6) cd
Tylenchus spp.	377.0	(17.4) d

Means followed by the same letters in a column are not significantly different at (P< 0.05) using Duncan test. Values in Parenthesis are square-root transformed

spp. were the most abundant at 23.29% in the soil; while *Pratylenchus* spp., *Meloidogyne* spp. and *Tylenchus* spp. were the only genera identified in seedling roots. The mean relative abundance of for soil samples was 33.33%. For this site, *Hemicricomoides* spp., *Tylenchorhynchus* spp., *Hemicycliophora* spp., and *Rhabditis* spp. had the least relative abundance of up to 0.40% in soil.

Fourteen nematode genera were identified in soil and root samples of mango seedlings from Manya site; whereas twenty-two nematode genera were identified in soil samples of matured trees. Samples obtained from Klagon site also revealed a total of fifteen nematode genera in the roots and soils of matured mango trees (Table 8). In another study conducted in a different region in the Cerrado area of Federal District, Brazil, nine nematodes were identified at the end of a survey on plant-parasitic nematodes associated with mango (Sharma, 1978). Another survey in Southeastern Florida identified ten nematode genera connected with mango and tree condition (McSorley *et al.*, 1981). In Pakistan, eleven nematode genera were identified after a survey was conducted on plant-parasitic nematodes and fungal communities associated with mango decline of Southern Punjab (Anwar *et al.*, 2012). Milne *et al.* (1975) also identified sixteen nematode genera in a survey of mango nurseries and declining field plantings. The present results reveal nematode diversity and population densities, both in soil and root samples. However, the nematodes associated with mango in the soil are more diverse as compared to those in the roots. Reducing nematode infestation in mango fields demands an integrated pest management of nematodes (Mokrini *et al.*, 2023). There is a possibility of some nematode genera being more aggressive compared to others. In a previous study, the impact of seasonal changes on populations of plant parasitic nematodes associated with mango were observed (Siddiqui, 2007). Nematodes identified included *Hoplolaimus indicus*, *Helicotylenchus indicus*, *Rotylenchulus reniformis*, *Tylenchorhynchus mashoodi*, *Tylenchus filiformis* and *Hemicriconemoides mangiferae*. Nematodes sampled from three depths (10, 20 and 40 cm) revealed seasonal fluctuations on nematode populations. Nematode population densities were highest and lowest at 10 and 40 cm depths, respectively. High nematode population densities were observed in areas with high soil moisture content. In the present study, the highest nematode populations were isolated

TABLE 6. Population density and relative abundance of nematode genera identified in soil and root samples (200g soil and 10g of mango seedling roots) obtained from Manya at seedling stage

Nematode genera	Population/ 200 g soil	Relative abundance(%) soil	Population/ 10 g roots	Relative abundance(%) roots	Relative abundance(%) root+soil
Tylenchus spp.	35.00	12.37	0.00	0.00	11.99
Heterodera spp.	5.00	1.77	1.00	11.11	2.05
Rotylenchus spp.	11.00	3.89	0.00	0.00	3.77
Meloidogyne spp.	43.00	15.19	5.00	55.55	16.44
Pratylenchus spp.	11.00	3.89	2.00	22.22	4.45
Tylenchulus spp.	16.00	5.65	0.00	0.00	5.48
Paratylenchus spp.	15.00	5.30	0.00	0.00	5.14
Scutellonema spp.	6.00	2.12	0.00	0.00	2.05
Aphelenchus spp.	8.00	2.83	0.00	0.00	2.74
Xiphinema spp.	7.00	2.47	0.00	0.00	2.40
Bursaphelenchus spp.	1.00	0.35	0.00	0.00	0.34
Longidorus spp.	13.00	4.59	0.00	0.00	4.45
Helicotylenchus spp.	110.00	38.87	1.00	11.11	38.01
Hoplolaimus spp.	2.00	0.71	0.00	0.00	0.68
Total	283.00		9.00		
Grand total	292.00				

from the top 15 cm of soil, which also had higher soil moisture content.

The varying nematode species identified can be attributed to differences in soils and mango varieties present at different locations and stages of growth. Porazinska *et al*. (2012) also indicated that the nematode population or diversity in the tropics (including Ghana) is higher than that of the temperate zones (e.g. Brazil, Paskistan and Florida) due to factors such as temperature, light, moisture, soil type and nutritional factors.

In Cerrado area of Fedral District, Brazil, *Helicotylenchus* spp. was the most dominant species with relative abundance of 74.2% (Sharma, 1978); while in Pakistan, *Rotylenchulus* spp. had the highest population density of 121 per 100 cm³ (Anwar *et al*., 2012). In North Sinai, *Hoplolaimus* spp. had the highest population density of 22 per 250 cm³ (Korayen *et al*., 2014). In Jazon Province, Southwest Saudi Arabia, a survey by Mokbel (2014) revealed that *Tylenchorhynchus* spp. had the highest population density (150 per 250 cm^3). Milne *et al.* (1975) also found *Pratylenchus* spp. and *Helicotylenchus* spp. to be the most prevalent genera in mango nurseries in South Africa.

The present study, however, has showed that *Meloidogyne* spp. and *Helicotylenchus* spp. were the most dominant nematode genera associated with mango seedlings in general, and with relative abundance of 40.18 and 16.44% at Somanya and Manya, respectively. While comparing the nematode populations at two sites in Greater Accra, it was found that Klagon site had the largest nematode population (1,845); whereas Manya site had the lowest (1131). The variation in nematode populations could be attributed to the sandy nature of Klagon site soil, which is conducive to nematode reproduction as opposed to the clayey nature of Manya site soil, which tends to impede nematode reproduction (Stanton and

TABLE 7. Population density and relative abundance of nematode genera in the Mango samples (soil 200g at 0-15cm and 15-30cm, 10g of roots) from Manya at matured stage (17 years)

Nematode genera	Population/ 200 g soil		Relative abundance (%) soil		Population/ 10 g roots	Relative abundance (%) roots	Relative abundance (%) (roots + soil)
	0-15 cm depth	15-30 cm depth	0-15 cm depth	15-30 cm depth			
Tylenchus spp.	233.00	93.00	39.69	36.90	0.00	0.00	38.86
Helicotylenchus spp.	33.00	15.00	5.62	5.95	0.00	0.00	5.72
Heterodera spp.	5.00	0.00	0.85	0.00	0.00	0.00	0.60
Tylenchulus spp.	100.00	32.00	17.04	12.70	0.00	0.00	15.73
*Paratylenchus*spp.	32.00	5.00	5.45	1.98	0.00	0.00	4.41
Hemicriconemoides spp.	24.00	19.00	4.09	7.54	0.00	0.00	5.12
Xiphinema spp.	7.00	0.00	1.19	0.00	0.00	0.00	0.83
Meloidogyne spp.	19.00	4.00	3.24	1.59	0.00	0.00	2.74
Longidorus spp.	18.00	6.00	3.07	2.38	0.00	0.00	2.86
Radophulus spp.	1.00	0.00	0.17	0.00	0.00	0.00	0.12
*Tylenchorhynchus*spp.	1.00	1.00	0.17	0.40	0.00	0.00	0.24
Bursaphelenchus spp.	3.00	0.00	0.51	0.00	0.00	0.00	0.36
Aphelenchoides spp.	5.00	3.00	0.85	1.19	0.00	0.00	0.95
Rotylenchulus spp.	11.00	8.00	1.87	3.17	0.00	0.00	2.26
Pratylenchus spp.	12.00	4.00	2.04	1.59	0.00	0.00	1.91
Aphelenchus spp.	64.00	3.00	10.90	14.29	0.00	0.00	11.92
Anguina spp.	1.00	0.00	0.17	0.00	0.00	0.00	0.12
Scutellonema spp.	1.00	2.00	0.17	0.79	0.00	0.00	0.36
Trichodorus spp.	0.00	8.00	0.00	3.17	0.00	0.00	0.95
*Mesocriconema*spp.	0.00	1.00	0.00	0.40	0.00	0.00	0.12
Hemicycliophora spp.	16.00	15.00	2.73	5.95	0.00	0.00	3.69
Hoplolaimus spp.	1.00	0.00	0.17	0.00	0.00	0.00	0.12
Total	587.00	252.0					
Grand total	839.00						

TABLE 8. Population density and relative abundance of nematode genera identified in soil and root samples (soil 200g at 0-15cm and 15-30cm, 10g of roots) obtained from Klagon at matured stage (11 years)

Nematode genera	Population/ 200 g soil		Relative abundance (%) soil		Population/ 10 g roots	Relative abundance (%) roots	Relative abundance (%) (roots + soil)
	0-15 cm	15-30 cm	0-15 cm	15-30 cm			
Hemicriconemoides spp.	52.00	26.00	4.93	3.31	0.00	0.00	4.23
Helicotylenchus spp.	464.00	345.00	44.02	43.95	2.00	33.33	43.96
Tylenchus spp.	52.00	23.00	4.93	2.93	3.00	50.00	4.23
Aphelenchoides spp.	6.00	0.00	0.57	0.00	0.00	0.00	0.33
Heterodera spp.	4.00	0.00	0.38	0.00	0.00	0.00	0.22
Criconemella spp.	2.00	5.00	0.19	0.64	0.00	0.00	0.38
Paratylenchus spp.	325.00	291.00	30.83	37.07	0.00	0.00	33.39
Xiphinema spp.	98.00	59.00	9.30	7.52	0.00	0.00	8.51
Rotylenchulus spp.	10.00	3.00	0.95	0.38	0.00	0.00	0.70
*Hoplolaimus*spp.	2.00	2.00	0.19	0.25	0.00	0.00	0.22
Tylenchulus spp.	29.00	13.00	2.75	1.66	0.00	0.00	2.28
Hemicycliophora spp.	3.00	8.00	0.28	1.02	0.00	0.00	0.60
Aphelenchus spp.	6.00	9.00	0.57	1.15	0.00	0.00	0.81
Pratylenchus spp.	1.00	0.00	0.09	0.00	0.00	0.00	0.05
Meloidogyne spp.	0.00	1.00	0.00	0.13	1.00	16.67	0.11
Total	1054.00	785.00			6.00		
Grand total	1845.00						

Stirling, 1997). The nematode populations were higher in soil samples at depth 0-15 cm, and this could be due to differences in availability of nutrients and close proximity to the plant.

CONCLUSION

Twenty-four nematode genera were found to be associated with mango soil and root samples obtained from the Eastern region of Ghana; while in the Greater Accra, thirty-six nematode genera were detected in root and soil samples. At the Klagon site, a total of fifteen nematode genera were identified.

Soil samples from matured mango orchards were generally more infected by nematodes, than roots from their mango seedlings counterparts. *Meloidogyne* spp. and *Helicotylenchus* spp. were the most dominant nematode genera associated with mango seedlings obtained from Somanya site. *Helicotylenchus* spp. had the highest relative abundance in mango seedling samples collected from Manya site. *Tylenchus* spp. and *Helicotylenchus* spp. had the highest relative abundance in mango tree samples obtained from Manya and Klagon, respectively. Soil samples at depth 1(0-15 cm) contained a higher population of nematodes as compared to depth 2 (15-30 cm). There is therefore need to apply nematode management strategies to limit nematode population densities from reaching economic thresholds.

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