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Product Quality and Safety

Plant-parasitic nematodes associated with Moringa tree (*Moringa oleifera* Lam.) in Adamawa, North Eastern Nigeria

M.Y. Jada, M.Y. Adamu, M.B. Aji, G. Abdullahi*

Department of Crop Protection, Modibbo Adama University of Technology, Yola, Adamawa State, Nigeria

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Abstract. *Moringa (Moringa oleifera Lam.) is becoming an economically important crop because of its nutritional value, therefore, more land area is currently being devoted to its cultivation particularly by vegetable farmers. But right now, little is known about plant-parasitic nematodes as one of its probable pest problems. A survey was, therefore, carried out to determine the plant-parasitic nematodes (PPN) associated with Moringa tree in Adamawa State, Nigeria. Nine of the 21 local government areas (LGAs) of the state were randomly selected; and 10 moringa farms, indicating at least two household/home gardens, were picked from each of the selected local government area for the survey of PPN. In each selected sampling site, soil samples were taken from the base of randomly selected moringa plants to a depth of 15-25 cm using hand trowel and hoe. Composite sample from each LGA from root and soils were taken to Laboratory for nematode extraction. Nematodes were extracted from both soil and roots using Baermann Tray method. The Moringa tree root rhizosphere revealed the presence of 14 genera of plant-parasitic nematodes with specimens from Meloidogyne, Scutellonema, Aphelenchoides, and Hoplolaimus genera being more abundant and frequent. They recorded average prominence value of 123.96, 93.31, 63.83 and 61.83, respectively. Whereas in the roots, Meloidogyne and Scutellonema specimens were found more than the remaining plant-parasitic nematodes genera with an average prominence value of 50.92 and 22.26, respectively*.

Keywords: genera, moringa root, root rhizosphere, prominence value

Introduction

Moringa or drumstick (*Moringa oleifera* Lam.) is a non-timber tree that originated from India sub-continent belonging to the Morinaceae family (Pandey et al., 2011). It is particularly known as Drumstick and is cultivated all over the world from Africa to South and North America apart from its area of origin; with Asia producing 80%, Africa 11% and America 6% (ABC, 2015). Moringa (Drumstick) is highly valued because of its high content of vitamins (A, B_1, B_2, B_3, B_6, and C), minerals (Ca, K, Fe, Mg, P and Zn) and proteins (ABC, 2015). In Nigeria particularly in the Guinea and Sudan savannah it is cultivated in every home garden or as a fence by the resource poor farmers that use its leaves as vegetable soup. In the last 15 years the crop is cultivated in urban and peri-urban areas either as sole or mixture with other crops (vegetables: pepper, tomato, sorele, onion, amarathus; cereals: sorghum, maize, millet; legumes: groundnuts and cowpea) throughout the year consequent to the discovery of its nutritional value. It is now cultivated on an area of 0.25 to 1.5 ha by most farmers that grow it in the country. Again, most restaurants and elite houses make it one of their daily meals because it is high in micronutrients (Ca, Fe and vitamins) as well as proteins (Kimba et al., 2010; Kotikal and Math, 2016). Its seed oil and the leaves are used for medical purposes and in the production of different ointments (Kotikal and Math, 2016). Different insect and non-insect pest of Moringa has been reported in Nigeria (Radovich, 2009; Ojiako et al., 2012; Okonkwo et al., 2014; Yusuf and Yusuf, 2014) but, the non-insect pest does not yet include plant parasitic nematodes.

Prot (1984) reported that *Meloidogyne incognita* as being associated with Moringa in Senegal. In Niger Republic Haougui et al. (2017) reported about 11 PPN in association with Moringa. However, in north-eastern Nigeria, there is no information on PPN associated with Moringa; despite its extensive and intensive cultivation in peri-urban and urban areas as well as by the rural farmers. Therefore, this work was undertaken to determine the plant-parasitic nematodes genera compositions in roots and rhizosphere of Moringa plants in Adamawa State, North-Eastern Nigeria.

Material and methods

Sampling sites and procedure

The survey was carried out between August to October, 2017 rainy season in Adamawa State. Nine (viz: Ganye, Mayo Belwa, Demsam Yola North, Fufore, Girei, Song, Mubi North

*e-mail: gatsaranyi@yahoo.com

and Mubi South) out of 21 local government areas (LGAs) were selected for survey of plant parasitic nematodes (PPN) on Moringa roots and rhizosphere based on Moringa production and geographical spread in the state (Agaba and Fawole, 2012; Haougui et al., 2017). However, across all the sampled areas, Moringa were found to be cultivated with other economic tree crops like Mango (*Mangifera indica*), Guava (*Psidium Guajava*), Citrus (*Citrus* spp.), Baobab (*Andasonia digitata*), Banana (*Musa* spp.) and Pawpaw (*Carica papaya*). It was also inter-cropped with vegetable crops and cereals like tomatoes, pepper, eggplant, amarantus, cochorus, sorrelle and maize (Table 1).

Table 1. Location of study sites and common crops cultivated with Moringa trees

LGA	Geographical coordinates	Other crops
Ganye	8°28N La 12°02E Lo	sugar cane, banana, groundnut, rice, maize, garden egg
Mayo-Belwa	9°03N La 12°03E Lo	tomato, pepper, garden egg, sorelle, ancova
Demsa	9°27N La 12°09E Lo	tomato, pepper, maize, rice
Fufore	9°15N La 12°36E Lo	onions, sorelle, rice, maize, tomato, pepper
Yola-North	9°16N La 12°20E Lo	tomato, pepper, lettuce, amaranthus, sorelle
Girei	9°21N La 12°32E Lo	tomato, pepper, maize, sorghum, rice
Song	9°49N La 12°37E Lo	onions, pumkin, sorghum, maize, tomato, pepper
Mubi-North	10°16N La 13°11E Lo	onions, sorghum, maize, tomato, pepper
Mubi-South	10°11N La 13°44E Lo	onions, sorghum, maize, tomato, pepper

LGA-Local Government Area; La-Latitude; Lo- Longitude

For sampling purposes, the state was divided into South, Central and Northern zones to ease sampling which was purposeful. In the Southern zone, three LGAs namely Ganye, Mayo-Belwa and Demsa (Table 1) were selected based on the moringa production. In these areas, Moringa was found to be cultivated on average of 0.25 ha only for border crops estimated to be around 0.25 ha. In the Central zone (Yola) where the state capital is located, 4 LGAs viz: Fufore, Yola-North, Girei, and Song were selected. The first three are around the Benue River Basin and the 4th one is nearby; with an average area of 0.5-1.5 ha being cultivated to Moringa because of its high demand. In the Northern zone, Mubi-North and Mubi-South were selected, and an average size of 0.25-1.5 ha of Moringa farms were found. From each of the selected LGAs, 10 farmers' farms were selected from 3 village areas (towns) at random for picking the moringa roots and its rhizosphere samples.

All samples were taken using zig-zag method of Barker (1985) 10 samples (sub-samples) were taken at 20-30 cm away from the tree base and to depth of 15-30 cm. At each sub-sample site 100-150 g of soil plus 50 g roots were taken and put in strong polythene bag with pencil labeling then transported to the Research laboratory of the Department of Crop Protection laboratory, Modibbo Adama University of Technology Yola, for nematodes extraction and identification. The 10 sub-samples were thoroughly bulked for each farm giving a total of 90 soils and roots samples each.

Nematodes extraction and identification procedure

Nematodes were extracted from 100 g of soil from each sample using the Baermann tray method as described by Barker (1985). The roots (10 g) of each sample were cut into pieces and macerated (Coyne et al., 2007) then nematodes were extracted using Baermann method (Barker, 1985). From the nematode suspension extracted in each case, 2 ml was drawn and 2 ml of boiling water plus 2 ml of 4% formaldehyde were added to kill and fix the nematodes (Forie et al., 2001; Baimey et al., 2009). These nematodes were then counted and identified to genera level (Mai and Mullin, 1996; Hunt et al., 2005; Coyne et al., 2007). This was repeated 10 times to estimate the nematodes specimen associated for each sample.

Data analysis for the nematodes

The plant-parasitic nematodes genera associated with Moringa were analyzed by determining their mean density per local government, the relative density, the frequency of occurrence in the samples and prominent value. The mean density in this work refers to the average number of individual nematodes specimens per 100 g soil or 10 g roots in each local government. Relative density (RD, %) of each nematode genus was calculated using the formula below (Haougui et al., 2017).

RD (%) = (No. of Nematode specimen in a genus/Total No. of Nematodes).100

The frequency of occurrence (FO, %) for each nematode is the percentage of samples where the nematode is found and is calculated using the formula (Agaba and Fayode, 2012):

FO (%) = (No. of samples containing a nematode / Total sample size).100

Prominent value (PV, %) is calculated using De Waele et al. (1998) formula:

PV (%) = Population Density ($\sqrt{}$FO/10).100

In addition, before cutting roots from each sample into bits (pieces) they were observed for presence of root galls caused by nematodes in the *Meloidogyne* genus. The root galls were counted and galling index ranked on a scale of 1-5 as described by Tayler and Sasser (1978).

Results

Plant-parasitic nematodes in Moringa rhizosphere

Plant parasitic nematodes found in rhizosphere of Moringa plants in Adamawa State vary in terms of presence frequency and abundance (Table 2). Result of nematodes extracted from soil samples showed the presence of 14 genera; with Ganye having only 10 genera, Demsa, Mubi-North and Mubi-South had

13 genera each. The soil samples from Moringa rhizosphere from the remaining 7 LGAs had 14 genera each. Ten genera (*Meloidogyne, Scutellonema, Aphelenchoides, Xiphinema, Paratylenchus, Hirschmaniella, Trichordorus, Hoplolaimus* and *Tylenchus*) from the Moringa rhizosphere were common to all the LGAs. Considering the analysis of PPN communities in the 9 LGAs *Meloidogyne, Scutellonema, Aphelenchoides* and *Hoplolaimus* occurred in all samples (Frequency of occurrence = 100%) from Ganye and Mubi-South. Mayo-Belwa recorded 100% frequency of occurrence for *Meloidogyne, Scutellonema* and *Hoplolaimus.* While two other LGAs also recorded 3 genera each with 100% frequency, which are *Scutellonema, Aphelenchoides* and *Hoplolaimus.* Yola-South and Mubi-North had *Meloidogyne*, *Scutellonema* and *Hoplolaimus*. Demsa had 100% frequency of occurrence in two genera *(Meloidogyne* and *Scutellonema)*, Fufore *(Meloidogyne* and *Paratylenchus)* and Song *(Meloidogyne* and *Paratylenchus).* Girei only recorded 100% frequency distribution for *Meloidogyne* alone. The lowest frequency distribution of 10% was recorded for *Tylenchus* in two LGAs (Ganye and Mubi-South), *Xiphinema, Trichodorus* and *Longidorus* in Fufore local government area. Plant-parasitic nematodes communities of the 9 LGAs showed that *Scutellonema* had the highest prominent value (PV) at Ganye with 226.86, followed by *Meloidogyne, Aphelenchoides, Pratylenchus* and *Hoplolaimus* with PV's of 118.2, 92.29, 61.86 and 59.96, respectively.

Table 2. Important plant-parasitic nematodes genera from soils samples of Moringa in 9 LGAs of Adamawa State

Local Government Area	Nematodes	Mean nematodes density	Frequency, %	Prominent value
Ganye	*Meloidogyne,*	1074.50	100	118.42
	Scutellonema	2058.50	100	226.86
	Aphelenchoide	837.40	100	92.29
	Xiphinema	195.40	70	18.04
	Paratylenchus	561.30	100	61.86
	Pratylenchus	227.00	60	19.38
	Hirschmaniella	94.50	30	5.70
	Trichordorus	33.60	20	1.65
	Hoplolaimus	544.10	100	59.96
	Tylenchus	25.00	10	0.87
Mayo-Belwa	*Meloidogyne,*	1300.00	100	129.54
	Scutellonema	504.00	100	54.62
	Aphelenchoide	340.70	89	35.40
	Xiphinema	35.00	33	1.69
	Paratylenchus	317.00	89	30.76
	Pratylenchus	40.00	33	2.02
	Hirschmaniella	228.00	56	17.00
	Trichordorus	12.00	11	0.44
	Helicotyleachus	35.40	22	1.62
	Criconemoides	4.50	11	0.17
	Rotylenchulus	28.6	44	1.65
	Hoplolaimus	770.00	100	83.54
	Longidorous	9.00	11	0.33
	Tylenchus	42.5	33	2.70
Demsa	*Meloidogyne,*	1461.50	100	156.22
	Scutellonema	989.50	100	89.87
	Aphelenchoide	887.80	78	62.77
	Xiphinema	316.20	44	19.51
	Paratylenchus	239.00	56	17.28
	Pratylenchus	37.00	22	1.49
	Hirschmaniella	273.60	56	20.31
	Trichordorus	89.80	22	4.67
	Helicotyleachus	192.10	56	15.24
	Criconemoides	56.10	22	2.23
	Rotylenchulus	80.70	22	4.19
	Hoplolaimus	413.10	78	38.23
	Tylenchus	220.4	67	18.45
Yola-North	*Meloidogyne,*	841.40	80	82.74
	Scutellonema	756.10	100	83.33
	Aphelenchoide	511.30	100	56.35

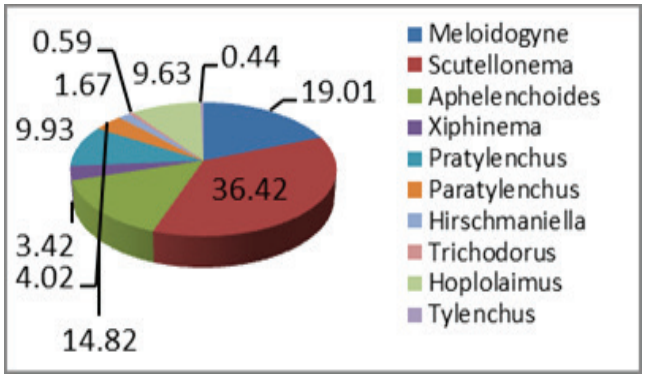
	Xiphinema	445.60	90	46.59
	Paratylenchus	463.30	80	45.67
	Pratylenchus	466.70	90	48.79
	Hirschmaniella	855.10	70	32.74
	Trichordorus	269.90	60	23.04
	Helicotyleachus	361.90	80	35.67
	Criconemoides	156.10	40	10.81
	Rotyleachulus	44.00	20	2.17
	Hoplolaimus	512.20	100	56.45
	Longidorous	165.20	30	9.97
	Tylenchus	345.20	80	34.03
Fufore	*Meloidogyne,*	1551.80	100	171.02
	Scutellonema	489.80	80	48.28
	Aphelenchoide	488.10	90	51.08
	Xiphinema	120.00	10	4.18
	Paratylenchus	520.90	100	57.41
	Pratylenchus	59.70	40	4.16
	Hirschmaniella	218.80	50	16.89
	Trichordorus	35.00	10	1.22
	Helicotyleachus	93.00	40	6.48
	Criconemoides	92.70	40	6.46
	Rotylenchulus	11.70	20	0.58
	Hoplolaimus	521.70	60	44.53
	Longidorous	4.20	10	0.15
	Tylenchus	39.56	50	3.08
Girei	*Meloidogyne,*	965.10	100	106.69
	Scutellonema	681.00	90	71.20
	Aphelenchoide	414.60	80	40.87
	Xiphinema	254.10	50	19.80
	Paratylenchus	352.40	80	34.74
	Pratylenchus	406.40	50	31.67
	Hirschmaniella	565.00	50	44.3
	Trichordorus	229.70	50	17.90
	Helicotyleachus	252.10	70	48.42
	Criconemoides	213.20	50	16.61
	Rotylenchulus	376.60	70	34.72
	Hoplolaimus	557.30	80	54.93
	Longidorous	147.10	40	17.23
	Tylenchus	293.6	70	27.07
Song	*Meloidogyne,*	1017.70	100	146.82
	Scutellonema	698.80	90	101.49
	Aphelenchoide	823.90	80	79.14
	Xiphinema	183.50	70	19.91
	Paratylenchus	493.80	90	56.28
	Pratylenchus	398.30	100	49.90
	Hirschmaniella	478.00	50	12.94
	Trichordorus	616.10	80	59.96
	Helicotyleachus	252.20	60	21.53
	Criconemoides	314.80	20	15.32
	Rotylenchulus	327.20	50	25.50
	Hoplolaimus	592.90	90	69.83
	Longidorous	221.10	50	17.23
	Tylenchus	333.50	70	30.75
Mubi-North	*Meloidogyne,*	1022.20	100	112.65
	Scutellonema	680.70	100	75.02

	Aphelenchoide	599.40	100	66.06
	Xiphinema	21.50	30	1.30
	Paratylenchus	474.40	70	43.74
	Pratylenchus	5.00	20	0.25
	Hirschmaniella	25.00	20	1.23
	Trichordorus	35.00	20	1.72
	Helicotyleachus	209.80	60	17.91
	Criconemoides	24.20	30	3.86
	Rotylenchulus	155.40	30	9.38
	Hoplolaimus	694.60	100	76.55
	Tylenchus	314.80	40	31.08
Mubi-South	*Meloidogyne,*	1327.50	100	146.30
	Scutellonema	875.50	90	91.53
	Aphelenchoide	820.70	100	90.53
	Xiphinema	456.60	70	42.10
	Paratylenchus	566.40	80	55.83
	Pratylenchus	146.20	50	11.39
	Hirschmaniella	168.70	50	13.15
	Trichordorus	186.00	50	14.49
	Helicotyleachus	398.60	60	33.77
	Criconemoides	110.90	40	7.73
	Rotylenchulus	20.40	10	0.71
	Hoplolaimus	657.60	100	72.47
	Tylenchus	71.00	10	2.47

In Mayo-Belwa *Meloidogyne* had the highest prominent value of 129.5 followed by *Scutellonema* that recorded 54.62 PV. The lowest PV of less than 1.00 thus 0.17, 0.33 and 0.44 were observed for *Criconomoides, Longidorous* and *Trichadorous.* The highest PV of 156.22 was observed for *Meloidogyne* in Demsa, followed by *Scutellonema* 89.87 and *Aphelenchoides* 62.77. In Yola-North *Scutellonema* showed the highest PV of 83.33 followed closely by *Meloidogyne* with 82.94. *Meloidogyne* recorded the highest PV of 171.02 followed by *Pratylenchus, Aphelenchoides* and *Scutellonema* with PV's of 57.41, 51.08 and 48.28, respectively, in Fufore. While in the same area *Rotylenchulus* recorded PV of only 0.58. In Girei location *Meloidogyne* showed the highest PV of 106.69 followed by *Scutellonema* and *Hoplolaimus* with PVs of 71.20 and 54.93, respectively.

Meloidogyne genus also recorded the highest PV of 146.82 followed by *Scutellonema* (101.49), *Aphelenchoides* (79.14) and *Hoplolaimus* (69.83) in Song. In Mubi-North *Meloidogyne* showed PV of 112.65 followed by *Hoplolaimus* (76.55), *Scutellonema* (75.02) and *Aphelenchoides* (66.06), while *Pratylenchus* recorded PV of 0.25 only (Table 2).

Figure 1a,b,c,d,e,f,g,h,i shows the relative densities of different nematodes in the soil of all sampled LGAs. In most cases, four nematodes genera with the highest relative densities (RD, %) were found: *Meloidogyne* (from 14.78% in Yola-North-d to 35.47% in Mayo-Belwa-b), *Scutellonema* (from 9.82% in Song-g to 36.42% in Ganye-a), *Aphelenchoides* (from 9.82% in Song-g to 36.42% in Ganye-a) and *Hoplolaimus* (from 6.93% in Fufore-f to 16.89% in Demsa-c). In Song (Figure 1g) were recorded relative density values of 15.06, 9.82, 11.58 and 18.33%, respectively; in Mubi-North (Figure 1h) - 23.71, 15.82, 13.93, and 16.13%; in Mubi-South (Figure 1i) - 22.8, 15.09, 14.4, and 13.13%; in Yola-North (Figure 1d) - 14.78, 13.28, 8.98 and 9.0%, and in Fufore (Figure 1e) - 36.64, 11.57, 11.48 and 12.32%. It could also be seen that in Fufore *Meloidogyne* alone constitute more than a quarter (36.64%) of the nematode population. In the southern part (Demsa, Mayo-Belwa and Ganye LGAs) also, the four nematodes genera (*Meloidogyne, Scutellonema, Aphelenchoides* and *Heplolaimus*) were found with the highest relative density forms the most of the nematode population. In Ganye (Figure 1a) the relative density values of nematodes were 19.01, 36.42, 14.82 and 4.02%; in Mayo-Belwa (Figure 1b) - 35.47, 3.75, 9.29 and 21.01%, while in Demsa (Figure 1c) they were 37.80, 18.82, 16.89 and 7.86%, respectively. *Meloidogyne* alone occupate 35.47% of all nematodes in Mayo-Belwa and *Scutellonema*, respectively with 36.42% in Ganye. The Southern LGAs are known to have more rain days in a year. Ganye is also cultivating sugar cane and other vegetables together with Moringa (Table 1).



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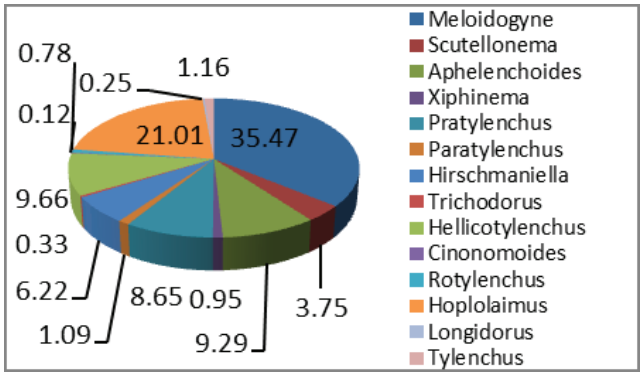

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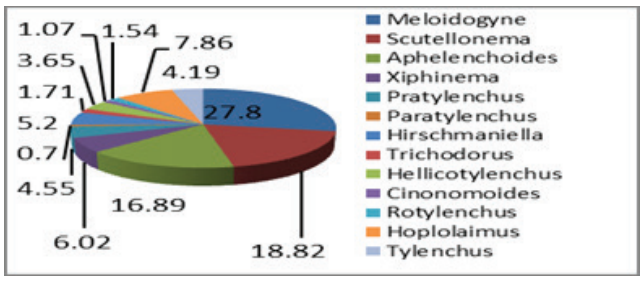

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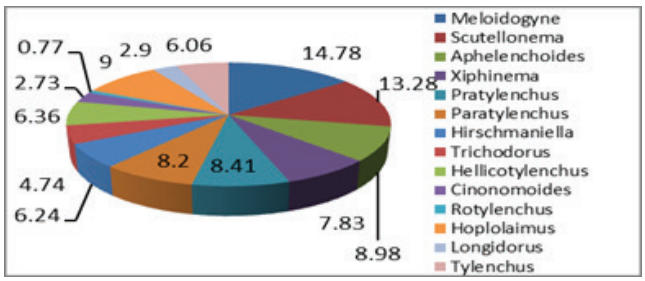

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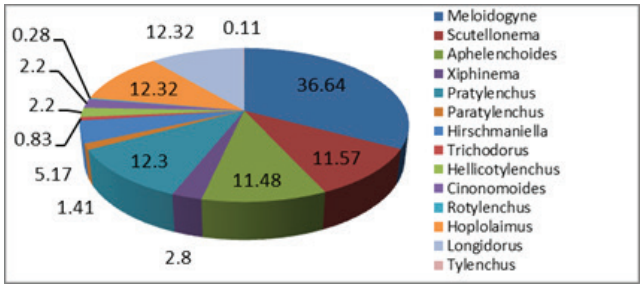

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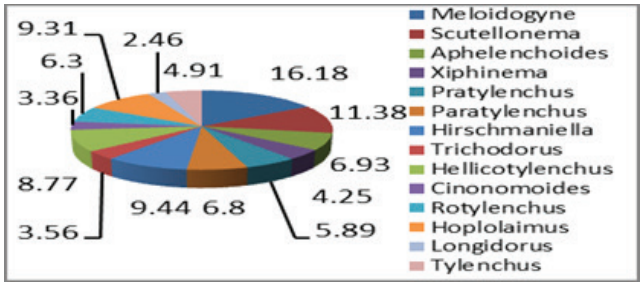

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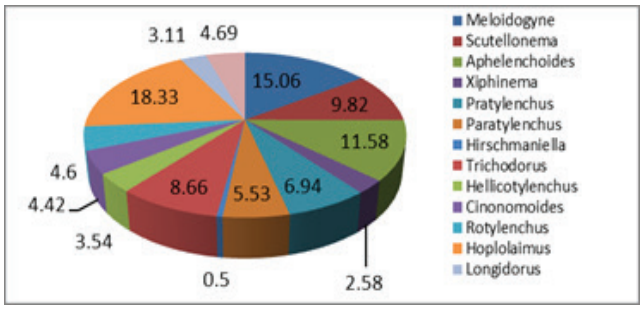

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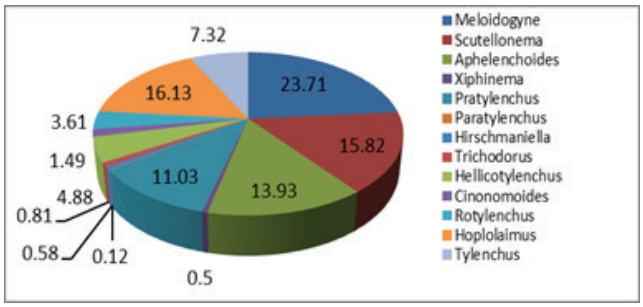

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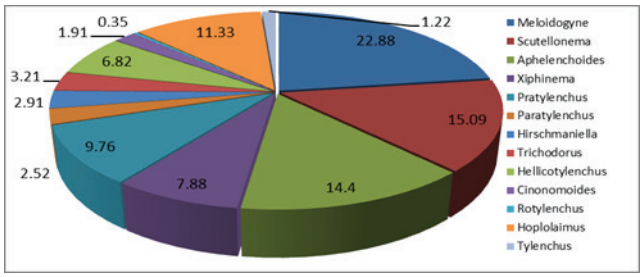

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Figure 1. Nematodes relative density (%) in soils from different LGAs: a) Ganye, b) Mayo-Belwa, c) Demsa, d) Yola-North, e) Fufore, f) Girei, g) Song, h) Mubi-North and i) Mubi-South

Table 3. Distribution of plant-parasitic nematodes genera by LGA in Moringa rhizosphere

Plant-parasitic nematodes genus	Local Government Area								
	Ganye	Mayo-Belwa	Demsa	Fufuore	Yola-North	Girei	Song	Mubi-North	Mubi-South
Meloidogyne,	++	++	++	++	++	++	++	++	++
Scutellonema	++	++	++	++	++	++	++	++	++
Aphelenchoide	++	++	++	++	++	++	++	++	++
Xiphinema	++	++	++	++	++	++	++	++	++
Paratylenchus	++	++	++	++	++	++	++	++	++
Hirschmaniella	++	+	+	+	++	++	++	++	+
Trichordorus	+	++	++	++	++	++	++	++	+
Helicotyleachus	+	+	+	+	++	++	++	++	+
Criconemoides	-	+	+	+	++	++	++	++	++
Rotylenchulus	-	+	+	+	++	++	++	++	++
Hoplolaimus	-	+	+	+	+	++	++	+	++
Longidomus	-	+	-	++	++	++	++	++	++
Tylenchus	+	+	++	+	++	++	++	+	++

Key: (+)= Nematodes specimens 100; (++)= Nematodes specimens more than 100; (-)= No nematodes specimen

Plant parasitic nematodes recorded from the soils were found to be variably distributed as shown (+) = Nematodes specimens 100; (++) = Nematodes specimens more than 100; and (-) = No nematodes specimens (Table 3). Ganye soils could not record about four genera of plant parasitic nematodes, while the remaining local government recorded all the genera except Demsa where *Longidorus* was not recorded from any of the sampled farms.

Plant-parasitic nematodes in roots of Moringa

Twelve plant-parasitic nematodes genera were found in Moringa roots from the 9 LGAs (Table 4). Interestingly, only three genera: *Meloidogyne*, *Scutellonema* and *Hoplolaimus* were common to all LGAs. Meanwhile the fourth one *Aphelenchoides* was found in Moringa roots from all the LGAs with the exception of Mayo-Belwa. Moringa roots from Girei gave the highest number of nematodes genera (12) followed by those from Demsa (11). Also, from all the local governments surveyed in Adamawa State, Nigeria*, Meloidogyne* has the highest density of 725.9, 617.7, 530.0, 534.8, 497.8, 440.7, 371.8 and 350.5 specimens in Moringa roots for Demsa, Mubi-North, Fufore, Song, Mayo-Belwa, Mubi-South, Yola-North and Ganye, respectively, but in Girei (363.4) it is second to *Scutellonema* (383.1). Similarly, *Meloidogyne* spp. has 90-100% frequency in roots of Moringa from 7 local government areas (Ganye, Demsa, Fufore, Girei, Mubi-North, Mubi-South and Mayo-Belwa). However, even for the remaining two LGAs, their frequency of occurrence is up to 70%. It is *Scutellonema* genus that follows in terms of frequency of occurrence in almost all the LGAs. The lowest frequency of occurrence of 10% was observed in the genus *Tylenchus* from Girei. Considering the prominent value of the nematode genera, *Meloidogyne* spp. had the highest with 71.38 followed by 66.31 in Demsa and Mubi-North. In Fufore, *Meloidogyne* still recorded a prominent value of 60.31 and Song had 49.31. In Figure 2-b,a,c, it could be seen that the relative density of *Meloidogyne* plus *Scutellonema* constitute about 80-99%, 39-64% and 32-56% in Mayo-Belwa, Ganye and Demsa, respectively.

In Fufore, *Meloidogyne* spp. alone constituted up to 65.67% relative density (Figure 2e), while in Yola North (Figure 2d), *Meloidogyne* recorded 46.07% and *Scutellonema* 26.44% relative density which adds up to 72.51% of all nematode communities recorded. Furthermore, in Girei 49.28% of all nemetodes recorded from Moringa roots are from the two genera: *Meloidogyne* (23.99%) and *Scutellonema* (25.29%) (Figure 2f). Song and Mubi-North had relative density up to 80.91% and 65.77% of *Meloidogyne* and *Scutellonema*, respectively (Figure 2g,h).

From Table 5, it is shown that the root of Moringa from 6 LGAs had no galls (Galling index = 1) despite the high population of *Meloidogyne* genus specimens in both soil and roots. However, roots of Moringa from Demsa, Mubi-North and Mubi-South showed light galling (Galling index = 2). The total population of *Meloidogyne* in soil plus roots of Moringa is the highest (2187.3) in Demsa, those in Mubi-North and Mubi-South were less than what was obtained in other local governments.

Nematode distribution in the sampled area from roots is shown in Table 6. Gannye recorded 4 nematodes genera from all the sampled locations and Demsa recorded 8 from all locations with one genus found to be less distributed.

Table 4. Important plant-parasitic nematodes in roots of Moringa from 9 LGAs of Adamawa State

Local Government Area	Nematodes genus	Mean nematodes density	Frequency, %	Prominent value
Ganye	*Meloidogyne*	350.50	90.00	36.61
	Scutellonema	227.60	90.00	23.76
	Aphelenchi	212.70	80.00	20.90
	Hoplolaimus	1440.20	80.00	13.82
Mayo-Belwa	*Meloidogyne*	497.80	100.00	47.02
	Scutellonema	237.00	67.00	15.75
	Hoplolaimus	151.50	67.00	11.37
Demsa	*Meloidogyne*	725.90	100.00	71.38
	Scutellonema	692.20	89.00	59.27
	Aphelenchoide	217.10	44.00	13.48
	Xiphinema	144.00	33.00	7.29
	Paratylenchus	176.50	33.00	7.76
	Pratylenchus	32.10	22.00	1.67
	Hirschmaniella	303.10	44.00	17.64
	Trichordorus	105.50	22.00	3.52
	Helicoty	16.10	11.00	0.59
	Hoplolaimus	105.00	33.00	4.51
	Longidorous	87.00	11.00	3.20
Fufore	*Meloidogyne*	530.00	100.00	60.61
	Scutellonema	55.40	40.00	3.86
	Aphelenchi	77.50	40.00	5.40
	Hoplolaimus	154.60	60.00	13.20
Yola-North	*Meloidogyne*	371.8	70.00	34.28
	Scutellonema	213.40	80.00	21.03
	Aphelenchi	135.20	60.00	11.54
	Pratylenchus	25.00	10.00	0.87
	Hoplolaimus	61.70	50.00	4.81
Girei	*Meloidogyne,*	363.40	100.00	40.05
	Scutellonema	383.10	60.00	32.70
	Aphelenchi	122.40	50.00	9.54
	Xiphinema	94.50	30.00	5.70
	Paratylenchus	72.50	30.00	4.44
	Pratylenchus	28.50	30.00	1.72
	Trichordorus	54.80	30.00	3.31
	Helicotyleachus	35.30	20.00	1.74
	Criconemoides	54.70	30.00	3.30
	Rotylenchulus	61.50	30.00	3.01
	Hoplolaimus	236.80	80.00	23.34
	Tylenchus	6.50	10.00	0.23
Song	*Meloidogyne*	534.80	70.00	49.31
	Scutellonema	272.20	60.00	23.24
	Aphelenchi	56.10	30.00	3.39
	Pratylenchus	80.00	30.00	4.83
	Hoplolaimus	53.90	40.00	3.76
Mubi-North	*Meloidogyne*	617.70	100.00	66.31
	Scutellonema	429.70	90.00	43.88
	Aphelenchi	211.90	90.00	21.08
	Pratylenchus	79.50	20.00	2.69
	Hoplolaimus	253.70	80.00	21.65
Mubi-South	*Meloidogyne,*	440.70	90.00	46.08
	Scutellonema	211.20	90.00	21.08
	Aphelenchi	108.10	60.00	9.23
	Pratylenchus	60.20	30.00	3.63
	Hoplolaimus	87.2	60.00	7.44

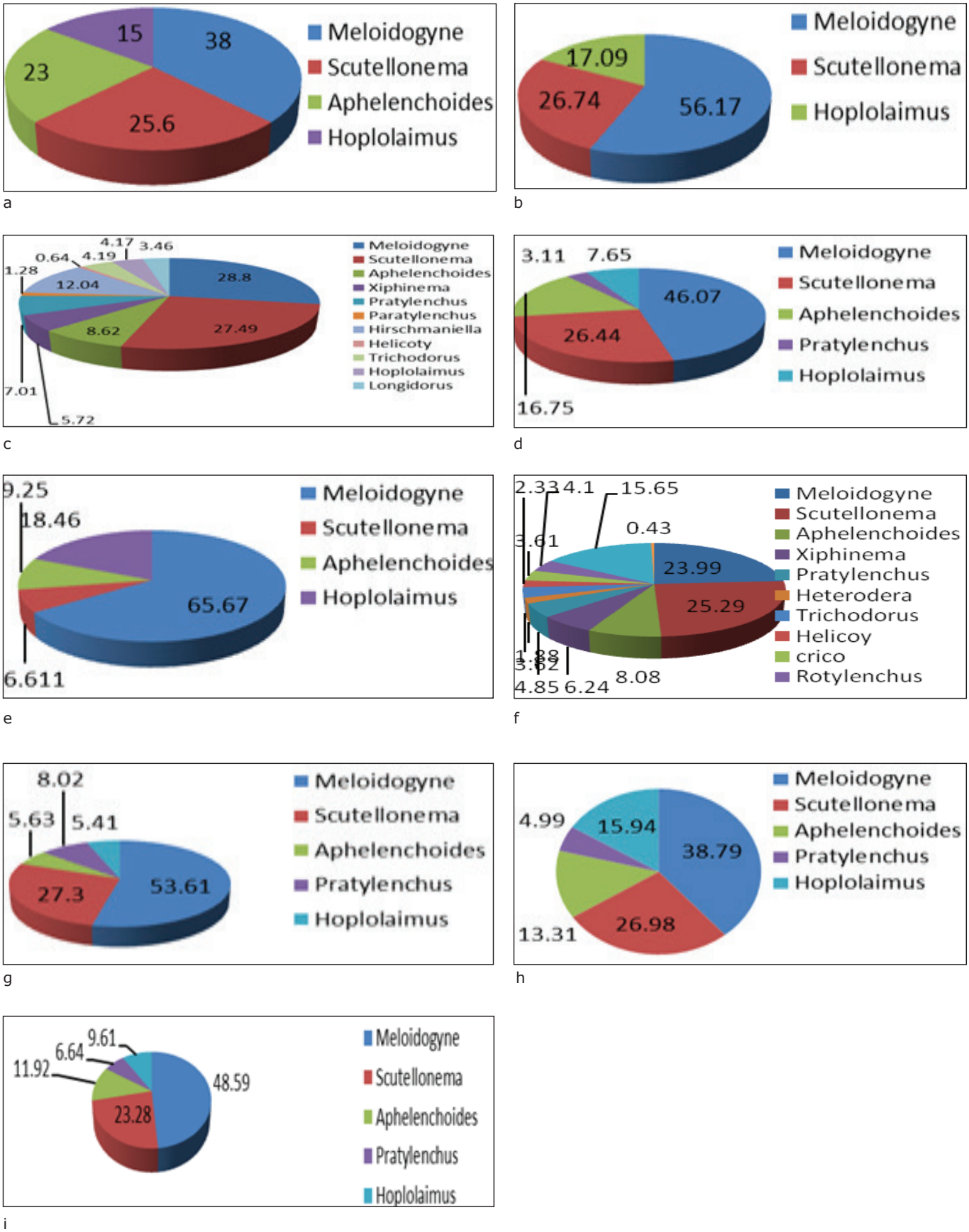

Figure 2. Nematodes relative density (%) in plant roots from different LGAs: a) Ganye, b) Mayo-Belwa, c) Demsa, d) Yola-North, e) Fufore, f) Girei, g) Song, h) Mubi-North, i) Mubi-South

Table 5. Total mean *Meloidogyne* specimens in soil and roots, number of root galls and Galling index

Local Government Area	Total mean meloidogyne density (250 g of soil + 10g of roots)	No. of galls	Galling Index
Ganye	1425.00	0.00	1.00
Mayo-Belwa	1797.80	0.00	1.00
Demsa	2187.80	25.20	2.00
Yola-North	1212.40	0.00	1.00
Fufore	2101.80	0.00	1.00
Girei	1331.50	0.00	1.00
Song	1606.50	0.00	1.00
Mubi-North	1945.20	31.30	2.00
Mubi-South	1462.90	15.60	2.00

Key: Galling index scale of 1-5 was used (Anamika, 2015) where 1= No of galls, 2= 0-50 galls, 3= 51-100 galls, 4= 101-200 galls and 5= more than 200 galls

Table 6. Distribution of plant-parasitic nematodes genera by LGAs in Moringa roots

Plant-parasitic nematodes speicies	Local Governments Area								
	Ganye	Mayo-Belwa	Demsa	Fufuore	Yola-North	Girei	Song	Mubi-North	Mubi-South
Meloidogyne	++	++	++	++	++	++	++	++	++
Scutellonema	++	++	++	+	++	++	++	++	++
Aphelenchoide	++	-	++	+	++	++	++	++	++
Xiphinema	-	-	++	-	-	+	-	-	-
Paratylenchus	-	-	++	-	-	+	+	+	+
Hirschmaniella	-	-	++	-	-	-	-	-	-
Trichordorus	-	-	++	-	-	+	-	-	-
Helicotyleachus	-	-	+	-	-	+	-	-	-
Criconemoides	-	-	-	-	-	+	-	-	-
Rotylenchulus	-	-	-	-	-	+	-	-	-
Hoplolaimus	++	++	++	++	+	++	+	++	+
Tylenchus	-	-	-	-	-	+	-	-	-

Key: (+)= Nematode specimens < 100; (++)= Nematode specimens > 100; (-)= No nematode specimen

Discussion

The results presented above showed 14 genera of plant-parasitic nematodes found in Moringa rhizosphere in Adamawa state, Nigeria. Haouguit et al. (2017) reported 11 genera to be associated with Moringa in Niger Republic (Tadware, Karey-gorou and Sanrando Dirtrict). The large number of genera associated with Moringa in these areas could be attributed to different crops cultivated together with Moringa like vegetables (tomato, pepper, maize, and sorghum), some tree crops (guava, mango and citrus). The presence of some of these genera on vegetables were reported earlier in Nigeria (Agaba and Fawole, 2012). They reported about 13 genera in soil of peeper in Benue state, Nigeria. Eleven genera of PPN were reported in soil of Cassava in South Western Nigeria (Abidemi et al., 2012). They include *Meloidogyne*, *Paratylenchus, Rotylenchulus*, *Aphelenchoides*, *Tylenchus, Aphelenchus, Xiphinema* and *Hoplolaimus.* The occurrence of up to 14 genera in Moringa rhizophere could be associated with continuous cultivation of those areas throughout the year even in dry season using irrigation there by allowing different crops to be grown as intercrop in Moringa fields.

In related studies, 20 genera of plant-parasitic nematodes were reported from soil of eggplant (*Solanus melongena* L.) in Kaduna and Kano states of Nigeria (Abdulsalam et al., 2016). Similarly, Adedejo and Fawole (2014), reported 6 nematodes genera in soil of some cocoa, coffee and cashew plantations in South Western Nigeria. Also, in three LGAs of River State, Nigeria, Asimiea et al. (2015) it was reported that 5 nematodes genera were associated with Cassava (*Helicotylenchus*, *Meloidogyne*, *Pratylenchus, Scutellonema* and *Gracilacus*). Of all nematodes genera, *Meloidogyne* is believed to be the most dangerous; causing serious yield loss on different crops (Haougui et al., 2008; Fawole, 2009).

The presence and dominance of the first 4 genera (*Meloidogyne, Scutellonema*, *Aphelenchoide* and *Hoplolaimus*) in 8 out of 9 LGAs in this study of ours is an indication of their level of association with Moringa irrespective of the presence of other crops. Similar observations were made on Moringa elsewhere (Prot, 1984 and Haugui et al., 2017). Furthermore, the presence of this genera in this part of Nigeria indicates their spread in the country as they were earlier reported on other crops in central Nigeria (Agaba and Fawole, 2012; Anjolin et al., 2013), South-Western Nigeria (Adebite et al., 2006; Adebjo and Fawole, 2014), South-east of Nigeria (Asimiea et al., 2015) and North-western Nigeria (Abdulsalam et al., 2016). Again, it could be clearly seen that the Moringa soils in the areas surveyed are heavily infested and could lead to retarded growth and high yield loss particularly for the crops accompanying Moringa (Haougui et al., 2008; Haougui and Biz, 2009; Baimey et al., 2009; Agaba and Fawole, 2012 and Haougui et al., 2017).

However, Rodriguez-Kabena (1987) observed that some plant-parasitic nematodes species in a multi-species community like the one we have in the Moringa soils in Adamawa will not have significant depressive effect on the plant growth.

On one hand, the presence of *Hoplolaimus* could be as a result of sorghum and cowpea cultivated in these areas in rainy season, particularly in sampling locations of Song, Girei, Demsa, Mubi-North and Mubi-South. Earlier on Baujard et al. (1995) reported *Hoplolaimus* on millet, sorghum and cowpea in the Sahalian zones of Niger Republic. However, the genus *Scutellonema* has the highest prominent value in soil of Moringa studied here. Thus, it may not only be the Moringa plant, but other vegetables crops cultivated in this area might have contributed to such trend. In other studies similar to ours, Agaba and Fawole (2012) reported *Scutellonema* in soils of pepper in Benue state, Nigeria. However, in a review of insect and non-insect pests of Moringa, plant-parasitic nematodes were not listed by Kotikal and Marth (2016) in the same region.

In roots the result in the present study shows that about 12 nematodes genera are found in or on roots of Moringa but only 3 genera are found consistently in all Moringa roots from the LGAs sampled and these are *Meloidogyne, Scutellonema* and *Hoplolaimus*. This indicates that these 3 genera are the major threat to Moringa production if they are establish to retard growth and performance in same. Also, among the 3 genera, *Meloidogyne* is believed to be the most dangerous, attacking over 2000 plant species (Moens et al., 2010; Agaba and Fawole, 2012, Haougui et al., 2017). Some roots-knot nematodes *Meloidogyne* spp. have been reported in or on the roots of vegetable crops in different parts of Nigeria (Agaba and Fawole, 2012; Abdulsalam et al., 2016) as well as other parts of west Africa on tomato (Haougui et al., 2008) and Haougui and Bizo (2009) on pepper in Niger Republic, Baimey et al. (2009) on some vegetable crops in Benin Republic.

In this survey there is no visible effect of root-knot nematodes on the growth and performance of the Moringa plants except few tiny root-nodes/galls on some limited moringa plants. Similar observations were made by Prot (1984) in Senegal and Haougui et al. (2017) in Niger Republic. In this study of ours, the tiny roots galls (Galling index = 2) were only observed on Moringa roots from 3 LGAs, while roots from the remaining 6 LGAs had no galls (Galling index = 1). Similarly, Prot (1984) and Haougui et al. (2017) observed no galls on Moringa roots, noting that the tree is only serving as a reservoir for source of inoculum to other host plants that might be intercropped with Moringa. The roots of Moringa have a pepperish smell while being broken which causes tears from eyes, this could be one of the reasons for poor *Meloidogyne* establishment. The tiny root galls observed may not have effect because Oludayo and Olufemi (2012) observed no effect of infestation by *Meloidogyne* incognita, on Moringa. The other two genera, *Scutellonema* and *Hoplolaimus* may not be a serious threat to vegetables cultivated together with the Moringa plant because they were earlier reported on Moringa in Niger Republic (Haougui et al., 2017) with no serious problem. *Hoplolaimus* has been reported on Millet, Sorghum and Cowpea in the Sahel area (Baujard et al., 1995) these crops are found cultivated with Moringa plant in our study area. Cayne et al. (2005) also reported *S. bradys* and *Meloidogyne* spp. on yam in south western Nigeria. Suwadugo et al. (2009) earlier on reported 12 genera on cowpea root and rhizosphere in Burkina faso which include *Meloidogyne*, *Pratylenchus*, *Tylenchorhynchus*, *Telotylenchus*, and *Criconemela*. They also reported that their occurrence and abundance varied with variation in agroecological zones of the country. In this case, our area under study is in Northern Guinea savanna with similar ecological variables, hence, the variation observed here could be linked to the various cropping systems.

Conclusion

In conclusion, 14 and 12 plant-parasitic nematodes genera were extracted from the Moringa soil and roots, respectively in Adamawa State, North Eastern Nigeria. Therefore, the four most abundant genera (*Meloidogyne, Scutellonema Aphelenchoide* and *Hoplolaimus*) need to be further studied to determine their pathogenicity on Moringa tree. Also, farmers should be careful with the crops to intercrop with Moringa since it is a perennial crop to avoid nematodes population build-up. The study also revealed that the nematode genus *Meloidogyne* is consistently having the highest population density, frequency in occurance and prominent values in all sampled Moringa roots and soils. Therefore, any farmer that will intercrop Moringa with other crops; crops or varieties highly susceptible to *Meloidogyne* spp. should be avoided. The pathogenicity of *Scutellonema* and *Hoplolaimus* for vegetable crops and other crops commonly being intercropped with Moringa should be studied. Finally, even though these nematodes have not been established to retard growth or reduce yield in Moringa, there is the need to study nematode control measures in Moringa fields in Adamawa State.

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