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Preliminary Survey and Assessment of Nematodes Profile Ravaging Elite Plantain (*Musa paradisiaca* L) Cultivars in Southern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author GMU designed the study, authors GMU, NCO, CMOA and SKE wrote the protocol, authors GMU and NCO wrote the first draft of the manuscript. Authors SKE, CMOA, SKE and GMU managed the literature searches, analyses of the study, analysis and authors GMU, CMOA and SKE managed the experimental process. Authors GMU and NCO identified the species of Nematodes. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To identify the nematodes profile (species) and determine their population density ravaging elite plantain cultivars in southern Nigeria.
Study Design: The study was a survey of 318 plantain accessions planted in-situ and maintained in farmers' fields within the study area. Cluster analysis was performed to generate the clusters groups or elite cultivars from which soil and root corm samples were taken from ratoon crop of each cultivar location for analysis.
Place and Duration of Study: The laboratory experiments were conducted in the Department of

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Genetics and Biotechnology, University of Calabar, Cross River State in 2014 and 2015.
Methodology: The tray extraction (Modified Baermann) method was adopted for soil nematodes while the root maceration followed by incubation method was adopted for the root corm nematode extraction. The Genstat software was used for the analyses of data generated from the study.
Results: Results of nematode densities (population) per 10 g of root corm, ravaging elite plantain cultivars showed significant ($p<0.05$) differences in the population of nematodes infesting plantain crop in the root corm for the two cropping cycles of 2014 and 2015 investigated. The burrrowing nematode populations were highest in Bakpri (dwarf mutant) plantain cultivars (461/10g corm tissue in 2014 and 493/10g corm tissue in 2015 respectlvely) compared to all other cultivars. Ekumkwam cultivar seem to have the least population of burrowing nematodes of 9/10g corm tissue in 2014 and 13/10g corm tissue in 2015 respectively.
Results of nematode densities per 100g of soil, ravaging elite plantain cultivars reveal some significant ($p<0.05$) differences in the population of nematodes infesting plantain crop for the two cropping cycles of 2014 and 2015 investigated. Nematodes population in root soil were highest in the Bakpri (dwarf mutant) plantain cultivars (12,344/100 cm^3 soil in 2014 and 10,416/100 cm^3 soil in 2015 respectively) compared to all other cultivars. Ikpobata (cooking banana) cultivar seem to have the least population of nematodes (93/100 cm^3 soil in 2014 and 78/100 cm^3 soil in 2015 respectlvely).
The results also shows that the profiles of nematodes found to be ravaging elite plantain cultivars in the study area were the burrowing nematodes *Radophilus similis*, the ectoparasitic and spiral nematodes, *Helicotylenchus multicintus* and the soil migratory nematodes, *Practylenchus goodeyi*. Of the total nematode populations extracted from both rhizosphere or root soil from the fourteen (14) locations, they varied ($P<0.05$) significantly in density and concentration. The results showed that the ectoparasitic and spiral nematodes, *Helicotylenchus multicintus* had the highest profile density of 68.45% of all nematodes extracted from the root soil in all the elite cultivars sampled. The soil migratory and sedentary nematodes, *Practylenchus goodeyi* had a profile population of 27.12% while the burrowing nematodes, *Radophilus similis*, showed the least profile density in soil consisting of 3.51% while the unidentified organisms in the extracts were 0.02% in their profile density.
Results of nematodes profile density isolated from 10g root corm of all elite plantain cultivars revealed that, the burrowing nematodes, *Radophilus similis* had the highest profile density in the root corm constituting about to 76.11% of the total nematodes extracted from the root corm while the migratory nematodes *Practylenchus goodeyi* showed a nematodes profile density of 22.84%. Unidentified organisms were 0.54% while the ectoparasitic nematodes, *Helicotylenchus multicintus* constituted the least 0.51% profile density.
Conclusion: This study has shown that the low yield experienced by farmers in plantain fields in this agro-ecosystem can highly be attributed to high nematodes densities and significant profile densities which have not allowed for the full realization of the productive potentials of elite plantain cultivars in the area despite their nutritional and economic benefits. In view of the perceived potential of Plantain Parasitic Nematodes to destroy and reduce the yield of plantains, conscious efforts must be made to develop a sustainable management option for these pests. The use of soil mulch, local soil additives and plant extract as alternatives to synthetic Nematicide is strongly advocated in the region in view of the effect of pesticides on the environment and food chain.

Keywords: Nematode density; nematode profiles; Elite plantain cultivars; ravaging.

1. INTRODUCTION

Plantain cultivation has become a feature of great socio-economic importance in the Nigerian rain forest belt from the point of view of food security and job creation [1]. Plantain belongs to the non-traditional sector of the rural economy, where they remain a very important source of rural income.

Plantains are predominant in West and Central Africa, where they are cultivated either in perennial backyard production systems or for few years (usually in 1 - 3 production cycles) in plots intercropped with cocoa, oil palms, cocoyam, mango, cassava and citrus [2].

Plantain has remained one of the most highly staple food crops in southern Nigeria [3]. Among staple foods, plantains have the second highest calorie of energy after cassava. On the average, plantain supplies 9.5% the total calorific intake among the consumers [4]. The indispensability of plantain products in the region as the main source of iron food for man and livestock has led to the increasing demand for plantain despite the exorbitant price and low production profile in the country.

The production of plantain in the country and especially in the south, has been associated with a number of problems and limiting factors such as disease pathogens, parasitic nematodes, poor genetic composition of the accessions, low soil fertility, and traditional farming practices which have hindered the realization of its full productive potential under farmers' field conditions.

Plant parasitic nematodes are ever present in farmers' field, but the damage they cause is often attributed to other pests and disease pathogens, nutritional disorders or other abiotic factors [5]. In developing countries like Nigeria in particular, where resources and facilities are scares, it is difficult to accurately identify and quantify the nematode problems.

Nematodes belong to the animal kingdom. Sometimes called eelworms and are wormlike in appearance but are quite distinct taxonomically from the true worms. Most of the several thousand species of nematodes live freely in fresh or salt waters or in the soil and feed on microscopic plants and animals [6].

Nematode species attack and parasitize plants and animals in which they cause various forms of damages. Several hundred species, however, are known to feed on living plants, causing a variety of plant damage.

Because nematodes are difficult or impossible to be seen in the field and their symptoms are often non – specific, the damage they inflict on their host are often attributed to other more visible causes [7].

Farmers and researchers alike often underestimate their effects. A general assessment is that plant parasitic nematodes reduce agricultural production by approximately 11 percent globally [8], reducing production by millions of tons every year.

The amount of damage nematodes cause depends on a wide range of factors such as their population density, the virulence of the species or strain and the resistance (ability of the plant to yield despite nematode attack) of the host plant. Other factors also contributes to the least extent, including climate, water availability, soil conditions, soil fertility and the presence of other pests and diseases [9].

However, despite the awareness on the nematode – crop relationship and influencing factors, much still remains to be desired or learned in relation to plant parasitic nematodes and their modus operandi. Damage thresholds for nematodes on various crops in various parts of the world, for example are often unknown and the threat which nematodes pose to agriculture is often not considered enormous because of the absence of specific symptoms associated with nematodes pests as pathogens.

Many Nematode species have been reported to be associated with plantain production [10,11 and 12]. However, the most economically important species destroy the primary roots, corms, disrupting the anchorage system and resulting in toppling of the plants. These include the burrowing nematode, *Radopholus similis*, the lesion nematode, *Pratylenchus coffeae and Practylenchus goodeyi* and the spiral nematode, *Helicotylenchus multicintus* [13].

Some sedentary endoparasitic nematodes such as root-knot nematode, *Meloidogyne* spp. [14] and the reniform nematode, *Rotylenchulus reniformis* [15] also parasitize plantains. Nematodes infestation of plantain fields has various effects on the plantain plant and has plague the plant for centuries resulting in poor productivity, low yield, diseased plants, food scarcity, losses to farmers and a significant reduction of the farmers' income. Interestingly, is the fact that all these damages to the plant and farmers are mostly and too often attributed to other pathogens (viruses, fungi, Bacteria) and abiotic factors while neglecting the primary causative agent.

Although, some work have been carried out on nematodes densities and profiles ravaging plantain cultivars in some areas, little or nothing has been done in this regards on the available cultivars in this region. In addition, the transgenic plantain cultivar that was developed with the resistant gene (cysteine proteinase inhibitor gene) which was reported to confer 98 - 99 percent resistance against plantain nematodes [16] is yet to take it turn in this agro-ecology as genetically modified plantain suckers. This may be attributed to the delay in the passage of the biotechnology bill in Nigeria and/or the ethical issues concern with the use of genetically modified crops as well as the non - availability of the genetically modified suckers and the cost.

It is against this backdrop that this present study was undertaken in the study area to unravel the nematodes density and profiles associated with each of the available elite plantain cultivars, which have been ravaging the plantain crops over the years in the area causing significant losses in plantain yield, food shortages and great losses to farmers and remaining intractable. This will enable for planned bioremediation, development of resistant cultivars through conventional or marker assisted breeding and improvement of the available cultivars for increase plantain crop yield, food security, increase biodiversity and sustainable development. It is therefore the intention of this research to bridge the gap in knowledge of nematodes and the damage they inflict on their host elite plantain cultivars in this agro-ecology.

2. MATERIALS AND METHODS

2.1 Study Location

The study was carried out in the rain forest environment of southern Nigeria from 2013 to 2015 completing two (2) plantain cropping cycles on the average.

2.2 Sources of Experimental Materials

Fourteen (14) cultivars of plantain were used for the study. They were obtained from in situ identification of 300 plantain accessions locally maintained by farmers in the rain forest environment of Nigeria. The 300 plantain accessions were assessed and evaluated in situ for their agronomic and yield performance noting their coordinates (GPS readings). Data were taken for growth and yield parameters twice at growth and fruiting stages for each accessions found in farmer's field.

The generated data were subjected to cluster analysis using Genstat software from which 14 elite cultivars used in the study were identified and characterized. Both quantitative and qualitative attributes were used in the grouping of accessions into 14 major cultivars.

Coordinates for the 14 major elite cultivars identified were recorded in areas of most abundance of each cultivar with their local names as follows;

Table 1. Major Elite plantain cultivars identified with their coordinates in the study locations with local names

Elite plantain cultivars	Latitude (N)	Longitude (E)	Altitude (m.a.s.l)
Enugu plantain	06° 02.835'	008° 41. 104'	210m
Ebi Egome plantain	05° 56.540'	008° 50. 457'	131.98m
Ogoni Red plantain	06° 54.583'	009° 17. 799'	178m
Kigwa Brown plantain	06° 48.617'	009° 15. 301'	183m
Ejorgom plantain	06° 30.723'	009° 10. 687'	119m
Bakpri plantain	04° 97.778'	008° 36. 013'	54m
Owomoh plantain	05° 55.882'	008° 26. 391'	175m
Kainjen plantain	05° 58.200'	008° 63. 520'	181m
Ikpobata plantain	06° 28.427'	009° 08. 845'	97m
Mgbeghe plantain	05° 38.710'	008° 46. 024'	119m
Kenkwa plantain	06° 04.445'	008° 54. 776'	129.6m
Uhom plantain	05° 42.188'	008° 03. 233'	56m
Ekwumkwam plantain	06° 33.462'	008° 52. 290'	110m
Ingwam plantain	06° 39.995'	008° 51. 607'	92m

Fig. A = Ogoni Red French Plantain
Fig. B = Kigwa Brown False Horn Plantain
Fig. C = Enugu Black False Horn Plantain
Fig. D = Ebi Egome False Horn Plantain
Fig. E = Owomoh True Horn Plantain
Fig. F = kenkwa False Horn Plantain
Fig. G = Kainjen False Horn Plantain
Fig. H = Uhom False Horn Plantain
Fig. I = Ekumkwam French Plantain
Fig. J = Ikpobata (Cooking banana) French plantain
Fig. K = Mgbeghe False Horn Plantain
Fig. L = Ingwam French Plantain
Fig. M = Bakpri (dwarf mutant) French Plantain
Fig. N = Ejorgom True Horn Plantain

2.3 Collection of Experimental Materials /Sampling Elite Plantain Cultivars

The experimental materials used for the study were rhizosphere and root corm of each cultivar taken from farmer's field. From each location for the identified cultivars above, 1kg of soil was taken directly from the root zone of each cultivar in farmer's field using a soil augur, spade and cutlass to a depth of 25 cm in each case.


A. Root Soil sample **B. Root Corm sample**

Similarly, the root corm (high mat) from each cultivar was cut off from the ratoon crops of each cultivar in the farmer's field.

The collected root soils and 1kg corm samples were conveyed to the biological science laboratory in Calabar for nematodes extraction.

2.4 Experimental Design and Layout

The study was taken in-situ in farmers' field conditions. Soil samples and root corm samples for nematodes extractions and profile study were taken from three different locations where each elite cultivar was found. This gives a total of forty two (42) treatments.

2.5 Extraction of Nematodes from Rhizosphere Soil of Elite Plantain Cultivars

Plant parasitic nematodes are generally extracted from the rhizosphere of plants they infect or from the soil surrounding the roots on which they feed. Soil was taken from root zone of each elite cultivar using a soil augur. Soil samples were taken from three different farms having same cultivar to a depth of 0 – 25 cm.

Root soils from cultivars in plantain farms were collected as earlier described and taken for nematode extraction as follows.

The Baermann funnel consisting of a fairly large (12 – 15 cm) diameter glass funnel to which was attached to a piece of rubber tubing with a pinchcock placed on the tubing. The funnel was placed on a stand and filled with water. Two hundred (100 g) root soil sample of each cultivar was placed in the funnel on a porous, wet strength paper. The funnel was supported by a 5 – 6cm circular piece of wire screen in the beaker, over which a piece of cloth was fastened with a rubber band. The beaker was then inverted in the funnel with the cloth and all the soil below the surface of the water and this was allowed to stand over for 24 hours.

This process was to allow the active live nematodes move actively and migrate through the cloth to the water and sink to the bottom of the rubber tubing just above the pinchcock, from where more than 90 percent of the live nematodes were recovered in the first 5 – 8 ml of water obtained from the rubber tubing. This was emptied into a shallow dish for microscopic observation and counting using the AMSTRON 2000 Light Microscope fitted with an LD 64 MP camera.

2.6 Extraction of Nematodes from Necrotic Root Corms (High Mat) of Elite Plantain Cultivars

The nematodes were extracted from necrotic corms (High mat) obtained from ratoon crops of the 14 plantain cultivars. The infected corm (high mat) from each sample were carefully washed and chopped into several pieces using a kitchen knife. The chopped pieces were rinsed in clean water and incubated for 24 hours to allow for stoppage of physiological and biochemical processes in the chopped pieces of the plant parts.

The nematodes were extracted from the chopped pieces of corm using the modified Baermann funnel method and the Cobb sieving method [17,18]. The chopped pieces of plantain corm were put in a kitchen blender containing 500 ml of sterile distilled water and gently ground at very low speed for 25 seconds. The suspension was passed through a 40 μm diameter sieve tube to remove water and other fine plant particles. The remaining corm tissue was transferred into a wire mesh of 1 mm in diameter which was covered with tissue paper and submerged in water in a trough.

The active nematodes moved through the tissue paper into the clean water and were concentrated by decantation in a bowl. By adopting the keys of Speijer and De Waele as reported in [18,19,20] nematodes were identified on the basis of morphological and biochemical characteristics using a light Microscope AMSTRON 2000 fitted with an AM Camera 1000 MP and guide.

2.7 Killing, Fixing and Counting of Nematodes

The extracted nematodes in each case were fixed and heated to between 55 -65°C in a beaker by immersing in boiling water to kill nematodes thus allowing them assume their normal shape for easy identification. An equal volume of the hot fixative to that of the nematodes suspension was poured into nematode suspension (i.e 2 ml of hot fixative into 2 ml of nematode suspension to give a total of 4 ml).

The fixative used for this study was prepared by mixing

10 ml of Formalin (40% formaldehyde)
89 ml of Distilled water and
1 ml Glycerol

This has the advantage of keeping nematode from drying out while maintaining their structure after death.

Counting of nematodes was done with the aid of a compound microscope and counting dishes.

Fig. 1 and 2. Killing, fixing, viewing and counting of nematodes density under a high powered resolution light Microscope AMSTRON 2000 fitted with an AMSCOPE Camera 1000 MP

Fig. 3. Root nematodes in corm tissue

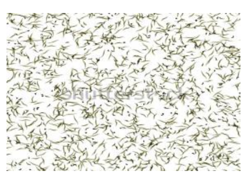

Fig. 4. Soil migratory nematodes in water

After 24 h of extraction, nematodes were relaxed in water (60°C) for 3 min and fixed with 40: 1: 89 (formalin: glacial acetic acid: distilled water) and nematodes were mounted on aluminum double-cover glass slides and specimens were identified [4,21] using morphological characteristics such as shape (spiral, flat, stylet) and nature (burrowing, sedentary or migratory).

2.8 Data Collection and Analysis

Nematodes density per 100 g of root soil and Nematodes profiles affecting plantain fields and plants in the study locations were counted and identified using the prescribed methodology, AMSTRON high powered Microscope and an AM 64 AMSCOPE camera. Nematode identification and count data were done directly using available instruments and laboratory and field guide. The experimental layout which was designed in a simple Randomized Complete Block Design (RCBD) in three replicates was analyzed using the Genstat software at 5% level of significance.

3. RESULTS

3.1 Results of Soil Nematodes Density Ravaging Elite Plantain Cultivars

Plantain crops heavily infested by nematodes *generally* show black or purple necrotic lesion in epidermal or cortical tissues and stunted plants growth, with resultant reduction in plant girth size, number of fingers per hand and bunch, number of hands per bunch, fewer number of leaves and bunch weight. The effects also include dieback and lesions in the corm in areas of heavy infestation [22].

Photos of some infected plantains

Results of nematode densities per 100 g of soil, ravaging elite plantain cultivars in southern Nigeria as presented in Tables 2 and Fig. 1 above reveal some significant ($p<0.05$) differences in the population of nematodes infesting plantain crop for the two cropping cycles of 2014 and 2015 investigated. As presented above, nematodes population of soil were the highest in the Bakpri (dwarf mutant) plantain cultivars (12,344/100 cm³ soil in 2014 and 10,416/100 cm³ soil in 2015 respectively) compared to all other cultivars. This was highly responsible for the small fingers, hands and bunch size observed in the study area for this cultivar. Ikpobata (cooking banana) cultivar seem to have the least population of nematodes (93/100 cm³ soil in 2014 and 78/100 cm³ soil in 2015 respectively). The results further showed that the rate of infestation of nematodes was significantly ($p<0.05$) higher in 2014 cropping cycles for eight of the elite cultivars like Enugu, Ebi egome, Ogoni Red, Kigwa brown, Ejorgom, Bakpri (dwafr mutant), Owomoh and ingwam plantain cultivars while nematodes population were significantly ($p<0.05$) higher in 2015 for kainjen, Mgbeghe and Ekumkwam plantain cultivars than the previous season. There was no statistical ($p>0.05$) differences in the soil nematode populations for Ikpobata (cooking banana) during the two cropping cycles. The results as presented in Table 2 and Fig. 1 above also showed that soil nematodes population extracted from Enugu plantain and ingwam plantain did not vary ($p>0.05$) significantly in 2014. Similarly, soil nematodes densities in 2015 were not statistically ($p>0.05$) different between Ogoni Red and Uhom plantains, between Enugu and Ikpobata plantains and between Kigwa, Owomoh and Ingwam elite plantain cultivars.

3.2 Results of Root Corm Nematodes Density Ravaging Elite Plantain Cultivars

Plantain crops heavily infested by nematodes *generally* show black or brown necrotic root corms and stunted plants growth, with resultant reduction in growth and yield of plantain as in reduced plant girth size, number of fingers per hand and bunch, number of hands per bunch, fewer number of leaves and bunch weight. The attendant effect sometimes include dieback and necrotic lesions in the corm in areas of heavy infestation [7,12,23].

Table 2. Total nematodes densities (population) extracted from 100 g of soil/rhizosphere of Elite plantain cultivars

S/N	Elite plantain cultivars	GPS reading /Locations	Genome /Type	Total nematode density/100g soil 2014	Total nematode density /100g soil 2015
1	Enugu Black plantain	06° 02.835' N 008° 41. 104' E	AAB False horn	433±24**i**	109±18**i**
2	Ebi Egome plantain	05°56.540'N 008° 50. 457'E	AAB False horn	610±43**h**	356±32**g**
3	Ogoni Red	06°54.583'N 009° 17. 799'E	AAB French Plantain	1818±102**e**	1072±96**e**
4	Kigwa Brown plantain	06°48.617'N 009° 15. 301'E	AAB True Horn	239±18**j**	233±15**h**
5	Ejorgom plantain	06°30.723'N 009° 10. 687'E	AAB French Type	7,688±1,508**b**	5,917±2,122**b**
6	Bakpri Plantain	04°97.778'N 008° 36. 013'E	AAB False Horn	12,344±4,048**a**	10,416±2,019**a**
7	Owomoh Plantain	05°55.882'N 008° 26. 391'E	AAB False Horn	367±38**i**	311±21**gh**
8	Kainjen Plantain	06°28.427'N 009° 08. 845'E	AAB False Horn	4,834±649**c**	5,012±2,438**c**
9	Ikpobata plantain	06°28.427'N 009° 08. 845'E	ABB French plantain	93±11**k**	78±09**i**
10	Mgbeghe Plantain	05°38.710'N 008° 46. 024'E	AAB False Horn	1,024±303**f**	3,011±168**d**
11	Kenkwa Plantain	06°04.445'N 008° 54. 776'E	AAB False Horn	772±73**g**	550±26**f**
12	Uhom Plantain	05°42.188'N 008° 03. 233'E	AAB True Horn	2,002±104**d**	1,141±183**e**
13	Ekumkwam Plantain	06°33.462'N 008° 52. 290'E	AAB False Horn	196±17**j**	366±112**g**
14	Ingwam Plantain	06°39.995'N 008° 51. 607'E	AAB False Horn	451±46**i**	266±86**h**
	LSD (0.05)			**79.33***	**101.56***

Data are means of triplicates measurements and extraction for each of the years. = significance differences at 5% level of probability.*
Same letter on same column indicates no statistical significant (p>0.05) difference.
N = Latitude, E = Longitude

Results of nematode densities (population) per 10g of root corm, ravaging elite plantain cultivars in southern Nigeria as presented in Tables 3 and Fig. 2, showed significant ($p<0.05$) differences in the population of nematodes infesting plantain crop from the corm for the two cropping cycles of 2014 and 2015 investigated. As presented above, burrowing nematode populations were highest in the Bakpri (dwarf mutant) plantain cultivars (461/10g corm tissue in 2014 and 493/10g corm tissue in 2015 respectively) compared to all other cultivars. This may be responsible for the small fingers, hands and bunch size observed in the study area for this cultivar. Ekumkwam cultivar seem to have the least population of burrowing nematodes of 9/10g corm tissue in 2014 and 13/10g corm tissue in 2015 respectively. The results further revealed that the rate of infestation of nematodes was significantly ($p<0.05$) higher in 2015 cropping cycles for eight of the elite cultivars including Ebi Egome, Kigwa Brown, Bakpri (dwarf mutant), Owomoh, Ikpobata (cooking banana), Mgbeghe and Ekumkwam plantain cultivars while root corm nematode populations were significantly ($p<0.05$) higher in 2014 for Enugu, Ogoni Red, Ejorgom, kainjen, Kenkwa and Inwam plantain cultivars than the subsequent season.

3.3 Results of Soil Nematodes Profile Ravaging Elite Plantain Cultivars

Three nematode species and some unidentified microorganisms were recovered from the rhizosphere of plantain from the fourteen cultivars surveyed. The nematodes were classified and identified to include *Practylenchus goodeyi, Rodopholus. similis* and *Helicotylenchus. Multicintus* and others which could not be easily identified. Of the three nematode species identified and encountered across locations, soil populations of the *practylenchus goodeyi. Helicotylenchus multicintus*, and *Radopholus. similis* significantly varied among the different plantain cultivars in both years of study. High populations of *Radopholus similis* were found on both years in Bakpri (dwarf mutant) plantain growing in marshy swamp and muddy soils of Esierebom, Calabar South.

The results as presented in Tables 4 and 5 show the profiles of nematodes found to be ravaging elite plantain cultivars in the study area of same nomenclatures ranging from the burrowing nematodes *Radophilus similis*, the ectoparasitic and spiral nematodes, *Helicotylenchus multicintus* and the soil migratory nematodes, *Practylenchus goodeyi*. Of the total nematode populations extracted from both rhizosphere or root soil from the fourteen (14) locations, vary greatly ($P<0.05$) in density and concentration. The results showed that the ectoparasitic and spiral nematodes, *Helicotylenchus multicintus* had the highest profile density of 68.45% of all nematodes extracted from the root soil in all the elite cultivars sampled. The soil migratory and sedentary nematodes, *Practylenchus goodeyi* had a profile population of 27.12% while the burrowing nematodes, *Radophilus similis*, showed the least profile density in soil consisting of 3.51% while the unidentified organisms in the extracts were 0.02% in their profile density. The results are reflected in the charts below.

On the contrary, results of nematodes profile density isolated from 10 g root corm of all elite plantain cultivars revealed that, the burrowing nematodes, *Radophilus similis* had the highest profile density in the root corm constituting about to 76.11% of the total nematodes extracted from the root corm while the migratory nematodes *Practylenchus goodeyi* showed a nematodes profile density of 22.84%. Unidentified organisms were 0.54% while the ectoparasitic nematodes, *Helicotylenchus multicintus* constituted the least 0.51% profile density. The results are also shown in the chart below.

In addition to the high spiral nematode, *Helicotylenchus multicintus* population observed in the soil, *Practylenchus goodeyi* populations was also found in the soil in fair proportion. Significant population of *Practylenchus goodeyi* was also isolated from the root corm. This confirms their mode of feeding which shows that they remained stationary and fixes their stylet to the root in the presence of abundant food.

4. DISCUSSION

The essence of this study was to assess the significance of nematodes population and profiles (species) that ravage plantain fields in this agro-ecosystem. Since the symptoms of nematodes are most times attributed to abiotic factors and other biological pathogens, this finding will help research efforts to be geared towards investigation on the most common means of reducing their populations and their unknown effects in plantain fields. The results further showed that nematodes are the most common pathogens which are found everywhere and yet remained unnoticed because of their unspecified symptomology. Most of the symptoms of their inoculum produced in their plant host tissues are either major symptoms of one pathogen or the other or attributable to abiotic and nutritional deficiency in plants.

The results have also revealed that reducing nematode populations in our plantain fields would reflect an increase in plantain yield and more income to the farmers.

Plantains have remained the major driver of our rural economy over the years [9,23] and it is sad watching the dwindling yield of this important plant amidst problems of low genetic make-up of cultivars, poor and infertile soil due to increasing urbanization, pest and diseases and short shelf life of plantain fruits. With the alarming rate of youth employment in the country and the high cost of living, there is an urgent need to remove and eliminate any noticeable barrier to food security and income generation activities. This was responsible for this survey and assessment study.

The results have further revealed the identities (profiles) of the nematodes ravaging our elite plantain cultivars and create a heightened need to focus research efforts at developing a common antidote that can reduce nematodes populations within the agro-ecosystem without altering the biodiversity herein and ecological balance. Yes, there are nematicides for control but they are mostly synthetic which alters the ecological balance with attendant bioaccumulation along the food chain. Cultural practices like the use of mulch have proven effective in some localities.

Table 3. Total nematodes densities (population) extracted from the Elite plantain cultivars in 10 g of root corm

S/N	Plantain cultivars	GPS reading /Locations	Genome /Type	Nematode Density/10g Corm 2014	Nematode Density /10g Corm 2015
1	Enugu Black plantain	06° 02.835’ N 008° 41. 104’ E	AAB False horn	106±16**fg**	99±08**g**
2	Ebi Egome plantain	05°56.540’N 008° 50. 457’E	AAB False horn	178±21**d**	201±27**de**
3	Ogoni Red	06°54.583’N 009° 17. 799’E	AAB French Plantain	222±38**c**	210±30**d**
4	Kigwa Brown plantain	06°48.617’N 009° 15. 301’E	AAB True Horn	19±02**i**	33±04**i**
5	Ejorgom plantain	06°30.723’N 009° 10. 687’E	AAB French Type	306±42**b**	291±29**b**
6	Bakpri Plantain	04°97.778’N 008° 36. 013’E	AAB False Horn	461±44**a**	493±49**a**
7	Owomoh Plantain	05°55.882’N 008° 26. 391’E	AAB False Horn	87±09**g**	119±20**fg**
8	Kainjen Plantain	06°28.427’N 009° 08. 845’E	AAB False Horn	295±39**bc**	263±27**c**
9	Ikpobata plantain	06°28.427’N 009° 08. 845’E	ABB French plantain	134±21**e**	166±19**e**
10	Mgbeghe Plantain	05°38.710’N 008° 46. 024’E	AAB False Horn	53±11**h**	79±09**gh**
11	Kenkwa Plantain	06°04.445’N 008° 54. 776’E	AAB False Horn	48±07**hi**	36±05**hi**
12	Uhom Plantain	05°42.188’N 008° 03. 233’E	AAB True Horn	111±10**f**	132±18**f**
13	Ekumkwam Plantain	06°33.462’N 008° 52. 290’E	AAB False Horn	09±01**j**	13±01**i**
14	Ingwam Plantain	06°39.995’N 008° 51. 607’E	AAB False Horn	61±7**h**	55±4**h**
	LSD (0.05)			**17.78***	**22.19***

*Data are means of triplicates measurements and extraction for each of the years. * = significance (p<0.05) differences at 5% level of probability.*
Same letter on same column indicates no statistical significant (p>0.05) difference.
N = Latitude, E = Longitude

Table 4. Results of nematode profiles extracted from 100 g rhizosphere soils for the Elite plantain cultivars in 2013/ 2014 and 2014/2015

	Elite Plantain cultivars	GPS coordinates	Genome / bunch phenotype	2014 Nematodes density/100 g root soil	2014 Nematodes profile	2015 Nematodes density/100 g root soil	2015 Nematodes profile
1	Enugu black plantain	06° 02.835' N 008°41.104' E	AAB / False horn	3	Radopholus similis	9	Radopholus similis
				43	Practylenchus goodeyi	11	Practylenchus goodeyi
				56	Helicotylenchus multicintus	89	Helicotylenchus multicintus
2	Ebi Egome plantain	05°56.540'N 008°50. 457'E	AAB / False horn	19	Radopholus similis	7	Radopholus similis
				318	Practylenchus goodeyi	94	Practylenchus goodeyi
				273	Helicotylenchus multicintus	255	Helicotylenchus multicintus
3	Ogoni red/Dominican red plantain	06°54.583'N 009 17. 799'E	AAB / French plantain	18	Radopholus similis	59	Radopholus similis
				565	Practylenchus goodeyi	123	Practylenchus goodeyi
				1235	Helicotylenchus multicintus	879	Helicotylenchus multicintus
4	Kigwa Brown plantain	06°48.617'N 009° 15. 301'E	AAB / True Horn	2	Radopholus similis	6	Radopholus similis
				27	Practylenchus goodeyi	34	Practylenchus goodeyi
				209	Helicotylenchus multicintus	202	Helicotylenchus multicintus
5	Ejorgom plantain	06°30.723'N 009° 10. 687'E	AAB / French Type	1003	Radopholus similis	695	Radopholus similis
				1344	Practylenchus goodeyi	1209	Practylenchus goodeyi
				5541	Helicotylenchus	4013	Helicotylenchus

	Elite Plantain cultivars	GPS coordinates	Genome / bunch phenotype	2014 Nematodes density/100 g root soil	2014 Nematodes profile	2015 Nematodes density/100 g root soil	2015 Nematodes profile
					multicintus		multicintus
6	Bakpri Plantain	04°97.778'N 008° 36. 013'E	AAB / False Horn	09	Radopholus similis	189	Radopholus similis
				226	Practylenchus goodeyi	1318	Practylenchus goodeyi
				11655	Helicotylenchus multicintus	8909	Helicotylenchus multicintus
7	Owomoh Plantain	05°55.882'N 008° 26. 391'E	AAB / False Horn	11	Radopholus similis	16	Radopholus similis
				12	Practylenchus goodeyi	204	Practylenchus goodeyi
				344	Helicotylenchus multicintus	91	Helicotylenchus multicintus
8	Kainjen Plantain	06°28.427'N 009° 08. 845'E	AAB / False Horn	108	Radopholus similis	154	Radopholus similis
				172	Practylenchus goodeyi	203	Practylenchus goodeyi
				4554	Helicotylenchus multicintus	4655	Helicotylenchus multicintus
9	Ikpobata plantain	06°28.427'N 009° 08. 845'E	ABB / French plantain	6	Radopholus similis	3	Radopholus similis
				17	Practylenchus goodeyi	21	Practylenchus goodeyi
				76	Helicotylenchus multicintus	57	Helicotylenchus multicintus
10	Mgbeghe Plantain	05°38.710'N 008° 46. 024'E	AAB / False Horn	10	Radopholus similis	308	Radopholus similis
				201	Practylenchus goodeyi	970	Practylenchus goodeyi
				804	Helicotylenchus multicintus	1705	Helicotylenchus multicintus
				09	unidentified	28	Unidentified

	Elite Plantain cultivars	GPS coordinates	Genome / bunch phenotype	2014 Nematodes density/100 g root soil	2014 Nematodes profile	2015 Nematodes density/100 g root soil	2015 Nematodes profile
11	Kenkwa Plantain	06°04.445'N 008° 54. 776'E	AAB / False Horn	16	Radopholus similis	35	Radopholus similis
				133	Practylenchus goodeyi	107	Practylenchus goodeyi
				576	Helicotylenchus multicintus	408	Helicotylenchus multicintus
				47	Unidentified	0	Unidentified
12	Uhom Plantain	05°42.188'N 008° 03. 233'E	AAB / True Horn	07	Radopholus similis	130	Radopholus similis
				194	Practylenchus goodeyi	234	Practylenchus goodeyi
				1801	Helicotylenchus multicintus	777	Helicotylenchus multicintus
13	Ekumkwam Plantain	06°33.462'N 008° 52. 290'E	AAB / False Horn	2	Radopholus similis	11	Radopholus similis
				14	Practylenchus goodeyi	103	Practylenchus goodeyi
				178	Helicotylenchus multicintus	253	Helicotylenchus multicintus
				04	Unidentified	10	Unidentified
14	Ingwam Plantain	06°39.995'N 008° 51. 607'E	AAB / False Horn	31	Radopholus similis	35	Radopholus similis
				43	Practylenchus goodeyi	58	Practylenchus goodeyi
				377	Helicotylenchus multicintus	173	Helicotylenchus multicintus
	LSD (0.05)			**15.11***		**21.92***	

Data are means of triplicates measurement and extractions for each of the years.
** significant at 5 % level of probability*

Table 5. Results of nematode densities and profiles extracted from 10 g root corm for the Elite plantain cultivars in 2014 and 2015

	Plantain cultivars	GPS coordinates	Genome / bunch phenotype	2014 Nematodes density/10 g root corm	2014 Nematodes profile	2015 Nematodes density/10 g root corm	2015 Nematodes profile
1	Enugu black plantain	06° 02.835' N 008°41.104' E	AAB / False horn	92	Radopholus similis	99	Radopholus similis
				10	Practylenchus goodeyi	4	Practylenchus goodeyi
				0	Helicotylenchus multicintus	0	Helicotylenchus multicintus
2	Ebi Egome plantain	05°56.540'N 008°50. 457'E	AAB / False horn	159	Radopholus similis	201	Radopholus similis
				17	Practylenchus goodeyi	12	Practylenchus goodeyi
				2	Helicotylenchus multicintus	0	Helicotylenchus multicintus
3	Ogoni red/Dominican red plantain	06°54.583'N 009 17. 799'E	AAB / French plantain	192	Radopholus similis	210	Radopholus similis
				21	Practylenchus goodeyi	3	Practylenchus goodeyi
				11	Helicotylenchus multicintus	1	Helicotylenchus multicintus
4	Kigwa Brown plantain	06°48.617'N 009° 15. 301'E	AAB / True Horn	16	Radopholus similis	33	Radopholus similis
				3	Practylenchus goodeyi	6	Practylenchus goodeyi
				0	Helicotylenchus multicintus	0	Helicotylenchus multicintus
5	Ejorgom plantain	06°30.723'N 009° 10. 687'E	AAB / French Type	271	Radopholus similis	291	Radopholus similis
				31	Practylenchus goodeyi	0	Practylenchus goodeyi
				5	Helicotylenchus	4	Helicotylenchus

	Plantain cultivars	GPS coordinates	Genome / bunch phenotype	2014 Nematodes density/10 g root corm	2014 Nematodes profile	2015 Nematodes density/10 g root corm	2015 Nematodes profile
					multicintus		multicintus
6	Bakpri Plantain	04°97.778'N 008° 36. 013'E	AAB / False Horn	553	Radopholus similis	515	Radopholus similis
				7	Practylenchus goodeyi	21	Practylenchus goodeyi
				2	Helicotylenchus multicintus	2	Helicotylenchus multicintus
7	Owomoh Plantain	05°55.882'N 008° 26. 391'E	AAB / False Horn	84	Radopholus similis	119	Radopholus similis
				3	Practylenchus goodeyi	8	Practylenchus goodeyi
				0	Helicotylenchus multicintus	0	Helicotylenchus multicintus
8	Kainjen Plantain	06°28.427'N 009° 08. 845'E	AAB / False Horn	271	Radopholus similis	263	Radopholus similis
				19	Practylenchus goodeyi	2	Practylenchus goodeyi
				4	Helicotylenchus multicintus	1	Helicotylenchus multicintus
9	Ikpobata plantain	06°28.427'N 009° 08. 845'E	ABB / French plantain	106	Radopholus similis	166	Radopholus similis
				11	Practylenchus goodeyi	8	Practylenchus goodeyi
				17	Helicotylenchus multicintus	2	Helicotylenchus multicintus
10	Mgbeghe Plantain	05°38.710'N 008° 46. 024'E	AAB / False Horn	48	Radopholus similis	79	Radopholus similis
				1	Practylenchus goodeyi	2	Practylenchus goodeyi
				1	Helicotylenchus multicintus	1	Helicotylenchus multicintus
				3	unidentified	6	Unidentified

	Plantain cultivars	GPS coordinates	Genome / bunch phenotype	2014 Nematodes density/10 g root corm	2014 Nematodes profile	2015 Nematodes density/10 g root corm	2015 Nematodes profile
11	Kenkwa Plantain	06°04.445'N 008° 54. 776'E	AAB / False Horn	41	Radopholus similis	27	Radopholus similis
				1	Practylenchus goodeyi	0	Practylenchus goodeyi
				2	Helicotylenchus multicintus	2	Helicotylenchus multicintus
				5	Unidentified	10	Unidentified
12	Uhom Plantain	05°42.188'N 008° 03. 233'E	AAB / True Horn	84	Radopholus similis	122	Radopholus similis
				9	Practylenchus goodeyi	3	Practylenchus goodeyi
				23	Helicotylenchus multicintus	6	Helicotylenchus multicintus
13	Ekumkwam Plantain	06°33.462'N 008° 52. 290'E	AAB / False Horn	09	Radopholus similis	13	Radopholus similis
				3	Practylenchus goodeyi	3	Practylenchus goodeyi
				0	Helicotylenchus multicintus	0	Helicotylenchus multicintus
				3	Unidentified	3	Unidentified
14	Ingwam Plantain	06°39.995'N 008° 51. 607'E	AAB / False Horn	43	Radopholus similis	49	Radopholus similis
				12	Practylenchus goodeyi	2	Practylenchus goodeyi
				8	Helicotylenchus multicintus	4	Helicotylenchus multicintus
	LSD(0.05)			13.22*		21.09*	

Data are means of triplicates measurements and extraction for each of the years.
** Significant at 5% level of probability*

It is our future research intentions to harness weedy botanicals that can suppress the populations of this unknown enemy within plantains farmer's field in this agro-ecology.

The attendant effect of nematodes damage on plantains result in reduced yields and a global annual loss of 19.7% as been reported by [13,24].

Various control strategies have been employed to manage the menace of plant parasitic nematodes in plantain production with varying degrees of successes. Cultural practices such as fallows and rotations with non-hosts have been used. However, lack of land has rendered fallows unimportant. Similarly, crop rotation will always be a difficult strategy to implement because of the wide host ranges of nematodes [14,24]. Physical treatment such as the immersion of suckers in hot water at 55°C for 15 to 25 min has been useful [25], this method will however be of little significance in field establishment. However; failure to monitor the recommended temperature and time limit could prove counter-productive. Biological control has not been employed much as pathogens and parasites of important nematodes of plantains have not yet been identified. Chemical (synthetic pesticides) method of control has been used with greater measure of success [26]. However, their use constitutes an assault on the environment and a threat to mankind [27]. In this present study, we conducted a survey of plantain fields to identify nematodes associated with plantain roots and rhizosphere soils in twenty farms in southern Nigeria with particular emphasis in the elite cultivars which remains a major source of food and income to a wide range of populace. The information would form the basis of formulating an integrated pest management (IPM) strategy to increase the production of plantain in the country.

Many Nematode species have been reported to be associated with plantain production [6,17,20,28]. However, the most economically important species destroy the primary roots, corms, disrupting the anchorage system and resulting in toppling of the plants. These include the burrowing nematode, *Radopholus similis*, the lesion nematode, *Pratylenchus coffeae and Practylenchus goodeyi* and the spiral nematode, *Helicotylenchus multicintus* [29].

Some sedentary endoparasitic nematodes such as root-knot nematode, *Meloidogyne* spp. [30] and the Reni form nematode, *Rotylenchulus reniformis* [22,31] also parasitize plantains. Nematodes infestation of plantain fields has various effects on the plantain plant and has plague the plant for centuries resulting in poor productivity, low yield, diseased plants, food scarcity, losses to farmers and a significant reduction of the farmers' income. Interestingly, is the fact that all these damages to the plant and farmers are mostly and too often attributed to others pathogens (viruses, fungi, Bacteria) and abiotic factors while neglecting the primary causative agent.

Although, some work have been carried out on nematodes densities and profiles ravaging plantain cultivars in some areas, little or nothing has been done in this regards on the available cultivars in this region. In addition, the transgenic plantain cultivar that was developed with the resistant gene (cysteine proteinase inhibitor gene) which was reported to confer 98 - 99 percent resistance against plantain nematodes is yet to take it turn in this agro-ecology as genetically modified plantain suckers. This may be attributed to the delay in the passage of the biotechnology bill in Nigeria and/or the ethical issues concern with the use of genetically modified crops as well as the non - availability of the genetically modified suckers and the cost.

Similar results on nematodes have been reported in most West African countries. For instance,the highest observed population of *R. similis* (464/5 g root) occurred at Adanwomase region of Ghana whilst the lowest of (163/5 g root) occurred at Adomakokrom respectively. Compared with soil samples, nematode numbers extracted from root samples were higher. This was not the case in our findings as soil nematodes outnumbered root corm nematodes. Plant Parasitic Nematodes have the potential to rob the plantain farmer of his profits, a menace which was reported in the West African sub-region by Osei et al. [13,17,31]. Nematodes caused on the average 50% plantain yield reduction and 20% absolute loss where *P. coffeae* followed by *R. similis* were identified as the major biotic constraint to plantain production in Nigeria [27,32]. The banana weevil, *Cosmopolites sordidus* and the fungus, *Mycosphaerella fijiensis*, the cause of black sigatoka disease are other significant biotic constraints to plantain production but higher losses are anticipated by *P. goodeyi* and *R. similis* than by either *M. fijiensis* or *C. sordidus* [24,32]. From the Ivory Coast, [18,33] reported the menace of *P. goodeyi, R. similis, H. multicintus* and *P. coffeae* on plantain production.

All these reports suggest that nematodes affect plantain growth and yield negatively.

It is against this backdrop that this present study was undertaken in the study area to unravel the nematodes density and profiles associated with each of the available elite plantain cultivars, which have been ravaging the plantain crops over the years in the area causing significant losses in plantain yield, food shortages and great losses to farmers and still remains intractable. This will enable for planned bioremediation, development of resistant cultivars through conventional or marker assisted breeding and improvement of the available cultivars for increase plantain crop yield, food security, increase biodiversity and sustainable development. It is therefore the intention of this research to bridge the gap in knowledge of nematodes and the damage they inflict on their host elite plantain cultivars in this agro-ecology.

5. CONCLUSION

This study has shown that the low yield experienced by farmers in plantain fields can highly be attributed to high nematodes densities and profiles which have not allowed for the full realization of the productive potentials of elite plantain cultivars in the area despite their nutritional and economic benefits. In view of the perceived potential of Plantain Parasitic Nematodes to destroy and reduce the yield of plantains, conscious efforts must be made to develop a sustainable management option for these pests. The use of soil mulch, local soil additives and plant extract as alternatives to synthetic Nematicide is strongly advocated in the region in view of the effect of pesticides on the environment and food chain.

This study has been able to show that low plantain yields in the regions can be attributed to nematodes whose population in our tropical soils is unprecedented. The study has also been able to identify the profiles of nematodes ravaging plantain crops in the region. This can enhance planned integrated pest management approach, development of resistant cultivars with particular emphasis on the major types based on the profile study and for the region specifically. Molecular assisted selected and breeding can also be carried out on the region based on this important baseline information and data.

Finally, with the awareness created on the 'unknown enemy within the plantain farmers field', great precaution on how to tackle this unknown enemy within will henceforth be taken by plantain farmers for maximum yield and increase income.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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