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SOIL AND ROOT NEMATODE PESTS OF BELL PEPPER (*Capsicum anuum*)

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ABSTRACT

The soil yielded a total of 746 nematodes from 15 genera, while the roots recorded 216 nematodes from 6 genera. *Gracilachus* species, 10.6% were widespread in soil while *Meloidogyne* species, 35.2% exhibit the highest population in roots, an observation that could be ascribed to species strategy for life sustenance in soil and root environment. Disparity in nematode abundance was recorded between roots and soil with certain genera occurring only in soil while some were found in roots as well as soil. This scenario was observed across the five farm where samples were collected for the study. The results established that *Meloidogyne* species are weighty parasite of bell pepper (*Capsicum anuum*) as it occurs more often than all other species in bell pepper roots. This research also affirms that nematodes constitute a prominent pest family of bell pepper (*Capsicum anuum*) in the study area.

Key words: Abua, Bell pepper, *Capsicum anuum*, Farms, Nematodes, Pests.

I. INTRODUCTION

Bell pepper (*Capsicum anum*) is a vegetable crop originated from North America (FAO, 2010). It is grown virtually in every country of the world including Nigeria. In Nigeria, bell pepper constituted a good market for rural dwellers.The bell pepper crop (*Capsicum annum L)* belong to the Solanaceae family (Norma *et al.*, 2009; FAO, 2010).The species name *anuum* implied annual; however, the crop can survive different seasons and may grow into a perennial shrub depending on the soil type wherein it is cultivated and care (Norman *et al*., 2009; Acevdo-Rodriguez & Strong, 2012).The crop has attained popularity recently owing to its importance as food and agent of economic development in developing countries including Nigeria (Jean, 2000; FAO, 2010). It has the highest economic value among the commonly cultivated vegetables crops after tomato in the study area. It has soothing effect on the digestive system, offers relief from symptoms of colds, sore throats and circulation problems (Park e*t al*., 2016). Fresh products of bell pepper are excellent source of certain mineral elements and vitamin including calcium and vitamin C respectively (Jean, 2005).

The crop has been reported as susceptible to nematodes (Stanton & Graham, 2014). According to Sitepu and Mustike, (2000) and Thuy *et al*.(2012), multitude of these tiny eel worms in soil including the reniform species infect bell pepper in cultivated fields in different ways.

The infections of plant parasitic nematodes on the roots tissues of plants inhibit growth, weaken the plant nodules and impair nitrogen fixation (Imafidor, 2007). According to Imafiodr and Ekine (2016) and Coyne *et al.* (2018), nematodes constitute more serious injury to crop production annually compared to insect pests in African. Loss in yield due to these tiny unseen pathogens in various countries is enormous (Nzeako *et al.*, 2014) and has been projected to be 55.7 % worldwide (Nicol*et al*, 2000; Sasser, 2009; McSorley, 2003). These losses occur most often in the Tropics were environmental conditions are most favorable and their relatively moderate soil temperature which facilitate root rotten encourage rapid proliferation of certain species of nematodes like *Meloidogyne* species (Imafidor & Nzeako, 2008; Coyne, 2018). Crop problems inflicted by eel worms are not easily checked because of their non-conspicuous nature, as a result are missed in any pests control program (Abduzor & Haseeb, 2010). Moreover, these invisible foe of human endeavors do not only inflict damage in isolation but form affiliation with other soil inhabiting microbes and compound crop destruction (Abduzor & Haseeb, 2010; Nzeako *et al*, 2013., Imafidor & Ekine, 2016).

Following the attack of plant parasitic nematodes on crops, food production could to a large extend depend on the farmer's understanding of the role of these eel worms in regulating production rate. The activities of these non-visible hostile enemy of the farmer's effort could lead to reduced food productivity and limits supply which in turn may result to food insecurity; yet these microbes are frequently looked down as pest of crops because the injury they imposed are downstream and sometimes are not conspicuous and their tiny appearance make effect of infection obscure and hard to identify (Caveness, 1982; Coyne, 1994; McSorley, 2003; Imafidor & Ekine, 2016). Nevertheless, this study is aimed at surveying soil and roots of bell pepper to identify the nematode pest affiliated with the crops.

II. MATERIALS AND METHOD

Study Area

This study was conducted in five bell pepper farms in Abua designated A,B,C,D and E. Abua is a community in Rivers State Nigeria. Abua lie between latitude 4.5 and 5.4 degree North of the equator and between 6 and 12° East of the

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Meridian. Abua is hedged round by Rivers except from the North end which is forested. Abua is the breadbasket of Rivers State, Nigeria. The people engage themselves in farming of green vegetable and bell pepper.

Ethical Clearance

Bush entry permission was sought from the community chief from were samples were collected for the study. Farm owners were contacted and all the bell pepper stands uprooted were paid for.

Collection of Soil Samples

Random sample of soil collected from the rhizosphere of the bell pepper (*Capsicum anuum*) in each farm with the aid of an improvised soil auger. A total of thirty soil samples were collected from each bell pepper grown farm. Soil samples were collected from the crop rhizosphere at depths 0-15 cm in the early hours (7 am -8 am) of each day all through the period of survey. The samples of soil were packed into properly labeled 5 by 10 cm bags and were transported to the laboratory for nematode extraction.

Collection of Root Samples

In each bell pepper farm, ten bell pepper stands were randomly selected and uprooted. The root samples were taken at the same time from the same location as for soil with the aid of a kitchen knife. The samples were placed into a well labeled 5 by 10 cm bags, and were transported to laboratory for nematode extraction.

Nematode Extraction

Nematodes were extracted using the Bearmann's extraction technique (Imafidor and Ekine, 2016).

Identification of nematodes

Nematodes were identified using the light microscope x4 and x10, and identification was done using a pictorial key (Jonathan, 2002; Meketeet *al*, 2012).

The soil samples in each sample bag were poured into a 5-10cm plate and were thoroughly mixed to form a bulk sample. A total 25 sub samples were taken from the bulk samples in each farm. These soil samples were spread evenly on a circle of tissue paper supported on a plastic sieve standing in a plastic plate. Water was added to the extraction plate gently until the soil become wet but not immersed. The extraction set-ups were left undisturbed for 48 hours. After the 48 hours, the soil was removed and the supernatant discarded. The nematodes aliquot were emptied into clean grease free specimen bottles and allowed to sediment and fixed with 5 % formalin and stored for microscope view, 0.1ml of the nematodes aliquot were taken with a pipette placed on glass slides and observed using x4 and x10 objectives of light microscope.

The bell pepper roots from each sample bag were thoroughly washed in tap water to remove soil particles, and cut into 2cm segments before removing a 5g fresh mass sub-sample. The 5g sub-sample of root were macerated in an electric blender for 10-20 seconds at low speed. Each macerated sub sample of the root was spread evenly on a piece of tissue paper supported on plastic sieve standing on a plastic plate. Water were added to the plate until the samples were wet but not immersed. The set up was left undisturbed for 48 hours. The root samples were removed, discarded and the nematode suspension poured into a clean specimen bottles and were fixed with 5% formalin and stored, 0.1ml of the nematodes aliquot was taken with a pipette and placed on a glass slide and examined for nematodes species using the x4 and x10 objectives of light microscope.

Data analysis

The analysis of data was done using analysis of variance (ANOVA) in SPSS

III. RESULTS & DISCUSSION

Population of soil nematode pests of bell pepper

Soil sampling in this study produced a total of 746 nematodes belonging to 15 genera from all the farms. Among the extracted species of nematodes in soil, 159 (21.3%) were reported from farm A, 134 (18.0%) were reported from farm B while 140 (18.8%), 150 (20.1%) and 163 (21.8%) species were found occurring in farm C, D and E respectively. The individual nematodes found occurring in this study were *Radopholus, Tylenchorhynchus, Pratylenchus, Meloidogyne, Ditylenchus, Heterodera, Tylenchus, Hoplolaimus, Gracilachus, Criconema, Helicotylenchus, Caloosia, Longidorus, Rotylenchus* and *Scutellonema*. The total assemblage of *Radopholus* species were 42 among which 6 (14.3%) were found in Farm A, 4 (9.5%) were found occurring in Farm B while 20 (47.6%) and 12 (28.6) were extracted from Farm D and E respectively with no species of the genera reported from C. *Tylenchorhynchus* species recovered were 59, among which 16 (27.1%) occurred in Farm Site A, while site B had 8 (13.6%) and C, D and E reported 21 (35.6%), 6 (10.2%) and 8 (13.6%) respectively. *Pratylenchus* species extracted in this study amounted 48, 26 (52.2%) occurring in Farm A, farm C and D shows 12 (25.0%) and 10 (17.2%) species respectively with no species appearing in B and E. *Meloidogyne* species were 58 and were extracted in all farms with an uneven distribution; 12 (20.7%), 10 (17.2%), 16

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(27.6%), 10 (17.2%) and 10 (17.2%) were reported from farm A,B,C,D, and E respectively. *Ditylenchus* species encountered were 36 with an unsteady distribution of 8 (22.2%) occurring in farm A, 6 (16.7%) were found in site C while 12 (33.3%) and 10 (27.8%) were extracted from farm D and E in that order. The total occurrence for *Heterodera* species were 53, among which 9 (17.0%) were found appearing in farm A, 14 (26.4%) were extracted from farm C while 9 (17.0% and 21 (39.6%) were reported from farm D and E with no species recorded in farm B. The actual incident of *Tylenchus* species were 62 with an uneven distribution of 16 (25.8%), 13 (21.0%), 4 (6.5%), 15 (24.2%), and 14 (22.6%) occurring in Farm A, B, C, D and E in that order. *Hoplolaimus* species recorded were 71, among 20 (28.2%) were extracted in farm A, 24 (33.8%) were found in site B while 7 (9.9%), 8 (11.3%) and 12 (22.6%) were reported in farm C, D and E respectively. The total population of *Gracilachus* species reported were 79, among which 7 (8.9%) occur in farm A, 22 (27.8%) appear in farm B while farm C, D and reported a total assemblage of 18 (22.8%), 11 (13.9%) and 21 (26.6%) respectively. Other nematodes reported in this were *Criconema* species, *Helicotylenchus* spp., *Caloosia* spp., *Longidorus* spp., *Scutellonema* and *Rotylenchus* species with a total assemblage of 51, 69.34, 39, 16 and 29 with an uneven distribution across the Farm sites were soil samples were collected.

Table 1: Population of soil nematode pests of bell Pepper in Abua

Nematode	**Farms**					**Overall abundance**
	A (%)	**B (%)**	**C (%)**	**D (%)**	**E (%)**	
Radopholus	6 (14.3)	4 (9.5)	0	20 (47.6)	12 (28.6)	42 (5.6)
Tylenchorhynchus	16 (27.1)	8 (13.6)	21 (35.6)	6 (10.2)	8 (13.6)	59 (7.9)
Pratylenchus	26 (54.2)	0	12 (25.0)	10 (20.8)	0	48 (6.4)
Meloidogyne	12 (20.7)	10 (17.2)	16 (27.6)	10 (17.2)	10 (17.2)	58 (7.8)
Ditylenchus	8 (22.2)	0	6 (16.7)	12 (33.3)	10 (27.8)	36 (4.8)
Heterodera	9 (17.0)	0	14 (26.4)	9 (17)	21 (39.6)	53 (7.1)
Tylenchus	16 (25.8)	13 (21.0)	4 (6.5)	15 (24.2)	14 (22.6)	62 (8.3)
Hoplolaimus	20 (28.2)	24 (33.8)	7 (9.9)	8 (11.3)	12 (16.9)	71 (9.5)
Gracilachus	7 (8.9)	22 (27.8)	18 (22.8)	11 (13.9)	21 (26.6)	79 (10.6)
Criconema	0	9 (17.6)	3 (5.9)	14 (27.5)	25 (49.0)	51 (6.8)
Helicotylenchus	13 (18.8)	20 (29.0)	15 (21.7)	13 (18.8)	8 (11.6)	69 (9.2)
Caloosia	6 (17.6)	4 (11.6)	6 (17.6)	12 (35.3)	6 (17.6)	34 (4.6)
Longidorus	12 (30.6)	0	11 (28.2)	10 (25.6)	6 (15.4)	39 (5.2)
Scutellonema	0	8 (50.0)	7 (43.8)	0	1 (6.3)	16 (2.1)
Rotylenchus	8 (27.6)	12 (41.4)	0	0	9 (31.0)	29 (3.9)
Total	159 (21.3)	134 (18.0)	140 (18.8)	150 (20.1)	163 (21.8)	746

n/N x 100 (n = Individual nematode occurrence, N = total nematodes extracted: 746)

pv- 0.357

Population of root nematode pests of bell pepper (*Capsicum anuum*)

From the roots of bell pepper, 216 nematodes were extracted. Among the recovered root nematodes, 25.9% were found occurring in farm A, Farm B yielded a total nematode assemblage of 19.9%, farm C reported 27.8 while farm D and E shows 18.1% and 8.3% species respectively. From the roots of pepper, *Melodogyne* species occur more than all other species reported with an overall population of 76 (35.2%) while the population of *Radopholus* were 37 (17.1%), *Helicotylenchus* species was 36 (16.6%) while *Hoplolaimus* species had 25 (11.6%) and *Pratylenchus* species recorded the least abundance of 18 (8.3%).

Table 2: Population of root nematodes pests of pepper (*Capsicum anuum*)

Nematodes	**Farm**					Over all pop		
	A(%)	**B (%)**	**C (%)**	**D (%)**	**E (%)**		F	sig
Hoplolaimu	8 (32.0)	0	3 (12.0)	11 (44.0)	3 (12.0)	25 (11.6)		

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Helicotylenchus	13 (36.1)	12 (33.3)	7 (19.4)	4 (11.1)	0	36 (16.6)	7.557	0.000
Ditylenchus	15 (62.5)	0	9 (37.5)	0	0	24 (11.1)		
Meloidogyne	20 (26.3)	13 (17.1)	20 (26.3)	15 (19.7)	8 (10.5)	76 (35.2)		
Radopholus	0	13 (35.1)	11 (29.7)	0	4 (10.8)	37 (17.1)		
Pratylenchus	0	5	10 (55.6)	9 (24.3)	3 (16.7)	18 (8.3)		
Total	**56 (25.9)**	**43 (19.9)**	**60 (27.8)**	**39 (18.1)**	**18 (8.3)**	**216**		

Abundance of nematodes in relation to soil and roots

The result of this study reported a total of 962 nematodes from fifteen genera and species. Among which 15 were found occurring in soil while 6 were reported from the root tissues of bell pepper.The nematodes so reported were *Radopholus*, *Tylenchorhynchus*, *Pratylenchus*,*Meloidogyne*, *Ditylenchus*, *Heterodera*, *Tylenchus*, *Hoplolaimus*, *Gracilachus*, *Criconema*, *Helicotylenchus*, *Caloosia*, *Longidorus*, *Rotylenchus* and *Scutellonema*. Eight genera reported in soil were absent in root, however all the genera reported in the root were also found in the soil.

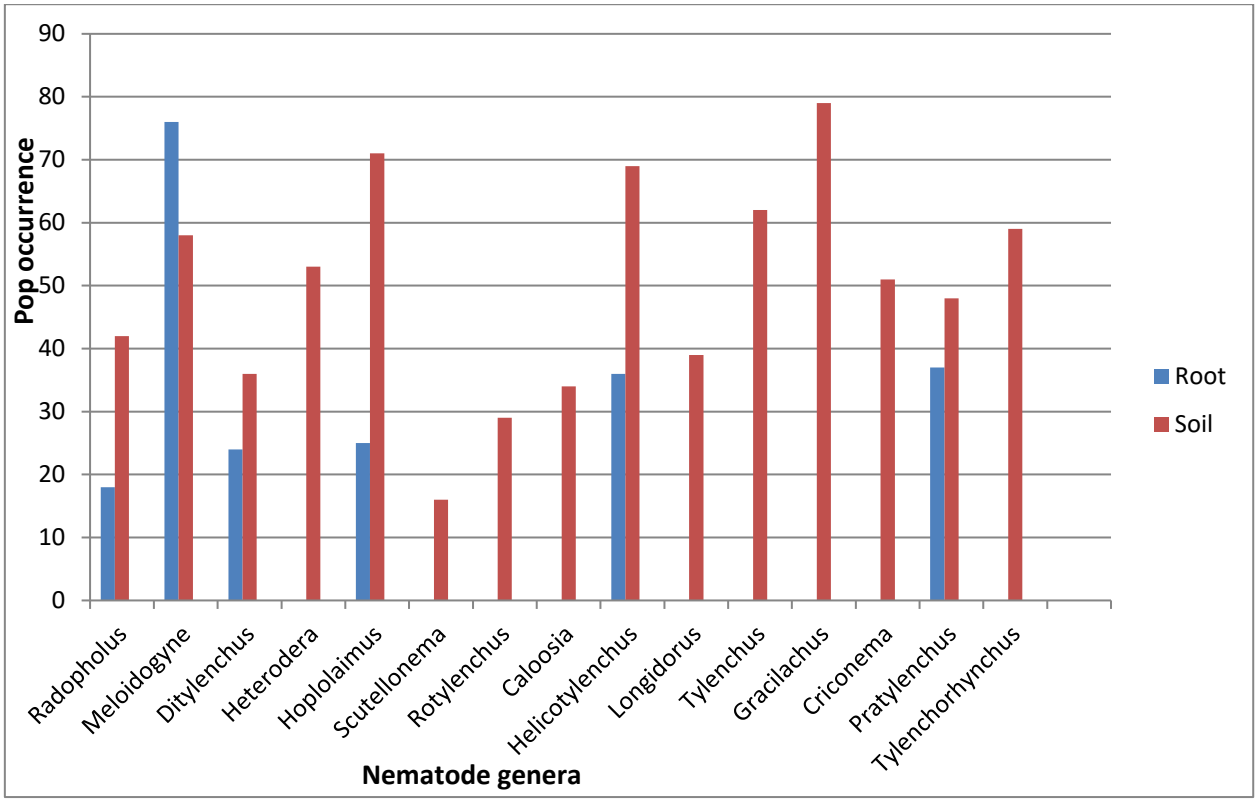

Figure 1: Variation of nematode abundance in relation to soil and root of bell pepper

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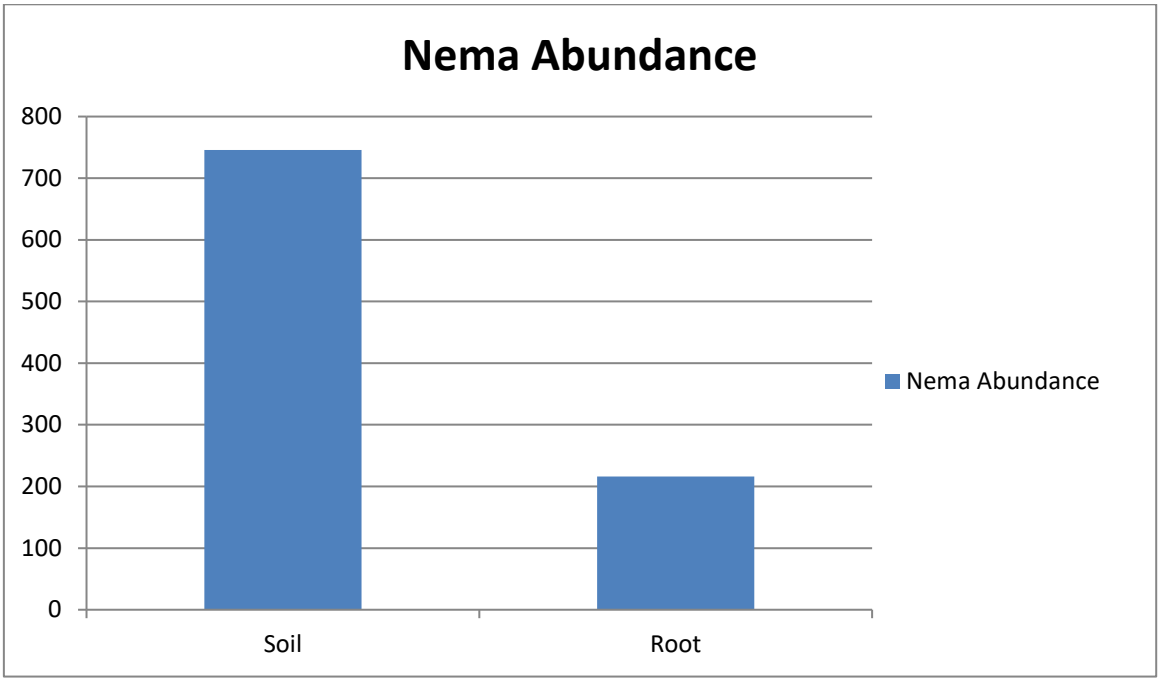

Figure 2: overall population of nematodes in soil and root

Discussion

Table 1 reports the abundance of plant parasitic nematodes of bell pepper across all the Farms were soil samples were collected for extraction. The study recorded a total population of 746 nematodes in soil. The result is indicative that nematodes are typical pests of the crop bell pepper (*Capsicum anuum*) in the study area. This observation agrees with Imafidor and Ekine (2016) who recorded high prevalence of nematodes on cassava cultivated soil. The soil bioassay shows that Farm E 21.8%, recorded the highest species abundance closely followed by farm A, 21.3% while the least populated farm was B 18.0%. Farm C and D shows an assemblage of 18.8% and 20.2% respectively. The concentration of nematodes across the sampled farms suggests that nematode species exhibit uneven distribution in fields irrespective of farming system. The continual appearance of nematodes in all the sampled farms as seen in this study could be impute to the monoculture farming practice observe in the research fields. The result further established that bell pepper is a suitable host plant for plant parasitic nematodes.

The study revealed the presence of 15 nematode genera in the soil across the sampled farms. This result is relatively higher than 8 soil nematodes reported associated with cucumber crop in Abua (Gboeloh *et al*., 2018). This result suggests that the study area exhibit favourable atmosphere as to support nematode reproduction and abundance. Soil nematodes, like other soil organisms propagate and develop speedily in every environment that may support life. Among the 15 nematode genera reported in the soil, only 7 genera including *Radopholus*, *Tylenchorhynchus*, *Meloidogyne*, *Tylenchus*, *Hoplolaimus*, *Gracilachus* and *Caloosia* species were found appearing in all the Farms. This result agrees with (Mohamed *et al*., 2013; Imafidor & Ekine, 2016; Gboeloh *et al*., 2019). This observation could be attributed to nematode survival strategy and host specificity of the indigenous nematodes of the study area. The nematode species so reported in this study has been reported elsewhere as pests associated with pepper (Thuy *et al*., 2012).The result further shows that the distribution of nematodes cannot be predicted since certain species appear in some farms and are missing in some other farms with the same cropping and farming system. This observation agrees with Imafidor and Ekine (2016) which reported nematodes dynamics on cassava cultivated fields.

The most frequently reported nematode in the soil were *Gracilachus* species 10.6% with the highest abundance, closely followed by *Hoplolaimus* species 9.5% and *Helicotylenchus* species 9.2% while *Scutellonema* species 2.1% occur less than all other species reported. This result disagrees with Ekine *et al* (2018) which reported high presence of *Meloidogyne* species in cassava cultivated soil . This observation could be ascribed to the intrinsic features of the individual nematode species which better adapt them for survival in every environment. The result can also be attributed to the ability of specific genera of nematode to outweigh inter-specific competition in the soil.

Six nematode genera were identified as pests of roots tissue of bell Pepper (*Capsicum anuum*) in this survey. The overall nematode abundance of bell pepper root was 216 with the highest occurrence experienced in farm C and A with 27.8% and 25.9% respectively. Farm E 8.3% reported the least number of root nematodes in the study. The nematode population abundance recorded were relatively low compare to results elsewhere (Luc *et al*., 2012). The low nematode population from the root of bell pepper in this study could be attributed to little or absence of predators in soil within the study area.

This result disagrees with Elele (2016); who recorded high nematode assemblage in the root of eggplant on a similar study. This disparity could be attributed to study location, time of study and variance in terms of constituent soil properties. The relatively high population abundance of root nematode reported in sites A and C suggests that soil environment was hostile to nematodes in these farms which could have prompt more nematodes borrow into the roots of bell pepper for survival. It could also mean that plant parasitic nematodes in farm A and C were better adapted for parasitism in these sites. The borrowing habit exhibit by parasitic nematodes is an intrinsic behaviour for escape external predatory and increases species chances of survival in root tissue of plants.

The actual abundance of endophytic nematodes in root tissue of bell pepper as observed in this study was not significant ($p>0.05$) across the Farm sampled.

A disparity in nematode proliferation and abundance was observed between roots and soil with certain genera occurring only in soil while some were found in roots as well as soil. Yet the total abundance of plant parasitic nematodes was lower in roots when compare with the abundance in soil. An observation which was statistically significant ($p<0.05$), (Figure 1). This remarks indicates that the soil environment was more favourable for nematode propagation and survival than the root tissues of bell pepper in the study. This result disagrees with Elele (2016) which reported a lofty population of nematodes from the roots of eggplant. Nematodes have evolved a variety of technique to enable them stay alive in soil environment among which are borrowing into crop roots and continual tricking host by constantly moving around the root rhizosphere (Nicol, *et al*, 2005).

Analysis on the overall occurrence and profusion of nematodes in this study showed that *Meloidogyne* species, 17.1% has the highest abundance, appearing more than all other species in roots and coming fifth most populated genera in soil. *Meloidogyne* species is versatile in nature and could inflict plants injuries in isolation (Imafidor, 2007; Coyne *et al*., 2018).The population of a very popular pest of pepper *Rodopholus* species in this study was low compare with the population of *Gracilachus,* a non-pepper associated species. This result is indicative that place, time and soil features may determine nematode prevalence in fields.

IV. CONCLUSION

Nematodes constitute a prominent pests' family of bell pepper (*Capsicum anuum*) in the study area with the root knot species showing the highest prevalence in roots and inflicting the crop with injuries of economic concern in all cultivated fields. However, species abundance in soil were not the same as a non-popular genus, *Gracilachus* species were frequently dominant than all other species. An evident that suggests that nematode occurrence in field is unpredictable.

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