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Plant Parasitic Nematodes Parasitism On The Nutritional Status Of Yam (*Dioscorea* Species) Tubers In Nigeria.

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Abstract

Yam; Dioscorea species of cropsare multivariantstaples in Nigeria and are plagued by plant parasitic nematodes (PPNs).Four species of Dioscorea; D. rotundata (white yam), D. cayenensis (yellow yam), D. alata (water yam), D. dometerum were selected to determine therelationaship between PPNsload and the nutritional status of the tubers. Proximate analyses of the tubers were carried out usingstandard scientific methods while the Bearmann's and Sieving methods were used to determine the PPNsload of the tubers. D. cayensis (38.89%) had the highest nematode load while D. dometorum(8.47%) was the least infected. PPNsload decreased as tuber depth increased (outermost layers; 77.4% and the innersmost; 0%).Scutellonema species (48.0%)was the most prevalent PPN in all the yam tubers.Moisture content of the stored tubers influenced the mobility of PPNsin tubers. However, moisture content ofD.cayensis and D.rotundatadeclined as nematode load decreased while that of D.alata and D.dometurumshow no association between PPN load and moisture content of the yam tubers. PPNs parasitism influencedcrude carbohydrate and crude protein concentrationsof yam tubers. Fibre content of the tubers varied in relation to the specific tuber layers.D. dometurum was resistant to PPNs in the study. The long shelf live of yam tubers made them reservior hosts of numerous plant parasitic nematodes which promoted the dispersal of the worm pests. Pre-planting sterilzation of tubers is recommended to curb the transmission of PPNs to new agroenvironments.

Keywords*: Dioscorea spp., nematode load,crude protien, tuber depth and reservoir hosts and agroenvironment.*

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I. Introduction

There is severe food scarcity and insecurity in sub Saharan Africa, greatly occasioned by the detoiration of farm produce both in the field and storageresulting from pest attacks (FAO, 2009) and poor storage facility. Majority of the crops are attacked in the field, while,others are attacked in storage. One of the pests that occur in both the field and in storage is the plant parasitic nematode(Amusa and Mohammed, 2003; Mwanki, 2003;Williams and Gleason, 2003;Ogaraku, A.O. and Usman, 2008;Nzeako *etal*., 2013). Nematodes;the round worms are ubiquitious, diverse and highly adaptable to almost any niche in the aquatic and terresterial ecosystems (Ferris, and Berkelman, 2003 and Nzeako *etal*., 2015). Their ecological flexibility of nematodesmakes them one of the most successful animals on earth,however, their variable ecological rolesaccentuates them as suitable indicators of intricate alterations in the ambient physicochemical status of the environment.Nematodes' diverse trophic affiliations in the ecosystem makes some species extreme obligate biotrophs that cause huge loses to crops in the field and storage (Coursey, 1967; Nweke, 1991; GCDT, 2014, Nzeako *etal*., 2016 and2019). Plant parasitic nematodes (PPN)are specialist obligates of crops andconstitute a minute segment of the ambigous set of nemaparasites that attack livingthings. PPNs are responsible for about 2.3% of the world annual agro-yield loss ofeconomic crops (Nayak *etal*., 1987, Kushwaha and Polycarp, 2001;Abad and Williamson, 2008; Shehu *etal*., 2010; Ibitoye and Attah, 2012).All plant taxa are infected by plant parasitic nematodes, however, some show great host specificity such as *Ditylenchusdipsaci*, *Anguinatritici* and *Scutellonema* spp., while some are great generalist parasites such as *Meloidogyne* spp., and *Pratylenchus* spp., (Nzeako and Imafidor, 2010). Nematodes invasion and migration in the plant tissues alters the root architecture, causes significant reductions in nutrients and water uptakes and consequentlyhampers crop yields (Curtis *etal*., 2007).

Amongst the PPNs of great economic importance in Nigeria is*Scutellonema* spp., that is specific to the *Dioscorea* spp., of crops (yam) (Sasser, 1980, Adesiyan, *etal*., 1990).Generally, phytoparasitic nematodes impact negatively on the growth and development of *Dioscorea* spp., resulting to poor yeilds and marketabilty of tubers. Yam; *Dioscorea* spp., in all its varieties is a major staple in Nigeria and west African sub region

(Adegbite,2006; Nzeako,*et al.*, 2010,). Nigeria remains the highest producer of the crop in ton per hecter worldwide but not the highest beneficiary in terms of foreign exchange acrueing from its export (Page, 2006, GCDT, 2014, NRCRI, 1998, FAO, 2007, 1998, Izekor and Olumese,2010, Nsikak *etal*., 2013). Nigeria's premier status in yam production isnot due to improved yield per hectre cultivated nor due to improved planting materials, rather, due to increased population of farmers embanking on yam production in the last five decades (Mwaniki, 2003; FAO, 2009, 2010, Shehu *etal*., 2010; Ibitoye and Attah, 2012). Yam as a crop has huge socioeconomic significance in Nigeria as it constitutes one of the important items in traditional marriage ceremony,child birth, burial and religious rites of the populace (Nzeako, *etal*., 2010, Ibitoye and Onimisimm, 2013, GCDT, 2014).

The wide geographical tolerance or adaptation of the *Diocorea* spp.,of crops in sub Saharan African had made it a crop for all the regions including Nigeria, especially, at the subsistent level. Also, the economic returns from yam farming and its unique role in the management of the health state; hypertension had made it a dominant target crop for supplemental vocation for people from all works of life in Nigeria. Yam is not a staple for the poorin the population, since, its consumption is more in the high socioeconomic group (GCDT, 2014). It has been recognised as a suitable crop for poverty alleviation interventions because of its reletively long shelf-lifethat is beyound twelve months that enables it to be stocked during harvest periods when it is abundant and cheap (Onwueme, 1978,Nweke, 1991; Nzeako *et al*., 2015). This characteristic makes yam a highly valued cash crop, usually stored for up to 8 months and sold by poor farmers when the supply is low.

The impact of PPNs infetation of yam in the field results to great decrease in tuber sizeand tissue integrity in storage. This is a major contributor to very low agricultural performance in terms of productivity within the Nigerian agroecosystem. Low agricultural productivity hampers the effort of the government to achieving food security and sustainability in the country especially, for a crop of high sociocultural and economic status like *Dioscorea* spp. To this end,it isimportant to determine the post harvest nutritional status of naturally infected tubers in a yam producing region of Rivers State, Nigeria. Again, it is speculated that PPNs load of yam tubers influences the overall crude protein content of individual yam tubers (Caillaud *etal*., 2008; Wei and Brent, 2006). This propositionimplies that; the higher the PPNs load, the higher the protein content of the yam tuber or*vizvisa*. However, this assertion needs validation. This study is designed to determine the nutritional status of PPNs infected yam tubers from Rivers State, Nigeria.The study will also; determine the relationship between Tuber Nematode Load (TNL) in relation to crude carbohydrate, crude protein, dietry fibre, and moisture contents of four yam species; *D. rotundata*, *D. cayenensis*, *D. alata* and *D. dometorum*.This study would unravel the misconception associated with PPNs load in relation to the protein, carbohydrate, moisture and fibre contents of yam tubers in storage.

Table 1. The nutitional content of yam

S/N	Nutrient (%/g/mg)	Value	S/N	Nutrient (%/g/mg)	Value
1	Moisture (%)	81,00-165.0	8	Phosphorus (mg)	17-61.0
2	Calories (%)	71.00-135.00	9	Iron (mg)	8.0-12.0
3	Carbohydrate (g)	16-31.8	10	Potassium (mg)	214-397
4	Protein (g)	1.4-3.5	11	B–carotene (mg)	0.0-10.0
5	Fat (g)	0.2-0.4	12	Riboflavin (mg)	0.01-0.011
6	Fibre (g)	0.40-10.0	13	Niacin (mg)	0.01-0.04
7	Calcium (g)	12-69.	14	Ascorbic acid (mg)	4.00-18.0

Standard nutritional content of 1g of yam as stated by FAO

II. Materials and Methods

2.1. Study Area and Collection of Samples

The study was carried out in four communities; Beeri,Taaba, Kaani and Nyo-buru in Khana L.G.A of RiversState. The Local Government Area is located between4.700′N and 7.350′E, occupies an area of 560km2 andhas a population of 294.217 (National census Commission, 2006). The studyarea experiences an annual maximum temperature of32ºC and a minimum of 27ºC. The average annualrainfall of the area is 2500 mm with July andSeptember having the highest. The vegetation of thestudy area is the tropical rainforest type. Samples of *D. rotundata* (white yam), *D. cayenensis* (yellow yam), *D. alata* (water yam), *D. dometerum* (three-leaf yam or the African bitter yam) were randomly collected fromthe study area. These were placed in appropriately labeled polythene bags and transported to the laboratory for analyses.

2.1.1. Exclusion Criteria: This work considered only stored tubers of yam and seasonal variation was not considered.

2.2. Extraction of plant parasitic nematodes of the yam tissues

Individual seed yams were washed in running tap to remove soil and debris. Thesewere cut into 3 parts(anterior, middle and posterior). On each of the designatedparts; concentric circular parts were cut off to representthe outer, middle and core of the sectioned parts of the yam tuber. The cut circular sections were macerated and placed on the modified Bearman's sieve for the extraction of endophytic nematodes (Hooper,1970, Baker *et al*., 1985, Hooper *et al*., 2007,Golden, 1985a and b).The extraction setup was left for 48 hours after which the macerates were discarded, 10% formalin was added to the aliquots and allowed to sediment, after which the supernatant of approximately 90% was decanted. The sediment of about 10% was poured intolabelled universal bottles for microscopic examination. Nematode identification was done using Goodey and Goodey (1963).

2.3. Determination of Crude Protein Content

Protein analysis of the yam tuber was accertained following Kjeldahl Method as stated by the Analytical Organization of Analytical Chemists, (AOAC,2016) which involved digestion, neutralization and titration techniques. Determination of protein was based on total N contentx, a factor=6.25.

2.4. Determination of Carbohydrate content: This was done using the **Cleg**Method (AOAC,2000). Method is on difference: 100 **-** (weight in grams [protein + fat + water + ash + alcohol] in 100 g of food) *Measured in mg/ml.*

2.5. Determination of Moisture Content: This was done using the Air Oven method as described in AOAC(2016).

2.6. Lipid Content Determination-Soxhlet Extraction Method as stated in AOAC(2016).

2.7. Ash Content Determination-The Furnace Method as decribed in AOAC(2016).

2.8. Nematode Identification

Nematodes were identified according to Goodey and Goodey (1963) and Golden (1985).

III. Results

3.1 Table 2. Plant Parasitic Nematodes population in yam tubers

The plant parasitic nematode load of the yam tubers revealed the occurrence of five nematodes species; *Meloidogyne* spp., *Scutellonema* spp., *Hoploliamus* spp.,*Pratylenchus* spp. and *Helicotylenchus* spp., at varying intensities in the various *Dioscorea* species sampled. There was variability in the endophytic nematode load and specificity amonsgt the yam varieties with *D. cayensis* harbouring the highest load of 69(38.98%),*D. alata*;47(26.56%), *D. rutundata*; 46(25.98%) and *D. dometorum*;having 15(8.47%). Although, the occurrence of the five nematodes species recorded in the study were consistent amongst all the *Diocorea*spp.,tubers; *Scuttellonema* spp., had the highest parasite density while the least density was recorded for *Helicotylenchus* spp.*Dioscorea*varieties were in this study were suitable hosts toplant parasitic nematodes with varying levels of resistance and tolerance.*D. dometorum* was regarded as resistant to plant parasitic nematodes as it harboured the lowest density of endophytic worms in the study (Table 2) which could be due to its unsuitability to nematode reproductivity (Figure 1). However, the the other three sampled yam varieties displayed variability in their suitability to plant parasitic nematodes population.

Table 2. Plant Parasitic Nematodes population in yam tubers

Nematode species	Yam Species (%)				Total (%)
	D. cayensis	*D. alata*	*D.dometorum*	*D. rutunda*	
Meloidogyne spp.	22(42.30)	15(28.84)	2(3.84)	13(25.00)	52(29.71)
Scutellonema spp.	31(36.90)	22(26.19)	9(10.71)	22(26.19)	84(48.00)
Hoploliamus spp.	5(33.33)	3(20.00)	2(13.33)	5(33.33)	15(8.57)
Pratylenchus spp.	6(35.29)	5(29.41)	2(11.76)	4(23.52)	17(9.71)
Helicotylenchus spp.	5(55.55)	2(22.22)	0(0.00)	2(22.22)	9(5.14)
Total (%)	69(38.98)	47(26.56)	15 (8.47)	46(25.98)	177

2.9. Specific Tuber layer protein content

Mean crude protein concentration of the yam tubers in relation to yam tuber specific layer and nematode load showed a decrease in protein concentration as nematode load increased. This pattern of distribution of plant parasitic nematode was observed in all the yam tubers except *D.cayensis* where the the outermost layer contained more protein than the inner layers. The concentration of crude protein along the three considered layers of the tubers (specific tuber layer protein content)varied within the tuubers and across the yam varieties. There was a surface to core variation in the concentration of protein in the tubers examined. Variability in crude protein levels of the various yam layers gradually increased from surface to the core of the tubers in three *Dioscorea* species except the *D.dometorum* (table 5).Nematode load decreased as depth increased with the outermost layer harbouring 77.4% of the overall nematode load and the innermost; the core bearing no worms in all the yam species. This trend influenced protein concentration in the tubers examined. In all yam tubers protein content was lowest at the outermost surface except in *D.dometurum* where the outermost layer bore the highest protein concentration. This implied that tissue digeneration occurred in the region with high parasitic load such that protein depriciated. However,host specific factors may have contributed to the relatively high protein load of *D. dometorum*in addition to plant parasitic nematode resistance attributed to the yam species. There was no significant difference in protein concentration of at specific tuber layers across the yam varieties (p>0.05) however, the study revealed that the heavily infected tubers harboured lesser carbohydrate than the relatively less infected tubers.

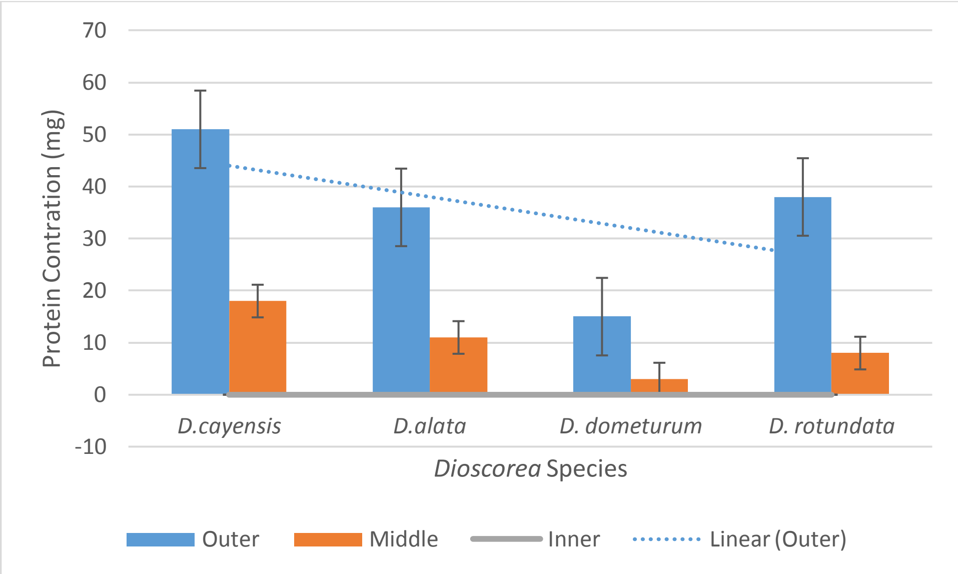

Figure 1., Specific Tuber Layer Nematode load

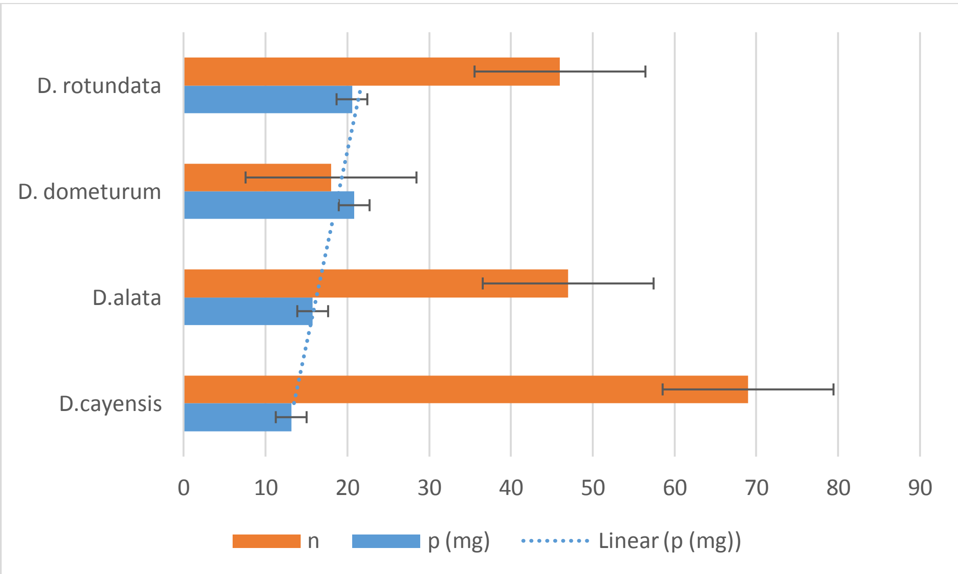

Figure 2. Gross protein and nematode load of yam tubers

Table 5. Comparison between protein content (mg) and layer specific nematode load

Layer of tuber	**Species of yam**							
	D.cayensis		*D.alata*		*D. dometurum*		*D. rotundata*	
	p (mg)	n	p (mg)	n	p(mg)	n	p(mg)	n
Outer	3.50±.04	51	3.94±.06	36	7.0±00	15	6.56±04	38
Middle	4.38±.02	18	5.69±.01	11	7.7±00	3	7.0±.01	8

Inner	5.25±.05	0	6.13±.07	0	6.13±07	0	7.0±.00	0
Total (%)	13.13±03	69	15.76±04	47	20.83±03	18	20.56	46

p =protein content of tuber, n=plant parasitic load of tuber

PLATE 1A-C: *Pratylenchus* spp., *Meloidogyne* spp., and *Meloidogyne* spp., adult

3.3. Tuber specific layer nematode load and moisture content

D. cayennsis retained more water in the tissues than the other three sampled yam tubers, however, two different patterns of moisture retention was observed the specifictubers layers in relation to the nematode load of the yam tubers.In *D.cayensis* and *D.rotundata*, nematode load decreased as moisture content declined while, in *D.alata* and *D.dometurum* the middle layer of the tubers retained more moisture than the outermost and core(Table 4). The gross moisture content of the tubers indicated *D. dometorum* as being relatively less hydrated than the other yam species. The study also, showed that the outermost layers of the various tubers contained higher nematode load than the middle and core (Figure 4). There was a significant difference between the nematode load and moisture content amongst the yam species and within the specific layers of individual yam tubers (p> 0.05).

Table 4. Comparison between Tuber Layer Specific Nematode Load and moisture content

Layer of tuber	**Species of Yam**							
	D.cayensis		*D.alata*		*D. dometurum*		*D. rotundata*	
	n	m	n	m	n	m	n	m
Outer	51	66.53±.07	36	59.87±.03	15	79.76±.04	38	74.3±.07
Middle	18	62.28±.02	11	65.77±.03	3	80.79±.01	8	63.0±.01
Inner	0	60.25±.01	0	59.96±.04	0	78.22±.08	0	60.1±.03
Total (%)	69	189.06±10	47	185.6±03	18	158.77±06	46	197.4±04

n = Specific Tuber Layer Nematode Load, m=moisture content of tuber(%)

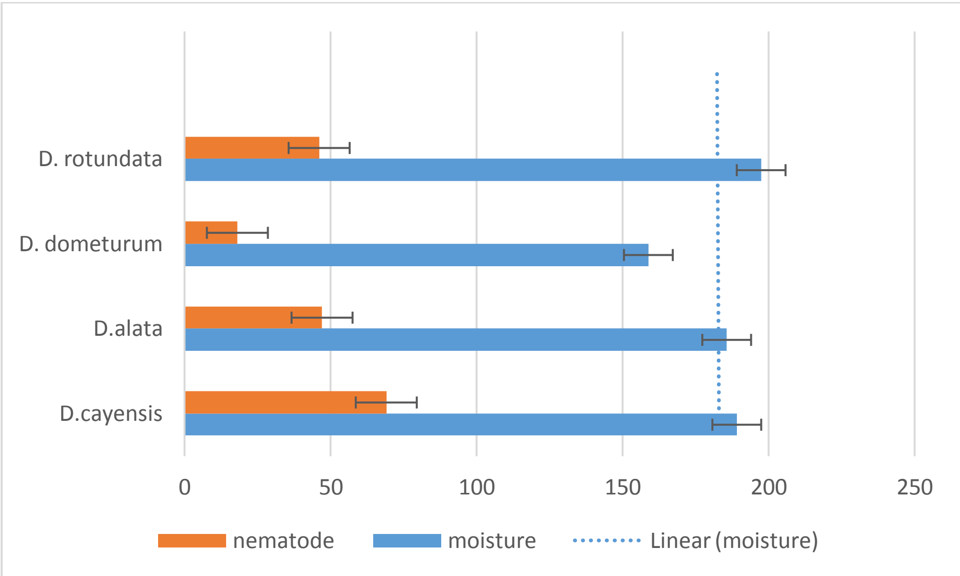

Figure 4. Gross nematode load and moisture content of the yam tubers

2.10. Comparison between tuber layer specific nematode load and carbohydrate content (mg/ml)

The crude carbohydrate composition varied within the specific layers of individual yam tubers and across the varieties of yams. *D. cayensis* and *D.rotundata* expressed drastic reductions in carbohydrate at the outermost layers of the yam which progressively increased as nematode load reduced. This trend was not observed in *D.alata* and *D. dometurum* where tuber carbohydrate content was not drastically depleted at the outermost layer. The carbohydrate integrity of the specific tuber layers showed the influence of nematode parasitism on carbohydrate composition of the tubers (Figure 5 and Table 6). The study revealed that the heavily infected tubers contained relatively lower concentration of carbohydrate than the relatively less infected tubers. There was a significant difference ($p<0.05$) between the carbohydrate concentration of the specific tuber layers in all the yam varieties but none ($p>0.05$) between the different *Dioscorea* species.

Table 6. Comparison between Tuber Layer Specific Nematode Load and carbohydrate content (mg/ml)

Layer of tuber	Species of yam							
	D.cayensis		*D.alata*		*D. dometurum*		*D. rotundata*	
	n	c	n	c	n	c	n	c
Outer	51	1.93±.07	36	30.03±.07	15	13.45±.05	38	1.73±.07
Middle	18	27.22±.08	11	25.34±.06	3	13.72±.08	8	27.22±.08
Inner	0	31.35±04	0	30.30± 01	0	15.25±.05	0	31.35±.05
Total (%)	69	60.5±00	47	85.67±04	18	42.42±05	46	60.3±05

N=nematode in of yam, c= available carbohydrate content mg/ml)

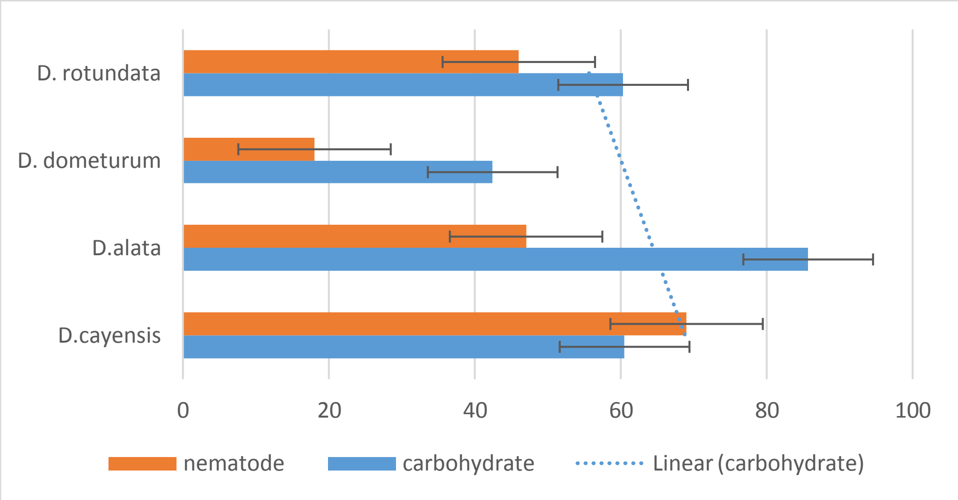

Figure 5., Gross nematode parasitism on total carbohydrate concentration

2.11. Comparison between tuber layer specific nematode load and fibre content

The fibre constitution of the specific layers of the yam tubers varied from the outermost to the innermost layerin all yam species which replicated the recorded trend of endophytic nematode load across the tuber layers, however, the trend was not consistent in all yam varieties. The fibre content of *D. rotundata* highest in comparison to the other sampled varieties. This trend could be due to host specific factors. There was a significant difference ($p<0.05$) between the tuber specific layer fibre content of individual yam tubers but was not ($p>0.05$) amongst the yam varieties.

Table 7. Comparison between Tuber Layer Specific Nematode Load and fibre content (mg)

Layer of tuber	Species of yam (%)							
	D.cayensis		*D.alata*		*D. dometurum*		*D. rotundata*	
	n	f	n	f	n	f	n	F
Outer	51	6.78	36	18.95	15	4.13	38	28.87
Middle	18	7.89	11	17.71	3	3.04	8	15.53
Inner	0	9.8	0	15.26	0	3.46	0	8.83
Total (%)	69	24.47	47	51.92	18	10.63	46	53.23

n=nematode in of yam, f= content (mg)

IV. Discussion

4.1 Plant Parasitic Nematodes population in yam tubers

Five species of plant parasitic nematodes; *Meloidogyne* spp., *Scutellonema* spp., *Hoploliamus* spp, *Pratylenchus* spp., and *Helicotylenchus*spp., were reecovered from the various species of yam tubers used in the study. *Scutellonema* spp., had the highest overall occurrence amongst the yam species followed by*Meloidogyne* spp., and the least was *Helicotylenchus*spp. (Table, 1., and figures 1-4).*Scutellonema*spp.,was the most abundant and suitable nematode species of the sampled *Dioscorea*speciestubers. *D. cayensis* harboured the highest nematode load followed by *D. alata*,while *D. dometorum* had the least infection (Chin *etal*., 2018). The *Dioscorea* varieties were suitable hosts tosome plant parasitic nematodes with varying levels of resistance and tolerance as stated by Abad and Williamson(2010).Nematode load of the specific yam tubers indicated the suitability of *Dioscorea* cropsto plant parasitic nematode infectivity which manifested in the endophytic density of theparasites. *D. dometorum* was regarded as resistant to plant parasitic nematodes as it harboured the lowest density of endophytic worms in the study (Table 2) which could be due to its unsuitability to plant parasitic nematodes reproductivity.The relatively low parasite load of *D. dometorum*revealed the resistance of the yam species to plant parasitic nematodes. This attribute of *D. dometorum* could be used in the cultural management of plant parasitic nematodes in susbsistency (Table 2, Figures 1-4).The intensity of PPNs decreasedfrom the surface to the core of the tubers. The pattern ofendophytic distribution of PPNs in theyam tubers reflected the penetration competence ofthe parasitic worms.

This study shows that *Dioscorea*spp., of crops maintained progressiveprasitism*invivo* because, field acquired infections remained viable as tubers aged in storage. Field infection of yam tubers implicates it as an important agent of nematode propagation and dispersal in the agroecosystem. Apart from this, nematodes cycles are retained in the dormant tubers until planting season comes which confirms that nematodessuitableto the *Dioscorea*spp., of crop assume quiscence during the dormant stage (storage) of the tubers(Nzeako*etal*., 2019). The endophytic population of *Scutellonema* spp. was higher than that in the other varieties of *Dioscorea* spp.,because of its physiological characteristics of initiating sustainable feeding sites that are sufficient for the completion ofPPNs lifecycle. Plants species usually respond to signal from nematodes to initiate and maintain feeding sites sufficient for completion of nematode lifecycles. *Diocorea* spp. tubers displayed relatively little or no manifestation of symptoms due to their high tolerance ability as demonstrated in *D. cayensis* and *D. rotundata* (Cook and Evans, 1987; Trudgill, 1991). Nemaode parastism of plant tissue generally induces the infected cells to develop proliferative nurturing cells; characterized by granulated cytoplasms with hypertrophied nuclei and nucleoli (Watsonn and Shorthouse, 1979). Several studies also, stated that plant parasitic nematode induced morphogenesis in plant tissues increases as nematode load increases (Watsonn and Shorthouse, 1979, Vovlas *et al.*, 2015, Palomares-Rius *etal*., 2017).The ability to harbour high densities of parasitic nematodes in yam tubers during stsorage makes the use of local plantings materials (yam tubers) a high risk practice because they harbourhigh density of endophytic nematodes that are consequently transferred to the field during planting. This hinders any effort by farmers at controlling plant parasitic nematodes of yam using locally available seed yams.

4.2 Specific Tuber Layer Nematode Load and moisture content

Yam tuber looses water in storage resulting in the usual lose of weight and size of stored tubers. The loss of weight of tubers usually affects endogenous obligate nematodes. In this study the moisture content of the different layers of the yam (Specific tuber layers, STL)varied, however, two patterns of moisture dynamism was observed amongst the tuber layers. The pattern observed in *D.cayensis* and *D.rotundata* showed that the nematode load decreased as moisture content declined (Table 4 and Figure 4).In this pattern, there was a progressive top-bottom decline in moisture content which was also, replicated in endogenous nematode density of the STL. The second pattern of moisture dynamics manifested by *D.alata* and *D.dometurum*showed middle-tuber layer high moisture contentration which was not replicated in the nematode load pattern (Table 4.). Curtis *etal*. (2007) implicated plant parasitic nematodes invasion and endophytic migration in the alteration ofthe root architecture, significant reduction in nutrient uptake and crop yield.In this study,the tubers sampled manifested dormancy (Cook and Evans, 1987; Ogaraku and Usman, 2008).. Consequently, the field acquired PPNs infections may have induced increased metabolism that prompted an oxidative boost (FAO, 2009) in the tubers.The study opines that the conventional loss of water by the yam tubers on storage affected the endophytic migration of PPNs species. However, the none-penetration of nematodes into the core of the tubers in all the yam varieties indicated the directionof moisture flow which was opposite to the direction of the migratory worms and migratory competence of the nematode juveniles. The conventional outward flow of moisturefrom the core to the periphery of the yam tubers influenced the concentration of PPNs at the periphheral layers of the tubers and the subsequent trapping of nematodes along their migratory paths in the tissues of the yam tubers.

4.3 Specific Tuber layer protein content

Mean crude protein concentration of the tubers in relation to tuber specific layers and nematode load respectively revealed a decrease in protein concentration as plant parasitic nematode load increased. This nematode density pattern was consistent in all the yam species except in the *D.dometorum*;where the the outermost layer contained more crude protein than the inner layers. However, *D. dometorum* had the highest crude protein contentamongst the sampled *Dioscorea* tubers followed by *D.rotundata***,** *D. alata* and *D. cayensis*which partially reflected the PPNsstatus of the different the yam tubers. The relatively highPPNs load of*D. cayensis* and *D. alata* may be responsible for the lower crude protein contentrecorded in the yam species (Table, 5). Thisresult suggests that nematodiasis of the *Diocorea* tubers influencedthe protein concentration of the specific tuber layers where feeding sites were established (Plowright, and Kwoseh, 2000).The establishment of feeding sites by nematodes inplant tissues causesthe release of several stylet borne proteinous secretions(Mitchum *etal*., 2013, Jones, 1981, Williamsom and Kumar,2006, Goellner *etal*., 2001, Sobezak *etal*., 2011). A lot of these proteinsdegenerate the tissue integrity of the plant host in a bid to manipulate the metabolism of the the infected cells especially, amongst the sedentary nematodes species (Barcala *etal*., 2010, Damiani *etal*., 2012, Williamson and Kumar, 2006, and Kaloshian *etal*., 2011). The protein profile of the infected tissues varied from the uninfected sites in the study, due to drastic cellular changes associated with nematodiasis of the tubers (Gheysen and Fenoll, 2002). According to Mitchum *etal*. (2013), some of the cellular changes leading to establishment of feeding sites in plant hosts include; alterations to the nuclei, cytoskeleton, hormone status and metabolism of the selected cell(s), and extenssive changes in cell wall architecture. These alterations are more prevalent in suceptible host's endophytic environments than in resistant ones (Gheysen and Fenoll, 2002; Hammes*etal*., 2005, Jammes*et al.*,2005; Ithal *etal*., 2007, Szakastit *etal*., 2009, Barcala *etal*., 2010, Hofmann *etal*., 2010). Considering the array of activities that accompany establishment of feeding sites by PPNs, Mitchum *etal*.(2013) opined that PPNs effectors should be used as molecular probes to understanding plant cell cycle, cell wall architecture and cellular metabolism, among other processes which this study agrees with.As insigtful as this opinion is, the protein status of *D. dometorum*in this study appeared to be relatively resistant to PPNs infection due to the host specific factors of the yam speciesaccentuated in the progressive increase in the crude protein content of the tuber as nematode load deminished.

4.4 Tuber Layer Specific Nematode Load and Carbohydrate Content (mg/ml)

Carbohydrate composition varied within the specific layers of the yam tubers and across the varieties of yams, however, *D. cayensis* and *D.rotundata* manifested a top-down reduction in carbohydrate concentration (Table 6 and Figure 5). This trend was not observed in *D.alata* and *D. dometurum*where tuber carbohydrate concentrationshowed relatively no top-down depletion.Nematode parasitism was implicated in the general alteration of plant tissues (Hammes*etal*., 2005,Ithal *etal*., 2007, Szakastit *etal*., 2009). Such as degenration of the carbohydrate integrity of the specific layers of tubers.This trend was not obvious in*D.dometorum*which could be attributed to the resistant nature of the yam species to PPNsbuild up in the tuber.The result shows that carbohydrate depriciation in the yam tubers was associated with high PPNsload.

4.5 Tuber Layer Specific Nematode Load and fibre content (g)

The fibre constitution of the specific layers of the yam tubers varied from the outermost to the innermost layer in all yam species. This trend was also replicated in the endophytic nematode load of the layers. The fibre composition of the yam tubers showed variable responses to nematode attack which could be due to host specific factors of the yam varieties.

V. Conclusion

Parasitism by PPNs on *Dioscorea* crops was influenced by both envirnmental and hosts specific factors in the study. PPNsinfection on yam tuber was depth related because the overall PPNsload wasconcentrated at the peripheral regions of the tubers that are closest to the soil environment. The penetrationand migratory competenceof the nematodes were host specific and only aggressively mobile species such as;*Pratylenchus* and *Scutellonema* were found within the deeper layers of the tubers.Total PPNsload of the *Dioscorea* spp.,tubers did not contribute significantly (P<0.05) to the over all crude protein status of the tubers. However, PPNsinfection of the specific layers of the tubers influenced the decline inthe crude protein content of the tubers significantly (P<0.05) in relation to the uninfected portionsof the tubers which was also, observed in the carbohydrate concentration. PPNsinfection influence on the fibre interigrity of the tuberswas tuber depth related. Moisture content of the stored tubers influenced the mobility of nematode juveniles in the tubers. However, *D. dometurum* was relatively resistant to PPNs while*D. cayensis*,*D.alata* and *D.rotundata* were suitable to PPNs infection. The study opines that tuber resident nematodes were trapped in motion as tubers lost moisture conventionally. The study opines that the long shelf live of *Diocorea*spp., tubers makes them reservior hosts of numerous PPNs in the soil thereby making the *Dioscorea* species of crops reliable agents of dispersal of PPNsin the agroecosystem.Pre-planting sterilization of tubers is recommended to curb the transmission and dispersal of PPNs in the agroecosystem.

Conflict of Interest

The research hereby states that there is no conflict of interests in relation to any sections of this study by the authors.

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