DISTRIBUTION AND POPULATION DENSITIES OF PLANT-PARASITIC NEMATODES ASSOCIATED WITH GINGER (*ZINGIBER OFFICINALE*) IN KADUNA STATE, NIGERIA

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ABSTRACT

Ginger (*Zingiber officinale*) is an important cash crop in Nigeria. In spite of the economic importance of plant-parasitic nematodes reported on ginger, little or no information is available as regards plant-parasitic nematodes diversity and abundance on ginger in Nigeria. This work was conducted in 2018 to identify plant-parasitic nematodes associated with ginger in Kaduna state and to determine their population densities. Three Local Government Areas (LGA) were visited and between 12 to 16 ginger farms were sampled per LGA. A total of 42 soil samples was collected at a depth of 0 - 30 cm of the plant rhizosphere. Plant-parasitic nematodes were extracted from the soil using modified sieving and decanting method. Identification to genera level was done using identification keys viewing with dissecting microscope at X40 magnification. Nineteen (19) genera of plant-parasitic nematodes were identified, with 12 genera occurring in all LGA(s). *Scutellonema* (113.33), *Meloidogyne* (110), and *Pratylenchus* (93.33) were the most abundant per 100 ml of soil when locations are combined. Plant-parasitic nematodes population average was 870-950 per 100 ml of soil. All locations showed a high percentage similarity of plant-parasitic nematodes diversity and were statistically similar. This high diversity and population abundance can be among the reasons for the low productivity of ginger in Nigeria. It is therefore important to educate farmers on the economic importance of plant-parasitic nematodes on ginger and its management. Further research using the most occurring genera to establish the threshold population densities capable of causing economic yield loss needs to be conducted.

Keywords: Plant-parasitic nematodes, survey, ginger, genera, rhizosphere.

INTRODUCTION

Ginger (*Zingiber officinale* Roscoe) is among the earliest known rhizomatous spices valued the world over (Sawa, 2017). Though the entire plant is refreshingly aromatic, the underground rhizome is the most useful part of this plant. The rhizome is valued as an important raw material in pharmaceutical, confectionary and beverage industries (Sawa, 2017: Singh and Singh-Dhillon 2015). It is a perennial herb belonging to the family, *Zingiberaceae* but also grown as annual (Fikre and Kifle, 2013). The crop is native to tropical rainforest of Asia. Today, it is grown in over 30 countries of the world (FAOSTAT, 2017) mainly as a cash crop (Mazza, 2015). In Nigeria, ginger is an important cash crop, and Nigeria is among the leading world producers (Ojiako *et al*., 2007) and exporters of this crop (Asumugha, 2002). Research has shown increase in ginger production in Nigeria in the past years (FAO, 2009). Kaduna state remains the country's leading producer where the crop was known to be introduced first in 1927. The crop is mainly grown by predominantly peasant farmers as a cash crop, in places like Jaba, Jama'a, Kachia and Kagarko local Government areas of the state (Nmadu and Marcus, 2013; USAID-NEXTT, 2017). In recent times however, cultivation of ginger has now spread to all the country's geographical zones (Duniya, 2003; Bernard, 2008).

In spite the benefits of this crop and it prospect in Nigeria as an export crop, the production of ginger is significantly affected by biotic and abiotic factors (Abraham *et al.,* 2020). Among the biotic factors, are nematodes (Paret *et al*., 2010; Sharma *et al*., 2010). Nematodes feeds on the rhizomes, roots and base of the pseudo stems. It causes swellings or knots, rot of root, root cracking and deformation etc. In the above ground parts, it causes stunting of the plant, chlorosis and marginal necrosis of leaves. It also causes reduced vigor and tillering and dark brown necrotic lesion. These symptoms are caused not only by a single nematode species but different species of nematodes in a complex. Nematodes also predisposes the rhizome to fungal and bacterial attack through their entry points on the rhizome. As a result of these, about 74% weight of the rhizome can be loss (Meenu and Jeba, 2019). However, research recommendations in Nigeria in the area of pests and diseases of ginger are minimal and reports of pest damage on the crop especially of nematodes related are scanty (Ibedu *et al*., 1990). The objective of this study therefore was to identify the diversity and determine the plant parasitic nematodes population abundance in soils under ginger cultivation in Kaduna state.

MATERIALS AND METHODS

Surveyed locations

Survey was conducted in 2018 rainy season to determine the occurrence and distribution of plant parasitic nematodes associated with ginger (*Zingiber officinale*) in Kaduna State and to determine their population densities. Three Local

Government Areas [LGAs] i.e. Jaba, Kachia and Kagarko (Fig. 1) known to be the leading producers of ginger in the state were selected for the survey. In each LGA, between 12 to 16 farms were selected for the sample collection with the assistance of Agricultural Development Project (ADP) management staff members who aided our linking up with the farmers' for easy access to the farms.
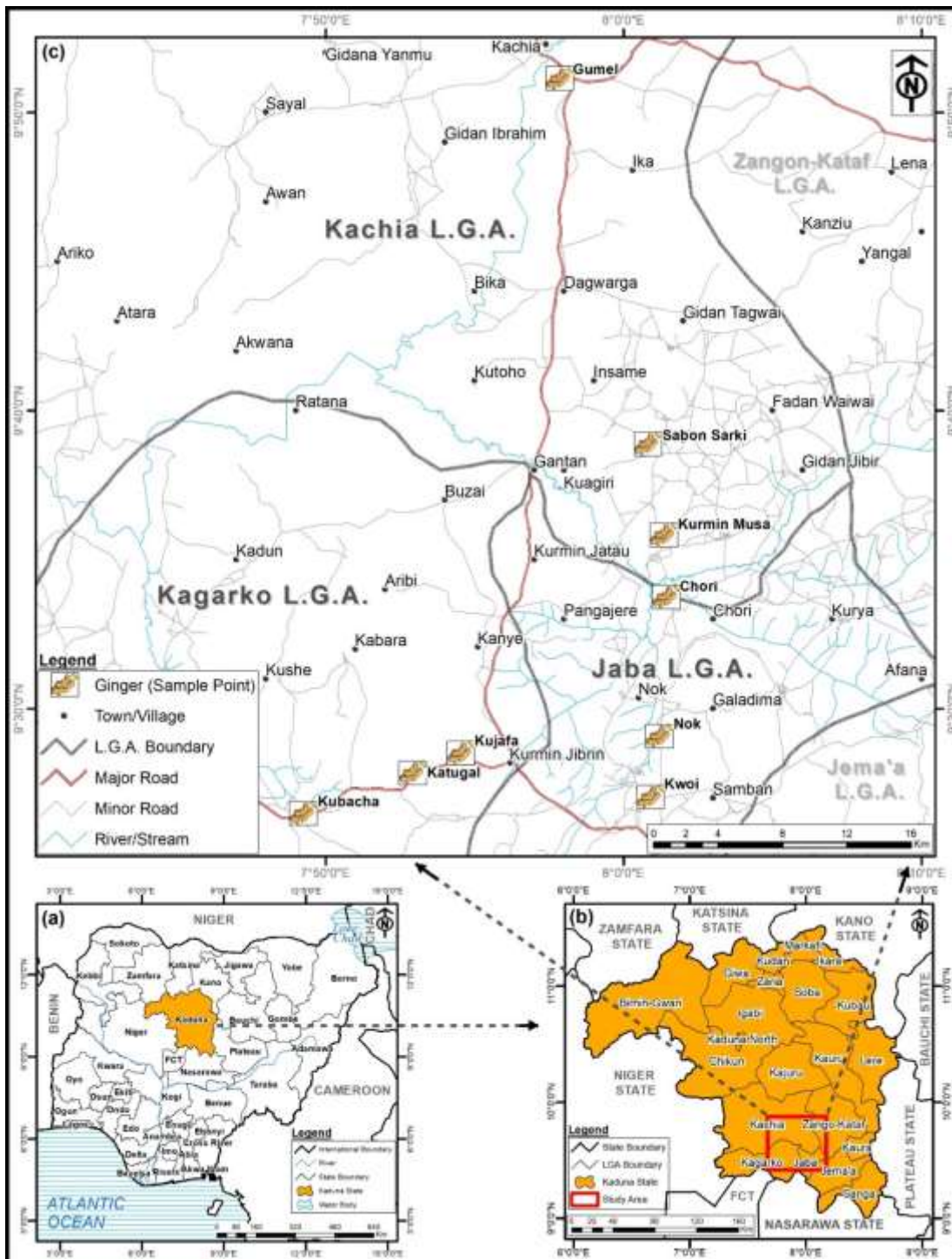

Figure 1: (a) Nigeria showing Kaduna State, (b) Kaduna State showing Kachia, Kagarko and Jaba L.G.As. (Study Area), (c) Study Area showing Sample Points. Source: Fieldwork/Map Gallery, Geography Department, ABU Zaria

Soil sample collection

Sample collected was basically soil from the rhizosphere of the plants with the aid of a soil auger. This was collected at a depth of 0 – 30 cm and within a radius of 25 cm from the base of the plants. Between 12 to 16 selected farms were surveyed in each LGA. Each of the selected farms, ranges from 0.5 to 1 hectre and 35 to 50 soil cores were randomly collected in a zigzag pattern in each farm, bulked per farm to form a composite sample weighing about 1.5 to 2.5 kg. Each of the composite sample was packaged in a polyethylene bag, properly labelled and then transported to Ahmadu Bello University Zaria Nematology laboratory for nematode extraction.

Extraction of nematodes from the Soil Samples

Extraction of the plant-parasitic nematodes from the soil samples was done using the modified sieving and decanting techniques as described by Coyne *et al.* (2007). One hundred millilitres (100 ml) of soil was collected from each of the composite soil sample and poured gently into a fifteen-litre plastic bucket containing five litres of water. These was stirred

Data analysis

The distribution and population density of nematodes were calculated using the formulae of Norton (1989) but with modifications on the percentage similarity as follows:

$$\text{Absolute density (\%)} = \frac{\text{Number of nematodes in all the samples}}{\text{Total number of samples collected}} \times 100$$

$$\text{Absolute Frequency (\%)} = \frac{\text{Number of samples containing nematodes}}{\text{Total number of samples collected}} \times 100$$

$$\text{Percentage Similarity (\%)} = \frac{KS}{a + b + c + \cdots} \times 100$$

Where:

K= Number of comparing locations;

S = Number of nematode genera that the comparing locations have in common;

a, b, c, = Number of nematode genera in each of the comparing locations.

RESULTS AND DISCUSSIONS

The result of this study showed a high diversity of plant-parasitic nematodes associated with ginger in Kaduna state of Nigeria. A total of 19 genera of plant-parasitic nematodes were identified to be associated with ginger in Kaduna state (Table 1) with most of the genera in the order Tylenchida which is the only order in class Chromadoria mostly harbouring the highest diverse plant-parasitic nematodes. However, variation occurs in genera diversity between locations. Kachia recorded 18 genera while Jaba and Kagarko L.G.A(s) recorded 14 genera each (Table 2). This agrees with the works of Thakur and Shamar (2015) who recorded 15 genera of plant parasitic nematodes to be associated with ginger in India. The increase number of genera from this work may be influenced by location, varietal differences and management practices. Twelve (12) genera

thoroughly, then allowed to settle for 30 seconds. Three-quarters of the water was then slowly poured through a set of sieves (with 75μm nested on 45μm). The remaining soil in the bucket was filled with the same volume of water and the initial procedure was repeated.

Nematodes and tiny soil particles trapped by sieves were gently rinsed with water into a labelled beaker which was then poured into a setup of extraction tray containing a double cotton wool filter paper held in place by a clamping ring. These was allowed to stay for 24 hrs. After 24 hours, the filtrate containing nematodes was standardized to 100 ml by adding distilled water using a measuring cylinder. Ten millilitres of the nematode/water suspension was poured into a Doncaster (1962) counting dish for visual identification and counting of the different nematode genera using a dissecting microscope at X40 magnification. Each sample was counted twice and the average recorded. Identification of nematodes to genus level was done using Mai and Mullin (1996).

were identified to occur in all locations (Aphe*lenchus*, *Aphelenchoides*, *Helicotylenchus*, *Hemicycliophora*, *Longidorus*, *Meloidogyne*, *Pratylenchus*, *Rotylenchus*, *Scutellonema*, *Tylenchorhynchus*, *Tylenchus* and *Xiphinema*) which may define their level of importance as relate to ginger cultivation. Earlier report showed 9 genera identified to be important in ginger cultivation (Thakur and Shama, 2015). This variation may also be due to management practice, varietal differences and location. Among the 12 listed nematodes are those classified as threat to world agricultural production causing an estimated yield loss of 80-118 billion dollars annually, these include: *Meloidogyne*, *Pratylenchus*, *Xiphinema* and *Longidorus* (Nicol *et al*., 2011; Sasser and Freckman, 1987; Hodda *et al*., 2012)

Table 1. Generalized classification of the plant-parasitic nematodes identified to be associated with ginger in Kaduna state

Phylum	Class	Order	Family	Genera
Nematoda				
	Chromadorea			
		Tylenchida		
			Aphelenchidae	*Aphelenchus*
			Aphelenchoididae	*Aphelenchoides*
			Belonolaimidae	*Belonolaimus, Tylenchorynchus*
			Criconematidae	*Criconemoides, Hemicycliophora*
			Heteroderidae	*Heterodera*
			Meloidogynidae	*Meloidogyne*
			Paratylenchidae	*Paratylenchus*
			Pratylenchidae	*Pratylenchus*
			Tylenchidae	*Tylenchus*
			Hoplolaimidae	*Hoplolaimus, Helicotylenchus, Rotylenchus, Ditylenchus, Scutellonema*
	Anoplea			
		Dorylaimida		
			Longidoridae	*Longidorus, Xiphinema*
		Triplonchida		
			Trichodoridae	*Trichodoru*

Table 2: Abundance and occurrence of Plant parasitic nematodes associated with ginger in Jaba, Kachia and Kagarko Local Government Areas of Kaduna State, during the field survey

Nematode Genera	Location		
	Jaba	Kachia	Kagarko
Aphelenchus sp.	+	+	+
Aphelenchoides sp.	+	+	+
Belenolaimus sp.	-	+	+
Criconemoides sp	-	+	+
Ditylenchus sp.	-	+	-
Helicotylenchus sp	+	+	+
Hemicycliophora sp.	+	+	+
Heterodera sp.	-	+	-
Hoplolaimus sp	-	+	-
Longidorus sp.	+	+	+
Meloidogyne sp	+	+	+
Paratylenchus sp	+	+	-
Pratylenchus sp	+	+	+
Rotylenchulus sp	+	+	+
Scutelonema sp	+	+	+
Tylenchorhynchus sp.	+	+	+
Tylenchus sp.	+	+	+
Trichodorus sp.	+	-	-
Xiphinema sp	+	+	+
Total	14	18	14

+=detected, - = not detected

Population densities (average) was observed to be relatively high for most of the genera. In Jaba LGA *Scutellonema* (150) had the highest density per 100 ml of soil followed by *Aphelenchus* (120) *Rotylenchus* (110) and *Meloidogyne* species (100). While *Belenolaimus, Criconemoides, Ditylenchus, Hoplolaimus* and *Heterodera* did not record any number (Table 3). In Kachia LGA also *Meloidogyne* (130) had the highest number, followed by *Rotylenchus* (100) and *Hoplolaimus* (80) while *Trichodoru* had zero (Table 3). Kagarko LGA shows *Pratylenchus* (170) recording the highest number followed by *Scutellonema* (150) and *Meloidogyne* (100) (Table 3). When all

locations are combined, *Scutellonema* (113.33) recorded the highest density followed by *Meloidogyne* (110) and *Pratylenchus* (93.33). Earlier reports by Kaur and Sharma (1988), Makhnotra (1994) and Thakur and Shamar (2015) reported the *Pratylenchus* and *Meloidgyne* to be highest in terms of frequency of occurrence and population densities in fields under ginger cultivation. *Ditylenchus* (3.33), *Belenolaimus* (13.33) and *Heterodera* (13.33) recorded the lowest densities. Though Kachia LGA had the highest diversity of genera (19) (Table 2), it also gave the lowest population density (870) of genera per 100 ml of soil. But the overall

average density per 100 ml of soil for all location is 916.66 (Table 3).

The frequency of occurrence also indicated *Scutellonema and Aphelenchoides* to be the most occurring genera in Jaba LGA, which is significantly higher than all species except *Rotylenchus*, (Fig. 2). In Kachia LGA however, *Meloidogyne* species was the most occurring genus and was significantly higher than all species (Fig. 3). Kagarko LGA showed *Scutellonema* and *Pratylenchus* to be the most occurring genera and were statistically similar, but significantly higher than all genera (Fig. 4). *Meloidogyne* species however was significantly higher among the remaining genera. Bulus *et al.* (2017); Abdulsalam *et al*. (2017); Jibrin *et al*. (2013) reported *Scutellonema, Pratylenchus* and *Meloidogyne* species among the frequently encountered genera in soils of northern Nigeria under different crop cultivation. Thakur and Shamar (2015) also listed *Meloidogyne* among the most occurring nematodes under ginger cultivation. Also Koshy *et al.* (2005) reported *Meloidogyne* as the most economically important nematode in ginger production. *Meloidogyne* species is economically important because it causes gall formation and root rots of the underground rhizomes (Okorocha *et al*., 2014).

Percentage similarities indicates that when two locations are compared, Kachia and Kagarko LGA(s) gave the highest percent similarities but was not significantly higher than when Jaba is compared with Kachia and Jaba compared to Kagarko (Fig. 5). However, when the three locations were compared together, it recorded a significantly lower percent similarity than any two locations compared (Fig. 5).

Longidorus and *Xiphinema* are known to be virus vectors, their occurrence in high number may be associated with some viruses affecting ginger in the region. Abraham *et al*. (2020) reported the occurrence of an important virus disease associated with ginger in Kaduna state. This means, further studies may reveal other viruses likely to be vectored by nematodes.

Table 3 : Average Population densities of the plant-parasitic nematodes association with ginger in the surveyed Local Government Area(s)

| Population/100 ml of soil				
Location	Jaba	Kachia	Kagarko	All locations
Plant parasitic Nem.	N=12	N=16	N14	N=42
Aphelenchus sp.	120	60	70	83.33
Aphenlenchoides sp.	60	40	30	43.33
Belenolaimus sp.	-	10	30	13.33
Criconemoides sp	-	40	70	36.67
Ditylenchus sp.	-	10	-	3.33
Helicotylenchus sp	60	30	60	50
Hemicycliophora sp.	40	70	30	46.67
Heterodera sp.	-	40	-	13.33
Hoplolaimus sp	-	80	-	26.67
Longidorus sp.	20	30	20	23.33
Meloidogyne sp	100	130	100	110
Paratylenchus sp	60	20	-	26.67
Pratylenchus sp	80	30	170	93.33
Rotylenchulus sp	110	100	60	90
Scutelonema sp	150	40	150	113.33
Tylenchorhynchus sp.	30	60	30	40
Tylenchus sp.	40	30	50	40
Trichodorus sp.	20	-	-	6.67
Xiphinema sp	60	50	50	53.33
Total	950	870	930	916.66

Where N= number of samples collected
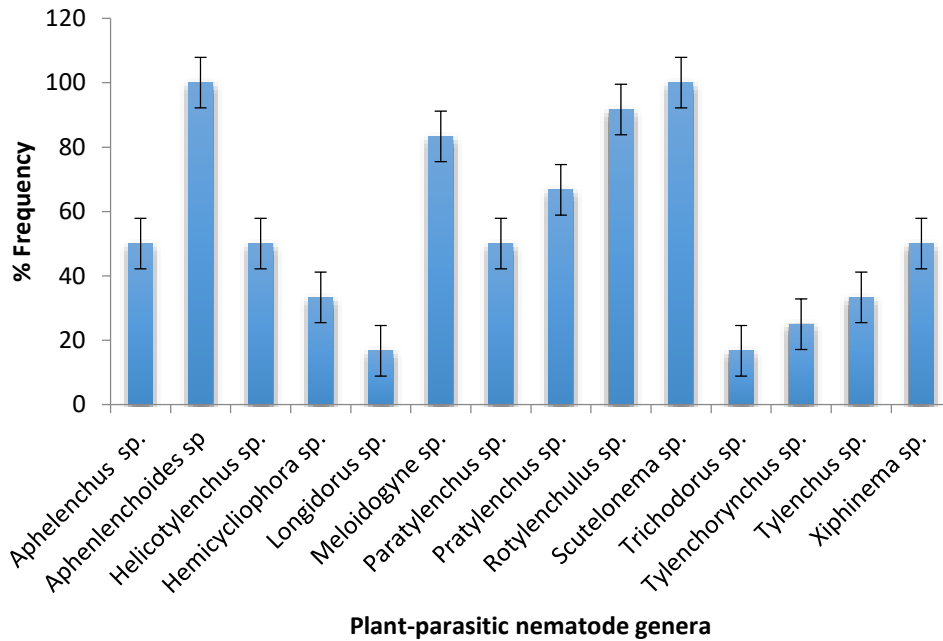
Sample size (N) = 12

Fig. 2: Frequency rating of plant-parasitic nematode genera associated with ginger in Jaba LGA of Kaduna State, Nigeria during the field survey in 2018. Bars indicate standard error of means at 5% probability level.
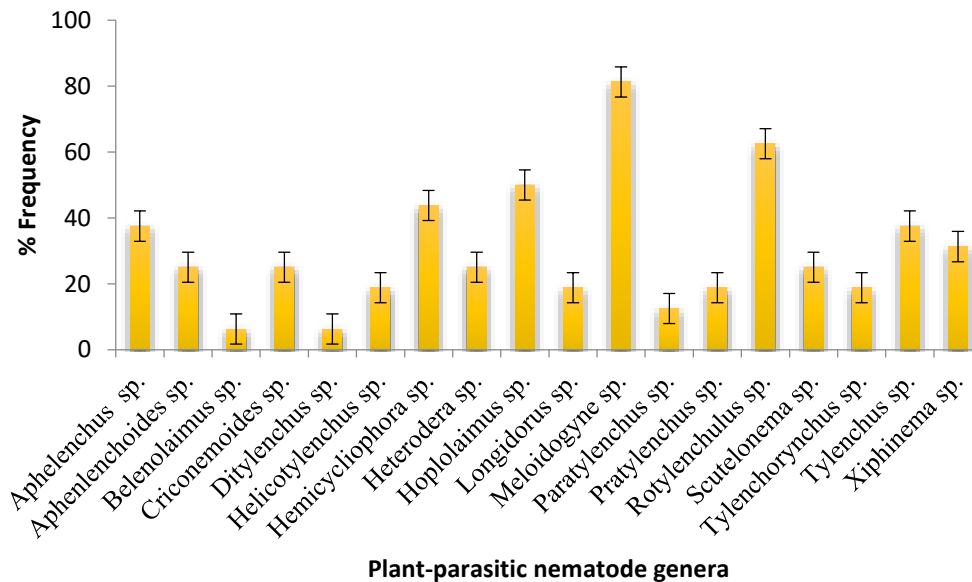
Sample size (N) = 16

Fig. 3: Frequency rating of plant-parasitic nematode genera associated with ginger in Kachia LGA of Kaduna State, Nigeria during the field survey in 2018. Bars indicate standard error of means at 5% probability level.
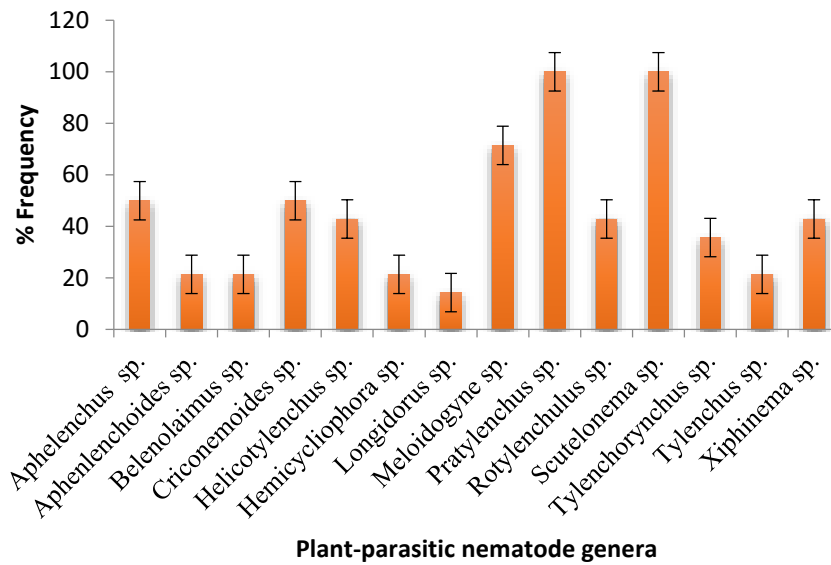
Sample size (N) = 14

Fig. 4: Frequency rating of plant-parasitic nematode genera associated with ginger in Kagarko LGA of Kaduna State, Nigeria during the field survey in 2018. Bars indicate standard error of means at 5% probability level.
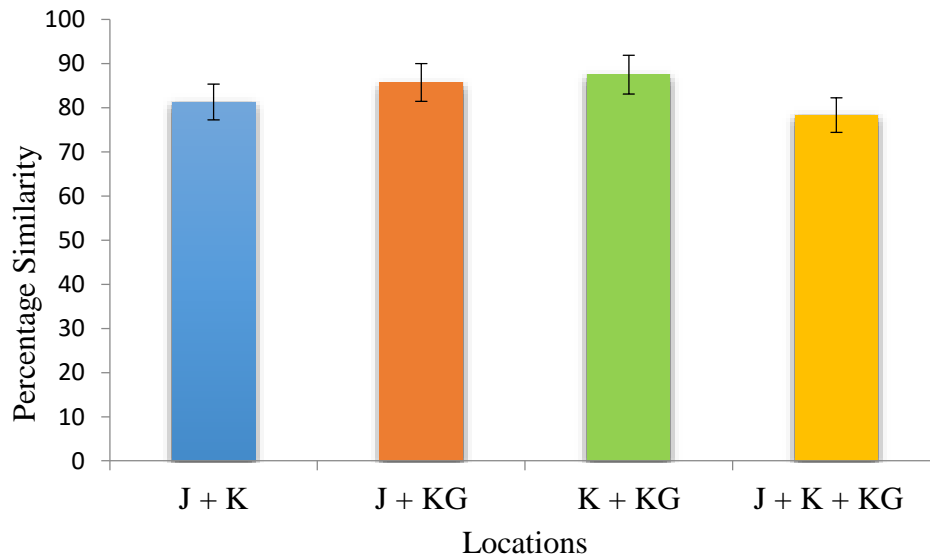

Fig. 5: Similarity (%) of Plant-parasitic nematodes genera recovered among ginger fields in Jaba (J), Kachia (K) and Kagarko (KG) LGAs of Kaduna State. Bars indicates standard error of means at 5% probability level.

CONCLUSION

This finding reveals high diversity of plant-parasitic nematodes associated with ginger in Kaduna state. Perhaps this is a key factor resulting to low yield of ginger in the region, since plant-parasitic nematodes causes damage to crops directly and in a complex with other pathogens. To the best of our knowledge, this is the first report of the diversity of plant-parasitic nematodes associated with ginger and first report of *Scutellonema* sp occurring in high number under ginger cultivation in Nigeria. Further research should focus on the most occurring genera to establish the population thresholds capable of causing economic yield loss. Awareness on nematodes problems and management should also be created among farmers.

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Conflict of interest

Authors whose names are listed in this paper hereby certify that they have no conflict of interest.

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