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Spatial distribution and community analysis of plant-parasitic nematodes associated with rice (*Oryza sativa* L.) in Benue State, Nigeria

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Abstract
Plant-parasitic nematodes (PPNs), also known as phyto-parasitic or plant-destructive nematodes are microscopic, translucent, bilaterally symmetrical, pseudocoelomic, multicellular worm-like organisms which feed on plant root mostly, and seldom on other vegetative parts. Although these PPNs have been reported to constitute threat to rice production, documentation of their spatial distribution and densities in major rice-producing areas of Benue state, Nigeria is absent. Using multi-stage sampling procedure, surveillance for PPNs, their densities and community analyses were conducted in six major rice-producing local government areas (LGAs) of Benue. The LGAs included Agatu, Apa, Gwer West, Guma, Kwande and Makurdi LGAs and a total of 108 samples were collected comprising 54 soil and 54 root samples. Nine plant-parasitic nematode genera which included Criconemoides, Tylenchorhynchus, Trichodorus, Hirschmanniella, Xiphinema, Helicotylenchus, Scutellonema, Pratylenchus and Meloidogyne were recovered. In order of ranking, *Meloidogyne* sp., *P. zeae* and *H. oryzeae* had the highest population densities across all LGAs included in the study. The highest density of PPN was recorded in Kwande (ca. 133 PPNs/10mL of nematode suspension) while lowest population density was recorded in Makurdi (ca. 77 PPNs/10mL of suspension). Although *Meloidogyne* sp. recorded the highest average population density in all LGA except in Gwer West LGA where *H. oryzae* recorded the highest average population density of approximately 13 PPNs/10mL of suspension. Community analysis also revealed that *Meloidogyne* sp. was the most spatially distributed PPN closely followed by *P. zeae* and *H. oryzae* with prominence values of 37.78, 21.84 and 20.91, respectively. However, in the soil, the highest prominence value was recorded in *H. oryzae* making it the most spatially distributed PPN in the soil.

Keywords: Nematodes, parasitism, rice, surveillance, benue

Introduction

Rice belongs to the order Poales and the grass family Poaceae [1]. *Oryza sativa* and *Oryza glaberrima* are the known two species of rice, for which the former is cultivated throughout the world while the latter is grown partially in western part of Africa [1]. Rice (*Oryza sativa* L.) has overtime become one of the most important staple crops grown in the world. In fact, it is the third most grown cereal worldwide after maize and wheat; with China, India and Indonesia as the current leading producers [2]. Although world rice production in 2019 was 850,302,164 tonnes, it is estimated that rice production will increase by 114 million tons by 2035 [3]. In Africa, Nigeria is currently the second highest rice-producing country with an estimated production statistic of 4.5 million tonnes after Egypt [3]. Although the crop is grown all over Nigeria, some selected states have immensely increased its production as a result of the federal government of Nigeria's anchor borrower's scheme.

The 2021 first quatre report of Nigeria Guide – an agrarian outfit community, Kebbi, Benue, Ebonyi, Ekiti, Jigawa, Kaduna, Kano, Ogun, Niger and Cross River are the top 10 rice-producing states in Nigeria. and within consumed across all socioeconomic classes. The grains of the crop are commonly boiled and eaten with sauce, stew, vegetable soup or used to prepare a popular Nigerian delicacy called "jollof rice". In some instances, the grains are used to make pap or fermented to produce local gin. Rice husk, an abundant by-product of paddy, finds wide industrial application aside from its conventional use as energy source. It can be processed into rice husk board, fertilizer, bricks, briquettes, charcoal, cement, etc. [4]. Although a number of challenges have beleaguered rice production in Nigeria, the activities of pests and diseases are malign and result in either low yield or poor grain quality [5, 6].

Of these pestiferous activities are those of plant-parasitic nematodes. Plant-parasitic nematodes (PPNs), also known as phyto-parasitic or plant-destructive nematodes are microscopic, translucent, bilaterally symmetrical, pseudocoelomic, multicellular worm-like organisms which feed on plant root mostly, and seldom on other vegetative parts. These PPNs can be sedentary or mobile has they carry out their parasitic activities [7]. They feed on cell sap of their host during the course of their parasitism. About 4,300 species of PPNs have been documented and this account for 7% of the phylum Nematoda [8]. Plant parasite nematode are largely recognized by the presence of a stylet and sub-ventral and dorsal esophagous glands which plays significant role in evolutionary adaptations for plant parasitism [9]. Plant destructive nematodes constitute a major challenge to food security at large [10].

The damaging activities of these parasitic nematodes on rice have long been reported. Fortuner [11] stated that yield loss in an adequately fertilized soil declined by 23% as a result of the damaging effects of *Hirschmaniella oryzae*. Veech [12] stated that economic losses linked to phyto-parasitic nematodes attack on rice was in the range of 18% to 25%. Up to 80%. Yield losses caused by *Meloidogyne graminicola* have been reported in various climes of the world [13]. Pratylenchus brachyurus have also been reported to reduce rice yield [14]. Although over 4,100 species of plant nematodes have been identified, new species are continually being described while others, previously viewed as non-damaging are becoming pests as cropping patterns changes [15, 16]. Despite the damages and economic implications of PPNs, there are no empirical data of their spread and distribution on rice fields in Benue state. Promulgation of sustainable policies and effective management frameworks are hinged on the availability of reference point data. Such data should provide current statuses of the pest of interest in time and space. It is against this background that this study was conducted to establish for the first time, a baseline surveillance of PPNs distribution and spread in the major rice-growing local government areas of Benue state.

Materials and methods

Description of Survey Areas and sample collection

The survey was conducted in six (6) rice-producing local government areas (LGAs) of Benue State which were selected based on a purposive sampling information [from preliminary documentations on rice by Benue State Agricultural and Rural Development Authority (BNARDA)]. All the selected areas have been under rice cultivation for several years and majority of the farmers in the survey areas were involved directly or indirectly in subsistence agriculture characterized by small farm holdings with an average farm size of 1.5 – 2.0 hectares. From each location, six (6) samples comprising three soil and three root samples were randomly collected from three (3) different rice fields in each community in the six (6) local government areas (LGAs) of Benue State included in the study. The LGAs were Agatu, Apa, Gwer West, Guma, Kwande and Makurdi. A total of 200 g of soil sample each time, was taken at a depth of 5 – 20 cm from the rhizosphere while root sample was also taken from sampled plant. A total of 108 samples were collected comprising 54 soil and 54 root samples. Georeference points of each field where samples were collected was done using an offline Universal Transverse Mercator (UTM) Geomap Global Information System (GIS) (Table 1). Soil and root samples once collected, were kept inside well-labelled translucent cellophane bags and stored in a mobile cooler so as to prevent nematode desiccation due to overheating. Samples were then taken to the laboratory of the Department of Crop and Environmental Protection, Federal University of Agriculture Makurdi, where nematodes were extracted from the soil using modified Baermans Tray method.

Nematode Extraction and Identification

Extraction of nematode was done using the modified Cobb's decanting and sieving method [17]. A precision weighing scale was used to weigh 250g of composite sample collected from the three random soil samples in each farm. Soil was drenched in water, gently stirred for 2 minutes, and then decanted with duplicate passes over a series of sieves in the order of 600, 250, 150, 75, and 44-µm pores. Nematodes and soil debris caught on the sieves were backwashed into a metal basin and poured onto a cotton filter suspended above a collecting tray. After 48 hours, the cotton filter was removed and nematodes in the water beneath the filter were collected and settled into 100-mL bottles. Nematodes were counted from 10 mL of a well-mixed 100 mL solution. For the root samples, a subsample of 10 g roots was washed, chopped into 1 to 2 cm pieces and ground for 1 to 2 minutes using a blender and nematodes were extracted using the above-mentioned technique. Three subsamples with equal volume (10 mL) were counted three times, and the average was used to estimate the PPNs prevalence and densities.

Table 1: Georeference positions of locations in Benue state where samples were obtained from for the study

LGA	Community	Designated Farm	Latitude (°N→)	Longitude (°E→)	LGA	Community	Designated Farm	Latitude (°N→)	Longitude (°E→)
Kwande					Agatu	Usha	Farm 1	7.9201	7.8290
	Ikyogen	Farm 1	6.6892	9.3938		Usha	Farm 2	7.9289	7.8288
	Ikyogen	Farm 2	6.6888	9.3939		Usha	Farm 3	7.9288	7.8288
	Ikyogen	Farm 3	6.6889	9.3949		Oshigudu	Farm 1	7.8364	7.8652
	Jato Aka	Farm 1	6.8950	9.4916		Oshigudu	Farm 2	7.8364	7.8651
	Jato Aka	Farm 2	6.8976	9.4852		Oshigudu	Farm 3	7.8468	7.8567
	Jato Aka	Farm 3	6.8167	9.4717					
	Adikpo	Farm 1	6.8890	9.2435	Apa				
	Adikpo	Farm 2	6.8842	9.2548		Angwa	Farm 1	7.6308	7.8794
	Adikpo	Farm 3	6.8805	9.2682		Angwa	Farm 2	7.6363	7.8855
Gwer West						Angwa	Farm 3	7.6317	7.8782
						Ugbokpo	Farm 1	7.6825	7.8835
	Naka	Farm 1	7.5698	8.1804		Ugbokpo	Farm 2	7.6825	7.8835
	Naka	Farm 2	7.5708	8.1825		Ugbokpo	Farm 3	7.6832	7.8834

	Naka	Farm 3	7.5723	8.1855		Olojo	Farm 1	7.6980	7.8856
	Adikpo	Farm 1	7.5365	8.1952		Olojo	Farm 2	7.6973	7.8854
	Adikpo	Farm 2	7.5377	8.1955		Olojo	Farm 3	7.6980	7.8858
	Adikpo	Farm 3	7.5449	8.1965					
	Unande	Farm 1	7.5633	8.1702	Guma				
	Unande	Farm 2	7.5652	8.1704		Daudu	Farm 1	7.9705	8.6105
	Unande	Farm 3	7.5648	8.1691		Daudu	Farm 2	7.9665	8.6102
Agatu						Daudu	Farm 3	7.9666	8.6083
						Iye	Farm 1	7.9658	8.6065
	Weato	Farm 1	7.9560	7.8238		Iye	Farm 2	7.9654	8.6061
	Weato	Farm 2	7.9566	7.8237		Iye	Farm 3	7.9656	8.6059
	Weato	Farm 3	7.9288	7.8287		Uikpam	Farm 1	7.9598	8.6165
						Uikpam	Farm 2	7.9602	8.6159
						Uikpam	Farm 3	7.9666	8.6083

Table 1 Contd: Georeference positions of locations in Benue state where samples were obtained from for the study

LGA	Community	Designated Farm	Latitude (°N→)	Longitude (°E→)
Makurdi				
	Antsa	Farm 1	7.7680	8.5870
	Antsa	Farm 2	7.7670	8.5835
	Antsa	Farm 3	7.7676	8.5827
	Ikpam	Farm 1	7.7486	8.5716
	Ikpam	Farm 2	7.7513	8.5718
	Ikpam	Farm 3	7.7541	8.5712
	Tse-Ichwa	Farm 1	7.7619	8.5687
	Tse-Ichwa	Farm 2	7.7595	8.5680
	Tse-Ichwa	Farm 3	7.7633	8.5667

Plant-parasitic nematodes were identified to genus level in a count plate under a binocular microscope. Identification of nematode genera in frequent aliquots (10 mL/each) in each soil and root sample was depended on the morphological characters of the plant-parasitic nematode forms according to Mai and Lyon [18].

The Hawksely counting slide was used for determining the number of each nematode genus was recorded and where possible, to species level.

Data Analysis

Descriptive statistics was used to obtain mean values of nematode density. Bar charts were plotted using Microsoft Excel 2019. Community analysis of phyto-parasitic nematodes associated with rice fields in Benue State was done using Norton techniques [19] and spatial maps were generated using ARCGIS 10.2 software.

$$\text{Absolute Frequency (AF)} = \frac{Number of sample of a genus}{Number of sample collected} \times 100$$

$$\text{Relative Frequency (RF)} = \frac{Frequency of a genus}{Sum of frequency of genera} \times 100$$

$$\text{Absolute Density (AD)} = \frac{Average population density nematode}{100 ml soil}$$

$$\text{Relative Density (RD)} = \frac{Average Number of individual genus}{Number of all nematode genera} \times 100$$

Prominence Value (PV) = Absolute density × Square root of Absolute Frequency

$$\text{Relative Prominence Value (RPV)} = \frac{PV of genus}{sum of PVs of all genera} \times 100$$

Results

A total of nine plant-parasitic nematode genera which included Criconemoides, Tylenchorhynchus, Trichodorus, Hirshmaniella, Xiphinema, Helicotylenchus, Scutellonema, Pratylenchus and Meloidogyne were recovered from surveyed rice fields in Benue State (Figure 1). Two species of Helicotylenchus – *H. dihystera* and *H. multicinctus* were recovered in addition to other species from the other nematode genera. Although the plant-parasitic nematodes were found to be variably distributed on different farms, a similar trend of their occurrences was observed as it related to the prevalence of *Meloidogyne* sp., *Pratylenchus zeae* and *Hirschmaniella oryzeae*. Figures 1A-1F showed that *Meloidogyne* sp., *P. zeae* and *H. oryzeae* had the highest population densities across all the local government areas (LGAs) included in the study. In Agatu LGA (Fig. 1A) *Meloidogyne* sp. Had the highest population average densities of 15.67 PPNs/10 mL of nematode suspension, 11 PPNs/10 mL of nematode suspension and 15.33 PPNs/10 mL of nematode suspension in Weato, Usha and Oshigudu farms, respectively. *Pratylenchus zeae* with average population densities of 7.33 PPNs/10 mL of nematode suspension, 3.67 PPNs/10 mL of nematode suspension and 7 PPNs/10 mL of nematode suspension in Weato, Usha and Oshingudu, respectively was closely followed by the high populations of *Meloidogyne* sp. in rice farms in Agatu. *Hirshmanniella oryzeae* was also found and came third in the ranking of plant-parasitic nematodes with relatively high population densities in the farms surveyed.

Similar trends were observed in Figures 1B, 1C, 1D, 1E and 1F although with different population density values and distribution of the nematodes at farm levels. As shown in the Figures Tylenchorhynchus, Trichodorus and *H. dishystera* had the least population densities at farm levels. In some farms these nematodes were not even recovered. For example, *Tylenchorhynchus* sp. was not recovered from Oshigudu, Agatu LGA (Fig 1A), Uikpan, Guma LGA (Fig. 1C), Atukpo, Gwer West (Fig. 1D), Ikyogen, Kwande LGA (Fig. 1E) and in Ikpan, Makurdi LGA (Fig. 1F). Furthermore, even where *Tylenchoryhnchus* sp. did occurred, its average population density was between 1 – 0.33 PPN/10mL nematode suspension. *Trichodorus* sp. was not recovered from Ugbokpo and Olojo, Apa LGA (Fig. 1B), Uikpa, Guma LGA (Fig. 1C), Naka, Gwer West LGA (Fig. 1D) and Ikyogen and Jato-Aka, Kwande LGA (Fig.

1E), Unande, Gwer West LGA (Fig. 1D), and in Ikpam and Antsa, Makurdi LGA (Fig. 1F). Where *H. dihystera* was found its average density was in the range of 0.33 to 0.66 PPN/10 mL of nematode suspension.

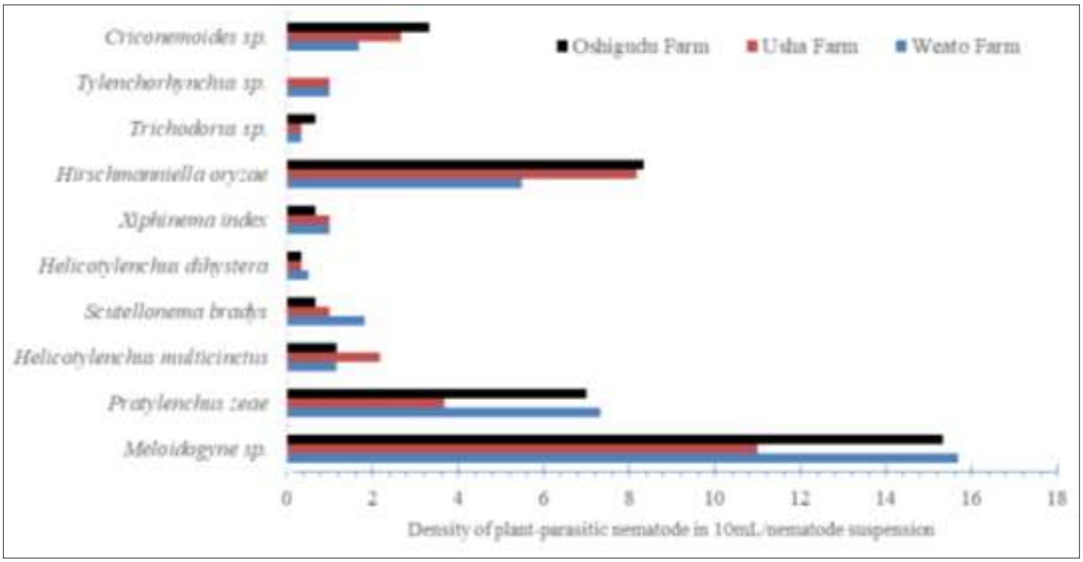

Fig 1A: Agatu LGA

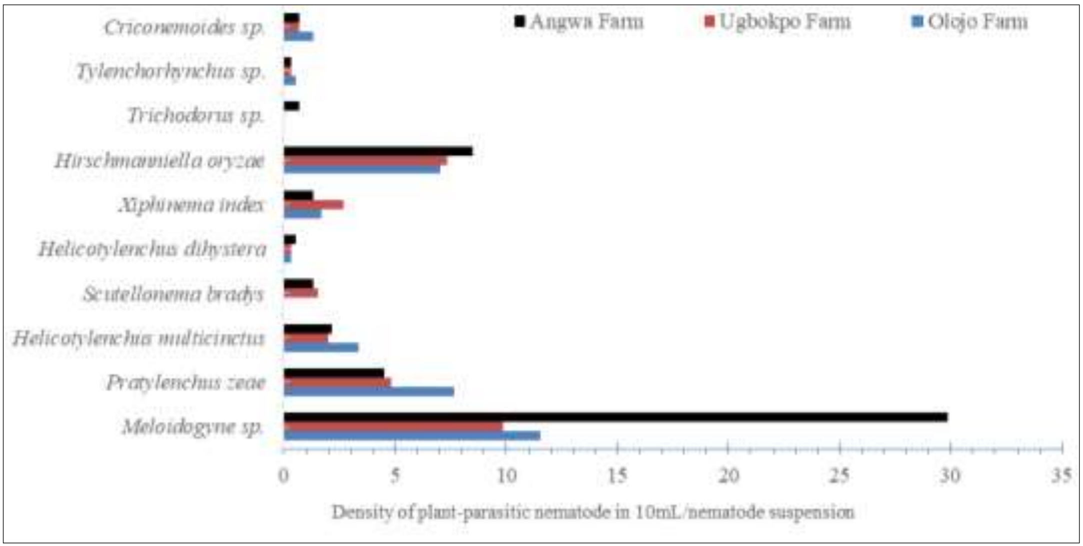

Fig 1B: Apa LGA

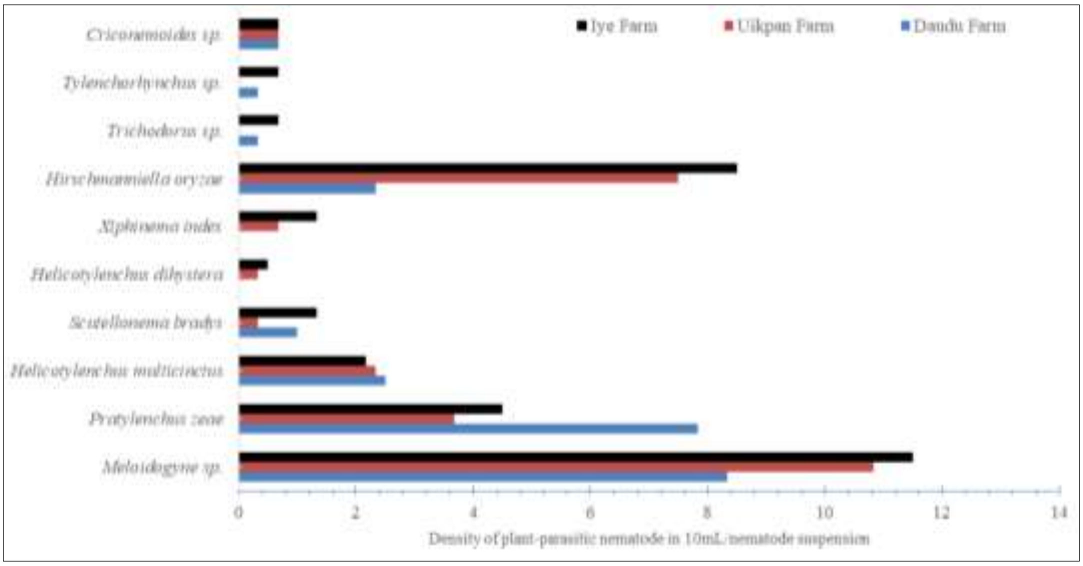

Fig 1C: Guma LGA

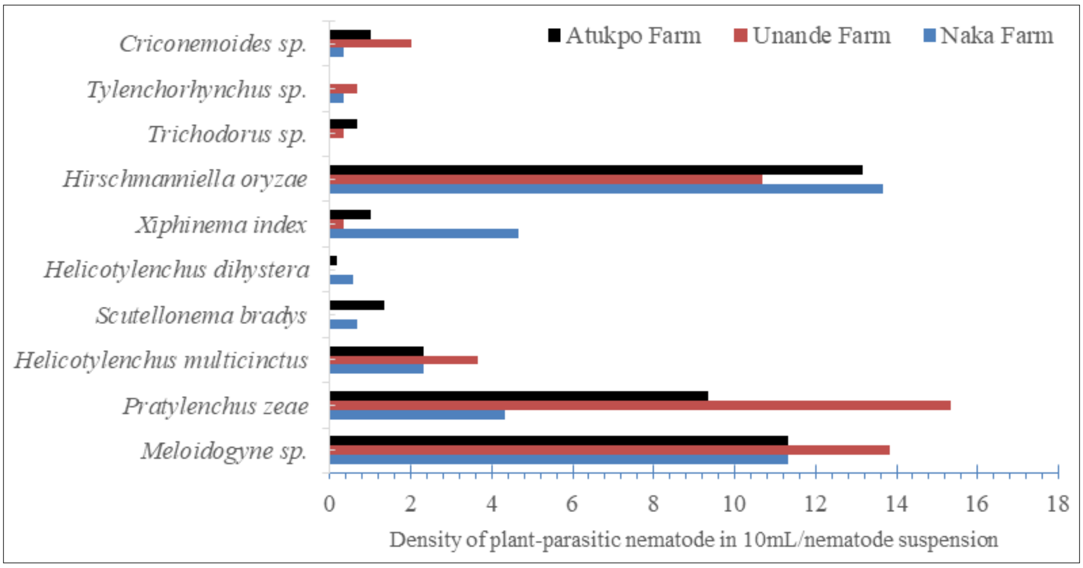

Fig 1D: Gwer West LGA

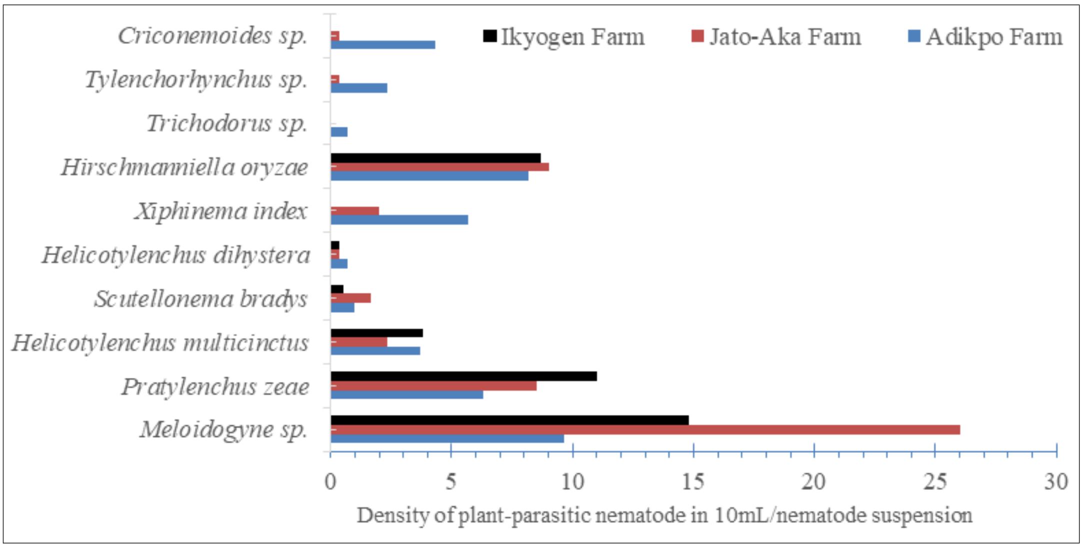

Fig 1E: Kwande LGA

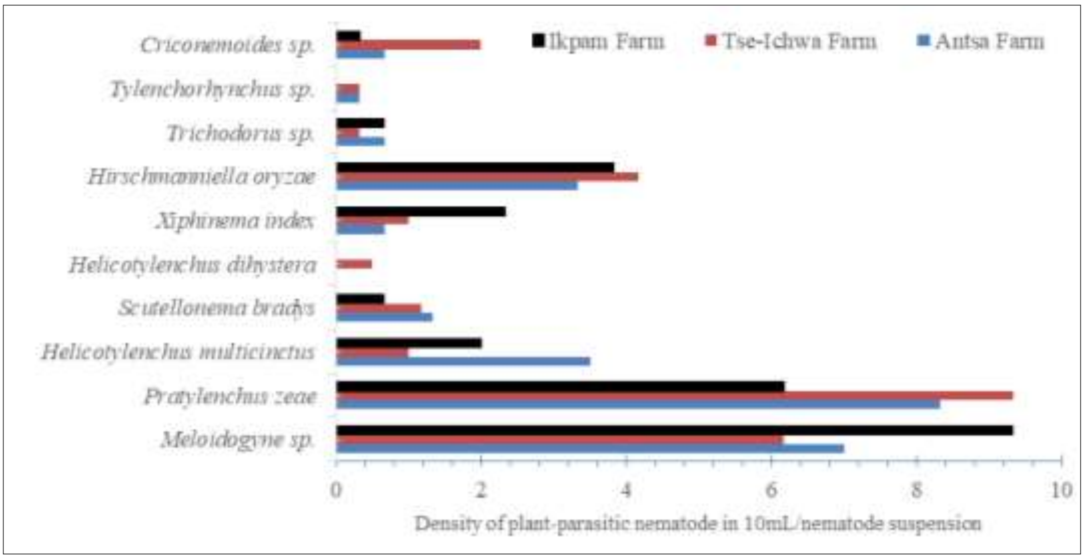

Fig 1F: Makurdi LGA

Fig 1: Plant-parasitic nematodes recovered from some rice fields in six local government areas of Benue State, Nigeria. Block A = Agatu LGA; Block B = Apa LGA; Block C = Guma LGA; Block D = Gwer West; Block E = Kwande; Block F = Makurdi LGA

Samples obtained from Kwande LGA rice fields had a population density of approximately 133 PPNs/10 mL of nematode suspension (Fig. 2). This represented the highest number of PPNs recorded from the six LGAs included in the study. The lowest population density was recorded in Makurdi (approximately 77 PPNs/10 mL of nematode suspension). The average values of population densities of PPNs as presented in Fig. 2 also showed variations in the population densities of each PPN across the LGAs included in the study. Although *Meloidogyne* sp. recorded the highest average population density in all LGA except in Gwer West LGA where *Hirschmaniella oryzae* recorded the highest average population density of approximately 13 nematodes/ 10mL of nematode suspension.

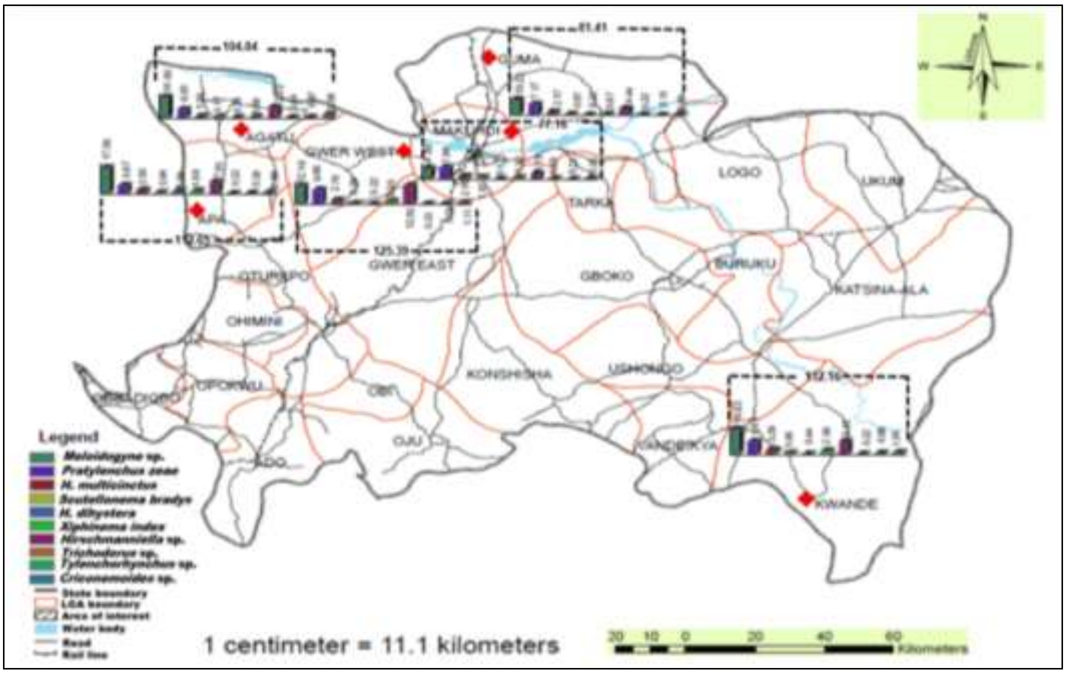

Fig 2: Map of Benue state showing total densities (broken lines) and average populations (charts) of PPNs encountered in the study areas.

Community analysis of the plant-parasitic nematodes recovered as shown on Table 2 revealed that *Meloidogyne* sp. was the most prevalent PPN recovered from the roots of rice plants surveyed. *Meloidogyne* sp. had the highest absolute frequency (18.26), absolute density (7.67) and prominence value (37.78). This implied that *Meloidogyne* sp. occurred the most in the roots and was the most distributed of all the nematodes recovered from the roots of rice in the surveyed areas. It was closely followed by *Pratylenchus zeae* and *H. oryzae* with prominence values of 21.84 and 20.91, respectively. The least spread plant-parasitic nematode recovered from the roots rice in the study was *Helicotylenchus dihystera* with prominence value of 0.14. With respect to the soil, *Hirschmaniella oryzae* was found to have the highest absolute frequency (92.59), absolute density (11.39) and prominence value (109.6). *H. oryzae* was the most frequent and widely spread nematode in the soil across rice fields in the surveyed areas. It was closely followed by *P. zeae* and *Meloidogyne* sp. which had prominence values of 91.45 and 69.23, respectively.

Table 2: Community analysis of the plant-parasitic nematodes recovered

Species	No. of samples	Positive samples	AF	RF	AD	RD	PV	Rel. PV
Root								
Meloidogyne sp.	54	44	18.26	61.59	7.67	22.52	32.78	40.44
Pratylenchus zeae	54	48	5.07	17.10	9.7	28.48	21.84	26.95
Helicotylenchus multicinctus	54	38	1.94	6.54	3	8.81	4.18	5.16
Scutellonema bradys	54	35	0.46	1.55	1.43	4.20	0.97	1.20
Helicotylenchus dihystera	54	19	0.07	0.24	0.54	1.59	0.14	0.18
Hirschmaniella oryzaea	54	50	3.37	11.37	11.39	33.44	20.91	25.80
Tylenchorhynchus sp.	54	16	0.48	1.62	0.33	0.97	0.23	0.28
Rhizosphere								
Meloidogyne sp.	54	44	81.48	14.72	7.67	20.76	69.23	20.89
Pratylenchus zeae	54	48	88.89	16.05	9.7	26.25	91.45	27.59
Helicotylenchus multicinctus	54	38	70.37	12.71	3	8.12	25.17	7.59
Scutellonema bradys	54	35	64.81	11.71	1.43	3.87	11.51	3.47
Helicotylenchus dihystera	54	19	35.19	6.35	0.54	1.46	3.2	0.97
Xiphinema index	54	25	46.3	8.36	1.56	4.22	10.61	3.2
Hirschmaniella oryzaea	54	50	92.59	16.72	11.39	30.83	109.6	33.07
Trichodorus sp.	54	16	29.63	5.35	0.33	0.89	1.8	0.54
Criconemoides sp.	54	24	44.44	8.027	1.33	3.6	8.87	2.68

AF= Absolute frequency; RF = Relative frequency; AD = Absolute density; RD = Relative density; PV = Prominence value; Rel. PV = Relative prominence value

Discussion

Plant-parasitic nematodes (PPNs) are notorious for their destructive activities on a wide range of crops of socio-economic importance. Even with the fight against hunger especially in sub-Saharan Africa, little attention has been given to the damaging impacts of PPNs. This has left most farmers, especially smallholder farmers to their fate as crop yields are mostly suboptimal. Moreover, documented surveillance reports on associated plant-parasitic nematodes to these crops could have implications on their yield as well as in the design of regulatory policies and implementation. Rice as a staple crop of immense economic importance in Nigeria is not left out of this parasitic quagmire occasioned by PPNs.

The current study has revealed that though variably distributed, nine parasitic nematode genera were recovered from rice farms surveyed in the major rice-producing local government areas of Benue state. The presence of *Meloidogyne* sp., *Pratylenchus zeae*, *Helicotylenchus dihystera*, *Helicotylenchus multicinctus, Hirschmaniella oryzae, Scutellonema bradys, Tylenchorhynchus sp., Xiphinema index*, *Trichodorus* sp. and *Criconemoides* sp. Signal additional threat to rice production in the state. Each farm possessed its own characteristics community of plant-parasitic nematodes, with divergent population densities. In a similar study conducted in Akwa Ibom State, Nigeria, Udo *et al*. [20] revealed that only three nematode genera including Heterodera, Hirschmanniella and Meloidogyne were detected on rice farms. With 12 plant-parasitic nematodes genera recorded across the different rice production sites sampled, the present research identified in addition 6 plant parasitic nematode genera, namely *Meloidogyne graminicola*, *Hirschmaniella oryzae, Pratylenchus* spp., *Helicotylenchus* spp., *Criconemoides* spp. and *Tylenchorhynchus* spp. were reported as being associated with rice production in Ecuador [21].

In Togo Gnamkoulamba [22] documented twelve plant-parasitic nematode genera which included Hirschmanniella, Meloidogyne, Xiphinema, Scutellonema, Helicotylenchus, Heterodera, Criconema, Pratylenchus Trichodorus and Tylenchid. It is noteworthy to observe that even within farms in the local government areas where the current study was conducted, differences were observed in the composition of plant-parasitic nematodes associated with rice farms. These differences may be due to geographical, weather and edaphic disparities, among other possible factors. As opined by numerous authors, the prevalence and average densities of nematode genera vary with ecological variations [22, 23, 24, 25, 26, 27].

Using community analyses and based on the prominence values, the study has also showed that *Meloidogyne* sp. was the most spatially spread plant-parasitic nematode within the roots of rice while *Hirschmaniella* sp., was the most spread PPN within the rhizosphere of rice fields in the study areas. Previous studies have shown that these two genera of plant-parasitic nematodes are well-adapted to flooded conditions with potent ability for yield reduction [28, 29]. *Meloidogyne* spp. cause problems in all types of rice agrosystems [30]. In a pathogenicity experiment conducted by Jaiwal *et al*. [31], evidence was provided of the damaging potential of M. graminicola on rice seedlings. The nematode significantly reduced growth of rice shoots by 63.5%. In an earlier finding, Plowright and Bridge [32] earlier recorded 80% seedling death as a result of *M. graminicola* infection. The wide spread of *Meloidogyne* spp. in all rice farms where this surveillance was carried-out calls for concern, especially with the high population densities recorded in each local government areas. The rice-rice cropping sequence is the most common rotation and the farmers mostly use the same rice variety during each cropping season. This might have contributed to the high prominence value in addition to other conditions such as a long history of rice cultivation.

Hirschmanniella oryzae is the most documented plant-parasitic nematode associated with rice on flooded plains [16]. Maung *et al*. [33] also noted that *H. oryzae* is the most common plant-parasitic nematode on rice farms with long history of flooding. Rice mostly cultivated during the peak of rainfall in Benue state, is for the most part grown in farms that are intermittently flooded or on “fadama” areas (low-lying plains underlain by “shallow” aquifers found along major river systems as defined by the National Fadama Development Project in Nigeria). This practice is commonplace in rice-producing communities as it is a rain-fed crop due to inadequate access to irrigation facilities. Since the rice farms are intermittently flooded, it was not surprising to find that *H. oryzae* was the most spatially distributed plant-parasitic nematode with the highest prominence value in soil samples obtained from the study areas. This may be due to the fact that *Hirschmaniella* spp., just like *Meloidogyne* spp. that have the ability to survive anaerobiotic environments [11].

The root lesion nematode, *Pratylenchus zeae* was also detected in most rice farms included in this survey. Although not in the same quantum as *Meloidogyne* spp. and *Hirschmanniella oryzae*, *P. zeae* signals serious threat to rice agrosystems in the study areas. Sometimes the mere presence of these PPN may constitute the likelihood of a secondary infection. For example, *Pratylenchus penetrans* alone can cause significant yield loss [34], but it has also been associated with the disease complex called black root rot in combination with other fungi such as *Rhizoctonia fragaria*. The presence of *Criconemoides* sp., *Tylenchorhynchus* sp., *Trichodorus* sp., *Scutellonema bradys*, *Xiphinema index* and *Helicotylenchus* spp., in some of the farms surveyed is indicative of potential inocula build-up in the field as a result of diversification of crop host or alternate crops these nematodes were associated with. For instance, over time, *Scutellonema bradys* has been majorly associated with yam production [35, 36, 37, 38]. However, in 2015 *S. bradys* was reported as major threat to potato (*Solanum tuberosum*) production in Nigeria, Benin, Cameroon and Ghana [39]. These sought of diversification in plant host range has been reported in a number of species of plant-parasitic nematodes and continue to increasingly enrich the spatial distributions of these nematodes.

Conclusion and recommendations

The current surveillance study has divulged the parasitic nematodes associated with rice agrosystems in Benue state, Nigeria for the first time. With the widespread and densities of Meloidogyne, Hirschmaniella and Pratylenchus in surveyed rice farms, the need for deployment of sustainable control measures that will mitigate the populations of these nematode genera in these areas is pertinent. These mitigation strategies must also be extended to controlling other genera of PPNs encountered such as Helicotylenchus, Scutellonema, Tylenchorhynchus, Scutellonema, Trichodorus and Xiphinema in order to forestall damages associated with these group of nematodes. Awareness creation campaigns across all actors along the rice value chain should be organized to raise knowledge on the deleterious nature of PPN and possible mitigation strategies for their effective management. Donor agencies, government, NGOs, CBOS, Rice Farmers Association of Nigeria (RIFAN) through partnerships with relevant federal and state ministries, agencies and departments (MDAs) must collaborate to address the issue of PPNs attack on rice in Benue state, Nigeria.

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