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PREVALENCE OF PLANT-PARASITIC NEMATODES IN RICE FIELDS IN GHANA

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ABSTRACT

Rice (*Oryza sativa* L.) is one of the most cultivated crops worldwide whose production in sub-Saharan Africa is extensively affected by root nematodes. The objective of this study was to identify and establish the distribution of plant-parasitic nematodes (PPNs), in rice growing fields within different regions of Ghana. Soil and root samples were taken from rice fields, namely fourteen from Volta Region, eleven from the Soil and Irrigation Research Centre (SIREC), Kpong (Eastern Region); and five from Dawhenya (Greater Accra Region). The soil samples were taken from 0-30 cm depths, together with root samples. A total of twenty-four nematode genera were identified in soil and root samples from the three regions. These included: *Aphelenchus* spp., *Belonolaimus* spp., *Ditylenchus* spp., *Dolichodorus* spp., *Helicotylenchus* spp., *Hemicriconemoides* spp., *Hemicyclophora* spp., *Heterodera* spp., *Hirschmaniella* spp., *Hoplolaimus* spp., *Longidorus* spp., *Meloidogyne* spp., *Paralongidorous* spp., *Paratylenchus* spp., *Pratylenchus* spp., *Radopholus* spp., *Rhabditida* spp., *Rotylenchulus* spp., *Scutellonema* spp., *Trichodorus* spp., *Tylenchornchus* spp., *Tylenchulus* spp., *Tylenchus* spp. and *Xiphinema* spp. In the Volta Region, *Tylenchus* spp. was the most abundant (29.01%) in the soil; while *Meloidogyne* spp. was most the abundant (36.86%) in the roots. In Dawhenya regions, *Meloidogyne* spp. was the most abundant (26.96%) in the soil; while *Tylenchus* spp. was the most abundant (25.94%) in the roots. In the Eastern Region, *Meloidogyne* spp. was the most abundant (41.7%) in the soil; while *Pratylenchus* spp. was the most abundant (36.1%) in the roots. These nematodes threaten rice production in Ghana, if not managed well in farmer's fields.

Key Words: *Meloidogyne* spp., *Oryza sativa*, Volta region

RÉSUMÉ

Le riz (*Oryza sativa* L.) est l'une des cultures les plus cultivées au monde dont la production en Afrique subsaharienne est largement affectée par les nématodes des racines. L'objectif de cette étude était d'identifier et d'établir la répartition des nématodes phytoparasites (NPP) dans les rizières de différentes régions du Ghana. Des échantillons de sol et de racines ont été prélevés dans les rizières, à savoir quatorze de la région de la Volta, onze du Centre de Recherche sur les Sols et l'Irrigation (SIREC), Kpong (région de l'Est) ; et cinq de Dawhenya (région du Grand Accra). Les échantillons de sol ont été prélevés à des profondeurs de 0 à 30 cm, ainsi que des échantillons de racines. Au total, vingt-quatre genres de nématodes ont été identifiés dans des échantillons de sol et de racines des trois régions. Ceux-ci comprenaient : *Aphelenchus* spp., *Belonolaimus* spp., *Ditylenchus* spp., *Dolichodoros* spp., *Helicotylenchus* spp., *Hemicriconemoides* spp., *Hemicyclophora* spp., *Heterodera* spp., *Hirschmaniella* spp., *Hoplolaimus* spp., *Longidorus* spp., *Meloidogyne* spp., *Paralongidoros* spp., *Pratylenchus* spp., *Pratylenchus* spp., *Radopholus* spp., *Rhabditida* spp., *T.* spp., *Tylenchornchus* spp., *Tylenchulus* spp., *Tylenchus* spp. et *Xiphinema* spp. Dans la région de la Volta, *Tylenchus* spp. était le plus abondant (29,01 %) dans le sol; tandis que *Meloidogyne* spp. était le plus abondant (36,86%) dans les racines. Dans les régions de Dawhenya, *Meloidogyne* spp. était le plus abondant (26,96 %) dans le sol; tandis que *Tylenchus* spp. était le plus abondant (25,94 %) dans les racines. Dans la région orientale, *Meloidogyne* spp. était le plus abondant (41,7%) dans le sol; tandis que *Pratylenchus* spp. était le plus abondant (36,1 %) dans les racines. Ces nématodes menacent la production de riz au Ghana, s'ils ne sont pas bien gérés dans les champs des agriculteurs.

Mots Clés : *Meloidogyne* spp., *Oryza sativa*, région de la Volta

INTRODUCTION

Rice (*Oryza sativa* L) is the main food crop of more than half of the world population. In Ghana, however, rice production only meets 30-40% of the demand; thus the country greatly depends on massive rice imports. Moreover, rice production and its continuous intensification within the country, could impact plant-parasitic nematodes and their pest status (Coyne *et al.*, 1999). More than 35 genera and 130 species of plant-parasitic nematodes (PPNs) have been associated with rice damage (Gerber *et al.*, 1987); though only 29 species are known or suspected to cause significant yield loss (Bridge *et al.*, 2005).

Plant-parasitic nematodes occur in almost all rice environments; they are diverse and their distributions span different between ecosystems (Prot and Rahman, 1994). In a survey by Udo *et al.* (2011) in South Eastern Nigeria, nematodes identified on rice included *Heterodera* spp., *Hirschmaniella* spp., and

Meloidogyne spp. Nematodes have also been found in rice fields in the Philippines (Pascual *et al.*, 2014); including *Aphelenchoides* spp., *Hirschmaniella* spp., *Meloidogyne* spp., *Criconematidae*, *Pratylenchus* spp., *Rotylenchulus* spp., *Rotylenchus* spp., and *Tylenchorynchus* spp.

In a study conducted in Ghana on rice fields in the forest zone (Ashanti, Brong Ahafo, and Eastern Regions) and the savannah zone (Northern and Upper East Regions), a diversity of nematodes was reported (Coyne *et al.*, 1999). Fifty-one species from 29 nematode genera were identified in 145 fields (upland, hydromorphic, rainfed lowland, and irrigated lowland ecosystems) within the savannah and forest agroecological zones. Within the upland/hydromorphic rice fields *Pratylenchus* spp. consisted of about 80% and *Ditylenchus* spp. (78%) as the most abundant nematode species. However, within the forest zone fields *Coslenchus franklinae* and *Helicotylenchus* spp., were most prevalent and consisted of

84 and 76% of nematode species respectively. *Hirschmanniella* spp. were found in 100% of samples and were more prevalent in the savannah zone compared to other nematodes in lowland rice. However, within the forest zone *Xiphinema bergeri* consisted of 71% of nematodes identified in lowland rice (Coyne *et al.*, 1999).

A number of land use changes have taken place in Ghana, which have involved intensification of agricultural production and the introduction of new technologies. These soil management changes may have contributed to shifts in the occurrence and density of nematode species, whose diversity, distribution and population densities need to be understood for proper rice production in Ghana. Therefore, objective of this study was to identify and establish the distribution of plant- parasitic nematodes (PPNs) in rice growing fields in three regions of Ghana.

MATERIALS AND METHODS

Study sites. The study was conducted in three regions of Ghana, namely, Greater Accra, Eastern and Volta. Fourteen locations were randomly selected from rice growing fields in seven rice-producing areas in the Volta region, namely Tsawornu, Akrofu, Sadzikorfe, Gbefi, Kpando, Ve-golokuati and Aveyime. Aveyime is under the production and management of the Aveyime rice project which has over 100 ha of rice fields within the Volta Region. The large hectare (ha) of land under cultivation in Aveyime provided basis for its division into 8 sites for sampling purposes. The soil types are tropical black clays (earths).

Eleven sites were also randomly selected at SIREC, Kpong in the Eastern region, a rice production centre under university of Ghana. The soil is clayey and is classified as a Typic Calcicustert (Amatekpor and Dowuona, 1995), a vertisol, deriving from garnetic-Ferrous hornblende gneiss parent material. Five sites cultivated to rice in Dawhenya within the Greater-Accra region, were also sampled,

and the soil types were tropical black clays (earths).

These areas have a tropical climate, characterised by moderate temperatures, 21–32°C, for most of the year. The regions have two rainfall regimes in the year; the first is from March to July and the second is from mid-August to October. The Geographical Positioning System (GPS) for the various sampling sites is provided (Table 1).

Nematode extraction from soil. The sucrose-centrifugation method of nematode extraction was used; whereby 200 cubic centimeters of the soil sample was taken into a container and covered with water twice the volume of the soil. The soil and water were mixed uniformly and left to rest for 10 minutes. The supernatant was poured through 20/500 mesh stacked sieves. The 500 mesh sieve was tapped gently to enhance drainage. The 20 mesh sieve trapped organic debris, while the 500 mesh sieve trapped nematodes and silt. The soil left in the container was again covered with about 500 ml of water, mixed uniformly and allowed to settle for 10 minutes, before being decanted through the above mentioned sieve. The latter process was repeated to ensure that all nematodes in the soil were recovered and trapped on the 500 mesh sieve. The soil particle containing the nematodes were guided to one end of the 500 mesh, sieve by rinsing other ends with water from the wash bottle. The contents were poured into a measuring beaker and then poured into a centrifuge tube. The contents in the centrifuge bottle were centrifuged at 1700 rpm for 5 minutes, and the supernatant discharged, leaving the soil particles with nematodes. A 35 millimeter sugar solution was poured on the remaining soil particles of the centrifuge tube and centrifuged at 1000 rpm for 1 minute. The sucrose solution with the nematodes was then poured onto the 500 mesh sieve tube sieve. The nematodes were thoroughly rinsed with water, to get rid of the sucrose. The nematodes in the remaining solution were washed gently

TABLE 1. The Geographical Positioning System coordinates for thirty (30) sites from three Regions (Volta, Greater-Accra, and Eastern)

Region	Town	Site #	Latitude			Longitude		
			Degrees	Minutes	Seconds	Degrees	Minutes	Seconds
Volta	Tsawornu	Site 1	5	59	0.21	0	27	0.25
	Akrofu	Site 2	6	37	60	0	22	60
	Sadzikorfe	Site 3	7	0	0.8	0	26	11.1
	Kpando	Site 4	7	0	0	0	18	0
	VeGolokuate	Site 5	6	59	32.12	0	25	32.12
	Gbefi	Site 6	6	59	55.1	0	22	53.8
Volta	Aveyime	Site 1	6	16	29.937	0	30	30.102
	“	Site 2	6	9	9.244	0	22	29.407
	“	Site 3	6	16	23.277	0	34	27.315
	“	Site 4	6	11	11.984	0	20	5.919
	“	Site 5	6	16	23.277	0	34	27.315
	“	Site 6	6	10	59.999	0	28	0.001
	“	Site 7	5	39	13.319	0	10	3.378
	“	Site 8	5	53	45.002	0	31	7.297
Eastern	Kpong	Site 1	6	7	58.419	0	4	28.995
	“	Site 2	6	7	57.037	0	4	18.439
	“	Site 3	6	7	58.352	0	4	25.987
	“	Site 4	6	26	7.581	0	2	53.903
	“	Site 5	6	24	19.981	0	3	51.505
	“	Site 6	6	8	12.267	0	4	26.804
	“	Site 7	6	8	12.348	0	4	27.368
	“	Site 8	6	7	59.8	0	5	38.2
	“	Site 9	6	7	57.7	0	4	24.1
	“	Site 10	6	7	58.7	0	4	16.6
	“	Site 11	6	7	52.4	0	4	42.9
Greater-Accra	Dawenya	Site 1	5	53	38.99	0	11	20
	“	Site 2	5	51	35.474	0	10	0.761
	“	Site 3	5	51	27.54	0	10	11.528
	“	Site 4	5	46	41.012	0	5	53.348
	“	Site 5	5	46	34.082	0	4	1.643

into a beaker and then transferred into another clean centrifuge tube to a volume of 10 ml.

Nematode extraction from rice roots. This was done using the root maceration and Bearman funnel method. The soil particles remaining on the roots after these were pulled

from the soil were washed off as much as possible under running water to ensure that nematodes recovered using this method were solely from the roots. About 10 g of the fresh roots were weighed and cut into 1cm pieces each. The root pieces were blended twice for each 5 seconds round. The nematodes were

extracted using a modified Baermann method for 48 hr (Hooper, 1990). The funnel was filled with about 100 ml water to ensure that it touched the mesh to encourage movement of nematodes into the water. The set up was left for about 48 hours and the water which contained the extracted nematodes was drained into a 100 ml glass beaker. The solution was sieved through 500 mesh sieve and the trapped nematodes in the solution were poured into another beaker and then transferred into a clean centrifuge tube for storage at 4°C until counted and identified.

Nematode count and identification.

Nematodes were counted from three aliquots of 2 ml subsample from a 25 ml sample. Nematodes were identified to the genus level; and population densities were expressed as number of nematodes per 10 g of fresh root and 200 cm³ of soil.

Relative abundance of nematode populations. Population density (PD) of nematodes per 200 cm³ of soil and 10 g plant root samples, and relative abundance (RA%) were calculated according to Norton (1978) as follows: PD = average number of nematodes per 200 cm³ of soil and 10 g plant root samples, RA% = the number of individuals of a nematode genus or species / the total number of nematodes identified and counted from 200 cm³ soil or 10 g rice root × 100.

RESULTS

Twenty-four nematode genera were identified in combined soil and root sample extractions from the Volta, Eastern and Greater Accra regions. These included: *Aphelenchus* spp., *Belonolaimus* spp., *Ditylenchus* spp., *Dolichodorus* spp., *Helicotylenchus* spp., *Hemicriconemoides* spp., *Hemicyclophora* spp., *Heterodera* spp., *Hirschmaniella* spp., *Hoplolaimus* spp., *Longidorus* spp., *Meloidogyne* spp., *Paralongidorus* spp., *Paratylenchus* spp., *Pratylenchus* spp.,

Radopholus spp., *Rhabditida* spp., *Rotylenchulus* spp., *Scutellonema* spp., *Trichodorus* spp., *Tylenchornchus* spp., *Tylenchulus* spp., *Tylenchus* spp. and *Xiphinema* spp.

Nematodes in soil and plant roots in Volta region.

Sixteen nematode genera were encountered in the soils of the various locations (Table 2). A total of 517 nematodes were recovered from the soil samples. Aveyime had the most nematodes (387) compared to all other locations combined (130). The highest population densities of *Pratylenchus* spp. (40) and *Scutellonema* spp. (20) were found in one location (Tsawornu) in the Volta region. The highest population densities of *Tylenchus* spp. (41) was found in site 6 and site 7 in Aveyime. The highest population densities of *Heterodera* spp. (13) and *Aphelenchus* spp. (11) were found in site 1 in Aveyime. The highest population densities of *Meloidogyne* spp. (16) and *Tylenchulus* spp. (14) were found in site 8 in Aveyime. No nematodes were recovered from Akrofi and Gbefi communities. Fewer nematode were found in Sardzikorfe (9) and Vegolokuate (11) compared to other locations. In the Volta region, *Tylenchus* spp. (29.0%) and *Pratylenchus* spp. (17.79%), were the most abundant in the soil. Low relative abundance was observed for *Belonolaimus* spp. (0.4%) *Ditylenchus* spp. (1.0%) *Hirschmaniella* spp. (0.6%) *Rhabditida* spp. (0.2%) *Rotylenchus* spp. (0.2%) *Trichodorus* spp. (0.8%) (Table 2).

A total of 632 nematodes were recovered from the root samples, with Gbefi having the largest number (220) among the study locations. In the Volta region, twelve and sixteen nematode genera were encountered in the roots and soils of rice from the various locations respectively (Table 2).

Meloidogyne spp. occurred in the largest quantities in roots and particularly in Gbefi, Tsawornu and Kpando; with 100, 50 and 42 second-stage juveniles (J2) per 10 g roots, respectively. The highest population densities

TABLE 2. Relative abundance of nematode genera in 200 cc soil and 10 g roots of rice from fourteen locations/sites in the Volta region

Nematode genera	Population density (200 cc soil)	Relative abundance (200 cc soil)	Population density (10 g root)	Relative abundance (10 g root)	Total population (Soil +Roots)	Relative abundance (Soil+Root)
<i>Aphelenchus</i> spp.	19	3.7	0	0.0	19	1.7
<i>Belonolaimus</i> spp.	2	0.4	0	0.0	2	0.2
<i>Ditylenchus</i> spp.	5	1.0	39	6.2	44	3.8
<i>Helicotylenchus</i> spp.	25	4.8	3	0.5	28	2.4
<i>Heterodera</i> spp.	33	6.4	79	12.5	112	9.7
<i>Hirschmaniella</i> spp.	3	0.5	60	9.5	63	5.5
<i>Meloidogyne</i> spp	46	8.9	233	36.8	279	24.3
<i>Paratylenchus</i> spp	12	2.3	168	26.5	180	15.7
<i>Pratylenchus</i> spp.	92	17.8	4	0.6	96	8.4
<i>Radopholus</i> spp.	0	0.0	1	0.2	1	0.1
<i>Rhabditida</i> spp.	1	0.2	0	0.0	1	0.1
<i>Rotylenchus</i> spp.	1	0.2	0	0.0	1	0.1
<i>Scutellonema</i> spp.	65	12.6	32	5.1	97	8.4
<i>Trichodorus</i> spp	4	0.8	0	0.0	4	0.3
<i>Tylenchulus</i> spp.	39	7.5	1	0.2	40	3.5
<i>Tylenchus</i> spp	150	29.0	10	1.6	160	13.9
<i>Xphinema</i> spp.	20	3.9	2	0.3	22	1.9
Total	517	100	632	100	1149	100

of *Pratylenchus* spp. in roots were also found in Gbafi, and Kpando with 80 and 42 nematodes per 10 g roots respectively. Similarly, the highest population densities of *Hirschmaniella* spp. in roots were found in Gbafi, Tsawornu and Kpando with 10, 20 and 28 nematodes per 10 g roots respectively. *Ditylenchus* spp. was also found in 10 g roots from Gbafi (10), Tsawornu (10), Kpando (14), VeGolokuate (3) and Aveyime (2). *Heterodera* spp. was found in 10 g roots from Tsawornu (40), Kpando (35) and Aveyime (4).

Relative abundance (%) of nematodes varied in the roots, *Meloidogyne* spp. (36.9%) were the most abundant, followed by *Paratylenchus* spp. (26.58%), *Heterodera* spp. (12.5%), *Hirschmaniella* spp. (9.5%) *Ditylenchus* spp. (6.2%) and *Scutellonema* spp. (5.1%). Low relative abundance was recorded for *Tylenchulus* spp. (0.2%),

Helicotylenchus spp. (0.5%) *Xphinema* spp. (0.3%), *Pratylenchus* spp. (0.6%) and *Radopholus* spp. (0.2%). *Meloidogyne* spp. (24.3%) was therefore the most abundant nematode, and *Paratylenchus* spp. (15.7%), *Tylenchus* spp. (13.9%), and *Heterodera* spp. (9.7%) had their relative abundances in this order (Table 2).

Nematodes in soil and plant roots in Dawhenya region. Sixteen nematode genera were found in Dawhenya (Table 3). A total of 858 nematodes were recovered from the soil samples. Site 5 (285) and site 1 (220) had the most nematodes compared to other locations. The highest population densities of *Meloidogyne* spp. (90) and *Longidorus* spp. (65) were found in site 1 in Dawhenya. Site 5 had the highest population densities of *Tylenchulus* spp. (55), *Ditylenchus* spp. (15)

TABLE 3. Relative abundance of nematode genera in 200 cc soil and 10 g roots of rice from five sites in Dawhenya, Greater Accra region

Nematode genera	Population density (200 cc soil)	Relative abundance (200 cc soil)	Population density (10 g root)	Relative abundance (10 g root)	Total population (Soil +Roots)	Relative abundance (Soil+Root)
<i>Aphelenchus</i> spp.	5	0.6	0	0.0	5	0.5
<i>Ditylenchus</i> spp.	25	2.9	10	6.3	35	3.5
<i>Hemicriconemoides</i> spp.	15	1.8	5	3.2	20	2.0
<i>Hemicycliophora</i> spp.	5	0.6	5	3.2	10	1.0
<i>Heterodera</i> spp.	80	9.4	40	25.3	120	11.9
<i>Hirschmaniella</i> spp.	15	1.8	5	3.2	20	2.0
<i>Longidorus</i> spp.	90	10.6	0	0.0	90	8.9
<i>Meloidogyne</i> spp.	230	26.9	10	6.3	240	23.7
<i>Paratylenchus</i> spp.	10	1.2	5	3.2	15	1.5
<i>Pratylenchus</i> spp.	50	5.9	10	6.3	60	5.9
<i>Rotylenchulus</i> spp.	25	2.9	0	0.0	25	2.6
<i>Scutellonema</i> spp.	30	3.5	0	0.0	30	2.9
<i>Trichodorus</i> spp.	30	3.5	0	0.0	30	2.9
<i>Tylenchulus</i> spp.	133	15.5	22	13.9	155	15.3
<i>Tylenchus</i> spp.	65	7.6	41	25.9	106	10.5
<i>Xiphinema</i> spp.	45	5.3	5	3.2	50	4.9
Total	853	100	158	100	1011	100

Heterodera spp. (30) *Hirschmaniella* spp. (10) *Pratylenchus* spp. (25) *Trichodorus* spp. (15) and *Xiphinema* spp. (30). *Aphelenchus* spp. and *Hemicycliophora* spp. was found in a single location only (site 2 and site 5 respectively). Site 4 had the least number (83) of nematodes. In Dawhenya, Greater Accra region, *Meloidogyne* spp. (27%) and *Tylenchulus* spp. (15.6%), were the most abundant in the soil (Table 3).

Within the rice roots, *Tylenchus* spp. (25.9%) were the most abundant, and *Heterodera* spp. (25.3%) and *Tylenchulus* spp. (13.9%) had their relative abundances in this order. *Meloidogyne* spp., *Pratylenchus* spp., and *Ditylenchus* spp. each had relative abundances of 6.3%. Low relative abundances for *Hemicriconemoides* spp., *Hemicycliophora* spp., *Hirschmaniella* spp., *Paratylenchus* spp. and *Xiphinema* spp., (3.2%) were observed.

A combination of soil and root nematodes, showed *Meloidogyne* spp. (23.7%) as the most

abundant, and *Tylenchulus* spp. (15.7%), *Heterodera* spp. (11.9%). *Tylenchus* spp. (10.5%), and *Longidorus* spp. (8.9%) had their relative abundances in this order. Low relative abundance for *Aphelenchus* spp. (0.5%), *Hemicycliophora* spp. (1.9%) and *Paratylenchus* spp. (1.5%) were observed (Table 3).

Nematodes in soil and plant roots in SIREC region. Eleven genera of plant-parasitic nematodes were found in soil samples obtained from SIREC, Kpong (Table 4), thus giving a maximum number of 691 nematodes. Site 8 (178) and site 9 (108) had the most nematodes in their soils, compared to the other locations. The maximum population densities of *Meloidogyne* spp. (101) and *Scutellonema* spp. (61) were found in site 8. The highest nematode numbers for *Ditylenchus* spp. (11), and *Dolichodorus* spp. (6) were from sites 7 and 1 respectively. However, the the highest

TABLE 4. Relative abundance of nematode genera in 200 cc soil and 10 g roots of rice from eleven locations in SIREC, Kpong, Eastern region

Nematode spp.	Population/ 200 g soil	Relative abundance	Population/ 10 g roots soil (%)	Relative Abundance roots (%)	Population density (soil + roots)	Relative abundance (soil+roots)
<i>Aphelenchus</i> spp.	1	0.1	18	2.1	19	1.2
<i>Ditylenchus</i> spp.	13	1.9	2	0.2	15	1.0
<i>Dolichodorus</i> spp.	6	0.9	0	0.0	6	0.4
<i>Heterodera</i> spp.	22	3.2	44	5.0	66	4.2
<i>Hirshmaniella</i> spp.	39	5.8	8	0.9	47	3.0
<i>Hoplolaimus</i> spp.	5	0.7	1	0.1	6	0.4
<i>Meloidogyne</i> spp.	280	40.6	234	26.9	514	32.9
<i>Paralongidorus</i> spp.	0	0.0	2	0.2	2	0.1
<i>Pratylenchus</i> spp.	1	0.1	306	35.1	307	19.6
<i>Radopholus</i> spp.	0	0.0	71	8.2	71	4.6
<i>Scutellonema</i> spp.	206	29.9	92	10.6	298	19.2
<i>Tylenchorynchus</i> spp.	0	0.0	7	0.8	7	0.4
<i>Tylenchus</i> spp.	116	16.8	82	9.4	198	12.7
<i>Xiphenema</i> spp.	0	0.0	4	0.5	4	0.3
Total	689	100	871	100	1560	100

population densities of *Hirschmaniella* spp. (13) and *Tylenchus* spp. (22). were from site 4. Lower numbers of *Aphelenchus* spp. (1), *Ditylenchus* spp. (6) *Hoplolaimus* spp. (5) *Pratylenchus* spp. (2) *Xiphinema* spp. (2). were also extracted from the soils.

Nematode population densities of soil samples varied from the various sampling sites in SIREC, Kpong. *Meloidogyne* spp. (40.6%) was found to be the most abundant in the soil. *Scutellonema* spp. (29.9%) and *Tylenchulus* spp. (16.8%) had the next highest abundances. Low relative abundances were observed for *Aphelenchus* spp. (0.1%), *Dolichodorus* spp. (0.9%), *Ditylenchus* spp. (1.9%), *Hoplolaimus* spp. (0.7%) and *Pratylenchus* spp. (0.1%) respectively (Table 4).

Within the roots, *Pratylenchus* spp. (35.1%) were the most abundant, and *Meloidogyne* spp. (26.9%), *Scutellonema* spp. (10.6%), *Tylenchus* spp. (9.4%), and *Radopholus* spp. (8.2%) had their relative abundances in this order. Very low relative abundances less than 5% were observed for *Ditylenchus* spp. (0.2%), *Hirschmaniella* spp. (0.9%), *Hoplolaimus* spp. (0.1%) and *Paralongidorus* spp. (0.2%). Combination of soil and root nematodes showed *Meloidogyne* spp. (32.9%) as the most abundant, and *Pratylenchulus* spp. (19.6%) *Scutellonema* spp. (19.2%) and *Tylenchus* spp. (12.7%) with relative abundances in this order. Comparatively low relative abundances of less than 5%, for *Aphelenchus* spp. (1.2%), *Ditylenchus* spp. (1.0%) *Dolichodorus* spp. (0.4%) *Heterodera* spp. (4.2%) *Hirschmaniella* spp. (3.0%) *Hoplolaimus* spp. (0.4%) *Paralongidorus* spp. (0.1%) *Tylenchorynchus* spp. (0.4%) were observed (Table 4).

DISCUSSION

Results of this survey demonstrate that a diversity of nematode genera is present in rice fields in Ghana. Twenty-four nematode genera were identified in soil and root samples from the Volta, Eastern and Greater Accra regions.

More than 200 species of plant-parasitic nematodes have been reported to be associated with rice, however, only a few of them are considered economically important pests of rice (Kyndt *et al.*, 2014). Some of them such as the white tip nematode (*Aphelenchoides besseyi*), rice root knot (*Meloidogyne graminicola*), rice root (*Hirschmaniella* spp.), rice stem (*Ditylenchus angustus*), rice cyst (*Heterodera oryzicola*) and root lesion (*Pratylenchus* spp.) nematodes are economically most important. Some of these nematodes were found in our study.

A survey conducted between 1994 and 1997 in Ghana on rice fields in the forest zone (Ashanti, Brong Ahafo, and Eastern regions) and the savannah zone (Northern and Upper East regions) showed the presence of most of these nematodes (Coyne *et al.*, 1999). These included *Aphelenchus* spp., *Ditylenchus* spp., *Helicotylenchus* spp., *Heterodera* spp., *Hirschmaniella* spp. *Hoplolaimus* spp., *Meloidogyne* spp., *Paralongidorus* spp., *Paratylenchus* spp. *Pratylenchus* spp., *Rotylenchulus* spp., *Scutellonema* spp., *Tylenchorynchus* spp. *Tylenchus* spp. *Trichodorus* spp., and *Xiphinema* spp. Other nematode species identified by Coyne *et al.* (1999) were: *Aphelenchoides* spp. *Criconemoides* spp., and *Rotylenchus* spp. These nematodes were, however, absent in our study. Babatola (1984) reported that root-knot nematode, *Meloidogyne* spp. and the root lesion nematode, *Pratylenchus* spp. have both been observed to be parasitic nematodes on rice and reduce rice yields, both of these nematodes were identified in our studies. *Hirschmaniella* spp. *Heterodera* spp., *Meloidogyne* spp., and *Pratylenchus* spp. have been reported as the most important root nematodes by Bridge *et al.* (2005).

In the present study, *Meloidogyne* spp., and *Pratylenchus* spp. were most abundant in both soil and roots of rice plants. These nematodes are therefore of importance in rice cultivation in Ghanaian fields, and their population densities in soils should be managed

effectively. In another study conducted in Ecuador, *Meloidogyne graminicola* was the most widespread and abundant nematode, occurring in both rainfed lowland and irrigated areas under rice cultivation (Triviño *et al.*, 2016). This nematode has also been reported to cause damage in rice plantations from the Philippines (Prot *et al.*, 1994), Bangladesh (Munir *et al.*, 2002), Nepal (Padgham *et al.*, 2004), Pakistan (Pokharel *et al.*, 2005), and Costa Rica (Soriano *et al.*, 2000). Coyne *et al.* (1999) have also observed that *Pratylenchus* spp. was more prevalent in rice fields that had been continuously cultivated for years.

The rice fields in Aveyime have been used in rice cultivation for many years, thus the association of *Meloidogyne* and *Pratylenchus* spp. with rice in this area. In a study conducted by Udo *et al.* (2011), *Meloidogyne* spp. was absent in the roots, but present in the soil. In the current study, however, *Meloidogyne* spp. was identified in both root and soil samples. According Pascual *et al.* (2014), *Hirshmaniella* spp. are the most common nematodes on irrigated rice fields, with a long history of rice farming where watering of plants was regular. However, in our studies *Hirshmaniella* spp. population densities were generally low. The low populations of this nematode if managed properly through land and crop rotations, together with tolerant varieties will prevent yield losses from these nematodes which have been observed in for e.g., China reaching 30% (Liao *et al.*, 2000).

Coyne *et al.* (1998) in a study in Ivory Coast identified *Helicotylenchus* spp. (100%) and *Pratylenchus* spp. (96%) as the most prevalent nematode genera in the forest-savanna zone and savannah zone respectively. The present study, however, revealed *Meloidogyne* spp. as the most prevalent nematode in both root and soil samples, however low populations of *Helicotylenchus* spp. (2.4%) in both roots and soil samples were observed from the Volta region. A study

by Talwana *et al.* (2008) showed that the nematode genera: *Pratylenchus* spp., *Meloidogyne* spp. and *Helicotylenchus* spp. occurred on all cereal crops.

Although the population densities of nematodes from the present survey were generally lower compared to nematode numbers recovered by other researchers, the interaction between nematodes and other plant-pathogenic soil organisms, particularly fungi and bacteria, in the development of some disease complexes makes them very important even at very low densities.

CONCLUSION

Twenty-four nematode genera were identified in root and soil samples from the three regions in Ghana. Nematode spread and distribution among the three regions varied in both root and soil samples. *Meloidogyne* spp. was the most abundant nematode in soil planted to rice in Dawhenya and Eastern regions respectively, and the most abundant nematode in roots of rice samples from Volta region. The rice nematode *Hirschmaniella* spp. were generally low in both soil and root samples for the three regions. Management of nematode populations below specific threshold in rice cultivation is necessary through land rotations and fallowing.

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