

Plant-parasitic nematodes associated with sweet potato rhizosphere soil in the Semi- Deciduous Forest and Coastal Savannah Zones of Ghana

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ABSTRACT

A survey was conducted in nine major sweet potato producing districts across the semi-deciduous forest and coastal savannah zones of Ghana to determine the prevalence of plant-parasitic nematodes parasitizing the crop. Soil samples were collected at 90-days after planting from the rhizosphere of sweet potato crop and analysed using Modified Baermann tray method from 100 farms across the study area. Seven plant-parasitic nematode genera were extracted from soil samples collected and morphologically identified under a microscope with four of them, namely *Meloidogyne*, *Pratylenchus*, *Rotylenchulus*, and *Helicotylenchus* being the most prevalent. *Scutellonema* sp. occurred in 89% while *Tylenchus* sp. occurred in 33% of the districts sampled. The ring nematode, *Criconemella* sp. was found in only two of the nine districts covered; Ketu North and Akatsi South which incidentally recorded 100% of the seven nematodes encountered in the survey. The abundant nematode was *Meloidogyne* sp. which represented 39% and *Criconemella*, the least (0.1%) of the total nematodes recovered in the survey. This study has shown that high diversity, incidence and density of economically important plant-parasitic nematodes are associated with sweet potato crop. Development of appropriate management strategies to mitigate the negative effects of plant-parasitic nematodes on sweet potato is recommended.

Keywords: Food security; *Ipomoea batatas*; Nematodes diversity; Rhizosphere soil; Synergistic effect

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Introduction

Sweet potato (*Ipomoea batatas* L. (Lam.) is a major staple crop recognized for its contribution to food security, particularly in developing countries where hunger and malnutrition are high (Makini *et al.*, 2017). It is a preferred crop cultivated throughout the tropical and sub-

tropical regions due to its wide adaptability to a wide range of environmental conditions and low cost of production (Woolfe, 1992). Due to its high yielding, nutritional and food security potential, sweet potato production has increased in Ghana from 89,600 to 145,886 tons between 1996 and 2017 (FAOSTAT,

2017). The crop is grown largely for its starchy, and sweet-tasting tuberous roots which serve as food, feed or industrial crop (Odebode, 2008) and is a rich source of carbohydrates, vitamins A and C, thiamine, niacin, and riboflavin containing significant amounts of calcium and iron (Oversweet, 2009). Varieties such as the orange and yellow flesh varieties have high beta-carotene content thereby used in addressing the issue of vitamin A – deficiencies among children and women (Makini *et al.*, 2017; Odebode, 2008). Sweet potato yield and quality are however reduced by the activities of plant-parasitic nematodes such as root-knot nematodes (*Meloidogyne* spp.), lesion nematodes (*Pratylenchus* spp.) and reniform nematodes (*Rotylenchulus* spp.), being a major production constraint (Olabiyi, 2007; Coyne *et al.*, 2003; Cervantes-Flores, 2000). Apart from the direct damage caused by the feeding activities of plant-parasitic nematodes, they also provide avenues for penetration and establishment of several secondary pathogenic organisms in the roots of the crop which constrains sustainable production. Despite the importance of plant-feeding nematodes in sweet potato production, little is known about the genera composition, distribution, frequency

and abundance of the pest associated with the crop in Ghana. Knowledge of these will aid in the development of sustainable management strategies against phytonemtod es parasitizing the sweet potato crop. The study was therefore aimed at determining the genera composition, frequency and abundance of plant-parasitic nematodes in sweet potato rhizosphere soil across the study area.

Materials and Methods

Sampling

Soil samples from sweet potato rhizosphere were collected from 100 farms in nine districts across different agro-ecological zones of Ghana (Table 1). All farms sampled were monoculture systems and no nematode management practices were employed by farmers. Soil samples were collected at 90-days after planting in an N-shaped pattern across each of the selected farms averaging 0.5 acres using a 15-cm soil auger. Three soil cores at a depth of 20 cm from each farm were collected and pooled into one composite sample. Each sample was then carefully placed into a cooler with Styrofoam and disposable ice packs, transported to the laboratory, stored at 4°C for 24 hours before processing.

TABLE 1
Districts, Agro-ecological zones, regions and number of sweet potato farms surveyed

<i>Districts</i>	<i>Agro-Ecological Zone</i>	<i>Region</i>	<i>Number of farms selected</i>
Ketu South	Semi-deciduous Forest	Volta	10
Akatsi South	Semi- deciduous Forest	Volta	13
Ketu North	Semi-deciduous Forest	Volta	11
Twifo Heman Lower Denkyira	Coastal Savannah	Central	12
Komenda Edina Eguafio Abirem	Coastal Savannah	Central	12
Abura Asebu Kwamankese	Coastal Savannah	Central	10
Upper West Akim	Semi-deciduous Forest	Eastern	12
Fanteakwa North	Semi-deciduous Forest	Eastern	10
Upper Manya Krobo	Semi-deciduous Forest	Eastern	10
Total			100

Nematode extraction and identification

Nematodes were extracted from 200 cm³ soil subsamples using the Modified Baermann tray method (Coyne *et al.*, 2007) for 48 hours after carefully breaking up soil lumps and sieving samples through a 1.27 cm mesh. Second stage juveniles of nematodes extracted from the different soil samples were preserved in 4% formalin for identification. Nematodes were counted from 1-ml aliquot of each sample under stereo microscope at magnification 40x. Plant-parasitic nematodes were identified to the genera level using gross body morphological features (Mai & Mullin 1996). Plant-parasitic nematodes were counted and expressed as nematodes per 200 cm³ of soil. For each genus, percent frequency was calculated as the total number of samples in which a particular nematode genus was detected, divided by the total number of samples collected and multiplied by 100 (Osei *et al.*, 2005) to express as a percentage. The relative abundance (RA) of the nematode genus was determined as the

sum of nematodes for all samples containing that genus divided by the number of positive samples (Osei *et al.*, 2005). The values so obtained were expressed as a decimal logarithm ($\log x + 1$). A nematode was regarded as frequent in the soil when it was observed in at least 30% of the soil samples.

Results

Nematode diversity expressed in terms of the number of genera differed between the districts. Seven plant-parasitic nematode genera, namely *Meloidogyne*, *Pratylenchus*, *Rotylenchulus*, *Helicotylenchus*, *Scutellonema*, *Tylenchus* and *Criconemella* were encountered in the survey. All of them belong to the order Tylenchida and of five different families *viz* Meloidogynidae, Pratylenchidae, Hoplolaimidae, Tylenchidae and Criconematidae respectively. *Meloidogyne*, *Pratylenchus*, *Rotylenchulus*, and *Helicotylenchus* nematodes were the most prevalent (100 %) across the districts (Table 2)

TABLE 2

Diversity and occurrence of plant-parasitic nematode genera in sweet potato rhizosphere soil from nine districts in the semi-deciduous forest and coastal savannah zones of Ghana

District	<i>Meloidogyne</i>	<i>Pratylenchus</i>	<i>Rotylenchulus</i>	<i>Helicotylenchus</i>	<i>Scutellonema</i>	<i>Tylenchus</i>	<i>Cricone-mella</i>
Ketu South	+	+	+	+	+	-	-
Akatsi South	+	+	+	+	+	+	+
Ketu North	+	+	+	+	+	+	+
Twifo Heman Lower	+	+	+	+	+	+	-
Denkyira Komenda	+	+	+	+	-	-	-
Edina Eguafo Abirem	+	+	+	+	+	+	-
Abura Asebu Kwamankese	+	+	+	+	+	+	-
Upper West Akim	+	+	+	+	+	+	-
Fanteakwa North	+	+	+	+	+	-	-
Upper Manya Krobo	+	+	+	+	+	+	-

+ = Present, - = Absent

Meloidogyne was the most frequently encountered nematode genus extracted from all samples collected. Seven of the districts recorded 100 % *Meloidogyne* populations in the soil samples with Upper West Akim and Fanteakwa North districts recording 80 and 90 % incidence of *Meloidogyne* spp. respectively (Fig 1). *Rotylenchulus* spp. recorded 100

% incidence in soil samples collected from farms in Ketu South, Komenda Edina Eguafo Abirrem and Abura Asebu Kwamankese but was present in 50 % of soils from Upper Manya Krobo district. Similarly, in Ketu South, Komenda Edina Eguafo Abirem and Abura Asebu Kwamankese districts, *Helicotylenchus* spp. were observed in every sample (Fig. 1).

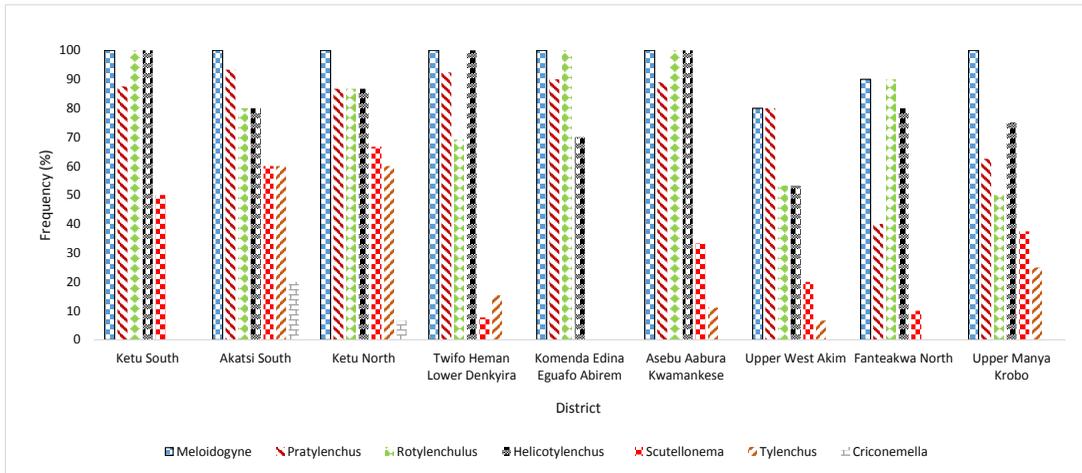


Fig. 1: Frequency of plant-parasitic nematodes genera recovered from soils of sweet potato from different districts in semi-deciduous forest and coastal savannah of Ghana

The highest total nematodes density (all genera) of 4226 per 200 cm³ was observed in samples from Abura Asebu Kwamankese district with Ketu South district recording the least plant-parasitic nematodes density of 918 per 200cm³ (Table 3). *Meloidogyne* population density (7278.8 per 200 cm³) was highest (Table 3). Of all the districts, Komenda Edina Eguafo Abirem recorded the highest number of *Meloidogyne* individuals (Table 3). Contrary, larger populations of *Rotylenchulus* were recovered from both Abura Asebu Kwamankese and Fanteakwa

North districts in coastal savannah and semi-deciduous forest zones respectively (Table 3). *Criconebella* spp, did not only record the lowest incidence (Fig.1) but also was the least abundant (Fig. 2). Generally, *Meloidogyne* spp. were the most abundant across the districts except in Fanteakwa North and Abura Asebu Kwamankese where *Rotylenchulus* nematodes were the most abundant recording 47 and 33 % respectively (Fig. 2). In three districts; Upper Manya Krobo, Akatsi South and Ketu South, *Meloidogyne* spp. relative abundance was more than 50 % (Fig. 2).

TABLE 3

Mean number of plant-parasitic nematodes recovered from sweet potato rhizosphere soil in nine districts of the semi-deciduous forest and coastal savannah zones of Ghana

District	Diversity and populations/200 cm ³ of plant-parasitic nematodes							Total
	Meloidogyne	Pratylenchus	Rotylenchulus	Helicotylenchus	Scutellonema	Tylenchus	Cricone-mella	
Ketu South	536.0 (2.7)	90.1 (2.0)	163.6 (2.2)	87.6 (1.9)	41.1 (1.6)	0.0 (0.0)	0.0 (0.0)	918.4 (3.0)
Akatsi South	949.2 (3.0)	206.9 (2.3)	260.3 (2.4)	64.8 (1.8)	58.3 (1.8)	77.2 (1.9)	11.5 (1.1)	1628.2 (3.2)
Ketu North	542.5 (2.7)	148.7 (2.2)	424.6 (2.6)	102.3 (2.0)	27.5 (1.4)	79.0 (1.9)	2.9 (0.5)	1327.5(3.1)
Twifo Heman Lower Denkyira	1264.0 (3.1)	397.6 (2.6)	339.2 (2.5)	592.9 (2.8)	7.5 (0.9)	61.9 (1.8)	0.0	2663.0 (3.4)
Komenda Edina Eguafo Abirem	1043.0 (3.0)	598.2 (2.8)	313.4 (2.5)	969.0 (3.0)	0.0 (0.0)	0.0 (0.0)	0.0	2924.0 (3.5)
Abura Asebu Kwamankese	1036.0 (3.0)	619.3 (2.8)	1404.0 (3.1)	971.4 (3.0)	183.7 (2.3)	12.0 (1.1)	0.0	4226.0 (3.6)
Upper West Akim	579.0 (2.8)	292.9 (2.5)	441.0 (2.6)	212.0 (2.3)	23.0 (1.4)	2.0 (0.3)	0.0	1550.0 (3.2)
Fanteakwa North	743.0 (2.9)	28.2 (1.5)	1088.0 (3.0)	433.9 (2.7)	10.0 (1.0)	0.0 (0.0)	0.0	2303.0 (3.4)
Upper Manya Krobo	585.9 (2.8)	109.1 (2.0)	97.6 (2.0)	249.3 (2.4)	36.5 (1.6)	157.0 (2.2)	0.0	1235.4 (3.1)
Total	7278.8 (3.9)	2491.0 (3.4)	4531.5 (3.7)	3683.2 (3.6)	387.6 (2.6)	389.1 (2.6)	14.4 (1.2)	18775.6 (4.3)

Figures in brackets are ($\log x + 1$) transformed data

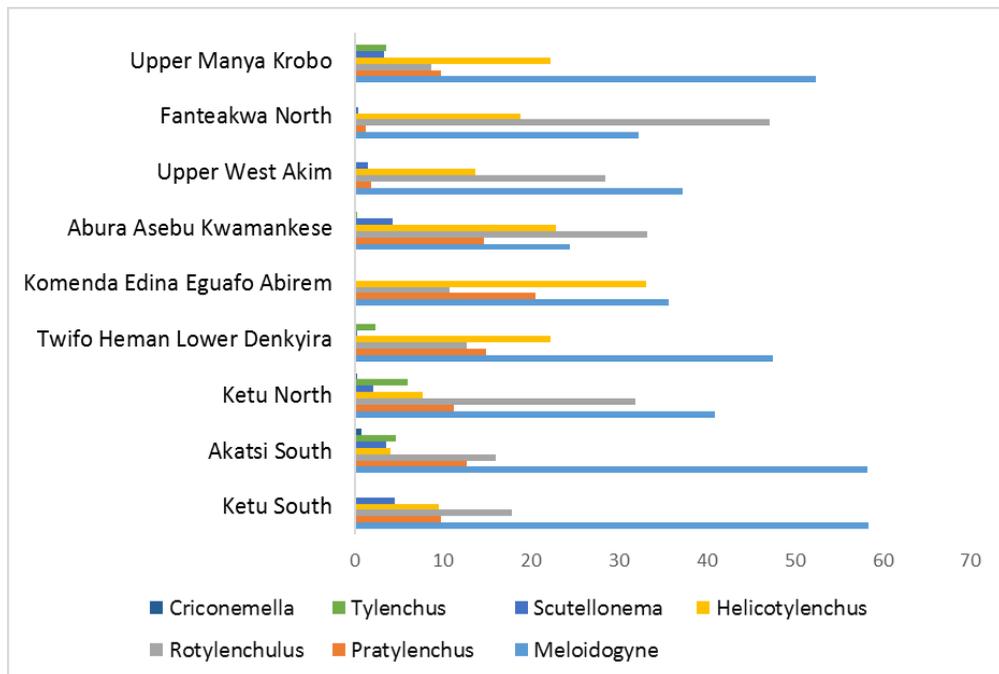


Fig. 2: Relative abundance of plant-parasitic nematodes genera extracted from sweet potato rhizosphere soil in nine districts in the semi-deciduous forest and coastal savannah zones of Ghana

Discussion

Seven plant-parasitic nematodes genera of the order Tylenchida and belonging to five different families were identified in some major sweet potato growing districts of the semi-deciduous forest and coastal savannah zones of Ghana. Nematodes of the order Tylenchida are considered the most important nematode pests of cultivated plants. The nematodes identified in this study are economically important pathogens reported to be associated with sweet potato production (Karuri *et al.*, 2016; Olabiyi *et al.*, 2016; Haougui *et al.*, 2011) in several producing regions globally. The production constraint and losses caused by the activities of plant-parasitic nematodes on sweet potato production may exacerbate due to the limited information, ineffective nematode management strategies employed by farmers and the synergistic interaction between plant nematodes and other microorganisms. *Meloidogyne*, *Rotylenchulus*, *Pratylenchus* and *Helicotylenchus* spp. were the most prevalent nematode pests with high incidence, population densities and abundance in all surveyed farms in the districts. *Meloidogyne* spp. are a globally distributed pest consisting of more than 126 species (Moens *et al.*, 2009). Of these, *M. incognita*, *M. indica*, *M. javanica*, *M. hapla*, *M. graminicola*, *M. arenaria*, and *M. triticooryzae* are considered the most destructive and devastating threat to crop production (Mangala & Mauria, 2006; Jones *et al.* 2013; Postnikova *et al.*, 2015). Root-knot nematodes are serious pests of sweet potato and cause high economic damage through the penetration of roots by the infective juveniles. Their penetrative activities lead to gall formation on roots of the plant leading to a reduced uptake of water and nutrients leading to stunted growth, leaf chlorosis, abnormal flower production and low yields. The extent of damage on crops has been found to depend on factors such as

the initial population density of the pest and susceptibility of the cultivar. High population density of *Meloidogyne* spp., across the districts therefore pose serious threat to sweet potato production as continuous cultivation of susceptible cultivars may cause higher yield loss to farmers.

The association and parasitism of the reniform nematode, *Rotylenchulus* spp. on sweet potato have been reported under both field and screen house studies (Montasser *et al.*, 2019; Karuri *et al.*, 2016). This nematode species unlike *Meloidogyne*, reduces yield in sweet potato through pruning of roots leading to reduced absorption of nutrients and water. Again, their activities reduce host quality by causing deeper root cracks leading to low storage quality of sweet potato (Henn, 2006). Understanding the interaction between nematode species is key for effective management. It was observed that at both Abura Asebu Kwamankese and Fanteakwa North districts, high reniform nematodes population led to reduction in population of *Meloidogyne* spp. Osman *et al.* (2012) reported a reduction in population parameters of root-knot nematodes in the presence of *R. reniformis*. The spiral nematodes, *Helicotylenchus* spp, are common plant-feeding nematodes found in association with several crops including sweet potato (Karuri *et al.*, 2016). Their feeding activities lead to the formation of necrotic lesions in the root which under severe conditions coalesce leading to root necrosis and die-back. Lesion nematodes, *Pratylenchus* spp., are economically important pests to several crops. Its recovery from sweet potato rhizosphere soil in the current study is in line with previous work which identified *P. coffeae*, *P. brachyurus* and *P. goodeyi* (Niere & Karuri, 2018; Coyne *et al.*, 2003) as common and important pest of sweet potato production. In the presence of *Meloidogyne*, these nematodes, according

to Agu (2004), retard leaf growth in sweet potato and cause lesions on both feeder and storage roots. Other nematodes genera such as *Scutellonema*, *Tylenchus* and *Criconemella* spp. recovered from the sweet potato rhizosphere soil in the current study have all been found and reported to be associated with the crop (Kurari *et al.*, 2016 Coyne *et al.*, 2003). The physical environment should not be compromised in attempts to devise management strategies to curb the menace of nematodes in sweet potato production in Ghana.

Conclusion

Based on the results of this study, sweet potato farms across the districts presented high diversity, incidence and abundance of economically important plant-parasitic nematodes. The nematode abundance reported, however, varied due to factors such as edaphic and climatic conditions. Notwithstanding these, the high frequency and abundance of plant-feeding nematodes in the districts deserve the attention of crop protectionists and plant breeders to develop sustainable management strategies and practices against the identified pests to improve yield and enhance livelihood.

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