Prevalence of plant-parasitic nematodes associated with tomatoes in three agro-ecological zones of Ghana

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ABSTRACT

A study was conducted between August 2014 and May 2015 to identify plant-parasitic nematodes taxa associated with tomato (*Solanum lycopersicum* L.) and to assess the knowledge, perceptions and experiences of growers of the crop on occurrence and management of the parasites on their farms in nine communities within the semi-deciduous forest, the forest/savanna transitional and the savanna agro-ecological zones of Ghana. Semi-structured questionnaires were designed and administered to 54 randomly selected growers from the nine communities. Composite rhizosphere soil and tomato root samples were collected from two farms in each of the nine communities, and nematodes extracted, identified and recorded. The study revealed that many growers (73%) could not distinguish between nematode infestation, nutrient deficiency and moisture stress and, therefore, lacked knowledge on nematode control. Most of the growers (63%) continually cropped their land to tomato for periods of 4 –7 years without fallowing. All growers applied only inorganic fertilizer to their crops. Symptoms of nematode infestation were widespread in fields with high yield losses. Tomato was a host to *Helicotylenchus* spp. (11.5% in soil), *Hoplolaimus* spp. (1.0 % in soil), *Meloidogyne* spp. (37.4% in soil and 69.3% in roots), *Pratylenchus* spp. (20.6% in soil and 13.7% in roots), *Rotylenchulus* spp. (11.0% in soil and 12.2% in roots), *Scutellonema* spp. (9.5% in soil and 4.9% in roots), *Tylenchus* spp.(7.6% in soil) and *Xiphinema* spp.(1.4% in soil) across the nine communities surveyed. Semi-deciduous forest and Savanna agro-ecological zones had the highest and least population densities of nematodes, respectively. These nematodes, if not managed efficiently, could also serve as constraint to tomato production in the country.

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetables in the world, second only to potato in terms of consumption (Panthee & Chen, 2009). The crop is a major source of lycopene, a dietary carotenoid (Di Mascio *et al.,*1998), which is known to combat cancer, heart diseases and premature aging (Wener, 2000). Tomatoes are also high in vitamins A, B and C and contain good amounts of potassium, iron, and phosphorus (Wener, 2000). The crop is low in saturated fat, cholesterol and sodium. Cooking or processing it is actually beneficial to health because it increases the bioavailability of lycopene as heating up tomato breaks down its cell walls and release more lycopene.

It is regarded as a high value cash crop and cultivated by many households in all the agro-ecological zones of Ghana (Diao, 2010). The crop alone makes up to 38 per cent of vegetable expenditure in Ghana (Wolff, 1999). Cultivation of the crop has been an important economic activity in Ghana, especially in the Upper East, BrongAhafo and Ashanti regions with yield estimates up to 7.5 metric tonnes per hectare (Robinson & Kolavali, 2010). Production of tomato in Ghana is seasonal and varies within agro ecological zones as a result of the variable climatic conditions experienced in the country and for that matter moisture availability for production in the various production zones (Amikuzuno & Ihle, 2010). Most of the tomato in Ghana is produced under rain fed conditions with the exception of the Upper East Region where it is cultivated under irrigation (Robinson & Kolavali, 2010). Dry season irrigation production in the Upper East Region supplies markets with fresh tomatoes from late December to April or May while the Southern zone notably Ashanti BrongAhafo regions supply the country from June to December (Robinson & Kolavali, 2010).

Average tomato yields in the country appear to be in decline despite its importance (Robinson & Kolavalli, 2010). The total land area under tomato cultivation in 2004 was 29,561 ha with an average yield of 7.56 t/ha. However, in 2013, average yield of tomato fell to 7.38 t/ha on 46,100 ha of land (FAOSTAT, 2013). This can be attributed to several factors with the most important being the susceptibility of the crop to various diseases including plant parasitic nematodes.

Plant-parasitic nematodes account for annual worldwide agricultural losses of close to $80 billion (Agrios, 2005). In Ghana, tomato yield losses of between 73 per cent and 100 per cent due to nematodes have been reported (Hemeng, 1981). Osei *et al*., (2012) have also observed plant-parasitic nematodes associated with tomato. Typical symptoms of nematode injury can involve both above ground and below ground plant parts. Foliar symptoms of nematode infestation of roots generally involve stunting and general unthriftiness, premature wilting and slow recovery to improved soil moisture conditions, leaf chlorosis and other symptoms characteristic of nutrient deficiency (Agrios, 2005). Nematode diseases are difficult to manage because, above ground symptoms usually result from below ground infections, which are not easily observed by growers. Nematode damage to most crops is usually always related to the initial numbers of the nematode in soil. Control strategies are, therefore, aimed at reducing these initial numbers (McSorley & Gallaher, 1991). These strategies generally can be divided into non-chemical treatments and chemical treatments. Non-chemical treatments include soil solarization and hot water treatment of planting materials, crop rotation and use of cover crops, rogueing and burning diseased plants, land fallowing, flooding, organic amendments, use of nematode-suppressive plants, ploughing, biological control, and host plant resistance. The chemical treatment on the other hand involves the use of synthetic nematicides.

Sustainable tomato production can only be achieved through knowledge of occurrence and management of nematodes parasitizing tomato. Furthermore, understanding the diversity, current distribution and population densities of plant parasitic nematodes is very essential for the implementation of nematode management strategies. Therefore, a survey was conducted in Ghana in 2014 to assess tomato growers' knowledge, perceptions, and experiences on plant-parasitic nematode occurrence and their management in the semi-deciduous forest, forest/ savanna transitional, and savanna agro-ecological zones of the country. The survey was also to identify taxa of plant-parasitic nematodes associated with tomato in these agro-ecological zones.

Materials and methods

Selection of sites for questionnaire survey and collection of soil and root sample

Three communities were purposefully selected from each of the three agro-ecological zones where tomato is widely produced (Table1). These communities were Afrancho, Akumadan and Asuosu in the semi-deciduous forest agro-ecological zone, Tanoso, Techimantia and

Tuobodom in the forest/savanna transitional agro-ecological zone, and Pwalugu, Vea and Tono in the savanna agro-ecological zone.

The semi deciduous rain forest is characterized by a bimodal rainfall pattern, a major rainy season which occurs around March to July and a minor one which occurs around September to November (FAO, 2014). Average annual rainfall is 1500 mm. The soils are mostly porous, well drained and generally loamy. Soils here are distinguished from those of the savannah zone by the greater amounts of organic matter (1.5 – 3.0 %) in the surface resulting from higher accumulation of biomass (Oppong-Anane, 2001). The forest/savanna transitional zone is also characterized by a bimodal rainfall pattern, a major rainy season which occurs around March to July and a minor one which occurs around September to November (FAO, 2014). Average annual rainfall is 1300 mm. The soils here are well drained and loamy. There is an appreciable accumulation of organic matter (0.3 – 1.7 %) in the surface (Oppong-Anane, 2001). The savanna zone is characterized by a unimodal rainfall pattern which occurs around May to September (FAO, 2014). Average annual rainfall is 1000 mm. Soils of the savanna zone, are low in organic matter (less than 1.5% in the topsoil), have high levels of iron concentrations and are susceptible to severe erosion (Oppong-Anane, 2001).

Two farms were selected at random from each community for soil and tomato root samples collection and their owners interviewed with a questionnaire including four other growers.

TABLE 1

Selected agro-ecological zones and communities, from which growers were interviewed on plant-parasitic nematode infestations on their farms and soil and root samples collected

Agro-ecological zone	*Community*	** GPS coordinates*	*No. of growers*
Semi-deciduous forest	Afrancho	07° 23’N 01° 57’W	6
	Akumadan	01° 60’W 01° 45’E	6
	Asuosu	05° 59’N 01° 46’W	6
Forest/savanna transitional	Tuobodom	07° 38’N 01° 54’W	6
	Tachimentia	07° 10’N 02° 01’W	6
	Tanoso	07° 27’N 01° 5 8’W	6
Savanna	Vea	10° 45’N 10° 40W	6
	Pwalugu	10° 36’N 00° 51’S	6
	Tono	10° 50’N 01° 5’W	6
Total			54

* GPS coordinates were taken from a single position in each community.

Questionnaire survey to assess grower's knowledge, perception, experiences, and economic impact of plant-parasitic nematodes

A questionnaire survey was conducted in November 2014 to obtain baseline data concerning growers land use intensity, knowledge, perception, and experiences on occurrence and management of plant-parasitic nematodes on their farms. Fifty-four (54) tomato growers with varying farm sizes were randomly selected from the study areas in the three agro-ecological zones and interviewed with pre-tested semi-structured questionnaires. Pictures of nematode infested plants showing symptoms were included to facilitate farmer's responses.

Collection of rhizosphere soil and root samples of tomato

Tomato roots and rhizosphere soils were collected in November, 2014. Two farms (1 acre) each from the nine communities were randomly selected and sampled over a period of three weeks for the presence of nematodes. Composite soil samples were taken from the rhizosphere of tomato plants on each of the farms and root samples of tomato plants whose rhizosphere soil were sampled collected. The samples for this study were collected from farms with well-established tomato plants (Pectomech), these were obtained from farms when the soil had the optimum amount of moisture (40 - 60% field capacity). The soil samples were taken from depths of 15 cm and 30 cm and bulked together using a 5 cm diameter soil core from 10 randomly selected sites. The soil core and footwear were cleaned after sampling each farm to avoid cross-contamination of soil samples and spread of nematodes between farms. GPS coordinates of each farm was captured with a handheld GPS device (Garmin eTrex 20, Switzerland).

Assessment of root knot nematode galls on tomato roots

Tomato roots were washed separately and dried with tissue paper. Galling was scored using the rating chart by Bridge & Page (1980) presented below:

0 = no knots on roots
1 = few small knots difficult to find
2 = small knots only but clearly visible; main roots clean
3 = some larger knots visible, but main roots clean
4 = larger knots predominate but main roots clean
5 = 50% of roots knotted; knotting on parts of main root system
6 = knotting on some of main roots
7 = majority of main roots knotted
8 = all main roots knotted; few clean roots visible
9 = all roots severely knotted; plant usually dying
10 = all roots severely knotted; no root

Extraction and identification of nematodes

Nematodes were extracted from the soil using the sieve and sucrose centrifugation method. Each soil sample was thoroughly mixed and a 200 cm^3 subsample was used for the extraction, identification and quantification of the nematodes. The infested soil was placed in a bucket of running water until the soil was covered by at least two times its volume. The solution was then mixed vigorously until the soil was sufficiently dispersed and then allowed to settle for 3 min. The liquid supernatant was then poured through a 200 mesh sieve nested onto a 400 mesh sieve. The 400 mesh sieve was washed thoroughly with water until as much clay and other fine particles were washed out of the sieve. The remaining sample with the nematodes was then transferred into a 50 ml centrifuge tube. Centrifugation was carried out at 1700 rpm for 5 min in a MR 23i benchtop centrifuge (Jouan – Thermo Scientific, U.S.A.). The supernatant was discarded and, if necessary, successive samples centrifuged until a final pellet was obtained from the collective population of nematodes. The tubes were filled with sucrose solution at room temperature and stirred with a spatula to break up the pellet. The sample was centrifuged to 1000 rpm for 1 min and the supernatant poured through the 400 mesh sieve and transferred into labeled vials up to 10 ml mark using a fine spray water bottle.

Nematodes were extracted from infested tomato roots, using modified Baermann funnel method (Whitehead, 1968). The roots were chopped into 1 cm pieces and about 10 g was blended for two to five second bursts and transferred to a glass funnel lined with a two ply tissue paper placed on a wire mesh. Funnels were left for 48 h and the water (containing nematodes) was poured separately into 250 ml beakers. 2 ml of each suspension were transferred to counting dishes for recording. Nematodes selected for identification were mounted in a drop of water on a microscopic slide and placed on a hot plate at 60 ^{o}C for few seconds, which enabled nematodes to straighten out. Extracted nematodes were examined directly under a compound light microscope (Exacta – OptechBiostar B5P, Germany). Nematodes were identified to the genus or species level based on their morphological features as described by Siddiqi (1989), Luc *et al,* (1990), Siddiqi (2000) and the University of Nebraska Lincoln nematode identification website and recorded.

Data analysis

Population density (PD) of nematodes per 200 cm^3 of soil and 10 g plant root samples, frequency of occurrence (FO) and relative percentage of abundance (RA%) were calculated according to Norton (1978) as follows: PD = average number of nematodes per 200 cm^3 of soil and 10 g plant root samples, FO = (number of fields containing a particular genus or species /total number of fields sampled) and RA% = the number of individuals of a nematode genus or species / the total number of nematodes identified and counted from 200 cm^3 soil or 10 g tomato root ×100. Regression analysis was performed on the data for nematodes in 200 cm^3 rhizosphere soils and 10 g tomato roots obtained from the nine localities using General Statistics (Genstat) version 12.0.

Results

Growers' knowledge and perceptions of plant-parasitic nematodes occurrence and their control

The survey indicated varied educational levels among the growers with most of them (51.9%), attaining only primary education, 44.4 per cent attaining secondary education and only 3.7 percent attaining tertiary education (Table 2). Most of the growers (63%) continually cropped their tomato fields for 4 - 7 years, whiles others (22.2%), cultivated tomato on the same piece of land for 7-10 years, without any form of fallowing. A few growers (13%) cropped their land for 1-3 years and only 1.9 percent of them cropped theirs for more than 11 years (Table 2). This study revealed that, 63 percent of the growers in the study areas, practiced crop rotation, whiles the remaining 37 percent, never rotated their tomato with any crop. All the growers interviewed applied only inorganic fertilizers on their fields in the course of the growing season. Majority of the growers (55.6%) across the three agro-ecological zones sourced their tomato seeds from certified agro dealers. About 42.5 percent of the growers used their own seeds from previous harvest, whiles only 1.9 percent got theirs from friends and neighbours. Majority of growers (79.6%), had no knowledge on plant-parasitic nematodes, and therefore, could not distinguish among stress from nematode infestations, nutrient deficiencies, and moisture. However, other farmers (20.4%), had some knowledge about plant-parasitic nematodes. Varieties of tomato mostly cultivated across the areas surveyed were Pectomech (60%), Wosowoso (26%), Powerano (10%), and an unnamed variety (4%).

All the growers indicated that all the varieties showed symptoms similar to the pictures of nematode infested plants shown them during the interview but could not tell which variety was more susceptible compared to the other. Approximately 45 percent of the growers had no idea as to how they were spread within and among farms, while 21.6 percent attributed their spread to rain (Table 2). A few farmers (20.6%) thought the spread of these symptoms were associated with the planting of infected seeds, whilst 12.5 percent perceived the spread to be soil borne. About 66 percent of growers indicated that nematodes could not be controlled, however, 34 percent of them indicated that control of nematodes was possible. Among those that believed nematodes could be controlled, 74.5 percent, 8.9 percent and 6.8 percent stressed application of appropriate chemicals, use of healthy seeds, and land fallowing, would effectively control nematodes, respectively (Table 2). About 9.8 percent of the respondents had no idea of any control measure for nematodes. Approximately 33 percent of growers estimated to harvest between 0.73 - 0.96 t/ha each season, whiles only 3.7 percent estimated to harvest between 0.36 – 0.48 t/ha per season. About 35 percent, however, realized yields of 0.49 – 0.72 t/ha per season. The highest yield (1.81- 2.40 t/ha) was realized by only 3.4 per cent of the growers and the lowest (less than 0.24 t/ha) realized by 17.5% of growers. Majority (63.7%) of the respondents attributed yield losses to the high incidence of nematode diseases (based on the pictures).

TABLE 2

Farmers' knowledge, perception and experience of plant parasitic nematodes on their tomato farms

Educational levels of growers	*Percentage of growers (%)*
Primary	51.9
Secondary	44.4
Tertiary	3.7
Period of cultivation	
1 – 3 years	13
4 – 6 years	63
7 – 10 years	22.2
11–15 years	1.9
Source of seeds for planting	
Agro dealers	55.6
Previous harvest	42.5
Friends/ Neighbours	1.9
Growers perception of plant parasitic nematodes pathogens	
Awareness	79.6
Ignorance	20.4
Growers perception of spread of nematode diseases	
Rain water	21.6
Infected seeds	20.6
Soil	12.5
No idea	45
Growers perception of control of nematode diseases	
Not controllable	66
Controllable	34
Growers that believe control was possible	
Means of control	
Use of appropriate chemicals	74.5
Use of healthy seeds	8.9
Land fallow	6.8
No idea	9.8

Identified taxa of plant-parasitic nematodes on tomato in nine communities sampled

Eight genera or species of plant-parasitic nematodes were consistently extracted from tomato roots and rhizosphere soil obtained from growers' fields across the three agro-ecological zones of Ghana. These nematodes consisted of *Helicotylenchus* spp, *Hoplolaimus* spp., *Meloidogyne* spp., *Pratylenchus* spp., *Rotylenchulus* spp., *Scutellonema* spp., *Tylenchus* spp. and *Xiphinema* spp. from soil. *Meloidogyne* spp, *Pratylenchus* spp, *Rotylenchulus* spp. and *Scutellonema* spp. were also isolated from tomato roots. All nematodes belonged to the order Tylenchida with the exception of *Xiphinema* spp. which belonged to the order Dorylaimida.

Semi-deciduous forest zone recorded seven of the identified taxa of nematodes, whilst Savanna and the forest/savanna transitional zones recorded all eight taxa of nematodes. Savanna zone recorded the least nematode density (91), while semi-deciduous forest zone had the greatest nematode density (258) out of a total of 580 individual nematodes identified in 200 cm^3 of soil. Afrancho (in semi-deciduous forest zone) had the highest densities of *Helicotylenchus* spp. (20), *Rotylenchulus* spp. (16) and *Scutellonema* spp. (11) and *Tylenchus*spp. (19), while Akumadan (in semi-deciduous forestzone) had the highest density of *Meloidogyne* spp. (45) (Table 3).

Two hundred and five nematodes were extracted, identified and counted from root samples collected from the nine communities in the semi-deciduous forest, transitional and savanna agro-ecological zones of Ghana. The semi-deciduous forest and transitional agro-ecological zones had all four taxa of nematodes identified (Table 3). Afrancho had the highest nematode densities of *Pratylenchus* spp. (7), *Rotylenchulus* spp.(6) and *Scutellonema* spp. (4), while Tuobodom and Tachimantia had the highest density of *Meloidogyne* spp. (28) (Table 3).

TABLE 3

Diversity and density of taxa of plant-parasitic nematodes (200 cm^3 soil and 10 g tomato roots) from nine communities in the Semi-deciduous forest, forest/savanna transitional, and savannaagro-ecological zones of Ghana

Community	*Meloi*		*Praty*		*Helico*	*Roty*		*Scutello*		*Tylen*	*Xiphi*
	Soil	Roots	Soil	Roots	Soil	Soil	Roots	Soil	Roots	Soil	Soil
Afrancho	39	17	16	7	20	16	6	11	4	19	2
Akumadan	45	15	11	3	5	11	3	3	1	3	0
Asuosu	15	8	6	3	3	3	2	6	1	1	0
Tuobodom	40	28	22	5	10	10	6	7	3	6	0
Techimantia	16	28	9	3	8	4	0	8	0	2	1
Tanoso	25	13	22	3	13	10	4	7	1	6	0
Vea	10	10	3	0	3	2	0	4	0	3	2
Pwalugu	12	12	2	1	4	4	3	2	0	3	1
Tono	15	11	9	2	1	2	1	3	0	1	2

Values are counts of each nematode genus from corresponding community.
Meloi = *Meloidogyne* spp., Praty = *Pratylenchus* spp., Helico = *Helicotylenchus* spp., Roty = *Rotylenchulus* spp., Scutello = *Scutellonema* spp., Tylen = *Tylenchus* spp., Xiphi = *Xiphinema* spp.

Helicotylenchus spp., *Meloidogyne* spp. and *Rotylenchulus* spp. were present in the soils of all the farms sampled (Table 3). *Xiphinema* spp. were present in the soils of only five of the 18 farms sampled. *Meloidogyne* spp. was the most abundant nematode genus (relative abundance of 37.4%); *Pratylenchus* spp. had a relative abundance of 20.5 percent. *Scutellonema* spp. and *Tylenchus* spp. had lower relative abundance although they were found in the soils of all communities (Table 4). *Meloidogyne* spp. were identified in the tomato roots of all the farms sampled, while *Scutellonema* spp. were present in tomato roots of only five of the eighteen farms sampled. *Meloidogyne* spp. and *Scutellonema* spp. had the most (69.3%) and least (4.9%) abundant nematode genera in the tomato root samples respectively (Table 3).

TABLE 4

Frequency of occurrence of plant-parasitic nematodes and their relative abundance ($200\ cm^3$ soil) from nine communities sampled

Nematode genus	*FO*		*RA (%)*	
	Soil	*Roots*	*Soil*	*Roots*
Helicotylenchus spp.	18[a]	-	11.55[b]	-
Hoplolaimus spp.	8	-	1.03	-
Meloidogyne spp.	18	18[a]	37.41	69.27[b]
Pratylenchus spp.	16	14	20.52	13.66
Rotylenchulus spp.	18	12	11.03	12.20
Scutellonema spp.	14	5	9.48	4.88
Tylenchus spp.	10	-	7.59	-
Xiphinema spp.	5	-	1.38	-

[a] Represent number of farms where corresponding genera of nematodes were recovered.

[b] Represent relative abundance (%) of each nematode genus given as (n/N *x* 100). n = the number of individuals of nematode genus, N = the total number of nematodes identified and counted from soil.

Regression Analysis on plant-parasitic nematodes in soil and tomato root samples from nine communities sampled

When population densities of nematodes in 10 g of tomato roots and 200 cm3 of rhizosphere soil were regressed, the analysis revealed a positive relationship ($P < 0.05$, $R2 = 0.55$) between the population of plant parasitic nematode in the soil and those obtained from the roots. The mean change in the population density of plant parasitic nematodes in 200 cm3 of rhizosphere soil for a unit change in their population density in 10 g of tomato roots was about three nematodes (Fig. 1)

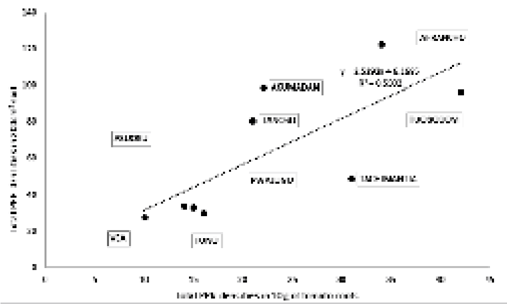

Fig. 1. Relationship between plant parasitic nema-todes recovered from 200 cm^3 of soil from root rhizos-phere and 10 g of tomato roots from

Root gall index (RGI) of tomato roots

Root galling indices of tomato (cv. pecto-mech) roots ranged from 2.0 to 7.0 (Table 5). Afrancho, Akumadan and Asuosu all in the semi deciduous forest zone recorded galling indices of 6.0, 6.3 and 5.0, respectively. Roots from Pwalugu and Tono also in savanna zone recor-ded indices of 6.3 and 2.3 respectively. Tomato roots from Tuobodom (7.0) and Vea (2.0) were the most and least galled respectively (Fig. 2).

TABLE 5

Tomato root galling indices of the mean of three tomato roots each from nine communities in Semi-deciduous forest, Forest/savanna transitional and Savanna agro-ecological zones of Ghana

Community	*Root gall index*
Afrancho	6.0
Akumadan	6.3
Asuosu	5.0
Tuobodom	7.0
Techimantia	5.3
Tanoso	5.6
Vea	2.0
Pwalugu	6.3
Tono	2.3

Fig. 2. Diseased tomato roots from Tuobodom showing galls (red arrows) (A) and healthy tomato roots from Vea (B).

Discussion

The survey showed that majority of growers had very little formal education. Most people with higher education perhaps, opted for jobs in the cities and, thus, had left farming activities in the hands of those with little or no formal education (Sessey, 2013). The general lack of knowledge of tomato growers about nematodes may have contributed to the high prevalence of nematode diseases often resulting from improper cultural practices such as non-removal of weeds during the off-season, which may serve as alternative hosts for these pests. Another observation relates to the growers not applying manure or organic fertilizers to their fields during the growing season, which had a negative impact on their crops. Adding manures to fields leads to increase in free-living and predatory nematodes populations, and results in decreased numbers of plant-parasitic nematodes (Nahar *et al*., 2006; Oka, 2010; Wachira *et al*., 2009).

Organic matter releases toxic compounds in the soil, thus, suppressing the persistence of nematodes and also changes the soil's microfauna and microflora. The organic matter, therefore, positively influences the activities of microorganisms, which aid in the control of nematodes. Land fallowing is among the methods for nematode control especially when these fields are left uncultivated for about 2 years (Flint, 1999). The identified growers cultivating their tomato fields for long periods without practicing any form of fallowing. A higher number of nematodes were recovered in the tomato rhizosphere soils and roots around the semi-deciduous forest and forest/savanna transitional agro-ecological zones, compared to the savanna agro-ecological zone of the country. The semi-deciduous forest and forest/savanna transitional zones received relatively high amounts of rainfall, thus, the soils had high moisture content most part of the year (FAO, 2014); thereby, creating a conducive environment for nematodes to thrive and infect tomato and other crops. However, the very high temperatures and long drought spells in the savanna agro-ecological zone, probably accounted for the comparatively lower nematode densities in that agro-ecological zone.

The numbers of nematodes recovered from this survey were by far fewer than nematode numbers reported by Osei *et al*., (2012), in a survey of plant parasitic nematodes in Ghana. However, the interaction between plant-parasitic nematodes and other plant-pathogenic soil organisms, particularly fungi and bacteria, in the development of disease complexes makes nematodes very important even at very low densities. Furthermore, the high reproductive rates of plant- parasitic nematodes under favourable soil conditions (Ananhirunsalee *et al.,* 1995), together with their short life cycle of about 30 days (Crow & Dunn, 2005); might result in a rapid build-up of the nematode population during the growing season and, therefore, cause serious economic damage to crops.

Meloidogyne spp. was the most prevalent nematode isolated from both soil and root samples. This nematode has been reported as the most important species affecting tomato worldwide (Sasser & Freckman, 1987). Osei *et al.,* (2012) in a previous survey, reported *M. incognita* as the most abundant nematode species on tomato in Ghana. *Rotylenchulus* spp. and *Pratylenchus* spp. were also identified in the isolations and have been found to parasitize tomato roots in several countries (Robinson *et al.*, 1997; Sikora & Fernandez, 2005), including Ghana (Osei *et al*., 2012). Therefore, these nematodes, if not managed, could also serve as constraints to tomato production. *Tylenchus* spp. were also encountered in the survey, but were not found by Osei *et al.,* (2012). *Tylenchus* spp., however, have been found to feed on algae, mosses, lichens and plant roots (Yeates, 1993) and, therefore, pose little threat to tomato production. *Helicotylenchus* spp., *Hoplolaimus* spp. and *Xiphinema* spp., which are known pests of vegetables and other crops, need to have their economic importance assessed. However, these nematodes, if not managed effectively, could also serve as constraint to tomato production. Representative populations from the various fields should be tested for their pathogenicity, through the use of genotypes with inherent resistance to enable exploration of the presence of biotypes of *Meloidogyne* spp. in Ghanaian soils, if available.

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