African Crop Science Journal, Vol. 16, No. 2, pp. 119 - 131
ISSN 1021-9730/2008 $4.00

OCCURRENCE OF PLANT PARASITIC NEMATODES AND FACTORS THAT ENHANCE POPULATION BUILD-UP IN CEREAL-BASED CROPPING SYSTEMS IN UGANDA

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(Received 3 December 2007; accepted 5 May, 2008)

ABSTRACT

Plant parasitic nematodes remain a major challenge to crop production that has hitherto received minmum research attention in sub-Saharan Africa. This paper gives the diversity of nematode genera and species associated with cereal crops and indicates the possibility of nemadode population build up due to production intensification especially in soils with high sand content. Twenty-two nematode species from 10 genera of plant parasitic nematodes were recovered in root samples collected from 5 cereal crops (barley, maize, millet, sorghum and wheat) collected from 293 sites in five major cereal growing areas of Uganda (230 maize samples, 18 millet samples, 21 sorghum samples, 18 wheat samples and 6 barley samples), grown singly or as intercrops. Of these, 12 nematode species were encountered in maize roots, namely *Aphelenchoides arachides*, *Aphelenchoides eltaybi*, *Ditylenchus* spp, *Helicotylenchus dihystera, Meloidogyne* spp., *Pratylenchus brachyurus, Pratylenchus goodeyi, Pratylenchus zeae, Scutellonema brachyurus, Scutellonema paralabiatum, Scutellonema clathricaudatum* and *Rotylenchulus borealis*. Based on populations of the nematode species recovered, four distinct nematode groupings were observed: those that were widespread and abundant (*Pratylenchus zeae* and *P. brachyurus*); those that were widespread but less abundant (*Scutellonema* spp., *Meloidogyne* spp., *Rotylenchulus* spp. and *Helicotylenchus* spp.); those that were localized but very abundant (*Pratylenchus goodeyi*), and those that were localized but less abundant (*Aphelenchoides* spp. and *Ditylenchus* spp.). Intensified maize cropping systems with/without non-cereal rotations increased risk of *Pratylenchus zeae, Scutellonema* spp. and *Helicotylenchus* spp. infection of maize.

Key Words: Barley, maize, *Meloidogyne* spp., millet, *Pratylenchus* spp., *Scutellonema* spp., sorghum, wheat

RÉSUMÉ

Les nématodes parasites des plantes demeurent un défi important à la production végétale qui a jusqu'ici suscité une faible attention de la part de la recherche en Afrique sous-Saharien. Cet article présente la diversité des genres et des espèces de nématode associés aux plantes céréalières et indique la possibilité d'accumulation de population de nemadodes due à l'intensification de la production, particulièrement dans les sols avec teneur élevée en sable. Vingt-deux espèces de 10 genres de nématodes parasites de plantes ont été récupérées dans des échantillons de racines colectées à partir de 5 plantes céréalières (orge, maïs, millet, sorgho et blé) rassemblées à partir de 293 sites dans cinq principales régions de production céréalières de l'Ouganda (230 échantillons de maïs, 18 échantillons de millet, 21 échantillons de sorgho, 18 échantillons de blé et 6 échantillons d'orge), cultivés en monoculture ou en cultures mixtes. De ces derniers, 12 espèces de nématodes ont été identifiées dans les racines de maïs. Il s'agit de *Aphelenchoides arachides, Aphelenchoides eltaybi, Ditylenchus* spp, *Helicotylenchus dihystera, Meloidogyne* spp., *Pratylenchus brachyurus*, *Pratylenchus goodeyi, Pratylenchus zeae, Scutellonema brachyurus, Scutellonema paralabiatum, Scutellonema clathricaudatum* et *Rotylenchulus borealis*. En référence aux populations de nématodes récupérées, quatre regroupements distincts de nématodes étaient observés : ceux qui étaient plus répandus et abondants (*Pratylenchus zeae* et *P. brachyurus*); ceux qui étaient très répandus mais moins abondants (*Aphelenchoides* spp. et *Ditylenchus* spp.) ; ceux qui ont été localisés mais très abondant (*Pratylenchus goodeyi*), et ceux qui ont été localisés mais moins abondant (*Aphelenchoides* spp. et *Ditylenchus* spp.). Le système de cultures intensifiées de maïs avec ou sans rotations d'autres cultures non céréalières augmente le risque d'infection du maïs par *Pratylenchus zeae*, *Scutellonema* spp. et *Helicotylenchus* spp.

Mots Clés: Orge, maïs, *Meloidogyne* spp., millet, *Pratylenchus* spp., *Scutellonema* spp., sorgho, blé

INTRODUCTION

Cereals constitute the world's most important food crops. This is due to their great adaptability, permitting successful colonisation in every type of ecological habitat; relative ease of cultivation; tillering habit giving higher yield per unit area; and good nutritive values (Vasil, 1999).

Among cereals, wheat, maize *(Zea mays)* and rice *(Oryza sativa)* occupy the most eminent positions in terms of production, acreage and source of nutrition, particularly in developing countries (CIMMYT, 1992). In Uganda, maize *(Zea mays)*, finger millet *(Eleusine coracana)*, sorghum *(Sorghum bicolar)* and rice *(Oryza sativa)* are the major cereal crops grown, maize being the most important cereal crop grown countrywide. It is a major staple in many rural and urban communities and has also recently been identified as one of the non-traditional cash crops.

Finger millet is the principal cereal grain and staple in northern, eastern and parts of western Uganda. Sorghum is drought-resistant and regularly out-yields maize in many drier parts of Uganda, it is more resistant to water logging and yields well in infertile soils and can be ratooned. Rice has gained popularity in Uganda because of its diversity and adaptability, high commercial value, high acceptance as food (because of its palatability and ease to cook), and ease to store and transport. It is grown as a rain-fed lowland crop in much of the Eastern and part of Northern Uganda, or upland crop in other parts of Northern and Western Uganda (Laker-Ojok, 1994; MAAIF, 1997).

Several introductions of new cereal varieties with various improved traits have been made to improve cereal production worldwide, but in many instances the yield potential of the new varieties has not been fully expressed. Production constraints of cereals are many including both abiotic and biotic factors, but establishing the relative importance of individual production constraints is often challenging. Pests and diseases of cereals have long been recognised as important constraints to cereals production worldwide and have received extensive research. However, plant parasitic nematodes have remained largely excluded from research attention. Data on the importance of nematodes, particularly individual species occurrence and community composition, population densities and pathogenicity are meagre. Moreover, plant parasitic nematodes have been reported to constitute serious impediment to cereal production in different areas of the world (De Waele and McDonald, 2000; Kollo, 2002; Nicol, 2002; Bridge *et al*., 2005; McDonald and Nicol, 2005).

In Uganda, nematological research on cereals has not received much attention, and there is no record of nematode pests occurring on cereals in the country. Previous studies have listed plant parasitic nematodes associated with banana (Kashaija *et al*., 1994) and root and tuber crops (Coyne *et al*., 2003); with some species found to be more parasitic and pathogenic causing economic losses to these crops; for example, *Meloidogyne* spp. on cassava *(Manihot esculenta)* (Coyne and Talwana, 2000), *Radopholus similis*, *Pratylenchus goodeyi* and *Helicotylenchus multicinctus* on banana (Speijer and Kajumba, 2000), *Meloidogyne* spp. and *Pratylenchus sudanensis* on yams *(Dioscorea* spp.*)* (Mudiope *et al*., 1998). Therefore, it is anticipated that plant parasitic nematodes do occur on cereals and can pose a significant threat to their production in Uganda.

The objective of this study was to assess the occurrence and distribution of the most common plant parasitic nematodes on cereal crops in Uganda and identify factors that enhance their population build-up.

MATERIALS AND METHODS

During 2004, root samples were collected at 293 sites in Uganda from maize (230 fields), millet (18), sorghum (21), wheat (18) and barley (6) in the districts of Iganga, Kapchorwa, Kumi, Masindi and Sironko, which represent the major cereal growing areas in Uganda (Laker-Ojok, 1994). For each field, the geographical position coordinates and altitude were taken using a Magellan® Geographical Positioning system. All fields were situated between 1080-2071m altitudes, the lowest being Kumi and the highest Kapchorwa.

Roots were sampled from 10 individual plants that were randomly selected in each field 10 -12 weeks after planting. Note was made of the above-ground plant symptoms, for examples stunting and chlorosis/yellowing; and below-ground symptoms, for example root necrosis, pruning, and stunting, that may be associated with nematode damage. Roots were pooled per crop per field and when in the laboratory, they were washed, surface-dried using paper tissue, chopped into about 2 cm segments and thoroughly mixed.

A 5 g (fresh weight) sub-sample per sample was taken for nematode extraction using a modified Baermann funnel technique (Hooper *et al*., 2005) after maceration in a kitchen blender. Nematodes were identified to species level using morphometric parameters and counted under a compound microscope. Where no adults existed, nematodes were identified to genus level only. Identifications were confirmed by Drs. Antoinette Swart Mariette Marais and Esther van den Berg, Plant Protection Research Institute, Rietondale, Pretoria, South Africa.

Mean population densities were calculated for each species observed and the maximum density recorded. The nematode counts are presented as numbers in 100 g of fresh root. Nematode numbers consisted of adult females, males and second-stage juveniles. The exception was for sedentary endoparasitic nematodes for which only vermiform males and second-stage juveniles are reported. The frequency of occurrence for each species identified was calculated for each of the five districts. For each species, frequency and relative abundance were determined using the method applied by Adiko (1988) and Kashaija *et al*. (1994). Frequency corresponds to the number of sites where a species occurred. A species was considered widespread when it appeared in more than 30% of the sites. Abundance corresponds to the average number of individuals of a species over the sample sites where the species was present. A species whose mean number was more than 10 individuals per 100 g of roots was considered abundant (Adiko, 1988).

Additionally, two maize fields in each of the districts of Iganga, Kumi, Masindi and Sironko were monitored for nematode population build-up during one growing season. The 4 districts were selected on the basis of maize having higher densities of plant parasitic nematodes during the survey. The fields were monitored for nematodes build-up at 3, 5 and 11 weeks after planting. Weeks 3 – 5 is a period of flower initiation in maize, while week 11 is a period of tassel emergence, which is followed by a long post floral period of 7 – 8 weeks (Purseglove, 1988). Information on cropping patterns, the cropping history, crop phenology, pests, diseases, crops grown, source of planting material, and frequency of cereal cropping, were collected from field observations and through informal farmer interviews. Other parameters included frequency of planting non-cereal crops where cereals were grown, and land and crop (maize) management practices.

Maize roots were sampled from 10 plants randomly selected along two pre-selected rows of 5m length, pooled and processed as described above. Additionally, a representative composite soil sample was obtained from each field for analysis of soil physical and chemical properties, such as soil texture (contents of sand, silt and clay); concentration of phosphorus, potassium, organic matter, nitrogen and pH. Soil texture was determined by total rapid hydrometer method based on Day's (1965) technique. Total nitrogen was determined by the Kjeldal method; available phosphorus by spectrometry exchangeable; potassium, calcium and magnesium by atomic absorption spectrometry (Okalebo e*t al*., 2002).

Regression analysis (backward elimination procedure) was carried out to explore respective causal relationships amongst these variables with nematode populations in roots as the response variable and soil physical properties, chemical properties, and cropping history in eight farmers' fields as the fixed variables.

RESULTS

Across sites, the major above-ground symptom of nematode damage was stunting and chlorosis (yellowing) which occurred in patches at 37% and 45% of the sampled sites, respectively; while the major below-ground symptom was root necrosis observed at 51% of the sites (Table 1). Small black lesions, which are characteristic of lesion nematodes were observed in 40, 42 48, 60 and 64% of samples collected from Kumi, Masindi, Iganga, Kapchorwa and Sironko, respectively. The lesions were frequently accompanied by root pruning especially of the feeder roots and slight to severe discolouration, especially on samples from Kapchorwa and Iganga.

There were, in total, 22 species of plant parasitic nematodes representing 10 genera that were identified in root samples collected from the 5 cereal crops (Table 2). By crop, 15 nematode species were recovered from maize roots, 14 from millet roots, eight from sorghum roots, five from wheat roots and three from barley roots (Table 2). The 15 species associated with maize were from seven genera, of which six species were associated with maize only (*Aphelenchoides arachidis* Bos, 1977, *A. eltaybi*, *Pratylenchus goodeyi* Sher and Allen, 1953, *Scutellonema paralabiatum*, *S. clathricaudatum* Whitehead, 1959 and *Rotylenchulus borealis*). *Meloidogyne* spp., *Pratylenchus* spp. and *Helicotylenchus* spp. occurred on all cereals.

Similar to the taxonomic composition (Table 2), frequency of occurrence of the nematodes varied between crops and districts (Table 3). *Pratylenchus zeae* was the common nematode on maize in Iganga (94%) and Masindi (86%), on millet in Kumi (100%), Masindi (75%) and Sironko (100%), and on sorghum in Kumi (100%), Masindi (83%) and Sironko (100%) (Table 3). Higher nematode population densities were recorded on maize than any other crop sampled, with *P. goodeyi* and *P. zeae* having the highest populations/fresh root weight (Table 4), although in many cases the mean nematode population was far below the maximum number recorded. From the 293 cereal crops root samples, the most prevalent endoparasitic nematodes encountered were *P. zeae*, *Scutellonema* spp., *Helicotylenchus* spp., *P. goodeyi*, *Meloidogyne* spp and *P. brachyurus* with frequency occurrences of 70.9, 30.4, 19.1, 11.7 and 10.9%, respectively (Table 5; Fig. 1).

Six endoparasitic nematode genera were recovered from the maize fields monitored during the growing season, namely, *Aphelenchoides* spp., *Helicotylenchus* spp., *Meloidogyne* spp., *P. zeae*, *P. brachyurus* and *Scutellonema* spp. (Table 6). In general, the nematode population built up from the 3rd to the 5th week after planting and then decreased at 11 weeks after planting, except in Iganga in field 1 where plant parasitic nematode numbers increased continuously and in Kumi in field 2 where the nematodes population first decreased before increasing later in the

TABLE 1. Percentage of occurrence of plant-parasitic nematode damage-related symptoms on cereals in Uganda

District	Plant-parasitic nematodes related damage symptoms			
	Above ground plant parts		Roots	
	Yellowing	Stunting	Galling	Necrosis
Kumi	36	32	2	40
Kapchorwa	44	42	4	60
Masindi	46	28	0	42
Iganga	50	40	10	48
Sironko	50	44	4	64

TABLE 2. Occurrence of plant-parasitic nematodes in roots of cereal crops in Uganda

Nematode	Barley	Maize	Millet	Sorghum	Wheat
Aphelenchoides arachides		+			
Aphelenchoides eltaybi		+			
Aphelechus cf. deckeri			+	+	
Belonolaimidae-Telotylenchinae					+
Ditylenchus sp.	+	+	+	+	
Ditylenchus cf. acutus			+	+	
Ditylenchus myceliophagus			+		
Helicotylenchus sp.		+	+	+	
Helicotylenchus dihystera	+	+	+		+
Meloidogyne sp.		+	+	+	+
Mesocriconema sp.			+		
Pratylenchus sp.	+	+		+	+
Pratylenchus brachyurus		+	+	+	
Pratylenchus goodeyi		+			
Pratylenchus zeae		+	+	+	
Scutellonema sp.			+		+
Scutellonema brachyurus		+	+		
Scutellonema paralabiatum		+			
Scutellonema clathricaudatum		+			
Rotylenchulus sp.		+	+		
Rotylenchulus borealis		+			
Rotylenchulus leptus			+		

growing season (Table 6). Throughout the monitoring period, *P. zeae* was the most frequently encountered and prominent nematode species (Table 7).

From regression analysis, the apparent relationships between densities of the six nematode species and soil physical/chemical properties (Table 8) and cropping history (Table 9) were estimated (Table 10). Backward elimination regression procedure retained seven variables, namely, sand, clay and silt content, soil pH, nitrogen content, frequency of growing non-cereals, and years since maize was first grown in the field. Generally, nematode root infections were favoured by reduced silt-ness and clay-ness of the soil. For example, *Meloidogyne* spp., *P. zeae* and *Scutellonema* spp. populations in maize roots tended to increase with the sand content in the soil and reduced clay-ness of the soil. The soil type under which this study was conducted was loamy sand in Iganga; sandy loam in Kumi; clay loam in Masindi; and sandy clay loam in Sironko (Table 10). Additionally, soil pH was associated with a decline in *P. zeae* and *P. brachyurus* populations while nitrogen content was associated with a decrease in nematode population densities except *P. brachyurus*. Whether maize (and possibly other cereal) was grown continuously or frequently interrupted with growing of non-cereal crops increased nematode populations (Table 10).

DISCUSSION

The observation of the genera *Ditylenchus*, *Helicotylenchus*, *Meloidogyne, Pratylenchus*, and *Scutellonema* to occur more frequently on cereals than the other genera corroborate with other reports (De Waele *et al*., 1998; McDonald and Nicol, 2005). The presence of *Meloidogyne* spp. on cereals in Uganda suggests that root-knot nematodes can be important pathogens of maize although damage caused by *Meloidogyne* spp. on cereals is greatly under estimated worldwide (De Waele *et al*., 1998; McDonald and Nicol, 2005). Whereas some species, for example, *Aphelenchoides arachidis*, *Aphelenchoides eltaybi* and *Aphelechus cf. decker*i, were found

TABLE 3. Frequency of occurrence (percentage) of plant-parasitic nematodes of cereal crops in Kapchorwa, Sironko, Kumi, Iganga and Masindi (Uganda) based on root-sample extractions using a modified Baerman-funnel method

Crop	Nematode	Iganga	Kapchorwa	Kumi	Masindi	Sironko
Maize	*Aphelenchoides arachides*					12
	Aphelenchoides eltaybi	20				
	Helicotylenchus sp	20	18			20
	Helicotylenchus dihystera				14	
	Meloidogyne sp.			90		
	Pratylenchus sp.					90
	Pratylenchus brachyurus				20	
	Pratylenchus goodeyi		78			
	Pratylenchus zeae	94		87	86	
	Scutellonema paralabiatum		78	40		4
	Scutellonema clathricaudatum				30	
	Rotylenchulus sp.	2				
	Rotylenchulus borealis		10			
Millet	*Aphelechus cf. deckeri*		25			
	Helicotylenchus sp	60	25	66		
	Helicotylenchus dihystera				25	
	Meloidogyne sp.	100				50
	Pratylenchus brachyurus	100			50	
	Pratylenchus zeae			100	75	100
	Scutellonema sp.	20		66		
	Scutellonema brachyurus				50	
	Rotylenchulus sp.				50	
	Rotylenchulus leptus		50			
Sorghum	*Aphelechus cf. deckeri*	50				50
	Ditylenchus sp.			27		
	Helicotylenchus sp				17	
	Meloidogyne sp.	100		82		
	Pratylenchus sp.	100				
	Pratylenchus brachyurus			9	50	50
	Pratylenchus zeae			100	83	100
Wheat	*Belonolaimidae-Telotylenchinae*		17			
	Helicotylenchus dihystera		22			
	Pratylenchus sp.		6			
	Scutellonema sp.		11			
	Rotylenchulus leptus		72			
Barley	*Ditylenchus sp.*		83			
	Helicotylenchus dihystera		50			
	Pratylenchus sp.		17			

associated with cereals, their apparent threat to cereals is difficult to ascertain. *Aphelenchoides arachidis* is a seed-borne endoparasitic nematode of groundnut (*Arachis hypogea* L.) and cereals (McDonald *et al*., 1979) and was reported to be restricted in distribution to Nigeria where it is of significant economic importance (Khan and Misari, 1992). However, recently Lesufi *et al.* (2005) reported its occurrence in South Africa and, therefore, this current report indicates that the

TABLE 4. Combined maximum (and mean) plant parasitic nematode population densities per 100 g fresh root weight occurring on cereal crops in Uganda

Nematode	Maize (230)[a]	Millet (18)	Sorghum (21)	Wheat (18)	Barley (6)
Aphelenchoides arachides	1750 (120)				
Aphelenchoides eltaybi	3000 (155)				
Aphelechus cf. deckeri		1250 (114)	1500 (71)		
Belonolaimidae-Telotylenchinae				500 (56)	
Ditylenchus sp.					750 (375)
Helicotylenchus sp	3000 (404)	1000 (167)	1500 (83)	1500 (208)	1000 (333)
Helicotylenchus dihystera	500 (45)				
Meloidogyne sp.	8750 (2259)	9000 (2705)	4750 (1095)	2000 (486)	
Pratylenchus sp.			750 (36)	8250 (542)	750 (125)
Pratylenchus brachyurus	10000 (1260)	500 (69)	1500 (179)		
Pratylenchus goodeyi	72500 (8179)				
Pratylenchus zeae	65000 (7025)	11000 (1722)	18250 (3774)		
Scutellonema sp.	13250 (2167)	2000 (181)		500 (28)	
Scutellonema paralabiatum	13250 (2260)				
Scutellonema clathricaudatum	3250 (265)				
Rotylenchulus sp.	1250 (542)				
Rotylenchulus leptus		1000 (159)			

[a] Total number of fields sampled

TABLE 5. Frequency of occurrence and abundance of 8 major nematode genera in cereal fields in Uganda

Nematode species	Frequency of occurrence (%)	[1]Abundance
Aphelenchoides sp.	7.0	60
Helicotylenchus sp.	19.1	87
Meloidogyne sp.	11.7	265
Pratylenchus brachyurus	10.9	137
Pratylenchus goodeyi	17.0	1488
Pratylenchus zeae	70.9	4948
Scutellonema sp.	30.4	650
Rotylenchulus sp.	2.6	14

[1]Abundance (average number (N) of individuals of a species over the sample sites where the species was present)

nematode might be more widespread than previously known. Generally, *Pratylenchus zeae* was widespread and abundant; *Aphelenchoides* spp., *Meloidogyne* spp., *Pratylenchus brachyurus*, *Rotylenchulus* spp. and *Helicotylenchus* spp. were localized and scarce; *Scutellonema* spp. were widespread but not abundant, while *Pratylenchus goodeyi* were abundant but localised (Table 5). *Pratylenchus zeae* being widespread and abundant suggests that it is the major plant-parasitic nematode on cereals also in Uganda. It is well distributed across maize growing regions in Kenya (Kimenju *et al*., 1998), where it is regarded as a serious maize pest and it is among the most common lesion nematodes associated with maize in the tropics (De Waele *et al*., 1998; McDonald and Nicol, 2005).

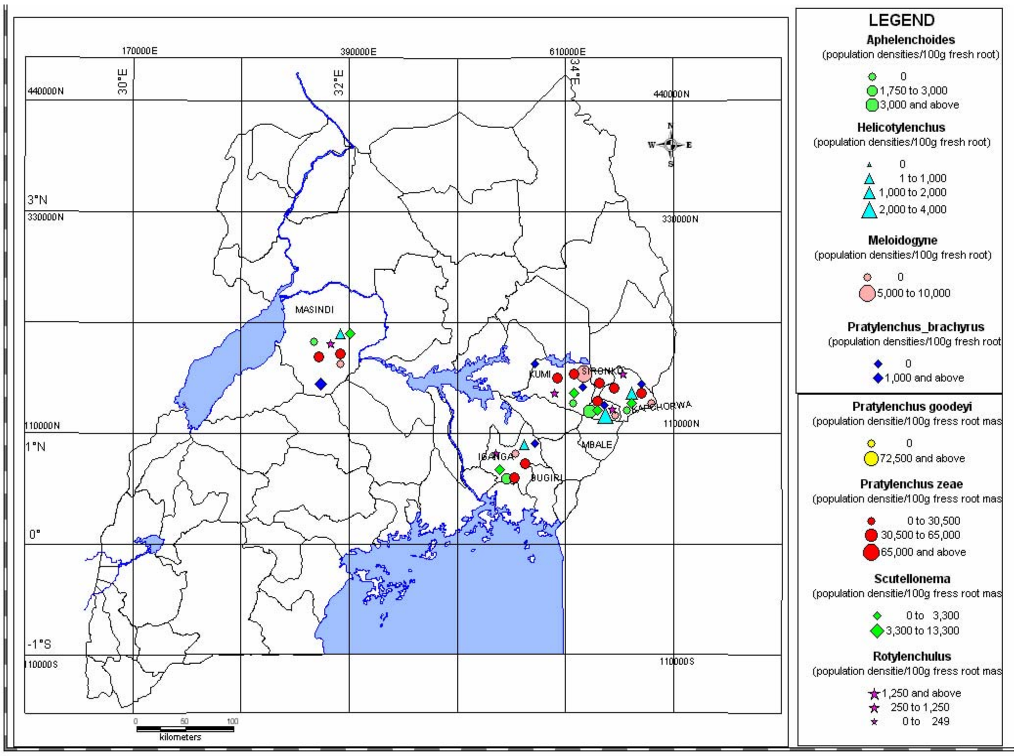

Figure 1. The distribution of plant-parastitic nematodes associated with cereals in the districts of Iganga, Kapchorwa, Kumi, Masindi and Sironko, Uganda during 2004.

The increase in nematode populations with season would be probably due to moisture (Wallace, 1983; Vrains, 1986; Jordaan *et al*., 1989) and ease of movement of the nematodes through the large soil pore diameter and soil particle size (Taylor and Sasser, 1978; Idowu, 1981; Prot and Van Gandy, 1981), which are typical properties of a generally sandy soil which was the predominant soil where the study was conducted. The results further show that intensifying maize-based cropping systems has a risk of nematodes population increases especially in fields located on soils with high sand content. This implies that maize-based cropping systems in Uganda have the potential of maintaining nematode populations at damaging levels and increasing nematode reproduction, thus reducing their potential use as rotation crops for other crops long known to be susceptible to nematodes, for example, vegetables, bananas and tobacco.

The associated decrease of nematode populations with soil nitrogen is a relevant indication that use of fertilisers may mitigate nematode infestation in cereals. This could be an effect on carbon – nitrogen ratio (Spiegel *et al*., 1982) or effect on soil pH (Norton, 1989; Cadet *et al*., 1994; Korthal *et al*., 1996).

CONCLUSION

Evidence from this study indicates that nematodes are widespread on cereal crops in Uganda. Their incidence and distribution is not dependent on the kind of cereal crop grown but intensification of cereal cropping in an area with sandy soils significantly increases the predominance of *Pratylenchus zeae*. The pathogenicity of many of these nematodes has never been studied in Uganda and thus, their individual influence on growth and development of cereal crops will have to be established.

TABLE 6. Nematode population densities (per 100 g fresh root) of major nematodes recovered in maize roots in Uganda, 3, 5 and 11 weeks after planting

Nematode species	Districts											
	Iganga			Kumi			Masindi			Sironko		
Weeks after planting	3	5	11	3	5	11	3	5	11	3	5	11
Aphelenchoides spp.	6900	4850	8000	1428	2499	893						
Helicotylenchus spp	5050	3600	7350	1428	2739	3278	2275	3640	2958			
Meloidogyne spp.	1000	3600	1200	1483	3585	3465	910	910	683			
Pratylenchus zeae	9250	26900	28500	19488	23968	6163	3035	8390	7854	7963	15925	11375
P. brachyurus	910	2275	1138	3101	8586	4770						
Scutellonema spp.	6000	8400	2600	3138	2015	6118	2503	6143	4095			

TABLE 7. Frequency of occurrence, mean population density and Prominence value (PV) of plant parasitic nematodes recovered from maize roots in the 8 fields monitored 3, 5 and 11 weeks after planting

Nematode species	Frequency of occurrence	Nematode population in 100 g of fresh root			Prominence value		
Weeks after planting		3	5	11	3	5	11
Aphelenchoides sp.	25	2156	1688	2188	1078	844	1094
Helicotylenchus sp.	75	2281	2969	1188	1975	2571	1029
Meloidogyne sp.	63	938	2875	2781	741	2271	2197
P. *brachyurus*	25	1125	3000	1531	563	1500	766
P. *zeae*	88	11031	18656	10656	10325	17462	9974
Scutellonema sp.	50	2781	4281	3313	1967	3027	2342

Prominence value = population density x “frequency of occurence/10

TABLE 8. Cropping history of the fields that were monitored for nematode population build-up

District	Trial site	Frequency of maize cropping over the last three years	Years since maize was first grown in the field	Frequency of growing non-cereals in the field during the last three years
Iganga	Kasale	3	6	3
	Magada	3	14	3
Kumi	Okum	3	10	3
	Kanyipa	2	4	2
Masindi	Kigengere	1	28	1
	Rwamudopyo	1	8	1
Sironko	Bunamuje	2	21	2
	Bulusambu	1	11	1

TABLE 9. Soil physical and chemical properties of maize fields that were monitored for nematode population build up in Uganda

District	Trial site	pH (H_20)	Soil texture	Organic matter (%)	Total N (%)	P (ppm) (Avail.)	Exch. bases (cmol.kg^{-1})		
							K^+	Ca^{2+}	Mg^{2+}
Iganga	Kasale	6.98	Loamy sand	2.32	0.11	6.98	0.31	1.80	0.41
	Magada	6.00	Loamy sand	0.58	0.06	6.00	1.13	7.48	1.21
Kumi	Okum	5.96	Sandy loam	1.33	0.08	5.96	0.68	4.43	0.95
	Kanyipa	6.78	Sandy loam	2.74	0.14	6.78	1.30	5.80	1.95
Masindi	Kigengere	5.57	Clay loam	3.88	0.15	5.57	2.48	10.24	4.70
	Rwamudopyo	5.77	Sandy clay loam	3.52	0.13	5.77	1.69	16.18	5.85
Sironko	Bunamuje	6.30	Sandy clay loam	4.64	0.07	6.30	1.23	7.38	2.33
	Bulusambu	6.40	Sandy clay loam	2.32	0.12	6.40	0.41	7.59	2.13

ACKNOWLEDGEMENT

We are grateful to Drs Antoinette Swart Mariette Marais and Esther van den Berg Plant Protection Research Institute in South Africa, for their help in confirming nematode identifications. The International Foundation for Science (IFS contract (C – 3504/1) and Innovations at Makerere Committee (I@mak.com, Makerere University) funded the study.

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TABLE 10. Regression analysis of population densities of six nematode species on soil physical/chemical properties and cropping history of eight farmer's fields

Density of nematodes as individuals (per 100g fresh root)	Intercept	Parameter estimates							R^2
		Sand (%)	Clay (%)	Silt (%)	Soil pH	Nitrogen (%)	Frequency of growing non-cereal crops in the field for the last three years	Years since maize was first grown in the field in years	
Aphelenchoides	41995.8*	-82.0*		-1191.9*		-9964.3*	-4091.4*		98.2
Helicotylenchus	21239.6*	-330.2*		-599.3*		-47572.0*			70.3
Meloidogyne	15420.1*	7.7*	-2022.6*				3552.8*	122.2*	96.2
P. brachyurus	-971.4*				-5.9*	71590.8*	4822.3*	564.9*	89.1
P. zeae	160467.7*	789.7*	-2935.9*		-11517.0*	-248436.4*	14506.8*	1091.6*	99.9
Scutellonema	-22997.8*	732.4*	-2109.0*			- 79889.2*	-7612.9*	718.6*	98.7

* Significant at $P \leq 0.05$ level

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