International Journal of Agricultural Policy and Research Vol.1 (3), pp. 080-086, May 2013
Available online at http://www.journalissues.org/journals-home.php?id=1

Original Research Paper

Effect of long-term soil management practices on nematode population in an Alfisol under continuous maize in Northern Guinea Savanna of Nigeria

Accepted April 15, 2013

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A field study was carried out at Samaru throughout 2006 and 2007 seasons by using some organic and inorganic treatments on nematode community dynamics under a long-term continuous maize trial established in 1997. The experiment was laid out in a randomized complete block design and the treatments involved were urea fertilizer, animal manure, and legumes. Results showed that the population of fungivorous nematodes; *Aphelenchoides* spp. was greater in plots amended with legumes and urea than plots amended with animal manure in two seasons. Populations of nematodes in this trophic group significantly ($p<0.05$) increased in 2007 season compared to 2006 season. Populations of plant parasitic nematodes were reduced by using animal manure treatment compared to urea and legumes especially with *Helicotylenchus* spp. having the highest population followed by *Hoplolaimus* spp., *Pratylenchus* spp. and *Scutellonema* spp. in that order. Plant parasitic nematodes were the most abundant group irrespective of soil amendment. They ranged from 91.9 to 98.9% in 2006 and 93.8 to 97.8% in 2007 of the total nematode community and had a colonizer-persister (c-p) value of 3. This suggests that they have slower reproductive ability compared to the fungivorus nematodes with a c-p value of 2 and can survive longer under low nutrient requirements and environmental stress. Also, it suggests that the plant parasitic nematodes were more responsive to host plant than to soil amendments.

Key words: Nematode community, long-term soil management, animal manure, legumes, urea fertilizer

INTRODUCTION

Soil nematodes are essential in coinhabited organic matter decomposition and nutrient cycling (Bulluck *et al.,* 2002). Although, nematodes are the most abundant microorganism in terrestrial and aquatic ecosystems (Bongers and Bongers, 1998), they represent a small portion of soil biomass (Barker and Koenning, 1998). Fungivorous nematodes are secondary consumers while plant parasitic nematodes are primary consumers (Beare *et al.,* 1992). In the Nigerian Northern Guinea Savanna agroecology, maize has become more important crop and preferred than sorghum and millet and has been grown intensively than estimated (FAO, 1985). With the current intensification of maize production, a rise in plant parasitic nematode (PPN) population could occur in infested plots which cultivated with maize continuously (Norton, 1983). This would naturally result in a yield reduction due to competition for nutrients and water. Therefore, assessing soil nematode populations especially plant parasitic nematodes is recommended. This is necessary as maize monocropping is becoming widespread as a result of increasing population and high consumption rate.

Soil fertility that can enhance maize yield may have great influence on nematode populations. Poultry litter and green manures were reported to suppress plant parasitic nematodes (Chindo and Khan, 1990; Abawi and Widner, 2000). In contrast, organic manure was observed to encourage nematode build-up and recycling (Bednarek and Gaugler, 1997). Green manure was reported to enhance the populations of fungivorous and bacterivorous nematodes only and their populations were observed to remain high for about six months after soil amendments (McSorley and Frederick, 1999). Fertility management practices were observed to have less effect on nematode population compared to crop species in studies involving organic and conventional field soils in North Carolina (Neher, 1999) and in the derived savanna of south western Nigeria (Ibewiro *et al.,* 2000).

Many reports (Bongers, 1990, Bongers and Ferris, 1999; Porazinska *et al.,* 1999) established a functional importance and life strategy indices for soil nematodes used as ecological indicators of environmental stress and provide useful measure of nutrient cycling. Nematodes with short life cycles reproduce quickly, have large nutrient requirements and are considered colonizers (r strategists) and hence have low colonizer-persister (c-p) value (Bongers, 1990). The slowly reproducing long-lived nematodes with lower nutrient needs are considered persisters (K strategists) and have higher c-p values (Bongers, 1990; Bongers and Ferris, 1999). The K strategists are more sensitive and take longer to recover from environmental stress. Nematodes are identified to genus and assigned a colonizer-persister (c-p) number from 1-5 based on life cycle and nutritional requirement of genus (Bongers, 1990). The formulae to calculate c-p value is described by (Bongers, 1990). This study was therefore designed to assess the effect of soil fertility amendments (inorganic versus organic) on plant parasitic nematode communities in a field soil under long-term continuous maize mono-cropping.

MATERIALS AND METHODS

The field study was carried out at the Institute for Agricultural Research (IAR) at Samaru, Zaria (Longitude 11'1591˚N; Latitude 7'6349˚E) in the Northern Guinea Savanna zone of Nigeria throughout 2006 and 2007 seasons under a long-term continuous trial that was established in 1997. The treatments consisted of urea fertilizer, animal manure, *Centrosema pascuorum* and cowpea- *Vigna unguiculata* (legumes) applied at the rate of 90 kg N ha^{-1}. The legumes were intercropped with maize but after harvest the residues were incorporated into the soil as green manure. The treatments were applied using a randomized complete block design with three replications. Plot size was 6 m by 6 m with a total of 63 plots in the experiment. The animal manure was incorporated into the furrows about 10cm deep below the original soil surface, a week before planting. Each experimental plot consisted of 8 ridges with the four inner ridges used as net plots while the two outer ridges on both sides of the net plot as sampling plots. The maize seeds variety Oba Super II, which is a long duration (110-120 days), drought tolerant, and N efficient hybrid was sown (Heuberger, 1998). At two weeks after planting (2 WAP), urea was split–applied (⅓) for plots requiring urea fertilizer treatment. The remaining two third (⅔) of the urea fertilizer was applied at 5-6 WAP. The method of application was the same as in the first application.

Six soil cores (20 cm deep) were collected for nematode assays from the base of each maize plant at taselling stage from each of the four sampling plots of eight-row plots. The 24 soil cores were collected on a diagonal transects of each plot and bulked. The soils were thoroughly mixed to give a composite sample for each plot, sub samples were placed in nylon bags and stored at 10^{o}C on the same day and kept for analysis. A 100g portion of soil was weighed out and placed on two sheets of kim wiper inside the extraction plates (Hooper, 1990). The soil samples were then spread evenly on top of the kim wiper. Twenty five ml of distilled water was poured inside the extraction plates and left for 2 days to allow the nematodes to migrate out of the soil samples into the water in the plates. The sieves (4 sets of 45 micrometer) were then removed gently and the extract collected in a 250ml beaker and left overnight to allow the nematodes to settle. The volume of extract was then concentrated to 10ml and poured into a 25ml measuring cylinder. The extract was thoroughly mixed and 1ml aliquot was taken and put into a Dohncaster counting dish for nematode counting under a dissecting microscope and differenciated (Hooper, 1970; 1990). Total numbers of nematodes/250cm^3 of soil were determined (but not corrected for extraction efficiency) from each treatment-replicate combination and nematodes were identified, into genera level and differenciated into plant parasitic and non-plant parasitic nematodes according to Bongers (1990).

All data were statistical analysed using the General Linear Model Procedure of SAS (SAS Inst., 1999) at each cropping season and also pooled over two years of maize cropping. Variance in nematode count was normalized by logarithmic transformation (Gomez and Gomez, 1984) and variance in proportion community composition was normalized with the arcsine transformation. Standard error of difference (SED) was derived from confidence limits from the least squares means procedure. Orthogonal contrasts were used to compare variability within and between soil amendments over the course of the experiment.

RESULTS

The soil is an Alfisol of the soil order Typic Haplustaff (USDA, 1998) with a sandy loam texture (536 gkg^{-1} sand, 327 gkg^{-1} silt, and 137 gkg^{-1} clay, pH (H_20) 5.11).. A total of 15 genera of nematodes were identified in soil samples from 2006 season and the same number in 2007 season. Bacterivorous (*Rhabditis*) nematodes were predominant in the experimental site "maize field soil" (Table 1). Fungivorous nematodes identified included the genera *Aphelenchoides* spp., and *Aphelenchus* spp. Plant parasitic

Table 1: Nematode genera identified at the experimental site throughout 2006 and 2007 cropping seasons combined[a]

Bacterivore	Plant parasitic nematode	Fungivores	Omnivores	Predators
Rhabditis[b]	*Helicotylenchus*	*Aphelenchoides*	NI	NI
	Hoplolaimus	*Aphelenchus*		
	Pratylenchus			
	Scutellonema			
	Longidorus			
	Xiphinema			
	Criconemoides			
	Tylenchus			
	Meloidogyne			
	Rotylenchus			
	Ditylenchus			
	Tylenchorhynchus			

a:Most abundant genera at top of list and least abundant at bottom of list
b:Family Rhabditidae; NI: Not identified.

nematodes consisted mainly of *Helicotylenchus*, *Hoplolaimus*, *Pratylenchus*, *Scutellonema*, and occasionally *Longidorus*, *Xiphinema*, *Mesocriconema*, *Tylenchus*, *M. incognita, Rotylenchus, Ditylenchus, and Tylenchorynchus* (Table 1).

The soil amendments had a consistent significant ($p<0.05$) effect on numbers of most plant parasitic nematodes (Table 2). In this respect, populations of *Helicotylenchus* and *Pratylenchus* genera were significantly affected by the tested soil amendments and increased from 2006 to 2007 while *Hoplolaimus* and *Scutellonema* genera decreased (Table 2). Numbers of *Helicotylenchus* spp. were highest ranging from 335 to 366 nematodes/250cm^{-3} soil in plots amended with legumes (Table 2). Numbers of *Pratylenchus* were significantly ($p<0.05$) lower in soils amended with animal manure than other amendments in two seasons compared to *Helicotylenchus* and *Hoplolaimus* (Table2). The dorminant species of plant parasitic nematode in both cropping seasons was *Helicotylenchus*. Also, the obtained results showed no significant difference in nematode populations between inorganic urea N fertilizer and legume amended treatments (Table 2) but there was a significant ($p<0.05$) decrease in nematode population at using manure treatment compared to the other treatments. Similar trend was observed when the two year data was pooled together.

Colonizer- persister value

The colonizer- persister (c-p) values for fungivorous and plant parasitic nematodes (PPN) are shown in Table 2. The c-p values indicate their functional importance and life strategies in soil. The fungivorous nematodes had c-p value of 2 while PPN had c-p value of 3 in both two seasons indicating that the fungivorous nematodes are short-lived, quickly reproduce and have larger nutrient requirement compared to the plant parasitic nematodes (Table 2). Therefore, the fungivorous nematodes are considered colonizers (r-strategists) due to their lower colonizer-persister value. The plant parasitic nematodes with c-p value of 3 are slower reproducing, long-lived with lower nutrient needs and are considered persisters (K strategists). This could be the reason for the higher population pressure observed for PPN in both years compared to fungivorous nematodes (Table 3).

Numbers of fungivorous (*Aphelenchoides* spp.) nematodes were higher in soils amended with legumes throughout 2006 and 2007 seasons (2.67% and 4.53% ; respectively) and inorganic urea N fertilizer (3.18% and 3.84%; respectively), than those with animal manure (1.12% and 2.17%; respectively) (Table 3). Numbers of fungivorous nematodes remained higher in treatments with legumes but numbers were not statistically different than soils containing inorganic urea N fertilizer in two seasons (Table 3). In both two years, consistent effects of soil amendments on fungivorous nematodes were observed (Table 3). Percentages of plant parasitic nematodes were higher in soils amended with animal manure (98.88% and 97.83%) in two seasons (Table 3). Also, consistent effects of soil amendments on the plant parasitic nematodes were observed in both two years.The relative abundance of plant parasitic nematodes in 2006 was 98.9% in plots treated with animal manure and 96.8%, and 97.3% in plots amended with urea fertilizer and legumes ; respectively (Table 3). Similarly, in 2007season, application of animal manure treatment gave the highest percentage (97.8%) while were 96.2% and 95.5% when the plots containing urea and legumes respectively. Plant parasitic nematodes were the most abundant group irrespective of soil amendment and ranged from 96.8 to 98.9% in 2006 and 95.5% to 97.8% in 2007 of the total nematode community (Table 3). Fungivorous nematodes comprised a lower percentage of the total community in 2006 (1.1% - 3.2%) than 2007 (2.2% - 4.5%) but were still greater in soils

Table 2: Effect of soil amendments on number of nematodes within trophic groups throughout 2006 and 2007 cropping seasons

Trophic group[a]	c-p values[b]	Amendment type [c] urea-N[c]	Animal manure [c]	Legumes[c]	SED
2006 season					
Bacterivores					
Rhabditidae	1	ND	ND	ND	
Fungivores					
Aphelenchoides	2	27	6	24	5.98
Plant parasitic nematode					
Helicotylenchus	3	304	214	335	22.52
Hoplolaimus	3	262	161	258	38.32
Pratylenchus	3	156	88	151	11.22
Scutellonema	3	98	53	104	10.32
Total nematodes		847	522	872	80.09
2007 season					
Bacterivores					
Rhabditidae	1	ND	ND	ND	
Fungivores					
Aphelenchoides	2	33	13	46	3.32
Plant parasitic nematode					
Helicotylenchus	3	361	263	366	42.97
Hoplolaimus	3	246	122	247	18.34
Pratylenchus	3	164	116	155	8.51
Scutellonema	3	88	48	103	8.49
Total nematodes		892	562	917	78.98
2006/2007 combined analysis					
Bacterivores					
Rhabditidae	1	ND	ND	ND	
Fungivores					
Aphelenchoides	2	30	7	33	4.36
Plant parasitic nematode					
Helicotylenchus	3	333	239	350	28.84
Hoplolaimus	3	254	142	252	26.78
Pratylenchus	3	160	102	153	9.55
Scutellonema	3	93	50	104	10.08
Total nematodes		869	542	894	75.40

a:Average number of nematodes/250cm3 of soil for each amendment type at tasselling growth stage; b: The c-p values for nematode families after Bongers (1990); c: Soil were amended with urea fertilizer, animal manure or legumes; SED: standard error of difference; ND: Not determined

amended with legumes and inorganic urea-N than plots amended with animal manure (Table 3). Similarly, in 2006 plant parasitic nematodes comprised of 92% to 99% of the community (LSD 0.52%) while in 2007 it comprised of 94% to 98% of the nematode community (LSD 1.09%) regardless of soil amendment. The increased populations of bacterivorous nematodes can be linked to higher populations of bacteria associated with the input of organic soil amendments in these treatments.

DISCUSSION

Low populations of plant parasitic nematodes were observed in response to applications of animal manure in this study (Table 2). The reduction in these populations could be due to the release of ammonium-N into the soil which is known to be effective in suppressing nematode populations (Chindo and Khan, 1990; Crow et at., 1996; Abawi and Widmer, 2000; Akhtar, 2000).

Numbers of fungivorous nematodes (*Aphelenchoides* spp.) were higher in legume amended than in animal manure amended soils (Table 2). This finding was expected as *Aphelenchoides* is a legume plant parasitic nematode though within the fungivorous trophic group (Bulluck et al., 2002). The increase in fungivorous nematode (*Aphelenchoides* spp.) in legume amended plots could be due to the presence of specific organic substrates in these amendments that favour growth and development of this nematode species (Bulluck et al., 2002). The fungivorous nematode may therefore affect both the legumes and Rhizobium in the nodules, and could play an essential role

Table 3: Effect of soil amendments on the percentage of nematodes in different trophic groups throughout 2006 and 2007

		Total nematode community (%)	
Year	**Amendment**	**Fungivore**	**Plant parasite**
2006	Animal manure	1.12c	98.88a
	Urea	3.18b	96.82b
	Legumes	2.67b	97.33b
SED		0.15	0.15
CV		6.90	0.27
2007	Animal manure	2.17c	97.83a
	Urea	3.84b	96.17b
	Legumes	4.53b	95.46b
SED		0.31	0.31
CV		12.90	0.57

SED- standard error of difference; Means with the same letter in the same column are not significantly different at 5% level of probability; CV-coefficient of variation.

in legume-Rhizobium symbiosis by causing a direct decrease in the primary production of the legumes (Ibewiro et al., 2000). Therefore, the net effect of nematodes on symbiotic N_2 fixation in legumes depend both on the legume species and on the specific nematode present (Ibewiro et al., 2000).

Comparing the cropping seasons (Table 2), the obtained results showed higher populations of plant parasitic nematodes in 2007 compared to 2006 season. This trend is consistent with the findings of Norton,(1983) and Afolami and Fawole,(1991), Weber et al.(1995), and Ibewiro et al.(2000) who showed that continuous cropping of maize favours the build-up of plant parasitic nematode thereby threatening sustainability of intensified cereal-based systems in the northern Guinea savanna of Nigeria. The generally, lower populations of nematodes which obtained in the animal manure amended plots could be due to the release of higher amounts of ammonium-N (especially from the poultry litter) into the soil compared to cow dung that have buffering ability to soil (Ogunwole,2005; Ogunwole et al ., 2010).

The observed relatively lower abundance of fungivorous nematodes in our study could be due to the fact that they are r-strategy colonizers as a result of their short life cycle and ability to quickly reproduce after incorporation of amendment into the soil. This case depends on large nutrient supply and cannot withstand environmental stress. This is evident in their low colonizer c-p persister value (c-p =2). Plant parasitic nematodes were the most relatively abundant.

This may be due to their slower reproductive ability resulting in their ability to live longer under low nutrient supplies and so are considered persisters (K strategists) and have higher c-p value (c-p =3) compared to the fungivorous nematodes (Bongers,1990; Bongers and Ferris,1999 Bongers and Ferris,1999). This agrees with the findings of Bongers (1990), Bongers and Ferris (1999), who reported that nematodes with lower nutrient needs (c-p 3-5) are considered persisters (K strategists) while those with larger nutrient needs (c-p 1-2) are called colonizers. The result obtained also suggests that the PPN were more responsive to host plant than to soil amendments.

This agrees with the findings of Neher (1999), who observed that crop species had more influence on nematode community structure than management practices.

Plant parasitic nematodes were found relatively unaffected in this study by soil amendments as no suppression of plant parasitic nematode occurred with the addition of organic amendments especially animal manure (Table 3).

This agrees with the findings of Mannion et al. (1994), McSorley and Gallaher,(1996) and McSorley et al.(1998), who observed that plant parasitic nematode *(Meladogyne incognita* and *Pratylenchus* spp.) were consistently not affected by organic soil amendment in Florida. This may be due to the susceptibility of hybrid maize crop to plant parasitic nematode indicating that plant parasitic nematodes are potentially more responsive to host plant than to soil amendment.

Plant parasitic nematode pressure was very high in both the years (Table 3)This agrees with findings of Neher (1999), who observed that crop species had influence on nematode community structure more than management practices.

However, in our study, different field were used for either organic or conventional agricultural production system while examining the effects of organic amendments in soils from the same field cropped to maize. Our result reflects long-term changes in soil plant parasitic nematode community structure in response to soil amendments and not differences with cropping system.

Conclusion

The study revealed that fugivorous nematodes had c-p value of 2 while PPN had c-p value of 3, showing that fungivorous nematodes were short-lived, reproduced faster and had larger nutrient requirement hence are considered colonizers (r strategists) compared to the PPN with lower nutrient needs due to their higher c-p value and are thus called persisters (K strategists). The higher population pressure obtained in 2006 and 2007 with PPN compared to fungivorous nematodes also indicated that PPN persisted longer in the soil. The fungivorous (*Aphelenchoides* spp) nematodes were significantly ($p<0.05$) higher in soils amended with legumes (2.67% and 4.53%) and urea fertilizer (3.18% and 3.84%), than those with animal manure (1.12% and 2.17%) in both years. Also, highest PPN was observed in soils amended with animal manure in both years (98.88% and 97.83%) and was significantly ($p<0.05$) higher than each of the other treatments. However, the high consistent population increase in the PPN community structure in both 2006 and 2007 showed that crop species had more influence than soil amendments as no suppression occurred with the addition of animal manure. Continuous cropping of maize favoured the build-up of PPN and would threaten sustainability of intensified cereal-based systems in the NGS of Nigeria.

ACKNOWLEDGEMENTS

The research reported in this publication was funded in part by the Ahmadu Bello University Board of Research. The authors thank Mr. Lawal and Mr Gaius for their technical assistance and Dr. Salahu for statistical advice.

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