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Mixed Cropping System on Diversity and Density of Plant Parasitic Nematodes

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Abstract

The potential of mixed cropping system on the diversity and suppression of nematodes was investigated at two locations in Ghana. The treatments in the study were; sole plantain, sole cassava and plantain+cassava systems replicated five and four times in a randomized complete block design (RCBD) at Kwadaso in the Ashanti and Assin Foso in the Central region of Ghana respectively. Growth parameters (height and girth) and components of yield (No. of suckers/plant, bunch weight/plant, No. of hands/plant, No. of fingers/plant) were studied on plantain in addition to No. of weevils per plant. On cassava, total biomass, tuber number and tuber weight (yield) were analyzed using GenStat software and means were separated with Fisher's least significance test at $\alpha = 0.05$. There were no differences in height and girth of plantain at Assin Foso. However, plant height was 25% and girth 13% more under sole plantain system over the mixed cropping system at Kwadaso. The sole plantain system recorded 60% and 75% more suckers than the Plantain-Cassava system at both locations. Mixed and sole cropping systems did not influence the diversity of nematode community but significant differences were observed in the density of the nematode taxa encountered under the two systems. Throughout the investigation at both locations, it was observed that the mixed cropping system recorded significantly ($P < 0.05$) lower nematode population densities in comparison to sole cropping system. It is therefore true that an agro-ecological strategy for pests and diseases control is the growing of a mixture of crops differing in their susceptibility to pests and pathogens

Keywords: mixed cropping system, monoculture system, nematode species

1. Introduction

Genetic uniformity of monocultures has been reported to predispose crops to pests and diseases outbreaks (Meung et al., 2003). Since the introduction of plant diversity increases the number of individual functional traits and potential ecosystem services (Hajjar et al., 2008; Malezieux et al., 2009) an agro-ecological strategy for pests and diseases control is the growing of a mixture of crops differing in their susceptibility to pests and pathogens (Smithson & Lenne, 1996; Wolfe, 1985). Mixed culture is recommended for reduction of risk of total crop failure, production of a variety of produce, and improvement of soil fertility where legumes are included which ultimately improve yield of associated crops.

Plant parasitic nematodes (PPN) are among the most important pests of crops worldwide (Yadav & Sehgal, 2010). Mono and mixed cropping systems are affected by PPN parasitism however; the type of mixed cropping system adopted might influence the diversity and density of PPN community. In Ghana, crops may be grown together in mixed cultures often following a system that has been long established and generally successful. It has been observed that crop losses due to pests and diseases are on the ascendency as improved crop cultivars are cultivated in monoculture systems. The greatest incentive to the Ghanaian farmer in practicing mixed culture therefore is food security.

Plantain (*Musa* spp.) is an important food source for many people in the tropics and sub-tropics of the world (Kainga & Seiyabo, 2012). In Ghana, plantain is a starchy staple crop of considerable importance, which contributes about 13% of the Agricultural Gross Domestic Product (GNA, 2007). About 90% of production is consumed locally because plantain is ranked high in food preference (Schill et al., 1996). Consequently it serves as an important source of family income as a result of its high price compared with other starchy staples (Dadzie & Wainwright, 1995). In addition, its production provides job opportunities (Robinson, 2000).

Cassava, *Manihot esculenta* on the other hand, is the most important vegetatively propagated food crop and the second most important food staple in terms of calories per capita in Africa (Nweke et al., 2002). The major nutritional component of cassava is carbohydrate. In Ghana, cassava accounts for a daily calorie intake of 30% and is grown by almost every farming family (FAO, 2006). The importance of cassava to many Africans is epitomized in Ewe (a language spoken in Ghana, Togo and Benin) for the plant, *agble*, meaning "there is life" (Manu-Aduening, 2005). The crop plays an important role in Ghana's economy; it contributes 22% of the Agriculture Gross Domestic Product (Al-hassan, 1989).

Nematode species which are detrimental to plantain are those which destroy the primary roots, disrupting the anchorage system and resulting in toppling of the plants. *Radopholus similis*, *Pratylenchus* species and *Helicotylenchus multicintus* are the most widespread and important (Gowen et al., 2005). Plant-parasitic nematodes most frequently found associated with cassava are *Meloidogyne* spp., *Pratylenchus brachyurus*, *Rotylenchulus reniformis* and *Helicotylenchus dihysteria* (Coyne et al., 2003). These nematode species appear however, of limited importance, with little evidence of significant effect on the crop. However, the significance of nematodes in the cultivation of cassava cannot be overemphasized as some nematodes may interact with other pathogenic organisms in the development of disease complexes (Bridge et al., 2005).

The banana weevil, *Cosmopolites sordidus* is another major pest of plantain. The weevil can confuse the diagnosis of a nematode problem because symptoms of damage are similar (Gowen et al., 2005). With fungi (*Cylindrocarpon* spp., *Fusarium* spp., *Rhizoctonia* spp. and *Cylindrocladium* spp.) the problem becomes even more complex as nematodes and fungi occur within the same cells and infestations result in the same types of discoloration and necrosis (Jones, 2000; Riséde & Simoneau, 2004). In preliminary studies on cassava in Nigeria, the presence of *M. incognita* substantially increased the incidence and severity of damage to storage roots by *Botrydiplodia theobromae* a causal agent of root rot (Dixon et al., 2003).

We must understand and manage these complex organisms so that we may continue to develop and sustain our food production systems (Barker et al., 1994). The potential of farming systems to manage nematode populations below the economic threshold level (ETL) must be investigated. Such a strategy might reduce the over reliance on synthetic chemicals which are detrimental to man and the environment. Therefore, the objective of this study was to evaluate the effect of plantain-cassava mixed culture on the diversity and density of plant-parasitic nematodes in southern Ghana.

2. Materials and methods

2.1 Treatments and Experimental Procedure

Three treatments; sole plantain, sole cassava and mixed plantain-cassava were replicated five and four times in a randomized complete block design (RCBD) at Kwadaso in the Ashanti and Assin Foso in the Central region of Ghana respectively. Both locations are in the forest belt and experience a bi-modal rainfall pattern. The variety of cassava used was "Doku" while the plantain was a local variety. Completely decomposed poultry manure was used to fertilize plantain (in both the sole and mixed culture plots) at a rate of 900 g/plant at planting time. A plot measured 12 × 12 m. At Kwadaso, plantain was planted on June 15, 2010 and cassava on June 23, 2010. Both cassava and plantain were planted at Assin Fosu on July 15, 2010. Plantain was planted at a spacing of 3 × 3 m while cassava was at 1 × 1 m at both locations.

2.2 Soil and Root Sampling for Nematode Assay

Soil samples were collected at two time periods; at the start of the trial before the planting of plantain and cassava and during 14 months after planting when cassava was harvested and about 70% of the first plantain crop had been harvested. Soil samples were randomly collected with a 5 cm soil auger to a depth of 20 cm. Roots of plantain were also sampled at the time of soil sampling. The soil samples, 200 cm^3 per treatment and 5 g of root samples were extracted using the modified Baermann funnel method. After 24 h of extraction, samples were fixed with TAF (Formalin-37% formaldehyde 7.6 ml, Tri-ethylamine 2 ml and distilled water 90.4 ml) and second, third and fourth stage nematodes were mounted on aluminium double-coverglass slides and specimens were identified (CIH, 1978) under a stereo microscope at magnification 100x using morphological characteristics such as the spear (stylet), head skeleton, lumen of the oesophagus, excretory pore and spicules.

2.3 Data Analysis

Statistical analysis was performed using Genstat 8.1 software. Yield, being continuous data was not transformed but nematode count data was log (ln (x + 1)) transformed to improve homogeneity of variance before analysis. Significant mean separation was determined with Fisher's least significance test at $\alpha = 0.05$.

3. Results and Discussion

Growth parameters (height and girth) and components of yield (No. of suckers/plant, bunch weight/plant, No. of hands/plant, No. of fingers/plant) were studied on plantain in addition to No. of weevils per plant. The different farming systems; Sole plantain (mono-cropping) and Plantain + Cassava (mixed cropping) did not show differences in plant growth parameters (height and girth) of plantain at Assin Foso. However, differences were recorded at Kwadaso. Plant height was 25% and girth 13% more under sole plantain system over the mixed cropping system at Kwadaso.

Table 1a. Plantain growth parameters, components of yield and weevil infestation at Assin Foso

Farming system	Height (m)	Girth (cm)	No. suckers	Bunch weight (kg)	No. hands	No. fingers	No. weevils
Sole Plantain	2.05	43.60	5.00	21,792	21,371	95,433	696 (2.8)
Plantain +Cassava	2.02	37.80	2.00	19,592	20,942	82,225	346 (2.5)
Mean	**2.035**	**40.7**	**3.5**	**20,692**	**21,156.5**	**88,829**	**521 (2.65)**
Lsd (5%)	0.97	7.03	1.93	8,292.8	6,386.7	28,844	245 (0.2)

Table 1b. Plantain growth parameters, components of yield and weevil infestation at Kwadaso

Farming System	Height (m)	Girth (cm)	No. suckers	Bunch weight (kg)	No. hands	No. fingers	No. weevils
Sole plantain	2.47	42.37	4.00	32,173	24,417	98,611	312 (1.9)
Plantain +Cassava	1.85	35.99	1.00	26,567	23,067	82,629	227 (1.6)
Mean	**2.16**	**39.18**	**2.5**	**29,370**	**23,742**	**90,620**	**269.5 (1.75)**
Lsd (5%)	0.14	3.29	1.34	7,953.9	3,265.6	3,865.7	94 (1.1)

Similarly, no differences were recorded in bunch weight (yield) at both locations. However, significant differences were observed regarding the No. of suckers/plant and No. of weevils/plant at both locations. The Sole plantain system recorded 60% and 75% more suckers than the Plantain-Cassava system at both locations (Tables 1a and 1b). The mixed cropping system negatively affected sucker production.

The significantly low weevil population recorded under the Plantain-Cassava system was 101% less than the population recorded under the Sole plantain system at Assin Foso (Table 1a). Similarly, the Plantain-Cassava system recorded 34% less weevils than in the Sole plantain system at Kwadaso (Table 1b). The results of the current study corroborate the finding that "the growing of a mixture of crops is an agro-ecological way of controlling pests and diseases" (Smithson & Lenne, 1996).

Three parameters; total biomass, tuber number and tuber weight (yield) were studied on cassava under the two farming systems (Sole cropping and mixed cropping). Differences observed were not significant in any of the parameters studied (Figures 1a and 1b).

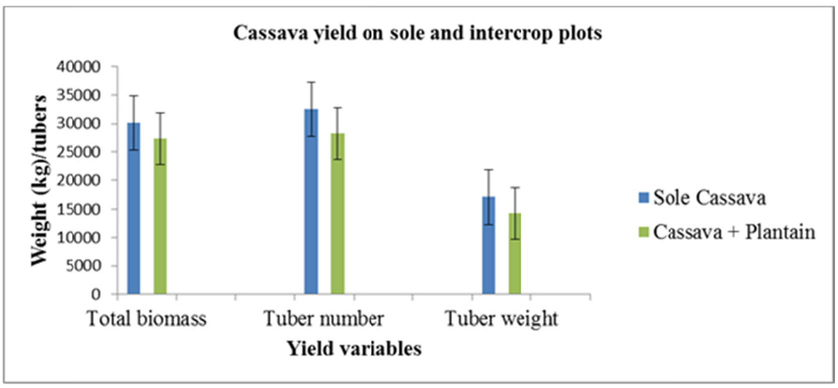

Figure 1a. Cassava yield in sole and intercrop systems at Assin Foso

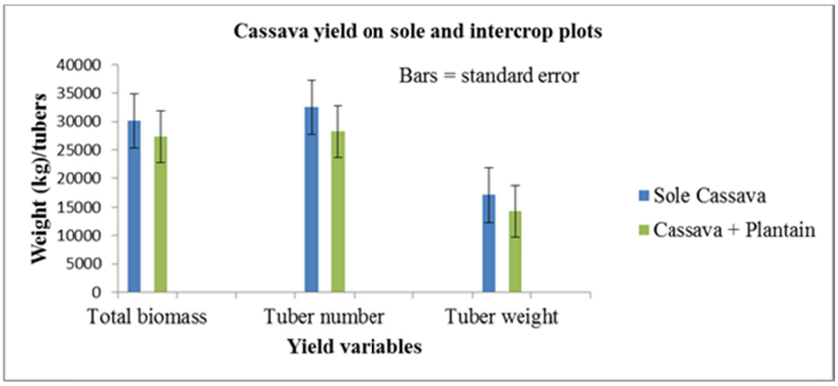

Figure 1b. Cassava yield in sole and intercrop systems at Kwadaso

Four plant parasitic nematodes belonging to the Order: Tylenchida were encountered at both locations at the beginning and at the end of experiment. The nematodes encountered were: *Meloidogyne* spp., *Pratylenchus coffeae, Rotylenchulus reniformis* and *Helicotylenchus multicintus*. From the initial soil samples, nematode population/200 cm^3 soil was comparatively higher at Assin Fosu with *R. reniformis* being the most abundant while *H. multicintus* predominated at Kwadaso (Figure 2).

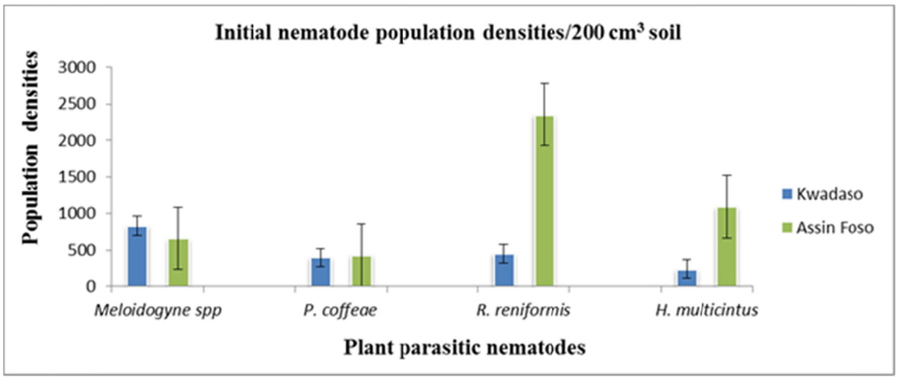

Figure 2. Initial nematode population densities/200 cm^3 soil

Throughout the investigation at both locations, it was observed that the mixed cropping system recorded significantly ($P < 0.05$) lower population densities regarding; *Meloidogyne* spp., *P. coffeae* and *R. reniformis* in comparison to sole cropping treatment. However, there were no differences in population of *H. multicintus* in both treatments at both locations. The sole cropping system recorded (82 and 637) % more *Meloidogyne* spp. and *R. reniformis* than the mixed cropping system at Assin Foso while (351 and 280) % more *Meloidogyne* spp. and *R. reniformis* were recorded at Kwadaso respectively (Tables 2a and 2b).

Table 2a. Plant parasitic nematodes/200 cm^3 in soil samples at harvest at Assin Foso

Farming system	*H. multicintus*	*Meloidogyne* spp.	*P. coffeae*	*R. reniformis*
Sole plantain	9.5 (0.58)[1] b	51.0 (1.56) c	42.0 (1.55) c	33.2 (1.47) b
Plantain + Cassava	9.2 (0.42) b	28.0 (1.42) b	14.2 (0.31) b	4.5 (0.29) a
Sole cassava	1.0 (0.00) a	8.8 (0.91) a	4.0 (0.42) a	9.0 (0.56) a
Mean	**6.6 (0.33)**	**29.3 (1.29)**	**20.07(0.76)**	**15.57 (0.77)**
Lsd (5%)	0.37 (0.29)	0.18 (0.01)	0.10 (0.07)	0.03 (0.06)

Note. Values are means of 4 replications. Means followed by the same letters do not differ significantly. [1]Log transformed [ln (x + 1)] data used in analysis in parenthesis.

Table 2b. Plant parasitic nematodes/200 cm^3 in soil samples at harvest at Kwadaso

Farming system	*H. multicintus*	*Meloidogyne* spp.	*P. coffeae*	*R. reniformis*
Sole plantain	71.4 (1.81)[1] b	307.0 (2.42) b	261.0 (2.12) b	293.0 (2.37) b
Plantain + Cassava	29.8 (1.45) b	68.0 (1.59) a	12.0 (0.88) a	77.0 (1.85) ab
Sole Cassava	1.0 (0.00) a	55.0 (1.65) a	7.0 (0.62) a	28.0 (1.11) a
Mean	**34.1 (1.09)**	**143.3 (1.89)**	**93.3 (1.21)**	**132.7 (1.78)**
Lsd (5%)	0.002 (0.001)	0.012 (0.014)	0.052 (0.002)	0.032 (0.015)

Note. Values are means of 5 replications. Means followed by the same letters do not differ significantly. [1]Log transformed [ln (x + 1)] data used in analysis in parenthesis.

The sole cassava system recorded significantly least population densities in all the four nematodes encountered at both locations which did not result in any differences in the parameters studied on cassava (Tables 2a and 2b). All the four nematode species have been reported to be associated with plantain and cassava cultivation (Coyne et al., 2003; Gowen et al., 2005). The insignificantly low nematode numbers recovered from the rhizosphere of cassava has confirmed the fact that nematodes are of limited importance, with little evidence of significant effect on the crop (Bridge et al., 2005).

Table 3a. Plant parasitic nematode population densities/5 g plantain root at Assin Foso

Treatment	*H. multicintus*	*Meloidogyne* spp.	*P. coffeae*	*R. reniformis*
Sole plantain	210 (1.26)[1]b	166 (2.15) b	104 (1.98) b	24 (1.18) b
Plantain+ cassava	4.2 (0.57) a	24 (1.18) a	18 (1.10) a	4.0 (0.56) a
Mean	**126 (0.92)**	**95 (1.67)**	**61 (1.54)**	**14 (0.87)**
Lsd (5%)	0.088 (0.071)	0.096 (0.115)	0.050 (0.034)	0.074 (0.02)

Note. Values are means of 4 replications. Means followed by the same letters are not significantly different. [1]Log transformed [ln (x + 1)] data used in analysis in parenthesis.

Table 3b. Plant parasitic nematode population densities/5 g plantain root at Kwadaso

Treatment	*H. multicintus*	*Meloidogyne* spp.	*P. coffeae*	*R. reniformis*
Sole plantain	148 (2.05)[1 b]	147 (2.10) b	297 (2.19) b	66 (1.59) b
Plantain+ cassava	22 (0.79) a	34 (1.14) a	76 (1.25) a	8 (0.64) a
Mean	**85 (1.42)**	**90 (1.62)**	**186.5 (1.72)**	**37 (1.12)**
Lsd (5%)	0.040 (0.017)	0.027 (0.033)	0.216 (0.019)	0.047 (0.005)

Note. Values are means of 5 replications. Means followed by the same letters do not differ significantly. [1]Log transformed [ln (x + 1)] data used in analysis in parenthesis.

Nematode population densities recovered from plantain roots under the sole cropping system were significantly ($P < 0.05$) higher than under the mixed cropping system. For instance, *Meloidogyne* spp. and *Pratylenchus coffeae* populations under the sole plantain system were (592 and 332%) and (478 and 291%) higher than under the mixed cropping system at Assin Foso and Kwadaso respectively (Tables 3a and 3b). Severe infestation of plantain root system by plant parasitic nematodes often result in toppling over of plants particularly at fruiting stage (Gowen et al., 2005) leading to significant yield losses.

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