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Associations of soil type and previous crop with plant-feeding nematode communities in plantain agrosystems

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ABSTRACT

Understanding the influence of soil properties and cultural practices on the communities of plant-feeding nematodes (PFNs) in agrosystems is a prerequisite for cost-efficient and environment-friendly pest control. Although plantain is a staple food crop in the Caribbean, the relationships between PFN communities and environmental factors are poorly understood in plantain agrosystems. In this study, which was conducted in Martinique (French West Indies), we quantified the PFNs in 301 root samples taken from 53 plantain fields that differed in climate, edaphic conditions, and cultural practices. The physico-chemical properties were also determined for the soil in each field. Coinertia analysis (CI) and General Linear Mixed Models (GLMMS) were used to investigate the relationships between the PFN communities, soil properties, and cultural practices. Four nematode taxa were found in plantain roots: *Radopholus similis*, *Pratylenchus coffeae*, *Helicotylenchus multicinctus*, and *Meloidogyne* spp. The lesion nematode *P. coffeae* was the most prominent PFN species, followed by the burrowing nematode *R. similis*, root-knot nematodes *Meloidogyne* spp., and the spiral nematode *H. multicinctus*. *P. coffeae* was significantly more abundant in ferralsols and nitisols (which have a low organic matter content and a high exchangeable cation content) than in andosols (which have a high organic matter content). Nematode abundances were apparently affected by the previous crops e.g., *P. coffeae* was slightly more abundant in fields where tuber plants such as sweet potato, yam, or dasheen were the previous crop; *R. similis* was particularly abundant in fields where banana or plantain was the previous crop; and *Meloidogyne* spp. were abundant in fields where a market garden was the previous crop. The results of this study will be useful for the design of PFN control methods in plantain.

1. Introduction

There is an increasing need to understand the biotic and abiotic drivers that shape the structure of plant-feeding nematode (PFN) communities in tropical agrosystems because such information is central to the design of cost-efficient and environment-friendly control methods. The structure of nematode communities in agrosystems depends on many factors including climate (Bakonyi et al., 2007; Duyck et al., 2012; Papatheodorou et al., 2004; Ruess et al., 1999), soil properties (Avendano et al., 2004; Ettema and Wardle, 2002; Godefroid et al., 2013; Goodell and Ferris, 1980; Ortiz et al., 2010; Quénéhervé, 1988), plant composition (Yeates, 1999), interspecific interactions such as competition or trophic interactions (Djigal et al., 2012; Ferris et al., 2012; Wardle et al., 2004), and cultural practices or past disturbance (Bongers, 1990; Chabrier and Quénéhervé, 2003; Neher, 2010; Verschoor et al., 2001).

Plantain is a major fruit crop in tropical and subtropical areas and is important for food security in many developing areas, including the Caribbean region (Lescot, 2004). In the Caribbean, plantains are often cultivated by smallholder farmers and sold in local markets. Unlike dessert bananas, which are primarily grown for export, plantains are generally managed with low chemical

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input and have a very short lifespan, i.e., 2–3 years for plantains vs. 7 years or more years for intensively managed dessert bananas (Quénéhervé, 2009). Because nematological research has mainly focused on dessert bananas, insufficient information is available regarding the composition of PFN communities in plantain agrosystems in the Americas and especially in the Caribbean. Previous research, however, has established that PFNs may cause severe damage to plantain roots (Brentu et al., 2004; Coyne et al., 2013, 2005) and may consequently cause substantial yield losses (Fogain, 2000; Jacobsen, 2009). A better understanding of the PFN communities associated with plantains is required to design efficient pest control methods (Coyne, 2007).

Bananas infected with PFNs are less able to take up water and nutrients, which results in stunting, delayed maturation, reduced bunch size, and finally in significant yield loss (Quénéhervé, 2009). In banana and plantain fields of the Caribbean, the burrowing nematode *Radopholus similis* Cobb and the lesion nematode *Pratylenchus coffeae* Zimmerman are particularly prevalent (Roman, 1978; Stover, 1972) and feed in root cells (Gowen et al., 2005). These migratory endoparasites cause necrosis and lesions on which other opportunistic pathogens can develop, reduce root biomass, and most importantly increase the susceptibility to toppling (Chabrier et al., 2005, 2002). *R. similis* is a native of the Pacific region but over the last several hundred years has invaded most of the banana-growing regions, including Latin America and the Caribbean, following the transport of infested *Musa* plants between countries (Marin et al., 1998). This species is now found in both dessert (Cavendish cultivars) and plantain bananas. *P. coffeae* is a widespread pantropical species associated with most tropical crops (Bridge et al., 2005; CABI, 2016). In Caribbean banana plantations, other harmful PFNs include the spiral nematode, *Helicotylenchus multicinctus* Cobb, and root-knot nematodes, *Meloidogyne* spp. (Cofcewicz et al., 2005; Roman, 1978).

The objective of the current study was to increase our basic understanding of PFN communities in plantain agrosystems in the Caribbean. To achieve this goal, we performed a large-scale survey in Martinique and used multivariate analyses and statistical models to explore the relationships between PFN communities, soil type, and cultural practices.

2. Materials and methods

2.1. Data collection

Between January and July 2011, a total of 301 root samples were collected from 53 plantain fields (*Musa* AAB, cv. Créole Blanche) located throughout Martinique island in the Caribbean. The fields ranged from 0.1–15 ha, and 90% were ≤3 ha. Field age ranged from 1 to 5 years. In each field, 5–10 root samples (about 500 g of fresh roots per sample) were independently collected from 0 to 30 cm depth at the base of randomly selected flowering plantains (one sample per plantain mat). Each root sample was washed with water and cut into small pieces (from 0.5 to 2 cm). For each root sample, a 50-g quantity was used for nematode extraction. Nematodes were extracted in a mist chamber for 10 days (Seinhorst, 1950) and were then identified and counted with the aid of a stereomicroscope. Nematode densities were expressed as numbers of individuals per 100 g of fresh roots. We thus obtained 5–10 measures of nematode densities in roots for each field We calculated the geometric mean of the abundance of each PFN species in each plantation.

Four soil samples from 0 to 30 cm depth were also collected from each field. The soil samples were collected near the roots of randomly selected flowering plantains. These samples were mixed to yield one composite sample per field. This composite soil sample was then subjected to physical and chemical analyses. Total carbon (C; $mg\,g^{-1}$ soil) and nitrogen (N; $mg\,g^{-1}$ soil) contents were quantified after dry combustion using a CNS elemental analyzer (Carlo Erba). Soil pH values were measured in 1:2.5 (w:v) soil: water suspensions, and total phosphorus (P; $\mu g\,g^{-1}$ soil) was determined by colorimetry (Petard, 1993). The cation-exchange capacity (CEC) was measured with ammonium acetate at pH 7. The contents of the main exchangeable cations, calcium (Ca^{2+}; cmol kg^{-1} soil), magnesium (Mg^{2+}; cmol kg^{-1} soil), and potassium (K^{+}; cmol kg^{-1} soil), were estimated with a flame spectrometer after exchange with ammonium acetate (Page, 1982). The N mineral (NH_4^{+}, NO_3^{-}, $mg\,kg^{-1}$ soil) content of the soil was determined colorimetrically in 1 M KCl extracts by flow-injection analysis (Bremner, 1965).

The crop that preceded plantain, the frequency of nematicide use, and the age of the plantain planting were determined by interviewing the farmers. Four classes of preceding crop were recognized: (1) long-lasting (≥1 year) wild fallow, (2) continuous plantain and/or dessert banana plantation, (3) vegetable market gardening, and (4) tuber plants (yam, dasheen, or sweet potato). Three classes of nematicide use were identified: "no nematicide" (nem0), "occasional treatment" (<2 treatment per year) (nem1), and "frequent treatment" (≥2 treatment by year) (nem2). Three classes of plantain planting age were recognized (1-year-old plantings (cycle1), 2-year-old plantings (cycle 2), and >2-year-old plantings (cycle3)).

Mean annual temperature and rainfall for the previous 30-year period for each field were obtained from Météo-France Martinique. We assigned a soil type to every field (andosol, ferralsol, vertisol, or nitisol) according to a soil type map (Colmet-Daage and Lagache, 1969). Andosols contain mainly allophanes and have a high meso- and macroporosity with substantial hydrological conductivity. Nitisols contain mainly halloysite and have a substantial macroporosity, while vertisols have poor meso- and macroporosity. Ferralsols are clayey soils but may have many macropores because of sand-like aggregates resulting from the combining of clays with organic matter.

2.2. Statistical analysis

Frequencies of occurrence (expressed as a percentage) and average densities were calculated for each PFN species found in

Table 1
Prominence value index of plant-feeding nematode taxa in 301 root samples collected in 53 plantain fields (*Musa* AAB, cv. Créole Blanche) from Martinique, French West Indies.

Nematode species	Frequency of occurrence (%)	Average density (geometric mean)	Prominence value
Radopholus similis	50.6	2249	1601
Pratylenchus coffeae	63	15098	11985
Helicotylenchus multicinctus	53.8	1534	1124
Meloidogyne spp.	70.5	1608	1351