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Response of soil nematode community composition and diversity to different crop rotations and tillage in the tropics

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ABSTRACT

Soil nematode community composition and diversity response to banana-pineapple (BA), banana-papaya (BP), banana-rice (BR) rotations and banana monoculture (CK) (12-year annual crops) under no-tillage (NT) and conventional tillage (CT) were assessed in the Wanzhong Farm in Hainan Island, China. Soil samples were taken at depth of 0–40 cm in 2014–2015. A total of 47 nematode genera with relative abundance over 0.1% were identified. *Acrobeloides* in BANT and BRCT, *Aphelenchus* in BANT, BACT, BRNT and BRCT, *Helicotylenchus*, *Rotylenchulus* and *Meloidogyne* in CKNT and CKCT were the dominant genera. In comparison with CK, BA, BP and BR increased the number of bacterivores, fungivores and omnivore–carnivores, and the concentration of bacterial PLFA and fungal PLFA. The no-tillage soils favored bacterivores, fungivores and high colonizer-persister (c-p) value omnivores and carnivores, but reduced plant parasites. Soil food web in the rotation combined with no-tillage systems was highly structured, mature and moderately enriched as indicated by Structure (SI), Maturity (MI) and Enrichment (EI) index values, respectively. Higher number of bacterivores and lower values of Channel index (CI) suggested bacterial-dominated decomposition in no-tillage soil. Soil nematode diversity and functional metabolic footprint were much greater after 12 years of crop rotation. The descriptive indicators were useful to provide insight into the effect of rotation and tillage, and the evaluative indicators were more comprehensive for interpreting the structure and function of the soil food web under different crop rotations and tillage.

1. Introduction

In agroecosystems, agricultural practices such as crop rotation, residue addition and no-tillage or reduced-tillage are beneficial for sustainable crop production due to their positive influences on soil physicochemical properties, microbial activity and biomass, and the composition and function of soil biota (Cunha et al., 2015; Kibet et al., 2016). For example, crop rotation can increase the input of organic C and N into the soil, which enhances soil fertility (Costa and Crusciol, 2016). When high amounts of crop residues are returned to the soil, crop rotation can influence the soil microbial habitat, improve soil structure (Meena et al., 2015), and increase biomass and diversity of soil fauna (Zhang et al., 2016). In addition, no-tillage involving surface crop residue application has been adopted as a means to promote soil aggregate stability and fertility, while simultaneously increasing the abundance and viability of soil biota (Ontl et al., 2015).

Composition and abundance of nematode fauna in agricultural soils are receiving increased attention because of the possibility of using them as a sensitive indicator of performance of farming systems or soil health (Neher, 2001). Nematodes in soils are classified as plant parasites, bacterivores, fungivores, and predators-omnivores based on their feeding habits. Each nematode trophic group has the potential of reflecting a different aspect of changes in soil conditions (Yeates et al., 1993). Bacterivores and fungivores are closely related to decomposition of soil organic matter, and the ratio of the numbers of these two trophic groups reflects the decomposition of organic matter and mineralization of nitrogen and carbon (Gu et al., 2015). Omnivores-predators are most sensitive to environmental disturbances resulting from changes in land use, which are higher in a natural land than in

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a disturbed agricultural land (Viketoft et al., 2011). Plant parasites attack many field crops and cause serious economical damage (Waweru et al., 2014). Higher population density and diversified structure of nematode communities should be widely used as a powerful ecological tool to assess soil condition as they respond to changes in the soil environment. Considering these indicative functions, many researchers have reported how soil nematodes respond to agricultural practices. For example, Forge et al. (2015) showed that in comparison with conventional tillage, no-tillage or reduced tillage significantly decreased *Pratylenchus neglectus* populations. Zhang et al. (2015a) showed that the response of nematode trophic diversity was sensitive to the residue and tillage effects. Crop rotation sequences including different crop varieties can also influence nematode abundance, diversity and community structure. Ponge et al. (2013) reported that free-living nematodes were more abundant in a lupin-meadow rotation system than in a continuous meadow system, and Turmel et al. (2015) found that maize monocultures was characterized by plant parasites (especially *Pratylenchus* and *Meloidogyne*) and a barley-maize rotation was dominated by bacterivores and fungivores.

Banana is the main agricultural crop in South China. Plant pathogenic nematode disease caused by long-term monoculture is recognized as the major factor limiting banana production. Zhong et al. (2015a) reported that crop rotation length and the choice of non-host companion crops in the banana rotation can influence population densities of harmful root-lesion nematodes. Furthermore, no-tillage or reduced-tillage practices that increase soil organic matter near the soil surface, compared to conventional tillage, can improve soil structure and soil biological properties in the banana phase of the crop rotation, and enhance banana yield stability (Zhong et al., 2015b). Until now, most studies on soil nematode communities have been focused either on the effects of different crop rotation or on the effects of tillage practices, with little attention to the interactive influence of both over three years. However, rotation and tillage are two important agricultural practices that are usually applied together in the crop fields of many countries. Therefore, the objectives of our study were to analyze the interactive effect of rotation and tillage on soil nematode and microbial community composition under a long-term experimentation in Hainan Island.

2. Materials and methods

2.1. Site descriptions

The experiment was carried out on the Wanzhong Farm in the city of Ledong (18° 36′ –18° 38′ N, 108° 47′ –108° 49′ E), Hainan Province, China. The region has a tropical monsoon climate with a mean annual temperature of 25.8 °C and a mean annual precipitation of 2065 mm. The test soil was classified as sandy loam according to the USDA texture classification system with 13.6% clay, 23.3% silt and 63.1% sand. The soil has initial properties of 7.12 g kg^{-1} total organic C, 0.76 g kg^{-1} total N, 0.59 g kg^{-1} total P, 1.21 g kg^{-1}, total K and pH 6.53. Soil pH was measured in 1:2.5 soil: KCl 1 M solution.

The experiment was a split-plot design with four replicates, initiated in 2002 with rotation management as the main plot and tillage system as the sub-plot. Detailed information about the treatments is showed in Table 1. The field experiment was divided into eight plots and the size of each individual plot was 170 m^2. Rotation management treatments were banana-pineapple rotation (BA) (three years of banana followed by three years of pineapple), banana-papaya rotation (BP) (three years of banana followed by three years of papaya), banana-rice rotation (BR) (three years of banana followed by three years of rice) and banana monoculture (CK). Tillage systems included a no-tillage (NT) and a conventional tillage (CT) treatment. Chemical N fertilizer (urea), P fertilizer (superphosphate) and K fertilizer (sulphate) were applied at the rates of 129 kg N ha^{-1}, 68 kg P ha^{-1} and 292 kg K ha^{-1}, respectively to a depth of 0–30 cm after transplanting every year. The manure used was cow manure compost (14.4 t ha^{-1}), with 53.3% water content, containing 145 g C kg^{-1}, 3.2 g N kg^{-1}, 2.5 g P_2O_5 kg^{-1}, 1.6 g K_2O kg^{-1} on a dry weight basis, which was basally applied before transplanting (June 25th, 2002–2014) to a depth of 0–30 cm every year. Lime was used (125 kg ha^{-1}) together with cow manure compost to increase soil pH. Soil in CT was mouldboard ploughed (40 cm deep) at the end of May and the crops of all treatments were re-sown at the end of June. All aboveground crop residues in CT were incorporated into the soil and residues in NT were left on the surface after crops harvest in the middle of May.

2.2. Soil sampling

All soil samples were collected at the same time in the last growing season (2014–2015). After the removal of above-ground plant debris, soil samples were collected using a soil corer (3.0 cm diameter) at a depth of 0–40 cm below the soil surface at the seedling stage (September 16, 2014), jointing stage (December 15, 2014), booting stage (March 17, 2015) and ripening stage (May 19, 2015) within the plant rows of banana plants, 50 cm from the base of the banana plant. For each sample, five random cores were combined to form one composite sample. The fresh soil samples were placed in individual plastic bags and then immediately stored at 4 °C.

A subsample of 100 g soil (fresh weight) was used for nematode extraction. Subsamples were first elutriated and sieved (mesh size 250 and 38 μm) with water. Nematodes from the suspensions were then extracted using a modified cotton-wool filter method (Liang et al., 2009). The abundance of nematodes was expressed per 100 g dry weight soil. Nematodes were counted using a dissecting microscope and identified using an inverted compound microscope. An average of 150 nematodes (100 nematodes at minimum) per sample were identified at 400 × to 1000 × magnification to genus or family level within one week of extraction or fixed in 4% formalin until identification. Nematodes were classified into the following trophic groups (Bongers, 1988): bacterivores (BF), fungivores (FF), plant parasites (PP) and omnivores-predators (OP).

Phospholipid fatty acids (PLFA) were used as indicators of total, bacterial and fungal biomass in the soil. Lipids were extracted from

Table 1
Description and site history of different treatments in the study area of a long-term crop rotation experiment at the Wanzhong Farm in Hainan Island, China.

Treatment	Crops	Planting Year
Monoculture (CK)	banana	June 2002–May 2014
Rotation 1 (BA)	banana and pineapple	Banana: June 2002–May 2005 and June 2008–May 2011; pineapple: June 2005–May 2008 and June 2011–May 2014.
Rotation 2 (BP)	banana and papaya	Banana: June 2002–May 2005 and June 2008–May 2011; papaya: June 2005–May 2008 and 2011–May 2014.
Rotation 3 (BR)	banana and rice	Banana: June 2002–May 2005 and June 2008–May 2011; rice: June 2005–May 2008 and June 2011–May 2014.

Note: In each rotation and monoculture plot, a no-tillage and a conventional tillage treatment were applied.