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No tillage and bagasse mulching alter fungal biomass and community structure during decomposition of sugarcane leaf litter in Lampung Province, Sumatra, Indonesia

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ABSTRACT

Soil fungi are the predominant decomposers of soil organic matter (SOM). To manage SOM in tropical agricultural soils, it is important to understand the effects of agricultural management on fungal communities and their decomposition of organic matter. Our study site was located in a sugarcane plantation in Lampung Province, Sumatra, Indonesia. The objectives of this study were to determine the following: (1) the effect of conversion from conventional tillage to no-tillage farming and the application of bagasse mulch on fungal biomass, community structure, and the relative ratio of fungal to bacterial biomass (F:B); (2) the combination effect of no-tillage with bagasse mulch on these fungal parameters; and (3) possible links between these fungal parameters and the decomposition rate of sugarcane leaf litter. We measured fungal biomass and F:B by phospholipid fatty acid (PLFA) analysis, and we evaluated fungal molecular diversity and community structure by modified terminal restriction fragment length polymorphism (T-RFLP) profiling. Fungal biomass was 2-fold greater with no-tillage and 2.5-fold greater with added bagasse mulch relative to conventional (tillage without mulch) plots. On the other hand, no-tillage also increased bacterial biomass and fungal OTU (operational taxonomic unit) richness, whereas bagasse mulch increased the F:B and inhibited a specific fungal OTU. Under a combination of no-tillage and bagasse mulch, the fungal biomass was 1.7-fold greater than in conventional plots, indicating that the combination did not have an additive effect on fungal biomass. The litter mass loss rate was negatively correlated with fungal biomass, and bagasse mulch suppressed the mass loss approximately 20% less than in the conventional plots. However, the mass loss rate in no-tillage plots did not differ from that in conventional plots. Overall, our results indicated that no-tillage and bagasse much increased litter fungal biomass and altered the fungal communities, and these changes were reflected in the litter decomposition and soil C dynamics. Further studies are needed to clarify the relationship between litter decomposition and fungal species identity.

1. Introduction

Soil fungi represent a major proportion of soil microbial biomass and are considered the dominant decomposers of organic matter in tropical soils (Yang and Insam, 1991; Lodge, 1993; Salamanca et al., 2006). Previous studies indicated that decomposition of organic matter is affected by the richness and community structure of fungal species as well as biomass (Setälä and McLean, 2004; Deacon et al., 2006), and a fungal-to-bacterial biomass ratio is considered to be associated with resource stoichiometry (Strickland and Rousk, 2010). However, few studies have focused on fungal communities and their contribution to decomposition in crop lands, especially in tropical regions. Although agricultural management efforts such as no-tillage and covering fields with crop residue (mulch) have been reported to affect fungal biomass (Hendrix et al., 1986; Frey et al., 1999; Helgason et al., 2009; Carrera et al., 2007; Elfstrand et al., 2007), their impact on soil fungal diversity and community structure is not clear (Wu et al., 2007; Nishizawa et al., 2010; Gil et al., 2011). Soils contain various types of organic matter, such as plant

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litter and decomposing insects and animals; thus, the fungal community structure can vary greatly among different types of organic matter (Horwath, 2007; Thorn and Lynch, 2007; Shaheen et al., 2008; Hanson et al., 2008). Therefore, the actual impact of no-tillage and mulch on soil fungal communities and their relationship to decomposition cannot be understood simply from bulk soil. In this study, we focus on the effect of no-tillage and mulch on fungal communities in litter, which is the first step in transferring organic matter into soil.

In recent years, the implementation of no-tillage and reduced tillage systems has increased in the sugarcane plantations of Brazil and Australia to reduce soil erosion and soil organic C loss (Galdos et al., 2009; Stirling et al., 2010). Tropical agricultural lands often have problems with soil degradation resulting from the loss of organic matter (Paustian et al., 1998; Bot and Benites, 2005; Hartemink, 2006). Soil C turnover is twice as fast in tropical regions as in temperate regions, which is likely due to lower cation exchange capacities (CEC), less stabilized C, and higher temperature and precipitation, leading to faster decomposition (Six et al., 2002). In general, practicing no-till agriculture and mulching helps to increase and maintain soil organic matter (SOM) (e.g., Machado and Silva, 2001; Jimenez and Lal, 2006; de Rouw et al., 2010; Neto et al., 2010; Verma et al., 2010; Fasinmirin and Reichert, 2011; Guto et al., 2012). No-tillage prevents soil C loss due to erosion after tilling (Conant et al., 2007) and increases the proportion of macroaggregates, which results in the accumulation of SOM within the aggregate structure (Six et al., 2006). In addition, the application of sugarcane bagasse (sugarcane fibers from which the juice has been extracted) to the soil has been found to increase SOM content (Taja and Vanderzaag, 1991; Barzegar et al., 2002), mainly by increasing C:N residue ratios and reducing soil erosion (Scopel et al., 2005; Jordan et al., 2010). Sugarcane leaf litter, which amounts to 6–8 tons dry weight/ha/year, is also an important soil input (Singh et al., 2008). Since it remains unclear the effect of different agricultural management on litter fungal communities which have a key role of SOM transition from litter to soil, our study would provide insight into predicting SOM dynamics in tropical agroecosystems.

Previous studies indicated that fungal biomass is greater under no-tillage than conventional tillage because fungal hyphal networks are not disturbed by the mechanical mixing that occurs during tillage (Beare et al., 1992; Helgason et al., 2009) and because fungal populations are enhanced by increasing the soil moisture content while increasing the soil porosity and presence of surface plant residues (Blevins et al., 1983; Hendrix et al., 1986; Frey et al., 1999). Changes in moisture conditions also alter the fungal community structure due to varying drought tolerance among fungal species (McLean and Huhta, 2000; Shi et al., 2002; Gleason et al., 2004; Robertson et al., 2006). The lack of physical soil disturbance may change the fungal community because tolerance to tillage-induced disruption of the hyphae differs among fungal species (Jansa et al., 2003; Schnoor et al., 2011). In addition, weed growth is often not suppressed under no- or minimum-tillage conditions because many weed seeds stay near the soil surface without tillage (Mohler and Callaway, 1995; Clements et al., 1996). It has been suggested that plants determine the composition and activity of a soil microbial community (Wardle et al., 1997).

Mulch also affects fungal communities, and its effect depends on the quality of the plant residue used as mulch. Low-quality resources (high C:N) favor fungi, whereas high-quality resources (low C:N) favor bacteria (Bossuyt et al., 2001), and the fungal community structure changes depending on the type of organic input (Lejon et al., 2007; Kubartova et al., 2009). For example, wheat, rye, and hairy vetch residue have been shown to promote the growth of specific fungal groups and decrease the overall fungal diversity compared to bare soil (Punja et al., 2008; Nishizawa et al., 2010). Previous studies on bagasse amendments have focused on changes in soil chemical characteristics, crop production, and soil moisture retention (Taja and Vanderzaag, 1991; Barzegar et al., 2002; Tabarant et al., 2011).

We aimed to better understand the changes in litter fungal communities that occur as a result of no-tillage and mulch application to the soil. Our objectives during this study were to determine the following: (1) the effect of conversion from conventional tillage to no-tillage and the application of bagasse mulch on fungal biomass, fungal to bacterial biomass ratio, and fungal species richness, diversity, and community structure; (2) the combination effect of no-tillage with bagasse mulch on these fungal parameters; and (3) possible links between these fungal parameters and the decomposition rate of sugarcane leaf litter at a sugarcane plantation in Sumatra, Indonesia.

2. Materials and methods

2.1. Site description

The field study was conducted at a sugarcane plantation (4°40′S, 105°13′E, altitude c.a. 45 m) in Sumatra, Indonesia, from September 2010 to January 2011. The experimental site was located within a large area (approximately 25,000 ha) of the plantation and on Alisol soil (FAO, 2001). The total precipitation amounts at this site during the dry season (May 2010 to September 2010) and the wet season (October 2010 to April 2011) were 854 and 2097 mm, respectively. The average air temperatures during the dry and wet season were 28.7 and 26.7 °C, respectively. We used a split plot design with soil tillage as the main factor and bagasse mulch as a secondary factor. The treatments were no-tillage without mulch (NT), no-tillage with mulch (NTM), conventional tillage without mulch (CT), and conventional tillage with mulch (CTM) repeated across five replicate blocks. Each plot was 25 m × 25 m with a 5-m buffer zone adjacent to the road. The conventional tillage treatment plots were ploughed three times to depths of 20 (first), 40 (second), and 20 cm (third) in July 2010. In the mulch treatment, 80 tons (wet weight) per hectare of bagasse mulch were spread on the soil surface from August 1 to 5. Eighty tons (wet weight) per hectare of organic BBA fertilizer, consisting of five parts Bagasse, three parts Blotong (filter cake), and three parts bagasse ash, were spread prior to ploughing in the CT and CTM plots and after planting in NT and NTM plots. Inorganic fertilizers (N:P:K 120:80:180 kg/ha) were applied in all treatments at the time of planting. Sugarcane seed stems were planted on July 21–30, 2010. Herbicides were not applied to any of the treatments.

2.2. Soil sampling and measurement of physical and chemical conditions and weeds sampling

Field soil was collected on September 23, 2010 and January 25, 2011. Three soil samples per plot were collected using a 100 cc corer at 0–5 cm depth and thoroughly mixed. The soil pH was determined by a 1:1 soil:H_2O suspension and 1:2.5 soil:1 M KCl suspension. The soil temperature at a 5-cm depth and the volumetric water content (0–10 cm) were recorded with a HydroSense soil moisture sensor (Decagon Devices, Pullman, WA, USA). Weeds were cut at ground level from 1 m^2 quadrants in each plot on January 25, 2011 and were oven dried at 80 °C for 24 h to determine the dry weight. Total soil carbon (C) and nitrogen (N) and the C:N ratio of sugarcane leaf litter, bagasse and weeds were analyzed using an elemental analyzer (CN coder MT-700, Yanaco, Kyoto, Japan). For analysis of the C and N content of the weeds, the leaves of two dominant species, *Brachiaria distachya* and *Borreria latifolia*, were selected.