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Soil macrofauna assemblage composition and functional groups in no-tillage with corn stover mulch agroecosystems in a mollisol area of northeastern China

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ABSTRACT

Macrofauna is an important component of soil ecosystems, and strongly affects agricultural sustainability. In order to evaluate the effects of no-tillage with corn stover mulch on soil macrofauna assemblages in the mollisol agroecosystems, the abundance, diversity, composition, and the functional groups of the soil macrofauna were investigated in Lishu Conservation Tillage Research and Development Station located in northeastern China. The experimental design was a randomized complete block with four replicates for each treatment, and included no-tillage with four different amount of corn stover mulch (0, 2.5, 5 and 7.5 t/ha) and conventional tillage. Soil macrofauna samples were collected in April, July and October 2015. The results showed that the abundance and group richness of soil macrofauna were significantly higher in the no-tillage with corn stover mulch systems compared to conventional tillage. The composition of the fauna communities were different between treatments, especially between conventional tillage and no-tillage with 5 t/ha corn stover mulch, no-tillage with 7.5 t/ha corn stover mulch. The biological index *V* of the seven taxonomic groups showed that Oligochaeta, Coleoptera, Araneae and Hymenoptera were very highly suppressed by conventional tillage, while the magnitude of response of the other groups to tillage varied between the mulch treatments, as well as with the sampling time. The abundance of decomposers and predators was significantly enhanced by no-tillage with corn stover mulch ($P < 0.05$), but not significant for herbivores. The study results also showed that the amount of corn stover mulch had an influence on the abundance of soil macrofauna communities; however, a significant positive relationship between the amount of corn stover mulch and abundance of soil macrofauna was only observed in April. It is thus concluded that no-tillage with corn stover mulch seems to be beneficial to biological soil components where it favored the establishment of abundant and diverse soil macrofauna communities than conventional tillage in the mollisol area of northeastern China.

1. Introduction

Many soil physical properties and chemical processes contributing to sustainable agricultural productivity rely greatly on the abundance, diversity and activities of the soil fauna (André et al., 2002; Abbott and Manning, 2015; Bender et al., 2016). Soil macrofauna encompass a wide range of organisms, and are involved in signaling processes which are conducive to soil quality and health (Lavelle, 1997; Bottinelli et al., 2015). They play an essential role in the formation of stable soil aggregates, distribution and size of soil pores, and dynamics of soil organic matter, by means of digging, degradation of detritus and enhancing microbial activities (Lavelle et al., 2006; Brussaard et al., 2007; Huhta, 2007). These processes in turn improve the structure, hydraulic properties, and chemical and nutritional characteristics of soil. In addition, soil macrofauna occupy almost all trophic levels in the soil food-webs. Many soil macrofauna are specific or nonspecific predators, while others are strictly herbivores, detritivorous or opportunistic omnivores (Marasas et al., 2001). An appropriate predator-herbivores ratio in soil macrofauna is necessary in sustainable agroecosystems in order to prevent pest outbreaks. Therefore, as interest grows in maintaining soil productivity, it becomes necessary to gain insight regarding soil macrofauna assemblages in agroecosystems.

Tillage and residue management as main agricultural practices have a profound impact on a soil environment (Karlen et al., 1994; Zhang et al., 2017). In order to maintain the natural stability of soil ecosystems and sustainable crop production, conservation tillage characterized by

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reduction or absence tillage and crop residues retention on the surface of soil has gained widespread acceptance in the past few decades (Gebhardt et al., 1985; Schnepf and Cox, 2006; Kassam et al., 2014). Compared to conventional tillage, this practice can abate soil erosion, enhance soil organic matter, improve soil structure and conserve soil moisture (Erenstein, 2002; Moussa-Machraoui et al., 2010; Palm et al., 2014; Stavi et al., 2016). These changes in the soil physio-chemical environment affect soil macrofauna, because their habitats have been modified (Kladivko, 2001; Rousseau, et al., 2013; Peigné et al., 2018). The responses of soil macrofauna to tillage and residue management vary among agroecosystems and geographical regions (Robertson et al., 1994). Nevertheless, the abundance and diversity of soil macrofauna in conservation tillage systems are generally greater than those in conventional tillage systems. Different functional groups of soil macrofauna respond to conservation tillage in different ways. Some studies have reported that no-tillage with residue mulch can increase the incidence of soil-inhabiting pests, while others have shown that tillage intensity had no influence on the number of pests or predators (House and Parmelee, 1985). Therefore, a comprehensive understanding of the effects of no-tillage and crop residues mulch on the soil macrofauna is necessary to achieve more precise management of soil fauna for beneficial purposes in agriculture.

Northeastern China is one of the major mollisol areas of the world, and is also the main corn production area of China. Agricultural practices used for cereal production in this region have long been based on conventional tillage where post harvest residues of corn were removed or burnt, after which the soil was plowed prior to sowing the new season’s crop, which had led to seriously degrading the soil (Lu, 2001; Yang et al., 2006; Ouyang et al., 2018). In recent years, conservation tillage has gradually replaced conventional tillage to protect and recover soil quality. In order to evaluate the effects of no-tillage with corn stover mulch on soil macrofauna, the abundance, diversity and composition of the soil macrofauna community, as well as the functional groups, are compared between conventional tillage and conservation tillage in the mollisol area of northeastern China. The following are determined: (1) whether or not no-tillage with corn stover mulch produces an increase in abundance and diversity, as well as the changes in the soil macrofauna composition; (2) what changes may take place among different functional groups; and (3) whether or not the diversity and abundance of soil fauna could have a positive correlation with the amount of corn stover mulch.

2. Materials and methods

2.1. Study sites

This study was conducted at the Lishu Conservation Tillage Research and Development Station of the Chinese Academy of Sciences (43°19′N, 124°14′E), Jilin Province, located in northeastern China. It has a temperate subhumid continental monsoon climate. The annual rainfall, which falls primarily between June and September, averages about 614 mm. The mean annual temperature is about 6.9 °C, and the highest and lowest monthly mean temperatures respectively occur in July (23.7 °C) and January (−13.5 °C). The soil is classified as mollisol (IUSS working group WRB, 2007) with initial properties of the 0–20 cm soil layer 11.3 g kg^{-1} soil organic matter, 1.2 g kg^{-1} total N, 0.98 g kg^{-1} total P, 24.3 g kg^{-1} total K, and pH (H_2O) 7.1 in 2007. This area has always been planted with corn. After harvest of the corn in the autumn, there was not planted any no other crops.

2.2. Experimental design

The experiment was established in 2007 using a randomized complete block design with four replicates. The size of each plot in each replication was 261 m^2 (8.7 m × 30 m). The treatments were no-tillage with no corn stover mulch (NT-0), no-tillage with 2.5 t/ha corn stover mulch (NT-33%), no-tillage with 5 t/ha corn stover mulch (NT-67%), and no-tillage with 7.5 t/ha corn stover mulch (NT-100%), with conventional tillage (CT) as a control. The no-tillage plots were left undisturbed, except for the surface drilling of the spring crop, and corn stover was evenly distributed over the field surface after harvest each year. The CT plots were rotary tilled to a depth of 25–30 cm before the crops and corn stover were removed from the field after harvest.

Sampling was conducted in April, July and October of 2015, which respectively correspond to the periods of sowing, jointing and mature stage of corn. During each sampling, three sampling points in each plot were selected along a diagonal line-transect. At each sampling point, one soil monolith of 25 cm × 25 cm to 15 cm depth was excavated and hand-sorted to collect macrofauna, according to the TSBF method (Anderson and Ingram, 1993). All macrofauna samples were preserved in 75% alcohol, except earthworms, which were fixed and preserved in 4% formalin, then taken to the laboratory to identify at the order or family level, and counted under a stereoscopic microscope (Yin, 1998). Soil macrofauna were further classified into predators, detritivores, omnivores and herbivores, based on their known feeding behaviors.

2.3. Data analysis

The total abundance (the total number of soil macrofauna per plot converted to individual/m^2), taxonomic richness (the sum of taxa found in three sampling points per plot), Shannon-Wiener index ($H' = -p_i \ln p_i$, where p_i is the share of the ith species in the sample) and Pielou's evenness index ($E = H'/\ln S$, where H' is the Shannon-Wiener index and S is number of taxa in the sample) were calculated within each sampling, so as to analyze the effects of treatments on the soil macrofauna communities. At the trophic group level, the abundances of the three main trophic groups of predators, herbivores and decomposers (detritivores + omnivores) were measured. The individuals of all soil macrofauna were divided into seven taxonomic groups, namely Oligochaeta, Coleoptera, Diptera larvae, Geophilomorpha, Hymenoptera, Araneae and other taxa. The abundance of each taxonomic group was measured to assess the different taxa groups’ responses to the treatments. Finally, the V index was calculated to express the magnitude of response of each taxa group to tillage according to Wardle (1995).

Repeated ANOVA measurements were performed to evaluate the effects of the treatments (NT-0, NT-33%, NT-67%, NT-100% and CT), the sampling time (April, July and October) and their interactions on the indices of the soil macrofauna community, abundances of trophic groups and seven taxonomic groups. Least significant difference (LSD) post hoc tests were used to compare the differences in these response variables among the treatments and sampling time. To satisfy assumptions such as the normality and homogeneity of variances, the data were log (x + 1) transformed prior to analysis. The statistically significant differences were then determined at the $P < 0.05$ level. The relationships between the soil macrofauna and the amount of corn stover mulch were analyzed by linear regression.

PERMANOVA, a permutational non-parametric analogue to MANOVA, was used to test the differences in the soil macrofauna assemblages among the treatments. Discrimination was based upon Sorensen (Bray-Curtis) (Anderson, 2001). Additionally, Principal component analysis (PCA) was performed to explore the effects of treatments on the soil macrofauna community composition at each sampling. The abundance data (Ind. m^{-2}) were log (x + 1) transformed before being subjected to PCA.

All statistical analyses were performed with SPSS 18.0 and PC-ORD 5.0 software.