APPLIED SOIL ECOLOGY 37 (2007) 247–255

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Effects of cover crops, compost, and manure amendments on soil microbial community structure in tomato production systems

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ARTICLE INFO

Article history:
Received 25 July 2007
Accepted 8 August 2007

Keywords:
Microbial community
FAME
Biolog
Hairy vetch
Cover crop
Black polyethylene
Mulch

ABSTRACT

Soil microbial community structure and crop yield was investigated in field tomato production systems that compared black polyethylene mulch to hairy vetch mulch and inorganic N to organic N. The following hypotheses were tested: (1) hairy vetch cover cropping increases crop yield and significantly affects soil microbial community structure when compared to the standard plastic mulch and synthetic fertilizer-based system; (2) within plastic mulch systems, organic amendments will increase crop yield and significantly affect soil microbial community structure when compared to synthetic fertilizer; (3) crop yields and microbial community structure will be similar in the hairy vetch cover cropping and the organic amended plasticulture systems. Treatments consisted of ammonium nitrate (control), hairy vetch cover crop, hairy vetch cover crop and poultry manure compost (10 Mg/ha), three levels of poultry manure compost (5, 10, and 20 Mg/ha), and two levels of poultry manure (2.5 and 5 Mg/ha). Black polyethylene mulch was used in all treatments without hairy vetch. Fatty acid analysis was used to characterize the total soil microbial community structure, while two substrate utilization assays were used to investigate the community structure of culturable bacteria and fungi. Crop yield was not significantly increased by hairy vetch cover cropping when compared to black polyethylene mulch, although microbial community structure was significantly affected by cover cropping. Under black polyethylene mulch, crop yields were significantly increased by the highest levels of compost and manure when compared to inorganic fertilizer, but there was no detectable effect on soil microbial community structure. When cover cropping was compared to organic amended plasticulture systems, crop yields were similar one year but dissimilar the next. However, hairy vetch cover cropping and organic amendments under black plastic mulch produced significantly different soil microbial community structure.

Published by Elsevier B.V.

1. Introduction

Conventional tomato production utilizing tillage, black plastic mulch, commercial fertilizer applied through drip irrigation, and pesticides, can improve the yield and quality of fresh-market tomatoes compared to bare soil production by warming soil earlier in spring, preventing evaporation of soil moisture, increasing fertilizer use efficiency, and suppressing

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0929-1393/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.apsoil.2007.08.003

weeds (Abdul-Baki et al., 1992). However, this intensive production system also can degrade soil quality, enhance runoff by covering the soil with an impervious surface, contribute to surface and groundwater pollution, and add to production cost (Rice et al., 2001). Alternative systems have been developed that use renewable organic resources and/or minimize tillage to build soil organic matter and improve soil quality. Minimum-tillage systems including cover cropping with legumes to fix nitrogen, recycle nutrients, and improve soil quality have been identified as viable alternatives for production of both agronomic and horticultural crops (Decker et al., 1994; Lu et al., 2000) and have distinct economic and environmental advantages over use of plasticulture or bare soil (Kelly et al., 1995; Rice et al., 2001).

In a system developed at the USDA Beltsville Agricultural Research Center (Abdul-Baki and Teasdale, 1997), raised beds are formed in the fall and seeded with hairy vetch. The vetch is mowed the following spring just before tomatoes are transplanted through the vetch residue without tillage. The hairy vetch mulch suppresses many annual weeds and provides much of the nitrogen needed by the tomato plants. This surface mulch also reduces raindrop impact on the soil which increases infiltration, reduces runoff and sediment losses from fields, and reduces splashing that can enhance development of foliar diseases (Mills et al., 2002). While tomatoes grown in black plastic mulch produce greater early plant growth and higher early yields, tomatoes grown with hairy vetch mulch have greater overall leaf area, higher total yields, and a longer season (Teasdale and Abdul-Baki, 1997).

Manure and compost are organic sources of nutrients that also have been shown to increase soil organic matter and improve soil quality (Wright et al., 1998). They usually need to be incorporated into soils to prevent loss of nutrients through volatilization or runoff, particularly nitrogen. Thus, they would be suitable for use in conjunction with a traditional tillage-based plasticulture system but could offer potential soil quality improvement in this otherwise soil-destructive system. This approach would provide an easier alternative system for growers to adopt than the minimum-tillage cover crop system that requires new equipment and additional fall operations.

Microbial communities perform essential ecosystem services, including nutrient cycling, pathogen suppression, stabilization of soil aggregates, and degradation of xenobiotics. Soil microbial biomass, activity, and community structure have been shown to respond to agricultural management systems. Soil microbial communities can reflect the impact of management on soil quality although the linkage between soil microbial communities and soil quality is not well understood. Since many soil properties associated with soil quality do not change rapidly in response to management, we evaluated soil microbial communities which would be expected to respond more rapidly to alternative management systems in a short study such as the 2-year experiment presented in this paper (Martini et al., 2004). In this study, we compare soil microbial communities in conventional plasticulture tomato production systems with and without organic soil amendments and in the alternative cover crop-based system. The following hypotheses were tested: (1) hairy vetch cover cropping increases crop yield and significantly affects soil microbial community structure when compared to the standard plastic mulch and synthetic fertilizer-based system; (2) within plastic mulch systems, organic amendments will increase crop yield and significantly affect soil microbial community structure when compared to synthetic fertilizer; (3) crop yields and microbial community structure will be similar in the hairy vetch cover cropping and the organic amended plasticulture systems.

2. Materials and methods

2.1. *Field experiment*

The experiment consisted of eight soil amendment systems for growing fresh-market tomatoes conducted on Downer-Ingleside loamy sand on the North Farm of the Beltsville Agricultural Research Center, Beltsville, Maryland, during the summer seasons of 2000 and 2001. The treatments were synthetic N only (control), three levels of poultry manure compost (5, 10, and 20 Mg/ha), two levels of poultry manure (2.5 and 5 Mg/ha), hairy vetch mulch, and (in 2001 only) hairy vetch mulch plus poultry manure compost (10 Mg/ha).

Poultry manure compost was produced at the Beltsville Agricultural Research Center Composting Facility. Compost used in 2000 consisted of poultry (turkey) litter mixed with orchard grass hay in a 1:3 (v/v) mixture, placed in a 50 m windrow and composted by the windrow method for 8 weeks. The final pH was 7.54, total organic carbon was 266 g/kg, total nitrogen was 14.9 g/kg, and total phosphorus was 15.7 g/kg (Sikora and Enkiri, 2003). Compost used in 2001 consisted of (by volume) 15% old hay, 15% mixed manure and bedding (from layers, 2–3 weeks old, 120 °C), 25% poultry (layers) manure, 30% leaves, and 15% straw. After composting by the windrow method for 9 weeks, the final pH was 8.89, total organic carbon was 74.8 g/kg, total nitrogen was 6.6 g/kg, and total phosphorus was 0.77 mg/kg.

Field preparation began in September of 1999 with the creation of raised beds, 1.5 m center-to-center and 15 cm high. Treatments were applied to plots consisting of four 12-m sections of beds and were arranged in a randomized complete block design with four replications. Hairy vetch seed (*Vicia villosa* Roth) was planted at 45 kg/ha on the top of designated beds on 10/16/99 and 10/4/00. The compost associated with the compost plus vetch treatment was applied before forming beds and planting vetch in October of 2000. The other compost and manure amendments were incorporated into designated beds and the beds reshaped on 5/8/00 and 5/8/01. Treatments were continued in the same plots in the same field in the second season.

In preparation for planting, hairy vetch was mowed and black polyethylene mulch was laid on all treatments except those with a surface mulch of hairy vetch residue. Drip irrigation tape was installed under black plastic mulch and on top of hairy vetch residue approximately 10 cm from the tomato row. 'Sunbeam' tomato seedlings (*Lycopersicon esculentum* Mill.) were transplanted into the center of each bed spaced approximately 50 cm apart on 5/18/00 and 5/16/01. Plants were irrigated throughout the season as needed. Fertilizer was injected every other week through the irrigation system. Nitrogen was applied as ammonium nitrate to provide