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Effect of organic, sustainable, and conventional management strategies in grower fields on soil physical, chemical, and biological factors and the incidence of Southern blight

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ARTICLE INFO

Article history:
Received 11 October 2006
Received in revised form
25 June 2007
Accepted 27 June 2007

Keywords:
Soil physical
Chemical and biological properties
Organic and conventional farms
Microbial communities
Functional diversity
Species diversity
Biolog
DGGE

ABSTRACT

The objectives of our research were to evaluate the impact of organic, sustainable, and conventional management strategies in grower fields on soil physical, chemical, and biological factors including soil microbial species and functional diversity and their effect on the Basidiomycete plant pathogen *Sclerotium rolfsii*, causal agent of Southern blight. Soils from 10 field locations including conventional, organic and sustainable farms were sampled and assayed for disease suppressiveness in greenhouse assays, and soil quality indicators. Soils from organic and sustainable farms were more suppressive to Southern blight than soils from conventional farms. Soils from organic farms had improved soil chemical factors and higher levels of extractable C and N, higher microbial biomass carbon and nitrogen, and net mineralizable N. In addition, soil microbial respiration was higher in soils from organic than sustainable or conventional farms, indicating that microbial activity was greater in these soils. Populations of fungi and thermophiles were significantly higher in soils from organic and sustainable than conventional fields. The diversity of bacterial functional communities was also greater in soils from organic farms, while species diversity was similar. Soils from organic and sustainable farms had improved soil health as indicated by a number of soil physical, chemical and biological factors and reduced disease.

1. Introduction

Organic production has increased in recent years in many areas of the United States. Organic systems do not use synthetic pesticides and in the long term may be more sustainable than conventional systems. Soils contain enormous numbers of diverse living organisms assembled in complex and varied communities. These organisms play an essential role in the sustainable function of all ecosystems, including recycling of nutrients, regulation of the soil organic matter and soil carbon sequestration, modification of soil physical structure and water regimes, enhancement of the efficiency of nutrient acquisition and plant health, suppression of undesirable organisms and detoxification of noxious chemicals (Coleman et al., 1978; Kennedy and Smith, 1995). In addition, even though microbial communities are a small fraction of the soil's total organic matter content, they provide a source and sink of nutrients and control soil organic matter mineralization. Changes in microbial communities can be used to predict the effects of ecosystem perturbations by organic and conventional management practices (Bending et al., 2000; Poudel et al., 2002; van Bruggen and Semenov, 2000).

There have been a number of reports that have indicated that organic farming practices have positive effects on soil

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doi:10.1016/j.apsoil.2007.06.007

microbial populations, processes and activities (Clark et al., 1998; Doran et al., 1996; Drinkwater et al., 1995). In a long-term field trial in which organic and conventional agricultural systems were compared, microbial biomass was higher in soils from organic plots (Gelsomino et al., 2004; Tu et al., 2005; Hu et al., 1997; Liu et al., 2007). Bossio et al. (1998) showed that different farming regimes, including organic, low-input, and conventional, influence soil phospholipid fatty acid (PLFA) profiles. Microorganisms with mono-unsaturated fatty acids increased with organic composts in organic and low-input systems. Soils under no-till and conventional till management were analyzed by PLFA and denaturing gradient electrophoresis (DGGE) profiling, and the results indicated that no-till soils had higher microbial populations and greater diversity of ammonia-oxidizing bacteria (Phillips et al., 2000). Fraser et al. (1994) reported a 10–26% increase in microbial biomass under organic management. The addition of animal or green manures on organic farms provided a significantly greater input of organic carbon, which increased bacterial populations. Mäder et al. (2002) reported results for a 21-year study of agronomic and ecological performance of biodynamic, bioorganic, and conventional farming systems in central Europe. They found enhanced soil fertility and higher biodiversity in organic than conventional plots and concluded this may render organic systems less dependent on external inputs. Moreover, other researchers have shown that incorporation of organic amendments increased soil microbial activity (Elliott and Lynch, 1994), microbial diversity (Girvan et al., 2004; Grayston et al., 2004), densities of bacteria (van Bruggen and Semenov, 2000), fluorescent *Pseudomonas* spp., pathogenic bacteria, fungi, and nematodes (Abawi and Widmer, 2000).

Although the majority of research has shown increased microbial diversity in soils from organic farming systems compared to conventional farming systems, some studies have found different results. Shannon et al. (2002) studied microbial communities in soils managed under organic and conventional regimes, and found conflicting evidence that the size, composition and activity of the soil microbial biomass were attributed to management practice. They found that differences in microbial communities in soils under different management practices were subtle rather than dramatic. Many of the parameters measured, including total carbon and microbial biomass carbon, often showed no consistently significant differences in soils under different management regimes.

Conventional farming systems have been associated with loss of soil fertility, soil erosion, and ground water pollution (Drinkwater et al., 1995). In addition, some conventional agricultural practices inhibit the activity and function of soil microbes. For instance, insecticide applications may promote changes in population biodiversity and dynamics by inhibiting or killing components of the soil microbial community. Fungicide application can cause significant changes to the relative sizes of the bacterial and fungal communities in soil (Sall et al., 2006; Sigler and Turco, 2002). Furthermore, commercial fertilizers used in conventional farming systems interact with microbial communities in soils in a number of ways either promoting growth directly by providing nutrients or indirectly by stimulating plant growth and enhancing root carbon flow (Buyanovsky et al., 1987). Alternatively, fertilizer inputs may acidify soil limiting microbial growth and activity (O'Donnell et al., 2001).

The objectives of our research were to evaluate the impact of organic, sustainable, and conventional management strategies in grower fields on soil physical, chemical, and biological factors including soil microbial species and functional diversity and their effect on Southern blight caused by the Basidiomycete plant pathogen *Sclerotium rolfsii*.

2. Materials and methods

2.1. Soil sampling

Soils from 10 farms in North Carolina with a history of organic, sustainable, or conventional crop production were sampled in August 2001, May 2002 and May 2003 (Table 1). Three of the farms were certified organic and did not use synthetic fertilizers or pesticides. They were located in Cedar Grove, NC (organic farm 1), Bear Creek, NC (organic farm 2), and Ivanhoe, NC (organic farm 3). Three of the farms sampled were classified as sustainable, meaning that synthetic pesticides were not used, however synthetic fertilizers were used. These farms were located in Graham, NC (sustainable farm 1), Bear Creek, NC (sustainable farm 2), and Clinton, NC (sustainable farm 3). Four conventional farms were sampled. These farms used monoculture, synthetic fertilizers, pesticide and herbicides. These farms were all located in or near Clinton NC (conventional farms 2–4) or in Faison NC (conventional farm 1). Details of the crops grown, pesticides used and soil fertility amendments are shown in Table 1.

Three composite soil samples were collected from each of the 10 farms in the fall of 2001, and late spring of 2002 and 2003. Composite samples were done by sampling approximately 20 kg of soil from each of three contiguous areas at each farm using a 2.5 cm soil auger in a serpentine pattern down each row to a depth of 20 cm and bulking samples. Bulked samples were kept separate by location within each field so three replications were maintained. Composite soil samples were stored in coolers on ice until returning to the lab. For soil dilution plating and Biolog analysis, the soils were transferred to a storage room and stored at 4 °C until the time of analysis; for DGGE analysis, the soils were stored immediately in a −20 °C freezer until the time of analysis. Biolog assays were done within 48–72 h after sampling soils and soil dilutions within a week after sampling.

2.2. Soil physical properties

Two undisturbed soil cores were removed from each of the three locations at each farm for bulk density and water release measurements. Undisturbed soil cores collected from each field with soil sampling rings of known volume were weighed and then dried in an oven and reweighed for bulk density assays. Soil porosity was calculated and soil water content was determined using standard procedures (Chancellor, 1976, Mehlich, 1973).