Soil Biology & Biochemistry 91 (2015) 32–39

Contents lists available at ScienceDirect

Soil Biology & Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

Enchytraeids as indicator of soil quality in temporary organic grass-clover leys under contrasting management: A feasibility study

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ARTICLE INFO

Article history:
Received 3 July 2015
Received in revised form
5 August 2015
Accepted 21 August 2015
Available online 3 September 2015

Keywords:
Soil enchytraeids
Grass-clover leys
Ley age and management
Slurry injection
Soil compaction
Trampling

ABSTRACT

One objective in organic farming is to sustain the quality of the soil resource. Because enchytraeids are an important soil faunal component, they stand as bioindicators of soil quality. We tested this candidature in a field experiment on loamy sand soil with 1- and 4-year old grass-clover leys subject to contrasting management regimes (cutting, slurry injection, grazing). Enchytraeid density, biomass and species composition was determined in 0–18 cm soil sampled in October, and again in March and May before and after slurry application, respectively. For soils retrieved in October, ley age had no consistent impact on enchytraeid density and biomass. Injection of slurry significantly affected the enchytraeid community at one sampling only but tended to sustain higher enchytraeid abundance in 1-year old leys throughout the year. One persistent feature was a larger enchytraeid community in the autumn than in the spring, regardless of management regime. Compared with leys used for cutting, grazed leys had consistently lower enchytraeid density and biomass. This was ascribed to soil compaction induced by heifer trampling. The number of species ranged from 11 to 18 in the autumn and from 7 to 13 in the spring with no distinct relation to management. Simpson's index of diversity did not differ among sampling dates and management regimes, including ley age. Although the enchytraeid community to some extent reflected differences in management regime, the patchy distribution and management induced interactions among soil physical, chemical and biological properties suggest that enchytraeid abundance is not a feasible stand-alone indicator of management impacts on soil quality in temporary grass-clover leys but may candidate as one of several biological key parameters in more comprehensive soil quality assessment schemes.

1. Introduction

In organic farming, one explicit objective is to maintain and eventually improve soil quality (a term often used synonymously with soil fertility and soil health) by adopting management that secures soil functionality and biological potentials. The assessment of soil quality involves quantitative indicators and was originally founded on soil properties directly related to crop productivity. Subsequently, more focus has been on bioindicators such as earthworm and soil mesofauna abundance, soil microbial biomass and activity, and the presence of specific plant pathogens (Pankhurst et al., 1997; Schjønning et al., 2004; Griffiths et al., 2010; Ferris and Tuomisto, 2015). To be of practical use in assessing soil quality, bioindicators should play a critical role in soil functioning, be easily measured by standardized methods, and reflect changes in management within a relevant time frame, e.g. by providing early warning of potential threats to soil quality.

Enchytraeids are amongst the most important components of the soil decomposer community (Didden, 1993; Topoliantz et al., 2000). Enchytraeids may stimulate soil microbial activity, the release of nutrients in plant available forms (Cole et al., 2000; van Vliet et al., 2004; Maraldo et al., 2011), and promote soil porosity and aggregation by burrowing, ingesting and excreting soil

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http://dx.doi.org/10.1016/j.soilbio.2015.08.023
0038-0717/

particles (Didden, 1990; Langmaack et al., 2001). Enchytraeid abundance has been adopted as bioindicators in recent assessments of management impact on soil quality in grassland systems (Griffiths et al., 2010; van Eekeren et al., 2010; Postma-Blaauw et al., 2012), but the effects of management on enchytraeid populations in terms of density, biomass and community structure are less well known for temporary, intensively managed grass-clover leys. In organic farming, forage for ruminants relies heavily on productive temporary grass-clover leys with considerable belowground inputs of organic matter (Acharya et al., 2012). The leys are used for grazing and cutting with regular application of cattle slurry e.g. by direct injection into the soil. The various management options are implemented either alone or in combinations and are envisioned to have a differential impact on soil structure and function.

Cutting (defoliation) affects the below-ground decomposer food web by changing the allocation of plant photosynthates and reducing the return of above-ground plant litter to the soil. When the above-ground plant biomass is cut and removed from the field, root turnover and exudation change dramatically with cascading impacts on rhizosphere organisms that rely on root derived substrates (Paterson and Sim, 1999; Hamilton and Frank, 2001).

Besides removing plant biomass during grazing, grazing animals may increase soil compaction due to trampling and leave a spatially heterogeneous input of organic matter, nutrients and water through deposition of dung and urine. Negative effects of soil compaction on mesofauna have previously been reported (Larsen et al., 2004; Mikola et al., 2009; Schon et al., 2011) and ascribed to reductions in habitable pore space. However, this adverse effect may be alleviated by the return of additional substrates in the form of dung and urine.

A few studies have examined the effects of slurry application on enchytraeids abundance, some of which report no effects (van Vliet and de Goede, 2006) and others positive effects (Domek-Chrucicka and Seniczak, 2005; Sokolowska and Seniczak, 2005). Although organic substrates contained in the slurry may represents an additional food source for enchytraeids, direct injection of anaerobically stored slurry may have detrimental effects because of its contents of ammonia and toxic compounds e.g. organic acids (Didden and Römbke, 2001).

Another important driver for enchytraeid abundance could be ley age, representing the time since the last soil disturbance. Postma-Blaauw et al. (2012) found the consistency of management was more important than the type of management *per se* (grassland or arable) for a diverse enchytraeid community. Thus frequent shifts in management regime may have a negative impact on enchytraeid abundance.

Based on three separate sampling campaigns, we examined the response of the enchytraeid community to contrasting management options (i.e. cutting, cutting with slurry injection, and grazing) in 1-yr-old and 4-yr-old organically grown grass-clover leys. We hypothesize that slurry injection increases the presence of enchytraeids due to a greater input of nutrients and organic matter, that grazing by heifers reduces enchytraeid abundance due to soil compaction, and that ley age has a positive impact on enchytraeid abundance and community structure.

Thus, our objective was to test the potential of enchytraeid abundance in evaluating soil quality beneath temporary grass-clover leys subject to intensive management regimes.

2. Materials and methods

2.1. Field experiment and treatments

This study draws upon an organic dairy crop rotation (ley-arable) experiment established at Foulumgaard Experimental Station (09°34′ E, 56°29′ N; mean annual precipitation 770 mm; mean annual temperature 7.7 °C). Fig. 1 shows monthly precipitation and soil (10 cm depth) and air (2 m above ground) temperatures during the study period. The soil is loamy sand, classified as a Typic Hapludult according to the USDA Soil Taxonomy System and has 7% clay (<0.002 mm), 10% silt (0.002–0.02 mm), 81% sand (0.02–2 mm), and 1.6% organic carbon. The field was converted to organic farming in 1987, when a 6-yr crop rotation replaced a conventional cereal dominated rotation. In 2004, a 6-yr rotation (Rotation 2; see Eriksen et al., 2015) was introduced (spring barley with undersown grass-clover, 1-yr-old grass-clover, 2-yr-old grass-clover, 3-yr-old grass-clover, 4 yr-old grass-clover, and spring barley (whole crop harvested) undersown with a nitrate catch crop of Italian ryegrass). The differently aged grass-clover leys included in this rotation was subject to five different managements (Eriksen et al., 2015) of which three was selected for the present study.

The grass-clover ley contains perennial ryegrass (*Lolium perenne* L.), white clover (*Trifolium repens* L.), and red clover (*Trifolium pratense* L.). We selected plots representing six contrasting management regimes (Table 1): 1-yr-old grass-clover used for cutting, no slurry added (CUT-1); 1-yr-old grass-clover used for cutting and slurry injection (CUT-1-SLU); 1-yr-old grass-clover used for grazing (eight heifers ha^{-1} from May to October; 1250 grazing days ha^{-1} yr^{-1}) with no injection of slurry (GRAZ-1). Soils subjected to the same managements were sampled in 4-yr-old grass-clover leys (CUT-4, CUT-4-SLU, and GRAZ-4, respectively). For the 1-yr-old leys four field replicates were available while the 4-yr-old leys were with two replicates. Anaerobically stored animal slurry originated

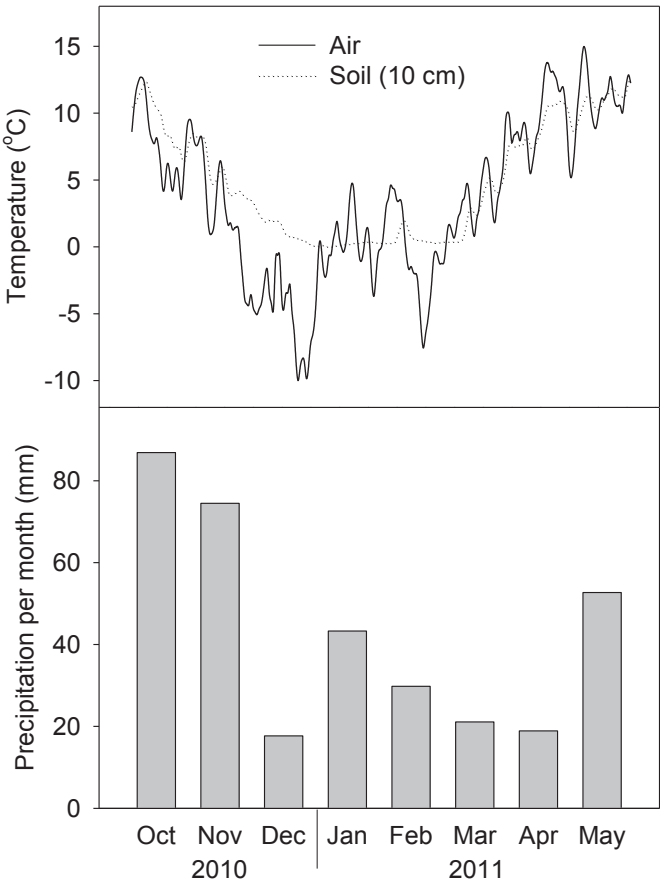

Fig. 1. Monthly precipitation (mm) and air (2 m above ground) and soil (10 cm soil depth) temperatures measured at the automatic weather station at Foulumgaard Experimental Station.