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Earthworm populations in twelve cover crop and weed management combinations

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ABSTRACT

Earthworm communities were assessed in twelve agronomic treatment combinations at the cessation of a three year winter cover crop–spring barley main crop in Ireland. Agronomic treatments had statistically significant effects on earthworm abundance and biomass; the above-ground biomass of cover crops species and other weed species was also significantly affected. A pea cover crop supported the largest earthworm communities, 221 ± 55 (±SD) individuals m^{-2} and live biomass $67.4 \pm 12.0\, g\, m^{-2}$, while having the smallest overall mean yield for cover crop biomass, 56.8 ± 56.7 g dry matter m^{-2}. By contrast, a mustard cover crop had the largest overall mean yield for cover crop biomass, $195 \pm 82.7\, g\, m^{-2}$, but earthworm populations similar to those in other cover crops and under natural regeneration. The lowest overall mean earthworm biomass ($23.1 \pm 1.8\, g\, m^{-2}$) of all agronomic combinations was recorded in a bare fallow treatment which had no overwinter vegetation. Earthworm species numbers between treatments were similar, with endogeic species such as *Allolobophora chlorotica, Aporrectodea caliginosa* and *A. rosea* being dominant. The pea cover crop probably supported the largest earthworm populations due to a high quality food supply. Conversely, brassicaceous cover crops such as mustard, while producing large above-ground biomass, did not support larger earthworm populations, but a biofumigation effect was not evident either. In conclusion, various winter cover crops as well as natural regeneration supported similar earthworm populations after a three year cover crop-spring barley main crop cycle, with some evidence for larger and more species-rich populations under some cover crops such as pea and oat, and somewhat smaller populations where no overwinter vegetation was present.

1. Introduction

Five percent (about 5.6 million ha) of the arable land in the European Union are under cover or intermediate crops during the winter, with values of 11% in France and 27% in Austria, chiefly as a soil erosion control measure (Eurostat, 2012). Investigations have been conducted into the potential of various winter cover crops in Ireland to reduce nitrate leaching in spring barley systems (Hooker et al., 2008) and internationally to contribute to various other environmental objectives including biological functioning (Ranells and Wagger, 1997; Francis et al., 1998; Macdonald et al., 2005). For example, Steenwerth and Belina (2008) reported that rye and trios (Triticale × Triosecale) cover crops enhanced soil N dynamics and microbial functions of N mineralisation, nitrification and denitrification in a vineyard in California, United States. Conversely, *Brassicaceae* cover crops in particular have been reported for their ability to suppress weeds (Haramoto and Gallandt, 2004), fungal pathogens (Muehlchen et al., 1990), insect pests (Brown and Morra, 1997) and nematodes (Zasada and Ferris, 2004). Wortman (2016) stated that potential nitrogen loss from croplands is 60% greater in bare soil compared to weedy fields. Cover crops also contribute environmental benefits in relation to biodiversity; for example by increasing ground cover for birds (Stoate et al., 2004; Parish and Sotherton, 2004), providing a source of soil organic matter (Haramoto and Gallandt, 2004; Steenwerth and Belina, 2008), increasing mycorrhizal fungi in main crops (Boswell et al., 1998), and supporting larger numbers of pest predators such as carabid beetles (Armstrong and McKinlay, 1997) and of beneficial seed predators such as fire ants in rye-vetch cover crops in the United States (Pullaro et al., 2006). However, there are knowledge gaps in the literature regarding the effects of cover crops on earthworm populations as studies are limited to a small number of cover crop types (e.g. Boström, 1995; Reeleder et al., 2006).

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Table 1
Description of study site.

Approximate location (lat, long)	52°86′N, 06°92′W
Field name	Road Field
Soil [a]	
Soil Type	Grey brown podzolic (Athy Complex)
Parent material	Calcareous limestone
Texture	Sandy loam
Drainage	Free draining
pH in water [b]	6.9
Organic carbon (%) [c]	3.0
Slope and aspect	Level
Climate [d]	
Annual precipitation (mm)	869
Mean annual temperature (°C)	10.5
Mean annual soil temperature (°C @ 10 cm)	11.9
Management history	Continuous intensive tillage 20+ years
Annual inorganic fertiliser application (kg N ha^{-1})	135

Source: [a] (Hooker et al., 2008), [b,c] (Schmidt et al., 2001), [d] Anon(2004–2007).

Furthermore, no study has compared the effects of several different cover crops on earthworm populations.

Earthworms play a key role as decomposers in terrestrial ecosystems (Hendrix et al., 1986; Edwards and Bohlen, 1996), and can affect the energy and nutrient cycling of ecosystems by selective activation of mineralisation and humification of organic matter (Lee, 1985; Edwards and Bohlen, 1996). Differences in tillage, nutrient inputs, and crop rotation can influence the size and species composition of earthworm communities (Edwards and Bohlen, 1996). Over the years, the benefits of using conservation, reduced or no tillage systems for increasing earthworm populations compared to conventional tillage have been well documented (Gerard and Hay, 1979; Edwards and Lofty, 1982; Hendrix et al., 1986; Reeleder et al., 2006). Furthermore, earthworm populations are likely to increase under favourable soil conditions where an increase in food supply has occurred (Curry and Byrne, 1997; Schmidt et al., 2003). Leguminous cover crops have the ability to obtain a large portion of their N from symbiotic N_2 fixation (Weil and Kremen, 2007) and can contribute large quantities of organic material high in N content to the soil (Hendrix et al., 1992; Kautz et al., 2010). Research suggests that legume intercrops, living mulches and cover crops are particularly beneficial in supporting large earthworm populations (Watkin and Wheeler, 1966; Schmidt et al., 2003; Pelosi et al., 2009; Kautz et al., 2010). However, in a separate study a mustard cover crop – even though it developed a large above-ground biomass compared to natural regeneration – did not result in large earthworm populations (Roarty, 2010).

The overall objective of the present study was to compare the effect of twelve overwinter vegetation covers including eight different cover crops, on earthworm abundance, biomass and species richness in a spring barley main cropping system. It was hypothesised that earthworm abundance and biomass would be correlated with cover crop plant biomass. It was also hypothesised that "bare fallow" in which the soil is left bare over the winter months by the combination of a shallow autumn cultivation and herbicide application would result in smaller earthworm populations compared to all other treatments. Earthworm populations were assessed twice during active periods at the cessation of a three year cover crop-spring barley main crop, when effects should be most apparent.

2. Materials and methods

2.1. Site description

This experiment originated from of an existing agronomic study that investigated various winter cover crops as a strategy to reduce nitrate leaching in spring barley cropping systems in Ireland from 2003 to 2006. The study was conducted on a sandy loam soil in the Road field at Teagasc Crops Research Centre, Oak Park, Carlow, Ireland, and earthworm sampling was conducted between autumn 2006 and spring 2007. A detailed description of the study site is given in Table 1.

2.2. Treatments and cultivation regime

A randomised-block field experiment was set up in 2003 consisting of twelve treatment combinations in a continuous spring barley main crop system, namely (1) bare fallow, (2) natural regeneration minus (NR−) cultivation, (3) natural regeneration plus (NR+) cultivation, (4) ryegrass, (5) phacelia, (6) mustard (Year 2 and 3), (7) mustard, (8) forage rape, (9) rye, (10) cereal/pea mixture, (rye and pea in Year 1, oat and pea in subsequent years), (11) oat, and (12) pea. During the first season of the experiment, treatment 6) mustard (Year 2 and 3) overwintered as natural regeneration and was subsequently sown with a mustard cover crop in years two and three. The cereal/pea mixture comprised rye and peas in the first season and oat and pea in the remaining two seasons. For full names and cultivars see Table 2. Each of the twelve treatment combinations was replicated four times, with individual plots measuring 6 m by 24 m (Roarty, 2010). The minimum internal border width within plots was 3 m from which earthworms were not sampled. Vegetation around the experiment consisted of overwintered barley stubbles and weed species similar to the natural regeneration treatments.

The experiment was run by the operational staff at the research centre. The plots were ploughed at the end of March/early April annually, using a 4Rev Kverneland and tilled using a Kongskilde Triple K cultivator. Spring barley (*H. vulgare* L. cv. Tavern) was sown using a Fiona seed drill and rolled immediately afterwards using a Väderstad Rollex 620 at the beginning of April. The spring barley main crop was harvested in August annually (2004–2006).

In late August/early September (2003–2005), following harvest of the previous spring barlrey crop (15 cm stubble height) and removal of the associated straw, seeds of the cover crops were

Table 2
Cover crop species and varieties sown during the experiment.

Cover crop	Latin name and Variety
Westerwold's ryegrass	*Lolium multiflorum* L. cv. Pollanum
Phacelia	*Phacelia tanacetifolia* Juss. cv. Angelia
Mustard	*Sinapis alba* L. cv. Albatross
Forage rape (canola)	*Brassica napus* L. cv. Hobson
Rye	*Secale cereale* L. cv. Humbolt
Oat	*Avena sativa* L. cv. Barra
Pea	*Pisum sativum* L. cv. Agadir