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Earthworm populations in two low-input cereal farming systems

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ABSTRACT

Earthworm populations in low-input integrated crop management (ICM: no application of insecticides, fungicides and growth regulators) and organic farming systems were compared. The study was performed as a 3-year field survey using a paired-farm approach in six different locations in northwestern Switzerland. Earthworms were extracted from soils sampled from 24 winter cereal fields using a combined method of extraction by mustard flour solution and handsorting.

Earthworm communities differed between these farming systems. Over all sites, the mean biomass, abundance and species richness of earthworms found in the low-input ICM fields were significantly lower than in the organic fields. Adult earthworms in organic fields were 114% more abundant than in ICM fields, but the frequencies of most species within the respective systems were similar in both farming systems. The numbers of earthworm species and juveniles were higher in organic fields. Five species – *Lumbricus terrestris* (L.), *Nicodrilus longus* (Ude), *Nicodrilus nocturnus* (Evans), *Nicodrilus caliginosus* (Sav.) and *Allolobophora rosea* (Sav.) – were significantly more numerous in the organic fields than in the ICM fields.

Multivariate analysis showed that the farming system explained most of the variance and was found to be the key factor in altering the earthworm fauna. Late ploughing in autumn was found to have a major negative effect on earthworm abundance, irrespective of the farming system. Farming practices that differ between these farming systems and may considerably influence earthworm populations and diversity are discussed.

1. Introduction

With the intensification of arable land use over the last four decades, deterioration of soil fertility and increases in soil pollution have emerged as major issues. Maintenance of soil and water quality is fundamental for future agricultural production (Scialabba and Hattam, 2002). Therefore, there is a requirement for sustainable farming systems which exploit the natural biotic mechanisms that maintain soil structure, fertility and drainage, and help to regulate and control pests, diseases and weeds.

Nowadays, sustainable and low-input farming systems are of increasing public interest. Agri-environmental schemes in Europe aim to support ecological functions and biodiversity in agroecosystems. This is related to both farming practices and site conditions. Organic farming is a system in which many ecological requirements have been fulfilled (EU regulations 2092/91/EEC), which has been assessed to be environmentally benign, and in which various abiotic as well as biotic benefits have been found (Stolze et al., 2000; Maeder et al., 2002; Hole et al., 2005). As a consequence, all EU-countries promote organic farming through agri-political measures (Lampkin et al., 1999).

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The role of earthworms in enhancing soil fertility is well known, and different farming practices have considerable effects on both earthworm abundance and species composition (e.g., Lee, 1985; Edwards and Bohlen, 1996). Earthworms contribute to physical, chemical and biological soil processes such as soil structure formation, e.g., formation of stable aggregates (Schrader and Zhang, 1997), and organic matter dynamics through nutrient cycling, decomposition of residues (Wolters and Ekschmitt, 1995), and soil pore water dynamics through their burrowing activities, which provide soil pores for aeration and water infiltration (Edwards et al., 1990; Pitkänen and Nuutinen, 1997). Consequently, the productivity of arable farming systems can be improved by the presence of abundant earthworm populations.

Positive effects of specific farm practices on earthworms such as direct drilled and minimal cultivation of cereals have been found (Edwards and Lofty, 1982a; Maillard and Cuendet, 1997). These are practices which are not always compatible with organic production due to the ban on herbicides.

The analysis of whole farm systems in numerous comparative investigations has shown that under organic farming regimes, with lower inputs of off-farm materials, higher abundance and biomass of earthworms are found in most cases compared with high-input conventional arable crops (e.g., Bauchhenss, 1991; Pfiffner, 1993; Pfiffner and Maeder, 1997; Scullion et al., 2002). A few studies performed on perennial crops such as orchards revealed similar results (Paoletti et al., 1995). Moreover, in a 10-year study by Hutcheon et al. (2001), earthworm species were found to differ in their response to conventional and integrated farming systems.

Only few on-farm studies include specific information on the influence of agricultural practices on species diversity and earthworm community structure. Most investigations addressed high-input conventional and organic farming systems (for review, see Hole et al., 2005). Furthermore, there is a lack of data from on-farm studies comparing low-input integrated and organic arable farming systems, which are currently promoted by agri-environmental programmes. In the present study, we focus on the effects of these two low-input farming systems on the earthworm fauna using a paired-farm approach at six different locations in northwestern Switzerland. Corresponding results for carabid and spider fauna using this trial design and comparing the same fields have already been published (Pfiffner and Luka, 2003). The key questions of this on-farm survey were, (1) are there any differences between the earthworm fauna of integrated and organically managed arable fields, and (2) what are the driving forces altering the earthworm populations in these two low-input farming systems?

2. Materials and methods

2.1. Study area

A 3-year field study using a paired-farm approach at six different locations in northwestern Switzerland was conducted (Table 1). Low-input ICM farming (ICM: Integrated Cropping Management) within the Swiss 'extensive cereal production' agri-environmental programme (Bundesrat, 1998) and organic or bio-dynamic farming were taken to be low-input farming systems. The present analysis will focus on the data collected from 24 differently managed cereal fields. During the investigation period of 1996–1998, two locations were studied per year. All farms were controlled and certified as ICM or organic farms and worked according to their official standards within the label programme of IP Suisse or Bio Suisse. This means that the whole farm was managed according to these standards. Only farms with a sufficiently long transition period and very similar soil conditions were selected for comparison. It was considered that the transition period should be at least 5 years depending on regime history and farming intensity. Moreover, the selection of typical farms within a given region was made in consultation with the official advisory services, providing a set of representative farms using common fertilizer and soil tillage management.

The low-input ICM farming system at the study sites applies no insecticides, fungicides or growth regulators to the cereal crops, although herbicides are permitted and were used. No pesticides and only organic fertilizers were applied to the organic and bio-dynamic fields. Crop rotations were similar in both systems. Sampling was carried out in winter cereal fields (mostly winter wheat), cultivated in a 7–9 year crop rotation, including at least one grass-clover crop. Field size ranged from 0.8 to 1.5 ha. Soil, relief conditions and exposition were similar in each location. Details on site characteristics and agricultural practices are shown in Table 1. Hereafter, the term 'organic' field includes bio-dynamic farming. Twenty-four winter cereal fields on 12 farms were investigated. The paired fields were adjacent or at least neighbouring plots. Two fields per farm were sampled in order to obtain more information and statistical power on the general situation within each farm.

Soils were analysed for the following parameters: organic carbon, pH, calcium, phosphate, potassium, magnesium and iron. Biotic parameters such as crop density were recorded at growth stage Z 30/31 (Zadoks et al., 1974) once during the growing season, using 10 samples of 0.5 m $\times$ 0.5 m. Total weed cover was assessed in five quadrants (2 m $\times$ 2 m) about 7 weeks before harvest.

2.2. Sampling methods

Earthworm populations were investigated using a two-step method from 1996 to 1998 after the winter cereal crop harvest. Six samples were taken once per field in the autumn after the cereal harvest (1 and 3 October 1996 at locations 1 and 2; 21 and 22 October 1997 at locations 3 and 4; and 21 and 22 October 1998 at locations 5 and 6), extracted with a 0.33% mustard flour solution and then sorted by hand (Högger, 1993; Emmerling, 1995). For the extraction, 15 l of mustard solution was used over a sampling time of 40 min. The sampling unit that was hand-sorted was 50 cm $\times$ 50 cm wide and 15 cm deep, and samples were separated by a distance of at least 15 m. With this well-established sampling method, anecic species (mustard extraction) as well as early diapausing and endogeic earthworms (handsorting) were efficiently recorded. The specimens collected were preserved in 4% formalin solution. Biomass loss during preservation was adjusted according to Cuendet (1995). Individual earthworms were identified as