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Earthworms in a 15 years agricultural trial

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ABSTRACT

Alternative cropping systems have been proposed to enhance sustainability of agriculture, but their mid and long-term effects on soil biodiversity should be studied more carefully. Earthworms, having important agro-ecological functions, are regarded as indicators of soil biological health. Species composition, abundance, and biomasses of earthworms were measured in autumn 2005–2007 (period 1) and 2011–2013 (period 2) in a trial initiated in 1997 near Paris, France. A conventional, an organic and a direct seeded living mulch-based cropping systems were compared. Earthworms were sampled in a wheat crop by combining the application of a chemical expellant and hand-sorting.

In period 1, earthworm abundance did not usually differ in the three cropping systems, but sometimes it was higher in the conventional system. Mean total abundance was 122, 121 and 149 individuals m^{-2} in period 1 and 408, 386 and 216 in period 2 in the organic, living mulch and conventional systems respectively. While earthworm abundance and biomass increased slightly in the conventional system between the two periods, they at least tripled in the other two systems. This was mainly due to the species *Aporrectodea caliginosa* and *Aporrectodea longa* in the living mulch cropping system, and to *A. caliginosa, Lumbricus castaneus,Lumbricus terrestris* and *A. longa* in the organic system.

After at least 14 years, organic and living mulch cropping systems contained between 1.5 and 2.3 times more earthworms than the conventional system. Considering the inter-annual variations in earthworm communities due to climatic conditions and cultural practices, earthworm communities should be assessed over several years before conclusions can be drawn. Moreover, since changes in cultural practices may take a long time to affect earthworm communities, mid and long-term trials are needed to assess the effects of cropping systems on soil biodiversity.

1. Introduction

Earthworms are known to improve soil physical, chemical and biological components (Eriksen-Hamel and Whalen, 2007; Fragoso et al., 1997; Jégou et al., 2000; Lavelle, 1997). Moreover, they are sensitive to crop management, easily collected by both specialists and farmers, and thus can be used to evaluate different environmental pressures (Blouin et al., 2013; De Lima and Brussaard, 2010; Daugbjerg et al., 1988; Jamar et al., 2010). They are thus considered as soil quality indicators (Doran and Parkin, 1996). According to Paoletti (1999), "in rural environments different farming systems can be assessed using earthworm biomass and numbers".

In the current context of soil protection and chemical input reduction in agrosystems (Médiène et al., 2011), effects of alternative cropping systems on biodiversity should be studied. Cropping systems without plowing are known to rapidly promote earthworm communities, especially the larger individuals (Chan, 2001; De Oliveira et al., 2012). The presence of a living mulch at the soil surface generally increases earthworm abundance and biomass (Brevault et al., 2007; Fonte et al., 2009; Tebrügge and Düring, 1999), encouraging species which feed at the soil surface, i.e., mainly epigeics and anecics. The effect of systems without chemical inputs, and in particular without pesticides is less obvious. Although pesticides may have deleterious effects on earthworms under laboratory conditions (Yasmin and D'Souza, 2010), field studies which compare effects of conventional and organic farming on earthworm communities show variable results (Hole et al., 2005; Nuutinen and Haukka, 1990). These results can be difficult to interpret because of several factors varying at the same time, e.g., manure inputs and soil tillage (Hole et al., 2005). Moreover, effects of cropping systems on earthworm communities

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are sometimes studied at only one sampling date in trials whose duration is not precisely specified (Crittenden et al., 2014; Liebig and Doran, 1999; Scullion et al., 2002) or which have been set up only a few years before the sampling (Nuutinen and Haukka, 1990). Few studies have been made on mid and long-term trials, with sampling intervals of several years.

Pelosi et al. (2009a) assessed earthworm species richness, abundance and biomass in three cropping systems which differ mainly in soil tillage, pesticide and fertilizer applications, and crop biomass production. These cropping systems were a conventional system, a direct seeded living mulch-based cropping system, called "living mulch cropping system" and an organic system. They were part of a long-term cropping system comparison trial (Debaeke et al., 2009), initiated in 1997. Samplings were made in this trial after 8–10 years, i.e., in 2005–2007 (period 1). The authors concluded that the different cropping systems did not influence total earthworm abundance but they modified specific and functional diversity as well as earthworm community biomass due to soil tillage and organic resource availability. In the living mulch cropping system, with a permanent plant cover and no plowing, diversity indices as well as anecic and epigeic abundance and biomass were higher than in organic and conventional systems. Endogeic earthworms, however, were more numerous in the last two systems. Organic and conventional systems did not differ in their earthworm abundance, biomass or diversity. To explain these results, authors mentioned lower yields and available trophic resources in the organic system than in the conventional one. Moreover, according to LD50 of active substances (ANSES, Agritox, 2005), it seemed that pesticides sprayed in the conventional system had no pronounced effect on earthworm mortality. Pelosi et al. (2009a) also reported variations in earthworm total abundance and biomass from one year to another, i.e., between autumn 2005, 2006 and 2007. However, this variability over time was not significant and did not influence effects of cropping systems on earthworms.

Here we assess earthworm communities in the same long-term trial in 2011–2013 (period 2), after 14–16 years, on the same crop i.e., winter wheat. Our objectives are to answer the following questions: are the differences observed at period 1 in earthworm abundance and biomass between conventional, organic and living mulch cropping systems maintained in period 2? Did switching from conventional to organic systems have any effect on the earthworm community? For that purpose, we compare earthworm communities in the long-term trial between the period 1 (2005–2007) and the period 2 (2011–2013).

2. Materials and methods

2.1. Site and cropping systems

Our experimental site was located 15 km south-west of Paris (48°48′N, 2°08′E). The experiment began in 1997 and the site, which is not irrigated, was under conventional agriculture before this date. The soil is a deep luvisol (FAO classification), with a neutral pH and an average texture of 58% silt, 25% sand and 17% clay. The climate is temperate, with a mean annual precipitation of 640 mm and a mean annual temperature of 10.4 °C.

The three experimental cropping systems are a living mulch cropping system, a conventional system and an organic one. In the conventional system, where weeds and pests were controlled with pesticides, the soil was plowed every year except after the leguminous crops. In the living mulch cropping system, the permanent plant cover was killed with herbicides in order to plant the crop with economic interest e.g., wheat. In the organic cropping system no manure or other external organic amendments were added. As in the conventional system, plowing was done every year in this last system except after the leguminous crops. The organic system was managed following the rules of the AB France label, without any use of synthetic pesticides or mineral fertilizers. Weeds were limited by soil tillage, crop succession, crop density, and changes in crop sowing date. Nutrient exports were limited by straw restitution. Soil P and K levels were recorded throughout the experiment. Because they were always high enough, no supplements were added.

The trial site was divided into two replicates. In each replicate, a 1 ha plot of each system was divided into two subplots in which the rotation was established, such that for every year, one of the two subplots had a winter wheat crop (Fig. 1). Management of the three systems, as well as crop rotations, C/N ratios of the top 20 cm of soil and organic matter contents are shown in Table 1. Calcium carbonate ($CaCO_3$) content of soils was 0.9 g kg^{-1} and pH varied between 7.0 and 7.5 in the three cropping systems. Between 1997 and 2008, alfalfa was not used in the living mulch cropping system, and was used one year out of five in the organic system. Since 2009, this crop has been used two years out of three in the two mentioned systems.

2.2. Earthworm sampling

Species composition, abundances and biomasses were assessed in the subplots involving the same crop, i.e., winter wheat, to limit potential effects of the crop. Samples were taken at the end of October or early beginning of November 2011–2013 and compared with data obtained from period 1 (2005–2007, Pelosi et al., 2009a). Pelosi et al. (2009a) provided data on total earthworm abundances and biomasses and by ecological categories in 2005–2007, but some information not published before will be analyzed in this study (i.e., abundance and biomass at the species level). Autumn is a period of high activity for numerous earthworm species (Bouché, 1972) and samples of periods 1 and 2 were all taken at that time to limit effects of seasonal variations. Rainfall and temperature data before sampling are summarized in Table 2. Five samples (40 × 40 cm), randomly located but at least 3 meters from the plot border, were made on each of the two replicates of each cropping system (Fig. 1). The total sampled area for each system is

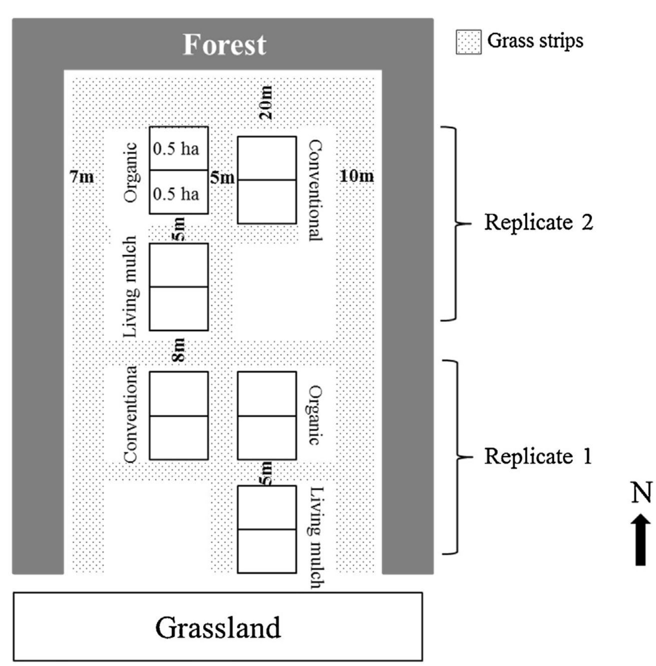

Fig. 1. Schematic representation of the experimental trial.