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Short Communication

Establishment of bioenergy crops on metal contaminated soils stimulates belowground fauna

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ABSTRACT

Soils of contaminated agrosystems represent potential arable land surfaces for the production of non-alimentary crops. The aim of this study is to monitor changes in belowground biodiversity (Collembola), potentially occurring following establishment of perennial biomass crop systems on contaminated agricultural land. We selected, within an agricultural trial, two different biomass crops, miscanthus (*Miscanthus x giganteus*) and switchgrass (*Panicum virgatum*) and an annual wheat crop (*Triticum* sp.) used as a control. About 20-fold more individuals were found under miscanthus and switchgrass than under wheat. The highest mean number of species was found under miscanthus being 30% greater than in switchgrass and 424% than in annual wheat. Furthermore, abundance and species richness of the three collembolan life-forms (epedaphic, hemiedaphic, and euedaphic) differed between the crops leading to distinctly different assemblages.

On metal contaminated soils, perennial bioenergy crops have the potential to increase belowground faunal diversity and abundance with the identity of crops as a critical factor driving soil animal assemblages.

1. Introduction

To meet the EU production target (+10% by 2020) for renewable fuel [1], will require allocating vast quantities of agricultural land to growing bioenergy crops, in majority perennial nonedible grasses. This, while there already appears to be little chance of the world's current arable acreage being sufficient to produce enough food to meet rising future demand [2]. Consequently, a renewed interest in looking for areas degraded by human activities as possible sources for bioenergy crops establishment has emerged [3]. Agriculture for biomass energy can move into such abandoned land that does not have competing uses [4,5]. For example, soils of contaminated agrosystems represent potential arable land surfaces for the production of non-alimentary crops, providing that such cropping systems do not lead to increased risks for the environment. In the case of contaminated agricultural soils, there remains a critical need for empirical data on the consequences of implementing new agroenergy productions systems on biodiversity conservation, especially on belowground fauna [6]. The aim of this study is to monitor changes in biodiversity belowground, potentially occurring following establishment of perennial biomass crop systems

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on contaminated agricultural land areas. Our basic hypothesis was that biomass crop establishment on contaminated soils allows for belowground diversity to increase by modifying important niche parameters such as food availability and quality or microhabitat conditions.

2. Materials and methods

We performed this study in an agricultural trial, referred to as "Biomass trial", designed in 2007 to assess the impact of energy crops on contaminated soils. Within this trial we selected two different biomass crops planted in 2007, miscanthus (*Miscanthus x giganteus*; English cultivar from Novabiom©, France) and switchgrass (*Panicum virgatum*; cave-in-rock cultivar from Novabiom©, France) and an annual wheat crop (*Triticum* sp.) used as a control. Controls and treatments (biomass crops) were triplicated leading to a total of 9 plots of at least 100 m^2. Prior to 2007 all the plots were cultivated with wheat. This trial was established within a ~1200 ha polluted agricultural area close to Pierrelaye (France, 49°01N; 2°10E). This area has been used during the 20th century for spreading sewage sludge from the Paris urban region. This led to the accumulation in the surface horizons of these soils of large amounts of organic matter, dissolved salts (carbonates, phosphates) and metal pollutants [7–9]. The soils, Orthic and Albic Luvisols [10], were sandy textured in the A and E horizons, and sandy-clay textured in the Bt horizon [9]. Selected soil characteristics extracted from above-mentioned literature are summarized in Table 1.

2.1. Sampling and determination of belowground diversity

We focused our attention on the Collembola as a proxy for soil biodiversity. Collembolans participate in decomposition processes, stimulate microbial activity by grazing [11], and thereby increase nutrient mobilization [12].

Three samples were collected in three sampling occasions (November 2009, June 2010, and November 2010) at each of the plots by means of soil corers (diameter: 5 cm, depth 10 cm). At the time of the experiment perennial grasses were established since three years. Each sample was individually placed into a plastic container, transported to the laboratory in cool boxes and stored, for at most 24 h, at 4 °C before further treatment. Collembola were extracted by the dry-funnel method and stored in 70% ethyl alcohol. Identification to species level followed several keys [13–15]. Finally, all species were allocated to one of three different life forms, i.e. epedaphic, hemiedaphic, euedaphic [16]. These life forms closely relate to both dispersal ability and various functional attributes such as reproduction, mobility, and metabolic activity [16,17]. Since seasonal variation was beyond the scope of our study, soil collembolan data from the three seasons were pooled in each sampling plot.

2.2. Statistical analyses

The effect of the factor "crop" (wheat, switchgrass or miscanthus) on Collembola community parameters was tested by means of GLMs. Data were log-transformed prior to analysis when necessary to ensure normal distribution and homogeneity of variance, except for the data expressed as percentages which were arcsin transformed. Significant differences between means were tested at the 5% confidence level using the Tukey HSD test. The Bray–Curtis index was calculated with the free PAST software version 2.02 [18] to analyse faunistic dissimilarity between sites.

All analyses, except when specified, were performed using the STATISTICA software package (ver. 10.0, StatSoft, Tulsa, StatSoft 1984–2013).

3. Results

The total number of collembolan species sampled at all plots was 21 (see Appendix). Both abundance and species richness (SR) of soil collembolans were significantly affected by the factor "crop" (Table 2).

About 20-fold more individuals were found under miscanthus (35,870 ± 14,501 m^{-2}) and switchgrass (32,470 ± 4,035 m^{-2}) than under wheat (1530 ± 442 m^{-2}). However, no significant difference of abundance was found between both biomass crops. Species richness was also significantly higher in miscanthus (15.7 ± 1.5) and switchgrass (12.0 ± 1.0) than under wheat (3.7 ± 1.1). Furthermore we also found significant differences between biomass crops with 30% more species under miscanthus compared to switchgrass. According to the Bray–Curtis index the level of community dissimilarity between wheat and either miscanthus or switchgrass was of approximately 91%, while it was still of 50.4% between miscanthus and switchgrass.

Regarding the functional structure, parameters (abundance and species richness) relative to the three life-forms (epedaphic, hemiedaphic, and euedaphic) strongly differed between the crops (Table 2).

The density of epedaphic species was higher in switchgrass (8755 ± 3698 m^{-2}) than in both miscanthus (963 ± 763 m^{-2}) and wheat (85 ± 147 m^{-2}; Fig. 1). The species richness of the epedaphic life-form was not different between biomass crops but was in both cases significantly higher (from 8 to 10-fold) than in wheat (Fig. 2). Conversely, density and SR of euedaphic species were constantly higher in miscanthus (10,540 ± 2228 m^{-2} and 6.3 ± 2.1, respectively) compared to both switchgrass (6545 ± 2477 m^{-2} and 3.0 ± 1.0, respectively) and wheat (255 ± 255 m^{-2} and 1.0 ± 1.0, respectively). Only the density of euedaphic species was higher in switchgrass compared to

Table 1 – Physico-chemical properties of the 0–15 cm soil of the biomass trial in Pierrelaye, France. WC: Water content on a soil dry weight basis.

	pH H_2O	WC (g/g)	C (g/kg)	N (g/kg)	C/N	Pb (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
Mean (SD)	7.56 (0.06)	0.21 (0.03)	67.0 (10.7)	2.55 (0.23)	26.4 (3.9)	350.2 (16.4)	187.5 (28.7)	639.9 (109.1)