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Foraging patterns of soil springtails are impacted by food resources

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ABSTRACT

Movement of soil microarthropods associated to searching or foraging behaviour has received scanty attention and remained largely unexplored. However, rare studies on soil Collembola suggested that their exploratory behaviour is an important feature of population dynamics. In the current study based on a microcosm experiment, we tested the influence of food sources tied to a distant patch on the foraging behaviour of springtails. The microcosms consisted of five separate 5 cm sections bound together. Only the last part of the microcosms (section 5) differentiated the three treatments with no food (*C*), microflora (*M*) or microflora + plant (*M* + *P*). Collembola were introduced into the first section. The mean covered distance of total collembolan differed between all the treatments. It continuously increased from 0.9 (±0.3) cm in *C* through 4.7 (±1.0) cm in *M* to 7.4 (±1.2) cm within *M* + *P*. Concomitantly, the mean covered distance was also influenced by the factor "life-form" with on average 7.3 cm covered by the epedaphic species which was 73.8% more than hemiedaphic and 82.5% more than euedaphic. Even if differences between life-forms were detected, our results also revealed differences of exploratory pattern between species belonging to the same life-form. Our study clearly shows that springtails are reactive to the quality of their environment, in particular food sources.

1. Introduction

Studying the movement *sensu lato* of organisms is a key topic in ecology (Dieckmann et al., 1999; Levin et al., 2003). Processes like migration, dispersal or foraging influence the dynamics of populations, the distribution and abundance of species and therefore the community structure. Migration is furthermore known to be involved in speciation processes and in the evolution of life-history traits (Winker, 2000). Consequently movements of organisms affect ecosystem functioning by modifying living assemblages and the nature and strength of biotic relationships. One main reason that forces organisms to move, explore or disperse is foraging. For example, animals can be attracted by the odour of their food (Auclerc et al., 2010; Salmon and Ponge, 2001). They may also be forced to move owing to overcrowding or antagonism from competing species (Ronce, 2007).

Many data and models of foraging, dispersal or migration are now available for many organisms (Nathan, 2001). However, with the exception of a few groups like ants (Lenoir, 2003) or soil living-herbivores (Schallhart et al., 2011), movement associated to searching or foraging behaviour within the soil has received scanty attention and remained largely unexplored (Hassall et al., 2006; Mathieu et al., 2010). However, rare studies on soil animals suggested that their searching and foraging behaviour is an important feature of population dynamics (Bengtsson et al., 1994a; Bengtsson et al., 2002b; MacMillan et al., 2009).

Collembola constitute a dominant, well investigated and diverse soil microarthropod group. Many studies have proven the direct or indirect contribution of Collembola to belowground functioning such as N mineralisation, soil respiration or leaching of dissolved organic carbon (Filser, 2002). Many indirect effects of Collembola on soil processes operate through interactions with the microflora. Several studies highlighted that Collembola critically depend on food sources provided by the soil microflora (Hopkin, 1997).

Gisin (1943) described three typical soil collembolan life-forms based on morphology and habitat. Briefly, epedaphic species are usually large bodied species, have a high metabolic activity, consume a food substrate of a high quality and are surface-dwellers. Conversely, euedaphic species are deep-living species that consume low-quality food and have a low metabolic activity. Euedaphic species are small-sized, colourless with reduced appendices (e.g. furca, antennae, leg). Finally, the hemiedaphic group includes species sharing intermediate attributes (Petersen, 2002; Rusek, 1989). Collembolan assemblages are thus well-structured on a vertical spatial scale matching the resources

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dispatched by plants either above- (litterfall) or belowground (roots and root exudates).

While several studies focused on the dispersal of springtails (Auclerc et al., 2009; Bengtsson et al., 2002a; Ojala and Huhta, 2001), few focused on foraging (Bengtsson and Rundgren, 1988; Bengtsson et al., 1994b; Hagvar, 2000). According to the fact that dispersal capacity relates beside other factors to locomotor activity, comparatively large epedaphic springtails with good jumping skills and well-developed legs should be more efficient foragers than euedaphic species. However, species with directional sense perception may also have a high probability to forage successfully (Mitchell, 1970).

In the current study based on a microcosm experiment, we thus wanted to test the influence of two food sources tied to a distant patch on the foraging behaviour of springtails.

2. Materials and methods

2.1. Microcosm setup

2.1.1. Substrate

The substrate used was sourced from a deciduous forest (*Fagus sylvatica*) located within the Campus of the University of Rouen. The soil was an endogleyic dystric Luvisol (FAO) developed on more than 80 cm of loess (lamellated siltloam) lying on clay with flints. The humus form is a dysmoder. The C:N ratio of the A horizon was of about 15.3 and the pH H_2O 3.9. We collected on a square meter the F and H organic horizons of the topsoil. Once in the laboratory, one part of the organic substrate collected was used in the microcosms and another part served to collect the Collembola to be introduced within them as explained below.

The microcosms, adapted from a previous experiment on nematodes (MacMillan et al., 2009), were made of 5 plastic tubes arranged in a row-like configuration (total length 25 cm, diameter 5 cm). Each plastic tube corresponds to a section (numbered 1–5) bound together with adhesive tape, and sealed at each end with a plastic cap to prevent escape of animals (Fig. 1). For all tests, the organic substrate filling the compartments 1–5 of the microcosms was first sterilized by autoclaving at 105 °C with two successive cycles of 1 h separated by 24 h, then was sieved at 5 mm and carefully mixed before filling the different sections.

Only the last part of the microcosms (section 5) differentiated the treatments:

- in the "microflora bio-assay", abbreviated *M* in the following text, the sterilised organic substrate dedicated to section 5 was reinoculated with soil microflora. A suspension of soil microflora was obtained after shaking 500 g of fresh organic substrate with 2.5 L of distilled water during 1 h. The suspension was then filtered in two successive steps: first at 250 μm and then using filters for qualitative microbial analysis (DURIEUX n°149). Ten millilitres of this suspension were transferred into each section 5. This was repeated three times waiting 12 h between each inoculate. The same amount of distilled water was added to the other sections.
- in the "microflora + plant bio-assay", abbreviated *M + P* in the following text, one week after reinoculation of microflora, a plant (*Hyacinthoides non-scripta* (L.) Chouard ex Rothm., 1944) was added to section 5. Plants of the same morphology, around 10 cm tall, were collected in the forest, their roots were washed with distilled water and slightly cut to homogenise their morphology.
- in the "control bio-assay", abbreviated *C* in the following text, no further treatment was applied to the substrate of the section 5 compared to compartments 1–4. In each section of the control bio-essay, 10 mm of distilled water was added three times as it was done in the two previous bio-assays.

The tubes used for the sections 5 were also pierced (1.5 cm in diameter) on top to allow the introduction of the microflora

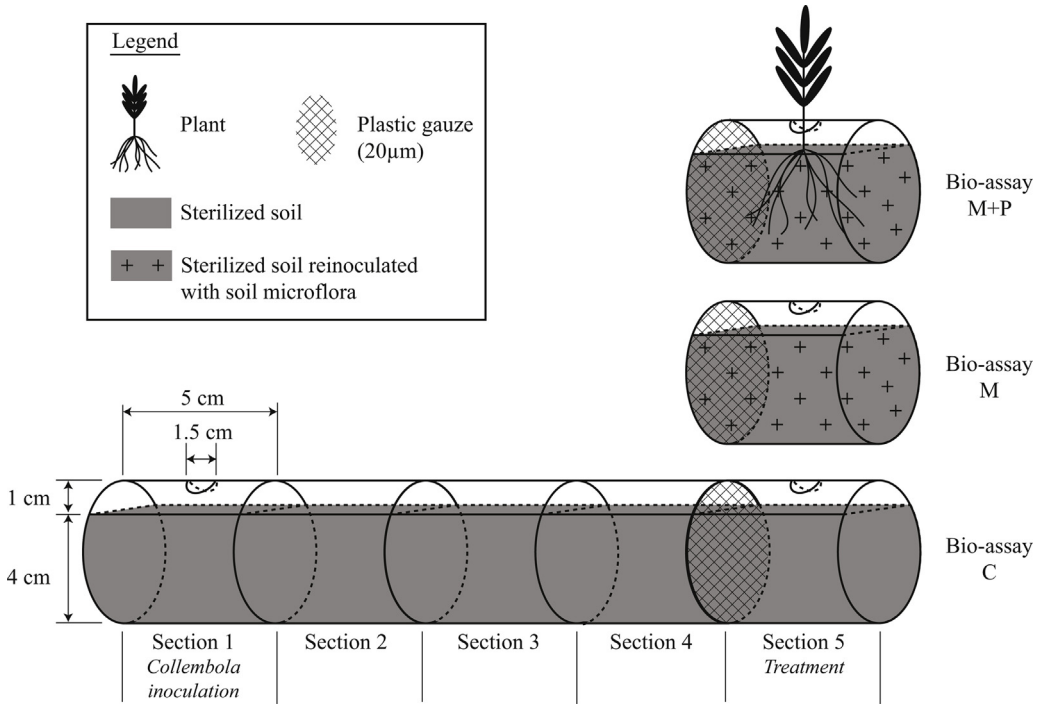

Fig. 1. Experimental design. Each microcosm was made of 5 plastic tubes arranged in a row-like. Bio-assays differed according to the 5th section either filled with sterilized soil (*C*: Control) or with sterilized soil and microflora (*M*: Microflora) or with sterilized soil and microflora and a plant (*M + P*: Microflora and Plant).Whatever the bio-assays, the section 5 was separated from section 4 with a fine-mesh (20 μm) plastic gauze to minimize or exclude propagation of soil biota to adjacent compartments.