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Development of Collembolans after conversion towards organic farming

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Summary

In Northern Germany, a diverse and complex experimental farm of the Federal Agricultural Research Centre (FAL) was set-up in 2001 covering all main aspects of organic farming. Previously, the 600 ha farm had been managed conventionally. Adjacent conventional farms were used as reference. The aim of this project was to study collembolans, microbial biomass and soil organic carbon in six organically farmed fields managed as a crop rotation of six different crops compared with an adjacent conventionally managed field. We hypothesised that the specific management in organic farming promotes soil biota. Soil samples were taken during the growing season in 2004. Collembolan abundances and microbial biomass were lower under organic management, but, generally, collembolan diversity was higher in organically farmed fields combined with a shifting in the dominance structure of the species. This result reveals that, even after three years, the soil biota is still changing with management conversion.

Keywords: Organic farming, Collembola, microbial biomass, soil biodiversity, management conversion

Introduction

Over the last decade, organic farming has become increasingly relevant worldwide, mainly because consumers have been increasingly aware of more healthy and safe food. Currently, more than 31 million ha of farmland are under organic management worldwide (Willer & Yussefi, 2006). Europe has 21% of the world's organic farmland (Willer & Yussefi, 2006). Within the last decade, the organically farmed area in Germany increased from 1.6% of the total arable land in 1994 to 4.5% in 2004.

Many studies have been undertaken to analyse the management effects of organic farming on biodiversity at different scales of time and space. A recently published meta-analysis (Bengtsson *et al*., 2005) revealed organic farming to be often but not always positive on species richness and abundance. Its effects are likely to differ between organism groups and landscapes. Contrary to above-ground invertebrates, like spiders and ground beetles, field studies on the effects of organic farming on below-ground invertebrates are still rare (Becker *et al*., 2001; van Diepeningen *et al*., 2006). Our aim was to study soil biota (collembolans and microorganisms) in organically farmed fields compared with a conventionally managed field of an adjacent farm within the same landscape.

We hypothesized that the specific management in organic farming promotes soil biota. We focussed on collembolans because they obviously support soil forming processes by catalysing microbial activity and decomposing processes (overview in Hopkin, 1997).

Materials and Methods

In Northern Germany, at Trenthorst (53°47'24'' N; 10°31'45'' E; 30 m above sea level), a diverse and complex experimental farm covering all main aspects of organic farming was set-up in 2001, managed by the Institute of Organic Farming (Federal Agricultural Research Centre). Previously, the 600 ha farm had been managed conventionally in a very intensive way. All the converted fields were managed and certified according to the EU 2092/91 norms.

In total, the experimental area covered more than 50 fields (10–20 ha each). Each field contained four sampling sites of 2 m in diameter for annual monitoring. We sampled six organically farmed fields, each managed as a crop rotation of six different crops (Table. 1). For comparison, we sampled a conventionally managed field of an adjacent farm. The soil type is a Luvisol (FAO) with a texture ranging from sandy loam to loamy sand and pH values around 6.5 to 7.1.

Table 1. *Current crops (mixed in some cases), total number of collembolan species, the corresponding Shannon-Weater diversity index and evenness from organically and conventionally managed fields*

Field	Management	Crops	Coll. species	Shannon-Weaver	Evenness
2	Organic Farming	Grass, clover	27	2.37	0.72
4		Peas, summer barley	25	2.72	0.84
6		Winter wheat	25	2.62	0.81
8		Grass, clover	18	2.07	0.72
10		Oat, cow beans	22	2.30	0.74
12		Triticale	15	2.42	0.89
51	Conventional farming	Winter barley	20	2.11	0.70

Table 2. *Relative collembolan species distribution [%] presented for those species being dominant in at least one sampled field; numbers greater than 10 % indicate dominance*

Dominant collembolan species	Organic farming						Conv. farm.
	2	4	6	8	10	12	51
Friesea mirabilis	2.0	7.6	6.6	0.2	4.6	13.9	3.8
Supraphorura furcifera	17.1	3.8	5.6	1.8	12.5	9.0	7.4
Stenaphorurella denisi	9.8	5.4	11.9	5.2	17.4	8.6	2.9
Mesaphorura krausbaueri s.l.	5.5	14.0	3.3	11.5	27.4	16.7	2.3
Parisotoma notabilis	0.1	5.4	7.9	20.8	0.3	10.2	10.3
Isotomiella minor	8.8	16.9	7.9	3.6	11.6	3.7	1.4
Cryptopygus thermophilus	9.5	6.4	24.5	32.8	1.8	3.7	4.3
Isotomurus palustris	28.1	9.6	4.0	8.4	1.2	12.7	43.0

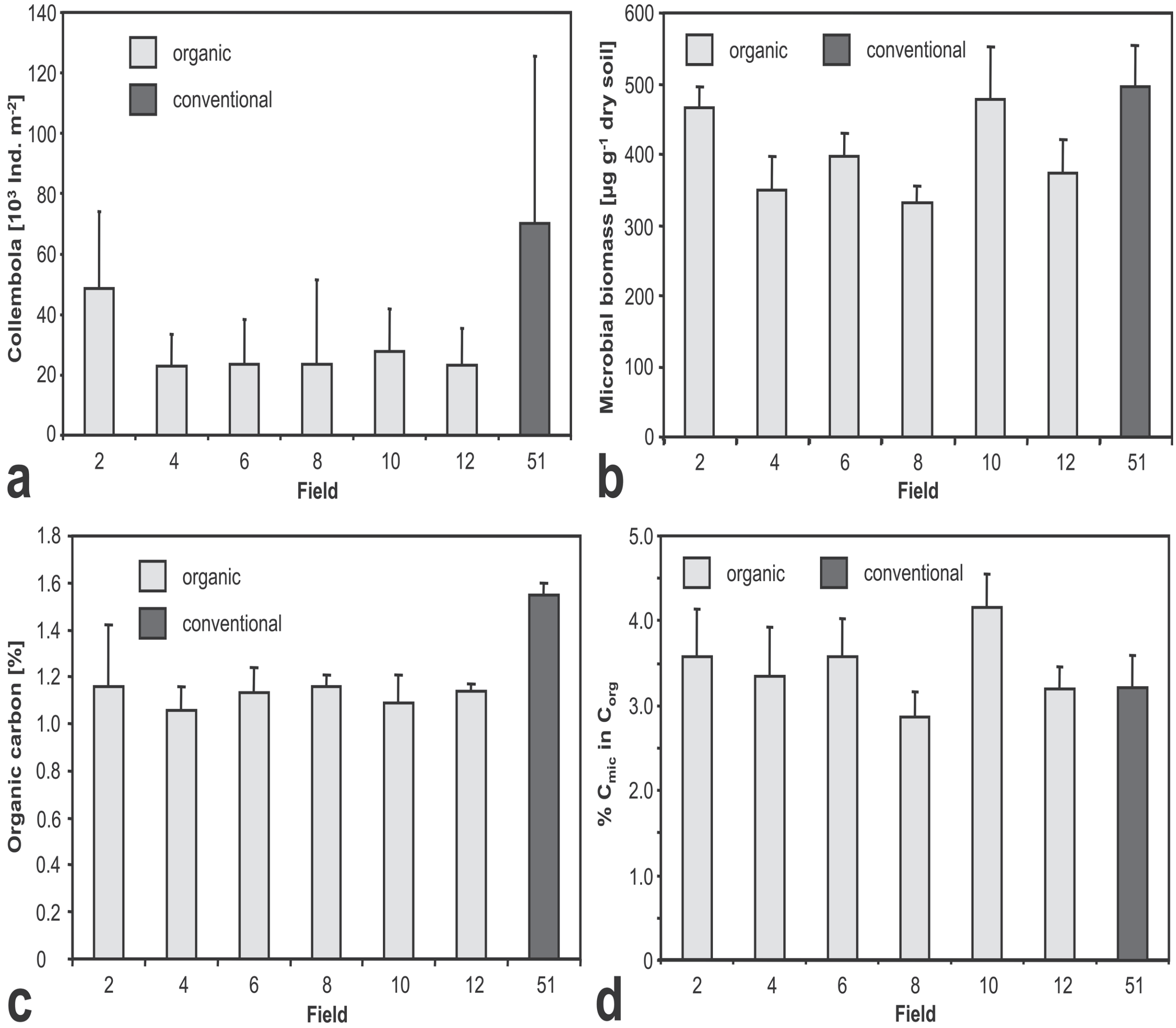

Fig. 1. Arithmetic means (+SD) of collembolan density (a), microbial biomass (b), organic carbon (c) and the microbial carbon (C_{mic}) to organic carbon (C_{org}) ratio (d) from fields managed by organic and conventional farming.

Sampling was conducted at the four defined sampling sites in all seven fields. For collembolans, soil cores from 0 to 10 cm soil depth were taken twice during June and July 2004. Each of the four sampling sites of each field was sampled three times on both dates. The soil cores were extracted for microarthropods according to the high gradient method of MacFadyen (1961). The collembolan species were identified according to the keys of Gisin (1960) and Dunger (1994-2004). Species represented by greater than 10 % of the total density were classified as dominant. For microbial biomass (C_{mic}) and organic carbon content (C_{org}) determinations, three bulked soil samples from all four sampling sites of each field were taken (0-30 cm). Cmic was analysed by substrate induced respiration (SIR method) according to Anderson and Domsch (1978). C_{org} contents were measured by dry combustion using an autoanalyser after pre-treatment of the soil samples with 0.1 n HNO_3 (DIN ISO 10694, 1995).

Results

The total abundance of collembolans differed widely among organically farmed fields ranging from 23000 (field 4) to 49000 (field 2) individuals m^{-2} on average (Fig. 1a). Overall, the means of individual density in organically farmed fields were significantly different (ANOVA: p = 0.008). In the conventionally managed field, the mean individual density of collembolans reached 70000 individuals m^{-2} with a high standard deviation of 55000 individuals m^{-2}. The difference between organically and conventionally farmed fields was not significant.

In total, 42 collembolan species out of five families were identified (Poduridae, Onychiuridae, Entomobryidae, Sminthuridae, Isotomidae). The organically farmed fields were characterised by higher species richness (22 species on average) than the conventionally farmed fields (20 species) (Table. 1). Species diversity was higher under organic farming, as indicated by higher Shannon Weaver index (2.42) and evenness (0.79) compared to conventional farming (Table. 1).

In the conventionally farmed field, Isotomurus palustris was the most abundant species covering 43 % of all collembolan individuals (Table. 2). Together with the second dominant species in this field (Parisotoma notabilis), they comprised > 50 % of the whole pool of individuals. In comparison, the organically farmed fields were characterised by a less heterogeneous species distribution (Table. 2). Although the dominant species of plot 8, 10 and 12 also included > 50 % of all collembolan individuals, we found three (field 8) and four (fields 10 and 12) dominant species sharing more than half of all individuals. Considering all organically farmed fields sampled, *Mesaphorura krausbaueri s.l.* was the most striking species being dominant at four out of six fields.

Generally, the microbial biomass (Fig. 1b) of the organically farmed fields (mean 415 µg g^{-1} dry soil) was significantly lower ($P = 0.04$) compared to the conventionally farmed field (495 µg g^{-1} dry soil). The differences between the organically farmed fields were also significant (ANOVA: $P < 0.001$). The mean C_{org} content of the organically managed fields was 1.12 %, which was significantly lower ($P = 0.009$) than the Corg content of the conventional field 51 reaching 1.55 % (Fig. 1c). The variation among the organically managed fields was low and not significant. The ratio of microbial carbon to organic carbon (Cmic in Corg) (Fig. 1d) in the conventionally farmed field (3.2 %) was lower than in the organically farmed fields (3.45 %), but not significantly. The Cmic in Corg ratio amongst organically managed fields varied significantly (ANOVA: $P = 0.02$). There were significant positive Pearson correlations between the collembolan densities and microbial biomasses (r2 = 0.70; $P = 0.019$) as well as Corg contents (r2 = 0.79; $P = 0.008$).

Discussion

We conclude from our results that the organic conversion processes are not yet completed. The soil biota reflects a dynamic in the conversion to organic farming even after three years. On one hand, we found decreased collembolan abundances. On the other hand, the collembolan species diversity is increasing. Comparable results have been presented by van Diepeningen et al. (2006) for soil nematode communities. Furthermore, the increasing C_{mic}-to-C_{org}-ratio indicates an improved bioavailability of organic carbon. Such heterogeneous patterns are quite comparable to those found directly after other agricultural management conversions, such as, for instance, a tillage conversion from ploughing to reduced or even no tillage.

It remains an open question, how the soil biota will develop in the future under the specific management conditions of organic farming in this area. For the collembolans, possible developments might be a shifting in the dominance structure of the species, changes in biodiversity and abundance, modifications in the decomposing food web etc. To answer such questions, the whole sampling procedure should be repeated on the same monitoring fields after another five years of continuous organic farming.

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