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### ► To cite this version:

Jérôme Cortet, Damien Ronce, Nicole Poinot-Balaguer, Christian Beaufreton, André Chabert, et al.. Impacts of different agricultural practices on the biodiversity of microarthropod communities in arable crop systems. *European Journal of Soil Biology*, 2002, 38 (3-4), pp.239-244. 10.1016/S1164-5563(02)01152-4 . hal-03218304

**HAL Id: hal-03218304**

**<https://hal.science/hal-03218304>**

Submitted on 5 May 2021

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# Impacts of different agricultural practices on the biodiversity of microarthropod communities in arable crop systems

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Received 14 August 2000; accepted 22 May 2001

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## Abstract

Two crop production systems, which differ on tillage and pesticides, were compared for biodiversity of soil microarthropod communities. A biodiversity index, which integrates different structure and density parameters (abundance, taxonomic richness, taxonomic diversity, coenotic diversity) was used. Results showed a greater biodiversity in minimum tillage systems compared to deep tillage systems. Pesticides seemed to be only a second order factor of variance on microarthropod biodiversity.

*Keywords:* Microarthropods; Biodiversity; Low input systems; Tillage; Pesticides; Arable crops

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## 1. Introduction

Soil microarthropods are often used as bioindicators of agricultural soil quality. Studies have shown the impacts of soil compaction [7,12–14], and others have compared different agricultural production systems, such as integrated, organic or conventional systems [1,5,6,8]. But, whereas differences in abundance or biomass are often explored, few studies have presented results on diversity.

This paper presents results of a comparison of the impact of two agricultural arable crop practices on soil microarthropod communities in two French regions, using a biodiversity index.

## 2. Materials and methods

### 2.1. Study site and description of cultivation systems

The study was carried out on the experimental farm of the Association de Coordination Technique Agricole (ACTA), situated in Courseulles (Calvados, Normandy), on which 10 different fields had been regularly monitored for 8 years previously, to compare two different agricultural systems: “Conventional” and “Integrated” (Table 1).

The climate is typically oceanic. During the study period, from January to June 1997, the minimum temperatures were recorded in January (with a mean of  $-3.7$  °C for the first week), and the maximum in June (with a mean of  $16.7$  °C for the first week). Precipitation was irregular, being low in early-mid spring (11.6 and 11 mm, respectively, in March and April, which correspond to the minimum), and relatively high in late spring–early summer (50 mm in June, which is the maximum reached). The site overlies typical Jurassic calcareous bedrock.

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Table 1

Soil cultivation and pesticides on the Courseulles site, for each field studied in 1997 and all the fields from 1991 to 1995

Fields (year of harvesting)	System	Tillage	Other soil cultivation	Herbicides (kg ha <sup>-1</sup> )	Insecticides (kg ha <sup>-1</sup> )	Fungicides (kg ha <sup>-1</sup> )
P1 Grand Parc (1997)	Con	Present	C, SPH	0.64	0.15	1.09
	Int	Absent	C, SPH	1.85	0.071	0.31
P3 Les Carfolands (1997)	Con	Present	SH, SPH	0.58	0.084	1.96
	Int	Absent	SH, SPH	1.85	0	0.71
P4 Le Meslier (1997)	Con	Absent	C, SPH	0.64	0.14	1.09
	Int	Absent	C, H, SPH	1.05	0	0.31
Mean of ten fields (1991–1995)	Con	Variable	Variable	1.70	0.23	1.94
	Int	Variable	Variable	1.53	0.087	0.88

Con: Conventional ; Int: Integrated; C: cultivating ; SPH: seeding + power harrows ; SH: sugarbeets harvesting ; H: harrowing

Three different fields were chosen for the study (Table 1). They were all sown with winter wheat (*Triticum aestivum* L.) during the sampling period. However, each had been cropped the year before with a different crop: fibre flax (*Linum usitatissimum* L.) at Grand Parc (P1), Sugar beet (*Beta vulgaris* var. *altissima*) at Carfolands (P3), spring protein peas (*Pisum sativum* L. *arvense*) at Le Meslier (P4).

Soil physico-chemical analyses showed a different texture for P1 compared to the other fields, with twice as much sand and only half the amount of silt.

Each field had been divided into two parts for 8 years, one for each system. However, each system in each field was maintained independently. Thus, sometimes, the “Integrated” part may have received more pesticides than the “Conventional” part. An average amount of pesticides, based on five cropping years and the 10 fields, has been calculated: even if the amount of herbicides is equivalent between the two systems, the amount of insecticides and fungicides is considerably reduced in the “Integrated” system. Furthermore, in 1997, the amount of herbicides was greater in the “Integrated” than in the “Conventional” system. On the other hand, in 1997, tillage was reduced in the “Integrated” systems, except in P4 that showed no differences in tillage between the systems but a supplementary harrowing in the “Integrated” one (Table 1).

## 2.2. Sampling methodology and statistical evaluation

For each system in the three chosen fields, and for each sampling date, five soil cores (5 cm diameter and 10 cm deep) were collected. Sampling was carried out monthly from January to June 1997, corresponding to the winter wheat growing season. After extraction using the Berlese method [2], animals were identified, counted and classified into five different taxa: oribatid mites, gamasid mites, “other mites”, collembolans and “other arthropods”.

The significant differences in abundance between the systems were assessed for each field and each taxon, on each sampling date (using the Mann–Whitney test, Statview software, SAS foundation).

Then, for each field, “Conventional” and “Integrated” systems were compared using the  $\Delta V$  index of biodiversity for four different taxa: oribatid mites, collembolans, “other mites” (all the mites excluding oribatid mites) and “other arthropods”. A complete description of the calculation of this index can be found in [3]. The main features are as follows:

$$\Delta V = [V(x) + V(S) + V(n) + V(H'x) + V(H'y)]/5$$

where  $x$  is the abundance of the taxonomic group;  $S$  is the number of taxonomic groups;  $n$  is the number of samples containing the taxon;  $H'x$  is the taxonomic diversity index; and  $H'y$  is the coenotic diversity index; and:

$$Vm = (Cm - Im)/(Cm + Im)$$

where  $Cm$  is the parameter  $m$  value in the Conventional system (for example  $H'x$ ); and  $Im$  is the parameter  $m$  value in the integrated system.

If  $Cm = Im$ , no differences can be observed between the two systems. If  $Cm < Im$ , the difference of biodiversity is negative. If  $Cm > Im$ , the difference of biodiversity is positive. Thus, the index ranges between  $-1$  and  $+1$ .

## 3. Results

### 3.1. Grand Parc (P1) site

The greatest population abundance in total microarthropods was in spring, particularly in April and May (Table 2). Significant differences in abundance of microarthropods were observed between the systems, especially concerning oribatid mites, which were more abundant in the “Integrated” compared with the “Conventional” system, from January to April. “Other mites” were also more abundant in the “Integrated” system in April. Total microarthropod populations confirmed these differences in January, February and April. However, in May, differences could not be

Table 2

Mean abundance and standard deviation of each taxon in Courseulles. from January to June 1997

P1 (Grand Parc)	January 1997		February 1997		March 1997		April 1997		May 1997		June 1997	
	Con	Int	Con	Int	Con	Int	Con	Int	Con	Int	Con	Int
Collembola	0.8 ± 0.84	0.6 ± 0.55	0.4 ± 0.55	2 ± 2.12	1 ± 1.41	2.6 ± 1.67	1.8 ± 2.95	3 ± 2.55	0.2 ± 0.45	0.4 ± 0.55	1.4 ± 2.19	2 ± 1.87
Oribatida	<b>5 ± 1.58</b>	<b>33.8 ± 33.3</b>	<b>10.6 ± 9.86</b>	<b>37 ± 25.1</b>	<b>5.2 ± 4.87</b>	<b>23.8 ± 12.8</b>	<b>21.4 ± 17.3</b>	<b>59.4 ± 32.1</b>	20.2 ± 9.42	40.6 ± 31.9	1.2 ± 2.17	1.2 ± 1.3
Gamasida	3.6 ± 5.27	2 ± 3.08	1.8 ± 1.3	2.4 ± 1.14	1 ± 0.71	1.2 ± 1.1	5.6 ± 5.86	5.2 ± 3.56	2.2 ± 1.79	1.4 ± 2.61	0	0.2 ± 0.45
Other mites	<b>2 ± 3.94</b>	<b>7.8 ± 6.38</b>	6.2 ± 4.82	6.8 ± 6.76	<b>7 ± 5.43</b>	<b>5.8 ± 4.76</b>	<b>11.6 ± 4.16</b>	<b>30.6 ± 9.89</b>	<b>29.6 ± 30.6</b>	<b>58 ± 45.2</b>	<b>42.2 ± 48.6</b>	<b>10 ± 4.74</b>
Other arthropods	0.8 ± 1.3	0.2 ± 0.45	0.6 ± 0.55	1.2 ± 1.64	2.6 ± 1.52	1.6 ± 1.52	1.8 ± 1.79	2.2 ± 1.92	1 ± 1	3.2 ± 2.39	1.4 ± 1.52	3 ± 2.35
Total	<b>12.2 ± 11.7</b>	<b>44.4 ± 40</b>	<b>19.6 ± 9.3</b>	<b>49.4 ± 28.4</b>	16.8 ± 10.7	35 ± 15.4	<b>42.2 ± 23</b>	<b>100 ± 43.4</b>	53.2 ± 27	104 ± 76.1	<b>46.2 ± 49.8</b>	<b>16.4 ± 7.02</b>
P3 (Les Carfolands)	January 1997		February 1997		March 1997		April 1997		May 1997		June 1997	
	Con	Int	Con	Int	Con	Int	Con	Int	Con	Int	Con	Int
Collembola	1 ± 1.73	0.4 ± 0.89	0.4 ± 0.55	0.8 ± 0.45	3.2 ± 3.9	1.6 ± 0.89	13.6 ± 12.5	13.8 ± 12.6	8.4 ± 5.59	0.8 ± 1.3	4.2 ± 3.56	15.8 ± 19.9
Oribatida	<b>2.2 ± 1.48</b>	<b>13 ± 5.79</b>	11.2 ± 10.8	10.2 ± 5.76	17.8 ± 8.17	9.2 ± 5.81	10 ± 3.24	16.4 ± 9.91	<b>24 ± 20.6</b>	<b>1.6 ± 1.52</b>	0.6 ± 0.89	0.6 ± 0.89
Gamasida	1 ± 0.71	1.4 ± 2.61	0.6 ± 0.89	2.2 ± 2.68	3 ± 4.64	1.6 ± 1.95	7.2 ± 5.12	20.2 ± 28.9	10.6 ± 13.1	1 ± 0.71	1 ± 0.71	0.4 ± 0.55
Other mites	0.8 ± 1.1	2.8 ± 2.68	3.2 ± 2.68	7 ± 6.2	<b>4 ± 3</b>	<b>32.8 ± 23.3</b>	17.8 ± 5.22	24.6 ± 13	9.2 ± 7.19	2.6 ± 1.95	25.8 ± 17.6	17 ± 16.4
Other arthropods	0.2 ± 0.45	0.4 ± 0.55	0.8 ± 1.1	1.2 ± 1.1	1.6 ± 1.52	2.2 ± 1.3	3.2 ± 3.11	8 ± 5.79	0 ± 0	1.8 ± 0.84	2 ± 2	2.2 ± 2.77
Total	<b>5.2 ± 2.95</b>	<b>18 ± 11.3</b>	16.2 ± 10.5	21.4 ± 8.59	29.6 ± 10.4	47.4 ± 30.2	51.8 ± 20.5	83 ± 33.8	<b>52.2 ± 24.9</b>	<b>7.8 ± 2.17</b>	33.6 ± 20.7	36 ± 37.8
P4 (Le Meslier)	January 1997		February		March		April		May		June 97	
	Con	Int	Con	Int	Con	Int	Con	Int	Con	Int	Con	Int
Collembola	2.4 ± 1.52	4.6 ± 4.39	1.4 ± 0.89	2.6 ± 2.07	4.6 ± 4.56	1.4 ± 1.95	3.8 ± 2.39	3.2 ± 2.59	0.6 ± 0.89	0.4 ± 0.55	4 ± 2.83	6 ± 4.69
Oribatida	39.8 ± 28.2	35.8 ± 15.8	33.8 ± 15.9	59.2 ± 28.5	16.2 ± 3.83	23 ± 12.5	<b>17.2 ± 5.17</b>	<b>53.4 ± 23.6</b>	22.2 ± 27.3	30.2 ± 18.7	1.6 ± 0.55	0.8 ± 0.84
Gamasida	2.2 ± 1.3	3.8 ± 2.17	2 ± 1	9.8 ± 6.06	3.8 ± 4.09	9.2 ± 4.76	6 ± 1.58	7 ± 1	6.4 ± 2.97	5.2 ± 1.92	1 ± 1.73	0.6 ± 0.89
Other mites	<b>28.8 ± 15.9</b>	<b>1.4 ± 1.52</b>	<b>13.6 ± 4.28</b>	<b>5 ± 2.12</b>	13.8 ± 2.28	9.6 ± 3.51	<b>35.8 ± 17</b>	<b>8.6 ± 4.62</b>	39.8 ± 46.9	6.8 ± 4.66	15.2 ± 20.2	33.6 ± 14.6
Other arthropods	0.6 ± 0.89	0.8 ± 0.84	1.8 ± 2.68	1 ± 1.22	1.2 ± 1.64	4.2 ± 2.95	2 ± 1.87	3 ± 1.58	0.8 ± 1.1	0.8 ± 1.3	1.8 ± 1.1	9.4 ± 18.8
Total	73.8 ± 31.5	46.4 ± 19	52.6 ± 19.9	77.6 ± 30.7	39.6 ± 13.3	47.4 ± 17.6	64.8 ± 19.8	75.2 ± 27	69.8 ± 76	43.4 ± 24	<b>23.6 ± 19.5</b>	<b>50.4 ± 21.1</b>

Con: Conventional system; Int: Integrated system. Significant differences between the systems (Con and Int) are expressed in bold characters (Mann–Whitney test with  $P < 0.05$ )

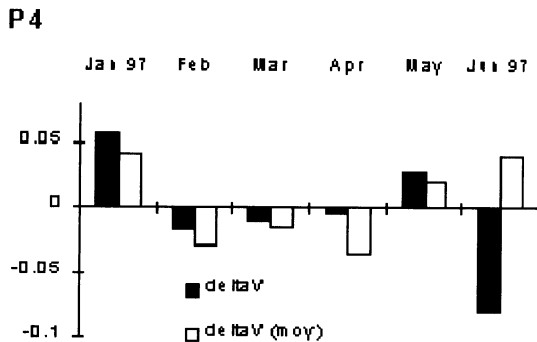
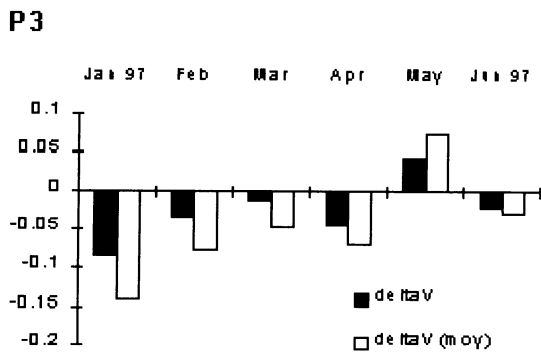
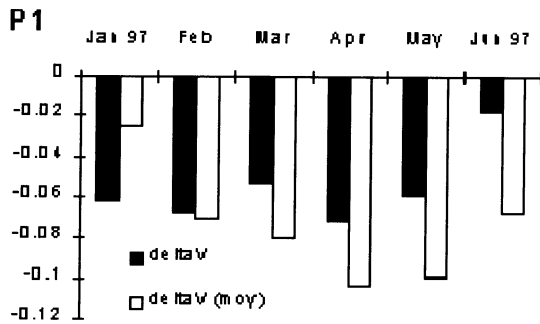


Fig. 1. The  $\Delta V$  index of biodiversity for “Integrated” and “Conventional” systems for each sampled field (P1, P3, P4) in Courseulles, from January to June 1997. The  $\Delta V$ : each parameter is calculated as the sum of means;  $\Delta V$  moy: each parameter is calculated as the mean of sums. If Conventional < Integrated, the difference of biodiversity is negative. If Conventional > Integrated, the difference of biodiversity is positive.

observed, and in June, greater abundance of total microarthropods was observed in the “Conventional” system.

From January to June, the index  $\Delta V$  indicated greater biodiversity in the “Integrated” compared to the “Conventional” system (Fig. 1). The greater differences between the systems were apparent in April and May.

### 3.2. *Les Carfolands (P3) site*

As in P1, the greatest abundance in total microarthropods was observed during spring, particularly in April (Table 2). Significant differences were observed between abundance of microarthropods, with greater abundance of oribatid mites in the “Integrated” system in January, and of other mites in February and March. The total microarthropod numbers were also significantly greater in the “Integrated” system in January. Significant differences between the systems could not be observed in April and June. However, in May, a greater population abundance was observed in the “Conventional” compared to the “Integrated” system for oribatids and total microarthropods.

These results were confirmed by  $\Delta V$  values, which indicated higher biodiversity in the “Integrated” system for all months, except May (Fig. 1). The most marked difference in biodiversity between systems occurred in January.

### 3.3. *Le Meslier (P4) site*

A high level of abundance of microarthropods occurred in spring (April and May), as in the other fields, and also in winter (Table 2; January and February). There were a few significant differences in abundance between the systems during the study. In January the abundance of “other mites” was greater in the “Conventional” than in the “Integrated” system. Similar results were observed in April. However, in April, the abundance of oribatids was greater in the “Integrated” than in the “Conventional” system. In June the total abundance of microarthropods was greater in the “Integrated” than in the “Conventional” system.

The  $\Delta V$  index indicated greater overall biodiversity under “Conventional” than “Integrated” management in January and May, but was slightly greater in the “Integrated” than in the “Conventional” from February to April (Fig. 1). Biodiversity was similar for the two systems in June.

## 4. Discussion

Any disturbance or stress imposed on a system interacts with environmental factors, which can vary with time and space. Thus, different factors, independent of agricultural practices, influence microarthropod populations in these arable crops. This is the case for climatic factors. Thus, abundance variations occurred over time in Courseulles, with a logical increase in population densities during spring, when precipitation and temperature were high and favourable for greater biological activity.

However, even if these factors can influence and cause fluctuations in microarthropod populations, biodiversity differences between the systems are often quite stable, with, except for some months in P4 and May in P3, greater

biodiversity in the “Integrated” compared to the “Conventional” system.

Results observed at Courseulles might be explained by tillage, which is known to decrease microarthropod abundance [12,14]. Thus, in January, which is the sampling date closest to the last soil cultivation, the biodiversity was greater in the “Integrated” system in P1 and P3 than in the “Conventional” one, but the opposite was observed in P4 site. These results are logical, since in P1 and P3, soil cultivation, particularly tillage, was more intense in the “Conventional” than in the “Integrated” system, and in P4, soil cultivation was more intense in the “Integrated” system than in the “Conventional” one. Furthermore, tillage is known to increase soil compaction that might have negatively affected microarthropod populations [13].

At the Courseulles site, pesticides could involve variations in function of two factors: the pesticide spraying history of each field and the diversity of microarthropod reactions to any given pesticide. Indeed, the different pesticides can have different effects on soil invertebrates [4]. Furthermore, even if qualitative and quantitative pesticide differences can be observed between the systems of each field, the pesticide spraying calendar should be taken into account when looking at the effects on microarthropods. Indeed, even if we can observe, from a general point of view, that pesticide use was less important in the “Integrated” than in the “Conventional” system (see the mean amount of pesticides used on ten fields during 5 years), this is not always true for each year. Thus, in 1997, the overall quantities of herbicides used were greater in the “Integrated” than in the “Conventional” system. These remarks are also valuable for each season of culture, since each system for each field was conducted independently from the other systems of other fields. Thus, for some sampling dates, particularly during spring when many pesticides were also sprayed in the “Integrated” system, the biodiversity was not always greater in the “Integrated” system, as it was observed in P3 and P4.

Physical modifications caused by soil cultivations (particularly tillage), are often considered as the more intensive [6,10,11]. At the Courseulles site, it was very difficult to differentiate and appreciate the role of each disturbance factor (soil cultivation and pesticides). Indeed, the P1 field, which had the largest biodiversity differences between the systems, was also the field that had the largest differences between the systems, concerning both pesticide use and soil cultivations. But, the impact of herbicides seemed to be low, since in 1997, even with higher quantities of herbicides used in “Integrated” compared to that in “Conventional”, the biodiversity is still higher in the “Integrated” system. However, analytical experiments, including a separate study of pesticides and soil cultivations would be necessary to understand the relative impacts of these two factors.

The previous types of culture should also be taken into account. At the Courseulles site, all of the sampled fields had a different previous culture that could explain in part the

variations in microarthropod populations between the fields. These results agree with those obtained by Jagers op Akkerhuis et al. [9], concerning the influence of type of culture and rotation on soil microarthropods. Indeed, they showed that microarthropod populations were different under different types of cultures.

## Acknowledgements

This project was performed under the ACTA programme: « Recherche d'indicateurs biologiques permettant d'évaluer l'effet de techniques et systèmes de production sur l'activité et la diversité biologique des sols ». This programme is financed by « Ministère de l'Agriculture et de la Pêche » and « Ministère de l'Education Nationale de la Recherche et de la Technologie ».

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