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The micro-edaphon in ecofarmed and conventionally farmed dryland cornfields near Vienna (Austria)*

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Summary. The micro-edaphon (testate amoebae, ciliates, nematodes), the activity of some soil enzymes (catalase, urease, saccharase), the CO_2 release, and a few abiotic factors (humus, bulk density, pH, soil moisture) were analysed in two ecofarmed (biodynamic method of R. Steiner) and two conventionally farmed dryland cornfields situated close together. The arithmetic means of four sampling occasions show many marked differences, but few of them can be guaranteed with a high statistical probability, most likely due to the low sample size. However, means and significant differences invariably show that the ecofarmed plots have a greater number of organisms, a greater CO_2 release, and greater enzymatic activities than the conventionally managed fields. One reason for this could be the humus content, which is significantly higher in the ecofarmed plots. No pronounced differences could be detected in species diversity and species richness. A preliminary comparison with "organically-biologically" and conventionally farmed fields under Atlantic climatic conditions shows differences in an order of magnitude similar to that found in the present study.

Key words: Ecofarming – Protozoa – Nematodes – Community structure – Soil enzymes – Humus – R. Steiner

If one considers the worldwide, increasingly emotionalized discussion about the advantages and disadvantages of ecofarming and conventional farming, one would expect the argumentation to be based on a solid scientific background. Unfortunately, this is not the case. Hard scientific data about this subject are rare and just appearing (Rühl 1978; Diercks 1983; Cacek 1984; Kromp et al. 1984; Rodale 1984; Diez et al. 1985; Gehlen and Schröder 1985; Huber 1985; Sahs and Lesoing 1985; Foissner et al. 1986). It seems that scientists once again lag behind the man in the street and many environmental groups.

An essential point in this discussion is the effects of different agricultural systems on the soil microbes and the soil animals because these organisms are factors in soil fertility and may act as indicators of soil quality (Ghilarov 1965; Franz 1975; Foissner 1986). The alternative systems are said to conserve life in the soil better than conventional agricultural practices. However, exact pedozoological data for this statement are almost non-existent, as indicated by the literature record of Johannsen et al. (1985). This is not unexpected because zoological research has been greatly neglected during the past decades (Ottow 1985).

Thus, we started a project to investigate some relevant groups of soil animals in ecofarmed and conventionally managed agricultural soils located nearby. Special emphasis is given to the protozoa, because they constitute a significant proportion (about 30%) in the soil animal community (Foissner 1985, 1986). Furthermore, they are valuable bioindicators because of their short generation time, wide distribution and great abundance (Foissner 1986). To get a more integrated view, the nematodes and some microbiological properties and abiotic factors of the soil were included in this programme (Foissner et al. 1986).

*Dedicated to the late Prof.Dr. M.S. Ghilarov

Materials and methods

Study sites. The two site pairs investigated are located in the Marchfeld near Vienna. This region has a Pannonian climate, characterized by dry and hot summers and cold winters with little snow. Strong east and west winds are frequent, which cause the desiccation of the upper soil layer. The 50-year averages of temperature and precipitation are 9.6°C (max. in July of +20°C, min. in January of -1°C) and 572 mm (max. in July of 73 mm, min. in January of 27 mm), respectively (Huber 1985). All sites are within the ancient basin of the river Danube on the so-called *Praterterrasse*.

The fields used in the comparison are side by side (max. distance about 500 m) and were cropped with corn in the year of the investigation and the year before. This guarantees very similar soil characteristics and a practically identical macro- and microclimatic situation. Thus, these factors need not be considered in the interpretation of the results.

The ecofarmed sites are managed according to the biodynamic method of Steiner (1963). For details of this system see Diercks (1983).

Site K: Flat terrace above gravel, about 160 m above sea level. Compact shallow calcareous greyish alluvial soil. Ecofarmed arable land since 1980. Crop rotation with vegetables and wheat. Fertilization with about 10 tonnes/ha per annum compost mixed with stone meal. Cropping was vegetables and legumes in 1983 and wheat in 1984 and 1985. Plant protection was by natural methods. No growth regulators were applied.

Site L: Conventionally farmed control to site K. Location and soil as described above. Fertilized with about 350 kg/ha per annum compound fertilizer (NPK). Cropping was potatoes in 1983 and wheat in 1984 and 1985. Plant protection was by pesticides. Growth was regulated by growth regulators.

Site M: Flat terrace above gravel and sand, about 160 m above sea level. Compact Tschernosem. Ecofarmed arable land since 1977. Crop rotation with vegetables and corn. Fertilization with green manure (legumes, etc.) and several special fertilizers used in biodynamic agriculture; no compost. Cropping was corn in 1983, wheat and green manure in 1984 and wheat in 1985. Plant protection was by natural methods.

Site N: Conventionally farmed control to site M. Location and soil as described above. Fertilized with about 500 kg/ha per annum compound fertilizer (NPK). Cropping was maize in 1983, barley in 1984 and wheat in 1985. Plant protection was by pesticides and growth was regulated by growth regulators.

Sampling and counting procedures. Samples were taken on 26.6.1984, 19.4.1985, 6.5.1985, and 4.6.1985. Ten cubes (5×5×10 cm) were taken from 5–15 cm soil depth at each site and on each sampling occasion. These were thoroughly mixed and pooled into 1 sample, from which a subsample ($n = 10$) of 0.4 g fresh soil was used to estimate the number of nematodes. The soil was suspended in about 8 ml tap water and examined at a magnification of ×40. The abundance and species richness of the Testacea were estimated from a subsample ($n = 10$) of 0.1 g fresh soil stained with aniline blue to discriminate between full and empty tests (Schönborn 1978). The examination of the suspension (about 3 ml) was performed at a magnification of ×100 (objective 10:1, ocular 10:1). Recovery experiments have proved that this direct counting method yields reliable counts (Foissner 1986; unpublished).

Active ciliates occurred very rarely. Thus, the culture method of Buitkamp (1979) was used to estimate their potential abundance 6 days after incubating a 50-g air-dried and remoistened (water-saturated) soil sample at room temperature. Six to ten replicates of each 10 μl of the run off were examined under ×40. For the estimation of the number of the fast-moving species Lugol's solution was added. For qualitative investigations about 50 g dry soil and litter were water saturated and investigated every week in the course of 1 month.

Biomasses were calculated as described in Foissner (1985).

Microflora and abiotic factors. CO_2 release was determined according to Isermeyer (1952) and catalase activity as suggested by Beck (1971) using the buffer of Sörensen (pH 6.8). Urease activity was estimated according to Schinner and Pfitscher (1978) and saccharase activity as proposed by Hofmann and Seegerer (1951) in the modification of Niederbacher (1981).

Soil moisture content was evaluated after air-drying (about 4 weeks at room temperature) and pH determined with a glass pH electrode in a 1:2.5 soil/water suspension. Humus content was calculated according to De Leenheer (ALVA 1972) and the bulk density through volume of soil dried at 105°C.

For CO_2 release, enzymatic activities, pH and humus content, air-dried (about 4 weeks at room temperature) soil samples were used.

Statistical analysis. The indices of Sörensen (1948) and Renkonen (1938) were used to describe species similarity and dominance identity. Clusters were constructed by the unweighted pair-group method with arithmetic means (UPGMA). For diversity and evenness see Mühlenberg (1976). The data were analysed with a two-way analysis of variance (Sokal and Rohlf 1981).

Results and discussion

There is a clear trend for the ecofarmed fields to have more soil organisms, a greater CO_2 release, a greater enzymatic activity and humus content, and a lower bulk density than those conventionally farmed (Table 1). However, few differences can be guaranteed with a high statistical probability. This is most likely caused by the low number of samples investigated, as indicated by the often very different arithmetic means.

A second distinction is also evident. The differences between the site pair K/L are much more pronounced than those between the pair M/N. This indicates that the high quantity of compost applied to site K is more effective than the extensive fertilization practised on site M.

The differences in the species comprising the faunas are much less pronounced. The clusters and the diversity values indicate that site-specific factors have a greater influence than different agricultural systems (Fig. 1, Table 1). In the dominant ciliate species, however, there is a greater similarity between the ecofarmed sites than between those conventionally managed (Fig. 1). In K and M *Homalogastra setosa, Halteria grandinella,* and *Histriculus muscorum* dominated, whereas *H. setosa, Paracolpoda steinii, Leptopharynx costatus,* and *Colpoda cucullus* were more abundant in L and N. This coincides roughly with our previous results, showing the same in two of five site pairs investigated (Foissner et al. 1986). The epigeous fauna exhibit more pronounced differences in this respect, either by direct effects of pesticides or by indirect influences via bush clearing frequently done in conventionally farmed areas. Bush clearing seems especially harmful to these animals because it destroys important habitat structures (Rühl 1978; Cacek 1984; Kromp et al. 1984; Bick 1985).

Table 1. Comparison of the micro- and meso-edaphon and some abiotic factors in ecofarmed (K, M) and conventionally (L, N) farmed arable land. The data show the arithmetic means of four sampling occasions and are compared by a two-way analysis of variance (ANOVA)

Parameter	Site pairs					
	K	L	ANOVA	M	N	ANOVA
Testacea						
Individuals g^{-1} dm[a]	76	23	$0.50 > P > 0.25$	87	60	$0.75 > P > 0.50$
Biomass mg 1000 g^{-1} dm	1.9	0.7	$0.50 > P > 0.25$	2.6	1.9	$0.75 > P > 0.50$
Number of species (quantitatively)	2	1	$0.50 > P > 0.25$	3	2	$0.50 > P > 0.25$
Number of species (qualitatively)	6	6	NT[b]	10	10	NT
Diversity (Shannon-Weaver; ln)	0.54	0.74	NT	1.66	1.50	NT
Evenness	0.39	0.67	NT	0.85	0.75	NT
Ciliophora						
Individuals g^{-1} dm	365	78	$0.50 > P > 0.25$	39	31	$P > 0.75$
Biomass mg 1000 g^{-1} dm	6.3	0.6	$0.50 > P > 0.25$	1.2	0.7	$0.75 > P > 0.50$
Number of species (quantitatively)	11	6	$0.05 > P > 0.025$	8	8	$0.75 > P > 0.50$
Number of species (qualitatively)	43	34	NT	51	39	NT
Diversity (Shannon-Weaver; ln)	1.12	1.39	NT	2.16	2.50	NT
Evenness	0.34	0.53	NT	0.70	0.79	NT
Nematoda						
Individuals g^{-1} dm	91	24	$0.10 > P > 0.05$	38	28	$0.50 > P > 0.25$
Microflora						
CO_2 release (mg g^{-1} dm)	0.32	0.19	$0.025 > P > 0.01$	0.22	0.21	$0.50 > P > 0.25$
Catalase activity (ml O_2 g^{-1} dm)	1.20	0.60	$0.025 > P > 0.01$	0.50	0.60	$0.25 > P > 0.10$
Urease activity (mg N g^{-1} dm)	0.08	0.07	$0.10 > P > 0.05$	0.06	0.06	$P > 0.75$
Saccharase activity (mg C_6 g^{-1} dm)	0.59	0.39	$0.25 > P > 0.10$	0.44	0.43	$0.75 > P > 0.50$
Abiotic factors						
Soil moisture (% of dm)	9.7	9.0	$0.25 > P > 0.10$	10.7	9.0	$0.01 > P > 0.005$
pH (in distilled water)	7.3	7.2	$P < 0.001$	7.2	7.2	$0.50 > P > 0.25$
Humus (%)	2.2	1.8	$0.10 > P > 0.05$	1.9	1.8	$0.10 > P > 0.05$
Bulk density (g cm^{-3})[c]	1.2	1.4	NT	1.3	1.5	NT

[a]dry mass of soil; [b] not tested; [c]means of two samples each

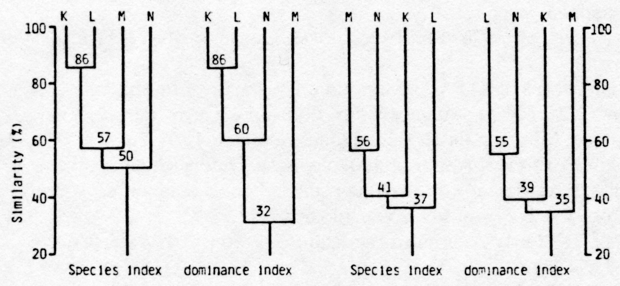

Fig. 1. Similarity in species content and dominance structure of protozoan species in ecofarmed (K, M) and conventionally farmed (L, N) arable land

The two ecofarmed dryland fields investigated are managed according to the anthroposophic method of Steiner (1963). This system does not allow any synthetic fertilizer and takes into consideration cosmic influences like the phases of the moon. The five site pairs previously investigated are under the influence of the Atlantic climate (annual precipitation about 1000 mm) and are managed in the "organically-biological" way, which allows the application of small quantities of alkaline, slowly soluble fertilizers and does not take into consideration cosmic influences (Foissner et al. 1986). Other differences between these systems are explained by Diercks (1983). A comparison of the present results with those of Foissner et al. (1986) shows that the differences between the ecofarmed and the conventionally managed plots are in the same order of magnitude. This indicates some independence of the results of the climatic situation and the ecofarming technique used, reducing the discussion perhaps to product quality and economical aspects which are beyond the scope of this paper. However, no final conclusion should be drawn, because our results are certainly too incomplete for this.

The results of this study compare well with those of Diez et al. (1985), Gehlen and Schröder (1985), Huber (1985) and Foissner et al. (1986). The investigation of Huber (1985) deserves special interest, because biodynamically farmed fields near Vienna were also investigated. He found a higher content of humus in the ecofarmed plots, higher microbiological properties, a higher level of nutrients, a higher content of nitrogen, a higher overall exchange capacity, and a more marked disequilibrium of the cation ratio in the sorption complex. No differences were found in the soil physics or in the content of noxious anorganic substances.

Gehlen and Schröder (1985) reported a greater humus content, a greater microbial biomass, a greater activity of the enzymes dehydrogenase and catalase and a greater number of earthworms in several ecofarmed soils of Germany. These authors suppose that the better humus management of the ecofarmed soils is chiefly responsible for the observed differences, because these are markedly reduced if the values are corrected to 1% humus. Our results point in the same direction. The biostimulatory effects of humus and the close correlation between the microbiological and protozoological properties and the total organic carbon content (humus) have now been well established (Franz 1975; Beck 1985; Schnürer et al. 1985; Foissner 1986). However, other factors are likely to be superimposed. Berger et al. (1986), for instance, found that the alkaline, slowly soluble fertilizer Thomasphosphate increased the biomass of the testate amoebae, whereas an acid, easily soluble compound fertilizer (NPK), which is not allowed in organic farming systems, reduced the abundance of the nematodes. The existence of a complex system of factors is strengthened by the results of Diez et al. (1985), who found the microbiological properties in ecofarmed plots to be 10%–20% greater than in conventionally farmed soils although no significant differences were detected in the humus content.

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