Acta Agrophysica, 2001, 52, 185-192

MICROBIOLOGICAL AND BIOCHEMICAL PROPERTIES OF SOILS UNDER CEREALS GROWN IN THE ECOLOGICAL, CONVENTIONAL AND INTEGRATED SYSTEM

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A b s t r a c t. Studies on the comparison of microbial and biochemical characteristics of soils were based on a field experiment established in 1994 at the IUNG Experimental Station in Osiny on soil (loamy sand) belonging to complex IV. In this experiment spring barley and winter wheat were grown in three crop production systems: ecological, integrated and conventional. Soil under wheat were analysed in 1996, 1997 and 1998, and under barley in 1997 and 1998.

Microbial biomass, numbers of bacteria and fungi, soil respiration and enzymes (dehydrogenase, phosphatases) activity were generally higher in the soil under the tested cereals grown in the ecological system than in the soil under these crops grown in the conventional or integrated system. These differences were detected during all three growing seasons, indicating long-lasting changes in the biological characteristics of the studied soil.

K e y w o r d s: microbiological-biochemical properties, soil, cereals, farming systems.

INTRODUCTION

Conventional (high input) cropping system aims at obtaining maximum crop yields through intensive soil fertilisation and pesticide application to protect plants against numerous pests and diseases. These practices often lead to deterioration of biological and physicochemical soil properties. Soil is the key component of all the terrestrial ecosystems and environment, in general [2,4,6,8,13,16]. In order to reduce these adverse effects, integrated and ecological or organic farming systems have been developed in recent years [2,6,8-10]. Bachinger [2] and Mäder *et al.* [9,10] showed that in organically fertilised soil, all the microbial characteristics measured (ATP content, biomass, respiration, dehydrogenase and phosphatase activities) were higher than in the soil receiving conventional agriculture treatments, including intensive mineral fertilisation.

Soil microorganisms and their activity are fundamental to innumerable processes and functions that are carried out in the soils such as decomposition of organic residues, nutrient cycling, formation of soil humus, aggregation, degradation of xenobiotics, plant protection, N fixation and many other processes [1,4,5,9,10]. For these reasons, it is generally accepted that some parameters of biological activity, e.g. microbial biomass, soil respiration, potentially mineralizable N, enzymes activity, could be used as valuable indicators of changes in the soil quality and fertility [4,9,12,13,16]. e.g., Myśków *et al.* [13] created an index of soil fertility which included CEC, soil organic C content and biological parameters such as numbers of microorganisms, dehydrogenase or alkaline phosphatase activity.

In this work, we present results on the comparison of microbial and enzymatic properties of the soil under cereals grown in the ecological, integrated and conventional farming system.

MATERIALS AND METHODS

Studies on the comparison of microbial and biochemical characteristics of the soil were based on a field experiment established in 1994 at the IUNG Experimental Station in Osiny on the soil (heavy loamy sand) belonging to the complex IV (a very good rye complex). In this experiment crops are grown in three different production systems: ecological, integrated and conventional. Treatments and main agrotechnical practices applied in this trial are described in Table 1. For the purpose of this work fields sown with spring barley and winter wheat in the three systems were chosen. Soil under barley was analysed in 1997 and 1998; under wheat in 1996, 1997 and 1998. Soil samples were collected two or three times during each growing season (May, June and July or August) from the depth of 0-20 cm, sieved through a 2 mm screen and stored in a refrigerator for not longer than 1 week. The samples were analysed for the following parameters: total numbers of bacteria and fungi by the plate dilution method on the soil extract agar [12] and the Martin's agar [11], respectively; dehydrogenase activity by TTC method [3], acid and alkaline phosphatase using p-nitrophanol as the substrate for these enzymes [14].

Microbial biomass C was measured by the fumigation-incubation method as described by Jenkinson and Powlson [7] with further modifications. The replicated (3 x 50 g) samples of moist soil (50-55% WHC) were weighed into 100 ml beakers, placed in a vacuum desiccator and fumigated for 18-24 h at 25 ^{o}C in vapours

T a b l e 1. Main treatments applied in the crop production systems: ecological (E), conventional (C) and integrated (I)

Treatments	E	C	I
Crop rotation	potato, spring barley, red clover/grass (1st year), red clover/grass (2nd year), winter wheat (aftercrop)	rape seed, winter wheat, spring barley	potato, spring barley, red clover/grass, winter wheat
Organic amendments	compost/manure, 35 t/ha (under potato)	rape and wheat straw	compost/manure, 35 t/ha (under potato)
NPK (kg/ha)	none	N; 90-180 P; 60-100 K; 80-150	N; 60-120 P; 50-80 K; 75-100
Plant protection: herbicides and fungicides	none	standard for intensive production	reduced
Insecticides	biological-Novodor	standard for intensive production	reduced

of ethanol-free chloroform (placed in a separate beaker). After fumigation, chloroform is removed and the desiccator is evacuated several times. Control samples are treated in the same way, except for fumigation. The fumigated and unfumigated (control) samples are placed into airtight jars (0.9-1 litre) in the presence of 20 ml of 0.5 M NaOH (in 100 ml beaker) to trap respired CO_2. After 10 days of incubation at 25° C, the beakers are taken out and 3.5 ml of saturated $BaCl_2$ solution added to each beaker. The excess of NaOH is titrated with 0.25 M HCl to pH 7.0 in the presence of phenolophtalein. The unfumigated samples with new NaOH solution are incubated for further 10 days at the same conditions. Microbial biomass C (μg C-CO_2 g^{-1} soil d.m.) is calculated from the equation:

$$\text{Microbial biomass C} = (F_C - UF_C)/K_C$$

where F_C - CO_2 released from the fumigated sample in 10 days; UF_C - CO_2 released from the unfumigated sample in 10-20 days; K_C - 0.45 (fraction of biomass C mineralised to CO_2).

Soil respiration (μg CO_2-C g^{-1}10 $days^{-1}$) was estimated from the cumulative CO_2-C evolved from the control soil samples (UF_C) during 10-20 days of incubation. Metabolic quotient (qCO_2-C) expressing specific metabolic activity of soil microorganisms is expressed as the rate of soil respiration per a unit of microbial biomass C.

RESULTS AND DISCUSSION

Differences detected for the compared systems with respect to the measured biological characteristics of the soil were generally similar, irrespective of the date of soil sampling during the 1996-1998 vegetation seasons. Therefore Table 2 and Fig. 1 present the results of analyses performed in May of these growing seasons.

Soil cropped to spring barley and winter wheat in the ecological system generally had significantly higher values of the tested microbial and enzymatic characteristics than the soil under these crops cultivated either in the integrated or conventional system (Table 2, Fig. 1). Similar results were published by Mäder *et al.* [9,10] who showed that many biological properties of the soil (microbial biomass, ATP content, basal respiration, enzymes activity) in the organic system were substantially higher than in the soil under a conventional system with organic and mineral fertilisation or in the soil receiving mineral fertilisers only. Enhanced microbial activity in the soil of organic or ecological farming systems is attributed mainly to the application of organic manures and higher amounts of diversified crop residues remaining in such soils than in soil under a conventional system [2,8-10,12]. Moreover, high doses of mineral fertilisers and pesticides, especially when improperly applied in the conventional farming, may adversely affect development and activity of the soil biota [13,16].

Activity of soil microorganisms or their physiological status is often characterised by metabolic quotient (qCO_2) which relates soil respiration rate to the microbial biomass pool (Table 2). It is assumed that a high qCO_2 indicates stress conditions, e.g. caused by nutrient deficiency, soil compaction, pesticides or heavy metal toxicity [1,5,10,16]. Our results and those published by other workers [9,10] showed that qCO_2 is higher for the soils treated with mineral fertilisers only or receiving organo-mineral fertilisation than for the soils in organic or ecological farming systems. This would indicate that microorganisms in the soil receiving higher input of organic matter need less energy for maintenance [10].

Soil microbial biomass that represents the living and most dynamic part of the soil organic matter, constitutes between 1 and 5% (w/w) of the total soil organic C

T a b l e 2. Microbial characteristics of soil under spring barley and winter wheat cultivated in the ecological (E), integrated (I) and conventional (C) system

System	Microbial biomass μg C-CO_2 g^{-1} soil d.m.			Numbers of bacteria $x10^6$ g^{-1} soil d.m.			Numbers of fungi $x10^3$ g^{-1} soil d.m.			Soil respiration μg C-CO_2 g^{-1} soil d.m.		Metabolic quotient qCO_2 $C_{respir}/C_{biomass}$		Biomass C/ Soil org. C (%)
							Spring barley							
	1997		1998	1997		1998	1997		1998	1997	1998	1997	1998	1998
E	351a		229a	68c		41a	266a		615a	82a	94a	0.23	0.41	2.82
C	153c		157b	112a		19b	166b		355b	46b	76b	0.30	0.48	1.99
I	231b		131b	99b		13b	242a		305c	90a	65c	0.39	0.50	1.70
							Winter wheat							
E	329a	324a	202a	23a	83a	23b	175b	310a	455b	84a	79a	0.26	0.39	2.43
C	213b	154b	195a	10b	22b	19b	166b	187b	623a	39b	63b	0.25	0.32	2.27
I	116c	140b	175b	18a	19b	25a	273a	288a	453b	81a	68b	0.58	0.39	2.03

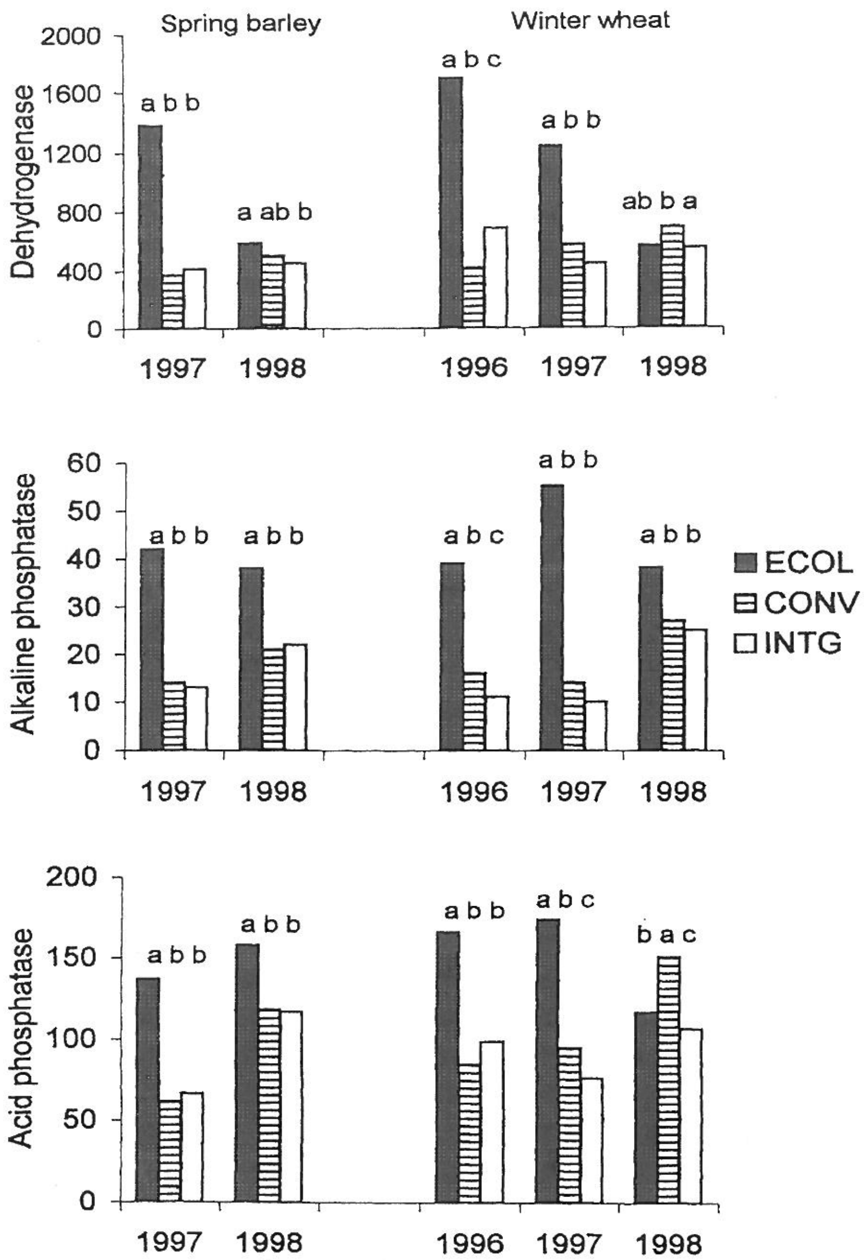

Fig. 1. Activity of dehydrogenase (mm^3 H_2 g^{-1} soil d.m.), alkaline and acid phosphatase (μg p-nitrophenol g^{-1} soil d.m.) in soil under spring barley and winter wheat cultivated in the ecological, conventional and integrated system.

Table 3. Frequency of occurrence* of the high (HI), intermediate (IN) and the low (LO) values of microbial and biochemical parameters measured in soil under cereals cultivated in the ecological (E), conventional (C) and integrated (I) system during 1996-98

Values	Systems/parameters		
	E	C	I
	Microbial biomass C		
HI	10	1	0
IN	1	8	2
LO	0	2	9
	Numbers of bacteria		
HI	7	4	1
IN	4	3	6
LO	1	5	5
	Numbers of fungi		
HI	7	2	3
IN	4	3	5
LO	1	7	4
	Soil respiration		
HI	5	2	3
IN	3	1	6
LO	2	7	1
	Dehydrogenase activity		
HI	10	2	0
IN	2	6	4
LO	0	4	8
	Acid phosphatase activity		
HI	9	3	0
IN	3	4	5
LO	0	5	7
	Alkaline phosphatase activity		
HI	11	1	0
IN	1	9	2
LO	0	2	10

*During 1996-98 growing seasons 10-12 analyses of soil under the studied systems were performed. For each analysis measured values of the parameters were compared with each other and ranked: high, intermediate and low. Numbers in this table indicate cases in which these ranks occurred for each system.

[1,4,10]. In the studied soil (Table 2), the biomass of microorganisms expressed as the percentage of soil organic C ranged form 1.70% to 2.62% and was the highest in the ecological soil under both crops tested. Since soil microorganisms play the most important role in the energy and nutrients flow through the soil ecosystem, high microbial pool and its activity is particularly important for plant nutrients release in soil of ecological or organic farming systems.

Table 3 summarises microbial and enzymatic properties of the soil measured during the three experimental years of growing cereals in the ecological, conventional and integrated system. During the 3-year period, 10 to 12 analyses (2 or 3 times per year) were performed and for each analysis the measured value of the particular biological soil parameter was compared between the systems and ranked as high, intermediate and low. As it can be seen from Table 3, the highest values of all the parameters were detected most frequently in the soil under cereals (barley and wheat) cultivated in the ecological system of crop production. The highest values of such properties as microbial biomass C, dehydrogenase and alkaline phospa-tase activities occurred in the ecological system in 10 or 11 out of 12 cases (analyses). Thus, it seems that these parameters may be considered as good indicators of changes in the soil biological properties in response to different soil management systems and for testing soil quality.

CONCLUSIONS

1. Microbial parameters and enzymes activity in the soil under spring barley and winter wheat cultivated in the ecological farming system were generally higher than in the soil under these crops grown in the conventional or integrated system.

2. These differences were detected during the three growing seasons studied, which indicats long-lasting changes in the biological characteristics of the examined soil as influenced by the farming systems.

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