Effect of land management without farmyard manure application on the amount and the activity of soil microbial biomass

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ABSTRACT

Four kinds of cereal crops were grown without farmyard manure application. The effect of farmyard manure was supposed to be replaced by post-harvest residues (PH treatment) or by ploughing the total by-product, i.e. straw (PZ treatment) into soil. After seven years of application, this soil farming system did not influence the contents of C_{ox} and N_t in soil. The amount of organic carbon had declined after the first year, but in the following years it remained at the same level (1.2%). The total nitrogen content increased from 0.143 to 0.166% without any considerable difference between the treatments. The amount of microbial biomass (C_{mic}) in PH treatment had been varying and in 2000 it decreased approximately by a half (from 215.96 to 132.00 mg C/kg of soil dry matter). The input of organic matter due to ploughing the whole by-product (PZ treatment) into soil acted favourably and the value of C_{mic} in 2000 was quite comparable with the average values of the individual years of 1994–1997. This land management and cereal growing caused a reduction of the ratio of microbial biomass carbon to soil organic carbon (C_{mic}/C_{org}). In the year 2000, the values decreased from 2.59 to 1.09% and from 2.88 to 1.82% in PH and PZ treatments, respectively. The amount of the biologically releasable nitrogen (N_{biol}) and the intensity of nitrification were the highest in the year 2000. There was a moderate negative correlation (r = –0.474) between the N_{biol} values and biomass amount values in PZ treatment, and a very close negative one (r = –0.972) in PH treatment. This relation became strong in both treatments when the values C_{mic}/C_{org} and N_{biol} were compared, i.e. r_{PH} = –0.863 and r_{PZ} = –0.921. The results confirmed that the amount and the quality of organic matter influence microbial biomass and its activity which is responsible for the nutrient release.

Keywords: biologically releasable nitrogen; microbial biomass; nitrification; plant residues; stagno-gleyic Luvisol; organic carbon

Soil organic matter dynamics and nutrient cycling are closely related to the activity of microorganisms. Microbial biomass (C_{mic}) as variable part of soil organic matter can be an indicator of soil changes (Anderson et Domsch 1989, Tesařová 1992, Sparling 1992, Šantrůčková 1993, Růžek 1995). The ratio of microbial biomass carbon to soil organic carbon (C_{mic}/C_{org}) seems to be a more sensitive parameter for soil organic matter monitoring than the individual parameter mentioned, i.e. microbial biomass carbon and soil organic carbon (Sparling 1992). The values of C_{mic} and C_{mic}/C_{org} vary with the type of ecosystem. In agroecosystems, C_{mic}/C_{org} values range from 0.3 to 4.8% (Tesařová 1992). Their decrease may be due to an increased return of overground and underground plant residues resulting in an increased input of the labile part of organic matter in comparison with the total carbon content (Graham et al. 2002). Crop rotation, type of soil cultivation and fertilisation vary under various land management, intervene in biological soil properties very markedly (Curci et al. 1997, Kandeler et al. 1999, Števlíková et al. 2001) and also affect the values of C_{mic}/C_{org} (Anderson et Domsch 1989, Šantrůčková 1993).

The main aim of this study was to evaluate the effect of the land management without farmyard manure application on certain soil properties and its biological status after seven years of this management.

MATERIAL AND METHODS

In 1994, the Department of Agricultural Systems, Faculty of Agronomy, established a stationary test on stagno-gleyic Luvisol at the experimental basis in Dolná Malanta (Slovakia). In this experiment, the cereals were grown without farmyard manure application. The effect of farmyard manure was substituted by ploughing post-harvest residues (PH treatment) or whole by-product (PZ treatment) into soil. The experimental site was located in a warm and moderately dry climatic region with the average year temperature of 9.7°C and the sum of precipitation amounting to 561 mm per year (altitude 175–180 m).

The soil samples for the microbiological characteristics determination were taken from experimental plots with four kinds of cereals under conventional soil cultivation and two fertilisation treatments (PH, PZ).

The sequence of crops which were grown in the crop rotation during the years of 1994–2000 is given in Table 1.

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Table 1. Crops cultivated on experimental plots

Year	Cultivated crops			
1994	grain maize	spring barley	pea	winter wheat
1995	spring barley	pea	winter wheat	grain maize
1996	pea	winter wheat	grain maize	spring barley
1997	winter wheat	grain maize	spring barley	pea
1998	grain maize	spring barley	pea	winter wheat
1999	spring barley	pea	winter wheat	grain maize
2000	pea	winter wheat	grain maize	spring barley

Modes of fertilisation

PH – post-harvest residues + balance fertilisation with inorganic nitrogenous fertilisers whose rate was calculated for the average yielding level as follows: grain maize – 7 t/ha (121 kg N/ha), spring barley – 5 t/ha (35 kg N/ha), pea (*Pisum sativum* L.) – 3 t/ha (29 kg N/ha), winter wheat (*Triticum aestivum* L.) – 6 t/ha (69.8 kg N/ha).

PZ – decreasing content of organic matter was supplemented by ploughing the whole by-product (plant residues + all mass of straw) of grown crops into soil. To support wheat and barley straw mineralisation, nitrogen was added and the nutrients were applied in the form of inorganic fertilisers on the balance principle (11.0–34.4 kg N/ha). Potassium and phosphorus were applied before the trial establishment (71 kg K/ha and 18 kg P/ha).

Ploughing to the depth of 0.3 m under maize and 0.2 m under other crops with the soil surface levelling before sowing represented the conventional cultivation.

In the course of 1994–1997, soil samples were taken from 0.0–0.2 m depth of the soil profile 5 to 6 times during the growing season. The evaluation of time dynamics of both the amount and the activity of microorganisms is stated in the following contributions: Števlíková et al. (2001), Vjatráková et al. (2001), Vjatráková et al. (2002). In autumn 2000, the soil samples were taken (Table 1) in one sampling term to evaluate the biological status of soil after another three-year period. In the contribution, the arithmetic averages of the investigated parameters in the respective years (1994–1997) are compared to the values achieved in 2000.

After soil samples sieving through a 2 mm sieve, the following parameters were determined:
- oxidizable organic carbon (C_{ox}) according to Tjurin (Arinuškina 1961)
- soil microorganisms biomass carbon (C_{mic}) by rehydratation method according to Blagodatskiy et al. (1987)
- on the basis of C_{ox} and C_{mic} values, the ratio of microbial biomass carbon to soil organic carbon (C_{mic}/C_{org}) was calculated
- contents of NH_4^+-N in fresh soil samples and after their 14-day incubation determined colorimetrically with Nessler agent in 1% K_2SO_4 extract
- content of NO_3^--N in fresh soil samples and after their 14-day incubation determined colorimetrically with phenoldisulphonic acid in 1% K_2SO_4 extract

Soil samples were incubated at 28°C and under moisture conditions corresponding to 60% of full water capacity. From those values the amount of biologically releasable nitrogen (N_{biol}) was calculated as a difference between inorganic content (NH_4^+-N + NO_3^--N) in soil after and before incubation, and also the intensity of nitrification according to the same scheme but considering only the content of NO_3^--N in soil.

Generally, stagno-gleic Luvisol of experimental stand was low in total nitrogen content from agrochemical point of view, showing neutral to slightly acid soil reaction.

Table 2. Average values of the evaluated parameters in years (1994–1997) and fertilisation

Source of variability	Evaluated parameters				
	C_{ox} (%)	C_{mic} (mg/kg dry soil)	C_{mic}/C_{org} (%)	Nitrification (NO_3^--N/kg dry soil)	N_{biol} (mg/kg dry soil)
Years					
1994 (*n* = 20)	1.29	228.48	2.74	11.83	11.81
1995 (*n* = 24)	1.21	196.24	2.38	12.05	11.31
1996 (*n* = 20)	1.22	265.58	2.89	8.27	7.79
1997 (*n* = 24)	1.23	226.63	2.27	11.13	10.71
Fertilisation					
PH (*n* = 88)	1.23	219.37	2.46	10.63	10.05
PZ (*n* = 88)	1.24	239.09	2.68	11.01	10.55

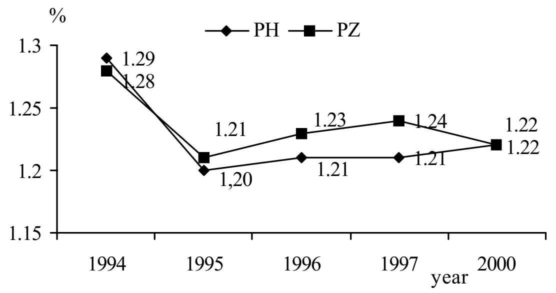

Figure 1. Oxidizable organic carbon

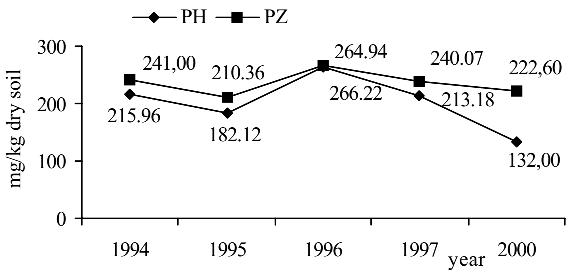

Figure 2. Microbial biomass carbon

The parameters investigated were evaluated by variance analysis. The differences between the average values of the parameters investigated under the fertilising treatments applied in respective experimental years and year 2000 were tested by *t*-test. The relationship between the amount of biologically releasable nitrogen (N_{biol}) and C_{mic} or C_{mic}/C_{org} within the fertilising treatments was statistically evaluated by correlation analysis.

RESULTS AND DISCUSSION

In agroecosystems, the soil quality depends to a large extent on organic carbon dynamics. The content of organic carbon matters seems to be a parameter which is not very variable in time while the soil environment is not affected by some sharp intervention (Pankhurst et al. 2002). After limiting the input of organic fertilisers for at least several years, the humus regime in soil returned back to the initial status which is characteristic for each soil type (Barančíková 2001).

The values of oxidizable carbon (% C_{ox}) were the highest at the beginning of the experimental period (1994) and decreased after the first year of the experiment, they remained; approximately at the same level in the next years including sampling in autumn 2000 as well (Table 2, Figure 1). Ploughing the whole by-product into soil (PZ treatment) caused a moderate increase of C_{ox} values in the course of the complete experimental span but without statistical significance (Tables 2 and 3, Figure 1). Comparing the average values achieved in respective years (1994–1997) with the value achieved in 2000, a significant

Table 3. Analysis of variance according to ANOVA for oxidizable organic carbon (C_{ox}), microbial biomass carbon (C_{mic}), ratio of soil microbial biomass carbon to soil organic carbon (C_{mic}/C_{org}), nitrification NO_3^--N, biologically releasable nitrogen (N_{biol})

Years	Source of variability	Count	*d.f.*	*F*-ratio
1994–1997	oxidizable organic carbon (C_{ox})			
	year	96	3	23.35^{++}
	fertilisation	96	1	1.63
2000	fertilisation	8	1	0.04
1994–1997	microbial biomass carbon (C_{mic})			
	year	176	3	10.10^{++}
	fertilisation	176	1	4.96^{+}
2000	fertilisation	8	1	35.33^{++}
1994–1997	ratio of microbial biomass carbon to soil organic carbon (C_{mic}/C_{org})			
	year	176	3	7.01^{++}
	fertilisation	176	1	2.78
2000	fertilisation	8	1	38.55^{++}
1994–1997	nitrification NO_3^--N			
	year	176	3	8.28^{++}
	fertilisation	176	1	0.35
2000	fertilisation	8	1	4.32
1994–1997	biologically releasable nitrogen (N_{biol})			
	year	176	3	10.03^{++}
	fertilisation	176	1	0.23
2000	fertilisation	8	1	6.69^{+}

$^{++}P < 0.01$, $^{+}P < 0.05$

Table 4. t-test for fertilisation PH

Evaluated parameters in years	Computed t	Level of significance
C_{ox} 2000 and 1994	–2.98	0.029^{+}
C_{ox} 2000 and 1995	0.60	0.706
C_{ox} 2000 and 1996	–0.48	0.332
C_{ox} 2000 and 1997	0.15	0.555
C_{mic} 2000 and 1994	–6.94	0.003^{++}
C_{mic} 2000 and 1995	–7.20	0.003^{++}
C_{mic} 2000 and 1996	–8.79	0.002^{++}
C_{mic} 2000 and 1997	–3.57	0.019^{+}
C_{mic}/C_{org} 2000 and 1994	–9.59	0.001^{++}
C_{mic}/C_{org} 2000 and 1995	–17.98	0.000^{++}
C_{mic}/C_{org} 2000 and 1996	–10.46	0.001^{++}
C_{mic}/C_{org} 2000 and 1997	–4.71	0.009^{++}
Nitrif. NO_3^--N 2000 and 1994	3.31	0.977
Nitrif. NO_3^--N 2000 and 1995	3.39	0.979
Nitrif. NO_3^--N 2000 and 1996	9.15	0.997
Nitrif. NO_3^--N 2000 and 1997	5.96	0.995
N_{biol} 2000 and 1994	4.19	0.988
N_{biol} 2000 and 1995	3.97	0.986
N_{biol} 2000 and 1996	10.27	0.999
N_{biol} 2000 and 1997	6.81	0.997

H_0: $\mu_1 = \mu_2$, H_1: $\mu_2 > \mu_1$; $^{++}P < 0.01$, $^{+}P < 0.05$

Table 5. t-test for fertilisation PZ

Evaluated parameters in years	Computed t	Level of significance
C_{ox} 2000 and 1994	–2.24	0.055
C_{ox} 2000 and 1995	1.26	0.852
C_{ox} 2000 and 1996	–0.57	0.303
C_{ox} 2000 and 1997	–1.04	0.188
C_{mic} 2000 and 1994	–2.28	0.053
C_{mic} 2000 and 1995	0.97	0.797
C_{mic} 2000 and 1996	–2.12	0.062
C_{mic} 2000 and 1997	–1.53	0.112
C_{mic}/C_{org} 2000 and 1994	–7.28	0.003^{++}
C_{mic}/C_{org} 2000 and 1995	–5.89	0.005^{++}
C_{mic}/C_{org} 2000 and 1996	–5.05	0.008^{++}
C_{mic}/C_{org} 2000 and 1997	–4.94	0.008^{++}
Nitrif. NO_3^--N 2000 and 1994	0.60	0.706
Nitrif. NO_3^--N 2000 and 1995	5.29	0.993
Nitrif. NO_3^--N 2000 and 1996	5.89	0.995
Nitrif. NO_3^--N 2000 and 1997	5.12	0.993
N_{biol} 2000 and 1994	5.82	0.995
N_{biol} 2000 and 1995	5.99	0.995
N_{biol} 2000 and 1996	7.41	0.998
N_{biol} 2000 and 1997	6.56	0.996

H_0: $\mu_1 = \mu_2$, H_1: $\mu_2 > \mu_1$; $^{++}P < 0.01$, $^{+}P < 0.05$

difference was found in one case only, i.e. in PH treatment in 1994, the C_{ox} value being statistically significantly higher than that determined after seven years (Table 4). The differences between the compared years on treatments with the applied whole by-product were not significant (Table 5). The balance of organic matter in this experiment, as it is stated in Vjatráková et al. (2002), was in favour of PZ treatment although only in one case (1996) a positive value was achieved.

The majority of soil microorganisms is chemoorganotrophic and, consequently, they are fixed to the stands sufficient in organic matters. The amount of microorganisms biomass in both treatments was variable with time (Table 2, Figure 2). The effect of individual years, which includes the weather conditions (temperature, distribution of precipitation), the quantity and quality of organic matter resources, was highly significant (Table 3). Microbial biomass values measured increased after ploughing the whole by-product in soil (Figure 2), and the differences between PH and PZ treatments were significant only at the lower level of significance (Table 3). Comparing the average values of the respective years 1994–1997 with year 2000, in PH treatment the amount of microbial biomass varied and in 2000 it was in most cases highly significantly the lowest (Table 4, Figure 2). In PZ treatment, time variability was similar, but t-test confirmed steadiness of the biomass amount values also after seven years of field trial duration (Table 5, Figure 2).

The amount of microbial biomass and its dynamic are fundamental parameters of the biological soil status evaluation (Granatstein et al. 1987, Šantrůčková 1993, Curci et al. 1997, Kandeler et al. 1999, Števlíková et al. 2002). Because the amount of microbial biomass is in a close relation to the carbon content, any agrotechnical inter-

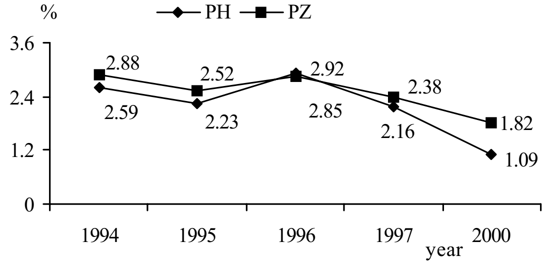

Figure 3. Ratio of microbial biomass carbon to soil organic carbon

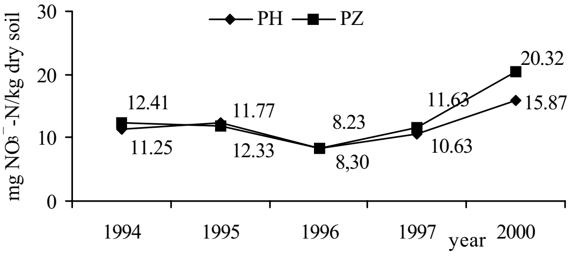

Figure 4. Nitrification

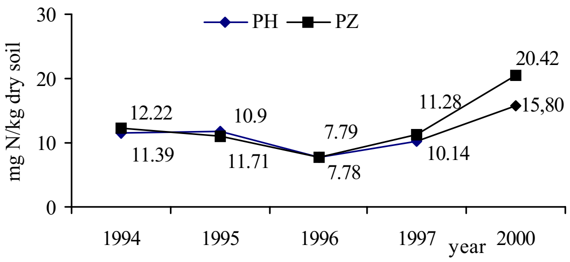

Figure 5. Biologically releasable nitrogen

ference in soil influencing carbon status will also cause a change in biomass. In agricultural soils of the same type occurring in the same climatic region but differing in both farming systems and grown crops, the values of C_{mic} according to Šantrůčková (1993) varied from 122 to 560 µg C/g depending on the content of C_{org}. The way of the soil cultivation affects the vertical distribution of organic matter in the soil profile and through it also the microbial biomass amount and its activity (Curci et al. 1997). The strongest effect was observed when passing from minimal to conventional soil cultivation (Kandeler et al. 1999), in the opposite direction the change was not so sudden (Pankhurst et al. 2002).

In the evaluation of the ratio of microbial biomass carbon to soil organic carbon, which is generally considered to be a more sensitive parameter of changes in the soil environment, we observed its significant decrease in 2000 in both treatments, more obviously, however, in PH treatment (Tables 4 and 5, Figure 3). The values C_{mic}/C_{org} fluctuated within the range stated by Tesařová (1992) for agroecosystems (0.3–4.8%), with the lowest value (0.86) achieved under winter wheat in 2000. According to Anderson and Domsch (1989), the range from 2.3 to 4% is considered to be an expression of balance in carbon cycling. Higher or lower values represent the losses or the accumulation of carbon in soil. Graham et al. (2002) explain the decrease of C_{mic}/C_{org} values by an incorporation into soil of higher amounts of the plant residues with a higher content of organic matter labile fraction.

The reduction of microbial biomass and the ratio of microbial biomass carbon to soil organic carbon in PH treatment in our trial without the farmyard application on the cereals growing was caused by an insufficient return of carbon; a negative balance of organic matter was also confirmed (Vjatráková et al. 2002). The opposite tendency was registered with the release of inorganic forms of nitrogen (N_{biol}). The values of biologically releasable nitrogen and nitrification after seven years of this land management were the highest (Figures 4 and 5), but without any statistical significance in comparison to the years of 1994–1997 analysed by *t*-test (Tables 4 and 5). The differences between the fertilisation treatments in the year 2000, however, were significant (Table 3) but only in releasing inorganic forms of nitrogen. Moderate (PZ treatment) to very close (PH treatment) negative linear correlation was found between the biomass amount and the quantity of biologically releasable nitrogen. This relation proved to be stronger in both treatments when C_{mic}/C_{org} and N_{biol} were compared (Table 6).

The content of inorganic nitrogen released is related to the natural mineralisation potency of soil and is influenced by the simultaneous course of mineralisation and immobilisation processes (Bízik 1989, Bielek 1998). The main agent of both types of the processes is soil organisms, especially microorganisms, which are besides abiotic factors affected by substrate resources. According to the results of Vaněk et al. (1997), the amounts of mineral and mineralizable nitrogen reached values of 30 to 50 ppm in soils unfertilised organically for a long time. After fertilisation with farmyard manure together with mineral fertilisers and with pea as the previous crop, the values increased to 80 ppm in arable soil layer.

The decisive part of nitrogen available for plants comes from microbial biomass mineralisation (Novák 1993). The turnover of nitrogen from dead microbial cells is approximately 5 times quicker than the turnover of other soil nitrogen. This is affected not only by abiotic factors but also by the input of substrate resources whose quality and quantity are important from the viewpoint of net nitrogen mineralisation (Bielek 1998).

CONCLUSION

After seven years of land management without farmyard manure application, the amount of microbial biomass markedly decreased in PH treatment (ploughing in post-harvest residues + balanced fertilisation with inorganic fertilisers). In PH treatment (ploughing post-harvest residues into soil + ploughing in straw, i.e. the whole by-product + balanced fertilising with inorganic fertilisers), this characteristic remained at the level of 1994–1997 average. The strong decrease of the ratio of microbial biomass carbon to soil organic carbon signals a balance deformation in carbon cycling.

The amount of inorganic nitrogen released after 14-day incubation of soil samples was the highest in the year 2000 and was in a negative correlation with the microbial biomass amount. This close negative relation became

Table 6. Correlation cofficients between the parameters chosen (5 pairs)

Fertilisation		N_{biol}
PH	C_{mic}	-0.97^{++}
	C_{mic}/C_{org}	-0.92^{+}
PZ	C_{mic}	−0.47
	C_{mic}/C_{org}	−0.86

Correlation coefficient is significantly different from 0 at $^{++}P < 0.01$, $^{+}P < 0.05$

even more obvious on comparison of C_{mic}/C_{org} values to those of the released inorganic nitrogen content.

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ABSTRAKT

Vliv obhospodařování půdy bez použití chlévského hnoje na velikost biomasy a její aktivitu

Způsob obhospodařování půdy při pěstování zrnin bez použití chlévského hnoje, který měl být nahrazen zbytky po sklizni (var. PH), resp. zaorání celého vedlejšího produktu (slámy, var. PZ), po sedmi letech neovlivnil obsah C_{ox} a N_t. Množství organického uhlíku se snížilo po prvním roce, ale v dalších letech se udrželo na stejné úrovni (1,2 %). Obsah celkového dusíku se z hodnoty 0,143 % zvýšil na 0,166 % bez výrazného rozdílu mezi variantami. Mikrobiální biomasa (C_{mic}) ve variantách PH kolísala a v roce 2000 klesla téměř na polovinu (z 215,96 na 132,00 mg C/kg sušiny zeminy). Přísun organické hmoty ve formě zaorání celého vedlejšího produktu (var. PZ) působil příznivě, hodnota C_{mic} byla v roce 2000 porovnatelná s průměrnými hodnotami z let 1994–1997. Tento způsob obhospodařování půdy a pěstování zrnin se projevil sníženým podílem C_{mic} z C_{org}. Hodnoty klesly v roce 2000 ve variantách PH z 2,59 na 1,09 % a ve variantách PZ z 2,88 na 1,82 %. Množství biologicky uvolnitelného dusíku (N_{biol}) a intenzita nitrifikace byly v roce 2000 nejvyšší. Hodnoty N_{biol} byly s množstvím mikrobiální biomasy ve variantě PZ v mírném (r = –0,474) a ve variantě PH až velmi těsném záporném lineárním vztahu (r = –0,972). Síla vztahu se zvýraznila v obou variantách při porovnávání C_{mic}/C_{org} a N_{biol} (r_{PH} = –0,863, r_{PZ} = 0,921). Výsledky potvrdily, že množství a kvalita organické hmoty ovlivňují mikrobiální biomasu a její aktivitu, která je zodpovědná za uvolňování živin.

Klíčová slova: biologicky uvolnitelný dusík; mikrobiální biomasa; nitrifikace; rostlinné zbytky; hnědozem; organický uhlík

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