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Soil organic matter changes according to the application of organic and mineral fertilizers within long-term experiments

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ABSTRACT

Within the long-term field experiments at IOSDV Jable near Ljubljana (subalpine climate, heavy hydromorphic silt loam) and at IOSDV Rakičan (Pannonian climate, sandy silt), the impact of organic matter management system and mineral nitrogen fertilization on the soil organic matter content was studied in the period 1998-2008. The following management systems were selected: system A - no organic matter, system B - farmyard manure ploughing in, system C - straw/catch crop ploughing in. Four different mineral N rates (N0, N1, N2, N3) were evaluated. During the three-year crop rotation, maize, wheat and barley (or, alternatively, oats) were sown each year. The annual balance of C_{org} was calculated on the basis of the quantity of added organic and mineral fertilizers, considering the quantity of C_{org} in the soil. In system A, at both locations, fertilizing with the highest amount of mineral N resulted in a higher C_{org} content. At both locations, positive effect of organic fertilization on the increase of the C_{org} content was registered where management systems with organic matter (i.e. systems B and C) applied, while statistically significant impact of mineral N on a higher C_{org} content was determined only in system C. Within all three systems, the highest C_{org} values were reached when the highest mineral N application volume was used. After 11 years, the C_{org} content in system A decreased irrespective of the mineral N fertilization at both locations. At IOSDV Jable, a small decrease of the C_{org} content was measured in BN0, while all other treatments at IOSDV Jable and at IOSDV Rakičan resulted in an increased C_{org} content.

The average absolute value of difference among the C_{org} contents in 2008 and 1998 in all ten treatments at IOSDV Jable was 1.8 t/ha C_{org}, while at IOSDV Rakičan it amounted to 3.5 t/ha C_{org}, which indicates a major influence of management system on the soil with a smaller clay content.

Key words: soil fertility, crop rotation, organic fertilizers, farmyard manure, straw, N fertilizers, humus content, humus balance

IZVLEČEK

SPREMEMBE VSEBNOSTI ORGANSKE SNOVI V TLEH V ODVISNOSTI OD GNOJENJA Z ORGANSKIMI IN MINERALNIMI GNOJILI ZNOTRAJ TRAJNIH POSKUSOV

V statičnem poskusu IOSDV Jable, blizu Ljubljane (predalpsko klimatsko območje, ilovnato meljasta hidromorfna tla) in IOSDV Rakičan (panonsko klimatsko območje, meljasto ilovnata tla) smo preučevali vpliv gospodarjenja z organskimi gnojili in vpliv gnojenja z mineralnimi dušikom na vsebnost organske snovi v tleh v letih 1998 do 2008. Vključeni sistemi gospodarjenja so bili: sistem A - gospodarjenje brez organskega gnojenja, sistem B - gnojenje s hlevskim gnojem, sistem C - zaoravanje slame/podorin. Preučevane so bile štiri stopnje gnojenja z mineralnim dušikom: N0, N1, N2 in N3. V triletnem kolobarju si sledijo koruza, pšenica, ječmen/oves. Letna bilanca C_{org} je bila izračunana na podlagi količin dodanih organskih in mineralnih gnojil, pri upoštevanju stanja C_{org} v tleh. Na obeh lokacijah je v sistemu A gnojenje z največjim odmerkom mineralnega dušika povečalo vsebnost C_{org} v tleh. Na obeh lokacijah je bil dokazan vpliv organskega gnojenja na povečanje vsebnosti C_{org}, v sistemih B in C, medtem ko je bil značilen vpliv gnojenja z mineralnim dušikom dokazan le v sistemu C. Najvišje vsebnosti C_{org} znotraj sistemov so bile pri obravnavanju z največjim odmerkom mineralnega dušika. Po enajstih letih se je vsebnost C_{org} v sistemu A na obeh lokacijah zmanjšala, ne glede na gnojenje z mineralnim dušikom. Vsebnost C_{org} je po enajstih letih narasla v vseh obravnavanjih sistemov B in C, razen pri obravnavanju BN0 v IOSDV Jable. Povprečna absolutna razlika vsebnosti C_{org} med letoma 2008 in 1998 znotraj vseh deset obravnavanj v IOSDV Jable je 1,8 t/ha C_{org}, v IOSDV Rakičan pa 3,5 t/ha C_{org}. Rezultati nakazujejo, da je vpliv različnega sistema gospodarjenja večji na lokaciji IOSDV Rakičan, kjer vsebujejo tla manjši odstotek gline.

Ključne besede: rodovitnost tal, kolobar, organska gnojila, hlevski gnoj, slama, mineralni dušik, vsebnost humusa, bilanca humusa

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1 INTRODUCTION

Soil organic matter (SOM) is one of the most important determinants of soil quality and is most commonly estimated by determining the soil organic carbon (SOC) content (Rasmussen et al., 1998). A usable way to calculate SOM is by multiplying the percentage of organic carbon by a factor; however, conversion factor varies between 1.6 and 3.3 and this large range is due to the inherent differences between soils and humus composition. Most commonly, a conversion factor 1.72 is used (Körschens et al., 1997; Körschens, 2001; Rasmussen et al., 1998). Definition of soil organic carbon requires a differentiation into two fractions: decomposable organic carbon (C_{decom}), which is mainly influenced by cultivation conditions and inert part of carbon (C_{iner}), which is uninvolved in mineralization and mostly dependent on the site conditions (Körschens, 1997).

It is widely recognized that SOC plays an important role in biological (provision of substrate and nutrients for microbes), chemical (buffering changes, soil porosity) and physical (stabilization of soil structure, soil thermal conditions) properties of the soil (Reeves, 1997). Considering this wide variety of performance indicators, Karlen (Karlen et al., 2003) pointed out that soil quality needs to be assessed with regard to what the soil is used for, as a particular type of soil may be of high quality for one function and may perform poorly for another. Critical levels of soil organic carbon content are difficult to establish since they vary according to soil texture and climatic conditions (Kay and Angers, 1999; Körschens , 1997; Ogle et al., 2005, Rasmussen et al., 1998).

It is recommendable to maintain a 1.5 to 3.5 % SOC content in topsoil, with the value varying in accordance with the soil structure (Tajnšek, 2003). According to Körschens (Körschens et al., 1997), the upper and the lower values of SOC differ in relation to clay contents; for soils with 4 % of clay, the proposed limits of SOC are between 1 % and 1.5 %, while for soils with more than 38 % of clay, the limit values of SOC are between 3.5 % and 4.4 %. Due to a slow response of organic carbon to the production management, monitoring of humus content requires long-term, several-decade lasting experiments (Körschens, 2001; Powlson et al., 1998; Ogle et al., 1998). Crop rotation, fertilization with organic and mineral fertilizers, a manner and time of ploughing and ploughing in of harvest residues or catch crops are factors that influence the content of SOC. Having replaced the conventional soil tillage with shallow or minimum tillage, soil humus content in the soil layer to 10 cm significantly increased (Angers and Carter, 1996; Campbell et al., 1996; Riley et al., 2008; Slepetiene and Slepetys, 2005). However, Schulz (Schulz et al., 2008) points out that significant differentiation of SOC content by tillage intensity could not be confirmed.

Bucur et al. (2007) studied the influence of soil erosion on humus losses in different crop systems in Romania; the highest losses were registered in continuous maize culture. Körschens (1997) thoroughly studied the influence of different crops on the decomposable SOC; clover (lucerne, alfaalfa) as a perennial crop with a wide root system proved to have the highest SOC content in comparison with cereals and row crops. With the application of organic manure, the SOM content increased (Delschen, 1999; Edmeades, 2003; Gerzabek ,1997; Körschens, 1997; Kristaponyte, 2005; Martens and Frankenberger, 1992; Nardi et al., 2004; Paustian et al., 2005). The application of higher amounts of mineral fertilizers (NPK or N) increase SOC amount (Haynes and Naidu, 1998; Purakayastha et al., 2008), while, according to Shevtsova and Nardi (Shevtsova et al., 2003; Nardi et al., 2004), fertilizing with mineral fertilizers had no significant effect on the humus content compared to the application of organic fertilizers.

As the humification (changing the primary organic matter into humus) and mineralization (changing humus into soil minerals) depend largely on the amount of precipitation, it is necessary that the latter are taken into account when interpreting the results (Zech, 1997). Under the average European climatic conditions the decomposable carbon in SOC is 0.2 %-0.6 %, corresponding to 8 to 24 t/ha (Körschens, 1997). By using methods of calculating the balance of humus we are given an opportunity to control the SOM content in arable soils in order to achieve higher yields and simultaneously avoid environmental pollution. In the trial, the method of calculating the balance of humus determined by Diez and Krauss was used (Diez and Krauss, 1992); this method, which we named the “Swiss method”, is believed to be an appropriate method for the central Slovenian climatic conditions.

The aim of our study was to examine, with the application of the “Swiss method”, the impact of organic and mineral fertilization on the humus content in the soil according to particular crop rotation at two different locations with a specific soil type and particular climatic conditions.

2 MATERIALS AND METHODS

2.1 Experimental layout

Two long-term experiments were established at IOSDV Jable and IOSDV Rakičan in 1993.

The trial was set up as a permanent experiment related to crop rotation with ten different fertilization combinations as a block trial with three repetitions. First, the trial area was divided into three plots, on which each year crops were sown in the following order: corn, winter wheat, barley/oats. Each plot was further divided into two subplots, on which different systems of fertilization with organic management were studied. Each subplot thus represented five variants differing according to the rate of fertilization with mineral nitrogen in the three repetitions. The basic plot size was 30 m^2 (5 × 6 m). Ten different treatments were included in the investigation:

- management system with no organic fertilizers (system A) and two different mineral rates (N0, N3),
- management system with farmyard manure ploughing in (system B) and four different mineral N rates (N0, N1, N2, N3),
- management system with straw ploughing in (system C) and four different mineral N rates (N0, N1, N2, N3).

Fertilizing plan for the nutrition of arable crops is shown in Table 1. At the harvest time, yield and straw quantities were measured for each plot. After harvesting every year soil samples from each plot were taken at a depth of 0-25 cm for further analysis.

Table 1: *Management systems, mineral N fertilization with regard to the crop, the average amount of mineral N in the three-year crop rotation (Miner. $N_{aver.}$) at the IOSDV Jable and IOSDV Rakičan locations for ten treatments.*

		Miner. N rates	Maize (kg/ha N)	Wheat (kg /ha N)	Barley/ Oats (kg /ha N)	Miner. $N_{aver.}$ (kg /ha N)	Treat.
System A	No organic fertilizers		/	/	/		
		N0	0	0	0	0	**AN0**
		N3	300	195	165	220	**AN3**
System B	Farmyard manure ploughing in (t/ha)		30 t/ha farmyard manure	/	/		
		N0	0	0	0	0	**BN0**
		N1	100	65	55	73	**BN1**
		N2	200	130	110	147	**BN2**
		N3	300	195	165	220	**BN3**
System C	Straw/catch crop ploughing in (t/ha)		Barley/oats straw + fodder radish	Maize straw	Wheat straw		
		N0	0	0	0	0	**CN0**
		N1	100	65	55	73	**CN1**
		N2	200	130	110	147	**CN2**
		N3	300	195	165	220	**CN3**

2.2 Humus balance calculation method

The method of calculating the balance of humus was determined by Diez and Krauss (Diez and Krauss, 1992). We named it the "Swiss method". The annual balance (H_n) is calculated on the basis of the ploughed-in quantity of organic matter (manure (Z_d), straw (Z_e), catch crop (Z_e), harvest residues (Z_e)) with the corresponding humification coefficient (H_{Kd}, H_{Ke}), taking into account the quantity of humus in the soil (H) with the appropriate mineralization coefficient (H_{Mk}). Results are given in the C_{org} value (t/ha), which is calculated on the basis of humus content (t/ha) multiplied by factor 0.58. The equation for calculating the balance of humus is shown in Table 2.

In the year of establishment of the experiment (1993) the soil analysis were conducted at the laboratories UFZ Leipzig-Halle, Germany (Tajnšek, 2003); the C_{org} content was determined according to ISO 10694, 1996-08. In the calculation of humus balance we considered this initial value of C_{org} in 1993 content, while presented results are for the period 1998-2008.

Statistical analysis was conducted with the Statgraphics Plus 4.0 program. Multifactor ANOVA was used in order to analyze the effect of different management systems on the humus content in the soil. Differences among treatments were detected by Duncan's Multiple Range Test ($p < 0.05$).

***Table 2**: The equation for the humus balance calculation with the corresponding parameters for each of the three management systems (system A, B, C) (modified by Diez and Krauss, 1992).*

Eq:	**(Ze**	×	**Hke)**	+	**(Zd**	×	**Hkd)**	-	**(H**	×	**Mkh)**	=	$\mathbf{H_n}$
	Annual amount of plant residues (straw, catch crop, harvest residues)		**Humification coefficient forplant residues**		**Annual amount of farmyard manure**		**Humification coefficient for farmyard manure**		**Amount of humus per hectare in the previous year n-1**		**Mineralization coefficient for an individual crop sown in a particular year**		**Amount of humus in year n**
System A	(roots[1]	×	0.02)					-	(HA_{n-1}	×	0.01)	=	HA_n
System B	(roots	×	0.02)	+	(farm. manure[2]	×	0.25)	-	(HB_{n-1}	×	0.01)	=	HB_n
System C	(roots (straw (fodder radish[3]	× + × + ×	0.02) 0.15) 0.1)					-	(HC_{n-1}	×	0.01)	=	HC_n

[1]The amount of straw t SS/ha × roots/straw ratio coefficient (0.5).
[2]The amount of farmyard manure 7.5 t SS/ha is considered only for maize (in the years 1999, 2002, 2005, 2008).
[3]Ploughing in of fodder radish as a catch crop is considered only after barley/oats (in the years 1998, 2001, 2004, 2007).

2.3 Weather and soil conditions

For the chemical and physical properties of the soil measured at the beginning of the trial cf. Tajnšek (2003). The soil type at the IOSDV Jable location (46 ° 8'N, 14 ° 34'N, 305 m above sea level) is *Umbric Planosols (Plu)*, while soil texture is determined as silt loam. The soil type at the IOSDV Rakičan location (46°38´N, 14°11´N, 184 m above sea level) is *Eutric Fluviosol (ELe)*, while soil texture is determined as sandy silt.

IOSDV Jable is located in the subalpine zone, where prolonged droughts are rare even in the summer, let alone in the winter and autumn. Its reference weather station is Brnik. In the period 1961-1990, the average annual temperature was 8.3 °C and ranged from 7.3 °C to 9.8 °C. The long-term average precipitation during the period 1961-1960 amounted to 1384 mm in the 987 mm to 1770 mm interval. During the trial period (1998-2008), the average annual temperature was more than 1°C higher compared to the long term average. In the years 2000, 2002, 2003 and 2008, the average annual temperature ranged from 9.7 °C to 10.2 °C. In the years studied, the average annual precipitation was 1323 mm; in 2004, 2005, 2008, on the other hand, it was 8-17 % higher in comparison with the long term average.

IOSDV Rakičan is located on the south-western edge of the Pannonian climate zone. Its reference weather station is Murska Sobota. In the period 1961-1990, the average annual temperature was 9,2 °C, ranging from 8.2 °C to 10.1 °C. The long-term average precipitation during the period 1961-1990 was 814 mm in the 563 mm to 1064 mm interval. From 1998 to 2008, the average annual temperature was 1.3 °C higher in comparison with the long-term average temperatures. The hottest years were 2000, 2002, 2007 and 2008, with average annual temperatures above 11 °C. In the years studied, the average annual precipitation was 747 mm; in 2003, however, it was approximately 30 % smaller compared to the long-term average precipitation.

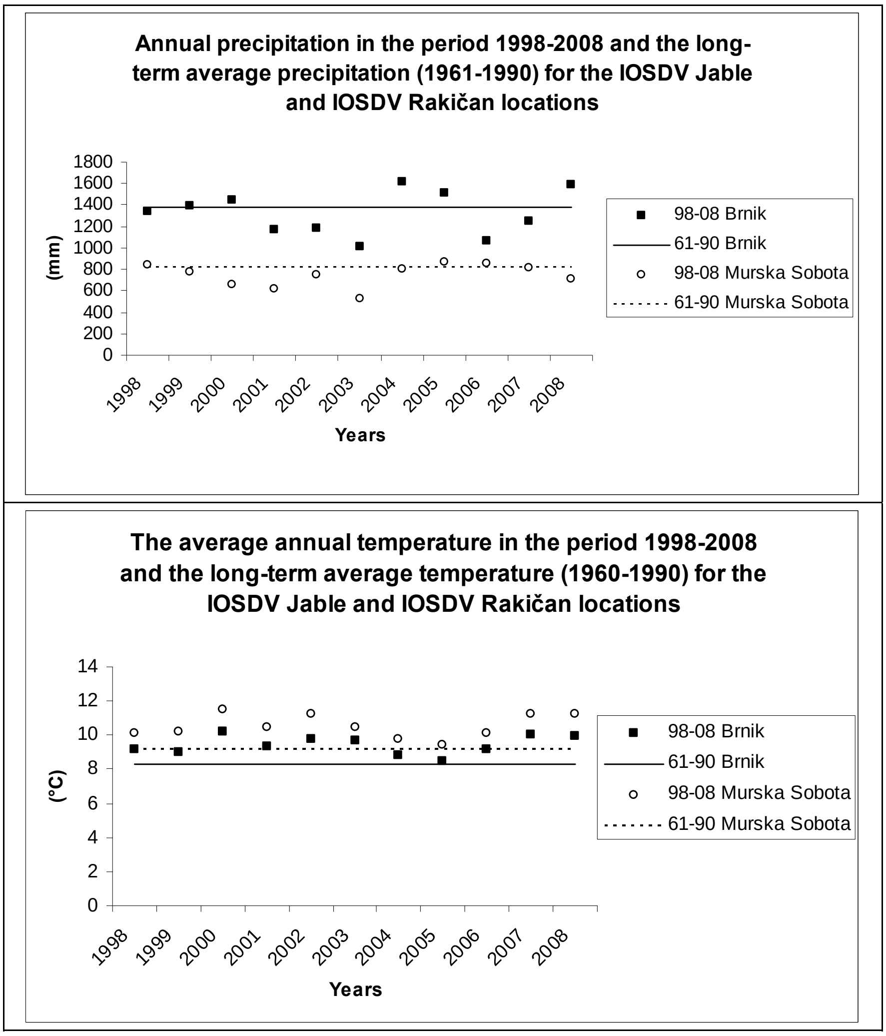

Figure 1: *Annual precipitation for the period 1998-2008 and the long-term average precipitation (1961-1990) for the IOSDV Jable (weather station Brnik) and IOSDV Rakičan (weather station Murska Sobota) locations (above) and the average annual temperature for the period 1998-2008 and the long-term average temperature (1960-1990) for both locations (below).*

3 RESULTS AND DISCUSSION

3.1 IOSDV Jable

Results showing the C_{org} content at the IOSDV Jable location for the period 1998-2008 and the average C_{org} content for the period of 11 years are given in Table 3. The initial value of C_{org} at the beginning of the trial in 1993 was 55.48 t/ha C_{org}. Over the period 1998-2008, the impact of organic and mineral fertilization on the content of C_{org} was confirmed. In system A, fertilizing with mineral nitrogen significantly affected the increase of the C_{org} content. On average, the C_{org} content rose from 50.6 t/ha C_{org} in an AN0 control to 52.2 t/ha C_{org} in AN3, which corresponds to 3.2%.

Table 3: *The C_{org} content (t/ha) during the period 1998-2008 and the average C_{org} content (t/ha) for the same period for ten treatments (including three different management systems: A, B, C and nitrogen fertilization: N0, N1, N2, N3) at IOSDV Jable at a depth of 0-25 cm, calculated by the "Swiss method".*

IOSDV Jable C_{org} (t/ha)												
Treat.	**1998 Bar.**	**1999 Mai.**	**2000 Whe.**	**2001 Bar.**	**2002 Mai.**	**2003 Whe.**	**2004 Oats**	**2005 Mai.**	**2006 Whe.**	**2007 Oats**	**2008 Mai.**	**Aver 11yr.**
AN0	53.02 a* ±0.08	52.48 a ±0.10	51.99 a ±0.12	51.48 a ±0.11	50.95 a ±0.12	50.50 a ±0.12	50.12 a ±0.14	49.61 a ±0.19	49.13 a ±0.18	48.43 a ±0.18	48.43 a ±0.20	50.60 a ±0.14
AN3	53.70 b	53.54 b	53.15 b	52.69 b	52.39 b	52.02 b	51.77 b	51.67 b	51.31 b	51.29 b	51.02 b	52.23 b
BN0	54.17 c	54.74 d	54.23 d	53.72 d	54.31 d	53.84 d	53.43 d	53.99 d	53.48 d	53.22 d	53.80 d	53.91 d
BN1	54.44 d	55.13 e	54.67 e	54.17 e	54.83 ef	54.40 e	54.05 e	54.71 e	54.27 e	54.15 e	54.79 e	54.51 e
BN2	54.60 de	55.39 ef	54.95 ef	54.50 f	55.19 fg	54.78 f	54.45 ef	55.15 ef	54.75 ef	54.63 e	55.38 ef	54.89 ef
BN3	54.70 e	55.57 f	55.17 f	54.75 f	55.50 g	55.10 f	54.79 f	55.65 f	55.26 f	55.28 f	56.03 g	55.25 f
CN0	54.13 c	53.90 c	54.84 c	53.22 c	53.04 c	52.70 c	52.64 c	52.78 c	52.36 c	52.57 c	52.53 c	53.04 c
CN1	55.11 f	55.09 e	54.84 ef	54.58 f	54.55 de	54.29 e	54.46 ef	55.05 e	54.77 ef	55.33 f	55.48 fg	54.87 ef
CN2	55.44 g	55.98 g	55.77 g	55.55 g	55.88 h	55.65 g	55.84 g	56.73 g	56.55 g	57.47 g	57.89 h	56.25 g
CN3	55.74 h	56.69 h	56.47 h	56.29 h	56.88 i	56.63 h	56.88 h	57.68 h	57.51 h	58.51 h	59.10 i	57.13 h

*a-i – The same letter in the column indicates that there is no significant difference among treatments (Duncan multiple range test. $p<0.05$).

In the system with farmyard manure ploughing in (system B), the C_{org} content was, in all treatments, significantly higher compared to the C_{org} content in system A. In 2001 and 2003, fertilization with a higher amount of mineral nitrogen (BN2, BN3) demonstrated a positive impact on the increase of the C_{org} content; in 2007 and 2008, on the other hand, only the treatment with the highest amount of mineral nitrogen (BN3) proved to have the same effect. In other years, the mineral nitrogen fertilization influenced the C_{org} content; the differences among treatments could, however, not be statistically confirmed. The C_{org} content in system B increased by an average of 3.3 t/ha C_{org} to 4.7 t/ha C_{org} compared to the average C_{org} content in AN0.

In the system with ploughing in of straw and catch crops (system C), the C_{org} content was, in all treatments, significantly higher compared to the C_{org} content in the AN0 control. Unlike system B, differences among treatments (CN0, CN1, CN2, CN3) in system C were statistically confirmed in all the studied years. Increasing the amount of mineral nitrogen resulted in a higher C_{org} content, in accordance with Haynes and Körschens (Haynes and Naidu, 1998; Körschens, 1997). The C_{org} content in system C increased by an average of 2.4 t/ha C_{org} to 6.5 t/ha C_{org}, which equals the 4.8-12.9 % rise compared to the average value of C_{org} content in AN0.

After 11 years, the C_{org} content in system A decreased - in the AN0 control by 4.6 t/ha C_{org} (8.6%), in AN3, where the mineral nitrogen was added, by 2.7 t/ha C_{org}, corresponding to 5.0%. Fertilization with the highest amount of mineral nitrogen resulted in a minor reduction of the C_{org} content compared to the AN0 control (Figure 2). The results suggest that the degree of mineralization in system A is greater than the degree of humification.

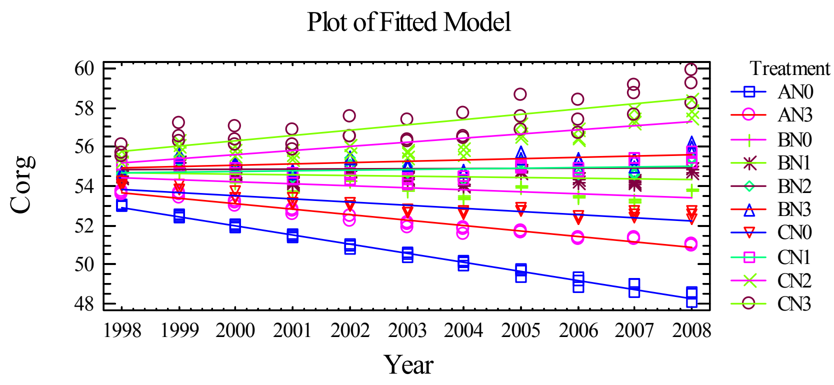

Figure 2: *The C_{org} content (t/ha) in the period 1998-2008 for ten different treatments at the IOSDV Jable location.*

In system B, the C_{org} content in the treatment without the mineral nitrogen (BN0) decreased by 0.4 t/ha C_{org} (0.7%) compared to the initial value of the C_{org} content in the year 1998. By increasing the amount of mineral nitrogen, the C_{org} content rose by 0.4 t/ha C_{org} in BN1, by 0.8 t/ha C_{org} in BN2 and by 1.3 t/ha C_{org} in BN3. In comparison with the initial value in 1998, the C_{org} content in system C in 2008 was higher only in the treatments where mineral nitrogen was added; in CN1, the C_{org} content increased by 0.4 t/ha C_{org}, in CN2 by 2.5 t/ha C_{org} and in CN3 by 3.4 t/ha C_{org}.

Each year, the maximum C_{org} content was reached in the treatment CN3. The average value of difference of the C_{org} content between CN3 and AN0 throughout the eleven-year period was 6.6 t/ha C_{org}, varying from 2.7 t/ha C_{org} in 1998 to 10.6 t/ha C_{org} in 2008.

3.2 IOSDV Rakičan

Results for the C_{org} content at the IOSDV Rakičan location for the period 1998-2008 and the average C_{org} content for the eleven-year period are given in Table 4. The initial value of C_{org} in 1993 was 37.27 t/ha C_{org}. In the years studied (1998-2008), the impact of organic fertilization on the C_{org} content was confirmed. In system A, fertilizing with mineral nitrogen (AN3) increased the C_{org} content; the difference between treatments could, however, not be statistically confirmed. On average, the C_{org} content in AN3 increased to 35.47 t/ha, which is 2.8% more than the average value of the C_{org} content in the AN0 control.

In system B, the C_{org} content was, in all treatments, significantly higher compared to the AN0 control. Despite the differences in absolute values, we were unable to confirm statistically significant differences among treatments with a different degree of added mineral nitrogen (BN0, BN1, BN2, BN3). The C_{org} content in system B increased by an average of 4.1 t/ha C_{org} to 5.2 t/ha C_{org}, which was 11.9-15.1 % higher compared to the average value of C_{org} content in AN0.

In the straw ploughing in system (system C), the C_{org} content was higher in all treatments with regard to the C_{org} content in AN0. Fertilization with the lowest amount of mineral nitrogen (CN1) had insignificantly increased the C_{org} content in the years until 2005; from this year on, however, the impact was statistically significant. Among the treatments where medium (CN2) and the highest (CN3) amount of nitrogen was applied, there were no statistically significant differences. The C_{org} content in system C increased by an average of 3.8 t/ha C_{org} to 6.9 t/ha C_{org} compared to the average value of the C_{org} content in AN0, i.e. by 10.9% to 19.8%.

At IOSDV Rakičan, the C_{org} content in system A decreased after 11 years; in the AN0 control by 2.4 t/ha C_{org} (6.6 %), in AN3 where mineral nitrogen was added by 1.2 t/ha C_{org}, which equals to 3.4.0 %. These results are comparable to the results measured at IOSDV Jable (Figure 3). By increasing the amount of mineral nitrogen in system B, the C_{org} content increased by 3.5 t/ha C_{org} (BN1), by 4.1 t/ha C_{org} (BN2) and by 4.2 t/ha Corg (BN3). According to the C_{org} content in 1998 in system C, the C_{org} content increased in all treatments; in CN0 by 2.0 t/ha C_{org}, in CN1 by 4.0 t/ha C_{org}, in CN2 by 4.7 t/ha C_{org} and in CN3 by 5.6 t/ha C_{org}.

Each year, the maximum C_{org} content was reached in CN3. The average value of difference of the C_{org} content between CN3 and AN0 throughout the eleven-year period was 6.9 t/ha C_{org}, varying from 2.9 t/ha C_{org} in 1998 to 10.8 t/ha C_{org} in 2008

***Table 4**: The C_{org} content (t/ha) during the period 1998-2008 and the average C_{org} content (t/ha) for the same period for ten treatments (including three different management systems: A, B, C and nitrogen fertilization: N0, N1, N2, N3) at IOSDV Rakičan at a depth of 0-25 cm, calculated by the "Swiss method".*

IOSDV Rakičan C_{org} (t/ha)											
Trea.	**1998 Bar.**	**1999 Mai.**	**2000 Whe.**	**2001 Bar.**	**2002 Mai.**	**2003 Whe.**	**2004 Oats**	**2005 Mai.**	**2006 Whe.**	**2007 Oats**	**2008 Mai.**	**Aver 11yr.**
AN0	35.58	35.40	35.10	34.78	34.97	34.62	34.34	34.17	33.84	33.46	33.23	34.50
	a	a	a	a	a	a	a	a	a	a	a	a
	±0.18	±0.26	±0.28	±0.18	±0.47	±0.50	±0.54	±0.59	±0.61	±0.63	±0.72	±0.28
AN3	36.06	36.05	35.85	35.69	35.70	35.48	35.33	35.24	35.09	34.82	34.83	35.47
	a	a	a	a	a	a	a	a	a	a	a	b
BN0	37.10	38.24	37.89	37.59	39.01	38.66	38.39	39.63	39.34	38.96	40.1	38.63
	b	bc	bc	b	b	b	b	bc	bc	bc	bc	cd
BN1	37.39	38.68	38.39	38.15	39.66	39.31	39.08	40.3	40.06	39.74	40.92	39.24
	b	cd	bcd	b	bc	bc	bc	bcd	bcd	bc	bcd	de
BN2	37.39	38.67	38.40	38.21	39.86	39.59	39.40	40.74	40.53	40.19	41.52	39.49
	b	cd	bcd	b	bc	bc	bcd	cde	bcd	bcd	cd	e
BN3	37.56	38.89	38.64	38.48	40.02	39.78	39.57	40.94	40.78	40.45	41.74	39.72
	b	cd	cde	b	bc	bc	bcd	cde	cd	bcd	cd	e
CN0	37.17	37.83	37.61	37.59	38.66	38.43	38.57	38.83	38.61	38.48	39.19	38.26
	b	b	b	b	b	b	bc	b	b	b	b	c
CN1	37.67	38.48	38.41	38.59	39.98	39.85	40.18	40.78	40.83	40.90	41.64	39.76
	b	bc	bcd	bc	bc	bc	cd	cde	cd	cd	cd	e
CN2	38.22	39.07	39.15	39.55	40.70	40.70	41.02	41.75	41.93	42.09	42.92	40.65
	c	cd	ef	cd	cd	cd	de	de	de	de	de	f
CN3	38.49	39.35	39.44	39.98	41.52	41.56	41.86	42.61	42.88	43.07	44.12	41.35
	c	d	f	d	d	d	e	e	e	e	e	f

*a-i – The same letter in the column indicates that there is no significant difference among treatments (Duncan multiple range test. $p<0.05$).

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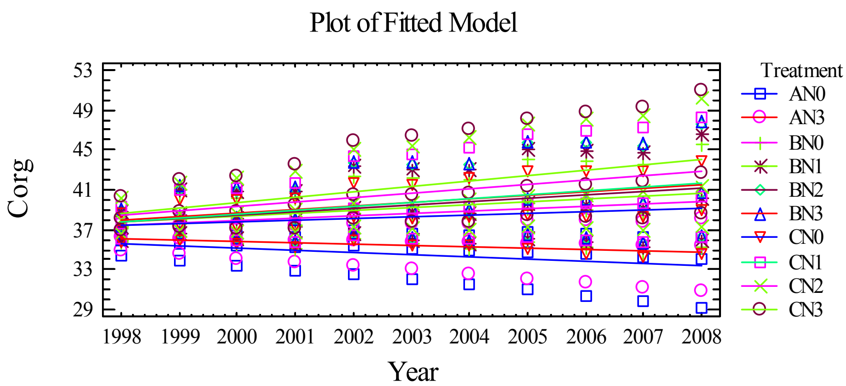

***Figure 3**: The C_{org} content (t/ha) in the period 1998-2008 for ten different treatments at the IOSDV Rakičan location.*

According to Table 5, a greater influence of management systems and mineral N fertilization could be reached at IOSDV Rakičan. As the average absolute value of difference of the C_{org} content for all treatments amounted to 3.5 t/ha and was almost two times higher as at IOSDV Jable, it is possible to conclude that soil with a lower clay content could be more influenced by different management usage.

***Table 5**: Balance of C_{org} content during the eleven-year period (C_{org} in 2008 minus C_{org} in 1998) and the average absolute value of the C_{org} content (x_{aver}) (t/ha) at the IOSDV Jable and IOSDV Rakičan locations.*

	IOSDV Jable	**IOSDV Rakičan**
Treatment	$\lvert C_{org2008}-C_{org1998}\rvert$ (t/ha)	$\lvert C_{org2008}-C_{org1998}\rvert$ (t/ha)
AN0	|-4.6|	|-2.4|
AN3	|-2.7|	|-1.2|
BN0	|-0.4|	|3.0|
BN1	|0.4|	|3.5|
BN2	|0.8|	|4.1|
BN3	|1.3|	|4.2|
CN0	|-1.6|	|2.0|
CN1	|0.4|	|4.0|
CN2	|2.5|	|4.7|
CN3	|3.4|	|5.6|
X_{aver}	1.8	3.5

4 CONCLUSIONS

During eleven-year period the application of organic fertilizers in the form of farmyard manure or straw significantly influenced the C_{org} content at two long-term experiments, with different soil and climatic conditions. At IOSDV Jable, within system B, the C_{org} content increased by an average of 3.3 t/ha C_{org} to 4.7 t/ha C_{org} compared to the C_{org} content in the AN0 control. Moreover, in the system with ploughing in of straw and catch crops (system C), the C_{org} content also increased by an average of 2.4 t/ha C_{org} to 6.5 t/ha C_{org}. At IOSDV Rakičan, within system B, the C_{org} content increased by an average of 4.1 t/ha C_{org} to 5.1 t/ha C_{org} compared to the C_{org} content in the AN0 control, while, in system C, the C_{org} content increased by an average of 3.8 t/ha C_{org} to 6.8 t/ha C_{org}. A significant impact of mineral N on the C_{org} content was determined in systems A and C at both locations, while in system B this impact could not be proven.

After 11 years, the C_{org} content in system with no organic fertilizers (system A) decreased irrespective of the mineral N fertilization at both locations. At IOSDV Jable, a small decrease of the C_{org} content was measured in BN0, while all other treatments at IOSDV Jable and IOSDV Rakičan resulted in an enlarged C_{org} content. The average absolute value of difference between the C_{org} content in 2008 and 1998 for all treatments at IOSDV Rakičan was almost two times higher as at IOSDV Jable. According to these results as well as according to other authors´ statements we determined that soil with a smaller clay content shows the greatest dependence on the selected management.

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6 REFERENCES

Angers, D.A., Carter, M.R. (1996): Aggregation and Organic Matter Storage in Cool, Humid Agricultural Soils. V: Structure and Organic Matter Storage in Agricultural Soils. Carter, M.R. and Stewart, B.A. (ur.). CRC Press, Boca Raton, pp. 193-211.

Bucur, D., Jitareanu, G., Ailincai, C., Tsadilas, C., Ailincăi, D., Mercus, A. (2007): Influence of soil erosion on water, soil, humus and nutrient losses in different crop systems in the Moldavian Plateau, Romania. Journal of Food, Agriculture & Environment, Vol. 5 (2): 261-264.

Campbell, C.A., McConkey, B.G., Zentner, R.P., Selles, F., Curtin, D. (1996): Long-term effects of tillage and crop rotations on soil organic C and total N in a clay soil in southwestern Saskatchewan. Canadian Journal of Soil Science, 76: 395-401.

Delschen, T. (1999): Impacts of long-term application of organic fertilizers on soil quality parameters in reclaimed loess soils of Rhineland lignite mining area. Plant and Soil, 213: 43-54.

Diez, T., Krauss, M. (1992): Berechnung von Humisbilanzen, SuB 06: III-9-III-11.

Edmeades, D.C. (2003): The long-term effects of manures and fertilisers on soil productivity and quality: a review. Nutrient Cycling in Agoecosystems, 66: 165-180.

Franko, U. (1997): Modellierung des Umsatzes der organischen Bodensubstanz. Archives of Agronomy and Soil Science, 41: 527-547.

Gerzabek, M.H., Pichlmayer, F., Kirchmann, H., Haberhauer, G. (1997): The response of soil organic matter to manure amendments in a long-term experiment at Ultuna, Sweden. European Journal of Soil Science, 48: 273-282.

Haynes, R.J., Naidu, R. (1998): Influence of lime, fertilizer and manure applications on soil organic matter content and soil physical conditions: a review. Nutrient Cycling in Agroecosystems, 51: 123-137.

Karlen, D.L., Ditzler, C.A., Andrews, S. S. (2003): Soil quality: why and how? Geoderma, 114: 145-156.

Kay, B.D., Angers, D.A. (1999): Soil Structure. V: Handbook of Soil Science. Sumner, M.E. (ur.). CRC press, Boca Raton, pp. A-229-A- 276.

Körschens, M. (1997): Abhängigkeit der Organischen Bodensustanz (OBS) von Standort und Bewirtschaftung sowie Ihr Einfluss auf Ertrag und Bodeneigenschaften. Archives of Agronomy and Soil Science, 41: 435-463.

Körschens, M., Schulz, E., Klimanek, E.-M., Franko, U. (1997): Die Organiche Bodensustanz - Bedeutung, Denifition, Bestimmung. Archives of Agronomy and Soil Science, 41: 427-433.

Körschens, M. (2001): How do organic fertiliser systems influence the C pool in long-term experiments? In: Applying compost benefits and needs. Seminar Proceedings, Brussels, 22-23 November, 2001; pp. 37-47.

Körschens, M. (2006): The importance of long-term field experiments for soil science and environmental research - a review. Plant Soil and Environment, 52, (Special Issue): 1-8.

Kristaponyte, I. (2005): Effect of fertilisation systems on the balance of plant nutrients and soil agrochemical properties. Agronomy Research, 3 (1): 45-54.

Martens, D.A., Frankenberger, W.T. Jr. (1992): Modification of Infiltration Rates in an Organic-Amanded Irrigated Soil. Agronomy Journal, 84: 707-717.

Nardi, S., Morari, F., Berti, A., Tosoni, M., Giardini, L. (2004): Soil organic matter properties after 40 years of different use of organic and mineral fertilisers. European Journal of Agronomy, 21: 357-367.

Ogle, S.M., Breidt, F.J., Paustian, K. (2005): Agricultural management impacts on soil organic carbon storage under moist and dry climatic conditions of temperate and tropical regions. Biogeochemistry, 72: 87-121.

Paustian, K., Collins, H.P., Paul, E.A. (1997): Management Controls on Soil Carbon. V: Soil Organic Matter in Temperate Agroecosystems. Paul, E.A., Elliott, E.T., Paustian, K., Cole, C.V. (ur.) CRC press, Boca Raton, pp.15-51.

Powlson, D.S., Smith, P., Coleman, K., Smith, J.U., Glendining, M.J., Körschens, M., Franko, U. (1998): A European network of long – term sites for studies on oil organic matter. Soil & Tillage Research, 47: 263-274.

Purakayastha, T.J., Rudrappa, L., Singh, D., Swarup, A., Bhadraray, S. (2008): Long-term impact of fertilizers on soil organic carbon pools and sequestration rates in maize-wheat-cowpea cropping system. Geoderma 144: 370-378.

Rasmussen, P.E., Goulding, K.W.T., Brown, J.R., Grace, P.R., Janzen, H.H., Körschens, M. (1998): Long-Term Agroecosystem Experiments: Assessing Agricultural Sustainability and Global Change. Science, 282: 893-896.

Reeves, D.W. (1997): The role of soil organic matter in maintaining soil quality in continuous cropping systems. Soil & Tillage Research, 43: 131-167.

Riley, H., Pommeresche, R., Eltun, R., Hansen, S., Korsaeth, A. (2008): Soil structure, organic matter and earthworm activity in a comparison of cropping systems with contrasting tillage, rotations, fertilizer levels and manure use. Agriculture, Ecosystems and Environment, 124: 275-284.

Shevtsova, L., Romanenkov, V., Sirotenko, O., Smith, P., Smith, J.U., Leech, P., Kanzyvaa, S., Rodionova, V. (2003): Effect of natural and agricultural factors on long-term soil organic matter dinamics in arable soddy-podzolic soils - modelling and observation. Geoderma, 116: 165-189.

Slepetiene, A., Slepetys, J. (2005): Status of humus in soil under various long-term tillages systems. Geoderma, 127: 207-215.

Shulz, F., Brock, C., Leithold, G. (2008): Effects of Farm Type and Different Intensities of Soil Tillage on Cash Crop Yields and Soil Organic Matter. In: 16th IFOAM Organic World Congress, Modena, Italy, June 16-20, 2008 (http://orgprints.org/11990)

Tajnšek, A. (2003): Vsebnost humusa in nekatere fizikalne lastnosti tal v odvisnosti od gnojenja z organskimi gnojili in dušikom v IOSDV Jable in IOSDV Rakičan. In: Deset let poskusov IOSDV v Sloveniji, Jable in Rakičan 1993-2003. Zbornik posveta. Tajnšek, A., Čeh Brežnik, B., Kocjan Ačko, D. (ur.) Ljubljana, pp. 25-34.

Zech, W., Senesi, N., Guggenberger, G., Kaiser, K., Lehmann, J., Miano, T.M., Miltner, A., Schroth, G. (1997): Factors controlling humification and mineralization of soil organic matter in the tropics. Geoderma, 79: 117-161.