Humus Content and Quality under Different Soil Tillage Systems

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Abstract: The main objective of our study was to compare the contents and quality of humic substances in selected soil types under different tillage regimes (deep, reduced, minimum). Non destructive spectroscopic methods such as UV-VIS and synchronous fluorescence spectroscopy were applied. After three years of experiments, no statistically significant differences in the total carbon content, labile carbon content, and humic substances carbon content were found. Humic substances quality and the absorbance in UV-VIS spectral range was the highest in Haplic Chernozem (minimum tillage). Fluorescence intensity varied in dependence on the soil types, however, the same main fluorophores in all samples were detected. Fluorescence of humic substances was the highest in Haplic Chernozem (minimum tillage). The determination of HS spectroscopic characteristics was found as a sensitive indicator for HS quality assessment.

Keywords: soil humic substances; tillage regimes; UV-VIS and SFS spectroscopy

Cultivated systems and their productivity are directly related to organic matter concentration and turnover (Smith *et al.* 1993). Soils vary widely in their organic matter contents. In undisturbed (native) soils, the amount present is governed by the soil forming factors of the age, parent material, topography, vegetation, and climate. The change of any factor causes the change of other components and results in the change of the way and intensity of the humification process (Stevenson 1982). Soil organic matter is a component with a significant influence on a number of properties and functions (e.g. biological, chemical, physical, xenobiotica co-transport, C-sequestration). Soil cultivation and management practices (fertilisation, manure application, crop rotation, tillage systems, and pollution) induced an important discussion about humus content and quality. As a result, many authors reported on the conservation tillage system that had been introduced in the less favourable soils under an economic pressure (Horáček & Liebhard 2004). Conservation tillage practices reduce the cultivation costs by 15% per acre compared to the conventional tillage as reported by OMAFRA (2002). It may also have beneficial effects on the soils properties, besides saving inputs, water, and mitigating wind erosion. However, some other authors described certain risks of a long-term continuous plough less system. Carter (1994) showed that despite its economic benefits, the adoption of reduced tillage for corn is limited due to the accompanying excessive soil moisture. Dwyer *et al.* (2000) and Jandák *et al.* (2008) also stressed an adverse effect on the plant growth and root system.

According to stability and decomposability, soil organic carbon is divided into the stable and labile

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forms. The stable forms are represented by the total carbon content, humic substances sum, humic acids sum and fulvic acids sum (Stevenson 1982; Piccolo 2002). The labile carbon is soluble in water, it is more active and undergoes short – time changes in the soil. According to Körschens (1996, 1999), this part of the soil organic matter may be useful to characterise the soil management practices. For detailed stable carbon characterisation non destructive spectroscopic methods such as UV-VIS, FTIR, SFS, and 13C NMR spectroscopy have been offered. The absorbance in UV-VIS spectral range is frequently used for the determination of colour indexes (Q4/6) which are related to the degree of condensation of the aromatic carbon in HS molecule (Del Vecchio & Blough 2004).

Synchronous fluorescence spectroscopy (SFS) is a useful tool for characterising HS quality. This method has some advantages over 13C NMR because it is easier and cheaper and more sensitive as stated by Milori *et al.* (2002) and Sierra *et al.* (2005). SFS spectra give a narrower and simpler spectrum and therefore are extensively used for multi –fluorophoric analysis (Milori *et al.* 2002).

The objective of our study was to find alterations in the total carbon content, labile carbon content, and humic substances content between soil types and between different tillage practices. Standard commonly used methods and UV-VIS and SFS spectroscopic methods were applied for the evaluation.

MATERIALS AND METHODS

Soil types were classified according to FAO as Haplic Chernozem, Luvic Chernozem, and Gleyic Luvisol. Haplic Chernozem (locality Hrušovany) was formed under aridic water regime, average year temperature 8–9°C and precipitation 461 mm, altitude – 219 m a.s.l. Luvic Chernozem (locality Unčovice) was formed under ustic water regime, average year annual temperature 7–8.5°C and precipitation 536 mm, altitude 202 m a.s.l. Gleyic Luvisol (locality Lesonice) was formed under udic water regime, average year temperature 7–8°C and precipitation 567 mm, altitude 524 m a.s.l. GPS of the selected localities and basic soil properties are given in Tables 1 and 2.

The following tillage regimes were observed:
P – plough till 0.22 m;
D – deep plough till 0.35–0.40 m;
M – minimum plough till 0.15 m.

The soil samples were taken from the topsoil (0–0.30 m) twice a year (spring and autumn) in three replicates from each variant.

Table 1. Selected localities and basic soil properties in studied soils

Soil type	Locality	GPS	pH/H_2O	pH/KCl	Conductivity (mS)	$CaCO_3$ (%)	CEC (mmol/kg)
Haplic Chernozem	Hrušovany	X = 48°51.899’ Y = 16°23.984’	7.1	7.7	0.120	0.40	280
Luvic Chernozem	Unčovice	X = 49°37.217’ Y = 17°08.759’	6.5	7.0	0.075	0.37	220
Gleyic Luvisol	Lesonice	X = 49°06.074’ Y = 15°43.871’	6.2	6.8	0.050	0.00	150

Table 2. Texture classes determined by pipette method

Soil sample	Texture classes (%)				
	2.00–0.25	0.25–0.05	0.05–0.01	0.01–0.001	< 0.001
Haplic Chernozem	4.38	23.82	22.88	19.56	29.36
Luvic Chernozem	0.20	13.24	49.64	17.68	19.24
Gleyic Luvisol	25.21	14.64	28.45	19.17	12.53

Total carbon content (TOC) was determined by oxidimetric titration (Nelson & Sommers 1982). The labile carbon content was determined by hot water extraction method (Körschens 1996). Humic substances (HS) carbon, humic acids (HA) carbon and fulvic acids (FA) carbon were determined by the short fractionation method (Podlešáková *et al.* 1992). The soil reaction (pH/H_2O, pH/KCl) was determined by the potentiometric method. Conductivity was determined by the potentiometric method.

Carbonates content was determined by the volumetric method. Cation exchange capacity (CEC) was determined by the Mehlich method with unbuffered 0.1M $BaCl_2$ (Table 1). The texture was determined by the pipette method (Table 2).

The absorbance in UV-VIS spectral range was measured in the mixture of 0.1M pyrophosphate sodium and 0.1M NaOH. UV-VIS spectrometer Varian Cary 50 Probe with optical fibre within the range 300–700 nm was used. Colour indexes (Q4/6) were calculated as ratios at A465/A665 nm. Synchronous fluorescence spectra (SFS) were measured using spectrofluorimeter Aminco Bowman Series 2 (Thermospectronics, Xe-lamp, scan sensitivity 60%, autorange 845 V, bandpass of both monochromators 4nm, $\Delta\lambda em - \Delta\lambda ex = 20$ nm between both excitation and emission monochromators, within the range 320 nm and 620 nm). Relative fluorescence indexes (F) from SFS spectra were calculated as ratios: 488/502, 360/488. Humic substances fluorescence was compared with Elliot Soil Humic Acids Standard (1S102H), purchased from IHSS, www.ihss.gatech.edu.

RESULTS AND DISCUSSION

Total carbon content and humic substances carbon contents were the highest in Haplic Chernozem (Hrušovany) during the whole period of the experiment. Figure 1 shows the data of total carbon content in the soils studied. The inter-annual variability might be explained by the effect of the cultivated crops. The highest values were under minimum plough (M).

Statistically significant differences between the tillage variants were not found. The labile carbon content varied with the soil types from 950 to 700 g/kg, 600–400 mg/kg, and 500–350 mg/kg in Haplic Chernozem, Luvic Chernozem, and Gleyic Luvisol, respectively (Figure 2). HS, HA, and FA carbon contents are shown in Figures 3–5. Humic substances contents varied with soil types and the tillage practices did not alter their contents. The results obtained also corresponded with the literature data published by Deen and Kataki (2003).

Figure 6 shows the colour indexes (Q4/6) calculated from UV-VIS spectra. Q4/6 values varied with the soil types from 2.8–6. Lower Q4/6 values indicating a higher HS quality were found in Haplic Chernozem. High Q4/6 indexes (more than 4) and low HS quality were found in Gleyic Luvisol. The selected UV-VIS spectral lines measured in spring 2007 and 2009 are shown in Figures 7 and 8. The effect of cultivation is evident and is represented by a lower absorbance under plough (P) tillage regime (Figure 8). Statistically significant differences in HS absorbance between the tillage variants in Haplic Chernozem were found (R^2 = 0.990).

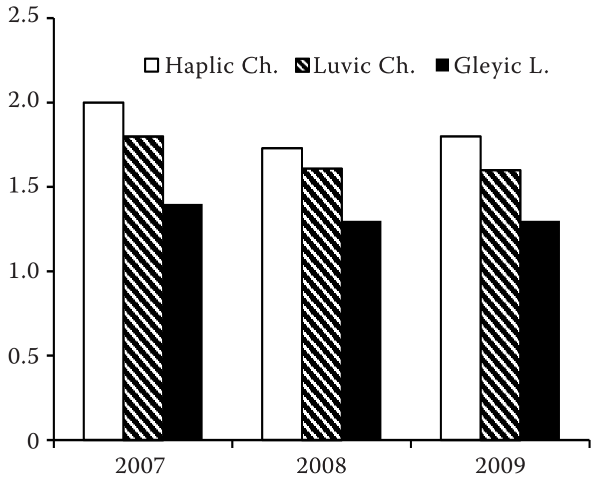

Figure 1. Total carbon content (TOC in %) in studied soils under plough (P)

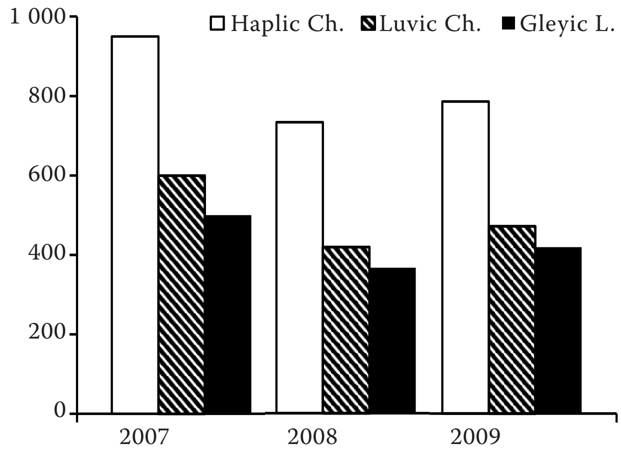

Figure 2. Labile carbon content (mg/kg) in studied soils under plough (P)

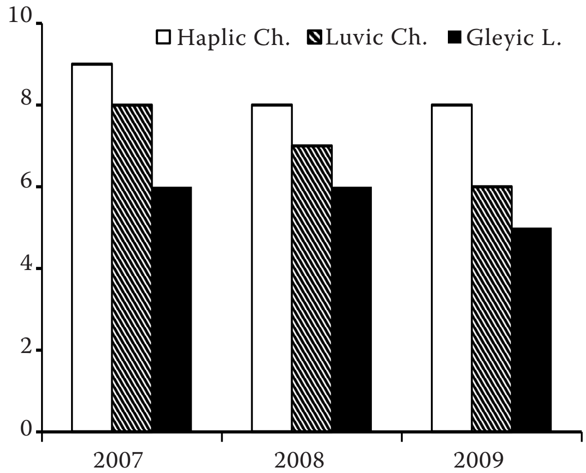

Figure 3. Humic substances (HS) sum (in mg/kg) in studied soils under plough (P)

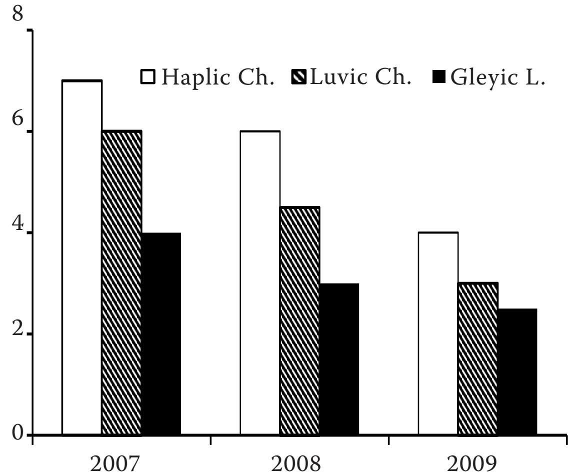

Figure 4. Humic acids (HA) sum (in mg/kg) in studied soils under plough (P)

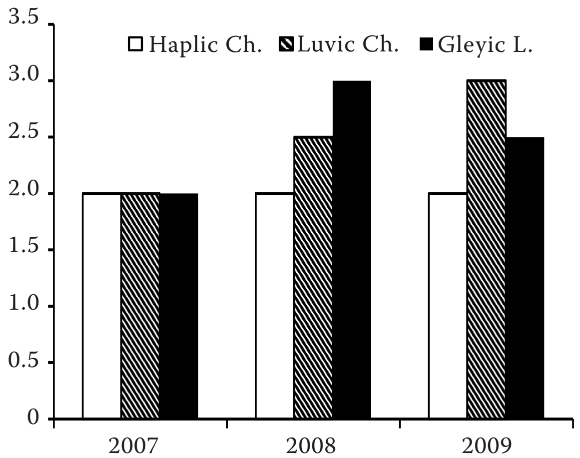

Figure 5. Fulvic acids (FA) sum (in mg/kg) in studied soils under plough (P)

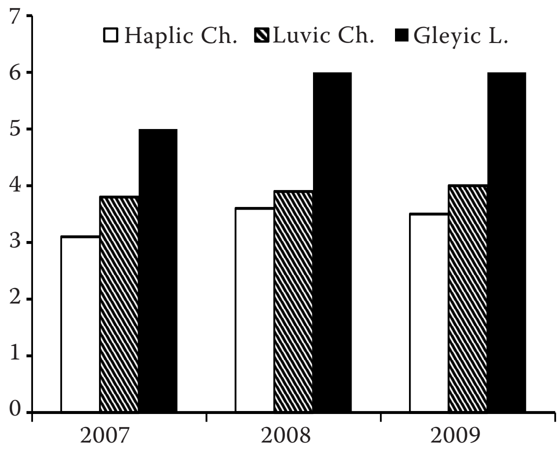

Figure 6. Colour indexes (Q4/6) in studied soils under plough (P) till 0.22 m

Synchronous fluorescence spectra measured in 2007 varied in intensity depending on the soil types, however, the same fluorophores were identified at: 467/487; 481/501; 492/512; 450/470; and 339/359 nm (Δλ = 20 nm) (Figure 9). The effect of the tillage practices on HS relative fluorescence intensity in Haplic Chernozem (Hrušovany) in 2009 is shown in Figure 10. SFS measurements corresponded with the data in UV-VIS spectral range. Interrelationship was detected between the optical and chemical HS properties by correlation analysis. Correlation was found (R^2 = 0.9182) between the relative fluorescence index (F) at 481/501 nm and humification degree. Humification degree was calculated as HA sum/TOC×100 and F was a ratio of relative fluorescence intensity at 481/501 nm. The results obtained corresponded

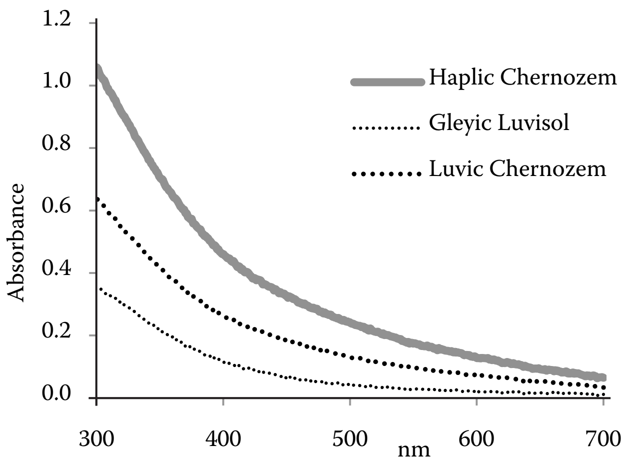

Figure 7. Humic substances UV-VIS spectra in studied soil types (2007)

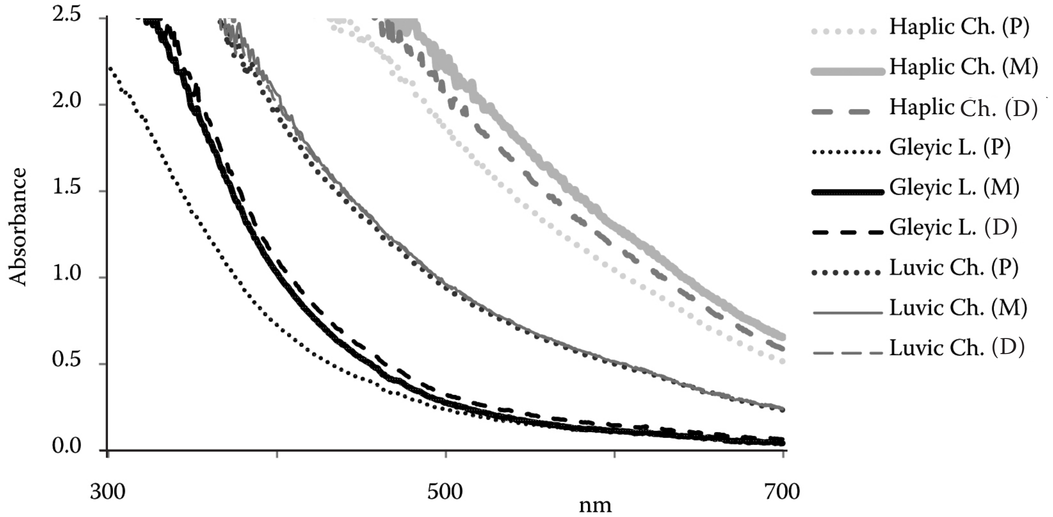

Figure 8. Humic substances UV-VIS spectra under plough (P), deep plough (D) and minimum plough (M) – 2009

with literature data given by Zsolnay *et al.* (1999) and Milori *et al.* (2002).

CONCLUSIONS

Spectroscopic methods were a useful tool for humic substances quality evaluation. Statistically significant differences in HS quality (Haplic Chernozem) under different tillage practices were detected. The total carbon content, labile carbon content, and humic substances content in the top soil were not altered by the tillage practices. We can conclude that the soil type and land management mainly affected HS quality.

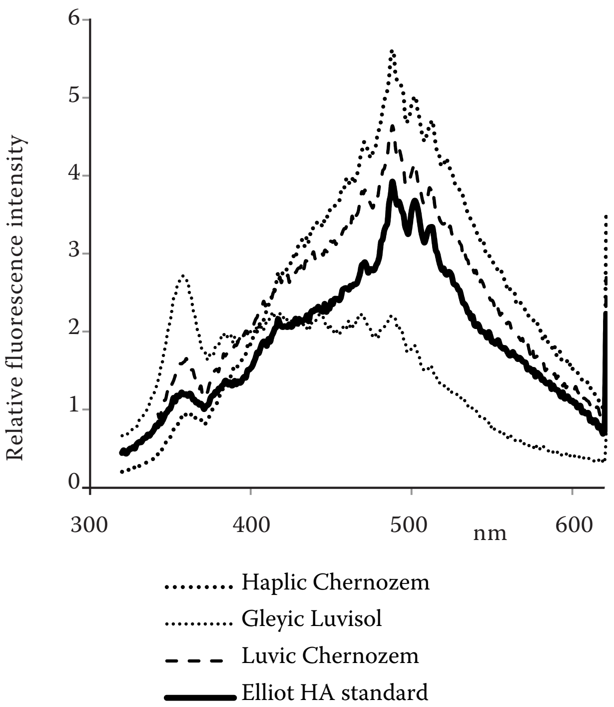

Figure 9. Humic substances synchronous fluorescence spectra in studied soil types (2007)

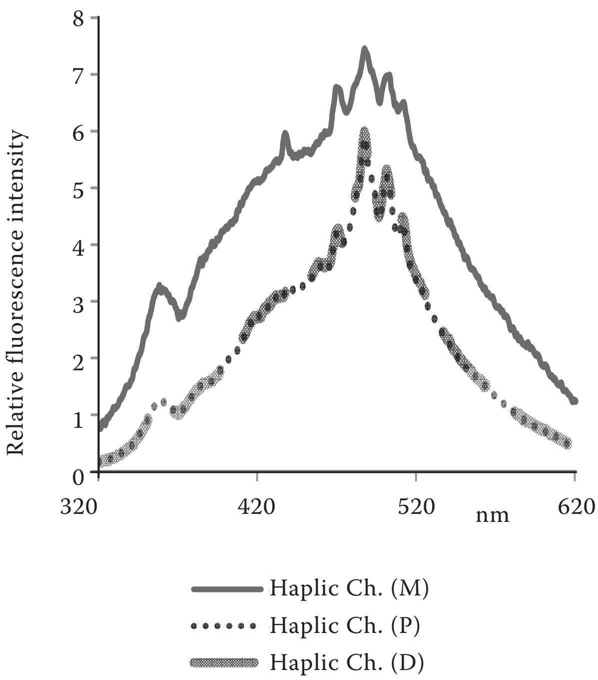

Figure 10. Humic substances synchronous fluorescence spectra under plough (P), deep plough (D) and minimum plough (M) – in Haplic Chernozem (2009)

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