IMPACT OF TILLAGE, FERTILIZATION AND PREVIOUS CROP ON CHEMICAL PROPERTIES OF LUVISOL UNDER BARLEY FARMING SYSTEM

DOPAD OBRÁBANIA, HNOJENIA A PREDPLODINY NA CHEMICKÉ VLASTNOSTI HLINITEJ PÔDY PRI PESTOVANÍ JAČMEŇA

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ABSTRACT

In this paper, we report on the results of our investigation into the effects of different tillage, fertilization and previous crop on the chemical properties of loamy soil under spring barley and winter barley. We observed an increase of humus quality. More marked changes were in CT ($r = 0.663$, $P < 0.05$) than in RT (0.648, $P < 0.05$) and N fertilization ($r = 0.678$, $P < 0.05$) and SB ($r = 0.761$, $P < 0.01$) as well. A higher amount of TOC positively affected on parameters of soil sorptive complex in CT as well as in N and in SM treatments. A higher amount of TOC positively effected the portion of Ca^{2+} under CT ($r= 0.795$, $P < 0.05$), but also increased exchangeable Na^{+} ($r= 0.830$, $P < 0.05$) and K^{+} ($r= 0.881$, $P < 0.01$) in RT and N treatments.

Keywords: Soil tillage; Fertilization; Soil organic matter; Soil sorptive parameters; Exchangeable cations.

ABSTRAKT

Zamerali sme sa na sledovanie dopadu rozdielných spôsobov obrábania, hnojenia a predplodiny na chemické vlastnosti hnedozeme v pestovateľskom systéme jarného a ozimného jačmeňa. Zaznamenali sme zvyšovanie kvality humusu hnedozeme. Intenzívnejšie v CT ($r = 0{,}663$; $P < 0{,}05$) ako v RT (0,648; $P < 0{,}05$) a v N variantoch ($r = 0{,}678$; $P < 0{,}05$) a po zaoraní SB ($r = 0{,}761$; $P < 0{,}01$). Vyšší obsah TOC tiež pozitívne ovplyvnil zastúpenie Ca^{2+} v CT ($r = 0{,}795$; $P < 0{,}05$), ale na druhej strane zvýšil aj zastúpenie výmenného Na^{+} ($r = 0{,}830$; $P < 0{,}05$) a K^{+} ($r = 0{,}881$; $P < 0{,}01$) v RT a N variantoch.

Kľúčové slová: Obrábanie pôdy; hnojenie; organická hmota; pôdny sorpčný komplex; výmenné katióny.

DETAILNÝ ABSTRAKT

V práci prinášame výsledky výskumu z obdobia rokov 2002-2004, kedy sme sa zamerali na sledovanie dopadu rozdielných spôsobov obrábania, hnojenia a predplodiny na chemické vlastnosti hnedozeme v pestovateľskom systéme jarného a ozimného jačmeňa. Jarný jačmeň odrody „ANNABEL" bol zaradený vždy po cukrovej repe (SB) a ozimný jačmeň (TIFFANY) po kukurici na siláž (SM). Experiment pozostával z dvoch spôsobou obrábania: konvenčný spôsob (CT) a redukovaný spôsob (RT). V CT z dôvodu intenzívnejšej mineralizácie a tým pádom rýchlejšiemu úbytku organickej hmoty pôdy boli zaorané pozberové zvyšky, kým v RT kvôli eliminácií rozdielov medzi obrábaniami pozberové zvyšky neboli zapracované. Experiment pozostával aj z dvoch úrovní hnojenia a to variant s hnojený (N) a nehnojený (0N).

Zaznamenali sme tendenciu zvyšovania celkového uhlíka (TOC) v CT, kde boli zaorané pozberové zvyšky SB. Počas vegetačného obdobia jarného, ale aj ozimného jačmeňa sme pozorovali zvyšovanie kvality humusu hnedozeme. Intenzívnejšie v CT (r = 0,663; $P < 0,05$) ako v RT (0,648; $P < 0,05$) a v N variantoch (r = 0,678; $P < 0,05$) a po zaoraní SB (r = 0,761; $P < 0,01$). Vyšší obsah TOC mal štatistický významný efekt na nárast hodnôt pH, sumy bázických katiónov, sorpčnej kapacity a stupňa nasýtenia sorpčného komplexu hnedozeme vo variantoch CT, N, SM. Vyšší obsah TOC tiež pozitívne ovplyvnil zastúpenie Ca^{2+} v CT (r = 0,795; $P < 0,05$), ale na druhej strane zvýšil aj zastúpenie výmenného Na^{+} (r = 0,830; $P < 0,05$) a K^{+} (r = 0,881; $P < 0,01$) v RT a N variantoch.

1. INTRODUCTION

World soils, prudently managed for achieving food security and producing biofuel feedstocks, can also mitigate climate change by absorbing atmospheric CO_2 and converting it into humus through the process of soil C sequestration. At present, the soil research is aimed at the turnover and sequestration of carbon in environment. This fact is confirmed in a lot of papers [18, 28, 1]. The soil organic matter (SOM) plays a major role in sustainable agricultural management and their dynamics are influenced by tillage, mulching, removal of crop residues and application of organic and mineral fertilizers. Tillage plays an important role in the manipulation of nutrient storage and release from SOM, with conventional tillage (CT) inducing rapid mineralization of SOM [17] and potential loss of C and N from the soil [3] and except amount also affect the turnover of soil organic matter [12]. The loss of SOM by the transformation processes (decomposition, mineralization and humification) of organic substances in soil requires the substitution of fresh organic matter [30]. Application of crop residues and fertilizers together increased total carbon content in CT and NT, with a higher increase in NT. No-tillage and fertilization also had a positive effect on changes in chemical properties [21]. Tillage and cropping systems induced changes in SOM content can be difficult to quantify due to the large background amounts already present and spatial variation [9]. Removal of crop residues from the fields is known to hasten soil organic carbon (SOC) decline, especially when coupled with conventional tillage [32, 14]. Applied manure and suitable crop rotation positively affected humus quantity and quality [25]. Crop residue retention is also important for sequestering soil organic C, controlling soil erosion, and improving soil quality [1]. Applied crop residues increase hydrolytic acidity, but on the other hand it decreases the values of the sum of exchangeable basic cations [33].

In this paper, we report the investigation results of different tillage, fertilization and previous crop effects on chemical properties of loamy soil under spring barley and winter barley during the years 2002 – 2004. The objectives of the study were (i) quantification of extent to which tillage, fertilization and previous crop treatments influenced chemical properties, (ii) comparison of tillage, fertilization and previous crop treatments effects (iii) determination of the relationship between soil organic matter and chemical properties with dependence on soil tillage, fertilization and the previous crop.

2. MATERIAL AND METHODS

2.1. Experimental site

The field experiment was located approximately 5 km north-east of Nitra (lat. 48°19'00''; long. 18°09'00''), in the western part of Slovakia (Central Europe). The weather conditions during the years 2002–2004 are in figure 1. Mean maximum and minimum temperatures (2002-2004) were 21.6 °C (from July to August) and – 2.1 °C (in January). The average annual temperature of air is 10.5 °C. During the years 2002– 2004 mean annual rainfall was 498 mm, with about 53 % of this amount falling from March to July. The experimental area was flat, with a slight incline southwards. The geological substratum consisted of few previous rocks with high quantities of fine materials. Young Neogene deposits were composed of various clays, loams, sand gravels on which loess was deposited in the Pleistocene epoch. More information about experimental station of SUA – Nitra (Dolná Malanta) was published by Hrnčiarová and Miklós [10]. The soil is an Haplic Luvisol [7] and on average it contained 318.8 $g.kg^{-1}$ of sand, 567.0 $g.kg^{-1}$ of silt and 114.3 $g.kg^{-1}$ of clay. The total soil carbon content was 9.9 ± 1.3 $g.kg^{-1}$, the total nitrogen content 1340 ± 80 $mg.kg^{-1}$, the sorptive capacity 142.1 ± 4.7 $mmol.kg^{-1}$ and base saturation percentage was 82.2 ± 4.3 %. On average, the soil pH was 6.29 ± 0.42.

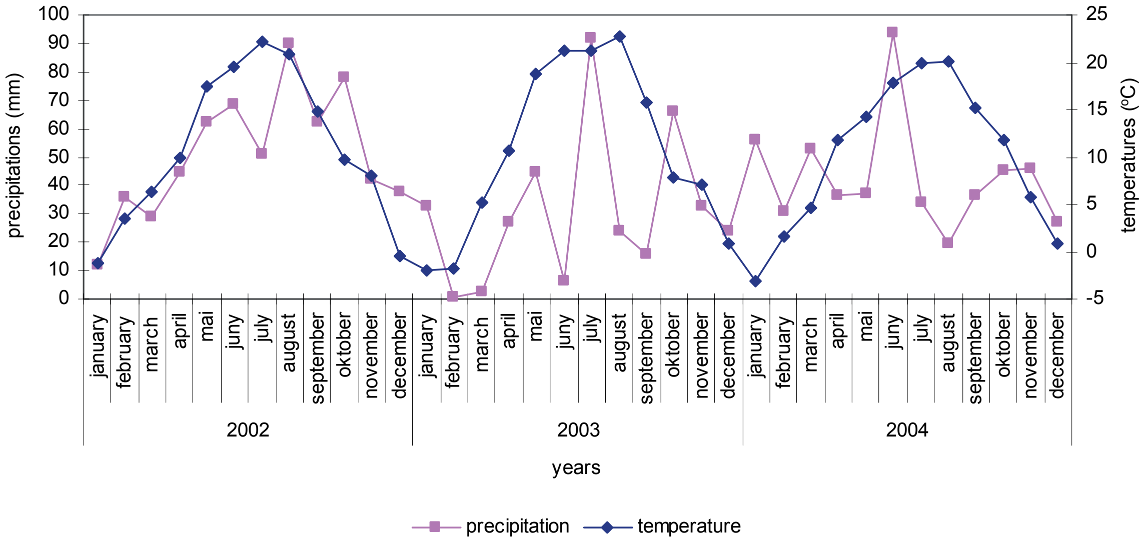
2.2. Experimental details

All the plots were of the following size: width 2 m and length 6 m and between plots was a harness 1 m wide. The field experiment had three repetitions of each of the studied factors (tillage system, fertilization and previous crop). The spring barley (SpB) variety "ANNABEL" (in March) and winter barley (WiB) variety "TIFFANY" (in October) were sown at a depth of 40-50 mm. In organised crop rotation for this experiment, the ANNABEL was always sown after sugar beet (SB) and the TIFFANY always after silage maize (SM). The experiment consisted of two tillage treatments. Conventional tillage (CT) means annual ploughing to depth of 0.20 m and reduced tillage (RT) means annual disking to a depth of 0.10 m. In all CT treatments, crop residues were returned to the soil, by reason of the mineralization processes reduction and soil organic matter loss. On the other hand in all RT treatments crop residues were not applied for the elimination of differences between investigated tillage systems. There were established two levels of plots with fertilization, variants with nitrogen fertilization (N) and without nitrogen fertilization (0N). Doses of N fertilizers during the growing season of spring barley were 80 kg $N.ha^{-1}$, and doses of N fertilizers during growing season of winter barley were 105 kg $N.ha^{-1}$. The used nitrogen fertilizer was DASA, which comprises 26 % of nitrogen. All treatments were protected against the detrimental

Tabuľka 1 Lineárne funkcie pomerov C:N v sledovaných variantoch (2002-2004)
Table 1 Linear models of C:N for investigated treatments during 2002-2004

Factor		Linear model	r
Tillage system	CT	y = 0.16x + 7.62	0.663^{*}
	RT	y = 0.23x + 7.21	0.648^{*}
Fertilization	0N	y = 0.19x + 7.53	0.626^{*}
	N	y = 0.21x + 7.27	0.678^{*}
Preceding crop	SB	y = 0.26x + 7.14	0.761^{**}
	SM	y = 0.10x + 7.87	$0.411^{n.s.}$

CT – conventional tillage; RT – reduced tillage; 0N – without nitrogen fertilization; N – nitrogen fertilization; SB – crop residues of sugar beet; SM – crop residues of silage maize; $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$



obr. 1 Klimatická charakteristika (zrážky a teploty) počas rokov 2002-2004 v lokalite Dolná Malanta
fig. 1 Climatic characteristics (precipitations, temperatures) over 2002-2004 in Dolná Malanta

Tabuľka 2 Štatistické vyhodnotenie parametrov sorpčného komplexu a zastúpenie katiónov v hnedozemi (Dolná Malanta)
Table 2 Statistical evaluation of parameters of soil sorptive complex and cation portions in Haplic Luvisol (Dolná Malanta) - Duncan test

		Tillage system		Fertilization		Previous crop	
		CT	RT	0N	N	SB	SM
H	(mmol.kg-1)	19.55a	22.90a	21.41a	21.05a	21.56a	20.89a
S		136.26a	139.99a	136.96a	139.29a	126.96a	149.31a
T		159.55a	159.21a	158.36a	160.39a	148.56a	170.20b
V (%)		86.91a	84.90a	85.55a	86.26a	85.23a	86.58a
Ca^{2+}	(mmol.kg-1)	104.53a	105.30a	103.25a	106.58a	102.53a	107.30a
Mg^{2+}		35.95a	36.68a	32.40a	40.23a	36.98a	35.65a
K^{+}		7.38a	5.89a	6.46a	6.81a	6.79a	6.48a
Na^{+}		6.31a	6.29a	5.98a	6.63a	6.23a	6.37a

Different letters (a, b, c) indicate that treatment means are significantly different at P<0.05 according to Duncan test
CT – conventional tillage; RT – reduced tillage; 0N – without nitrogen fertilization; N – nitrogen fertilization; SB – crop residues of sugar beet; SM – crop residues of silage maize;

Tabuľka 3 Korelačné koeficienty medzi TOC a parametrami sorpčného komplexu hnedozeme (Dolná Malanta)
Table 3 Correlation coefficients between TOC and soil sorptive complex parameters in Haplic Luvisol (Dolná Malanta)

		Tillage system		Fertilization		Previous crop	
		CT	RT	0N	N	SB	SM
H	(mmol.kg-1)	-0.656*	-0.310 n.s.	-0.448 n.s.	-0.682*	-0.513 n.s.	-0.627*
S		0.938***	0.286 n.s.	0.587*	0.785**	0.536 n.s.	0.820**
T		0.889***	0.245 n.s.	0.537 n.s.	0.714**	0.441 n.s.	0.771**
V (%)		0.818**	0.360 n.s.	0.557 n.s.	0.825***	0.535 n.s.	0.826***

CT – conventional tillage; RT – reduced tillage; 0N – without nitrogen fertilization; N – nitrogen fertilization; SB – crop residues of sugar beet; SM – crop residues of silage maize;
*P < 0.05; **P < 0.01; ***P < 0.001

effects of weeds, diseases and pests. The following sprays were used: Starane 250 EC (0.5 $l.ha^{-1}$), Lontrel 300 (0.3 $l.ha^{-1}$), Granstar 75 WG (25 $g.ha^{-1}$), Tango Super (1 $l.ha^{-1}$) and Vaztak 10 EC (0.1 $l.ha^{-1}$).

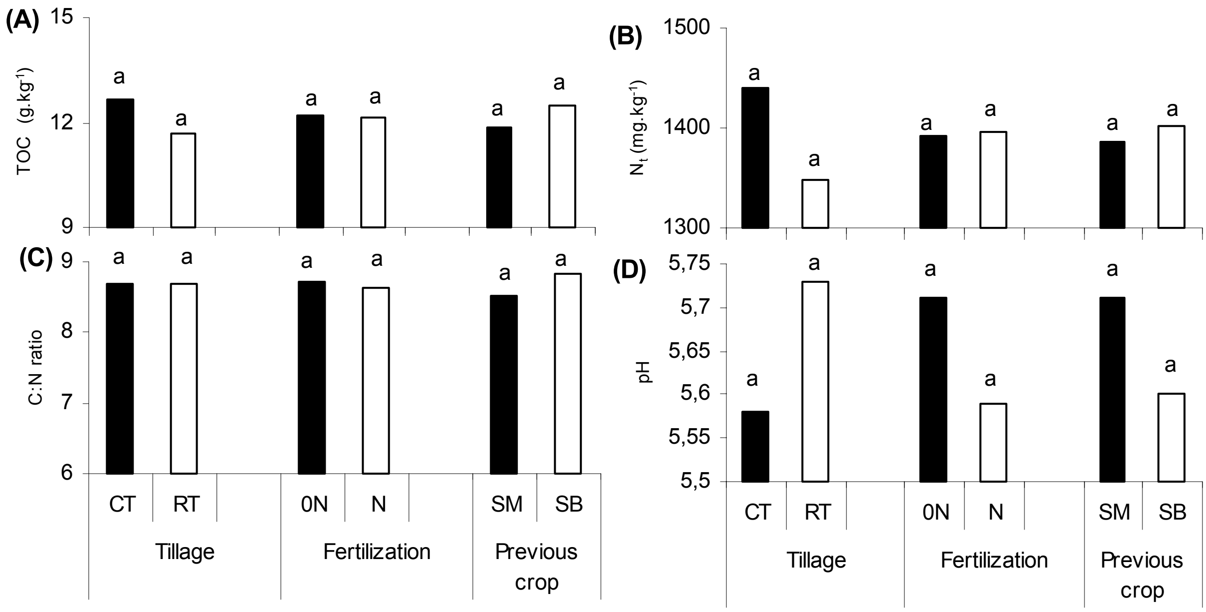
2.3. Soil sampling and analysis

Sampling for chemical analyses was carried out during the years 2002-2004, from depth 0 to 0.2 m (from A-horizon of Haplic Luvisol), twice per year (spring, autumn). For each sampled zone (including all treatments of tillage, fertilization and previous crop) three different locations were chosen randomly. On each location soil samples were collected and mixed to make an average sample weighing approximately 0.5 kg. Soil samples were dried at laboratory temperature and ground. In homogenous soil samples the chemical parameters of pH_{KCl} potentiometrically, sorptive characteristics of soil [8], as well as total carbon content (TOC) according to Tyurin [6], total nitrogen content [8] were determined. Obtained data was analyzed by using the statistic software Statgraphic Plus. Data for each tillage system, fertilization and previous crop were analyzed by analysis of Variance. Differences were considered significant at P < 0.05 and differences among treatments means were determined using the Duncan test. We used correlation analysis to determine the relationships between total carbon content and chemical properties. Significant correlation coefficients were tested on P < 0.05.

Tabuľka 4 Korelačné koeficienty medzi TOC a zastúpením katiónov v hnedozemi (Dolná Malanta)
Table 4 Correlation coefficients between TOC and cation portions in Orthic Luvisol (Dolná Malanta)

		Tillage system		Fertilization		Previous crop	
		CT	RT	0N	N	SB	SM
Ca^{2+}	(mmol.kg^{-1})	0.795*	0.776*	0.763*	0.830*	0.822*	0.757*
Mg^{2+}		0.570 n.s.	0.270 n.s.	0.336 n.s.	0.533 n.s.	0.789*	0.226 n.s.
K^{+}		0.732*	0.830*	0.729*	0.756*	0.861**	0.818*
Na^{+}		0.798*	0.881**	0.699 n.s.	0,965***	0.780*	0.861*

CT – conventional tillage; RT – reduced tillage; 0N – without nitrogen fertilization; N – nitrogen fertilization; SB – crop residues of sugar beet; SM – crop residues of silage maize;
*P < 0.05; **P < 0.01; ***P < 0.001



Values followed by the same letter within each column are not significantly different at P<0.05
CT – conventional tillage; RT – reduced tillage; 0N – without nitrogen fertilization; N – nitrogen fertilization; SB – crop residues of sugar beet; SM – crop residues of silage maize

obr. 2 Priemerné hodnoty (A) TOC (B) Nt (C) pomerov C:N (D) pH pri rozdielnom obrábaní, hnojení a predplodine
fig. 2 Mean values of (A) TOC (B) Nt (C) C:N ratio (D) pH in different tillage, fertilization and previous crop

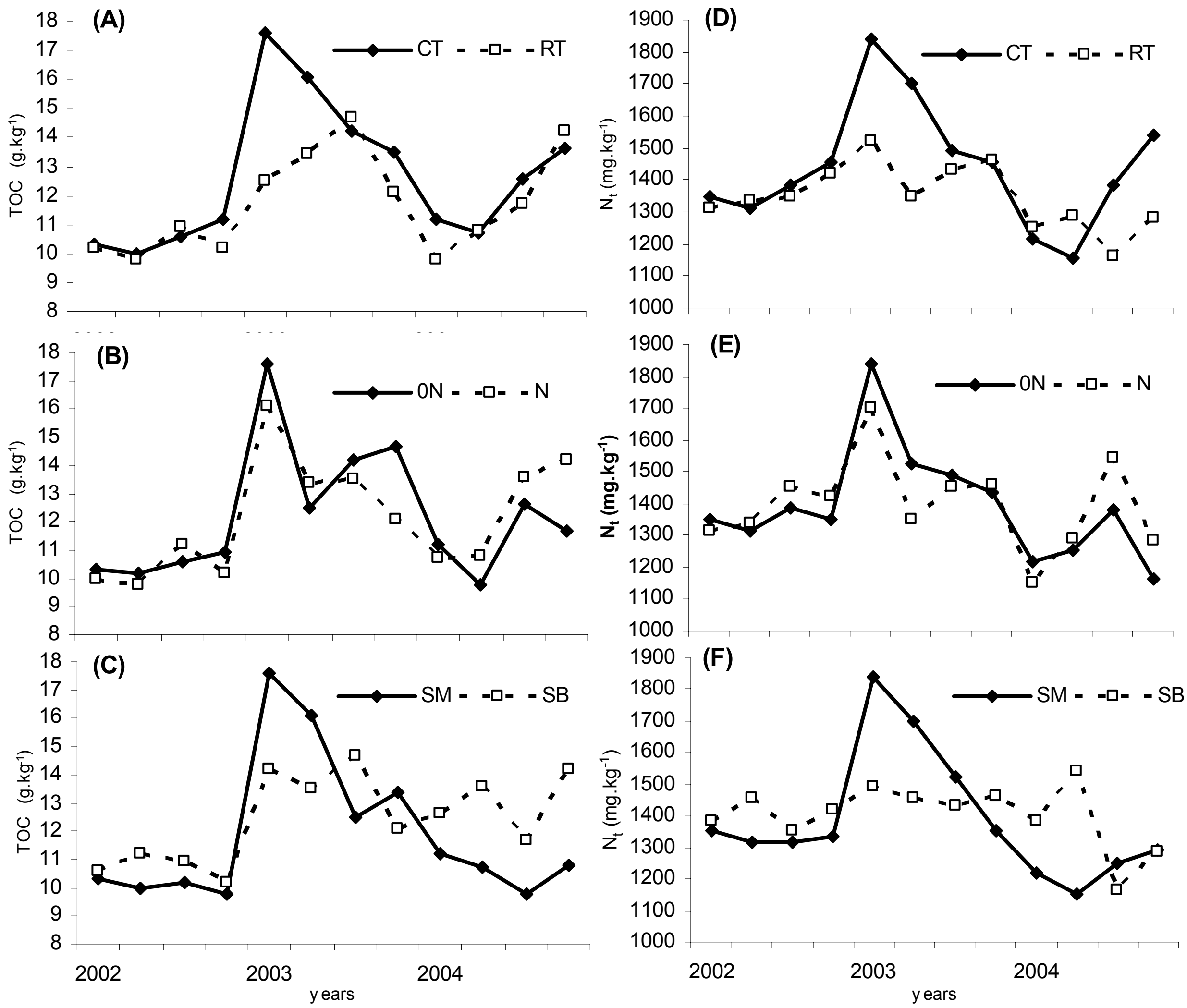
3. RESULTS AND DISCUSSION

3.1. Soil organic matter

The average amount of total organic carbon (TOC) was higher in CT (12.6 g.kg^{-1}) than in RT (11.7 g.kg^{-1}). In CT crop residues were ploughed and in RT treatments crop residues were not applied. Šoltysová and Danilovič [24] did not detect significant differences between tillage systems (conventional tillage and no-tillage NT) in humus content. Several works showed that an intensive tillage system reduces soil organic matter content [23, 21, 20, 22]. A higher amount of TOC was determined in variants with spring barley (12.5 g.kg^{-1}) than in variants with winter barley (11.9 g.kg^{-1}). Spring barley followed after sugar beet and winter barley followed after silage maize. There were no significant differences between tillage, fertilization and previous crop treatments in the amounts of TOC (figure 2a), which is in contrast with several authors [17, 26, 19]. The dynamics of TOC in different tillage systems, fertilization and previous crop variants are shown in figures 3abc.

The amount of nitrogen is also very important for the transformation processes of soil organic matter. Total nitrogen content (N_t) was higher in CT than in RT and higher in N treatments than in 0N and in SB than SM. Transformation processes of sugar beet residues are more intensive than crop residues of silage maize. There were no significant treatment effects on N_t, where mean N_t amounts were 1349 – 1440 $mg.kg^{-1}$ (figure 2b). The results of Šimanský and Tobiašová [20] showed a decrease of N_t with dependence on tillage, where higher decrease was determined in CT than RT. We did not determine any significant effects on dynamic of N_t in all variants (figures 3def). Changes in N_t content in soil affected by management are expected to follow changes in soil organic matter, because >95% of soil N is usually present in organic forms [27]. The highest content of quantitative parameters of soil organic matter (TOC and N_t) were determined in the year 2003. The year 2003 was dry in comparison to years 2002 and 2004 (figure 1). Transformation processes of soil organic matter are influenced by moisture, which activated a wide spectrum of microorganisms species, resulting in the loss of the total organic carbon content [20].

The most frequently used parameter for humus quality evaluation is C: N ratio. Tillage systems, fertilization and previous crop had no statistically significant influence on quality of soil organic matter (figure 2c). We detected linear models for investigated parameters with dependence on time (table 1). The quality of soil organic matter with a longer time period was better in CT (r=0.663, $P < 0.05$) than in RT (r=0.648, $P < 0.05$), which confirms the results of Paré et al. [16] and Dou and Hons [5]. In the investigated period N fertilization had



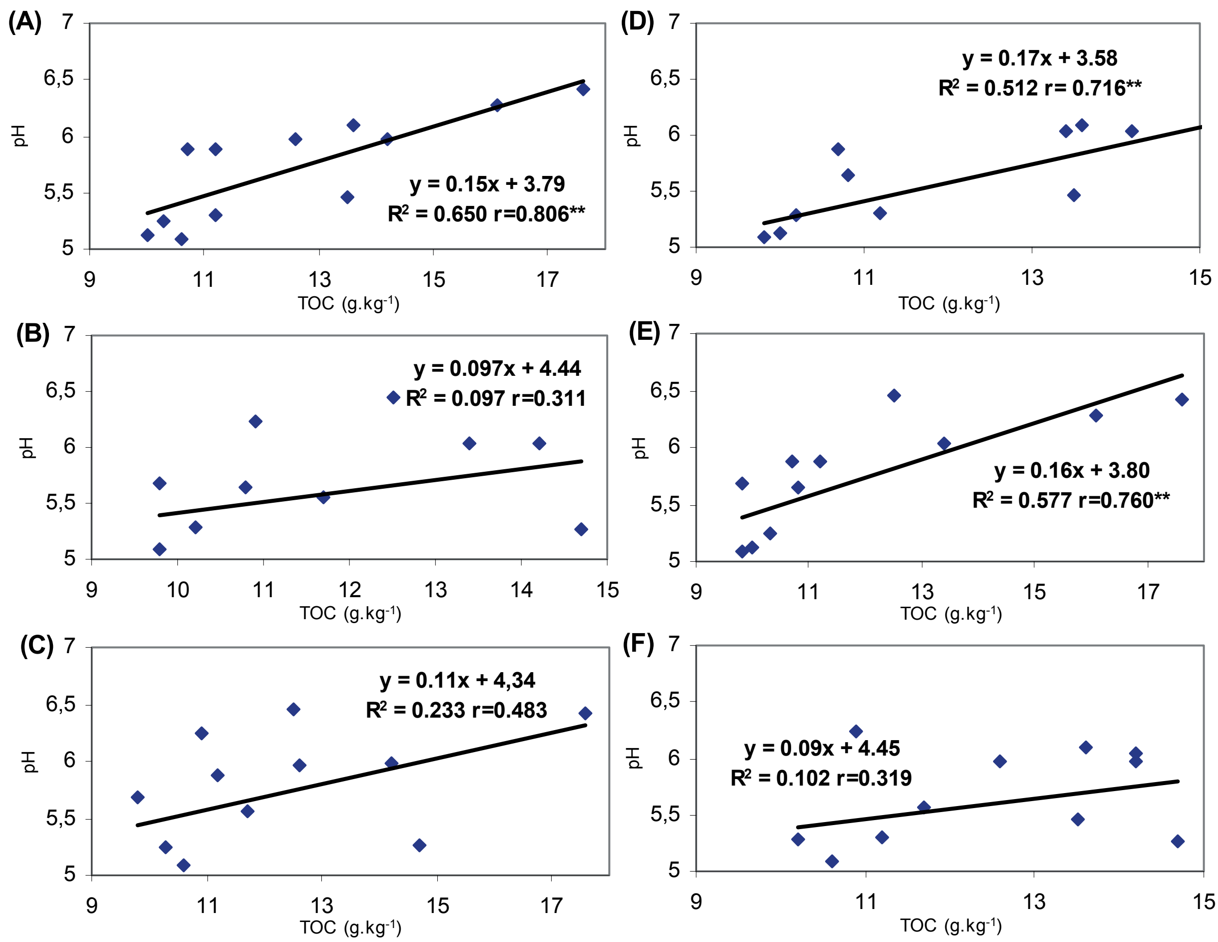
CT – conventional tillage; RT – reduced tillage; 0N – without nitrogen fertilization; N – nitrogen fertilization; SB – crop residues of sugar beet; SM – crop residues of silage maize

obr. 3 Dynamiky TOC a Nt pri rozdielnom spôsobe obrábania, hnojenia a predplodiny
fig. 3 Dynamics of TOC and Nt in different tillage, fertilization and previous crop

a more positive effect (r=0.678, $P < 0.05$) on C: N ratio in comparison to 0N (r=0.626, $P < 0.05$). The C: N ratio controls degradation of fresh plant residues [2] which is important in carbon sequestration [18]. Thus the ability of soils to sequester C is influenced by N [31]. Ploughed crop residues of sugar beet (SB) more positively affected C: N ratio (r= 0.761, $P < 0.01$) than crop residues of silage maize (SM). Sugar beet has a more favourable chemical composition than silage maize, which is reflected in intensive decomposition and the formation of more qualitative humus [11].

3.2. Soil pH, parameters of soil complex and exchangeable cations

Soil pH was not influenced by tillage, fertilization and previous crop (figure 2d), which is in contrast with results of Šimanský et al. (2008). Under CT (5.73±0.46) and RT (5.58±0.53), pH was weak acidic. Šimanský et. al. [21] found positive effects of tillage and fertilization on soil pH. In CT there was a significant positive correlation between pH and TOC (r = 0.806, P < 0.01), while in RT we did not observe any linear dependence (figure 4b). Thomas et al. [28] detected under the no-tillage system a negative correlation between pH and organic C, indicating that higher organic C content under NT may at least partially have an acidifying effect. Neff et al. [15] claim that fertilizer application changed soil pH. In N treatments a higher amounts of TOC led to rising of soil pH (r=0.716, $P < 0.01$). We also observed similar effects in 0N treatments, but without statistical significance (figure 4c). Thomas et. al. [28] showed on N fertilizer application resulted in a significant reduction in soil pH. Šimanský et. al. [21] recorded positive changes of soil pH due to crop residue application. Under SM we



CT – conventional tillage; RT – reduced tillage; 0N – without nitrogen fertilization; N – nitrogen fertilization; SB – crop residues of sugar beet; SM – crop residues of silage maize

obr. 4 Lineárne závislosti medzi pH a TOC (A) v CT (B) v RT (C) v 0N (D) v N (E) v SM (F) v SB

fig. 4 Linear dependence between pH and TOC (A) in CT (B) in RT (C) in 0N (D) in N (E) in SM (F) in SB detected a significant increase of soil pH values with an increase of TOC (figure 4e), but under SB this effect was not significant (figure 4f).

Applied crop residues (table 2) had a statistically significant influence on sorption capacity (T), which is in agreement with results of Šimanský et al. [22]. There were no significant differences between tillage, fertilization and preceding crop treatments in the values of hydrolytic acidity (H), the sum of exchangeable cations (S) and the base of saturation (V). Šimanský et. al. [21, 22] found a statistically significant influence between tillage management system, fertilization and parameters of soil sorption complex. Zaujec and Šimanský [33] claim that applied crop residues increase H, but decrease S, which reflect to T and V.

In CT between TOC and S, T, V positive correlations were determined (table 3), which indicate that higher organic C in this tillage system positively affects on the parameters of the soil sorptive complex. The same effect was not observed in soil under RT. A higher amount of TOC positively influenced soil sorptive parameters in N and SM treatments.

We did not detect any significant effects of tillage, fertilization and previous crop on exchangeable Ca^{2+}, Mg^{2+}, K^+ and Na^+ (table 2). Thomas et al. [28] also on Luvisol did not detect any significant effects of tillage and N fertilization on the portion of exchangeable cations. Ca^{2+} and Mg^{2+} were higher in soil under RT than in CT and higher in soil under N than in 0N. Values of exchangeable K^+ and Na^+ were higher in N than in soil under 0N, but on the other hand higher in CT with comparison to RT. Limousin and Tessier [13] determined the highest exchangeable Ca^{2+} in conventional tillage system and the lowest under interrow of no-tillage. Dalal [4] observed lower exchangeable Na^+ in soil under NT than under CT.

Correlation coefficients between TOC and exchangeable cations are in table 4. A higher amount of TOC positively effected portion of Ca^{2+} in all treatments, more marked under CT (r=0.795, $P< 0.05$) than in RT (r=0.776, $P< 0.05$) more in N (r=0.830, $P< 0.05$) as compared in 0N (r=0.763, $P< 0.05$) and also more in SB (r=0.822, $P< 0.05$) than in SM (r=0.757, $P< 0.05$). A higher TOC content increased Na^+ and K^+ contents, but was more marked in soil under RT and all N variants (table 4). Applied crop residues of sugar beet had an intensive effect on the increase of exchangeable Na^+ and on the other hand crop residues of silage maize on K^+. Thomas et al. [29] observed higher content leaching of sodium in soil under NT than under CT.

4. CONCLUSION

We detected a tendency of increasing of TOC by applied crop residues of sugar beet in soil under CT. During the growing of spring barley and winter barley we observed an increase in humus quality which was more marked in CT than in RT and N fertilization and SB, as well. Increasing of TOC statistically significantly increased soil pH values and the sum of exchangeable basic cations, sorption capacity and the base of saturation in soil under CT, N variants and SM treatments. A higher amount of TOC positively affected on parameters of soil sorptive complex in CT, as well as in N and in SM treatments. A higher amount of TOC positively affected the portion of Ca^{2+}, but also increased exchangeable Na^+ and K^+ in RT and N treatments. Our results showed statistically significant influence on sorption capacity by applied crop residues.

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