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Original Paper

Variability of selected chemical parameters in the soil profiles of gleyic fluvisols

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The changes of available phosphorus, potassium, total nitrogen and soil organic carbon were observed in Gleyic Fluvisols with the following crops: winter wheat (2005), grain maize (2006), spring barley (2007), soya (2008), winter wheat (2009), grain maize (2010). The experiment was carried out with the use of three soil tillage systems: conventional tillage, minimum tillage and zero tillage. Soil samples were collected from three different depths (0.00–0.15 m; 0.15–0.30 m; 0.30–0.45 m). The ratio of soil organic carbon to total nitrogen was also calculated. The contents of available phosphorus and potassium, total nitrogen and soil organic carbon were significantly influenced by the sampling depth. The highest content of observed parameters was detected in the depth of 0.00–0.15 m and the lowest one in the depth of 0.30–0.45 m. The difference between the mean content of observed parameters in the first and the third sampling depth reached 26.4 mg kg^{-1} in available phosphorus, 39.5 mg kg^{-1} in potassium, 329 mg kg^{-1} in nitrogen and 2.48 g kg^{-1} in soil organic carbon. Soil tillage affected the content of available phosphorus and potassium in the soil in a significant way. The resulting evaluation showed that the content of available phosphorus and potassium increased in the range of 2.5–4.3 mg kg^{-1} P and 5.3–8.7 mg kg^{-1} K. Soil tillage did not significantly affect the content of total nitrogen and soil organic carbon.

Keywords: gleyic fluvisols, soil tillage systems, chemical parameters, soil organic matter

1. Introduction

Soil tillage is an important factor influencing soil chemical properties. It is necessary to test the tillage technologies in specific soil conditions and use the technologies that allow maintaining soil fertility. Monitoring of soil properties variation is crucial, especially for long-term use of no-tillage (Šabatková et al., 2006).

Agrotechnics has different effects on nutrient intake, influences the speed mineralization and creates different conditions for the development of the root system and deepening of the topsoil profile. Lilienfein et al. (2000) and Šimanský et al. (2008) found out that intensive tillage leads to losses of organic matter in comparison with the reduced ways. Many other studies have shown that no-tillage increases the content of soil organic carbon in the surface soil layer (Duiker and Beegle, 2006; Šimanský et al., 2007; Bono et al., 2008; Yang et al., 2008; Kotorová a Šoltysová, 2011) in comparison with traditional tillage.

Nutrients are differently mobile in soil and their mobility depends on many factors, which include the soil moisture, soil reaction, granularity, stoniness and others. Amount of nutrients in the soil also influences intensity of fertilization, uptake of nutrient by plants, washing off of nutrients from the soil into the lower horizons and washing away of nutrients as a result of water erosion.

The quantity and distribution of nutrients in the soil is amended due to the different tillage. Nutrients applied in form of mineral fertilizers are different located at soil depths in depending on agrotechnics. Higher nitrogen content in the surface layers of soil was found at no-tillage compared with minimum and conventional tillage (Omonode et al., 2006; Dou et al., 2008). Higher phosphorus and potassium contents was also found by Novotná and Lošák (2007), Dong et al. (2009), Jokela et al. (2009) and Šoltysová and Danilovič (2009).

The nutrient contents are variable in individual depths of soil. Decline of nitrogen, phosphorus and potassium was found in the lower depths of soil at conventional tillage and protective technologies (Malo et al., 2005; Dou et al., 2008; Jokela et al., 2009; Šoltysová and Danilovič, 2011).

Besides the above mentioned quantity, the quality of soil organic matter is important as well. The ratio of organic carbon to total nitrogen content in the soil is calculated for quality assurance. The lower the C : N ratio is, the more intensive the decomposition of organic matter is (Tobiašová 2006).

The aim of this study was to evaluate the changes of selected soil chemical parameters in soil profile of Gleyic Fluvisols affected by different soil tillage.

2. Material and methods

The changes of selected soil chemical parameters in three levels of soil depth of Gleyic Fluvisols were studied in the years 2005–2010. The trials were carried out at the experimental station of Plant Production Research Centre – Research Institute of Agroecology Michalovce in locality Milhostov (maize growing area) on Gleyic Fluvisols.

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Experimental station is situated in the central part of the East-Slovak Lowland at an altitude of 101 m. The mentioned soil subtype, according to Novak classificatory scale (Zaujec et al., 2009), belongs to heavy and clayey-loamy soils with determined average content of clay elements higher than (<0.01 mm) 53 %. More detailed description of the site can be found in the study by Kotorová, Šoltysová and Mati (2010).

The average values of chemical properties of the topsoil (depth from 0.0 to 0.3 m) measured in 2005 are: available phosphorus content 50 mg kg^{-1} (Mehlich III), available potassium content 240 mg kg^{-1} (Mehlich III), available magnesium content 460 mg kg^{-1} (Mehlich III), exchangeable calcium content 5 200 mg kg^{-1} (Mehlich III), soil reaction (1 M KCl) 6.3, humus content 3.2 %, the type of humus is from humate-fulvic to fulvic-humate with humic acids and fulvic acids ratio from 0.8 to 1.2.

The territory has a continental character of climate with an average year temperature 8.9 °C (16.0 °C during vegetation period) and with average annual precipitation 550 mm (348 mm during vegetation period).

The experiment field was planted with winter wheat I. (*Triticum aestivum* L.) in the year 2005, grain maize I. (*Zea mays* L.) in the year 2006, spring barley (*Hordeum vulgare* L.) in the year 2007, soya (*Glycine max* (L.) Merr.) in the year 2008, winter wheat II. in the year 2009, and with the grain maize II. in the year 2010. The crops were fertilized with the following doses of pure nutrients:

- winter wheat (2005) – 120 kg ha^{-1} N (the dose divided for basic, regeneration and qualitative fertilization), 35 kg ha^{-1} P, 90 kg ha^{-1} K,
- grain maize (2006) – 90 kg ha^{-1} N, 30 kg ha^{-1} P, 90 kg ha^{-1} K,
- spring barley (2007) – 30 kg ha^{-1} N, 24 kg ha^{-1} P, 90 kg ha^{-1} K,
- soya (2008) – 50 kg ha^{-1} N, 45 kg ha^{-1} P, 80 kg ha^{-1} K,
- winter wheat (2009) – 150 kg ha^{-1} N (divided dose), 35 kg ha^{-1} P, 140 kg ha^{-1} K,
- grain maize (2010) – 90 kg ha^{-1} N, 26 kg ha^{-1} P, 50 kg ha^{-1} K.

Doses of nutrients for fertilization crops were determined based on results of many years of trials with nutrition crops performed in the Research Institute of Agroecology Michalovce. For each crop, the most effective variant of fertilization was recommended, considering the nutrients in the soil.

The trial was established with three types of tillage:

CT – conventional tillage – depending on the grown crop, stubble breaking and stubble or deep ploughing was done; pre-sowing soil treatment was done using a cultivator and sowing was done with the sowing machine Kinze 2000 (maize) or Great Plains (wheat, barley, soya),

Table 1 The available phosphorus and potassium contents in the soil profiles of Gleyic Fluvisols

Soil parameter	Tillage system	Soil depth in m	Experimental years						$\bar{x}$ Y
			2005	2006	2007	2008	2009	2010	
P in mg.kg^{-1}	CT	0.00–0.15	48.3	47.3	58.2	57.2	63.0	58.8	55.5
		0.15–0.30	45.3	40.4	39.5	49.6	41.0	52.7	44.8
		0.30–0.45	33.1	21.5	23.3	32.1	27.4	28.0	27.6
	MT	0.00–0.15	57.4	52.9	59.0	63.4	66.7	61.5	60.2
		0.15–0.30	44.6	44.0	42.5	56.9	41.7	51.1	46.8
		0.30–0.45	41.5	30.1	32.4	39.0	25.2	38.4	34.4
	ZT	0.00–0.15	53.6	52.5	62.5	53.7	66.2	60.1	58.1
		0.15–0.30	48.3	47.3	49.4	44.7	39.5	53.1	47.1
		0.30–0.45	35.6	27.3	34.8	34.3	30.4	33.2	32.6
K in mg.kg^{-1}	CT	0.00–0.15	242.4	206.9	234.9	243.2	251.5	259.4	239.7
		0.15–0.30	225.5	195.2	200.1	239.3	231.8	221.7	218.9
		0.30–0.45	200.6	175.0	193.3	200.5	207.6	209.2	197.7
	MT	0.00–0.15	262.9	231.3	269.2	277.0	267.9	276.5	264.1
		0.15–0.30	233.5	218.4	216.6	268.9	229.3	231.1	233.0
		0.30–0.45	214.4	195.9	214.8	224.2	198.7	219.1	211.2
	ZT	0.00–0.15	254.6	230.3	275.6	267.2	278.7	280.7	264.5
		0.15–0.30	234.1	210.4	228.3	269.0	237.3	230.3	234.9
		0.30–0.45	214.9	188.5	217.7	228.7	197.3	218.5	210.9

$\bar{x}$ Y – the mean for experimental years, P – available phosphorus content, K – available potassium content

MT – minimum tillage – shallow soil cultivation was done using stubble plough after forecrop harvesting, pre sowing soil treatment was done using cultivator and sowing was done with the sowing machine Kinze 2000 (maize) or Great Plains (wheat, barley, soya),

ZT – zero tillage – direct sowing was done with the sowing machine Kinze 2000 (maize) or Great Plains (wheat, barley and soya).

The size of all variant surfaces was 414 m^2 (18 × 23 m) and the randomized block design and four replications were used for this experiment. Soil samples were collected from three depths of 0.00–0.15 m (1st), 0.15–0.30 m (2nd) and 0.30–0.45 m (3rd), annually, in the autumn.

In the disturbed soil samples, the following chemical parameters of soil were analysed: total nitrogen was determined by Kjeldahl method (Hraško et al., 1962), available phosphorus and potassium by Mehlich III method (Mehlich, 1985) and organic carbon by Tyurin method (Hraško et al., 1962). The ratio of organic carbon to total nitrogen was determined by calculation.

Multi-factorial analysis of variance (ANOVA) was used to evaluate treatment effects on distribution of nutrients and organic carbon in the soil. Differences between treatments means were assessed by least significant difference (LSD) test (Grofík and Fľak, 1990). All statistical analyses were performed using the Statgraphics software package V.

3. Results and discussion

During the evaluated period in the depth 0.00–0.45 m the mean content of available phosphorus was in the range from 36.4 mg kg^{-1} to 53.1 mg kg^{-1}, the content of available potassium reached from 192.4 mg kg^{-1} to 256.7 mg kg^{-1}, total nitrogen content varied from 1,609 mg kg^{-1} to 1,930 mg kg^{-1} and content of soil organic carbon marked the values from 14.20 g kg^{-1} to 18.84 g kg^{-1} (Figure 1–4). In terms of criteria for assessing the results of chemical analyses of arable soil (Decree No. 338/2005 Collection of Law of the Ministry of Agriculture of the Slovak Republic) heavy Gleyic Fluvisols (depth 0.0 to 0.3 m in the studied years) belong to soils with satisfactory content of available phosphorus and satisfactory to good content of available potassium (Table 1). Determined total nitrogen content (Table 2) was in the medium supply (Fecenko a Ložek, 2000). After converting soil organic carbon on humus can be concluded that Gleyic Fluvisols marked medium to good supply of humus (Sotáková, 1982).

Significant effect of soil depth on the content of selected soil parameters was observed (Table 3). The highest contents of nutrients and soil organic carbon were detected in the top depth of soil (0.00–0.15 m) and the lowest in the depth 0.30 m to 0.45 m. The difference between the first and the third soil depth was in available phosphorus 26.4 mg kg^{-1}, in available potassium 39.5 mg kg^{-1}, in total nitrogen content 329 mg kg^{-1} and in soil organic carbon

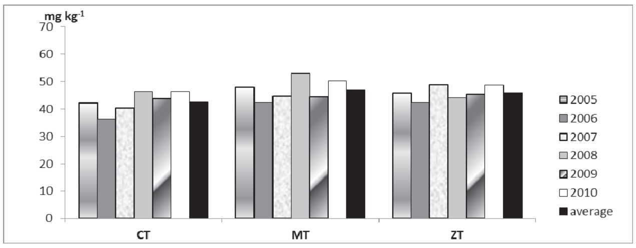

Figure 1 The available phosphorus contents in mg kg^{-1} in the depth of 0.00 – 0.45 m

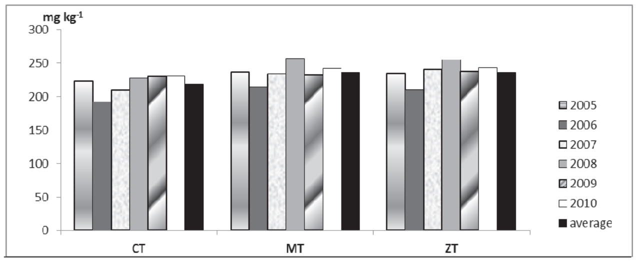

Figure 2 The available potassium contents in mg kg^{-1} in the depth of 0.00 – 0.45 m

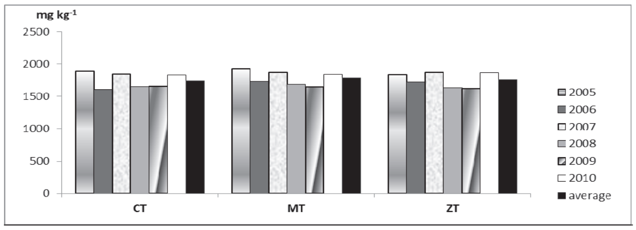

Figure 3 The total nitrogen contents in mg kg^{-1} in the depth of 0.00 – 0.45 m

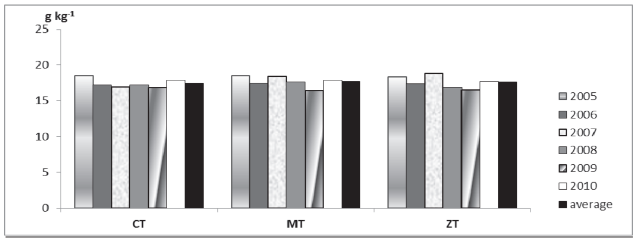

Figure 4 The soil organic carbon contents in g kg^{-1} in the depth of 0.00 – 0.45 m

2.48 g kg^{-1}. Lower levels of available phosphorus and potassium were found in deeper soil depths by Omonode et al. (2006) and Dong et al. (2009), of total nitrogen by López-Fando and Pardo (2009) and of soil organic carbon by Malo, Schumacher and Doolittle (2005), Šabatková et al. (2006), Dong et al. (2009) and others.

Significant effect of tillage on content of available phosphorus and potassium in the soil was observed. The increase in contents of available phosphorus and potassium in soil was found by comparing the initial state with the situation at the end of the experimental period. The balance showed that the contents of available phosphorus and potassium were increased at conventional tillage by about

4.3 mg kg^{-1} P and 7.3 mg kg^{-1} K, at minimum tillage by about 2.5 mg kg^{-1} P and 5.3 mg kg^{-1} K and at zero tillage by about 3.0 mg kg^{-1} P and 8.7 mg kg^{-1} K (Table 1). The increase in available phosphorus and potassium in the soil is related to their total input to soil. Vegetable residues of crop cultivated in crop rotation had different contents of phosphorus and potassium. Grain maize was twice grown in crop rotation. Post-harvest and root residues of maize contain a sufficient amounts of phosphorus and potassium. The probable cause of the increase of the contents of available phosphorus and potassium in the soil between the initial and final year of the experiment is cultivation of good forecrops and regular fertilization with mentioned nutrients.

The contents of total nitrogen in the soil were not significantly affected by tillage (Table 3). The decrease of content of total nitrogen between 2005 and 2010 was found at conventional (-60 mg kg^{-1}) and minimum (-91 mg kg^{-1}) tillage and slight increase at zero tillage (+32 mg kg^{-1}). The higher yields of crops and thus also higher uptake of nitrogen by grown crops are the probable causes of the decline in the total nitrogen content in conventional and minimum tillage in comparison with zero tillage. Higher yields of crops in conventional tillage in comparison with zero tillage found Hnát (2009) in grain maize, Fecák, Šariková a Černý (2010) in soya, Kotorová et al. (2011) in spring barley, grain maize,

Table 2 The content of total nitrogen, soil organic carbon and the ratio of soil organic carbon to total nitrogen in the soil profiles of Gleyic Fluvisols

Soil parameter	Tillage system	Soil depth in m	Experimental years						$\bar{x}$ Y
			2005	2006	2007	2008	2009	2010	
N_t in mg.kg^{-1}	CT	0.00–0.15	2 010	1 823	1 960	1 835	1 685	1 988	1 884
		0.15–0.30	1 893	1 555	1 910	1 688	1 708	1 940	1 782
		0.30–0.45	1 778	1 450	1 668	1 433	1 585	1 573	1 581
	MT	0.00–0.15	2 038	1 895	2 038	1 923	1 803	2 030	1 955
		0.15–0.30	1 913	1 720	1 870	1 700	1 690	1 848	1 790
		0.30–0.45	1 838	1 593	1 710	1 458	1 453	1 640	1 615
	ZT	0.00–0.15	1 975	1 925	1 993	1 840	1 723	2 053	1 918
		0.15–0.30	1 815	1 693	1 918	1 655	1 718	1 998	1 800
		0.30–0.45	1 728	1 575	1 723	1 428	1 420	1 563	1 573
$C_{org.}$ in g.kg^{-1}	CT	0.00–0.15	19.25	18.30	18.65	17.93	17.60	19.60	18.56
		0.15–0.30	18.68	17.13	17.95	17.43	17.10	18.52	17.80
		0.30–0.45	17.73	16.28	14.20	16.35	15.98	15.56	16.02
	MT	0.00–0.15	19.95	18.45	19.60	18.83	17.75	19.73	19.05
		0.15–0.30	18.28	17.63	18.85	17.35	17.10	18.30	17.92
		0.30–0.45	17.43	16.35	17.00	16.83	14.35	15.74	16.28
	ZT	0.00–0.15	19.18	18.10	19.28	17.85	17.70	19.04	18.53
		0.15–0.30	18.50	17.40	19.10	16.73	17.28	18.51	17.92
		0.30–0.45	17.38	16.58	18.13	16.05	14.53	15.69	16.39
$C_{org.}/N_t$	CT	0.00–0.15	9.58	10.04	9.52	9.77	10.45	9.86	9.87
		0.15–0.30	9.87	11.02	9.40	10.33	10.01	9.55	10.03
		0.30–0.45	9.97	11.23	8.51	11.41	10.08	9.89	10.18
	MT	0.00–0.15	9.79	9.74	9.62	9.79	9.84	9.72	9.75
		0.15–0.30	9.56	10.25	10.08	10.21	10.12	9.90	10.02
		0.30–0.45	9.48	10.26	9.94	11.54	9.88	9.60	10.12
	ZT	0.00–0.15	9.71	9.40	9.67	9.70	10.27	9.27	9.67
		0.15–0.30	10.19	10.28	9.96	10.11	10.06	9.26	9.98
		0.30–0.45	10.06	10.53	10.52	11.24	10.23	10.04	10.44

$\bar{x}$ Y – the mean for experimental years, N_t – total nitrogen content, $C_{org.}$ – soil organic carbon content, $C_{org.}/N_t$ – the ratio of soil organic carbon to total nitrogen

Table 3 Statistical evaluation of the contents of available phosphorus and potassium, total nitrogen and soil organic carbon and the ratio of soil organic carbon to total nitrogen

Variability source	Factor	Observed parameter				
		P in mg.kg^{-1}	K in mg.kg^{-1}	N_t v mg.kg^{-1}	$C_{org.}$ v g.kg^{-1}	$C_{org.}/N_t$
Soil depth	0.00 – 0.15	57.9 c	256.1 c	1 919 c	18.71 c	9.76 a
	0.15 – 0.30	46.2 b	228.9 b	1 791 b	17.88 b	10.01 ab
	0.30 – 0.45	31.5 a	216.6 a	1 590 a	16.23 a	10.25 b
Tillage system	CT	42.6 a	218.8 a	1 749 a	17.46 a	10.03 a
	MT	47.1 b	236.1 b	1 787 a	17.75 a	9.96 a
	ZT	45.9 ab	236.8 b	1 764 a	17.61 a	10.03 a
Experimental years	2005	45.3 ab	231.4 bc	1 888 b	18.49 e	9.80 ab
	2006	40.4 a	205.8 a	1 692 a	17.36 bc	10.31 c
	2007	44.6 ab	227.8 b	1 866 b	18.08 de	9.69 a
	2008	47.9 b	246.4 d	1 662 a	17.26 b	10.46 c
	2009	44.6 ab	233.3 bc	1 643 a	16.60 a	10.10 bc
	2010	48.5 b	238.5 cd	1 848 b	17.85 cd	9.68 a

P – available phosphorus content, K – available potassium content, N_t – total nitrogen content, $C_{org.}$ – soil organic carbon content, $C_{org.}$ / N_t – the ratio of soil organic carbon to total nitrogen, PS – zero tillage, letters (a, b, c, d, e) between factors refer to statistically significant differences (α = 0.05) – LSD test

winter wheat and soya and Kováč, Jakubová and Kotorová (2011) in winter rape.

Soil tillage affects the intensity of decomposition of soil organic matter. Soil organic matter is considered to be a key indicator during the valuation of soil quality (Barančíková, 2006). The values of soil organic carbon in the time period of six years in the depth 0.00–0.45 m were slightly higher (not significantly) for protective technologies (MT – 17.75 g kg^{-1}, ZT – 17.61 g kg^{-1}) compared to conventional tillage (17.46 g kg^{-1}). The same trend was retained in all three soil depths (Table 2). Non-significant differences of soil organic carbon content between conventional tillage and zero tillage were also recorded by Freixo, Machado, Santos et al. (2002).

Significant relationship was found at available phosphorus and potassium and total nitrogen contents in relation to the cultivated crop (Table 3). The maximum difference between individual years was 8.1 mg kg^{-1} for available phosphorus, 40.6 mg kg^{-1} for available potassium and 245 mg kg^{-1} for total nitrogen. The effect of a crop is influenced by the genetic material and by the intensity of cultivation in relation to yield (nutrition, tillage). Intensive fertilization led to an increased content of available phosphorus and potassium in the soil during the experimental period. Annual changes of soil chemical properties, although without relation to cultivated crops, were also found by Novotná and Lošák (2007).

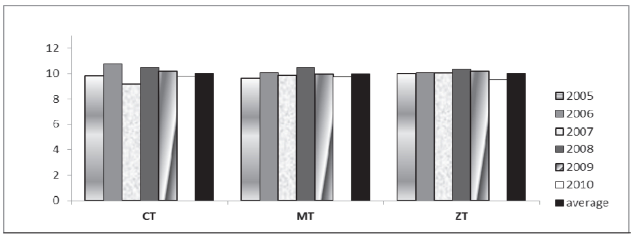

Figure 5 The ratio of soil organic carbon to total nitrogen in the depth of 0.00 – 0.45 m

Intensity of cultivation in relation to productivity was also demonstrated at soil organic carbon. Remains of crops (roots, postharvest and straw) were the sole source of organic matter. Achieved yields of cultivated crops did not compensate annual losses of soil organic carbon. Soil organic carbon was subsequently decreased. The highest decrease in content of soil organic carbon between 2005 and 2010 was found at conventional tillage (-0.66 g kg^{-1}), lower at minimum tillage (-0.63 g kg^{-1}) and the lowest at zero tillage (-0.60 g kg^{-1}). Significant relationship was found between the years, the crops and content of soil organic carbon. Annual changes of soil organic carbon were also found by Pospíšilová, Máchalová (2006) and Berner et al. (2008).

The calculated ratio of organic carbon to total nitrogen is the indicator of humus quality, e.g. indicates organic matter fortification by proteins (Sotáková, 1982). The ratio of organic carbon to total nitrogen varied from 9.14 to 10.76 at observed variants of tillage in total depth 0.00–0.45 m (Figure 5). Soil organic matter decomposition was intensive on the basis determined by values of ratio of organic carbon to total nitrogen. The ratio of organic carbon to total nitrogen was not significantly affected by the tillage. Similarly, Marriott and Wander (2006) showed no changes in the ratio $C_{org.}/N_t$ between different tillage systems.

The soil depth and year significantly affected the ratio of organic carbon to total nitrogen. With the increase of soil depth, the increase of ratio $C_{org.}/N_t$ values was observed (Table 2) what was consistent with the findings of Novotná and Lošák (2007).

4. Conclusions

From results obtained between 2005 and 2010 about the effect of different soil tillage on content and distribution of available phosphorus and potassium, total nitrogen, soil organic carbon and ratio of organic carbon to total nitrogen in condition Gleyic Fluvisols it is possible to formulate conclusions as follows:

1. The contents of available phosphorus and potassium in the soil were significantly dependent on tillage. The increase in content of available phosphorus and potassium in soil was found by comparing the initial state with the situation at the end of the experimental period.
2. The contents of total nitrogen and soil organic carbon were not significantly affected by tillage. The decrease in content of total nitrogen between 2005 and 2010 was found at conventional (-60 mg kg^{-1}) and minimum (-91 mg kg^{-1}) tillage and slight increase at zero tillage (+32 mg kg^{-1}). The content of soil organic carbon detected at the end of the experimental period in comparison to the year 2005 was lower by about 0.60–0.66 g kg^{-1} in selected soil tillage systems.
3. The calculated ratio of organic carbon to total nitrogen is the indicator of humus quality. This ratio varied from 9.14 to 10.76 at observed variants of tillage in total depth 0.00–0.45. The ratio of organic carbon to total nitrogen was not significantly affected by the tillage.
4. Contents of selected soil parameters were significantly dependent on soil depth. The highest contents of nutrients and soil organic carbon were detected in the top depth of soil (0.00–0.15 m) and the lowest in the depth 0.30 m to 0.45 m. The difference between the first and the third soil depth was in available phosphorus 26.4 mg kg^{-1}, in available potassium 39.5 mg kg^{-1}, in total nitrogen content 329 mg kg^{-1} and in soil organic carbon 2.48 g kg^{-1}.
5. Based on the obtained results it can be assumed that long-term application of direct sowing into uncultivated soil positively influences the distribution of nutrients and carbon sequestration. Higher increase of available potassium and total nitrogen and the lower decline content of soil organic carbon were observed with long-term use of direct sowing compared to a minimum and conventional tillage. Also, the values of ratio of organic carbon to total nitrogen were more optimal with direct sowing. In terms of reducing energy and economic costs using direct sowing and maintaining soil fertility suggest its greater use in agricultural practice.

5. Acknowledgement

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