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THE IMPACT OF CORN TILLAGE SYSTEM ON THE PROPERTIES OF ORGANIC MATTER IN THE HUMUS HORIZON OF BLACK EARTH (HAPLIC PHAEOZEMS) IN POZNAŃSKI LAKE DISTRICT****

Abstract: The subject of the study was the impact of three different combinations of corn tillage on the properties of organic matter – direct seeding into stubble as a control, seeding after deep plowing and seeding after application of manure and deep plowing. The experiment included humus horizons in black earth (Haplic Phaozems) in Poznański Lake District in the field of a ten-year conservation tillage system of corn monoculture. There are no significant differences in the fractional composition of humus one year after the introduction of the specified cultivation system.

The influence of tillage of various plant species on the properties of organic matter in soils, with special focus on the use of plant remains, has been an issue taken up by numerous researchers [3, 10, 14, 15]. Since 1997 the Department of Agronomy together with the Department of Soil Sciences and Land Protection at Poznań University of Life Sciences has conducted field and laboratory experiments considering long-term corn cultivation in monoculture in a non-tillage system. The acquired results allowed for defining the influence of such a tillage system and fertilizing plants with only natural fertilizers on some physical and chemical soil properties. The aim of the continuation of this experiment

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is to find the changes which occurred in the soil environment after 10 years of non-tillage and direct seeding into stubble in comparison with two other tillage systems, i.e. single conduction of deep plowing in the same soil without organic fertilization, as well as its single plowing with a full dose of manure.

MATERIALS AND METHODS

The research was conducted in the experimental field located 7.5 miles (12 kilometers) from the Poznań city center, along the route to Pniewy. This area belongs to the mezoregion of the Great Poland Lake District [7]. With respect to land configuration, the terrain is flat, a bit rolling and slightly declining to the south east. The soils in the experimental object originated from boulder clay of ground moraine from the Poznań phase of vistulian glaciation [8, 9] and according to the Polish Soil Classification [12], they belong to the subtype of black earths with a cambic horizon. They fall under the fourth complex of the agriculture suitability of soils (very good rye) and evaluation class IIIb. After a ten-year non-tillage, corn has been sown in the following three combinations: A – direct seeding into stubble as a control, B – seeding after deep plowing and C – seeding after application of manure and deep plowing. Each tillage scenario has been located in a different part of the experimental field with three repetitions on separate plots. The scheme of this field experiment is presented in Fig.1.

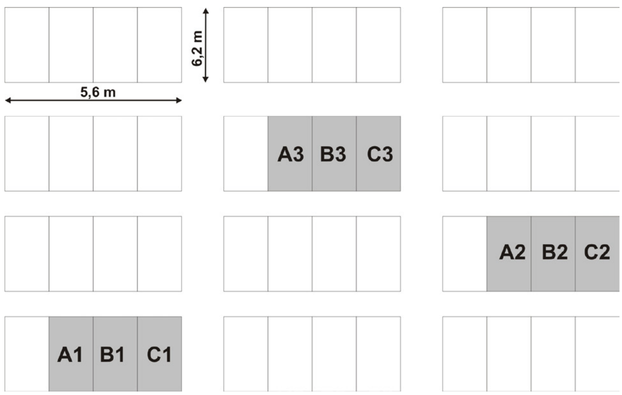

Fig. 1. Scheme of field experiment: A1, A2, A3 – direct seeding into stubble (control 0); B1, B2, B3 – seeding after deep plowing (30 cm); C1, C2, C3 – seeding after application of manure and deep plowing (30 cm).

After a full vegetation season, soils samples were collected from the humus horizon at the depths of about 2.76 inches (7 centimeters) and 8.66 inches (22 centimeters). Eighteen samples were collected altogether and the following parameters were measured: grain-size distribution by means of Bouyoucos' areometric method in Casagrande's and Prószyński's modification and the sieve method, pH value by means of the potentiometric method in H_2O and KCl of 1 mol dm^{-3} concentration, content of carbonates by means of Scheibler's method, content of $C_{org.}$ by means of Tiurin's method and humus fractional composition by means of Tiurin's method in Ponomariewa's and Plotnikowa's modification [5].

RESULTS AND DISCUSSION

Humus horizons of the investigated soils in all tillage combinations resemble one another with respect to grain size distribution, and their texture is characteristic of the moraine early post-glacial areas which compose black earths (Table 1).

TABLE 1. TEXTURE OF HUMUS HORIZON IN THREE DIFFERENT COMBINATIONS OF TILLAGE

Combination of tillage and field number	Depth (cm)	Percentage of particle-size fractions			Texture group*
		sand	silt	clay	
		2.0–0.5 mm	0.5–0.002 mm	< 0.002 mm	
Al	7	74	23	3	gp
	22	70	28	2	gp
A2	7	79	18	3	pg
	22	79	19	2	pg
A3	7	82	16	2	pg
	22	83	16	1	pg
B1	7	74	23	3	gp
	22	77	20	3	gp
B2	7	82	16	2	pg
	22	80	18	2	pg
B3	7	82	15	3	ps
	22	80	18	2	pg
Cl	7	78	20	2	pg
	22	79	19	2	pg
C2	7	80	18	2	pg
	22	81	15	4	pg
C3	7	83	15	2	pg
	22	81	16	3	pg

* pg – loamy sand, gp – sandy loam.

Loamy sands, where the content of silt varies from 15 to 20 percent, are dominant [11]. In the case of samples from plots A and B, the soil texture is sand loams with a significant addition of silt (20–28%). The content of clay is minor and varies from 1 to 3 percent. The reaction does not vary significantly between various horizons. This situation is clearly illustrated by the average results for different tillage combinations (Table 2). The highest pH values are shown in top horizon samples, enriched with carbonates (over 8 in H_2O and over 7 in KCl).

TABLE 2. VALUE OF THE pH CONTENT OF CARBONATES
IN THREE DIFFERENT COMBINATIONS OF TILLAGE

Combination of tillage and field number	pH				$CaCO_3$ (%)
	H_2O		KCl		
Al	8.5	alkaline	7.8	alkaline	5.7
A2	7.1	neutral	6.2	slight acid	0.0
A3	7.1	neutral	6.1	slight acid	0.0
Average (for 7 cm deep layer)	7.6	alkaline	6.7	neutral	
Al	8.6	alkaline	7.8	alkaline	5.7
A2	7.5	alkaline	6.7	neutral	0.0
A3	7.4	alkaline	6.6	neutral	0.0
Average (for 22 cm deep layer)	7.8	alkaline	7.0	neutral	
Average for A	7.7	alkaline	6.9	alkaline	
B1	8.6	alkaline	7.7	alkaline	5.7
B2	7.0	neutral	6.1	slight acid	0.0
B3	7.1	neutral	6.2	slight acid	0.0
Average (for 7 cm deep layer)	7.6	alkaiine	6.7	neutral	
B1	8.5	alkaline	7.8	alkaline	5.3
B2	7.5	alkaline	6.8	neutral	0.0
B3	7.5	alkaline	6.6	neutral	0.0
Average (for 22 cm deep layer)	7.8	alkaline	7.1	neutral	
Average for B	7.7	alkaline	6.9	neutral	
C1	8.5	alkaline	7.8	alkaline	5.3
C2	7.3	neutral	6.4	slight acid	0.0
C3	6.4	slight acid	5.5	acid	0.0
Average (for 7 cm deep layer)	7.4	neutral	6.5	neutral	
C1	8.5	alkaline	7.8	alkaline	5.3
C2	7.9	alkaline	7.1	neutral	0.0
C3	7.5	alkaline	5.6	slight acid	0.0
Average (for 22 cm deep layer)	8.0	alkaline	6.8	neutral	
Average for C	7.7	alkaline	6.7	neutral	

Total amount of $C_{org.}$ in the humus horizons of the investigated soils is relatively low and oscillates around 0.69–1.18% in all three tillage combinations. Intensive agricultural use of black earths leads to the drop in organic matter. This situation is widely observed *inter alia* in Kujawy [6].

Determination of the fractional composition of humus by means of Tiurin's method in Ponomariewa's and Plotnikowa's modification allowed the percentage determination of the participation of each fulvic and humic acids fraction, as well as non-hydrolyzing remains which are composed mainly of humins in the pool of organic carbon in each sample. The list of results with the description of each fraction is presented in Table 3.

In the case of direct seeding (tillage combination A), the results of the analysis do not confirm the decrease in the content of $C_{org.}$ along with the depth. In non-tillage systems, the quality of soil humus is most highly determined by the species of incubated plants and the time of incubation [2].

In most of the analyzed samples, fulvic acids dominate over humic acids. However, the values of Ckh/Chf proportion vary. The analysis of the humic acids' fractional composition has proved no proclivity towards the predominance of a given fraction. In the group of fulvic acids, fraction 2 (+Ca) is predominant. The content of humins is significant (18–23%). The only exceptions here are the samples from A2 where at the depth of 2.76 feet (7 centimeters) humins account for only 5% $C_{org.}$ and at the depth of 8.66 feet (22 centimeters) humic acids dominate over fulvic acids (Ckh/Ckf – 2.9), while in the pool of fulvic acids fraction 1 (+R_2O_3) is predominant.

In terms of deep plowing (tillage combination B), samples taken from the depth of about 2.76 in (7 cm) contain slightly more C_{org} than those taken at 8.66 in (22 cm). Fulvic acids dominate over humic acids but Ckh/Ckf varies significantly from 0.2 to 0.9. The analysis of the fractional composition of humic acids showed no tendency for the domination of a given fraction. In the analysis of fulvic acids, fraction 2 (+Ca) is predominant in all samples. The content of humins varies (from 5 to 24 percent) and there are no regularities.

In the case of deep plowing after the application of manure (tillage combination C), samples taken from the depth of 2.76 in (7 cm) contain a little more C_{org} than those taken at 8.66 in (22 cm). Experiments conducted in long-term tillage systems show that application of manure not only activates the growth of the organic carbon content in soil but also the percentage proportion of humic acids in the general C_{org} content [13]. In most of the analyzed samples, fulvic acids dominate over humic acids in the fractional composition of humus, while among humic acids, fraction 2 (i.e. humus fraction connected with Ca) is predominant. In the fractional composition of humic acids, the fraction connected with Ca is also predominant. The content of humins is the lowest in comparison to other tillage combinations.

TABLE 3. FRACTIONAL COMPOSITION OF HUMUS IN THREE DIFFERENT COMBINATIONS OF TILLAGE

Combination of tillage and field number	Depth (cm)	TOC (%)	KH				KF					Σ fractions	SCKH SCKF	Cpp
			Humic acids				Fulvic acids							
			1	2	3	Σ	1a	1	2	3	Σ			
A1	7	1.07	0.06*	0.22	0.08	0.36	0.06	0.07	0.33	0.05	0.51	0.87	0.7	0.20
			5.6**	20.6	7.5	33.7	5.6	6.5	30.8	4.7	47.6	81.3		18.7
A 2		0.78	0.12	0.09	0.09	0.30	0.03	0.16	0.20	0.05	0.44	0.74	0.7	0.04
			15.4	11.5	11.5	38.4	3.8	20.5	25.6	6.4	56.3	94.7		5.3
A3		0.82	0.12	0.07	0.07	0.26	0.03	0.15	0.22	0.02	0.42	0.68	0.6	0.14
			14.6	8.5	8.5	31.6	3.7	18.3	26.8	2.4	51.2	82.8		17.2
A1	22	1.09	0.04	0.09	0.13	0.26	0.06	0.07	0.50	0.05	0.68	0.94	0.4	0.15
			3.7	8.3	11.9	23.9	5.5	6.4	45.9	4.6	62.4	86.3		13.7
A2		0.82	0.09	0.30	0.08	0.47	0.03	0.09	0.00	0.04	0.16	0.63	2.9	0.19
			11.0	36.6	9.8	57.4	3.7	11.0	0.0	4.9	19.6	77.0		23.0
A 3		0.88	0.12	0.09	0.10	0.31	0.03	0.19	0.19	0.00	0.41	0.72	0.8	0.16
			13.6	10.2	11.4	35.2	3.4	21.6	21.6	0.0	46.6	81.8		18.2
BI	7	1.18	0.05	0.20	0.10	0.35	0.06	0.08	0.46	0.04	0.64	0.99	0.5	0.19
			4.2	16.9	8.5	29.6	5.1	6.8	39.0	3.4	54.2	83.8		16.2
B2		0.97	0.14	0.11	0.10	0.35	0.03	0.11	0.25	0.00	0.39	0.74	0.9	0.23
			14.4	11.3	10.3	36.0	3.1	11.3	25.8	0.0	40.2	76.2		23.8
B3		0.73	0.08	0.03	0.06	0.17	0.03	0.12	0.34	0.03	0.52	0.69	0 3	0.04
			11.0	4.1	8.2	23.3	4.1	16.4	46.6	4.1	71.2	94.5		5.5

TABLE 3. CONTINUATION

BI		0.98	0.03 / 3.1	0.06 / 6.1	0.15 / 15.3	0.24 / 24.5	0.05 / 5.1	0.07 / 7.1	0.57 / 58.2	0.00 / 0.0	0.69 / 70.4	0.93 / 94.9	0.3	0.05 / 5.1
B2	22	0.70	0.07 / 10.0	0.17 / 24.3	0.05 / 7.1	0.29 / 41.4	0.03 / 4.3	0.08 / 11.4	0.19 / 27.1	0.03 / 4.3	0.33 / 47.1	0.62 / 88.5	0.9	0.08 / 11.5
B3		0.74	0.07 / 9.5	0.00 / 0.0	0.05 / 6.8	0.12 / 16.3	0.03 / 4.1	0.13 / 17.6	0.36 / 48.6	0.02 / 2.7	0.54 / 73.0	0.66 / 89.3	0.2	0.08 / 10.7
Cl		1.04	0.05 / 4.8	0.16 / 15.4	0.06 / 5.8	0.27 / 26.0	0.06 / 5.8	0.05 / 4.8	0.48 / 46.2	0.08 / 7.7	0.67 / 64.4	0.94 / 90.4	0.4	0.10 / 9.6
C2	7	0.85	0.11 / 12.9	0.35 / 41.2	0.10 / 11.8	0.56 / 65.9	0.03 / 3.5	0.13 / 15.3	0.00 / 0.0	0.01 / 1.2	0.17 / 20.0	0.73 / 85.9	3.3	0.12 / 14.1
C3		0.75	0.13 / 17.3	0.09 / 12.0	0.09 / 12.0	0.31 / 41.3	0.03 / 4.0	0.16 / 21.3	0.23 / 30.7	0.00 / 0.0	0.42 / 56.0	0.73 / 97.3	0.7	0.02 / 2.7
Cl		0.93	0.04 / 4.3	0.09 / 9.7	0.13 / 14.0	0.26 / 28.0	0.05 / 5.4	0.07 / 7.5	0.51 / 54.8	0.01 / 1.1	0.64 / 68.8	0.90 / 96.8	0.4	0.03 / 3.2
C2	22	0.70	0.06 / 8.6	0.13 / 18.6	0.06 / 8.6	0.25 / 35.8	0.03 / 4.3	0.08 / 11.4	0.26 / 37.1	0.01 / 1.4	0.38 / 54.3	0.63 / 90.1	0.7	0.07 / 9.9
C3		0.69	0.06 / 8.7	0.17 / 24.6	0.07 / 10.1	0.30 / 43.4	0.03 / 4.3	0.10 / 14.5	0.25 / 36 2	0.00 / 0.0	0.38 / 55.1	0.68 / 98.5	0.8	0.01 / 1.5

* in the numerator – ratio of C% in fraction to total weight of sample; ** in the denominator – ratio of C% in fraction to TOC.

Explanations: KF-1a – free fluvic acids and slightly bound with mobile sesquioxides; KF-1 and KH-1 – free fluvic and humic acids and bound with non-silicate forms of sesquioxides; KF-2 and KH-2 – humic and fluvic acids bound with calcium; KF-3 and KH-3 – humic and fluvic acids bound with mineral part of soil; Cpp – carbon of non-hydrolyzable residue, mostly humins.

The advantage of fulvic acids over humic acids in most of the samples in all three tillage combinations and a relatively low proportion of humins (less than 25%) prove that the organic matter has undergone only preliminary humification. This situation is characteristic, for example, of organic horizons of forest soils [4]. Studies from the Brodnickie Lakeland prove that in black earths which are used as grasslands and in analogical arable land the amount of humins may exceed 50% of the total C_{org} [1].

In the fractional composition of humic acids in all tillage combinations, there is a great diversity in the predomination of a given fraction, regardless of the depth. In terms of the fractional composition of fulvic acids in most of the samples (in 16 from 18 samples) the fraction connected with calcium is dominant. Significant differences in the fractional composition of humus may occur even after forty years, which has been shown in studies conducted on arable soils with cambic horizons in Lithuania [14].

CONCLUSIONS

The results of the analysis of the humus fractional composition in the soil material taken from an experimental field led to the following conclusions:

1. There is no regularity in the diversity among various tillage combinations in the fractional composition. There are also no significant regularities in the diversity of each humus fraction with regard to the depth from which a sample was collected.

2. A year after the implementation of a change in the tillage system on the experimental field where previously a corn monoculture had been directly sown in the stubble for ten years, the humus horizon of black earths shows no visible changes in the character and the properties of organic matter.

3. The diversity among humus fractions dependant on a tillage system may expose in a few years, therefore it is advised to continue the research.

REFERENCES

[1] Bednarek R., Sewerniak P., Gruba R.: Ochrona i zagospodarowanie dorzecza Drwęcy. Wyd. UMK, Toruń, **1**, 19, 2007.

[2] Dębska B., Gonet S.: Polish J. Soil Sci., **40** (1), 57, 2007.

[3] Drąg M.: MSc Thesis, UTP, Bydgoszcz, 136, 2009.

[4] Dziadowiec H.: Rozprawy UMK, Toruń, 92, 1990.

[5] Dziadowiec H., Gonet S.: Prace Komisji Nauk. PTGleb., Warszawa, **120**, 26, 1999.

[6] Kobierski M., Różański S.: Pol. Tow. Subst. Hum., PTG, Toruń, 159, 2011.

[7] Kondracki J.: Wyd. Nauk. PWN, Warszawa, 138, 2001.

[8] Krygowski B.: PTPN, Poznań, 119, 1961.

[9] Mojski J.: PIG, Warszawa, 224, 2005.

[10] M y ś k ó w W.: IUNG, Puławy, 70, 1984.
[11] PTG: Roczn. Glebozn., **60** (2), 5, 2009.
[12] PTG: Roczn. Glebozn., **62**, 3, 2011.
[13] S ą d e j W., N a m i o t k o A.: Polish J. Soil Sci., **44** (20), 105, 2011.
[14] S l e p e t i e n e A., S l e p e t y s J.: Geoderma, **127**, 207, 2005.
[15] Z a u j e c A.: Pol. Tow. Subst. Hum., Toruń, 31, 2007.

WPŁYW SYSTEMU UPRAWY KUKURYDZY NA WŁAŚCIWOŚCI MATERII ORGANICZNEJ W POZIOMIE PRÓCHNICZNYM CZARNEJ ZIEMI (HAPLIC PHAEOZEMS) POJEZIERZA POZNAŃSKIEGO

Celem badań była ocena wpływu trzech różnych systemów uprawy kukurydzy: siew bezpośredni w ściernisko (obiekt kontrolny), siew po głębokiej uprawie oraz siew po nawożeniu obornikiem i głębokiej uprawie na właściwości glebowej materii organicznej. Badania prowadzono w poziomie próchnicznym czarnej ziemi (Haplic Phaeozems) Pojezierza Poznańskiego, na polu po 10-letnim okresie uprawy monokultury kukurydzy w systemie uprawy zachowawczej. Nie stwierdzono istotnych różnic w składzie frakcyjnym próchnicy po jednym roku od zastosowania różnych systemów uprawy.