Acta Agrophysica, 2001, 50, 225-234

QUANTITY AND QUALITY OF ORGANIC MATTER IN FOREST AND ARABLE SOILS DEVELOPED FROM SAND AND LOESS

H. Smal, M. Misztal, S. Ligęza, P. Dymińska-Wydra

Institute of Soil Science and Environment Management, Agricultural University
Leszczyńskiego 7, 20-069 Lublin, Poland

A b s t r a c t. Eight sandy and three loess forest and arable soils taken from the S-E region of Poland were used in the study. The following fractions of C were determined: total organic carbon, fraction soluble in 0.5 mol NaOH dm^{-3} (humic acids + fulvic acids), humic acids, fulvic acids, fraction soluble in 0.5 mol H_2SO_4 dm^{-3} (hemicelluloses) and residue. Quantity and quality of organic matter depended on horizon and soil use. The highest content was shown by fraction of humus acids and residue, whereas the lowest - hemicelluloses fraction. In most soils C ratio of humic to fulvic acids exceeded 1.0. On average, in humus horizons, it was higher in arable than in forest soils and in loess as against sandy soils. In sandy soils, a slightly higher content of humus fraction and lower residue one than in loess soils was found.

K e y w o r d s: organic carbon fractions, sandy and loess soils, forest and arable use.

INTRODUCTION

In natural conditions, the quantity and quality of organic matter depends on ecological conditions and are closely related to soil type [10,13]. Organic matter is a very dynamic soil constituent. In forest biocenoses it is found in abundance, whereas in arable soils the accumulation and decomposition of organic matter is a continuous process. Soil cultivation therefore and other anthropogenic factors may change the properties of humus substances. Therefore, a study to compare the state of humus compounds in soils under natural conditions and in soils influenced by the activity of man is important for a fuller understanding of the transformation of organic matter due to cultivation or fertilization.

The aim of the study was to determine the quantity and quality of organic matter in forest and related arable soils developed from the sand and loess located in the Lublin District (Southern-Eastern Poland).

MATERIALS AND METHODS

Soils from 11 locations in the Lublin region (Southern-Eastern Poland) were used in the study. Each location was chosen so that natural forest and arable land were in close proximity. The samples were taken from two horizons: humus and subhumus. Eight soils developed from sands were classified as Cambic Arenosols or Haplic Podzols and three formed from loess as Haplic Luvisols. The basic physico-chemical soil properties of the studied soils are shown in Table 1.

The quality of organic matter was determined by the modified Griffith-Schnitzer method [6]. During analysis the following fractions of C were determined: total organic carbon, humus acids soluble in 0.5 mol NaOH dm^{-3} (humic acids + fulvic acids), humic acids, fulvic acids, fraction soluble in 0.5 mol H_2SO_4 dm^{-3} (hemicelluloses), fraction non soluble - residue. The content of C in particular fractions was determined by the modified Tiurin method [1].

RESULTS AND DISCUSSION

The content of C_{tot} in Ah horizons of podzol forest soils ranged from 4.8 to 19.58 g C kg^{-1} (mean 12.59 g C kg^{-1}) and in subhumus horizons from 2.16 to 10.26 g C kg^{-1} with mean of 5.36 g C kg^{-1} (Table 2). Arable soils showed a lower range of C_{tot} content than related forest soils i.e. from 7.24 to 10.30 g C kg^{-1} (mean 9.27 g C kg^{-1}) in Ap horizons and from 2.04 to 6.0 g C kg^{-1} (mean 3.77 g C kg^{-1}) in subhumus horizons. The amount of C_{tot} in humus horizons of loess forested soils was higher (range from 14.25 to 25.46 g C kg^{-1}, mean 19.96 g C kg^{-1}), and in humus horizons of cultivated was comparable with the content in related horizons of sandy soils. Subhumus horizons of both, forest and arable loess soils showed C_{tot} content similar to sandy soils.

The content of organic carbon in humus horizons of the studied soils was comparable to the amounts stated for similar soils by Borowiec and Wybieralska [2], Czerwiński [3], Maciejewska [7], Skłodowski [10], Turski [13], Turski *et al.* [15].

All forest soils demonstrated much higher C_{tot} content than arable soils, both in humus and subhumus horizons. It is a well known relationship reported by many authors [11,12,14]. Skłodowski [11] stated that the C amount in humus horizons of the forest soils was 2.5 times higher than in related horizons of arable soils.

Table 1. Basic physico-chemical soil properties of the studied soils

Location/use	Horizon	Granulometric composition (%)			pH KCl	Hydro-lytic acidity	Sum of bases	CEC*
		1-0.05 mm	0.05-0.002 mm	<0.002 mm		(mmol kg^{-1})		
Sandy soils								
Wrzosów	Ah	84	15	1	3.65	69.4	4.0	73.4
forest	Bv	87	11	2	4.34	31.9	1.0	32.9
Wrzosów	Ap	78	22	0	3.86	41.6	5.6	47.2
arable	Bv	82	18	0	4.55	21.7	3.6	25.3
Albertów	Ah	76	23	1	3.70	64.5	2.2	66.7
forest	Bhs	78	21	1	4.25	26.6	2.1	28.7
Albertów	Ap	66	27	2	5.70	24.7	16.1	40.8
arable	Bhs	67	31	2	4.50	24.7	4.7	29.4
Ziarny	Ah	95	5	0	4.00	35.6	4.6	40.2
forest	Bv	90	6	4	3.95	45.4	3.4	48.8
Ziarny	Ap	94	6	0	4.00	29.2	5.0	34.2
arable	Bv	96	3	1	4.55	24.0	2.8	26.8
Firlej	Ah	94	6	0	3.35	43.0	1.3	44.3
forest	Ees	97	3	0	4.15	6.70	1.2	7.9
Firlej	Ap	91	7	2	3.75	56.2	5.3	61.5
arable	Bhs	97	3	0	4.30	12.0	3.5	15.5
Zalesie	Ah	73	23	4	3.73	69.1	21.0	90.1
forest	Bv	71	24	5	3.85	46.2	4.0	50.2
Zalesie	Ap	68	27	5	3.85	40.5	8.0	48.5
arable	Bv	71	23	6	4.24	20.8	4.0	24.8
Wandzin	Ah	66	29	5	3.83	55.5	13.0	68.5
forest	Bv	66	29	5	3.89	24.8	8.0	32.8
Wandzin	Ap	63	33	4	6.18	12.0	67.0	79.0
arable	Bv	60	36	4	5.28	13.5	17.0	30.5
Żurowe	Ah	88	9	3	3.24	103.5	19.0	122.5
Bagno, forest	AhBv	88	10	2	3.43	57.8	5.0	62.8
Żurowe	Ap	94	4	2	4.02	27.8	8.0	35.8
Bagno, arable	Bv	97	2	1	4.47	27.0	2.0	29.0
Gozdów	Ah	93	4	3	3.81	45.8	45.8	48.8
forest	Bv	94	2	4	4.36	26.3	26.3	28.3
Gozdów	Ap	91	6	3	3.95	28.5	28.5	34.5
arable	Bv	94	5	1	4.48	21.4	21.4	23.4

*CEC - Cation Exchange Capacity.

Table 1. Continuation

Location/use	Horizon	Granulometric composition (%) 1-0.05 mm	0.05-0.002 mm	<0.002 mm	pH KCl	Hydro-lytic acidity (mmol kg^{-1})	Sum of bases (mmol kg^{-1})	CEC* (mmol kg^{-1})
Loess soils								
Czesławice	Ah	20	71	9	4.31	52.5	80.9	133.4
forest	Eet	17	69	14	3.94	53.6	25.3	78.9
Czesławice	Ap	19	76	5	5.61	24.0	100.5	124.5
arable	Bt	21	57	22	5.64	14.6	175.0	189.6
Miłocin	Ah	26	64	10	3.35	78.0	24.0	102.0
forest	Eet	16	72	12	3.68	52.5	7.0	59.5
Miłocin	Ap	17	72	11	3.96	40.9	41.0	81.9
arable	Bt	18	63	19	3.87	24.8	74.0	98.8
Stasin	Ah	24	69	7	3.48	87.8	21.0	108.8
forest	Eet	14	76	10	3.85	52.5	7.0	59.5
Stasin	Ap	17	75	8	6.12	16.5	79.0	95.5
arable	Eet	17	72	11	4.40	23.3	23.0	46.3

*CEC - Cation Exchange Capacity.

Generally, C_{tot} content in humus horizons of the examined soils was about 2 to 3 times higher in comparison to subhumus horizons. Similar results were obtained by Czerwiński [3], Skłodowski [11], Turski *et al.* [15].

Among fractions separated, C of humus acids fraction soluble in NaOH (humic + fulvic acids) and non-soluble residue appeared in highest amounts. In Ah horizons of sandy forest soils the C content in humus acids fraction ranged from 3.68 to 8.51 g C kg^{-1} (mean 5.87 g C kg^{-1}) and in Ap horizons of related arable soils from 3.07 to 4.78 g C kg^{-1} (mean 4.17 g C kg^{-1}). In humus horizons of loess soils the C amount of this fraction was comparable to the content in related forest and arable sandy soils.

Alike C_{tot} content, a range and mean values of C in NaOH fraction were higher in forest than in arable soils and much lower in sub-humus as against humus horizons.

Results proved that hemicelluloses (fraction soluble in H_2SO_4) occurred in the lowest amounts. In all soils and horizons C content of this fraction was below 1 g C kg^{-1} and no clear differences were observed between the soils examined.

In the presented study C of humic and fulvic acids fractions were also determined and their ratio calculated (Table 2). HA:FA ratio varied in a wide range and

Table 2. Total organic carbon and carbon of fractions content

Location/use	Horizon	C_{tot}	C fractions: NaOH	Humic acids	Fulvic acids	Hemi-celluloses	Residue	HA:FA*
		(g C kg^{-1})						
Sandy soils								
Wrzosów forest	Ah	12.90	7.80	4.36	3.44	0.18	4.92	1.26
	Bv	5.22	2.31	0.78	1.53	0.35	2.56	0.50
Wrzosów arable	Ap	7.42	4.78	2.58	2.20	0.24	2.40	1.17
	Bv	2.16	1.11	0.86	0.25	0.21	0.84	3.44
Albertów forest	Ah	9.60	4.98	2.52	2.46	0.18	4.40	1.02
	Bhs	4.08	1.74	1.00	0.74	0.06	2.28	1.35
Albertów arable	Ap	8.70	4.13	3.00	1.13	0.18	4.40	2.65
	Bhs	2.20	0.95	0.62	0.33	0.18	1.07	2.42
Ziarny forest	Ah	9.75	4.27	2.90	1.37	0.30	5.18	2.11
	Bv	2.94	1.20	0.90	0.30	0.12	1.62	3.00
Ziarny arable	Ap	9.30	4.75	3.06	1.69	0.06	4.49	1.81
	Bv	3.54	2.34	1.08	1.26	0.18	1.02	0.85
Firlej forest	Ah	4.80	3.70	2.10	1.60	0.30	0.80	1.30
	Ees	2.16	0.90	0.42	0.48	0.18	1.08	0.87
Firlej arable	Ap	11.40	4.34	2.76	1.58	0.96	6.10	1.74
	Bhs	2.04	1.06	0.84	0.22	0.13	0.89	3.81
Zalesie forest	Ah	19.27	8.51	3.71	4.80	0.60	10.16	0.77
	Bv	8.45	3.67	1.00	2.67	0.49	4.29	0.37
Zalesie arable	Ap	10.29	3.79	2.10	1.69	0.79	5.71	1.24
	Bv	5.10	3.37	0.69	2.68	0.55	1.18	0.25
Wandzin forest	Ah	14.95	5.51	1.30	4.21	0.42	9.02	0.30
	Bv	6.98	3.86	1.07	2.79	0.25	2.87	0.38
Wandzin arable	Ap	7.24	3.07	2.00	1.07	0.55	3.62	1.87
	Bv	6.00	4.09	0.85	3.24	0.38	1.53	0.26
Żurowe Bagno forest	Ah	19.58	8.51	5.12	3.39	0.51	10.56	1.51
	AhBv	10.26	3.12	1.71	1.41	0.27	6.87	1.21
Żurowe Bagno arable	Ap	9.50	4.06	2.33	1.73	0.26	5.18	1.34
	Bv	4.73	1.31	0.79	0.52	0.13	3.29	1.51
Gozdów forest	Ah	9.89	3.68	2.74	0.94	0.25	5.96	2.91
	Bv	2.85	1.75	1.11	0.64	0.45	0.65	1.73
Gozdów arable	Ap	10.30	4.46	3.01	1.45	0.59	5.25	2.07
	Bv	4.39	1.67	0.91	0.76	0.13	2.59	1.19
Mean forest	humus	12.59	5.87	3.09	2.78	0.34	6.38	1.11
	subhumus	5.36	2.32	1.01	1.32	0.27	2.78	0.77
Mean arable	humus	9.27	4.17	2.61	1.56	0.45	4.64	1.67
	subhumus	3.77	1.98	0.83	1.15	0.24	1.55	0.72

*HA:FA - C of humic to C of fulvic acids ratio.

T a b l e 2. Continuation

Location/use	Horizon	C_{tot}	C fractions					HA:FA*
			NaOH	Humic acids	Fulvic acids	Hemi-celluloses	Residue	
		(g C kg^{-1})						
Loess soils								
Czesławice forest	Ah	14.25	6.66	3.00	3.66	0.39	7.20	0.81
	Eet	3.70	1.35	0.81	0.54	0.10	2.25	1.50
Czesławice arable	Ap	7.65	4.20	1.74	2.46	0.36	3.10	0.70
	Bt	2.40	0.69	0.40	0.29	0.21	1.50	1.37
Miłocin forest	Ah	25.46	8.12	5.30	2.82	0.73	16.61	1.87
	Eet	4.08	1.48	0.75	0.73	0.15	2.45	1.02
Miłocin arable	Ap	9.72	3.35	2.19	1.16	0.49	5.88	1.88
	Bt	3.40	0.57	0.15	0.42	0.17	2.66	0.35
Stasin forest	Ah	20.18	7.20	4.41	2.79	0.15	12.83	1.58
	Eet	6.60	1.90	1.17	0.73	0.14	4.56	1.60
Stasin arable	Ap	8.35	2.73	2.16	0.57	0.32	5.30	3.78
	Eet	2.14	1.08	0.52	0.56	0.08	0.98	0.92
Mean forest	humus	19.96	7.33	4.24	3.09	0.42	12.21	1.42
	subhumus	4.79	1.58	0.91	0.67	0.13	3.09	1.37
Mean arable	humus	8.57	3.49	2.03	1.40	0.39	4.76	2.12
	subhumus	2.64	0.78	0.36	0.42	0.15	1.71	0.88

was different for soils or horizons. In humus horizons of sandy forest soils it ranged from 0.30 to 291 (mean 1.11) and in arable from 1.17 to 2.65 (mean 1.67). Subhumus horizons of sandy soils did not differ substantially in HA:FA ratios and the mean index was the same for arable and forest soils. Similarly to sandy soils, in loess soils C of humic to fulvic acids the ratio varied in a wide range i.e. from 0.7 to 2.12 in humus horizons and from 0.35 to 1.6 in sub humus horizons. Values of HA:FA ratios found in this study are in agreement with the data of many authors [2,5,8,13]. These authors maintained that HA:FA ratio may vary in a wide range even within the same type of soils.

In most arable as well as forest soils, the HA:FA ratio exceeded 1,0. Moreover, the tendency of the higher values of that index was observed rather in arable soils than in forest soils, especially in humus horizons. It is clearly seen in mean ratio value. For humus horizons of sandy soils it was 1.11 and 1.67 in forest and arable soils, respectively and for related loess soils 1.42 and 2.12.

The ratio of humic to fulvic acids is an important index for soil humus quality evaluation. Generally, its higher values are indicative of well developed humification processes and are observed in arable soils in high agronomic culture [11,13]. The prevalence of humic over fulvic acids in both, arable and forest soils studied denote advanced humification processes there.

Percentage share of C fractions in C_{tot} depended on horizon and soil usage. In all soils studied soils, on average, the highest share was shown by humus acids (soluble in NaOH) and non soluble residue (Table 3). Share of C humus fraction in forest sandy soils ranged from 36.86 to 77.08% (mean 49.37%) and from 30.4% to 61.40% (mean 44.98%) in humus and subhumus horizons, respectively. In arable profiles of these soils it was not much different from the forest ones and varied from 36.83 to 64.42% (mean 45.79%) in humus horizons and from 27.70 to 68.33% (mean 51.59%) in subhumus horizons. Both, forest and arable loess soils showed a slightly lower range and mean of C humus acids fraction share and C_{tot} in comparison to sandy soils. For humus horizons of loess forest soils the values ranged from 35.68 to 46.73% (mean 38.10%) and for humus horizons of arable soils from 32.69 to 54.90% (mean 40.68%). Similarly sandy soils in loess soils no clear difference in share of C fraction NaOH-soluble was observed between arable and forest soils.

No clear relationship was stated in the proportion of humic and fulvic acids in sandy soils. For most horizons in the forest and arable soils the percentage share of humic acids in C_{tot} was higher than the proportion of fulvic acids but it appeared to be opposite for the others. A similar situation occurred in the loess soils. The results obtained are somewhat different from the findings by Skłodowski [11] and Turski [13] who showed that, as a rule, in arable soils organic matter consisted of a higher percentage of humic acids than of fulvic acids. According to these authors, fulvic acids prevailed over humic acids in forest soils. Słowinska-Jurkiewicz [12] in turn, has determined more fulvic than humic acids in three loess forests as well as arable Luvisols.

Among C fractions separated, the lowest percentage share was shown by fraction H_2SO_4-soluble. The maximum values exceeding 10% occurred in only two cases and in the other samples it was below 10%. The values obtained correspond to the data reported by Flis-Bujak [4], Słowińska-Jurkiewicz [12], Turski [13], and Wójcikowska-Kapusta [16] for similar soils.

A tendency towards a higher proportion of hemicelluloses in organic matter of arable than in related forest soils was observed. This is in agreement with findings of Turski [13].

As mentioned above, the humus acids fraction, together with the non soluble fraction of organic matter contributed significantly to the total C content. On average, the share of this fraction ranged from 41.90% (subhumus horizons of sandy

Table 3. Organic carbon content and percentage share of C fractions

Location/use	Horizon	Fractions share (%)				
		NaOH	Humic acids	Fulvic acids	Hemi-celluloses	Residue
Sandy soils						
Wrzosów forest	Ah	60.50	33.80	26.70	1.40	38.10
	Bv	44.25	14.94	29.31	6.50	49.25
Wrzosów arable	Ap	64.42	34.77	29.64	3.23	32.35
	Bv	51.38	39.80	11.58	9.72	38.90
Albertów forest	Ah	51.87	26.25	25.62	1.87	46.26
	Bhs	42.64	24.50	18.14	1.47	55.89
Albertów arable	Ap	47.47	34.48	12.99	2.06	50.47
	Bhs	43.18	28.19	15.00	8.18	48.64
Ziarny forest	Ah	43.79	29.74	14.05	3.07	53.14
	Bv	40.81	30.61	10.20	4.08	55.11
Ziarny arable	Ap	51.07	32.90	18.17	0.64	48.29
	Bv	66.10	30.50	35.59	5.08	28.82
Firlej forest	Ah	77.08	43.75	33.33	6.25	16.67
	Ees	41.66	19.44	22.22	8.33	50.01
Firlej arable	Ap	38.07	24.21	13.85	8.42	53.51
	Bhs	51.96	41.17	10.78	6.37	41.67
Zalesie forest	Ah	44.16	19.25	24.91	3.11	52.73
	Bv	43.43	11.83	31.60	5.80	50.77
Zalesie arable	Ap	36.83	20.41	16.42	7.67	55.49
	Bv	66.08	13.53	52.55	10.78	23.14
Wandzin forest	Ah	36.86	8.70	28.16	2.81	60.33
	Bv	55.30	15.33	39.97	3.58	41.12
Wandzin arable	Ap	42.40	27.62	14.38	7.60	50.00
	Bv	68.33	14.33	54.00	6.17	25.50
Żurowe Bagno forest	Ah	43.46	26.14	17.32	2.60	53.94
	AhBv	30.40	16.66	13.74	2.63	66.97
Żurowe Bagno arable	Ap	42.74	24.53	18.21	2.74	54.52
	Bv	27.70	16.70	10.99	2.75	69.55
Gozdów forest	Ah	37.21	27.70	9.50	2.53	60.26
	Bv	61.40	38.95	22.46	15.79	22.81
Gozdów arable	Ap	43.30	29.22	14.08	5.73	50.97
	Bv	38.04	20.73	17.31	2.96	59.00
Mean forest	humus	49.37	26.91	22.45	2.95	47.67
	subhumus	44.98	21.53	23.45	23.45	48.99
Mean arable	humus	45.79	22.52	17.27	4.76	49.45
	subhumus	51.59	25.62	25.98	6.50	41.90

Table 3. Continuation

Location/use	Horizon	Fractions share (%)				
		NaOH	Humic acids	Fulvic acids	Hemi-celluloses	Residue
		Loess soils				
Czesławice forest	Ah	46.73	21.05	25.68	2.73	50.54
	Eet	36.48	21.89	15.00	2.70	60.80
Czesławice arable	Ap	54.90	22.74	32.15	4.70	40.40
	Bt	28.75	16.66	12.08	8.75	62.50
Miłocin forest	Ah	31.89	20.82	11.08	2.87	65.24
	Eet	36.27	18.38	17.89	3.68	60.05
Miłocin arable	Ap	34.47	22.53	11.93	5.04	60.49
	Bt	16.76	4.41	12.35	5.00	78.24
Stasin forest	Ah	35.68	21.85	13.83	0.74	63.58
	Eet	28.79	17.73	11.06	2.12	69.09
Stasin arable	Ap	32.69	25.87	6.83	3.83	63.48
	Eet	50.47	24.30	26.17	3.74	45.79
Mean forest	humus	38.10	21.24	16.86	2.11	59.78
	subhumus	33.84	19.33	14.65	2.83	63.31
Mean arable	humus	40.68	23.71	16.97	4.52	54.79
	subhumus	31.99	15.12	16.87	5.83	62.18

arable soils) to 63.31% (subhumus horizons of loess forest soils). Similar results were obtained by Borowiec and Wybieralska [2], Pisarek [9], Słowińska-Jurkiewicz [12], Turski [13], Wójcikowska-Kapusta [16].

Generally, loess soils showed a higher percentage share of residue fraction in comparison to sandy soils.

CONCLUSIONS

1. The quantity and quality of organic matter in the soils studied, varied in genetic horizons and depended on soil use.

2. The results confirmed the known regularity of the higher content of C_{tot} in humus horizons than in subhumus horizons and its higher content in forest soils in comparison to arable soils. That also referred to the C fractions.

3. The highest content of C in g kg^{-1} as well as in percent of C_{tot} was demonstrated by the fraction of humus acids and residue, whereas the lowest - the hemicelluloses fraction.

4. In most soils the C ratio of humic to fulvic acids exceeded 1.0. On average, in humus horizons, it was higher in arable soils than in forest soils. Moreover, it appeared to be higher in loess in comparison to sandy soils.

5. In sandy soils, a slightly higher content of humus fraction and a lower one of residue than in Luvisol soils was found.

REFERENCES

1. **Arinuskina E.B.:** Methods of soil chemical analysis. Izdatielstvo Moskovskogo Universiteta, 130-139, 1961.
2. **Borowiec S., Wybieralska A.:** Differentiation of humus composition depending on type and utilization of soils. Roczn. Glebozn., 20, 67-79, 1969.
3. **Czerwiński Z.:** Content of humus, nitrogen and clay minerals in separate mechanical fractions of podzolic sandy soil. Zesz. Probl. Post. Nauk Roln., 40a, 1-13, 1963.
4. **Flis-Bujak M.:** Transformations of humus compounds in soils developed from loess as influenced by crop rotation with various share of cereals. Rozpr. hab. AR Lublin. Rozpr. Nauk., 56, 1-50, 1978.
5. **Gonet S.:** Properties of humus in soils with differentiated fertilization. Organic fertilizers (Pl). AR Szczecin, 1, 288-293, 1992.
6. **Griffith S.M., Schnitzer M.:** Analytical characteristics of humic and fulvic acids extracted from tropical volcanic soils. Soil Sci. Soc. Am. Proc., 39, 861-867, 1975.
7. **Maciejewska A.:** The content of humus and sorption properties of light lextured soils. Zesz. Probl. Post. Nauk Roln., 411, 319-324, 1993.
8. **Musierowicz A., Sytek J.:** Fractions of humus compounds in typical brown and grey-brown podzolic arable soils formed of loess. Roczn. Nauk Roln., 91, 97-111, 1966.
9. **Pisarek I.:** Properties of humus substances extracted from grey-brown podzolic soils. Zesz. Probl. Post. Nauk Roln., 411, 177-181, 1993.
10. **Skłodowski P.:** Transformations of organic matter in rusty and acid brown soils. Roczn. Glebozn., 37, 2/3, 127-137, 1986.
11. **Skłodowski P.:** Influence of soil use on transformation of organic matter. Roczn. Glebozn., 45, 3/4, 77-84, 1994.
12. **Słowińska-Jurkiewicz A.:** Studies on structure and physical properties of loess soils in Lublin region. Rozpr. habil., AR Lublin, 1984.
13. **Turski R.:** Humic compounds in Polish soils. Roczn. Nauk Roln., Ser. D., Monografie, 212, 1-69, 1988.
14. **Turski R., Słowińska-Jurkiewicz A.:** Soils developed from loess. LTN-Lublin, 1994.
15. **Turski R., Uziak S., Zawadzki S.:** The natural environment of the Lublin District. Soils. LTN - Lublin, 1993.
16. **Wójcikowska-Kapusta A.:** The effect of anthropogenic factor on chemical properties and content of some micronutrients in soils developed from loess. Rozpr. habil., Rozpr. Nauk. AR Lublin (209), Wyd. AR Lublin, 1998.