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Porosity and water useful for plants in Luvisols created from sandy silt and silt**

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Abstract. The results of the studies concerning the total and the differential porosity in Luvisols profiles created from sandy-silt and loess were presented. It has been stated that the total porosity of the soils created from sandy-silt formations was smaller than in the soils of loess origin and the differences were the most evident in the upper parts of the profiles of the forest soils. The amount of macropores in the forest soils, created from both parent materials was considerably higher than in the arable soils, while the soils created from sandy-silt formations were characterized by generally lower amount of mesopores and micropores than in the soils created from loess. The amount of water easily available for plants was considerably lower in the soils created from sandy-silt formations than in the soils of loess origin – it was especially well seen for the forest soils. The amount of water difficult available for plants was generally considerably higher than the amount of water easily available, in all the investigated soil profiles and it practically did not depend on the kind of parent material.

Keywords: porosity, pore size distribution, water useful for plants

INTRODUCTION

The air and water regimes of soils not only determine soil water balance but are also decisive for the conditions of plant growth, development and crop yield. They also influence water availability for the plant root system and water transfer with chemical compounds dissolved in it, into deeper soil layers (Arya *et al*., 1999; Greenland, 1981; Kutilek and Nielsen, 1994, Paltineanu, 2003; Rawls *et al*., 2003). Hence, the investigations on porosity and amount of water available for plants, which determines their growth and development and at the same time shapes crop yield, are carried out in many countries of the world (Bauer and Black, 1992; Brakensiek *et al*., 1981; Domżał, 1979; Droogers *et al*., 1997; Ehlers, 1973; Paltineanu, 2003; Walczak *et al*., 2002).

In sustainable agriculture, which assumes the thorough knowledge of natural properties of all the elements of plant and animal production environment, soil is one of its fundamental elements (Dębicki and Gliński, 1999). Therefore, a knowledge about soil properties has of fundamental importance for creation of optimum environment of plant growth and development, spacing of plant cultures and when making a decision about excluding some areas from agricultural production to undertake some renaturalisation measures. It is especially important for the soils created from parent materials, having similar grain-size distributions, morphologically close to each other but being of different origin and frequently with diverse physical properties (Lipiec, 1977). The examples of such soils are Luvisols of Central Europe for which the parent materials are genetically connected with Scandinavian glacier.

The aim of this study was to show the porosity and amount of water useful for plants in Luvisols created from sandy silt and silt under different use.

MATERIAL AND METHODS

The investigations were performed on arable as well as forest Luvisols, created in lessivage process taking place in climatic conditions of Polish Uplands (Cegła, 1963; Słowińska-Jurkiewicz, 1989; Turski *et al*., 1973; Witkowska-Walczak *et al*., 2002). The soil samples (100 cm^3 cylinders) were taken from two sites (Kolbuszowa Plateau, Nałęczów Plateau) situated in the south-east part of Poland. The profile No.1 represented a forest Luvisol, having typical morphology for this kind of soil: Ah-Eet-Eg-Bt-BtC. The profile No. 2 was the arable Luvisol with a profile composition: Ap-Eet-Bt. These both sites were localised on a top land being a culmination of the area. The next two profiles were morphologically close to respective profiles of

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the soils from Kolbuszowa Plateau. The profile horizons of the forest Luvisol (No. 3) were: Ah-AhE-Bt1-Bt2-C and the horizons of arable Luvisol (No. 4) were: Ap-Eet-Bt-C. The basic properties of the genetic horizons of investigated soil profiles are shown in Table 1.

Table 1. Basic properties of investigated soils

Profile number	Genetic horizon	Depth (cm)	% grains of diameter (mm)				$C_{org.}$* (%)	pH	
			2-0.05	0.05-0.02	0.02-0.002	<0.002		in KCl	in H_20
1	Ah	0 - 7	70	20	7	3	2.84	3.7	4.3
	Eet	7 - 23	65	23	7	5	0.38	4.0	4.5
	Eg	23 - 33	51	28	9	12	0.28	4.2	4.7
	Bt	33 - 65	74	10	3	13	0.06	4.2	4.7
	BtC	> 65	57	24	9	10	0.18	3.9	4.1
2	Ap	0 - 16	50	30	15	5	1.27	5.0	5.5
	Eet	16 - 60	51	31	14	4	0.7	5.3	5.7
	Bt	> 60	56	24	15	5	0.2	5.5	5.9
3	Ah	0 - 4	42	32	17	9	3.61	3.7	4.5
	AhE	4 - 24	20	35	29	16	0.67	4.0	4.6
	Bt1	24 - 50	20	35	23	22	0.37	4.0	4.6
	Bt2	50 - 80	32	31	24	13	0.13	4.0	4.8
	C	> 80	84	4	2	10	0.15	4.1	4.6
4	Ap	0 - 15	21	39	30	10	1.42	5.0	5.8
	Eet	15 - 25	16	44	34	6	0.54	5.5	6.1
	Bt	25 - 35	39	25	20	16	0.21	5.8	6.1
	C	> 35	24	39	25	12	0.11	5.4	5.8

*ISO 14235.

The total and differential porosity values were calculated on the base of water retention curves ie the relation between soil water potential and water content (moisture). The range of soil water potential was from 0.1 kJ m^{-3} (pF 0) to 1 500 kJ m^{-3} (pF 4.2) and for the measurements, the standard pressure chambers (made by Soil Moisture Company, Santa Barbara, California USA) were used. A total porosity was taken as the amount of water at 0.1 kJ m^{-3} (pF 0). The amount of macropores was calculated as the difference between the water content at 0.1 kJ m^{-3} (pF 0) and 16 kJ m^{-3} (pF 2.2). The amount of mezopores is the difference between water content at 16 kJ m^{-3} (pF 2.2) and 1500 kJ m^{-3} (pF 4.2) and the quantity of the micropores – as the value of moisture at 1500 kJ m^{-3} (pF 4.2). It was assumed that the amount of water useful for plants, called potentially useful retention (PUR), is in Polish conditions represented by the water content bound in the soil with a potential from 16 kJ m^{-3} (pF 2.2) to 1500 kJ m^{-3} (pF 4.2). The boundary between the easily and difficulty available water for plants is 100 kJ m^{-3} (pF 3) (Zawadzki, 1999).

RESULTS

The total and differential porosity values of investigated Luvisols were shown in Table 2. When analyzing the total porosity of the soils created from sandy-silt formations it can be noticed that it equals 33-52% in the soil profile 1 and 30-43% in the profile 2. In case of soils created from loess, the porosity ranges from 46 to 61% in the profile 3 and from 40 to 46% in the profile 4. The differences of porosity caused by the way of soil management are the most evident in the upper layers of the profiles. In profiles 1 and 3 (forest soils) the total porosity values in the horizon Oh were 52% and 61%, whereas in the profiles 2 and 4 (arable soils) in the horizons Ap the corresponding values were considerably lower – 37 and 43%, respectively.

Table 2. Total and differential porosity of the investigated soils

Profile number	Genetic horizon	Total porosity (% vol.)	Amount (% vol.) of		
			macropores (>18.5 μm)	mezopores (18.5–0.2 μm)	micropores (<0.2 μm)
1	Ah	52	20.5	25.2	6.3
	Eet	40	19.2	16.0	4.8
	Eg	39	16.3	16.2	6.5
	Bt	33	6.3	17.8	8.9
	BtC	45	11.4	24.8	8.8
2	Ap	37	5.5	26.5	5.0
	Eet	43	15.8	22.7	4.5
	Bt	30	5.9	20.4	3.7
3	Ah	61	27.6	20.9	12.5
	AhE	52	17.9	21.3	12.8
	Bt1	47	11.7	19.8	15.5
	Bt2	46	10.0	25.9	10.1
	C	47	10.5	27.4	9.1
4	Ap	43	6.5	25.9	10.6
	Eet	40	4.7	29.0	6.3
	Bt	43	7.8	22.4	12.8
	C	46	10.3	28.6	7.1

The differential porosity ie the distribution of macro- and micropores in the studied soils can be presented in the following way. The content of macropores in the forest sandy-silt soil (profile 1) decreased with the depth from 20.5% in the horizon Ah to 6.3% in the horizon Bt increasing in the horizon BtC to 11.4%. The values of this parameter were different in arable soil (profile 2), reaching the maximum in the lessivage horizon (15.8%) and giving the values of 5.5 and 5.9% in the Ap and Bt horizons, respectively. The distributions of macropores in the forest soil created from loess (profile 3) and in forest sandy-silt soil (profile 1) were very similar. However, the content of macropores in profile 3 was higher (from 27.6% in the horizon Oh to 10% in the horizon Bt2 with slight increase in the horizon C – to 10.5%). In arable soil created from loess (profile 4) the maximum amount of macropores (10.3%) was found in horizon C. In the upper part of the soil profile 4, ie the horizons Ap, Eet and Bt, the content of macropores ranged from 4.7 to 7.8%. The forest soils were characterised by the higher content of macropores comparing with arable soils. If in case of forest soils a high content of macropores is characteristic for the profile created from loess, in upper parts of profiles of arable soils (excluding parent material) we deal with the inverse phenomenon, connected with the small stability of aggregate structure of these soils. The content of mesopores changed as follows: in profile 1 it was from 25.2% in the horizon Oh to about 16% in the horizons Eet, Eg and Bt and 24.8% in the horizon BtC. In profile 2 the content of mesopores decreased slightly with depth from 26.5% in the horizon Ap to 20.4% in Bt. In profile 3, like in profile 1, this content initially decreased with depth, from 20.9% in the horizon Oh to 19.8% in the horizon Bt1 and further on it increased to 27.4% in the horizon C. In profile 4 it did not reveal any relation with the depth and was from 22.4 (Bt) to 29% (Eet). The analysis of the obtained results shows that in the forest soils below the lessivage horizon, the mesopores content was the highest from all the classes of pore sizes. In case of arable soils this property is even more evident and refers to the whole soil profile. It is especially important because the water available for plants is bound in these pores. The content of micropores in the soils created from loess (6.3-15.5%) was higher than in sandy-silt soils

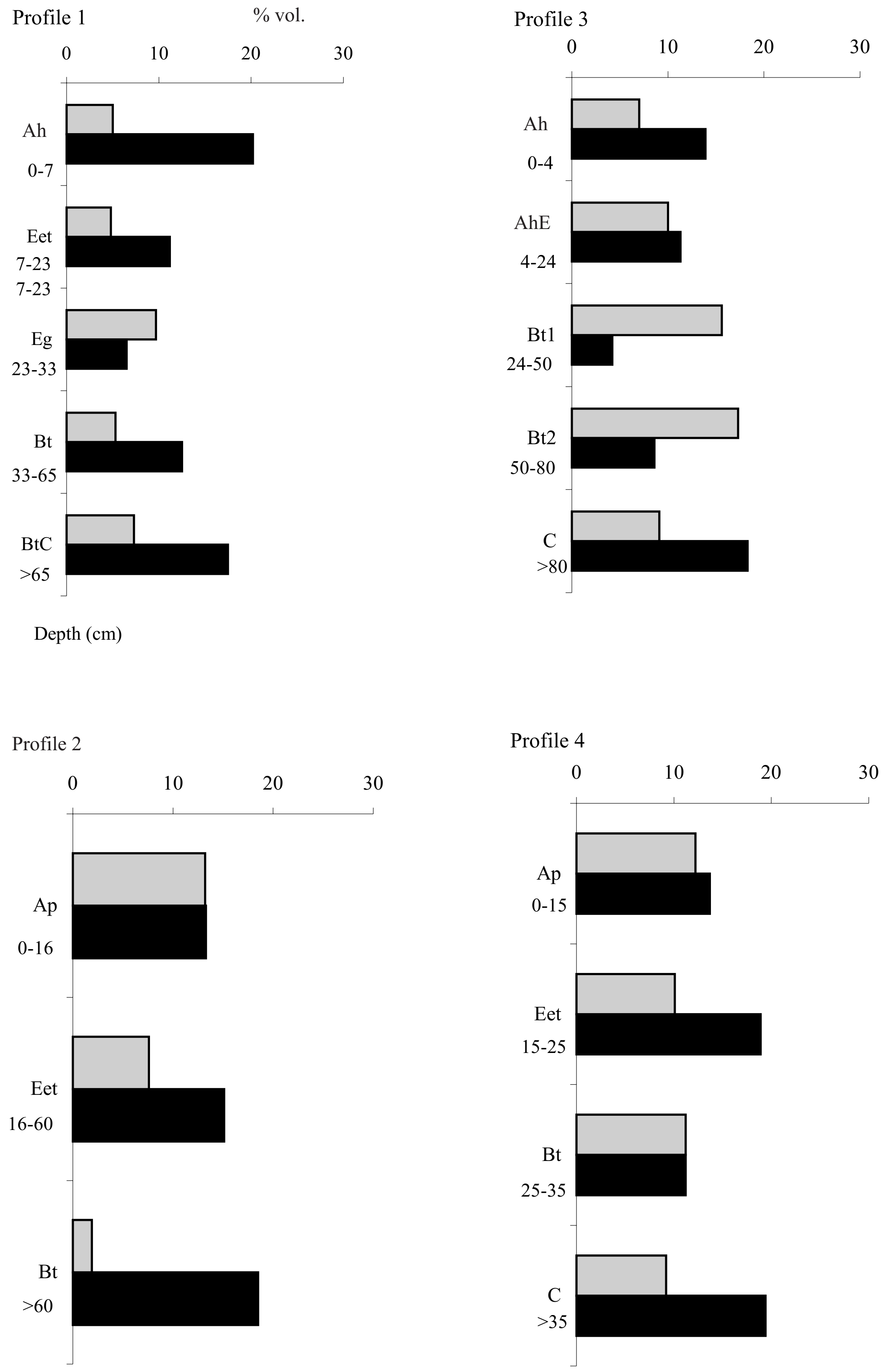

Fig. 1. Amount of water easily (grey) and difficulty (black) available for plants in the investigated soils.

(3.7-8.9%) and higher in forest (4.8-15.5%) than in arable (3.7-12.8%) soils. In the soils created from loess in Bt horizon of profile 3 and in the horizons Ap-Bt of profile 4, the content of micropores was higher than the content of macropores. Similar regularity, in case of sandy-silt formation, was observed only in illuvial horizon of the forest soil, however, it was not observed in the arable soil.

Water available for plants is the water retained in soil pores which have diameters 18.5-2 μm and the water not easily available – pores with diameters 2-0.2 μm. The content of both categories of water available for plants has been presented in Fig. 1.

The content of water easily available for plants in soils created from sandy-silt formations ranges from 4.8 to 9.7% in profile 1 (forest soil) and from 1.9 to 13.2% in profile 2 (arable soil). In the forest soil the content of water easily available for plants was the highest in the horizons Eg (9.7%) and BtC (7.3%) and the lowest in the horizon Eet (4.8%). In the arable soil, the water easily available for plants was 13.2% in the horizon Ap and below this horizon its content decreased rapidly to 1.9% in the horizon Bt. In the soils created from loess, the content of water easily available for plants was higher comparing to the profiles, discussed earlier. In profile3 (forest soil) this content ranged between 7 and 17.3% and in profile 4 (arable soil) – between 9.2 and 12.2%. In the forest soil, the richest in easily available water for plants was the horizon Bt2 (17.3%), whereas the least rich was the horizon Ah (7%). However, in the arable soil, similarly as in the case of analogical as regards the management, profile 2, the content of water easily available decreased down the soil profile from 12.2% in the horizon Ap to 9.2% in the horizon C. The water difficult available for plants in majority of horizons of the investigated soils occurred in the amounts much higher than the water easily available. An exception was in this respect the Eg horizon of the forest soil created from the sandy-silt formation, in which water difficult available for plants occupied 6.5% (at respective 9.7% of water easily available for plants) as well as the horizons Bt1 and Bt2 of the forest soil created from loess, in which this kind of water occupied 4.2 and 8.6% (at respective 15.6 and 17.3% of the water easily available). In arable soils created from the both types of parent material, the content of the water difficult available for plants was always higher than the content of easily available water.

The content of the water difficult available for plants in the soils created from the sandy-silt formation was in the range between 6.5 and 20.2% in profile 1 (forest soil) and between 13.3 and 18.5% in profile 2 (arable soil). In the forest soil the contribution of this kind of water was the highest in the horizon Ah (20.2%), decreasing down the profile to reach 6.5% in the horizon Eg; further down the profile it increased again to 17.5% in BtC horizon. In the arable soil the content of water difficult available for plants increased with the depth from 13.3% in the horizon Ap to 18.5% in the horizon Bt. In case of the forest soil created from loess (profile 3) the content of water difficult available for plants is somewhat smaller as compared to the soil created from the sandy-silt formation. Its distribution down the soil profile is similar as in profile 1. The content of water difficult available for plants was 13.9% in the horizon Ah, it decreased to 4.2% in the horizon Bt1 and reached its maximum – 18.6% in the horizon C. In the arable soil created from loess (profile 4) the content of water difficult available for plants did not show correlation with the depth and was higher than in the arable soil created from sandy-silt formation (profile 2). Its extreme values were: 11.2% in the horizon Bt and 19.4% in the horizon C.

CONCLUSIONS

1. The total porosity of the soils created from sandy-silt formations was lower as compared to the soils created from loess and the most evident differences were in the upper layers of the forest soils profiles.

2. The content of macropores in the forest soils, created from both parent materials, was considerably higher than in the arable soils.

3. The soils created from sandy-silt formations was characterized by generally smaller content of mesopores and micropores as compared to the soils created from loess.

4. The amount of water easily available for plants is considerably smaller in soils created from sandy-silt formations than from loess, what is especially clearly seen in the forest soils.

5. The amount of the water difficult available for plants is generally much higher from the content of water easily available for plants in all the studied soil profiles and it practically does not depend on the kind of parent materials.

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