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*MIROSŁAW ORZECHOWSKI[1], SŁAWOMIR SMÓLCZYŃSKI[1], PAWEŁ SOWIŃSKI[1],
BEATA RYBIŃSKA[2]

[1]*University of Warmia and Mazury in Olsztyn, Department of Soil Science and Soil Protection, Plac Łódzki 3, 10-727 Olsztyn*
[2]*Student*

Water repellency of soils with various content of organic matter in north-eastern Poland

Abstract: The objective of the work was to investigate hydrophobic properties of soil formations with various amounts of organic matter and occurring in young glacial landscape. The research was carried out in mineral, mineral-organic and organic (slightly and strongly silted mucks, sedge peat, alder wood peat, reed peat) soil formations. Water repellency is very important in soil protection. It favors the formation of stable aggregates and prevents from soil erosion. The study was carried out applying two methods – water drop penetration time test (WDPT) and alcohol percentage test (AP). Among 51 analyzed soil samples in WDPT test, 64.7% of mineral and mineral-organic soil formations were hydrophilic. Among organic soil formations 37.6% was slightly and strongly hydrophobic and they represented strongly silted mucks. Unsilted and slightly silted mucks, weakly and strongly decomposed peats, were very strongly (18.8%) and extremely (43.6%) hydrophobic. AP test showed that strongly silted mucks were moderately and very strongly hydrophobic. Slightly silted mucks, and peats were very strongly and extremely hydrophobic. It can be stated that water repellency decreases simultaneously with the degree of siltation of organic soil formations.

Key words: water repellency, mineral and mineral-organic soil formations, peats, slightly and strongly silted moorsh

INTRODUCTION

Soil hydrophilic and hydrophobic properties are significant in the protection of soil environment. Although hydrophobicity favors stable soil structure, it is the source of many negative properties and processes (Tisdall and Oades, 1982). Soils with high hydrophobicity, have low water retention abilities, which leads to unfavorable conditions for plant growth (Berglund and Persson, 1996). Low wettability of solid phase of surface horizons impedes the flow of rainwater to deeper horizons of the soil profile, which results in surface water erosion (Czachor, 2009). In hydrophobic soils, the filtration of rainwater occurs mainly through "preferential paths", made by cracks and holes (Łachacz and Kalisz, 2006).

The amount and type of soil organic matter significantly influences soil hydrophobic and hydrophilic properties (Bisdom et al., 1993; Maryganova and Szajdak, 2006). High hydrophobicity occurs in peats and mucks and they lose their abilities to retain water (Berglund and Persson, 1996; Szatyłowicz et al., 2006). In the investigated catenas, there are various types and kinds of soils (Komisja V Genezy, Klasyfikacji i Kartografii Gleb PTG, 2011). Soils are created from formations containing various amounts of organic matter, which has direct impact on soil hydrophobicity. During muck-forming process, surface horizons of organic soils become hydrophobic, cation exchange capacity becomes lower and base cations, mainly Ca and Mg, are leached (Berglund and Persson, 1996; Piaścik and Łachacz, 2001). Maryganova and Szajdak (2006) as well as Czachor (2009) stated that most soil functions, including hydrophysical properties depend on the quantity and quality of soil organic matter.

The aim of the research was to determine water repellency of soils of diffrentiated organic matter content (mineral, mineral-organic and organic) in young glacial landscape.

MATERIALS AND METHODS

The research was carried out in various types of soils formed from formations with various content of organic matter. The soils sites are located in three catenas: Reszel in Sepopol Lowland, representing the lithological-landscape zone of ice-dammed lakes plains, and Wągsty and Nawiady catenas located in Mazurian Lakeland in morainic zone (Gotkiewicz and Smołucha, 1996). Denudation processes occurring on slopes, contribute to the translocation of soil mate-

*e-mail: miroslaw.orzechowski@uwm.edu.pl

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rial from the upper parts and its accumulation in land depressions. As a result of flowing and transportation of soil material on the slopes, organic soils in land depressions become silted and covered with mineral deposits, and their properties become significantly different (Orzechowski and Smólczyński, 2002).

Fifty one soil samples were examined. They included mineral soil formations containing up to 10% of organic matter, mineral-organic soil formations (10–20% of organic matter) and organic soil formations (more than 20% of organic matter). Among organic soil formations, regarding silting degree there are: unsilted soil formations (which contain up to 25% of mineral fraction), weakly silted (25–50% of mineral fraction) and strongly silted (50–80% of mineral fraction), (Piaścik and Okruszko, 1990).

The soil samples from surface horizons were air-dried, ground and sieved through 2.00 mm sieves. The hydrophobicity was determined at 20°C using two simple methods: Water Drop Penetration Time – WDPT and Alcohol Percentage Test – AP. Soil formations were then classified into hydrophobicity categories according to Doerr (1998). In WDPT test 15 drops of distilled water were applied and median was calculated. In AP test, six alcohol concentrations were applied: 3; 5; 8.5; 13; 24, 36 and 50% vol. Both methods are simple and used for direct hydrophobicity measurements. The research was carried out on air-dried soil samples. Therefore the results reflect potential hydrophobicity and the results are regarded as approximate soil hydrophobicity (Dekker and Ritsema, 1994).

The following properties of soil samples were examined: texture by Bouyoucos-Cassagrande method modified by Prószyński, organic carbon by Tiurin method, soil reaction in H_2O and KCl potentiometrically, sorptive capacity by Kappen method, loss-on-ignition at 550°C as organic matter content (Mocek et al., 1997).

RESULTS AND DISCUSSION

Soils at Reszel catena contain more colloidal clay (<0.002 mm), organic carbon and have higher soil sorptive capacity than the soils at Wągsty and Nawiady catenas. In this catena, black earths occur at the top of the slopes and humous deluvial soils in lower parts of the slope. These soils are formed from loam, silty clay loam and clay loam containing 20–40% of clay fraction (PTG, 2009). The amount of organic carbon ranges between 16.2 and 57.4 $g \cdot kg^{-1}$ of soil. In mid-moraine depressions mucky soils as well as weakly and strongly silted peat-muck soils occur. Under muck horizon, (Mt), which thickness reaches 29 cm, medium decomposed (R2) reed peat occurs. In Wągsty and Nawiady catenas, located in hilly lakeland landscape, eroded lessive soils and brown pararendzinas were formed from loamy sand and sandy loam. Lower parts of the slope are occupied by proper, humous and brown deluvial soils formed from sandy loam and contain 4–15% of clay fraction. In the investigated soils the content of organic carbon ranges between 5.4 and 38.4 $g \cdot kg^{-1}$ of soil. Simultaneously with lowering of land, deluvial soils evolve into mucky soils as well as weakly and strongly silted peat-muck soils. The thickness of muck horizon ranges between 20 and 26 cm. Underneath, strongly decomposed (R3) alder peat and medium decomposed (R2) sedge peat occurs.

As it is shown in Table 1, studied soil formations have diffrent WDPT. The Water Drop Penetration Time (WDPT) test proved that all studied mineral soil formations, irrespective of texture and organic carbon content, were hydrophilic. Among mineral-organic soil formations, most were hydrophilic and only two were slightly hydrophobic. These soil samples represent mineral-organic horizons (AO) of mucky soils in the zone of ice-dammed lakes origin, where deluvial deposits are fine-grained and contain more organic matter than deposits in morainic zone. Among 51 analyzed soil samples in WDPT test 64.7% were hydrophilic and 35.3% were hydrophobic.

In WDPT test the greatest differentiation in water repellency was stated in organic soil formations. 37.6% of studied organic formations, represented by strongly silted mucks (Table 1, 2), were slightly and

TABLE 1. WDPT categories of investigated groups of soil formations

WDPT		Mineral formations		Mineral-organic formations		Organic formations	
categorie*	time [s]	n	[%]	n	[%]	n	[%]
1	<5	27	100	6	75.0	0	0
2	5–10	0	0	2	25.0	0	0
3	10–30	0	0	0	0	2	12.5
4	30–60	0	0	0	0	1	6.3
5	60–180	0	0	0	0	2	12.5
6	180–300	0	0	0	0	1	6.3
7	300–600	0	0	0	0	0	0
8	600–900	0	0	0	0	0	0
9	900–3600	0	0	0	0	3	18.8
10	3600–18000	0	0	0	0	7	43.6
Sums		27	100	8	100	16	100

Explanations: * categories according to Doerr (1998), n – number of samples.

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TABLE 2. WDPT categories of investigated groups of soil formations

Soil formations	Content organic matter [%]	Soil formations acc. to PTG 2008	WDPT categories
Mineral proper	0–3	LS*, SL, SCL, SiCL	1 hydrophilic
Mineral humous	3–10	LS, SL, L, CL	1 hydrophilic
Mineral-organic	10–20	mineral-organic formations	1, 2 hydrophilic and slightly hydrophobic
Organic – strongly silted – slightly silted and non silted	 20–50 50–75	 moorsh moorsh, sedge peat (R2)**, alder-wood peat (R3), reed peat (R2, R3)	 3, 4, 6 slightly and strongly hydrophobic 9, 10 very strongly and extremely hydrophobic

Explanations: * LS – loamy sand, SL – sandy loam, L – loam, CL – clay loam, SCL – sandy clay loam, SiCL – silty clay loam; ** R2 – medium decomposed peat, R3 – strongly decomposed peat.

TABLE 3. Hydrophobicity categories of soil organic formations in AP test

Soil formations	Ethanol percentage [% vol.]						
	3	5	8.5	13	24	36	50
1. Mucky soil – mineral-organic formations	2*	–	–	–	–	–	–
2. Peat-muck soil – moorsh strongly silted	–	–	2	2	–	–	–
3. Peat-muck soil – moorsh slightly silted	–	–	–	–	3	1	–
4. Peat-muck soil – reed peat, sedge peat (R2) – reed peat, alder-wood peat (R3)	 – –	 – –	 – –	 – –	 1 –	 2 2	 – 3

Explanation: * number of samples.

strongly hydrophobic (categories 3–6). Weakly silted mucks, unsilted medium (R2) and strongly (R3) decomposed sedge, alder and reed peats were strongly hydrophobic (category 9) and extremely hydrophobic (category 10). Increasing content of mineral fraction in organic soil formations resulted in lower hydrophobicity, which was also stated by Szatyłowicz et al. (2006).

The Alcohol Percentage (AP) test proved that mineral-organic soil formations were hydrophilic (Table 3). Strongly silted mucks were moderately and strongly hydrophobic, whereas weakly silted mucks were mostly very strongly hydrophobic. Similarly to WDPT test, the highest hydrophobicity was noted in peat formations, which were classified as very strongly and extremely hydrophobic. Particularly low wettability was stated in strongly decomposed (R3) reed and alder peats. Similar results were obtained by Łachacz and Kalisz (2006), Szatyłowicz et al. (2006) and Łachacz et al. (2009).

Correlation coefficients revealed statistical positive dependence between hydrophobicity of studied soil formations and the amount of organic carbon, and organic matter content. Statistically negative dependence was noted between the WDPT of soil formations and soil reaction (pH in H_2O), and base saturation (Table 4).

TABLE 4. Correlation coefficients between the hydrophobicity and some soil properties

Specification	pH		Corg	Organic matter	Cation exchange capacity	Base cation saturation
	H_2O	KCl				
Mineral, mineral-organic and organic formations, n=51						
WDPT	-0.4151*	-0.2489	0.5101*	0.7900*	0.4669*	-0.4160*
Mineral-organic and organic formations, n=18						
WDPT	-0.6624*	-0.6895*	0.45523*	0.7872*	0.2303	-0.4428*

Explanation: * significance level at α= 0.05.

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CONCLUSIONS

1. The analyses of hydrophobic properties revealed that mineral soil formations, irrespective of texture and organic matter content, were hydrophilic. Mineral-organic soil formations were hydrophilic and slightly hydrophobic, whereas, organic soil formations were highly hydrophobic.
2. The Water Drop Penetration Time (WDPT) test showed that 65% of soil formations were hydrophilic, 9% were slightly hydrophobic, 12% were strongly and very strongly hydrophobic and 14% were extremely hydrophobic. Various WDPT were noted in organic soil formations.
3. On the basis of Alcohol Percentage (AP) test it was noted that strongly silted mucks are moderately and strongly hydrophobic. Weakly silted mucks were mostly very strongly hydrophobic and unsilted strongly decomposed peats were very strongly and extremely hydrophobic.
4. Hydrophobicity of the investigated soils is significantly dependent on organic matter content, its state of decomposition and degree of silting.

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Streszczenie: Celem pracy było zbadanie właściwości hydrofobowych gleb wytworzonych z utworów glebowych o różnej zawartości materii organicznej, występujących w krajobrazie młodoglacjalnym. Badania przeprowadzono na glebach wykształconych z utworów mineralnych, mineralno-organicznych i organicznych. Utwory organiczne były reprezentowane przez mursze oraz torfy turzycowiskowe, olesowe i szuwarowe, słabo i silnie zamulone. Badania przeprowadzono przy użyciu dwóch metod: czasu penetracji kropli wody (WDPT) i testu procentowości alkoholu (AP). Spośród 51 analizowanych próbek glebowych, w teście WDPT 64,7% utworów mineralnych i mineralno-organicznych było hydrofilowych. W grupie utworów organicznych do kategorii słabo i silnie hydrofobowych zakwalifikowano 37,6% badanych próbek glebowych, reprezentowanych przez mursze silnie zamulone. Mursze słabo zamulone oraz torfy niezamulone, średnio i silnie rozłożone zaliczono do kategorii utworów bardzo silnie hydrofobowych (18,8%) oraz ekstremalnie (43,6%) hydrofobowych. Badania testem AP wykazały, że silnie zamulone mursze były umiarkowanie i bardzo silnie hydrofobowe. Mursze słabo zamulone i torfy były bardzo silnie i ekstremalnie hydrofobowe. Stwierdzono, że wraz ze wzrostem stopnia zamulenia utworów organicznych zmniejsza się ich hydrofobowość.

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