WATER REPELLENCY OF FERRALSOL AS A FUNCTION OF TEXTURE AND SOIL DEPTH

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ABSTRACT: Water repellency affects several soil properties such as infiltration, surface runoff, preferential flow and aggregate stability. The water repellency index (R) depends for example on content and the degree of decomposition of organic matter, pH-value, and land use. Various authors agree about the effect of these variables concerning hydrophobicity. But about the effect of the soil texture various statements are found. The aim of this work is to show the effect of texture and of depth (most investigations about water repellency have been restricted to the topsoil) of the water repellency of two Ferralsols with different texture. It could be shown that R of the sandy Ferralsol for all water contents was higher than for the clayey Ferralsol. There was no dependence of the water repellency on depth. The decrease in R of the sandy Ferralsol with drying from –300 hPa to 40 °C was unexpected. When soil is oven-dried (40 °C), the organic matter normally presents largely nonpolar groupings on its surface and becomes water repellent. However, we suggest that in this case the rapid drying of the sandy aggregates in the oven changed the coatings of mineral particles and due to that cracks were developed on the surface and created a decrease of the hydrophobicity.

Keywords: *hydrophobicity, wettability, oxisols*

INTRODUCTION: Soils normally are assumed to be completely wettable, although it is only true for pure quartz or organic free systems. Water repellency (R) can be used to quantify hydrophobicity. It can be calculated from the ratio of the sorptivities for two liquids of different viscosity and surface tension (Hallett & Young, 1999). Probably the most influencing variable for the water repellency is the soil water content, because the water content can alter the wetting properties and therefore the hydrophobicity of a soil is not static (Dekker et al., 1998, Goebel et al., 2004). Another critical variable for the occurrence of hydrophobicity is the quantity and quality of organic substance (Dekker et al., 1998; Ellies, 1975; Hartge et al., 1986; Ellies and Hartge, 1976; Janßen et al., 2004). Furthermore its distribution over the surfaces on the soil particles plays a key role (Bachmann, 1988; Hartge et al., 1986). The more decomposed is the organic substance, the greater is the wetting angle (Bachmann, 1995; Burghardt, 1985; Janßen et al., 2004; Zhang and Hartge,1991). However, there are different results about the effect of texture on water repellency in the literature. DeJonge et al. (1999), Chenu et al. (2000) and Ellies and Hartge (1976) showed that smaller soil size fractions exhibited the highest degree of water repellency and explained this by higher organic matter content in the fractions. In contrast results of Bisdom et al. (1993), McKissock et al. (2003) and Woche et al. (2005) show higher hydrophobicity for sandy soils. Woche et al. (2005) concluded that a coarser texture results in a thicker coating with hydrophobic organic matter. Bisdom et al. (1993) also explained that water repellency is often attributed to coatings present on sand grains. Since until now most investigations about water repellency were restricted only to material from the topsoil, the aim of this study was to examine the effect of soil texture and depth of two Ferralsols from southern Brazil.

MATERIAL AND METHODS: One clayey and one sandy Ferralsol of south Brazil were sampled. The aggregates had a diameter of about 2cm and originated from the first three horizons (Table 1).

To analyse sorptivity, the soil aggregates (20 replicates per horizon) were saturated and afterwards equilibrated to -6 kPa, -30 kPa and 40 °C and measured according to Hallett and Young (1999). The measurement was conducted with distilled water and with ethanol. The different viscosities and wetting characteristics of the two liquids allow for the calculation of the water repellency index (R) (using equations [1-3]).

Table 1. Morphological and chemical characteristics and texture of the Ferralsols.

Soil classes	Parent material	Horizon	Depth (cm)	Soil color	Sand -------	Silt g kg-1	Clay -------	pH	C/N

		A	0-35	5YR 3/3	733	64	203	5.1	14.4
Sandy loam Rhodic	Sandstone	AB	35-86	5YR 3/4	693	59	248	4.8	15.3
Ferralsol		BA	86-123	2.5YR 3/5	627	82	291	4.9	14.4
		A	0-22	2.5YR 2.5/4	60	418	522	4.7	13.5
Heavy clay Rhodic	Basalt	AB	22-56	2.5YR 3/4	32	292	676	4.8	14.2
Ferralsol		BA	56-102	10R 3/4	7	232	761	4.8	13.4

$Sw = [(\mu E/\gamma E)1/2/(\mu W/\gamma W)1/2] SE$ [1]

where, SW = Sorptivity water, SE = Sorptivity ethanol, μE = viscosity 95% ethanol solution 20°C = 0.0012 N s m-2, γE = surface tension 95% ethanol solution 20°C = 0.023 N m-1, μW = viscosity water 20°C = 0.0010 N s m-2, γW = surface tension water with 20°C = 0.073 N m-1.

$SW = 1{,}95SE$ [2]

$R = 1{,}95(SE/SW)$ [3]

RESULTS AND DISCUSSION: The repellency R increased continuously with increasing desiccation for the clayey Ferralsol (Figure 1a). Values of the water repellency stay beneath the critical threshold of R= 1.95. Thus, no serious water repellency occurs in all three horizons and for all water contents. However, the water repellency of the sandy Ferralsol (Figure 1b) showed values above R = 1.95. Water repellency R increased from pF 1.8 to pF 2.5, where it displayed the highest value. However, further desiccation to pF 5 lead to a decrease of the water repellency in all depths; in the first horizon (A) even a value of R smallert than1.95 was determined.

A significant effect of the depth could not be seen in the clayey Ferralsol. There was a slight tendency of an enhancement of R with increasing depth, but however there are no significant differences.

A B

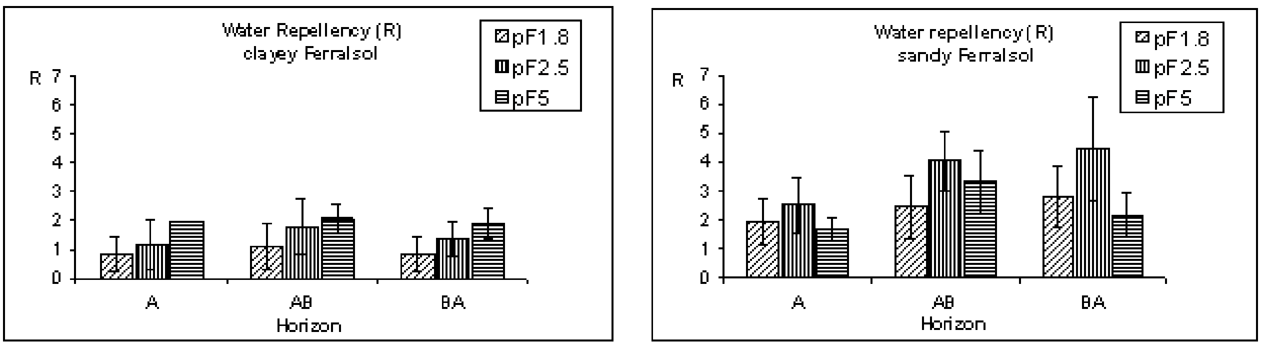

Figure 1: Water repellency of different horizons and/or depths for different water contents. 1a: heavy clayey Rhodic Ferralsol; 1b: sandy loam Rhodic Ferralsol. The bars show the standard deviation. The horizontal line at 1.95 R show the treshold of water repellency (R> 1.95 means equal to water repellent soil; R < 1.95 = subcritically water repellent).

Generally all values of R > 1 indicate hydrophobic properties, which are affected for example by the organic substance (Ellies, 1975; Bisdom et al., 1993; Giovannini et al., 1983; Janßen et al., 2004; Zhang and Hartge, 1991), its quality (Ellies and Hartge, 1976), the pH value (Bachmann, 1988), the micro organisms and their metabolites (Hallet and Young, 1999) as well as the vegetation (McGie and Posner, 1981).

The water repellency rose continuously for the clayey Ferralsol (Fig. 1a) when increasing desiccation. Doerr and Thomas (2000, cited in Goebel et al. 2004) argue that because an increase of the water content leads to a decrease of the water repellency due to the detachment of hydrophobic molecules from the mineral particles it also results in nonrepellent polar surfaces.

However, the texture plays an important role, too. Woche et al. (2005) concluded that wetting properties are primarily explained by soil texture, this result is in agreement with our results. The soils have similar chemical properties as pH value, C/N and the amount of different types of carbon (like Alkyl-C, O-alkyl-C, aromatic-C, Carboxylic-C and Carbonylic C; data not shown here) and similar land use. But the soils show significant differences in texture.

Our results exhibit that the sandy soil has a greater water repellency and hydrophobicity than the clayey Ferralsol. These results are in agreement with McKissock et al., (2003), Capril et al. (1995) and Goebel et al. (2004), stating that organic matter in sandy soils is more hydrophobic than organic matter in more clayey soils. Woche et al. (2005) concluded that a coarse texture favours, in combination with other factors (mainly pH), hydrophobic soil organic matter. However, this effect is still discussed controversely because other authors like de Jonge et al. (1999) and Ellies and Hartge (1976) observed that in water repellent soil the smaller soil size fractions exhibited the highest degree of water repellency at each water content. They explained this partly by higher organic matter content in the fractions with smaller particle size.

The water repellency R shows an unexpected decrease of the sandy Ferralsol from –300 hPa to 40 °C. When soil is oven-dried, the organic matter normally presents largely nonpolar groupings on its surface and becomes water repellent. Experiments of Goebel et al. (2004) and deJonge et al. (1999) show similar results.

Our data, however, showed that the maximum contact angle was not found for the material in the oven-dry state but rather at higher water content. De Jonge et al. (1999) furthermore described that mainly very coarse soils are affected by temperature and the more sandy soils have two peaks on the water repellency curves, which indicate that if temperature affects specific types of organic matter, the temperature effect is independent of the amount of organic matter. We suggest that in our case the rapid drying of the sandy aggregates in the oven (40 °C) changed the organic coatings of the mineral particles. Rapid desiccation may develop coarser cracks on the surface of the coatings and allow water infiltration and, thereby, a decreased hydrophobicity.

An effect of soil depth can not be seen for the clayey Ferralsol. There is a slight tendency of increasing hydrophobicity with increasing depth, but we could not detect significant differences for the quantity of the analyzed samples. This is in agreement with Woche et al. (2005).

CONCLUSIONS: Soil texture has a lasting effect upon hydrophbicity. The sandy Ferralsol has higher water repellency and/or is more hydrophobic than the clayey Ferralsol. No crucial effect of depth upon water repellency could be found in our investigations.

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