Experimental Study on Soil Water Repellency of Volcanic Ash Soils: Effects of Initial Water Content and Organic Matter Content
黒ぼく表土の撥水性評価に関する実験的研究：初期水分量と有機物含有量が及ぼす影響

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1. Introduction

Soil water repellency can severely reduce infiltration of water, promote surface runoff and erosion, and give rise to preferential flow (fingering flow) of water. The degree of soil water repellency depends on both of the organic matter content and the water content of soil. In general, the effect is stronger for dry soils and decreases with increasing water content. For soils consisting of initially high water content, water covered the organic matters coating on soil particles (or aggregates) can reduce hydrophobic property.

The main purpose of our study is to examine the effects of initial water content and the amount of organic matters influenced over the degree of soil water repellency. In order to evaluate soil water repellency, we conducted Water drop penetration time (WDPT) test, Ninety degree surface tension (NDST) test, Capillary rise test and Horizontal absorption test.

2. Materials and Methods

Soil sampling was carried out on the volcanic ash soil on which a coniferous forest was planted at Nishigo Village, Fukushima Prefecture. Soil profile at the sampling site consisted of three layers; i.e., litter 0-5cm, black surface soil 5-18cm, and light-brown subsoil 18-100cm. Organic matter content of the surface soil was approximately 20-25%. All the soil samples passed through 2mm sieve at the preliminary of each test. Both ignition loss method and dichromic acid method were applied for measuring organic matter contents of L_i (%) and C_o (%), respectively.

In WDPT test, small drops of distilled water from a hypodermic needle were placed on a soil surface, and the time for a water drop to infiltrate into the soil was recorded as WDPT. We distinguished the repellency classes followed by the classification of Bisdom et al (1993).

The degree of water repellency was determined by NDST test and given as the method consisted of preparing a series of aqueous ethanol solutions with varying surface tension (de Jonge et al., 1999). We recorded the minimum surface tension at which an ethanol drop from a hypodermic needle could remain on the soil surface for 5 sec. The lower the value of surface tension, the stronger the degree of water repellency signified.

In Capillary rise test, a cylindrical soil column with 30cm height and 1.2 cm inner diameter was immersed in water and as well as in 100 vol. % ethanol solution. We recorded the height of capillary rise h as a function of time, and then calculated the contact angle α using the equation $K' = K\cos\alpha$ (K' and K are the initial gradients obtained by using linear regression for less than 30 seconds of h^2 vs. t curves in Fig. 1 (Ishiguro & Koopal, 2000)).

We obtained sorptivity from Horizontal absorption test. A cylindrical soil column with 30cm length and 1.5 cm inner diameter was used. Three initial water contents of q_i =0.05 (air-dry), 0.19, and 0.46 and six water pressure head h_0 (-cm) of 2.5, 5, 10, 16, 22, and 28 were prepared. Sorptivity was determined from the slope of cumulative absorption I vs. square root of time $t^{1/2}$ (Fig.2).

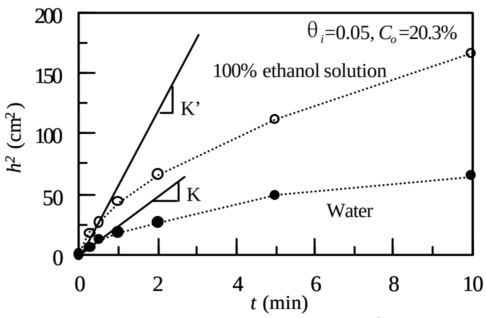

Fig. 1 Square of capillary rise height h^2 as a function of time t.

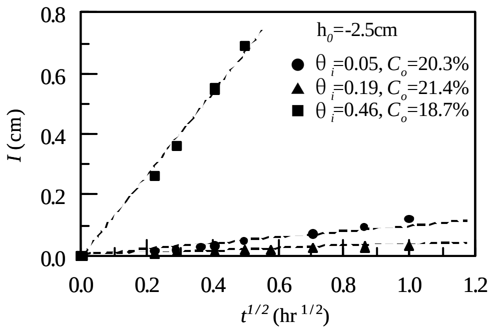

Fig. 2 Cumulative absorption I as a function of square root of time $t^{1/2}$.

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Key words: Soil water repellency, Volcanic ash soil

3. Results and Discussion

The results of WDPT test were shown in Fig 3. Water repellency (WR) are separated 3 zones; i.e., extremely WR zone of $C_o>10$ and $0.15<q_i<0.25$, transitional zone and non-repellent zone of $C_o<5$ and $q_i>0.35$. According to the results of NDST test in Fig. 4, q_i at which the peak NDST happened varies with C_o. The peaks were found at q_i =0.34 in cases of C_o=22.2 and 19.2 %, and at q_i =0.25 in a case of C_o=8.4 %.

The contact angles α obtained from Capillary rise test were tabulated in Table 1. The contact angles vary from 72 to 89 degrees depending on q_i, and the maximum value was found at q_i =0.19.

The results of Horizontal absorption test showed that soil water repellency could reduce the infiltration rate of water significantly. Sorptivities at q_i =0.19, for example, were about 1/50 smaller than those at q_i =0.46 as shown in Fig. 5 and Table 1.

Finally, we tabulate WR classification oftained from each test in Table 1. The highest WR obtained from WDPT, Capillary rise test, and Horizontal absorption test were found to be identically at q_i =0.19. However, NDST test result deviated and the highest WR occured at q_i =0.34.

Table 1. WR classification obtained from each test.

q_i	WDPT (class)	NDST (N/m)	Contact angle (degree)	Sorptivity (cm/hr$^{1/2}$)
0.05	severely	0.067	84	0.203
0.19	**extremely**	0.059	**89**	**0.038**
0.34	strongly	**0.054**	72	-
0.46	wettable	-	-	1.558

Acknowledgements

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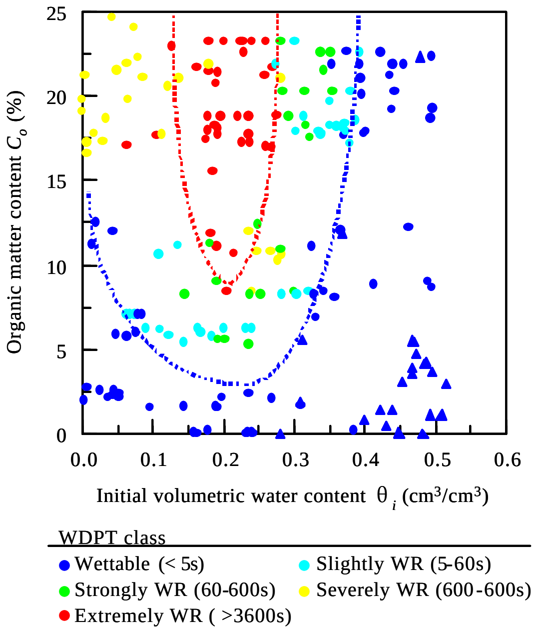

Fig. 3 Scatter diagram of soil water repellency obtained from WDPT tests.

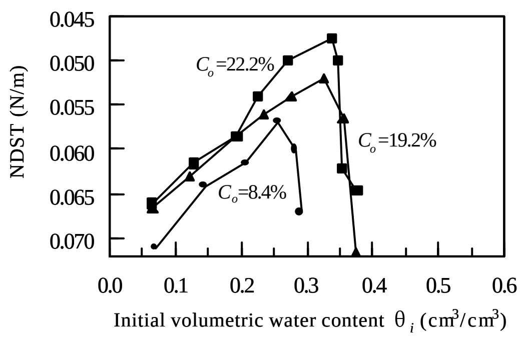

Fig. 4 Soil water repellency obtained from NDST tests.

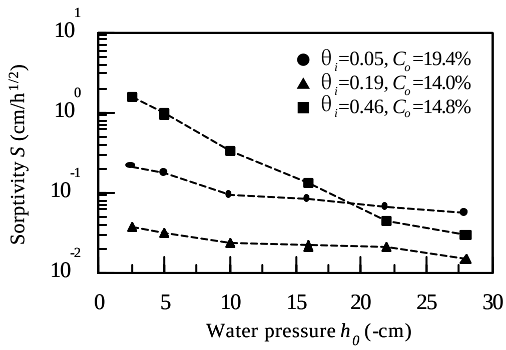

Fig. 5 Sorptivity S as a function of water pressure h_0.