Effects of Heating on Organic Matter Induced Soil Water Repellency

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Abstract

Soil organic matter plays an important role in making a soil wettable or repellent. Water repellency produced by heating of non-repellent organic matter in soil is common on burned forests and watersheds. The objective of the present study was to identify the effect of laboratory heating on wettability of organic material amended soils. Goat manure (GM), poultry litter (PL), Casuarina *(CE)* leaves, and three types of fine woody debris namely Alstonia (AL), Domba (DO), and Mango (MN) were used to represent organic materials which were heated to temperature levels of 27 °C, 60 °C, 100 °C, 200 °C for a 6 h heating duration. The water drop penetration time (WDPT) was used for the assessment of wettability. Samples with 50% GM showed the lowest WDPT of ~60 s, whereas those without organic material amendment showed the highest WDPT of 0 s within temperatures of 27 °C to 100 °C. Wettability of samples with animal manure did not show a considerable alteration with increasing temperature up to 100°C. Among the plant materials, 50% CE and DO showed WDPT>3600s. The WDPT of samples with 50% AL (57 s to 963 s), 50% MN (9s to 88s), and 5% CE (32s to 133s) increased with increasing temperature from 27 °C to 100°C. Wettability of most plant materials decreased when the temperature increased. All the animal manure and plant material amended soils, except those with 50% PL, became completely wettable (WDPT = 0 s) when the samples were exposed to 200°C. This might be explained as a result of the removal of organic matter as CO_2 and H_2O under high temperature heating. Reason for PL added soils to show a measurable WDPT after heating to 200 °C might be the incomplete removal of organic matter as a temperature higher than 200 °C is required for the loss of organic matter on ignition.

Key words: Heating, Organic matter, Water repellency

Introduction

Water repellent soil does not wet rapidly when water is applied on the surface. Water repellent soils are found worldwide especially in adverse type of soils under different cropping systems (Wallis and Horne, 1992). Soil organic matter plays an important role in making a soil hydrophyllic (wettable) or Hydrophorbic (repellent) (Leelamanie and Karube, 2007).

The basic cause behind the creation of water repellency in soil is the coating of mineral soil particles with hydrophobic organic substances. Organic matter induced water repellency in soil occurs by several means. The irreversible drying of organic matter induces water repellency. Some researchers report that surface layers of peat soils are difficult to rewet after drying. Organic substances leaching out from plant litter also induce water repellency in sand and coarse grained soil. Coating of mineral soil particles by hydrophobic microbial byproducts would encourage water repellency. In addition to the hydrophobic organic coatings, intermixing of mineral soil particle with hydrophobic organic matter would also create a water repellent soil.

Heating of potentially water repellent soils leads to change their wettability (Dekker and Ritsema, 1994). Heating of the hydrophobic organic matter in coatings or intermixed soils could increase the water repellency. Water repellency produced by heating of non-repellent organic matter in soil is common in burned forests of watersheds. Heating of hydrophobic material in coated mineral particles would vaporize the hydrophobic organic substances, which would re-condense at cooler sites. Heating of organic matter in intermixed soils helps to coat adjacent mineral particles with organic compounds.

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The severity of soil water repellency upon exposure to heat, mainly due to burning depends on several factors. Type of organic matter, vegetation, the severity of fire or the heating temperature, heating time, post-heating equilibration time are some of the factors that may affect the wettability of water repellent soil (Doerr *et al.*, 2005). The objective of the present study was to identify the effect of laboratory heating on wettability of organic matter amended soils.

Materials and Methods

Sample preparation

Arable top soil (0-10 cm) obtained from an agricultural land, Udupila, Mirissa, (Udults) used for the experiment. Soil was air dried and sieved through 2 mm sieve before mixing with organic materials.

Goat manure (GM), poultry litter (PL), Casuarina *(Casuarina equisetifolia,* CE*)* leaves, and three types of fine woody debris, Alstonia (*Alstonia macrophylla,* AL*)*, Domba (*Calophyllum inophyllum,* DO), and Mango (*Mangifera indica,* MN*)* were used to represent organic materials, where the soil without organic manure was used as the control. All organic material types were air dried ground with a mechanical grinder and sieved through 1 mm sieve prior to mixing with sieved soil to obtain 5 and 50% of added amounts.

Heat treatment

Four temperature levels of 27 °C, 60 °C, 100 °C, 200 °C, with three replicates per treatment were implemented. The time of heat exposure was 6 h. Samples placed in porcelain crucibles were placed in a preheated muffle furnace.. Thereafter, the samples were left under the laboratory conditions (27±3°C, 75±5% relative humidity) for 24 h prior to the wettability assessment.

Water drop penetration time test

The water drop penetration time (WDPT) was used for the assessment of soil wettability. Approximately 5-g cooled subsamples in weighing bottles were added with one drop of distilled water representing a volume of 50-µl onto the sample surface using a micropipette set at a height of 10 mm. The time taken for the complete penetration of the water drop was measured. Samples with a WDPT ≤ 1 s were considered non-repellent, 1-60 s slightly repellent, 60-600 s strongly repellent, 600-3600 s severely repellent and ≥ 3600s extremely repellent (Leelamanie *et al.*, 2008).

Results and Discussion

The WDPT of animal manure and plant materials amended soils at various temperatures are shown in Figure 1 (a) and (b), respectively. Samples with 50% GM showed the lowest WDPT of ~60 s, whereas the soil samples without organic material amendment showed the highest WDPT near 0 s under temperature ranging from 27 °C to 100°C. According to the WDPT data, the

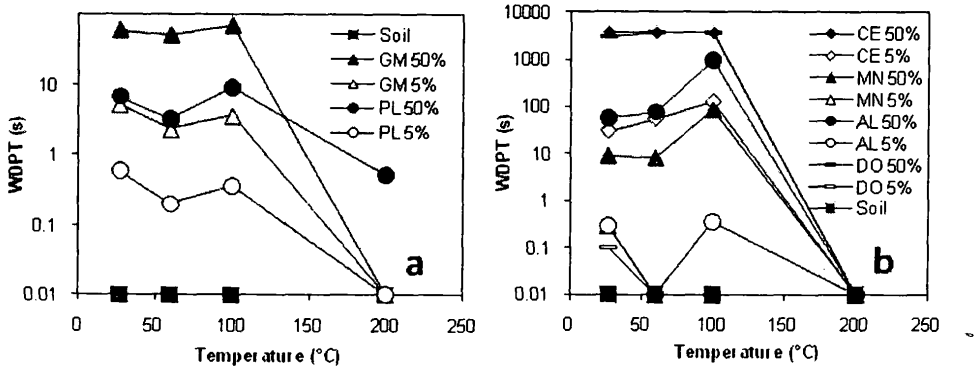

Figure 1. Water drop penetration time for (a) animal manure (b) plant materials amended soils at different temperatures.

wettability of samples with animal manure did not show a considerable alteration with increasing temperature up to 100 °C (Figure 1-a)

Among the plant materials, 50% CE and DO showed extreme water repellency indicating a WDPT of >3600 s. Similar to the animal manure, the wettability of samples with 50% CE, 50% DO, 5% AL, 5% DO, 5% MN plant materials did not show a considerable difference with increasing temperature up to 100 °C (Figure 1-b).

In contrast, the WDPT of samples with 50% AL (57 s to 963 s), 50% MN (9 s to 88 s), and 5% CE (32 s to 133 s) increased with increasing temperature from 27 °C to 100°C showing a decreasing wettability. Therefore, care should be taken when analyzing wettability and related properties of soils such as surface free energy as preheating in sample preparations would affect the measurements. All the animal manure and plant material amended soils, except those with 50% PL, became completely wettable reaching a WDPT of 0 s, when the samples were exposed to 200°C for 6 h period. This might be explained as a result of the removal of organic matter as CO_2 and H_2O under high temperature heating, because the presence of organic material is responsible for generating water repellency in soils.

Although these materials showed loss of organic matter with heating upto 200 °C, total removal of organic matter (loss on ignition) in all samples cannot be expected at this temperature. This might be the reason for PL to show a measurable WDPT after heating to 200 °C.

Most plant materials showed a decrease in wettability along with an increasing heating temperature up to a certain intermediate temperature level. This might be important because preheating of samples is included many laboratory experiments.

All the animal manure and plant material amended soils, except those with 50% PL, became completely wettable (WDPT = 0 s) when the samples were exposed to 200 °C for 6 h period.

Removal of organic carbon as CO_2 and H_2O under high temperature heating might be the reason for this, where heating to a higher temperature might be needed for the removal of organic matter on PL.

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