Water Repellent Effects of Organic Amendments on Saturated Hydraulic Conductivity of Surface Ultisols

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Abstract
Organic amendments have the potential to generate soil water repellency. Since water repellency limits surface water entry, it might impose severe impacts on soil hydrology. Extensive organic manure usage is practiced in Sri Lanka to maintain soil fertility without considering subsequent water repellency effects on soil hydraulic properties. Slightly induced water repellency is found to increase soil aggregate stability. The objectives of the present study were to explore the manure induced water repellency effects on saturated hydraulic conductivity (K_{sat}) and to find out any detrimental effects of extra 2% hydrophobic organic manure addition on the K_{sat}. A surface Ultisol soil was mixed with powders of cattle and goat manure, *Gliricidia sepium* and *Casuarina equisetifolia* leaves in 5%. Other samples were prepared by mixing 2% Casuarina and 5% of manure separately to induce slight hydrophobicity. The persistence and the degree of water repellency were tested using water drop penetration time test and sessile drop contact angle method. The K_{sat} was measured using the falling head permeameter. The measurements were taken at 1, 3, 7, 14 and, 30 day. The data were analyzed with ANOVA using SAS 9.1 statistical software. Under extra 2% Casuarina addition, water repellency increased slightly. The samples with only 5% manure showed higher K_{sat} (17-42 cm/h) on the 30th day. However, soil with extra 2% Casuarina, the values didn't extremely increase and, they were in the favorable range (10-20 cm/h) for the crop growth. The K_{sat} varied negatively with the increasing water repellency without significant differences at 0.05 probability level between those with and without 2% Casuarina, revealing that the slightly induced water repellency would not be detrimental on saturated hydraulic conductivity.

Keywords: Hydraulic properties, Organic manure, Saturated hydraulic conductivity, Water repellency
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Introduction

Application of organic amendments might make readily wettable soils water repellent. Soils amended with different organic manures such as cattle and goat manure as well as plant residues are reported show increased persistence of water repellency (Leelamanie, 2014). Since the water repellent soil surfaces limit water entry into soils, they act as barriers to the water flow imposing impacts on soil hydrological processes such as hydraulic conductivity, infiltration, and evaporation (Feng *et al.*, 2001). In addition, water repellency may create indirect effects on soil hydrophysical properties through the improved aggregate stability. The stabilized aggregates can reduce soil crusting and erosion to manage the hydraulic flow through the soil ultimately to maintain a sustainable crop production (Amezketa, 2008; LeBissonnais, 1996). Increased soil water repellency is found to cause 10–40% reduction in saturated hydraulic conductivity (K_{sat}) of all size fractions of a sandy loam soil subjected to fire (Fox *et al.*, 2007). The extreme water repellent conditions might have the potential of decreasing the K_{sat} into detrimental levels. However, in extremely wettable, non-repellent soils, the reduction in K_{sat} might create positive impacts by alleviating leaching and runoff losses. In general, a soil which is ideal for the crop production is found to be with a K_{sat} in the range of 1-15cm/h.

The extreme depletion of soil organic matter governed by high precipitation and temperature is considered to lessen the fertility of Sri Lankan soils. Therefore, an extensive use of organic manure has long been practiced in agriculture to increase and maintain the soil fertility without considering the subsequent effects of water repellency on soil hydraulic properties. Previous study on manure induced repellency on Sri Lankan Ultisols have proved that with the addition of extra 2% hydrophobic organic manure with normal manure application rate can increase the soil aggregate stability. The objectives of the present study were to explore the effects of manure induced water repellent conditions on K_{sat} of the soils and, to find out any detrimental effects of extra 2% hydrophobic organic manure addition on the soil water flow under saturation.

Methodology

The soils used in the experiments were collected from the Research and Training Facility of Faculty of Agriculture, University of Ruhuna, Mapalana. The soil belongs to red-yellow podzolic great soil group and falls under Rhodudults according to the USDA Soil Taxonomy. The collected surface bulk samples were thoroughly air–dried and sieved through the 2 mm sieve to exclude gravel and other non–soil materials. Cattle manure (CM) and goat manure (GM) were used as the animal manures and *Gliricidia sepium* (GS) and *Casuarina equisetifolia* (CE) leaves were used as the green manures. All the manures were air–dried, ground to be fine powders using a mechanical grinder, and passed through a 0.5 mm sieve to remove coarser materials. The prepared organic powders and the soil were mixed in different ratios to obtain samples with different hydrophobicities. The soil was amended with CM, GM, and GS separately at a rate of 5% in weight basis to obtain samples with field manure application levels along with a control sample under natural condition. Another set of samples were prepared by applying 2% of CE intermixed separately with 5% of CM, GM, and GL into soil as, this rate is previously found to improve the stability of soil aggregates. The persistence and the degree of water repellency of the samples were tested using the water drop penetration time (WDPT) test and the sessile drop contact angle method. The K_{sat} was measured using the falling head permeameter (Ogawa Seiki Co., Ltd, Tokyo, Japan).

The measurements were taken at 1, 3, 7, 14 and, 30 days intervals throughout the one month of experimental period. The data were statistically analyzed with analysis of variance (ANOVA), regression analysis and, correlation, at 0.05 probability level using Microsoft Excel 2007 data analysis tool pack and SAS 9.1 statistical software.

Results and Discussion

Among all the samples, the lowest initial WDPT and the soil-water contact angle (SWCA) were observed in the control sample which can be credited to the higher surface free energy level than that of water. The surface free energy of the control sample was around 188.15 mN m^{-1}, which was more than two times higher than that of water (72 mN m^{-1}), revealing readily wettable nature. Among the organic manure amended samples, the highest initial water repellency as measured by WDPT and SWCA was observed in the sample with 5% CE, whereas the lowest was observed in the sample with 5% GS disclosing the extremely high original hydrophobicity of CE and hydrophilicity of GS. The samples amended with CM and GM showed contact angles and WDPT values that were higher than those with GS, and lower than those with 5% CE. All the samples containing 5% organic manure intermixed with 2% CE showed higher initial WDPTs and SWCA than those with only 5% organic manure. These results revealed that the water repellency of samples amended with 5% organic manure increased with the mixing of 2% CE. However, the maximum reported WDPT under the induced hydrophobicity was less than 60 s.

The K_{sat} of the samples increased with the time over the one month of experimental period and that can be attributed to the declining water repellency of the soil with the organic matter decomposition. The control sample showed the highest values for both initial and final K_{sat} (19 and 43 cm/h, respectively) (Figure 1). Eventhough, the samples with intermixed 2% CE showed slightly higher initial water repellency, the initial K_{sat} was not significantly lower than those with only 5% organic manure. All the samples with only 5% organic manures showed higher K_{sat} values (17-42 cm/h) at the end of the experimental period. However, in those with extra 2% CE, the values did not increase up to extreme levels at the end of the test period, and they were in the favorable range (10-20 cm/h) which is ideal for the crop growth.

The K_{sat} of the samples within the whole experimental time period showed negative

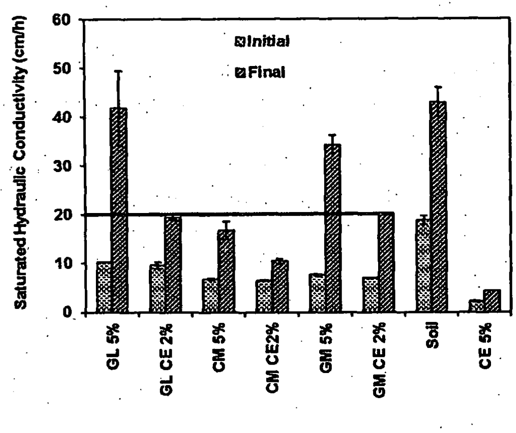

Figure 1: The K_{sat} of the samples tested as the intial and final values at the beginning and the end of the one month of experimental period.

logarithmic correlations with the increasing WDPT and SWCA of the samples (R^2= 0.76 and 0.78, respectively). The reason for this decrease in hydraulic conductivity with increasing water repellency might be due to the restriction of the water flow through water repellent soil matrix. A considerable difference in the relation of the K_{sat} to soil water repellency was not observed between the samples containing 5% organic manure with and without intermixed 2% CE.

According to the results, it is concluded that, all the organic manures used in the study can create water repellent conditions in the soil. The magnitude of the water repellency can be considered to be dependent on the original hydrophobicity of different organic manures.

Even though the addition of 2% CE had slightly increased the soil water repellency of those with field application levels. The addition of 2% CE with organic manures is seemed to cause severe no detrimental effects on initial K_{sat}. The slightly induced water repellent conditions can be considered to create favorable levels of K_{sat} for crop growth with the time. Further Comprehensive researches are necessary to explore the possible effects of manure induced water repellency on other soil hydrophysical properties.

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