Hydraulics of Repellency and Wattability of Soils

T.D.P. Liyanage and D.A.L. Leelamanie*
Department of Soil Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka

Abstract
Water repellent soils do not wet spontaneously when water is applied on the surface. Soil water repellency is found to cause various negative effects on soil systems. However, the effects of water repellency on soil hydraulic properties are still to be explored in detail. The purpose of this study is to explore the effects of water repellency on soil hydraulic properties using naturally hydrophobic dry zone sandy soils and organic matter amended wet zone loamy sand soils. Wet zone soil samples were amended with hydrophobic and hydrophilic organic matter. Initial hydrophobicity was determined using water drop penetration time (WDPT) and sessile drop contact angle tests. The infiltration rate was determined using double ring infiltrometer. Water entry value and water retention were determined using pressure head and suction head methods. Saturated hydraulic conductivity was estimated using falling head method. Evaporation rate was measured by drying pre wetted samples. According to the findings, increasing WDPT from 30s to >3600s, increased water entry value by nearly 80% and decreased saturated hydraulic conductivity by nearly 50% in hydrophobic samples. Initial infiltration rate was lower than steady state infiltration rate in naturally hydrophobic soils. Naturally water repellent soil had the highest water entry value irrespective of the coarse texture. However, water retention was low and saturated hydraulic conductivity was high in those samples corresponding to the sandy texture. Further experiment is needed to identify the exact effects of hydrophobicity on evaporation rate.

Key words: *Hydrophobicity, organic matter, soil hydraulic properties.*
***Corresponding author:** *leelamanie@soil.ruh.ac.lk*

Introduction

Water repellency is a phenomenon where the soils do not wet up spontaneously when a drop of water is placed on the surface. Instead of penetrating into the soil, water bead-up on the soil surface forming water drops. Soil water repellency is found to be a result of low energy surfaces where the attraction between molecules of solid - liquid interface is weaker than that of liquid-liquid (Leelamanie *et al.*, 2008). Water repellency is considered to be associated with both the content and the composition of soil organic matter (Doerr and Thomas, 2000).Organic materials that are responsible for water repellency may include long-chain aliphatic compounds, including long-chain acids, alcohols, and wax esters with extended polymethylene chains. Apart from organic matter, soil water repellency might be induced by factors such as soil texture, microorganism, fire, vegetation, and moisture content.

Soil water repellency affects infiltration, evaporation, erosion, and the hydrologic balance of soils (Feng *et al*., 2001). Other effects of water repellency can be considered as non-uniform wetting of soil profiles, increased surface runoff, and increased leaching of nutrients due to stimulated preferential flow (Dekker *et al*., 2001). Water repellent soils may also restrict seedling germination by reducing available moisture for germination and growth (Osborn *et al*., 1967). As water repellency is a barrier to water movement in the soil it might affect soil hydraulic properties. Therefore, precise and continuous measurement of hydraulic properties of hydrophobic soils is important to understand soil water interaction under hydrophobic conditions of a soil.

The objective of this study is to explore the effects of water repellency on hydraulic properties of soils with varying hydrophobicity. In this study, both naturally water repellent dry zone sandy soiland organic matter amended wet zone loamy sand soils to achieve different hydrophobicities were used. Soil samples were tested for infiltration rate, water entry value, saturated hydraulic conductivity, water retention, and evaporation rate, in relation to the initial hydrophobicity of the samples.

Materials and Methods

A surface Ultisol (0-5 cm) from Field Research and Training Facility, Faculty of Agriculture, University of Ruhuna, was used in the study as the wet zone soil. Naturally water repellent sandy regosols (0-5 cm) were collected from Hambantota. Dried leaves of *Cassuarina equisetifolia* (CE) and *Gliricidia makulata* (GL) were used as hydrophobic and hydrophilic organic matter amendments respectively, to obtain samples with varying hydrophobicity using wet zone soil. Infiltration rate test was studied as a field experiment with double ring infiltrometer for naturally hydrophobic dry zone sandy regosols while all the other experiments were conducted under laboratory conditions. Organic materials were ground with a mechanical grinder and passed through 0.5 mm sieve before mixing with air dried and sieved wet zone soil.Both CE and GL amended soil samples were prepared in 0 (Control), 5, 10, 25 and 50% contents. Initial hydrophobicity of all the samples was determined by water drop penetration time (WDPT) test and the sessile drop contact angle test.The WDPT was measured as the time taken for the complete penetration of a water drop placed on the smooth surfaces of the prepared samples filled into crucibles. Sessile drop contact angles were measured using digital micro photographs of a water drop (10µL) placed on the prepared monolayers on glass slides using samples. Water entry value and water retention were determined by suction head method and pressure head method. Saturated hydraulic conductivity was determined using falling head permeability measuring instrument. Evaporation was estimated during drying of prewetted samples(up to field capacity) under normal environmental conditions. Readings were taken at certain time intervals. At each level of moisture content, WDPT was measured to build up the characteristic water-dependent repellency curve.

Results and Discussion

All the organic matter amended samples showed increased WDPT and sessile drop contact angle with increasing organic matter content. Water entry value increased by nearly 80% with increasing WDPT from 30s to >3600s in hydrophobic samples (Figure 1). Water entry value of the soil from the 0-5 cm depth of naturally water repellent sandy soils increased by 20% compared with the 50% CE sample. The highest water entry value of naturally water repellent sandy regosols might be due to hydrophobic coatings. Saturated hydraulic conductivity decreased with increasing hydrophobicity of all the samples. The increasing WDPT from 30s to >3600s decreased saturated hydraulic conductivity by nearly 50%. The reason for this might be due to restricting of water movement through pore spaces by hydrophobic substances even under saturated conditions. Water repellent sandy regosols had the highest saturated hydraulic conductivity compared with 50% CE sample which had the highest initial hydrophobicity which might be considered as a result of sandy texture. All the samples showed the characteristic moisture retention curves with decreasing volumetric moisture content corresponding to increasing suction head. Water retention increased with increasing hydrophobicity of all the samples.When supplying energy to remove water as suction, the samples with higher organic matter content (higher hydrophobicity) tend to allow drainage of lower amount of water at low saturated hydraulic conductivity. As a result, the samples with high organic matter content might tend to retain more water than other samples. Water retention was lowest in water repellent sandy regosols. The reason might be, the sandy soil samples had a sandy texture which always enhanced saturated hydraulic conductivity imposing easy water drainage from the soil. None of the samples showed clearly identified differences of evaporation rates with varying hydrophobicity. All the samples showed the characteristic water-dependent repellency curve which can be drawn between water drop penetration time and the moisture content.

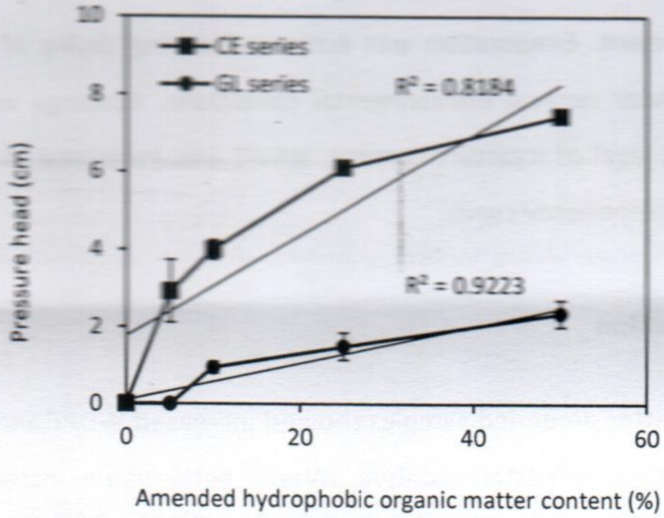

Figure 1: Pressure head with respect to organic matter content of CE (*Cassuarina equisetifolia*L.) amended samples and GL (*Gliricidia makulata* L.) amended samples.

Naturally water repellent sandy soils had an infiltration rate curve deviated from the characteristic infiltration rate curve of a normal soil. The hydrophobicity of the soils tends to slower the water infiltration into the soils. Therefore, the initial infiltration rate was usually lower than that in a normal soil. However, with continuous application of water the hydrophobicity decreased, where the infiltration rate began to increase corresponding to the decreased hydrophobicity. After the soil became saturate, the infiltration rate decreased because the pore spaces are filled with water restricting easy movement of water through the soil. Finally the infiltration rate achieved a steady state. However, the steady state infiltration rate was higher than the initial infiltration rate. Further experiments are required to determine the exact effects of hydrophobicity on evaporation.

Conclusions

The major findings of this experiment can be summarized as,

- Increasing hydrophobicity increased water entry value and water retention of soils.
- Increasing hydrophobicity decreased saturated hydraulic conductivity in soils.
- Effects of hydrophobic coatings around mineral soil particles on water entry value were considered to be more severe than inter mixed hydrophobic organic matter.
- Infiltration rate was affected in a way that initial infiltration rate was lower than the steady state infiltration rate in naturally water repellent sandy soils.
- The effects of hydrophobicity on soil hydraulic properties might be altered by other factors including soil texture.

References

Dekker, L.W., Oostindie, K., Ziogas, A.K., and Ritsema, C.J., 2001. The impact of water repellency on soil moisture variability and preferential flow.*Int.TurfgrassSoc. Res.J.,* 9, 498-505.

Doerr, S.H., Shakesby, R.A., and Walsh, R.P.D., 2000. Soil water repellency: Its causes, characteristics and hydro-geo morphological significance. *Earth Sci*. Rev., 51, 33-65.

Feng, G.L., Letey, J., and Wu, L., 2001. Water ponding depths affect temporal infiltration rates in a water repellent sand. *Soil Sci.Soc.Am*. J., 65,315-320.

Leelamanie, D.A.L., Karube, J., and Yoshida, A., 2008. Characterizing water repellency indices: Contact angle and water drop penetration time of hydrophobized sand. *Soil Sci. Plant Nutr.*, 54(2), 179–187.

Osborn, J., Letey, J., DeBano, L.F., and Terry, E., 1967. Seed germination and establishment as affected by non-wettable soils and wetting agents. *Ecology*, 48, 494-497.