Effects of Organic Matter Induced Hydrophobicity on Soil Microbial Activity as Measured by CO_2 Evolution

TDP Liyanage*, DAL Leelamanie and SD Wanniarachchi

Department of Soil Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka.

Abstract

Increasing atmospheric CO_2 concentration is the major cause of global warming. When developing strategies to mitigate global warming, soil Carbon stabilization is essential because soil acts as a major reservoir of terrestrial carbon. Among several techniques introduced to stabilize soil Carbon, hydrophobic protection seems to be more convenient and simple. However, the effects of organic matter induced hydrophobicity on soil organic matter (OM) decomposition and CO_2 evolution is not explored in detail. Therefore, objectives of the present study were to identify the behavior of microbial activity in soils amended with different organic materials and to examine the effects of hydrophobicity on OM decomposition and CO_2 evolution. Surface samples from an Ultisol (Red Yellow Podzolic soils) from Research and Training Facility of Faculty of Agriculture, University of Ruhuna were air-dried, sieved and amended with 5% of dried and ground organic matter powders. *Cassuarina equisetifolia* and *Gliricidia makulata* leaves, cattle and goat manure were used as the organic matters. The samples were incubated for, one month and CO_2 was trapped by NaOH method. Non- fumigated and chloroform fumigated samples were incubated under dark condition. The cumulative CO_2 evolution was recorded at 1^{st}, 3^{rd}, 7^{th} and 14^{th} days. According to the results, Gliricidia samples showed highest CO_2 evolution and Cassuarina samples showed the lowest. In non-fumigated samples, CO_2 evolution decreased with increasing hydrophobicity on 1^{st}, 3^{rd}, 7^{th} and 14^{th} day with a power correlation (R^2=0.92, 0.63, 0.74 and 0.80 respectively). This is because, hydrophobicity reduced OM decomposition and CO_2 evolution. In fumigated samples, the trend was deviated and strong correlations couldn't be observed. Hydrophobic organic matter can alter the microbial activity in the soils and reduce CO_2 emission due to reduction of OM decomposition over hydrophilic organic matter.

Keywords: Carbon stabilization, CO_2 evolution, Global warming, Hydrophobicity, Organic matter.

Introduction

The soil represents the largest reservoir of organic Carbon containing 1500 Gt in the top one meter and it alters the atmospheric CO_2 concentration in large scale (Lutzow, 2006). The increasing atmospheric CO_2 concentration causes severe environmental issues leading to the global warming. The ultimate outcome of the global warming is the climate change which would be a significant challenge for the human development.

Therefore, when developing global CO_2 mitigation techniques more attention should be paid on soil carbon stabilization. Several processes have been identified to achieve this including, binding of organic matter (OM) by aggregation, intercalation within phylosilicates, encapsulation in organic macro molecules and hydrophobic protection (Claudia et al., 2010). Among them, hydrophobic protection is expected as a potentially useful tool to limit decomposition of fresh OM and thus reduce CO_2 emission from global agricultural soils (Piccolo et al., 1999). During the OM decomposition, they are converted by microorganisms in order to generate energy and to produce new cellular metabolites to support their maintenance and growth. As the hydrophobicity reduces surface wettability and thus the accessibility of OM for microorganisms by directly restricting their living conditions, the organic matter decomposition might be reduced (Lutzow, 2006). Furthermore, hydrophobicity is suggested to reduce OM decomposition rate by improving soil aggregate stability (Claudia et al., 2010). The hydrophobicity is generated in a soil due to organic

***Corresponding author:** liyanagethanu@gmail.com

matter (Doerr and Thomas, 2000).

The OM decomposition rate in Sri Lanka is comparatively high due to the high environmental temperature and humidity. In most areas, farmers apply organic manures at high rates of 10–30 t ha^{-1} (Leelamanie et al., 2013). Therefore, it is essential to identify the effects of these manures on soil hydrophobicity development and CO_2 evolution and to develop methodologies to address the problems of global warming with the use of soil hydrophobicity concepts.

The objectives of this study were to identify the behavior of microbial activity in soils amended with different organic materials and to examine the effects of soil hydrophobicity on OM decomposition and CO_2 evolution.

Materials and Methods

Surface Ultisols from Research and Training Facility of Agriculture, University of Ruhuna were air dried and sieved. *Cassuarina equisetifolia* leaves, *Gliricidia makulata* leaves, cattle manure and goat manure were dried and ground using the mechanical grinder. The ground organic manures were mixed with soils at a rate of 5%.

The prepared samples were tested for CO_2 evolution as fumigated samples and non-fumigated samples. For the preparation of fumigated samples, 50 g of each soil samples were fumigated with 50-75ml of Chloroform solution for 24 hours within a sealed desiccator under vacuum condition.

For the CO_2 trapping by NaOH method, 50 g of both fumigated and non-fumigated samples were wetted up to 60% of the field capacity and put in to equal sized containers in triplicates. In each container, 2 vials with 5 ml distilled water and 10 ml 1M NaOH was kept separately and the containers were sealed tightly. The samples were allowed to incubate under dark conditions throughout the testing period. During the incubation, the remaining NaOH in vials, which didn't react with released CO_2, were titrated with 0.5 M HCl in the presence of phenolphthalein indicator followed by addition of 0.5M $BaCl_2$ to precipitate trapped CO_2 to avoid interferences. The test readings were used to determine the amount of entrapped CO_2 released by the soil samples due to microbial activity at the time intervals of 1 day, 3 days, 7 days and 14days. After each titration the NaOH vials were re-filled to determine the released CO_2 as a cumulative value. At the same time, 3 blank samples were tested to determine atmospherically entrapped CO_2.

Results and Discussion

During the whole incubation period, highest CO_2 evolution could be observed in 5% Gliricidia amended samples in both non-fumigated and fumigated samples while lowest CO_2 evolution could be observed in 5% Cassuarina amended samples (Figure 1). This can be considered as resulted by the differences in hydrophobicity of the two green manures. Cassuarina is found to be hydrophobic and Gliricidia is found to be hydrophilic. In animal manure amended non-fumigated samples, cattle manure amended samples showed lower CO_2 releasing than the samples amended with goat manure. This can also be related to the hydrophobicity as the initial hydrophobicity of cattle manure was higher than the goat manure in the tested samples.

In non-fumigated samples, the cumulative CO_2 evolution decreased with increasing hydrophobicity during the whole incubation period. This might be because, hydrophobicity is found to limit

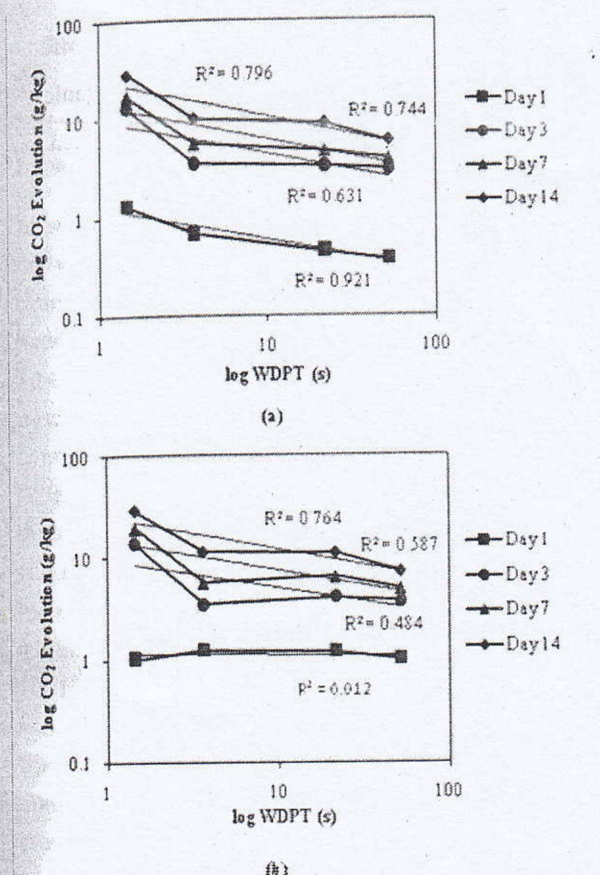

Figure 1: (a). Change in CO_2 evolution of non-fumigated samples in relation to the initial hydrophobicity.
(b). Change in CO_2 evolution of fumigated samples in relation to the initial hydrophobicity.

decomposition of fresh OM and thus reduce CO_2 emission from soils (Piccolo et al., 1999). As the hydrophobicity reduces surface wettability and thus directly restricts the living conditions of microorganisms by confining internal moisture conditions, the organic matter decomposition expected to be reduced (Lutzow, 2006). In addition, hydrophobicity reduces OM decomposition by improving aggregate stability as hydrophobic organic matter has greater effect over hydrophilic organic matter in improving aggregate stability (Leelamanie et al., 2013). However in fumigated samples, this trend deviated. This might be because fumigation alters the normal microbial activity in the soils. Fumigation ruptures microbial cells and releases cell walls and cellular contents into the soil. It has been reported that during the incubation, a "flush of decomposition" of the soil organic matter occurs due to the decomposition of dead microorganisms during fumigation. The remaining microbial biomass begins to degrade the dead microbial biomass increasing CO_2 evolution and altering the normal CO_2 evolution.

Conclusions

Hydrophobic organic matter can alter the microbial activity in the soils and reduce CO_2 emission due to reduction of OM decomposition over hydrophilic organic matter. Hydrophobicity is an important tool which can be used to mitigate global warming by restricting CO_2 evolution. Under fumigation the effects of hydrophobicity on CO_2 evolution are different than non-fumigation. Further experiments are required to test whether it is possible to diminish organic matter decomposition of local animal manure amended soils by improving hydrophobicity.

References

Claudia MBF, Fukamachi CRB, Cambronero YC, Dedecek RA, Mangrich AS, Narimoto KM, Milori DMBP, Simoes ML 2010; Hydrophobicity of an Entisol under loblolly pine (Pinustaeda) plantation, J. Pes. Flor.Bras., 30 (62), 93-99.

Ganter C 2007; Stabilization of Soil Organic Matter by Mineral Surfaces. Term Paper in Biogeochemistry and Pollutant Dynamics, M.Sc. Environmental Sciences, ETH Zurich, 1-13.

Leelamanie DAL, Karube J and Samarawickrama UI 2013; Stability analysis of aggregates in relation to the hydrophobicity of organic manure for Sri Lankan Red Yellow Podzolic soils. Soil Sci. and Plant Nutr., 59 (5), 683-691.

Lutzow MV 2006; Stabilization of organic matter in temperate soils: mechanics and their relevance under different soil conditions- a review. Europian Journal of Soil Science., 57, 426-445.

Piccolo A, Spaccini R, Haberhauer G, Gerzabek MH 1999; Increased Sequestration of Organic Carbon in Soil by Hydrophobic Protection. Natur wissenschaften., 86, 496–499.