International Biodeterioration & Biodegradation 106 (2016) 10–15

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

journal homepage: www.elsevier.com/locate/ibiod

Microbial transport of aerated compost tea organisms in clay loam and sandy loam – A soil column study

Henrik Haller [a, *], Anders Jonsson [a], Katia Montenegro Rayo [b], Anielka Dávila López [b]

[a] *Department of Ecotechnology and Sustainable Building Engineering, Mid Sweden University, Sweden*
[b] *Laboratorio de Biotecnologia, UNAN-Managua, Nicaragua*

A R T I C L E I N F O

Article history:
Received 25 July 2015
Received in revised form
29 September 2015
Accepted 1 October 2015
Available online 23 October 2015

Keywords:
Bioaugmentation
Bioremediation
Microbial transport
Clay loam
Sandy loam
Bulk density
Soil organic matter

A B S T R A C T

Soil bioaugmentation is a promising approach with applications in agriculture and in bioremediation of polluted soil. One way of supplying microorganisms to the soil that has received increasing attention during the last decade is by the addition of compost teas. The success of such strategies depends on whether the organisms are capable of migrating through the soil and reaching its target, i.e. the pollutants or soil pathogens. The structural conditions of the soil affect the microbial migration rate and this study aims to determine the migration rates of microorganisms found in aerated compost tea through both a sandy loam and a clay loam in soil columns. A considerably higher proportion of the microorganisms from the aerated compost tea were deposited at 2 cm in the sandy loam compared to the clay loam. Microbial deposition was concentrated to the top 2 cm in the sandy loam and then decreased abruptly at 10 cm whereas the clay loam presented an irregular pattern. Despite a favourable particle size distribution for microbial transport, the sandy loam retained a greater proportion of the microorganisms present in the aerated compost tea in the top 2 cm, presumably because the lower bulk density and higher soil organic matter in the clay loam aided transport and growth of microorganisms. The limited migration of aerated compost tea microorganisms in sandy soil suggests that its efficiency for bioremediation or pathogen control may be limited below 2 cm depth in similar soils. Our results indicate that in less dense soil with higher soil organic matter content the efficiency may be higher.

1. Introduction

Soil bioaugmentation is a promising approach with applications in agriculture and in bioremediation of polluted soil (Dechesne et al., 2005). One way of supplying microorganisms to the soil that has received increasing attention during the last decade is by the addition of compost teas (Scheuerell and Mahaffee, 2002, 2006; Scheuerell, 2004; Scheuerell and Mahaffee, 2006; Carballo et al., 2008; Naidu et al., 2010; Pant et al., 2011; Scharenbroch et al., 2011; St. Martin and Brathwaite, 2012). Research on the use of various organic by-products for in-situ soil bioremediation of contaminated sites is currently being conducted by the research team (Jonsson and Haller, 2014) and the potential of using compost teas to enhance the degradation of diesel fuel in soil has been explored in a pilot scale experiment in a tropical climate (Haller and Jonsson, 2014). The research is part of a strategy to develop sustainable remediation of polluted soils by utilizing appropriate technology for developing countries and low-priority regions i.e. technologies that are cheap and easily available near the contaminated sites (Jonsson and Haller, 2014). Compost teas are liquid soil amendments obtained when compost is drenched and extracted in water. The fact that there are two common production methods with somewhat different properties makes it necessary to distinguish between non-aerated compost teas and aerated compost teas. An increasing quantity of data has confirmed the ability of aerated compost teas to suppress a number of both air- and soil-borne plant pathogens (Scheuerell and Mahaffee, 2002, 2006; Scheuerell, 2004; Scheuerell and Mahaffee, 2006; Pant et al., 2011). To date virtually all research on aerated compost tea has focused on its potential to control plant diseases but its application has also been suggested for bioremediation purposes (Jonsson and Haller, 2014). Aerated compost teas are assumed to control subsurface pathogens by competition and the microbial degradation of pollutants is entirely dependent on the proximity of the pollutant

* Corresponding author. Mid Sweden University, Akademigatan 1, Department of Ecotechnology and Sustainable Building Engineering, SE-831 25, Östersund, Sweden.
E-mail address: henrik.haller@miun.se (H. Haller).

http://dx.doi.org/10.1016/j.ibiod.2015.10.002
0964-8305/

and the microorganism. Claims from advocates and retailers of aerated compost tea technology assume high mobility and survival rates of aerated compost tea microorganisms in soil but these testimonies often lack supporting data from research (Ingham, 2005).

Applications of aerated compost tea tend to increase soil microbial respiration and dehydrogenase activity; 50% increases compared to untreated media in multiple soil types have been reported (Pant et al., 2011) although the ability of aerated compost tea to increase microbial biomass and activity in soil was inferior to that of mineral fertilizer in short-term laboratory assays (Scharenbroch et al., 2011). The particular characteristics of different soil depths are not considered in these studies and little is known about the ability of the microorganisms in aerated compost tea to migrate through different types of soils. The success of bioaugmentation strategies in soil depends on whether the organisms are capable of migrating through soil and reaching their target, i.e. the pollutants or soil pathogens (van Veen et al., 1997).

The structural conditions of the soil affect the microbial migration rate, and understanding of the processes that govern the fate and transport of the introduced microorganisms is essential for addressing subsurface bioaugmentation (Ginn et al., 2003).

Microbial transport through soil depends on a complex set of physical and chemical conditions, including soil bulk density, substratum hydrophobicity, electrostatic interactions, moisture content, and presence of cations which are currently not very well understood (Abu-Ashour et al., 1994). It involves both vadose and saturated zone flow. The unsaturated zone tends to be less favourable for vertical transport than the saturated zone (Schäfer et al., 1998; Chu et al., 2003). Microbial transport is generally, facilitated by flowing water in the porous media and, for instance, pathogen transport through the subsurface typically coincides with increased water flow in soils caused by precipitation or irrigation (Gerba and Smith, 2005). The flow of water caused by the potential gradient in porous media, is by far the most important factor for determining their transport (Chenu et al., 2002; Harvey et al., 2002). When induced by water flow in porous media, microbial transport is called passive transport, as the motility of microbes themselves contributes little to the overall movement facilitated by the flow. To a limited extent, however, the microbial transport is also promoted by flagellar movement and even Brownian movement if passive transport is not available (Chenu et al., 2002; Ginn et al., 2003). The flow of water through soil is influenced by factors such as pore size distribution, degree of saturation and especially by macroporosity (Singh and Kanwar, 1991; Chu et al., 2003; Ginn et al., 2003).

Bacterial sizes are typically from 0.2 to 5 μm, which coincides with the particle size of coarse clay to fine silt (Matthess and Pekdeger, 1981; McGechan and Lewis, 2002). Microbes of that size can easily pass through the diameter of all but the finest soil pores but to be able to migrate any considerable distance, the flow is dependent on a continuous pathway. Furthermore the water flow is mainly conducted through macropores, creating unfavourable conditions for longer transport in micropores, especially under dry conditions (Ginn et al., 2003).

In contrast to chemical tracers such as bromide, bacteria are frequently trapped on their way through porous media. Three major mechanisms attributed to cause retention of microbes (and accompanying particles from organic matter or mineral colloids) are: cake formation, straining and physicochemical filtration (Abu-Ashour et al., 1994).

Surface cakes are formed by the deposition and aggregation of particulates and associated microbes above the media surface when microorganisms are too large to penetrate into soil.

A mat is formed on the soil surface which further affects soil permeability. Straining is essentially a mechanical process that occurs when a colloidal particle is physically larger than the pore throat it endeavours to pass through and typically affects only microbes (or clumps of such) < 5% of average grain diameter. Filtration (adsorption) occurs when the ratio of soil grain diameter to that of the microorganism is greater than 20. It is a physicochemical and biological process involving van der Waals forces, as well as the development of extracellular polysaccharides and the electrostatic diffusing double layer (Ginn et al., 2003; Banks et al., 2007).

The utility of aerated compost tea applications for soil pest control or bioremediation is thus largely dependent on the capacity of their microorganisms to migrate in soil and reach the pollutants or soil pathogens. This study intends to examine the vertical transport of the microorganisms present in aerated compost tea in two different soils: clay loam and sandy loam, in repacked soil columns under unsaturated field conditions. The two soil types both belong to the soil order ultisol, a highly weathered, acidic soil, common in tropical and subtropical regions in Africa, Asia, and South and Central America.

2. Material and methods

2.1. Soil and soil columns

2.1.1. Soil properties

Two soils, representative of tropical agricultural soil, yet with considerably different soil structures, were chosen for the experiment. The soils originate from two sites 6 km apart along the road to Las Pavas, in Chontales, Nicaragua. The same soils have previously been used in a pilot scale experiment for bioremediation of diesel-polluted soil in a tropical climate (Haller and Jonsson, 2014). Cores of clay loam were collected at the agroecological farm Casa Montesano (11°58′58.23″N 84°53′07.14″W) and sandy loam from a conventional cattle farm (11°54′34.92″N 84°53′06.28″W). The 30 top cm were collected. The physical and chemical properties of the soils are described in Table 1.

2.1.2. Soil columns

The soil columns were made of galvanized steel with a volume of 1.7 l (height 32 cm and diameter (id) 8.3 cm). The column was

Table 1
Physical and chemical properties of the tested soils.

	Clay loam	Sandy loam
General		
pH (H_2O)	5.3	4.9
Organic Matter (%)	6.8	3.9
CEC meq 100 g^{-1}	9.3	26.1
Bulk density g cm^{-3}	1.17	1.31
WHC g cm^{-3}	0.35	0.34
Soil texture		
Clay (%)	46.4	16.0
Silt (%)	29.6	23.6
Sand (%)	24.0	60.4
Nutrients and minor elements		
N (total ppm)	0.08	0.07
P (Mehlich III ppm)	22	18
K (available ppm)	187	108
Ca (ppm)	843	2308
Mg (ppm)	194	321
Na (ppm)	26	30
S (total ppm)	19	18
Fe (ppm)	82	37
Cu (ppm)	1.1	0.8
Zn (ppm)	2.9	1.5
Mn (ppm)	132	121
B (ppm)	0.6	0.3