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Soil bacterial functional diversity as influenced by organic amendment application

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Abstract

The aim of the present work was to assess the response of microbial functional diversity to organic soil amendment and the relationship between the microbial functional diversity and soil carbon availability. Household solid waste compost, horse and rabbit manure and chicken manure were applied at two doses. The same undisturbed soil type (Vertic Argiudoll) was used as reference. Soil suspensions were applied to Biolog EcoPlate™ and average color development (AWCD), richness (*R*) and Shannon–Weaver index (*H*) were calculated. The amendment incorporation resulted in significant increases ($p < 0.05$) in AWCD, *R* and *H* compared to the unamended plots. The regression functions showed linear relationships when *R* and *H* were related to soil organic carbon ($R^2 = 0.77$ and 0.72, respectively). Principal component analysis allowed the differentiation of treatments from the control and the undisturbed sites. The Biolog EcoPlate assay was sensitive to changes in the short term due to management practices.

Keywords: Microbial diversity; Community level physiological profiles; Biolog EcoPlate; Organic amendments

1. Introduction

Soil degradation as a consequence of land use intensification and inappropriate production technologies is one of the major environmental concerns. Conventional horticultural cropping can lead to deterioration of soil physical, chemical and biological properties, because of continuous soil removal and intensive use of pesticides and fertilizers (Albiach et al., 2000).

Management practices have a significant impact on soil organism populations and their activity (Roper and Gupta, 1995). To be compatible with sustainable agriculture, management practices must promote fertility and productivity in the long term, emphasizing the supply of nutrients cycled and fixed by soil biota (Beare, 1997). Since soil biota have a key role in carbon cycling, organic matter decomposition and maintenance of the edaphic fertility, preservation of soil microbial diversity is essential (Potter and Meyer, 1990). The use of organic amendments is an alternative practice to conventional horticulture, since they improve soil condition and act as a source of carbon and other nutrients, which favor microbial biodiversity and activity, and improve soil structure (Albiach et al., 2000).

Biological, especially microbiological attributes such as biomass and activities, are sensitive to soil management practices (Elliot, 1997). Modifications in biological properties may precede detectable changes in soil physical and chemical properties and thus provide an early

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signal of improvement or a warning of degradation (Pankhurst et al., 1995). Community level physiological profiles (CLPPs) based on the ability of microorganisms to oxidize different carbon substrates have been successfully used to differentiate microbial communities from several habitats (Garland, 1997; Gomez et al., 2004). The estimation of microbial functional diversity by carbon source use profiles has been reported to be a sensitive approach to detect modifications due to soil management (Stenberg, 1999; Gomez et al., 2004). Most of the literature published on CLPPs used the Biolog GN™ assay, which tests the metabolization of 95 carbon sources. The more recently developed Biolog EcoPlate™ assay allows testing a more reduced number of ecologically relevant substrates and the possibility of larger number of replicates. However, there is less information as regards the use of EcoPlate assay to detect changes in microbial functional diversity due to management practices.

The aim of the present work was to assess the short-term response of microbial community functional diversity to organic amendment incorporation, in an horticultural soil with a long history of conventional use. The relationship between the microbial functional diversity and soil carbon availability was also analyzed.

2. Methods

2.1. Site and experiment description

The study was carried out in a Vertic Argiudoll located in Zavalla, Argentina (32°43′27″ S; 60°55′18″ W). The main soil characteristics in the 0–15 cm surface layer were: clay = 260 g kg^{-1}, silt = 680 g kg^{-1}, organic matter = 32.7 g kg^{-1}, total N = 2.23 g kg^{-1}, pH in water (1:2.5) = 5.9. The soil had a good water storage capacity and was moderately well drained.

The experimental site has been under horticultural cropping for more than 20 years, with conventional management: moldboard plowing, rotovator, two or three crops a year, fertilization with urea, no amendment incorporation. Irrigation was performed with water having an electrical conductivity 2.3 dS m^{-1} and a sodium adsorption ratio 14.37.

In May 2001, amendment applications were performed with vermicompost from source-separated household solid waste (HSW), vermicompost from horse and rabbit manure (HRM) and chicken manure (CM). The amendments were applied at rates of 10 and 20 Mg ha^{-1} on a dry base (D10 and D20, respectively) in a complete randomized block design with three replicates and a control plot without any amendment (C). The analytical characterization of the amendments is shown in Table 1. Total carbon and ash, total nitrogen, water content, pH and electrical conductivity, and aerobic heterotrophic microflora of the amendment were determined by ignition, Kjeldahl distillation, gravimetric method, potentiometric method and plate count, respectively.

In April and November 2001, samples composed of 15 sub-samples were taken from the 0–15 cm layer. The same soil type without disturbance was sampled as reference. The undisturbed site was an area adjacent to the trial that had never been cultivated and remained with native herbaceous plant cover.

2.2. Soil measurements and statistical analysis

Community level physiological profiles (CLPPs) were assessed by the Biolog EcoPlate™ system (Biolog Inc., CA, USA). Each 96-well plate consists of three replicates, each one comprising 31 sole carbon sources and a water blank. Soil suspensions (soil 10 g, distilled water 100 ml) were shaken for 1 h and then pre-incubated for 18 h before inoculation to allow microbial utilization of any soluble organic compound from the soil (Dick et al., 1996). Tenfold dilutions were performed and aliquots of 100 µl from a 10^{-4} dilution were inoculated into the microplates (Zak et al., 1994). The plates were incubated at 25 °C, and color

Table 1
Amendment composition: vermicompost from source separated household solid waste (HSW); vermicompost from horse and rabbit manure (HRM); chicken manure (CM)

Amendment	C[a] (g kg^{-1})	N[b] (g kg^{-1})	C/N	Ash (g kg^{-1})	W[c] (g kg^{-1})	pH[d] (1:5)	EC[e] (dS m^{-1})	AHM[f] (CFU g^{-1})
HSW	255	14.1	18.1	540	518	6.88	1.9	3.7×10^7
HRM	188	15.1	12.4	660	412	6.82	0.4	5.6×10^7
CM	428	13.4	31.9	230	113	8.10	6.8	2.5×10^9

[a] C: organic carbon.
[b] N: total nitrogen.
[c] W: water content.
[d] pH (1:5; amendment:water).
[e] EC: electrical conductivity.
[f] AHM: aerobic heterotrophic microflora.