GLOBAL SYMPOSIUM ON SOIL ORGANIC CARBON, Rome, Italy, 21-23 March 2017

Does organic resource quality affect soil organic matter quality?

Yeboah Edward[1], Saran Sohi[2], Bernard Vanlauwe[3]*

[1]CSIR-Soil Research Institute, Academy Post Office, Kwadaso, Kumasi, Ghana, eyeboah5@hotmail.com
[2]University of Edinburgh, UK saran.sohi@ed.ac.uk
[3]International Institute of Tropical Agriculture, Nairobi, Kenya, b.vanlauwe@cgiar.org]
*Presenting author

Abstract

Soil organic matter (SOM) is an important index for soil quality and is key to sustainable crop production. Changes in total SOM matter following changes in soil management practices are not noticeable in the short to medium term. However, some fractions within the total SOM respond rapidly to changes in management practices which could be used to study the trajectory of soil carbon following changes in management practices. In this study, the effects of five organic inputs of different qualities on SOM were evaluated using density fractionation and fourier transmission infrared spectroscopy (FTIR). There was evidence of statistical significance ($P<0.001$) within the SOM pools. The intra-aggregate light fraction (IALF), isolated in sodium iodide solution at 1.82 g cm^{-3} after ultrasonic dispersion accounted for a very small proportion (about 3%) of total soil organic C but was not statistically different from the free light fraction (FRLF) which accounted for 7% (average across treatments) of the total carbon. The organomineral pool however, was significantly different from all the pools and accounted for almost 70% of the total soil organic carbon. Residue quality had less impact on total soil organic carbon. While the FRLF shows substrate of organic inputs, the IALF reveals products of microbial origin indicating the major role of soil microbes in the transformation of soil organic matter.

Keywords: Organic resource quality, Soil organic matter, density fractionation, Free light fraction, Intraaggregate light fraction, organomineral, FTIR

Introduction, scope and main objectives

The importance of soil organic matter to sustainable crop production through its influence on physical, chemical and biological properties of soil is replete in the literature. Organic matter content in soil is used as a key indicator of soil quality (Six et al., 2001). In recent times, the environmental service function of SOM such as carbon sequestration and climate change has received enormous research attention. In developing countries of the tropics however, the role of SOM in ensuring food security is probably far more important than its environmental service function. Food insecurity is a major problem in sub-Saharan Africa and decline in soil organic matter has been identified as a major constraint to sustainable crop production and food security. The total soil organic matter changes slowly and may not be noticeable in the short to medium term. However, there are pools or fractions in the total soil organic matter which respond rapidly to changes in soil management (Christensen, 1992; Sohi et al. 2001). The density fractionation methodology of Sohi et al., 2001 recognizes three pools which are chemically and functionally distinct. The free light fraction (FRLF) separated at the density of 1.82 g/cm^3 is less decomposed and shows recognizable cell structure. The intra-aggregate light fraction (IALF) obtained after ultrasonic dispersion shows finely divided plant material and has been associated with soil structural improvement. The FRLF and the IALF are thought to represent partly decomposed plant material at an early stage of decomposition, thus characterizing an early stage of the humification process. These fractions, with rapid turnover are assumed to play a dominant role in soil nutrient dynamics (Hassink, 1995). The third pool the organomineral, represent amorphous organic material, more stabilized mineral-associated fraction with longer turnover times (Cambardella and Elliot, 1992).

Fourier transform infrared spectroscopy (FTIR) may also be used to analyse soils qualitatively and semi-qualitatively (Gressel et al., 1995). Infrared light is used to increase the stretching and bending vibrations of chemical bonds. Because each group resonates at different frequencies and absorbs infrared light at specific wavelengths, different functional groups may be identified. The mid infrared spectral region, from 650 to 4000 cm^{-1}, is frequently referred to as the molecular fingerprint region because of the unique absorption features exhibited by many functional groups in that wave number range. Hassink (1995) reported the detection of a poorly resolved band around 2960 cm^{-1} accompanied by weak bands near 2926 and 2860 cm^{-1}, a region characteristic of C-H stretching absorptions in aliphatic hydrocarbon, in several Interplanetary Dust Particles (IDP). In this study, the trajectory of soil organic matter following incorporation of organic resources of different qualities in a field experiment, were assessed using density fractionation and spectroscopic techniques.

Methodology

For each soil treatment, FRLF and intra-aggregate light fraction (IALF) were sequentially isolated using sodium iodide (NaI)) solution (density 1.82 g cm^{-3}) before and after ultrasonic dispersion of aggregates respectively, according to the protocol of Sohi et al. (2001). The residual after isolation of the intra-aggregate organic matter is the organo-mineral fraction. The fractions isolated were oven dried at 40ºC and ball milled. Carbon and N contents as well as delta ^{13}C concentration of the bulk soil, FRLF, IALF and the organo-mineral fractions were measured using PDZ Europa Integra C-N isotope ratio mass spectrometer (Integra, Germany) at the Stable Isotope Facility in University of California, Davis, USA. The C and N were expressed on a dry soil mass basis, and also as a proportion of total soil organic carbon or soil N. The data were analysed using GenStat statistical package 12th edition and the ANOVA procedure (Payne et al. 2006). Means were separated according to the least significant difference (LSD) at ($P< 0.05$).

Results

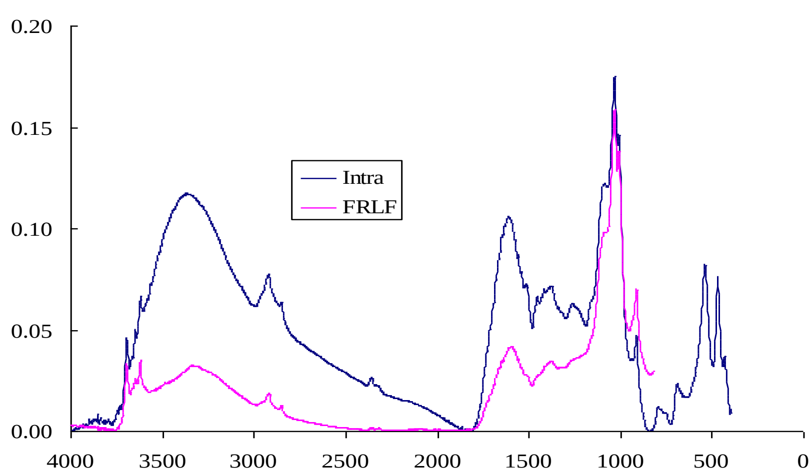

Fig. 1: Spectra characteristics of SOM pools from forest soil at Ayuom

Table 1: Infrared (FTIR) peak assignment for carbon (C) and nitrogen (N) forms in soil from forest soil at Ayuom

Pool	FTIR Peak frequency (wave number cm^{-1})	Possible functional groups
FRLF	3696.9, 3621.48	Outer and inner surface-OH in kaolinite
	3338.5	-NH stretches of amide
	2920.27	Asymmetric stretching vibrations of –CH, $-CH_2$
	1594.74	Stretching of aromatic C=C
	1034.6	Stretching of polysaccharide C-O, Si-O vibrations
	1009.58	C-O stretching of polysaccharide-like substances
	914	
IALF	3697.14	O-H on kaolinite surfaces
	3619.8	O-H-stretching vibrations
	3371.1	OH stretching of phenolic OH
	2922.2	Stretching vibrations of aliphatic C-H.
	1615.1	Aliphatic C-H
	1377.2	Aromatic and carboxylic anions (C=C stretching and –COO)
	1266.7	Stretching of aromatic C-O and phenolic OH
	1034.5	Stretching of polysaccharide C-O, Si-O signal
	795.8	Polysaccharide
	691.8	
	539.6	
	470.7	

Discussion

While the organomineral pool showed enriched ^{13}C from Cattle manure, maize stover and the control treatments, the FRLF and the IALF were rather enriched in the *C.juncea* and the *L.leucocephala* treatments respectively. The relatively higher enrichment in the maize and cattle manure treatments presumably is due to high C_4 concentration of these materials (maize already a C_4 material). The cattle manure may have been obtained from a source where the cattle were fed with C_4 grass and other forage. Analyses of pure cattle manure and maize stover using the mass spectrometer showed ^{13}C concentrations of 18 and 12.5 ‰ respectively indicating high enrichment of C_4 material in the manure source. The $\delta^{13}C$ value of 12.5 ‰ observed in maize stover is typical for C_4 materials. The most prominent absorptions for the FRLF of the forest soil at Ayuom included NH stretches of amide at 3338.5 cm^{-1} (Fig 3.7, Table 3.1), aliphatic C-H bonds at 2920 cm^{-1}, aromatic C=C bonds at 1594 cm^{-1} indicative of organic substrates and stretching of polysaccharide-like structures at wavelengths 1034 and 1009 cm^{-1} representing microbial transformed products.

Conclusions

The results of the study support the view that SOM pools are chemically and functionally distinct. While the FRLF shows substrate of organic inputs, the IALF reveals products of microbial origin indicating the major role of soil microbes in the transformation of soil organic matter. Residue quality affects the quality of soil organic matter pools but not on total soil organic carbon.

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