Integrated Physical-Chemical Procedure for Soil Organic Carbon Fractionation and Characterization During Transition to Organic Farming

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Abstract Two field experiments, in the south of Italy, were established in 2009 to study and characterize soil organic matter (SOM) during transition to organic farming. Experiments included a cereal/leguminous rotation fertilized with permitted amendments with three field replicates. A sequential fractionation procedure was used to separate different SOM fractions: light fraction (LF), two size classes of particulate organic matter (POM), mobile humic acid (MHA), and Ca-bound humic acid (CaHA). Isolated fractions were quantified and analyzed for their C and N content and carbohydrate and amino compound composition. The masses of the isolated fractions increased during 2-year course, with noticeable increases in LF and POM. Moreover, LF and POM were found more responsive than MHA to treatment and crop. The xylose/mannose ratio explained that MHA-carbohydrates were mainly of microbial origin, while LF- and POM-carbohydrates were of plant origin. Amino compounds constituted up to 30% of total soil N and were found to be more responsive to seasonal variation than to agronomic practices.

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Introduction

Total soil organic carbon (SOC) might not be a suitable tool to track the changes in organically based soil fertility within a 2- to 3-year transition period from conventional to organic farming. Labile SOC fractions are likely to be controlled by management to a much greater extent than is total soil organic matter (SOM). Isolating and quantifying these fractions will show the effects of management on SOM and better provide information about fertility status. Some SOM fractions that have been shown to respond to recent crop management include the particulate organic matter (POM), the light fraction (LF), and mobile humic acid (MHA) fraction. Certainly, these fractions have not been studied within the context of transition to organic farming. Further, the relative abundances of individual biochemical compounds (amino compounds, carbohydrates) in labile SOM fractions can help elucidate the sequestration and cycling patterns of plant and microbial tissues and of organic amendments during the transition to organic farming. The main objective of this work was to identify and characterize labile SOC fractions during the transition to organic farming.

Materials and Methods

Soil samples were collected from two fields under transition to organic farming in the south of Italy, at Foggia (FG) and Metaponto (MT). Experiments included a cereal/leguminous crop rotation with treatments of permitted amendments (compost or fertilizers) and three field replicates. Soils were sampled in September 2009, and after harvest of 2010 and 2011. Extraction of the LF and POM, MHA, and Ca-bound humic acid (CaHA) fractions was performed according to Cao et al. (2011). Soil, LF, 53-μm POM, and MHA were characterized for their contents of carbohydrates (Martens and Loeffelmann 2002) and amino compounds (Martens and Loeffelmann 2003). Further, isolated fractions were characterized by FT-IR spectroscopy. Experimental data of 2011 were subjected to analysis of variance using the multivariate general linear model procedure (SPSS 17.0, SPSS Inc.).

Results and Discussion

Main characteristics of isolated fractions are provided in Table 1. The amounts separated as 500-μm POM and CaHA did not allow further characterization, but some samples provided fair amounts that were analyzed for *C* and *N* content.

Table 1 Average characteristics of SOM fractions

Parameter	LF	53-μm POM	MHA	CaHA
C (g kg^{-1} fraction)	335.2	312.4	400.1	513.8
N (g kg^{-1} fraction)	19.5	24.8	35.8	47.0
% of SOC	3.81	3.55	9.75	0.21

Light fraction was found to be smaller than the MHA but more responsive to land management (Figs. 1 and 2). At FG site, light fraction-C (LF-C) increased after compost from 0.31 g C kg^{-1} soil in 2009 to 0.65 g C kg^{-1} soil in 2010 reaching 1.02 g C kg^{-1} soil after lentil in 2011. The POM-C, in 2010, did not largely vary compared to 2009, but it increased by 50% after compost and lentil in 2011 (Fig. 2) compared to 2010 values (Fig. 1). The MHA was found to be the largest fraction among isolated SOM fractions. MHA-C accounted for an average of 13.4% of total SOC at FG for both 2010 and 2011. Crop significantly ($P = 0.005$) affected MHA-C; MHA-C with compost treatment and lentil was 2.22 and 2.28 g C kg^{-1} soil for 2010 and 2011, respectively, while after compost and wheat, it was 1.76 and 2.11 g C kg^{-1} soil for 2010 and 2011, respectively (Figs. 1 and 2). In most cases, the compost treatment led to greater increase in the fraction-C than did the fertilizer treatment.

In MT site, the compost applied on C basis, 13.3 Mg ha^{-1} (compost-A), led to a very large increase in LF in 2010. LF-C in 2011 with compost-A was 1.65 g C kg^{-1} soil after lentil, which was greater than the MHA-C in MT with any treatments. Compost-A did not maintain the increase in LF-C in 2011 as LF-C decreased to 1.0 g C kg^{-1} soil but was still higher than the MHA-C with any treatment. At both experimental sites, FG and MT, SOC increased with compost treatments more than with the fertilizer treatment. It increased at FG during the 2-year course by 4–14% calculated as a proportion of the initial SOC.

Carbohydrates accounted to average of 30% of LF but less for MHA (Table 2). Glucose was the most abundant sugar in LF, while arabinose was the most abundant in MHA. Arabinose is described as a resistant sugar to decomposition. Xylose/mannose (Xyl/Man) ratio, used to assess the relative contributions of plant and microbial materials to a sample, was found about 0.9 for soil and showed the differences in the origin of carbohydrates for the isolated SOC fractions (Table 2). The ratio Xyl/Man showed that MHA-carbohydrates were of microbial origin, Xyl/Man ratio of 0.8, while LF- and POM-carbohydrates were more of plant origin. The amino compounds in soil and SOC were dominated by neutral amino acids. Amino compounds constituted up to 30% of total soil N with a major contribution of the humified fractions, MHA and CaHA. Amino compounds appeared to be likely responsive to seasonal variation more than to land management and agronomic practices. The glucosamine/ornithine (Glc-N/Orn) ratio describes the fungal/bacterial contribution to amino compounds in soil and SOC fractions. The ratio was found about 3.0 for soil amino compounds, and it suggested somewhat greater bacterial contributions than fungal to the MHA- and POM-derived amino compounds (Table 2).

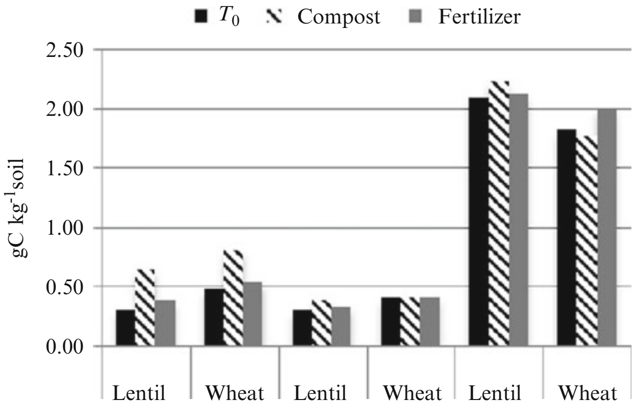

Fig. 1 SOM fractional C after T_0 (2009) and after different treatments and crops after 2010 harvest at Foggia site

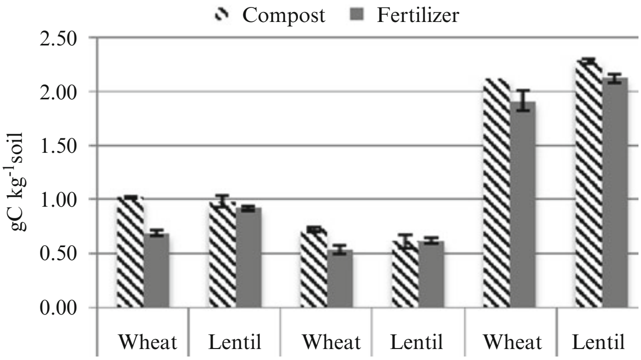

Fig. 2 SOM fractional C after different treatments and crops after 2011 harvest at Foggia site. *Error bars* represent the standard deviation

Table 2 Average biochemical characteristics of SOM fractions

Parameter	LF	53-μm POM	MHA
Total carbohydrates, %	30.0	4.6	2.0
Glucose, %	52.7	39.6	19.0
Arabinose, %	7.8	17.2	31.7
Xyl/Man	9.2	3.3	0.8
Glc-N/Orn	6.0	0.7	0.7

Xyl xylose, *Man* mannose, *Glc-N* glucosamine, *Orn* ornithine

Isolated SOM fractions were characterized by different FT-IR absorption bands and peaks at different intensities. Light fraction was characterized by a relative decrease, in 2011, at 1,037 cm^{-1} ascribed to C–O stretching of the polysaccharides, while POM did not show notable spectral changes. The MHA together with CaHA showed a relative increase at 1,620 cm^{-1} ascribed to aromatic C=C vibrations and COO^{-} groups.

Conclusion

Labile SOC fractions and their contents of carbohydrates and amino compounds were found responsive to changes in land use and environmental conditions. The integrated procedure of SOC fractionation and characterization is recommended for short-term studies of SOC.

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