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Differences of stabilized organic carbon fractions and microbiological activity along Mediterranean Vertisols and Alfisols profiles

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ABSTRACT

This study examined the chemical and structural properties of humic substances and microbiological activity in order to verify differences in carbon dynamics along soil profiles in two Vertisols (*Typic Haploxerert* and *Xeric Epiaquert*) and two Alfisols (*Mollic Haploxeralf* and *Ultic Haploxeralf*) developed under Mediterranean climate in Italy. Humification parameters, thermal methods, including differential scanning calorimetry (DSC) and thermogravimetry (TG), together with Fourier transform infrared (FT-IR) and fluorescence spectroscopies were used to characterize humic acids (HA). Microbiological activity of soils was assessed by basal respiration, metabolic quotient (qCO_2) and C_{mic}:C_{org} ratio. FT-IR spectra and thermal analysis DSC/TG of HA extracted from the upper horizons showed a higher aliphatic character, whereas HA extracted from the lower horizons had a higher content of aromatic structures and polysaccharides. Moreover, the fluorescence index of the HA (HIX_{flu}) showed a higher degree of aromatic polycondensation in the subsoils. The C_{mic}:C_{org} ratio was negatively correlated with the HIX_{flu} of HA ($P<0.05$), while qCO_2 was positively correlated with the labile components of HA (Exo1/(Exo2+Exo3)) ($P<0.05$). These results suggest reduced C availability in deep horizons where HA structures resulted in complex and thermally more stable molecules. Following discriminant function analysis all the chemical and microbiological properties with the exception of labile thermal fraction of HA and soil pH largely varied between B and the upper horizons. In deep horizons of both Vertisols and Alfisols the microbial biomass was nutritionally stressed with a low efficiency in C turnover. No correlation was found between specific soil processes, such as argilliturbation or clay illuviation and humic substances properties or soil microbial biomass and activity.

1. Introduction

Investigations of Vertisols and Alfisols usually focus on the properties of their mineral components, mainly nature and features of the clays (Righi et al., 1998; Nguetnkam et al., 2007; Bonifacio et al., 2009). These are involved in specific soil genetic processes, i.e. argilliturbation in Vertisols and illuviation in Alfisols, (Schaetzl and Anderson, 2005), and determine their taxonomic classification. However, little is known about the aspects concerning humic substances, microbiological activity and carbon (C) dynamics in such soils. Both humic substances and microbial biomass should be investigated together to obtain an overview of C dynamic along soil profile (Paul and van Veen, 1978; Jenkinson and Parry, 1989). As outlined by different authors (Coulombe et al., 1996; Fierer et al., 2003; Goberna et al., 2006), soil organic matter (SOM) turnover is usually rapid in the upper horizons, while it takes longer as the depth increases. Since the rate of C turnover depends on environmental conditions, soil management and soil solid component interactions (Jastrow et al., 2007; Lugato and Berti, 2008), the stabilization of organic matter in soil is also related to specific pedogenetic factors (parent material, landform and land use). The C stabilization processes are related to intrinsic resistance to degradation of organic compounds and to interactions of soil organic matter with the mineral fraction (Sollins et al., 1996). The recalcitrance is linked not only to the presence of compounds that are scarcely appealing for microrganisms, but also to the different reactions leading to humification process (Jastrow et al., 2007); therefore the humification process is considered an important mechanism of SOM stabilization (Krull et al., 2003).

With regard to the C-biomass pool, some indexes have been suggested as indicators of SOM turnover. The microbial quotient — i.e. the ratio of biomass C (C_{mic}) to soil organic C (C_{org}) reflects the contribution of microbial biomass to soil organic carbon (Anderson and Domsch, 1989). It can be usefully related either with the substrates

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available to the soil microrganisms or, conversely, to the fraction of recalcitrant organic matter in the soil (Brookes, 1995). Basal respiration rate per unit of microbial biomass (metabolic quotient — qCO_2), originally based on Odum's theory of ecosystem succession, has been widely used (Insam and Haselwandter, 1989; Anderson, 2003; Bastida et al., 2008), although its reliability as an index of either ecosystem disturbance or development has been criticised (Wardle and Ghani, 1995). This is because it enables an adequate evaluation of the efficiency of use of C resources by the soil microbial biomass and helps estimate the degree of substrate limitation for soil microbes (Dilly and Munch, 1998). The formation of stabilized organic compounds is largely determined by either SOM turnover or soil minerals, in fact humic acids are known to show significant differences according to their origin (Buurman et al., 2009). Among several analytical techniques, thermal and spectroscopic analysis (DSC: differential scanning calorimetry; TG: thermogravimetry; FT-IR: Fourier transform infrared; fluorescence spectroscopy) have been widely used to characterize soil humic substance structure and composition (Ricca et al., 1993; Dell'Abate et al., 2002, 2003; Senesi et al., 2003; Mafra et al., 2007). In particular, a previous study (Dell'Abate et al., 2002) reported that the different evolutions of SOM in two Vertisols apparently affected both the structure and composition of humic fractions. By contrast, no information is available on this relationship along Alfisol profiles.

The aim of this study was to assess the relationships between SOM characteristics and some edaphic genetic process (argilliturbation and clay illuviation) in two benchmark Vertisols and two benchmark Alfisols in southern Italy. SOM was analysed in terms of humic acid (HA) characteristics and soil microbial activity, in order to assess differences or similarities in SOM dynamics and C stabilization along their profiles.

2. Material and methods

2.1. Study area

Two free-drained Vertisols (pedon Vert-1 and pedon Vert-2) and two free-drained Alfisols (pedon Alf-1 and pedon Alf-2) were described and sampled according to the sequence of the genetic horizons (Schoeneberger et al., 2002) in regions of southern Italy (Sicily, Lucania and Apulia), where such soils are particularly widespread. The sampling points (Fig. 1), were chosen to encompass the widest possible variability of the soil-forming factors. The only common features among the soils surveyed were climate (Mediterranean), and slope (1–2%); the other pedogenetic factors (parent material, landform, and land use) differ significantly one from another. The soil-forming factors, together with the sampling date and the classification of the surveyed soil profiles are shown in Table 1.

2.2. Laboratory procedures

2.2.1. Soil analyses

Soil samples were air-dried and 2 mm sieved for laboratory analysis. Physico-chemical characterisation and subsequent classification analyses were carried out using the official methods of analysis (MiPAF, 2000). Particle-size distribution was determined by the pipette method without removing carbonates; soil pH was measured on 1:2.5 soil to water (w:v) mixtures. Total carbonate was measured

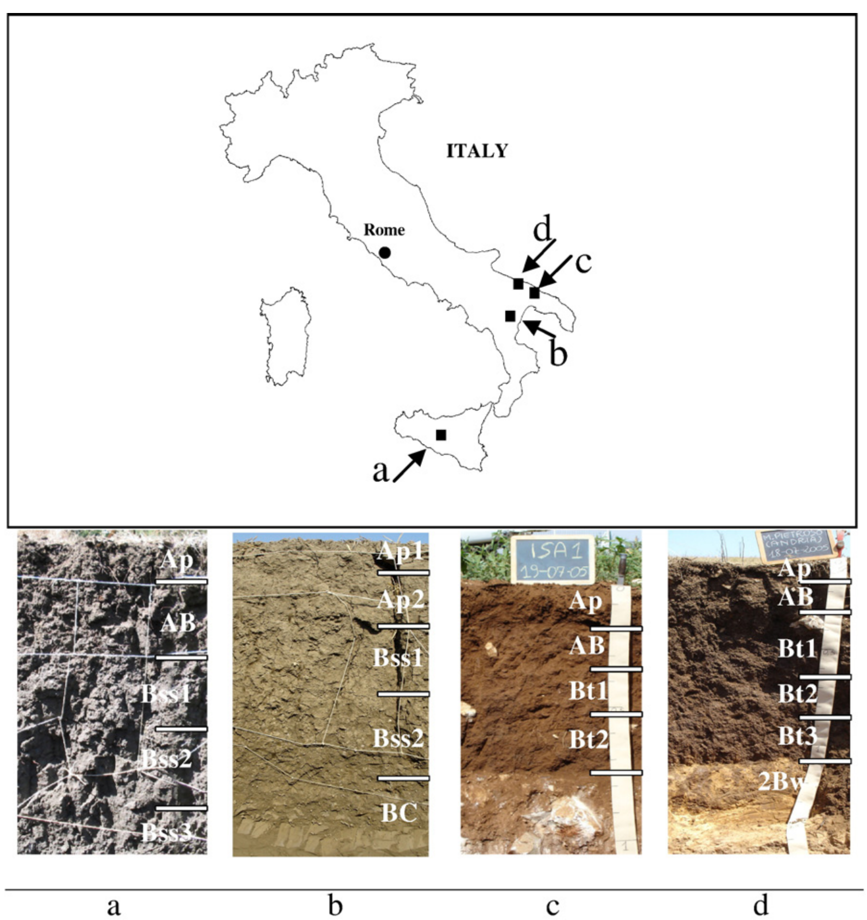

Fig. 1. Location of the study areas and soil profiles surveyed (a: Vert-1; b: Vert-2; c: Alf-1; d: Alf-2).