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# Soil carbon and nitrogen mineralization kinetics in organic and conventional three-year cropping systems

S. Marinari [a,*], A. Lagomarsino [b], M.C. Moscatelli [a], A. Di Tizio [a], E. Campiglia [c]

[a] Dipartimento di Agrobiologia e Agrochimica, Università degli studi della Tuscia, via S. Camillo de Lellis, Viterbo 01100, Italy
[b] Dipartimento dell'Ambiente Forestale e delle sue Risorse, Università degli Studi della Tuscia, Via S. Camillo de Lellis, Viterbo 01100, Italy
[c] Dipartimento di Produzione Vegetale, Università degli studi della Tuscia, Viterbo 01100, Italy

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ABSTRACT

The scientific literature regarding the use of C and N mineralization kinetics as a tool to highlight the effects of different cropping systems on soil C and N release is scarce. In this study we aimed to assess the effectiveness of these parameters in evaluating soil C and N potential release in organic (ORG) and conventional (CONV) three-year cropping systems. A long-term field study was established in 2001 at the University of Tuscia experimental farm (Viterbo, Italy) in a randomized block design. The soil is classified as *Typic Xerofluvent* or *Dystric Fluvisol*. In the CONV system the Good Agricultural Practice is adopted, whereas the ORG system is managed following the Regulation 2092/91/EEC. Both systems had a three-year crop rotation (pea – *Pisum sativum* L.; durum wheat – *Triticum durum* Desf.; tomato – *Licopersicum esculentum* Mill.). One of the main differences between the two systems is the soil N fertilization program: organic fertilizers (Guano: 6% N, 32% organic carbon and DIX10: 10% N, 42% organic carbon, both produced by Italpollina, Italy) and mineral nitrogen fertilizers ($NH_4NO_3$) were applied to ORG and CONV fields, respectively. Moreover, the rotation in the ORG system included common vetch (*Vicia sativa* L.) and sorghum (*Sorghum vulgare* L.) as green manure crops. Our results supported the hypotheses in that the two systems differed significantly on potentially mineralizable C ($C_0$) in 2008 and on potentially mineralizable N ($N_0$) as nitrate form ($N_0$-$NO_3^-$) in 2006 (318 μg C-$CO_2$ $g^{-1}$ 28 $d^{-1}$ vs. 220 μg C-$CO_2$ $g^{-1}$ 28 $d^{-1}$; 200 μg N-$NO_3^-$ $g^{-1}$ vs. 149 μg N-$NO_3^-$ $g^{-1}$ in ORG and CONV, respectively). The reduction of $N_0$ in soil during the crop rotation period could reflect the N microbial immobilization since a negative correlation between microbial biomass N:total N ratio and $N_0$ as ammonium form ($N_0$-$NH_4^+$) ($P < 0.001$) as well as a positive correlation between $N_0$-$NH_4^+$ and C:N ratio of microbial biomass ($P < 0.05$) were observed. Moreover, a lower potential mineralization rate of N was observed in soil with Guano (25%) than in soil with DIX10 (35%); nevertheless the former fertilizer might cover a longer period of crop N demand as a more gradual release of $N_0$ was observed. In this work we demonstrated that the use of mineralization kinetics parameters can offer a potential to assess the mineralization–immobilization processes in soils under different climatic and management conditions. Moreover, they can be used to evaluate the most suitable N release pattern of organic fertilizers used in various cropping systems.



## 1. Introduction

The conversion of agricultural systems to improve their sustainability can be achieved with a gradual change from strictly conventional practices (e.g., monocultures with massive mineral fertilization) through Good Agricultural Practices (GAPs) to the adoption of organic farming principles (Abubaker et al., 2008). Good Agricultural Practice (GAP) is based on the principles of risk prevention, risk analysis, and sustainable agriculture by means of Integrated Pest Management (IPM) and Integrated Crop Management (ICM) to continuously improve farming systems. GAP is of utmost importance in protecting consumer health and requires ensuring safety throughout the food chain (Akkaya et al., 2006). Organic farming systems rely on the management of organic manures and soil organic matter (SOM) to enhance soil chemical, biological, and physical properties, to optimize crop production (Watson et al., 2002) and to return nutrients back to the soil. Therefore, organic management of agricultural soils positively influences soil properties (Tu et al., 2006) since the addition of organic amendments improves SOM accumulation by increasing carbon (C) pools with a slow turnover time (Lal and Kimble, 1997).

* Corresponding author.
*E-mail address:* marinari@unitus.it (S. Marinari).

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SOM is considered to be a key attribute of soil quality (Gregorich et al., 1994) and is usually considered as one of the most important properties of soils because of its impact on ecosystem sustainability and its effects on other soil physical, chemical, and biological characteristics (Reeves, 1997). Moreover SOM can provide mineral nutrients for plants and micro-organisms through the mineralization process or biochemical oxidation of organic substrates. For this reason SOM content is the result of an equilibrium between the processes supplying new organic inputs and the rate of mineralization of the existing SOM (Stockdale et al., 2002). Cycles of C and nitrogen (N) are strongly linked in organic cropping systems. N is frequently considered to be one of the key crop growth limiting factors (Berry et al., 2002; Cavigelli et al., 2008; Möller et al., 2008). However, the synchronization between the supply of N by mineralization of organic manures and crop N demand cannot be easy to achieve (Pang and Letey, 2000; Gaskell and Smith, 2007). Simultaneously, readily degradable C compounds added to the soil can lead to an immobilization of mineral N (Dosch and Gutser, 1996). Mineralization and immobilization are thus soil microbial processes governed by C availability and are closely linked to both SOM quality and its active fractions (Hassink, 1994). Therefore, an active soil microflora and a considerable pool of accessible nutrients are two important priorities in organic cropping systems (Wander et al., 1994). Differences between composition of SOM in organically and conventionally managed soils have been demonstrated by some authors (Elmholt, 1996; Wander and Traina, 1996; Marinari et al., 2007). A rapid mineralization process of labile SOM consuming cellulose structures has been reported in soil under organic farming, while the attack of soil native organic matter has been observed in conventionally managed soil (Marinari et al., 2007). The microbially mediated N mineralization in organically managed soil is also important in order to sustain plant productivity without the use of mineral fertilizers. Several studies show that organic farming leads to higher soil quality with greater microbiological activity and enhanced nutrient availability when compared with conventional farming, due to versatile crop rotations, application of organic fertilizers, and absence of pesticides (Hansen et al., 2001; Shannon et al., 2002; Marinari et al., 2006). The increase of microbial biomass and activity under organic management leads to increased nutrient availability for plants (Zaman et al., 1999; Tu et al., 2003; Wang et al., 2004; Marinari et al., 2006). In fact, Tu et al. (2003) showed that enhanced soil microbial biomass and activity were associated with high net N mineralization rates, which resulted in larger N availability. Nevertheless, the crop growth in organic systems is very often N limited, and not C limited, which means that the soil C supply is largely sufficient to sustain long-term soil fertility.

In 2001, an experiment was established at the University of Tuscia experimental farm (Viterbo, Italy) to study crop yield in a three-year crop rotation (pea – *Pisum sativum* L.; durum wheat – *Triticum durum* Desf.; tomato – *Licopersicum esculentum* Mill) under organic and conventional management, and to study differences in soil quality and nutrient cycling between the two systems. Results from the fourth year reported by Lagomarsino et al. (2009) showed that the effect of organic fertilization was crop species dependent considering only one year of the three-year rotation. To escape this short-term bias of crop species in this paper we investigated the impact of organic management on soil C and N cycling considering the whole crop rotation. The mineralization kinetics parameters were used as a tool to assess C and N potential accumulation and mineralization during the whole crop rotation. The scientific literature regarding the use of C and N mineralization kinetic parameters as a tool to highlight the effects of different cropping systems on soil C and N release or to evaluate N potential mineralization organic fertilizers is scarce. For these reasons and with the aim to contribute to fill a gap in this specific field of agricultural research, the objectives of this study were: (i) to evaluate differences between organic and conventional cropping systems in terms of C and N potential mineralization; and (ii) to assess the potential mineralization kinetics of N in the two fertilizers applied in the organic cropping system in order to evaluate the nitrogen availability of the specific fertilizers, allowed in organic farming, through their time-dependent release.

## 2. Materials and methods

### 2.1. Site description

A long-term field study was established in 2001 at the University of Tuscia experimental farm (Viterbo, Italy, 42°26′N, 12°04′E, 310 m above see level), in order to compare organically (ORG) and conventionally (CONV) managed soil in a randomized block design with three replications. The soil is a clay loam and classified as *Typic Xerofluvent* (Soil Survey Staff, 2006) or *Dystric Fluvisol* (WRB, 2006). Soil characteristics at the start of the experiment were: clay loam texture according to USDA classification, pH 6.9, total nitrogen 0.12%, total organic carbon 0.85%. In the conventional cropping system (CONV) the Good Agricultural Practice (GAP), including the use of chemical fertilizers and pesticides, was adopted according to the Italian and European regulations (D.M. April 19, 1999 and Regulation 2078/92/EEC, respectively) (EC, 1991). The organic cropping system (ORG) system was managed following the Regulation 2092/91/EEC (EC, 1991). Both systems have a three-year crop rotation (pea – *P. sativum* L.; durum wheat – *T. durum* Desf.; tomato – *L. esculentum* Mill.). Tomato was irrigated according to potential evapotranspiration replacement (3500–4000 $m^3$ water $ha^{-1}$). In the ORG, the rotation started with common vetch (*Vicia sativa* L.) as a cover crop and sorghum (*Sorghum vulgare* L.) as a catch crop, both used as green manure before tomato transplanting and pea planting, respectively. Organic fertilizers (Guano: 6% N, 32% organic carbon, 15% $P_2O_5$, 3% $K_2O$, 3.5% humic acids, 7.5% fulvic acids and DIX10: 10% N, 42% organic carbon, 3% $P_2O_5$, 3% $K_2O$, 3.0% humic acids, 7.0% fulvic acids both produced by Italpollina, Rivoli Veronese, Italy) were used only in the ORG and mineral nitrogen ($NH_4NO_3$) fertilizers were applied in CONV. In Table 1 total C and N inputs (green manure + straw + fertilizers) supplied at each rotation cycle are reported.

The three species were simultaneously cropped in the experimental field that included 18 plots: 2 systems × 3 crops × 3 3 replicates.

### 2.2. Soil sampling

Soil samples were collected in February 2006 and 2008 in order to verify the effect of soil management on soil C and N mineralization potential. After removal of the litter layer two soil cores were taken inside each plot (0–20 cm depth) and then pooled together. Soils were sieved (<2 mm) in order to ascribe the observed potential mineralization activity only to microbial biomass excluding other living organisms. Soil samples were kept at 4 °C prior to analyses. Soil water content was adjusted to 60% of water holding capacity (WHC); then soil samples were left to equilibrate at room temperature in the dark for 24 h before incubation for C and N mineralization assays. Soil sieving affects aggregate size and stability, but as we reported above it is not a real measurement and thus does not take into account neither the real climatic conditions nor soil structure.

### 2.3. Chemical and biochemical analyses

Microbial biomass carbon ($C_{mic}$) was determined following the Fumigation Extraction (FE) method (Vance et al., 1987). Microbial