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# Assessing the use of composts from multiple sources based on the characteristics of carbon mineralization in soil

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ABSTRACT

In order to improve soil quality, reduce wastes and mitigate climate change, it is necessary to understand the balance between soil organic carbon (SOC) accumulation and depletion under different organic waste compost amended soils. The effects of proportion (5%, 15%, 30%), compost type (sewage sludge (SS), tomato stem waste (TSW), municipal solid waste (MSW), kitchen waste (KW), cabbage waste (CW), peat (P), chicken manure (CM), dairy cattle manure (DCM)) and the black soil (CK). Their initial biochemical composition (carbon, nitrogen, C:N ratio) on carbon (C) mineralization in soil amended compost have been investigated. The $CO_2$-C production of different treatments were measured to indicate the levels of carbon (C) mineralization during 50 d of laboratory incubation. And the one order E model (*M1E*) was used to quantify C mineralization kinetics. The results demonstrated that the respiration and C mineralization of soil were promoted by amending composts. The C mineralization ability increased when the percentage of compost added to the soil also increased and affected by compost type in the order CM > KW, CW > SS, DCM, TSW > MSW, P > CK at the same amended level. Based on the values of $C_0$ and $k_1$ from *M1E* model, a management method in agronomic application of compost products to the precise fertilization was proposed. The SS, DCM and TSW composts were more suitable in supplying fertilizer to the plant. Otherwise, The P and MSW composts can serve the purpose of long-term nutrient retention, whereas the CW and KW composts could be used as soil remediation agent.



## 1. Introduction

Due to the pressure of intensive human activity, improper farming and management practices pose serious threats to the sustainability of natural resources, resulting into challenges related to improper cultivation, over-cultivation, soil erosion and soil fertility decline. These factors are usually associated to one another, leading to lower soil fertility and decrease food security, resulting to poverty, non-point source pollution and natural resources degradation trap. Meanwhile, the development of agriculture and the economy leads the production of a variety of organic solid wastes, which include animal manure, municipal waste, plant litter, and so on (Masunga et al., 2016). These organic solid wastes are abundant, spot focused, which can cause strong pollution and environmental problems without promptly controlled (Price et al., 2013; Wei et al., 2013; He et al., 2013). Therefore, the organic solid waste disposal through composting is very important, and the compost production can increase agricultural productivity. Composting biodegradable parts of urban solid waste, agricultural waste, and recycling the compost can provide a wealth of nutrient resources, which can improve the soil as a soil organic amended for commercial agriculture (Gómez-Brandón et al., 2008). The volume of these wastes can be reduced by approximately 50% (Helfrich et al., 1998) and disposal cost can be recovered (Levy and Taylor, 2003). However, these organic solid waste compost are required to be adequately processed before applying to the soil. In addition, mature compost can kill the pathogenic microorganisms present in its compost, thereby avoiding a number of harmful effects on the soil properties, so the mature compost with a well high-temperature stage is eco-friendly (Senesi and Brunetti, 1996; Bernal et al., 1998; Yang et al., 2013; He et al., 2014).

In addition, investigation on the decomposition of the organic materials added to the soil is an important analysis of the organic matter balance in the soil. Also it is essential to understand how to improve soil fertility using the relative value of different materials (Saviozzi et al., 1993). The decomposition process, called mineralization, expresses a decrease in organic matter content and an increase in available minerals which are previously immobilized in organic form (Masunga et al., 2016). The mineralization of

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organic matter in a soil depends on two major factors, the soil type and the quantity of organic matter incorporated (Levi-Minzi et al., 1990). To carbon mineralization (C mineralization), the rate at which the soil organic matter is degraded to $CO_2$ depends mainly on the nature of its interactions with the soil matrix. In incubation experiments, the rate of the mineralization of soil organic matter and the amount of mineralizable C were found to be influenced by the characteristic of additional materials (Masunga et al., 2016), amount and quality of soil C pool (Riffaldi et al., 1996; Ahn et al., 2009), exchange capacity and microbial activity (Riffaldi et al., 1996).

In the other hand, Aslam et al. (2008) and Masunga et al. (2016) propose to use kinetic models for providing a mathematical support of the dynamics of C mineralization in incubation, which can be used to predict the ability of soils in supplying potentially mineralizable organic carbon, and organic matter balance. Utilizing C mineralization models based on $CO_2$ respiration rate stability, the C mineralization can be predicted in compost-amended soil. Some investigators have compared a few different kinetic models to describe the observed C mineralization in compost-amended soil, and some studies focus on the C mineralization ability from several (single) compost-amended soils (Aslam et al., 2008; Masunga et al., 2016). Currently, there is no systematic study about the effects of different mineralization models on the assessment of organic carbon.

In this paper, we selected eight typical organic waste composts which can reach the same degree of maturity. The compost samples were mixed with the soil at 5%, 15% and 30% field applications. A short-term laboratory incubation experiment was performed, to evaluate the effects of different organic waste compost on the C mineralization of a black soil. We used the first-order *E* model to describe the influences of different organic waste compost-amended soils on C mineralization (Aslam et al., 2008). The purpose of the laboratory aerobic incubation experiments was to illustrate the kinetic differences of C mineralization and to evaluate the organic carbon mineralization rate of different compost-amended soils. The ability to form organic C mineralization from organic waste compost-amended soil provided insight into the predictions of the soil's behavior in the natural environments. We studied the dynamic characteristics of $CO_2$ release and the carbon stock stability in the organic solid waste compost-amended soil, scientifically. It is important to sequestrate carbon and nutrient, thereby, promoting the total greenhouse gas (GHG) mitigation in organic waste compost-amended soil.

## 2. Materials and methods

### 2.1. Soil and composting sample properties

The black soil (CK) used in this study was collected from the upper 15 cm of an arable field located at Xiangfang Experimental Farm (Heilongjiang Province, China 45 °44′23″N, 126 °43′16″E). Soil samples were air dried at 25 °C, homogenized, manually ground with hands and passed through a 2 mm mesh sieve. The soil was stored in a refrigerator at 4 °C until they were used.

Eight trapezoidal piles were prepared by Shanghai Songjiang Composting Plant, using dairy cattle manure (DCM), kitchen waste (KW), cabbage waste (CW), Tomato stem waste (TSW), municipal solid waste (MSW), sewage sludge (SS), chicken manure (CM), and peat (P). Each composting plie was conducted with a single material. Each composting pile contained approximately 2 t of raw material (1.5 m high with a 2 × 3 m base). The piles were turned over by forklift, when necessary, in order to improve the fermentation process. Composting was considered finished when the temperature of the pile became stable and germination index approached 80%, then, approximately 2 kg of samples were collected from the mature composts, and stored at 4 °C for analysis (Wei et al., 2013). Water holding capacity was measured by saturating the soil/compost, gravity draining for 24 h, and then determining the moisture content of the saturated media by oven drying at 105 °C. Prior to these experiments, soils and composts were all wet to 60% of their water holding capacities. The eight compost samples were air-dried at room temperature and filtered using sieves (<2 mm mesh).

### 2.2. Mineralization experiment

The compost sample was mixed thoroughly with soil and a controlled moisture level was maintained at 60% of the maximum water holding capacity (WHC) with distilled water. The samples were aerobically incubated at 25 °C for 50 days. The compost samples were mixed with the soil at 0%, 5%, 15%, 30% compost (v/v), where 0% was the CK. In total 1 kg soil-compost mixture was placed into a sealed cylindrical plastic pot (5.15 cm internal diameter and 18 cm length). All treatments were prepared in triplicate. In addition, the plastic pots were modified to accommodate two polyethylene fittings to supply and exhaust air; the samples were aerated continuously with humidified air to avoid oxygen limitations (Aslam et al., 2008). The carbon dioxide concentration was measured on the influent and effluent air of the reactors every 12 h using an infrared $CO_2$ sensor (GXH-3010E1) (VanderGheynst et al., 2002). The $CO_2$ evolution rate was calculated, and the data of percentage of carbon evolved after 50 d was based on the cumulative release of $CO_2$ and the initial value of TOC. In addition, Total organic carbon (TOC) was measured based on potassium dichromate oxidation (Nelson and Sommers, 1982) and Total Nitrogen (TN) was measured by a modified Kjeldahl method (Bremmer and Sulvaney, 1982).

### 2.3. Mineralization kinetic models

We selected mineralization kinetic models which has biological significance and could be written in a discrete form with parameters having biological significance. The one order *E* kinetic (*M1E*) model was used in this study using the cumulative $CO_2$-C evolve during the period of incubation. The *M1E* model was originally proposed for N mineralization by Jones (1984). The model was already found useful in describing the decomposition process in the soil amended with different types of organic materials (Saviozzi et al., 1993). The *M1E* models which is another variation of the first-order model, is given by the equation:

$$C_{(t)} = C_0\{1 - \exp(-k_1 \cdot t)\} + C_1 \quad (1)$$

where $C_1$ (g $CO_2$-C kg$^{-1}$) represents a separate pool of an easily decomposable substrate that produces a mineralization flush during the first incubation interval. $C_0$ is the size of the active carbon fraction (g $CO_2$-C kg$^{-1}$), and $k_1$ is the mineralization rate constant for the decomposition of the active carbon fraction (day$^{-1}$).

### 2.4. Statistical analyses

The cumulative data of the mineralized carbon were fitted to mathematical equations by the non-linear least-square curve fitting technique (Marquardt-Levenberg algorithm) using MATLAB R2010 b software. The analytical data were subjected to a one-way ANOVA testing using Statistic 8.0 software.