European Journal of Soil Biology 78 (2017) 66–74

Contents lists available at ScienceDirect

European Journal of Soil Biology

journal homepage: http://www.elsevier.com/locate/ejsobi

Original article

Influence of pruning waste compost maturity and biochar on carbon dynamics in acid soil: Incubation study

Nikola Teutscherova [a, b, *], Eduardo Vazquez [b], Diana Santana [b], Mariela Navas [b], Alberto Masaguer [b], Marta Benito [b]

[a] Department of Crop Sciences and Agroforestry, Faculty of Tropical AgriSciences, Czech University of Life Sciences Prague, Kamýcka 129, Prague 6, Suchdol 16500, Czechia

[b] Departamento de Producción Agraria, Escuela Técnica Superior Ingenieros Agrónomos, Universidad Politécnica de Madrid, Avd. Complutense s/n, E-28040 Madrid, Spain

ARTICLE INFO

Article history:
Received 13 July 2016
Received in revised form
1 December 2016
Accepted 5 December 2016
Available online 18 December 2016

Handling Editor: C.C. Tebbe

Keywords:
Carbon mineralization
Microbial biomass carbon
Priming effect
Soil respiration

ABSTRACT

Compost is the most common organic fertilizer supplying nutrients and organic carbon to soil as well as improving soil physical, chemical and biochemical properties. On the contrary, biochar application to soil usually does not add nutrients, but can have effect on nutrient transformations and microbial community and alleviates soil acidity. Although these two products of organic residues recycling have different function in soil, their co-application could result in synergistic effect on soil biochemical properties. Therefore, the aim of present study was to determine how the application of biochar and compost in two stages of maturity (one month old after bio-oxidative phase; and final mature compost), applied alone or together, affects soil pH, water soluble carbon and nitrogen contents, carbon and nitrogen mineralization, microbial biomass and enzymes activities in acid soil in a short-term (60 days) incubation study. Additionally, same treatments were tested in a ryegrass growth assay. Application of all organic materials increased soil pH, which probably resulted in microbial community changes and overall decrease of microbial biomass carbon. Soil respiration was increased after application of immature compost (903 μg CO_2-C g^{-1}) or its mixture with biochar (823 μg CO_2-C g^{-1}), but we did not observe significant increase in respiration after biochar application respect to control (402 μg CO_2-C g^{-1}). Biochar decreased β-glucosaminidase activity and increased the activity of dehydrogenase. The higher values in β-glucosidase and dehydrogenase activities, as well as soil respiration, when immature compost and biochar were applied together, showed the synergism between these materials. Ryegrass growth was stimulated by all organic amendments, but combined application of immature compost and biochar resulted in growth increment lower than only biochar or only compost application. Adequate stabilization of pruning waste compost avoided priming of SOM induced by biochar co-application.

1. Introduction

Sustainable organic residues management is a key step in nutrients recycling and is essential in order to maintain soil fertility. To date, the most common form of organic wastes recycling is composting which consists of decomposition of organic matter (OM) by the action of thermophilic and mesophilic microorganisms. When pruning waste is used, the final product, pruning waste compost, is relatively cheap and suitable for soil application [1]. However, care needs to be taken in determining the compost maturity, which during composting process undergoes four stages: (i) initial stage (no decomposition), (ii) the thermophilic phase (high temperatures, rapid degradation), (iii) the end of bio-oxidative phase (drop of temperature), and (iv) maturation phase (stabilization). Final compost is stabilized, humified and pathogen-free product which continues mineralization in slower rate liberating nutrients after its application to soil. Depending on composting facility and actual demand, also compost at the end of bio-

Abbreviations: OM, organic matter; PE, priming effect; SOC, soil organic carbon; SOM, soil organic matter; TOC, total organic carbon; WSC, water-soluble carbon; WSN, water-soluble nitrogen.

* Corresponding author. Department of Crop Sciences and Agroforestry, Faculty of Tropical AgriSciences, Czech University of Life Sciences Prague, Kamýcka 129, Prague 6, Suchdol 16500, Czechia.

E-mail address: nikola.teutscherova@upm.es (N. Teutscherova).

http://dx.doi.org/10.1016/j.ejsobi.2016.12.001
1164-5563/

oxidative stage can be applied to soil, because according to some parameters at this point it could be considered mature enough to be applied to soil [1]. In some cases, when immature compost is used, its high content of water soluble carbon (WSC) can lead to stimulation of microbial activity followed by an increased carbon dioxide (CO_2) fluxes, a higher soil organic matter (SOM) decomposition that it is referred to as priming effect (PE), and a nitrogen (N) immobilization [2].

As an alternative to aerobic composting, organic residues can be processed anaerobically via fermentation or biogas digestion, or via pyrolysis by heating the material to high temperature in oxygen limited environment which leads to carbonization of organic matter and production of biochar. During pyrolysis, the major part of CO_2 trapped by plants to form biomass is converted into recalcitrant form of C with hundreds to thousands of years of stability [3], leaving only small part labile and accessible to microorganisms [4]. This labile part has been observed to participate in chemical and biochemical reactions and to influence C mineralization in soil [5]. The stimulation of native SOM caused by biochar has been reported to be short- to medium-term and depends on feedstock material and pyrolysis temperature [5] and, consequently, on microbial biomass changes caused by biochar application to soil [6]. Both positive [5] and negative [7] PE of biochar have been observed but the mechanisms and causes remain unclear. Biochar-induced stimulation or reduction of CO_2-C losses seems to be attributed to different composition of biochar depending on biochar labile C content. Hard-wood biochar was observed to cause the highest long-term decrease in soil organic carbon (SOC) mineralization [5], possibly for its great sorption capacity that could protect labile C from microorganisms. Despite its recalcitrance, application of labile substrate could lead to increased biochar C mineralization, as it was found by Hamer et al. [8] after glucose application. Furthermore, a number of studies have reported that adding biochar to soils may affect soil physical and chemical properties [3], which have further effect on nutrient turnover and transformation [3] and can influence soil microorganisms simultaneously. When biochar enters the soil system, it can trigger mechanisms to increase SOC mineralization directly by providing easily accessible C source leading to increased microbial activity or by causing the mining for N, or indirectly by removing obstacles in microbial activity [9]. Alternatively, by changing the microbial preferences [10] or decreasing labile SOC availability via sorption (among other mechanisms) biochar application can lead to overall decrease of SOC mineralization.

On the other hand, it should be taken into account that application of only biochar to soil may have an adverse effect on plant growth probably as a result of the adsorption of mineral nitrogen and dissolved organic C onto the surface of biochar [11]. To prevent nutrient immobilization, the co-application of biochar and fertilizer could compensate for biochar-induced N limitation for crops and N immobilization [12]. The application of biochar together with compost was investigated by Liu et al. [13], who found synergistic effect on soil fertility and plant growth. In limited amount of studies, biochar was applied together with easily degradable C source such as glucose [8], wheat straw [14], switchgrass or sugar cane residues [10] with highly inconsistent results. Nevertheless, information about existence of such a synergistic effect on biochemical properties is still limited, despite of its potential to help in elucidating complicated biochar-induced changes in soil.

The main aim of this study is to test whether hard-wood biochar, previously cited to have the greatest long term potential to decrease SOC mineralization [5], interacts with composts in two stages of maturation when applied together to the soil. In continuation, if this possible interaction reflects in a decreased priming of SOC and previously documented N mineralization [2] when pruning waste compost, rich in labile C, is applied to soil. Based on the information gap in this possible synergistic functioning of both products, we set a hypothesis, that different organic amendments will have different effect on microbial biomass and activity in the soil, and that this effect would be related to increased soil pH of these acid soils. To better understand changes in soil respiration, four soil enzymes participating in organic matter (OM) decomposition and nutrient cycling were selected and measured at the end of the 60-days incubation. Simultaneously, ryegrass assay was setup to determined possible detrimental or synergistic effects of application of biochar and both composts.

2. Materials and methods

2.1. Soil and organic materials

Soil used for the incubation was obtained from degraded ecosystem of *"raňa"* in SW Spain and classified as Plinthic Palexerult [15]. The climax vegetation of the area is cork-oak forest which was replaced by holm-oaks, olive groves and agricultural land, resulting in soil degradation, loss of SOC and low pH. Soil contained 80.1% of sand, 6.1% of silt and 13.8% of clay. Fresh soil was sieved (<2 mm) and basic properties determined (Table 1).

Biochar (Bc) was produced from holm oak (*Quercus* spp.) at temperature of 600 °C in oxygen-restricted environment in batch system and crushed to pass 2-mm sieve. Compost was produced from pruning waste, leaves and grass clippings (60–70% of the waste volume woody material, 30–40% green waste) in the composting facility "Migas Calientes" in Madrid. The mixture of waste was composted in trapezoidal windrow piles (2.5 m high, 5 m wide and 30 m long). Forced aeration was used during the first 30 days (bio-oxidative phase) followed by maturation period, during which the piles were turned periodically to maintain adequate O_2 levels. For the present study we used compost (<4 mm) in two stages of maturation, one-month old taken at the end of bio-oxidative phase (C1) and six months old compost (C2). Both C1 and C2 were relatively rich in C, low in N and with high pH values. The properties of Bc, C1 and C2 are listed in Table 1.

2.2. Incubation procedure and soil respiration

Soil sieved to 2 mm was amended with Bc, C1, C2, the mixture of C1 with Bc and C2 with Bc (S-Bc, S-C1, S-C2, S-C1-Bc and S-C2-Bc, respectively), in order to increase the SOC content by one per cent, from 2.58 to 3.58% total organic carbon (TOC) (equivalent to application of 24 t C ha^{-1}) in all cases. Application rates of all organic materials were calculated according to their C content. In case of mixtures, each component provided 50% of applied C. For incubation, equivalent to 100 g dry weight soil with addition of organic amendment containing 1 g of organic C, were placed in airtight plastic jars (0.5 L) for aerobic incubation with four replicates. All treatments and control were moistened until the 60% of their water holding capacity and incubated for 60 days at 25 °C in dark. Water content was regularly checked gravimetrically and adjusted with deionized water. Carbon mineralization was measured as CO_2-C loss using alkaline trap during the 60 days of incubation. The emitted CO_2 was trapped in 10 ml of NaOH which was titrated with HCl on days 1, 2, 6, 9, 16, 23, 30, 51 and 60 after carbonate precipitation with $BaCl_2$ [16].

2.3. Priming effect

Additionally, jars containing 50 g of each compost (C1 and C2), biochar (Bc), and 50 g of their mixtures, where 50% of C were derived from Bc and 50% from C1 (C1-Bc) or C2 (C2-Bc), were