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On-farm compost: a useful tool to improve soil quality under intensive farming systems

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ABSTRACT

Conventional agriculture that uses extensive tillage without organic inputs to soils can cause a degradation in soil quality. The improvement of soil organic matter (SOM) content can be achieved through the use of organic amendments. Application of organic amendments, such as compost, is a reliable tool to improve soil quality. On-farm composting is an ecological technology and can be used to recycle agricultural waste materials, such as animal manure or crop residues, that can be incorporated into the soil to improve soil quality. Therefore, the objective of this work was to characterize, by CPMAS-NMR spectroscopy and chemical properties, a commercial organic waste compost and an on-farm compost and, then, to compare their use as organic amendments on soil quality. A greenhouse study on intensive agricultural soils of Southern Italy was done. The following amendments, as soil treatment, were used: a municipal compost (MC), with C:N 13.3, and an on-farm compost (OF), with C:N 17.1, applied at the rate of 8.5 and 6.0 Mg DM ha^{-1}, respectively. After one, four, eight, twelve and fifteen months soil samples were collected and analyzed for chemical (pH, electrical conductivity, limestone, CEC, available phosphorus, organic carbon, total nitrogen and exchangeable bases) and microbial (urease, phosphomonoesterase, β-glucosidase, total hydrolytic activity and Biolog Ecoplate™) properties. MC compost was characterized by larger electrical conductivity and exchangeable Na^+ content with respect to OF compost, while this latter was characterized by about twice of organic carbon (470 g kg^{-1}). As showed by CPMAS-NMR spectroscopy, OF compost was characterized not only by cellulosic polysaccharides, but also significant amounts of both alkyl components and lignin derivatives. An effective increase of soil organic carbon (SOC) in plots under MC (+36%) and OF (+25%) composts, respectively, was reached at the end of the experiment. Soil amendments improved soil biological functions as revealed by a general trend of positive effects on hydrolase activity, phosphomonoesterase, β-glucosidase as well as urease. EC and exchangeable Na^+ were considerably larger only in the plots under MC compost (25% and 19%, respectively), with respect to control plot. The possible increase of soil salinity after compost amendment may negatively affect soil quality in the long-term. In conclusion, our results demonstrated that the supply of compost produced on-farm, can enhance soil biological and biochemical properties, without the drawbacks of municipal composts, representing a promising alternative to the latter and an important way to reuse wastes produced by cultivation and processing of vegetables.

1. Introduction

Landfill Directive (Council of the European Union, 1999) was published by European Union in 1999 to require, at member states, to reduce the amount of biodegradable waste dumped by

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promoting the adoption of measures to increase and improve sorting activities at the origin, recovery and recycling. The annual food and garden waste included in mixed municipal solid waste in the European Union is within 0.076–0.102 Pg, that represents 30–40% of the total annual municipal waste generation (European Commission, 2009).

Composting is one of the most ecological technologies for the management of the biowaste, allowing its material valorisation. It can be defined as the aerobic biological degradation and stabilization of organic substrates under controlled, thermophilic and aerobic conditions (Haug, 1993; Martínez-Blanco et al., 2010).

Industrial composting, to produce municipal solid waste compost, is widespread, but it implies the consumption of energy for waste transport and processing, (Haug, 1993).

On-farm composting could be an efficient, cost-effective and environmentally safe biological process for the recycling of residual agricultural biomasses (Maniadakis et al., 2004). It is a simple technology characterized by a small composting plants equipped with tools already available on a farm, where waste biomasses are transformed and stabilized through an aerobic biooxidation (Christian et al., 2009). In this way, the compost produced on-farm could contribute to solve the problem of disposing agricultural biomasses and vegetable feedstock and, at the same time, to provide for the farmer a self-supply of quality compost for the improvement of soil quality.

As observed, these two composting technologies present important differences and each one can be appropriate for different situations. For instance, on-farm composting can be a good alternative to industrial composting in intensive agricultural areas where a large investment in to dispose green waste, is required.

Intensive agricultural systems, such as cultivation under plastic tunnels, provides valuable economic profits to farmers and is a steadily growing agricultural sector that, in the last years, has reached more than 2 million ha worldwide (Scarascia-Mugnozza et al., 2011). In the Mediterranean Basin, such cultivation systems cover about 190,000 ha, mainly in Italy, Spain and Morocco (Pardossi et al., 2004). Such intensive agricultural systems negatively affect soil quality, because they are based on intensive tillage and frequent applications of pesticides and mineral fertilizers. A recent study (Scotti et al., 2015a) reported a significant decline in soil quality, principally through a reduction in soil organic matter (SOM) content, in agricultural areas in Southern Italy under permanent plastic tunnels. Systematic removal of crop residues and favourable conditions for SOM mineralization (high temperatures and continuous water and nutrient availability by fertigation) could contribute to soil degradation. Reduction of the carbon stock in agricultural soils is especially critical, because organic matter is pivotal for improving soil structure (Arthur et al., 2014) and chemical characteristics (Leifeld et al., 2002) and maintaining suppressiveness against soil-borne pathogens (Zaccardelli et al., 2013).

Application of organic amendments, such as compost, has been successfully proposed in many cases to improve soil structure and both chemical (Scotti et al., 2013) and biological fertility of the soils (Ros et al., 2003), as well as to suppress soil-borne pathogens (Zaccardelli et al., 2013).

Although a lot of studies focused on municipal solid waste (MSW) compost (Iovieno et al., 2009; Morra et al., 2010; Scotti et al., 2015b), little attention has been done so far to assess the possibility of an improve of soil quality by on-farm compost. Therefore, the objective of this study was to compare a commercial organic waste compost to an on-farm compost evaluating (i) their chemical features and (ii) the effects of compost amendments on soil quality, under intensive farming system, measuring chemical and biological soil properties.

2. Materials and methods

2.1. Study sites description

Experimental site was located in Southern Italy (40° 34′ 36.538″ N, 15° 1′ 30.932″ E) within Salerno District, a very productive area with roughly 4000 ha cultivated under greenhouses. The greenhouse types used in this area are low-cost, unheated polyethylene-covered structures (height 4–5 m) with soil-grown crops.

The study area has a Mediterranean climate with a dry summer (84 mm) and a relatively large mean annual rainfall of 988 mm yr^{-1}, with a mean monthly temperature ranging from 9.0 °C in January, to 23.6 °C in August (average of 30 years of observation at the Battipaglia meteorological station located near the study area).

Soils from an intensive farm system under greenhouse, were studied. The soil is a *Vertic Calcisols* (Fao, 1998; Regione Campania, 2004) with clay texture, basic pH, low electrical conductivity, total carbonate and soil organic carbon (SOC) content (9.15 ± 0.73 g C kg^{-1}) and an high cation exchange capacity (29.07 ± 0.12 $cmol_{(+)}$ kg^{-1}) (Table 1).

In the study period, farm cultivated in succession sweet pepper (*Capsicum annuum* L.), kohlrabi (*Brassica oleracea* L. var. gongylodes) and mini-watermelon (*Citrullus lanatus* Thunb.). Crop nutrition was carried out by ordinary fertigation; this practice was not stopped during the experimental study.

2.2. Compost and experimental design

In this study, two composts were used: (i) a commercial compost from organic fraction of municipal solid waste, named MC, (GeSeNu Srl, Perugia, Italy), with a C:N ratio of 13.3; (ii) a compost produced in the same farm of the experimental study, named OF, by the composting of plant residues, with a C:N ratio of 17.1.

OF compost was obtained through 45 days on-farm composting (active or thermophilic phase) of raw organic materials (corn 30%, lettuce 58%, compost as starter 2%, Table 2), previously chipped, with forced aeration of static piles, followed by a two months-curing period. In the composting system, assembled with farming facilities, mechanical aeration was temperature controlled and assured by air injection through a basal net of tubes connected to a blower. Pile wetting was through an irrigation system, manually activated when gravimetrically determined relative humidity (RH) was <50%. Composting temperatures were measured by PT100

Table 1
Physical and chemical properties (average ± standard deviation) of soil at the start of the trial.

Property	Soil
Texture classification	Clay
Sand, %	23 ± 2
Silt, %	37 ± 1
Clay, %	40 ± 2
Soil organic matter, %	1.6 ± 0.1
pH	8.1 ± 0.1
EC, dS m^{-1}	0.17 ± 0.03
Limestone, g kg^{-1}	4.0 ± 1.6
Soil organic carbon, g C kg^{-1}	9.2 ± 0.7
Total nitrogen, g N kg^{-1}	0.87 ± 0.15
C:N	10.9 ± 3.0
available P, mg P kg^{-1}	14.0 ± 1.2
CEC, $cmol^{(+)}$ kg^{-1}	29.0 ± 0.1
K^+, $cmol^{(+)}$ kg^{-1}	0.95 ± 0.03
Na^+, $cmol^{(+)}$ kg^{-1}	1.26 ± 0.01
Ca^{2+}, $cmol^{(+)}$ kg^{-1}	20.0 ± 0.2
Mg^{2+}, $cmol^{(+)}$ kg^{-1}	4.6 ± 0.1