2.34 | LIFE CARBONFARM PROJECT: TECHNOLOGIES TO STABILIZE SOIL ORGANIC CARBON AND FARM PRODUCTIVITY, PROMOTE WASTE VALUE AND CLIMATE CHANGE MITIGATION

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The LIFE CarbOnFarm project focus on the application of sustainable soil managements in agro-ecosystem based on the application of high quality composts derived from the recycling of local available agricultural biomasses. The main objectives are the improvement in quantity and quality of soil organic carbon, the restoration of biological properties, the maintenance of crop productivity, the decrease of energetic inputs, the control of soil green house gases emissions. These methodologies are applied at field scale, in five different farming systems in Italy. After two year of project activities sounds indications were obtained on the effective contribution of humified composts to soil fertility and crop yields.

The analyses of compost from agricultural biomasses revealed a large content of humified hydrophobic molecules, associated with a suppressive properties and biostimulation activity. The amended plots of each experimental site promoted a significant increase of SOC with an incorporation of exogenous OM in bulk soils and soil aggregates and limited effect on GHG emissions. The addition of OM inputs showed an overall improvement of soil biological activities, thereby producing also positive effects on crop productivity

Keywords: SOM management Compost quality, SOC characterization GHG emission, Crop productivity

INTRODUCTION, SCOPE AND MAIN OBJECTIVES

Soil organic matter (SOM) is the key compartment for the maintenance of soil fertility, acting as driving force for the overall sustainability of agro-ecosystems. The lowering content of SOM related to deforestation, land uses, agricultural managements, is acknowledged among the main factors affecting the observed loss of soil properties and crop productivity (European Commission, 2011; UNFCCC, 2015). An additional side effect of SOM losses is represented by the contribution to the greenhouse gases (GHG) emission from soils. The historical global SOC losses mainly associated with decomposition of OM inputs and mineralization of soil humus, account for 136±50 Pg, while the current annual fluxes are rounded up to 1.1 Pg yr-1 (IPCC, 2013).

The restoration of soil organic carbon (SOC) level in croplands is hence regarded as an updated and topical challenge for the sustainable development of agro-ecosystems (European Commission, 2010). An increasing effort is dedicated to support the adoption of adequate and suitable SOM managements aimed to revert the trend of SOC decline and enhance the potential of cultivated soils to become an effective sink of OC (Paustian, Rumpel and Pan, 2014; Young *et al.*, 2007). The use of recycled agricultural biomasses for SOM managements represent a powerful and viable method to improve the SOC, restore the soil fertility and warrant a suitable crop productivity (Bertora *et al.*, 2009; Scotti *et al.*, 2016).

The LIFE+ CarbOnFarm project (www.carbonfarm.eu) attempt to promote the application of sustainable practices for SOM managements in agro-ecosystems. The project strategies approach the environmental problems related to the decrease of SOC content in agricultural areas of Mediterranean countries, which are among the chiefly target objectives advised by EU Soil Thematic Strategy. The goal is the restoration of SOM level and functions in agricultural soils, attained through the valorisation of local recycled agricultural biomasses with high quality composts. The project strategies are applied at farm scale in five project sites, located in Piemonte and in Campania regions in Italy, reproducing the local farming systems. Different compost are applied, depending on the local availability of organic waste and biomasses. In farm sites of Piemonte, the compost is

produced from the solid fraction of anaerobic digestion of cattle slurry (solid digestate), while in Campania the compost is obtained by the farm biomasses and residues with *on-farm* composting facilities.
The improvement of SOC, the characterization of compost quality control of GHG emission and evaluation of crop productivity are the main concerned objectives. Here we present the intermediate results after two year of project activities

METHODOLOGY

Project sites and experimental set up
Piemonte:

- Public farm of Tetto Frati University of Torino (TF). Soil texture: loamy Cropping system: maize Compost type: solid fraction of anaerobic digestion of cattle slurry. Twenty-four randomized plots (60 m^2 each one) with 6 treatments and 4 field replicates: **0N**=no Nitrogen, mineral P and K; **TRA**= mineral fertilization (N, P and K); **CMP-B**/**CMP-A**=1000 and 2000 kg of C ha^{-1} with compost; **SS-B** /**SS-A**=1000 and 2000 kg of C ha^{-1} with fresh solid digestate

- Commercial Farm Grandi (GR). Soil texture: sandy loam. Cropping systems: open field horticultural crops. Compost type: solid fraction of anaerobic digestion of cattle slurry. Twenty-four randomized plots (28 m^2 each one) with 6 treatments and 4 field replicates: **0N**= no Nitrogen, mineral P and K ; **TRA=**mineral fertilization (N, P and K); **CMP-B**/**CMP-A**=1000/2000 kg of C ha^{-1} with compost; **SS-B** and **SS-A**= 1000 and 2000 kg of C ha^{-1} with fresh solid digestate

Campania

- Public farm of Castel Volturno University of Napoli (CV). Soil texture: clay loam. Cropping system: maize. Compost type: on-farm compost from cattle+buffalo manure and maize straw. Twelve randomized plots (50 m^2 each one) with 3 treatments and 4 field replicates: **TRA**=mineral fertilization (N and P); **CMP-B/CMP-A**=compost addition (10/20 t ha^{-1}) + P

- Commercial farm Idea Natura (ID). Soil texture: clay loam Cropping systems: horchards (peach, kiwi). Compost type: on-farm green compost from farm residues (horticultural crops, trimming, woody residues). Eighteen randomized plots for each systems (900 m^2 each one): two compost types: **S** summer and **W** winter; three level of compost: **0**= control (mineral fertilizers N, P, K), **1**=lower (10 t ha^{-1}), **2**=higher (20 t ha^{-1}); 3 field replicates

- Commercial farm Prima Luce (PL) Soil texture: clay loam. Cropping system: open filed horticultural crops. Compost type: *on-farm* green compost from farm residues (horticultural crops, trimming, woody residues). Twelve randomized plots (280 m2 each one) with 4 treatments and 3 filed replicates: **0N=**control no fertilization; **TRA=**traditional organo-mineral fertilizer (N= from 50 to 200 kg ha^{-1}, depending on the crop); **CMP-B/CMP-A=**on-farm green compost 10/20 tons ha^{-1}

Analyses

- **Compost quality**: C, N, and P contents, pH, EC; biological assays: phyto-toxycity, suppressivity; microbiological characterization coupled with metagenomic approaches; solid state Nuclear Magnetic Resonance (13CCPMAS NMR); Thermochemolysis Gas Chromatography Mass Spectrometry (THM-GC-MS); laboratory analysis of GHG emission from composts; 13C isotopic analyses

- **Soil**: soil aggregate stability; TOC, N content in bulk soils and soil aggregates; 13C isotopic analyses; THM-GC-MS and 13C CPMAS NMR; field GHG analyses with Photoacustic Field Gas Monitor (Figure 1); phospholipids fatty acids (PLFA); soil microbial respiration, biological activities and metagenomic analyses using T-RFLP technique

- **Crops**:

- maize and vegetables: photosynthetic status; above-ground biomass: crop yields; N and P contents
- peach and kiwi: size, weight, dry matter, firmness, colour (peach), soluble solids, acidity, N, polyphenols, antioxidant activity

RESULTS AND DISCUSSION

Compost: the characterization of organic materials revealed the attainment of highly humified mature composts characterized by the selective preservation of stable hydrophobic components represented by lignin compounds, plant and microbial lipids and plant bio-polyesters.

The biological assays showed a significant microbial activity in all biomasses as measured by total respiration and hydrolase activity. The innovative metagenomic analyses indicated that composts were characterized by a variable suppressive activity, and biochemical stimulation depending on molecular composition. The first outcomes indicate that *Streptomyces* can play a determinant role for the suppressive propriety of composts, and strengthen the working hypothesis that the phenolic components related to lignin derivatives positively affect the biological activity (Martinez-Balmori *et al.*, 2014). Also the different combination of hydrophobic fraction and bio-labile components (carbohydrates, peptide derivatives) act as important modulator in the bio-activity displayed by the humified fraction of composted biomasses.

SOC: after two year of SOM managements an average improvement of SOC content was found in field plots with organic amendments of each project sites. The widespread increase of TOC found in both bulk soils and size-aggregates ranged from 0.4 to 2.0 g kg^{-1}, depending on soil type and dose of organic amendment. The molecular characterization showed that the SOM managements produced an overall increase in the yields of both stable hydrophobic aliphatic and lignin components derived from added OM (Table 1), which are currently associated with the humification processes and stabilization mechanisms of SOC (Song *et al.*, 2013). The 13C-OC isotopic distribution further confirmed the incorporation of exogenous OC in soil aggregates.

The analyses of PLFA revealed a steady increase of microbial biomass in all OM amended field plots of TF, GR and CV, while specific larger yields of PLFA derivatives from mycorrizhal fungi in CMP-A and SS-A treatments of TF and GR project sites. Also in the PL soil an improvement of metabolic activity in CMP-A treatment was stressed by the observed increase of the microbial community efficiency, as summarized by the biodiversity Sannon's index and AWCD (average weight color development) indicator

Table 1 Example of composition and yields (µg g-1) of main SOM compounds identified by THM GC MS at 2 year for field treatments at GR and TF project sites

	GR Field treatments 2nd year								TF Field treatments 2nd year					
Compounds	t0	Trad	0N	SSB	SSA	CmpB	CmpA	t0	Trad	0N	SSB	SSA	CmpB	CmpA
Fatty acids C_{12}÷C_{28}	4465	4276	4125	4612	4575	4563	4596	3063	3020	2990	3190	3220	3330	3410
Bio-poly-esters (cutin and suberin) (C_{16}÷C_{22})	1039	972	1020	1084	1087	1114	1140	635	513	545	660	740	726	753
Alkanes (C_{25}÷C_{31})	95	82	79	95	97	108	110	89	60	80	95	85	100	120
Alcohols (C_{16}÷C_{26}) & Phytosterols (C_{28}÷C_{30})	167	145	139	180	185	207	215	162	143	133	189	153	206	217
Total alkyls	5766	5475	5363	5971	5944	5992	6061	3949	3736	3748	4134	4198	4362	4400
Guaiacyl	195	192	185	208	225	227	232	127	142	128	118	147	187	205
$(Ad/Al)_G$b	3.2	3.4	3.6	3.2	3.1	3.2	3.1	4.4	4.3	4.2	4.1	4.0	3.9	3.9
(Γ_G)b	3.4	3.9	3.8	3.3	3.2	3.1	3.2	3.0	3.2	3.0	3.1	2.8	2.9	2.8
p-Hydroxy-phenyl	181	152	172	206	232	245	256	64	58	55	64	72	71	74

Syringyl	164	170	154	189	196	194	205	174	185	174	177	202	215	208
$(Ad/Al)_S$b	4.0	3.9	3.8	3.9	3.8	4.1	3.9	3.5	3.4	3.5	3.4	3.0	3.1	3.1
(Γ_S)b	3.2	3.1	3.3	3.1	3.0	3.1	2.9	3.8	3.9	4.1	3.7	3.6	3.5	3.8
Total lignin	540	514	511	603	653	666	693	365	385	357	359	421	473	487

[a] Total range varying from Ci to Cj; b Lignin structural indexes: $(Ad/Al)_G$=G6/G4; $(Ad/Al)_S$=S6/S4; (Γ_G)=G6/(G14+G15); (Γs)=S6/(S14+S15).

Figure 1. GHG field sampling system

GHG emissions: the soil laboratory incubation performed to evaluate the GHG emissions (N2O, CO2 and CH4) for different organic materials used in soil amendments, highlighted the decrease of specific emission of all composts in respect to either mineral fertilizers (e.g. urea) and to fresh solid digestate, thereby supporting the advantage of SOC stabilization attained with the composting process. The field measurements revealed a slight increases of CO2 emissions from compost treatments in bare soils, that were nullified however by the almost matched larger values found during the crop cycle

Crops: averaged larger yields were found, in compost amended plots, for the horticultural crops at both GR and PL sites, without differences in nutrient uptakes (N, P). Significant improvements for compost treatments were shown in orchard systems for either yield or quality, suggesting a positive effect of humified compost on plant physiology. The main increase were related, for W1,2 and S1,2 soil managements, to global yield, dry matter, total polyphenol and soluble solids in kiwi system, while, for peach fruits significant increase were observed for average yield/plant (+47-100 %), average yield/ha (+60-100%), total dry matter and N contents.

CONCLUSIONS

The soil treatment with humified composts from agricultural biomasses produced the incorporation of stable exogenous OM components, in bulk soil and soil aggregates of different soil types. After two year of SOM managements, positive effect were noticed on SOC distribution, biological activity, GHG emission and crop productivity, thereby further supporting the role of mature compost as viable way to meet the requirements of sustainable development in agro-ecosystems while linking SOC management, GHG mitigation and maintenance of crop yields

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