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Use of composted agro-energy co-products and agricultural residues against soil-borne pathogens in horticultural soil-less systems

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ABSTRACT

One feedstock of composted agro-energy co-products and agricultural residues was physically-chemically-microbiologically characterized and investigated for the phytotoxic property and the disease suppression for finding next-generation "green composts" suitable for use in horticultural soil-less systems. The suppression of three composts made of crude steam-explosion liquid-waste of miscanthus ($SELW_M$), giant reed ($SELW_A$) and wheat straw ($SELW_{WS}$) mixed with the agro-waste mostly available in Southern Italy [C_{WS} ($SELW_{WS}$ + woodchip + tomato-waste), C_M ($SELW_M$ + coffee-ground + artichoke-waste) and C_A ($SELW_A$ + defatted olive marc + fennel-waste)] was tested by the *in vitro* and *in vivo* experiments against seven horticultural pathosystems (*Phytium ultimum*/Cucumber, *Phytophthora nicotianae*/Tomato, *Rhizoctonia solani*/Bean, *Sclerotinia sclerotiorum*/Lettuce, *Fusarium oxysporum* f. sp. *melonis*/Melon, *Fusarium oxysporum* f. sp. *lycopersici*/Tomato,and *Verticillium dahliae*/Eggplant). One compost (C_C) sourced from the differentiated municipal bio-waste with pathogen-specific property was employed as reference. The phytotoxicity of composts was assessed on lettuce and cress. *In vitro* bioassays carried out on pure colonies showed that raw compost water extracts (CWEs) were able to inhibit all of pathogens adopting a pouring technique, and that a well-cut diffusion method allowed the block of growth of the pathogens without physical interaction with compost microflora. The sterile-filtration of CWEs annulled inhibition of the pathogens, but *S. sclerotiorum* and *V. dahliae* were inhibited by sterile CWEs using a pouring procedure. *In vivo* tests performed under greenhouse conditions using peat-based plant growing media amended with each compost at dosage of 20% (v/v) showed multi-suppressive activity: C_{WS} suppressed most efficiently *P. ultimum*, *R. solani*, *P. nicotianae*, *F. oxysporum* f. sp. *melonis*, *F. oxysporum* f. sp. *lycopersici*, *V. dahliae*; C_M was capable to suppress *P. ultimum*, *R. solani*, *P. nicotianae*, *S. sclerotiorum*, *V. dahliae*; C_A was suppressive against *R. solani*, *P. nicotianae*, *V. dahliae*. The microbiological inactivation of composts by heating treatment reduced suppression in all of pathosystems, but for *S. sclerotiorum*/Lettuce and *V. dahliae*/Eggplant the loss of suppressivity was smaller in C_A, C_M and C_C. The predictive parameters to suppression were different: total fungal biomass for *P. nicotianae*; FDAH for *P. ultimum*; *Trichoderma* for *R. solani*; *Aspergillus*, *Pseudomonas* and *Streptomyces* for *F. oxysporum*. Instead, the parameters that drive suppression of *S. sclerotiorum* and *V. dahliae* were not well cleared. The use of composted agro-waste seems to be an efficient alternative to peat-based substrates for controlling diseases on a broad range of horticultural crops with inappreciable phytotoxic effects if added in moderate dose.

1. Introduction

Horticultural crops produced in peat-based growing media in soil-less systems are susceptible to a wide range of soil-borne pathogens which causes large yield loss in the nursery and greenhouse cropping systems. The development of non-conventional

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Table 1
Feedstock used in composting.

Composts	Steam-explosion liquid waste[a]	Agro-industrial residues (49%)[b]	Plant-waste (49%)[b]	Composting starter (2%)[b]
C_M	$SELW_M$	Coffee-ground	Artichoke	Matured compost
C_A	$SELW_A$	Defatted olive marc	Fennel	Matured compost
C_{WS}	$SELW_{WS}$	Woodchip	Tomato	Matured compost

[a] Litres of SELWs are variable because depend on the mixture sponginess to reach moisture of 65–70%.
[b] Percentage values are considered as dry weigh.

ecofriendly disease management strategies has been addressed essentially on the use of suppressive composts in horticulture (Bonilla et al., 2012; Hoitink et al., 1991; Hoitink et al., 2001). Capacity of compost to suppress plant diseases has been widely studied (Avilés et al., 2011; Bonanomi et al., 2007; Hoitink and Fahy, 1986; Hoitink et al., 1997; Lazarovits, 2001; Noble, 2011; Noble and Coventry, 2005). Compost amendment has been proposed to control of *Pythium ultimum* Trow. (Pascual et al., 2000, 2002; Scheuerell et al., 2005), *Phytophthora nicotianae* Breda de Haan (Hardy and Sivasithamparam, 1991; Widmer et al., 1999), *Rhizoctonia solani* Kühn (Termorshuizen et al., 2007; Tuitert et al., 1998) and *Fusarium oxysporum* Schl. (Cotxarrera et al., 2002). Composts sourced from the municipal solid organic waste (MCW) have been tested for controlling *P. ultimum* damping-off of cucumber, *Fusarium oxysporum* f. sp. *basilici* (Dzidzariya) Armstr. & Armstr. wilt of basil and *Sclerotinia sclerotiorum* (Lib.) de Bary root rot of lettuce (Pugliese et al., 2007). Composts sourced from the MCW and cow manure enhanced peat suppressiveness towards damping-off caused by *P. ultimum*, *R. solani* and *Sclerotinia minor* Jagger (Pane et al., 2011). Compost suppression is mainly related to the antagonistic microbial communities sourced from the organic matters used (Conrath et al., 2002; Hadar and Papadopoulou 2012; Lumsden et al., 1983; Manici et al., 2004), but also to its phytotoxicity level (Aslam and Van der Gheynst, 2008).

Biofuel chain waste, as the crude steam-explosion liquid waste (SELWs) obtained from the industrial detoxification of steam-exploded plant biomass for producing 2nd-generation ethanol, could be investigated as strategic feedstock for finding next-generation suppressive composts useful in horticultural cropping systems (De Corato et al., 2015). The SELWs are important in the biofuel European industry because large amounts of them must be disposed (Viola et al., 2016). Authors have investigated on the interesting antifungal activity of SELWs sourced from the miscanthus (*Miscanthus sinensis* × *giganteus*), durum wheat (*Triticum durum* L.) straw and giant reed (*Arundo donax* L.) due to presence of volatile microbial inhibitors. In fact, the SELWs have been proposed as an effective control tool against *Alternaria alternata* (Fr.) Keissler, *Botrytis cinerea* Pers. *ex* Fr., *Colletotrichum acutatum* Simmonds, *Cladosporium fulvum* (Cke) Cif., *Fusarium solani* (Mart.) Sacc. f. sp. *pisi*, and *Verticillium dahliae* Kleb. on tomato, strawberry, pea and eggplant under greenhouse conditions (De Corato et al., 2014). Moreover, raw SELW sourced from miscanthus has been proposed as an control tool against *Pseudomonas reactans* [syn. *Pseudomonas fluorescens* (Flügge) Migula] and *Pseudomonas tolaasii* T. Paine, both associated to *Pleurotus eryngii* (DC.: Fr.) Quél. yellowing in Southern Italy (Bruno et al., 2015). On the other hand, a wide range of agricultural and agro-industrial residues could represent an important source of organic matter suitable to be recycled into suppressive composts effective against *R. solani*, *S. minor*, *Fusarium oxysporum* f. sp. *melonis* (Leach & Currence) Snyd. & Hans. and other plant diseases in peat-based growing media (Borrero et al., 2013; Pane et al., 2013; Ronga et al., 2016; Suàrez-Estrella et al., 2007; Trillas et al., 2006). Nevertheless, tentative of composting of SELWs mixed with the agricultural residues and plant-waste have not been yet made for controlling plant disease.

The essence of this research work is to develop next-generation suppressive composts for their contribution to plant health by starting from hypothesis that composts derived from a wide range of feedstock can show variable degrees of suppression against different soil-borne pathogens. This work investigates the suppressive potential and the phytotoxicity of three "green composts" made of agro-energy co-products mixed with the agro-industrial residues and the plant-waste mostly available in Southern Italy, so as able to control of seven soil-borne pathogens in horticultural soil-less systems.

2. Material and methods

2.1. Composting and characterization of composts

Three feedstock were considered in composting and used for the experiments. The SELWs derived from the pre-treatment of steam-exploded biomass of miscanthus ($SELW_M$), giant reed ($SELW_A$) and wheat straw ($SELW_{WS}$). The agro-industrial co-products and plant-waste were purchased from the agro-industries and farmers located in Apulian areas and composted after drying. Composting was performed through the following four steps into an industrial composting plant. 1) Mixing phase: the $SELW_M$, $SELW_A$ and $SELW_{WS}$ were added to agro-industrial co-products (coffee-ground, defatted olive marc and woodchip), plant-waste (un-decomposed by-products of artichoke, fennel and tomato) and one commercial starter (Table 1) and mixed with them for 4 h by an impeller at a speed of 5 rev min^{-1}. 2) Absorption phase: three compost piles of less than 5 m^3 in volume were introduced into big boxes, daily upturned and maintained at room temperature behind a roofing until moisture reached 65–70%. 3) Bio-oxidative phase: piles were air-forced with 2–5 l min^{-1}, daily turned upward and maintained behind a roofing for 45-50 days. Pile wetting was automatically achieved when relativity humidity (RH) was less than 50%. Pile temperature was daily measured by thermometric probes placed in the pile core at 15 cm from the bottom pile. Pile peak heating reached or exceeded 65 °C for at least 6 days to achieve sanitization. 4) Curing: compost RH was adjusted at 65–70% and humic substances were found into compost piles during 2 months (unpublished data). Three matured composts were obtained (C_M, C_A and C_{WS}) at the end of process and they were tested at 3-month-old. One selected reference suppressive compost (C_C) was purchased by the local Company of composting. It was produced from the differentiated MCW through a type of composting lasting 3 months and tested at 2-year-old. CC has been previously tested by the same Company for its pathogen-specific property against *F. oxysporum*.

Samples of each compost were collected from ten different points in the pile, pooled, mixed and analysed by standard procedures. Water content of each compost was determined after drying at 105 °C for 72 h (water/dry matter). Compost water holding capacity was determined measuring water content held against gravity in a filter-paper-lined funnel. Five independent replications of each sample Dry Weight (25 g DW) were analysed for determining: pH, electrical conductivity (EC), content of macronutrients (total organic carbon and nitrogen, N-ammonium,