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Effects of the main extraction parameters on chemical and microbial characteristics of compost tea

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A B S T R A C T

The rising popularity of compost tea as fertilizer or foliar spray against pathogens has encouraged many researchers to evaluate its performance without standardizing its quality, so obtaining inconsistent and controversial results. The fertilizing and pesticide-like effects of compost tea are due to its chemical and microbiological properties. Therefore, this study aimed to identify the best combination of the compost tea extraction parameters for exalting both chemical and microbiological features. A factorial design was adopted to evaluate the effects of compost/water ratio, extraction time, storage duration and storage temperature in different combination on physical, chemical and microbiological characteristics of compost tea, and the results were elaborated through different statistical analyses. Compost tea nutrients and microorganisms were influenced by compost/water ratio and extraction time. In addition, the storage duration affected the microbial populations, whereas the storage temperature influenced only the fungal population of compost tea. Results suggested that the best combination of the studied parameters was: 1:2.5 compost/water ratio, 2 days of extraction time and the compost tea should be utilized immediately after the extraction, since the storage reduced the microbial populations.

1. Introduction

Conventional agriculture is generally characterized by the use of a great amount of external inputs such as synthetic fertilizers and pesticides, growth regulators, resulting in heavy reliance on not-renewable resources, reduced biodiversity, soil degradation, chemical residues in food, and health risks to farm workers handling pesticides (Matson et al., 1997; Drinkwater et al., 1998; Tillman, 1999; Zhu et al., 2000; Reganold et al., 2001). As a consequence, sustainable agriculture, and in particular organic farming, emerges with the aim of solving a series of environmental, safety, and health problems arising from the modern conventional agriculture (Biao et al., 2003; Adl et al., 2011). Sustainable farmers attempt to close nutrient cycle on their farms, maximize re-use, employ rotation system, protect environmental quality, and enhance beneficial biological interactions and processes (Vandermeer, 1995; Casado and de Molina, 2009). The fertility management in sustainable agriculture relies on a long-term integrated approach in order to produce higher yields (Badgly and Perfetto, 2007) rather than the more short-term solutions common in conventional agriculture (Watson et al., 2002).

Compost tea (CT) is a water extract of compost (Riggle, 1996; Ksheem et al., 2015) and it can be used to correct the nutrient deficiency during the crop production and/or to protect the cultivations. In particular, CT applied to soil affects the rhizosphere of the plant by carrying nutrients and microorganisms (Bess, 2000), whereas CT sprayed on leaf surfaces typically alters the set of organisms on the foliage through the inoculation of beneficial microorganisms that are antagonistic towards various plant pathogens (Noble and Coventry, 2005; Pane et al., 2011) and through the supply of microbial by-products and nutrients that help the survival of phyllosphere microorganisms.

One of the problems in exploring the effects of CT on plants is the lack of a standardized extraction process. Thus, it is not surprising that the results from various experiments with CT are inconsistent and often conflicting. In fact, the quality of CT may vary considerably because of differences in procedures used for preparation of the extracts, source, composition, quality, and maturity of the compost (Weltzien, 1992), length of storage, and possibly other factors (Al-Dahmani et al., 2003). St. Martin (2014) showed that the plant diseases suppressiveness of CT is higher for the vermicompost and vermicasting in comparison to compost, regardless

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their composition. Scheuerell and Mahaffee (2006) studied the effect of 30 compost teas on gray mold and their results agreed with prior reports of compost classes composed of manures and plant material appearing to be more suitable for producing disease suppressive compost teas than other classes of compost. Weltzien (1990, 1992) has shown that composts prepared with animal manures determined the most suppressive CT, compared to those obtained from composts prepared only with plant residues. In addition, compost should be 2–6 months old to be more suppressive (Tränkner, 1992). The compost/water ratio utilized for the extraction of CT can be considered a crucial parameter, in order to obtain CT of high quality. Previous studies (Zhang et al., 1998; Weltzien, 1990) have shown a suppressiveness potential of CT obtained using a compost/water ratio between 1:1 and 1:50, although most of the studies utilize a compost/water ratio between 1:3 and 1:10 (Scheuerell and Mahaffee, 2002). Few reports about the effect of extraction time on the final quality of the compost tea obtained under aerobic conditions are available in literature. In particular, Cantisano (1998) considered 1 day an optimal extraction time in order to obtain the best result for foliar feeding, and 7–14 days to obtain the best result for disease control. Ingham (1999) suggested 18–24 h as the optimal extraction time of CT, coinciding with the maximum activity of the microbial biomass. With regards to the storage of CT, if the mode of action is mainly due to competition, the compost tea suppressiveness is reduced with storage, whereas if the mode of action is due to stable metabolites secreted into the water, this reduction not occurred (Scheuerell and Mahaffee, 2002). A previous study (Yohalem et al., 1994) has shown that a compost tea can be stored for four months without losing its effectiveness in terms of suppression of conidia germination. In addition, at 20 °C no loss of efficacy of CT was observed, whereas a reduction of its efficacy was observed at −4 °C.

Since the fertilizing and the pesticide-like effects of compost teas are due to their chemical and microbiological properties, the aim of the present paper was to identify the best combination of compost/water ratio, extraction time, and storage duration and temperature to exalt the aforementioned features of compost tea.

2. Materials and methods

2.1. Compost and irrigation water

Compost was obtained at the CIHEAM-IAM (Centre International de Hautes Etudes Agronomiques Méditerranéennes – Istituto Agronomico Mediterraneo) composting facility, located in Valenzano (Apulia region, Southern Italy), using olive pruning residues, bovine manure and wheat straw as raw materials. Since the production and utilization of the CT mainly occurs on farm, quite common agricultural wastes (pruning residues, straw and manures) have been utilized in the experimentation. Therefore, the results of this study could have broad applicability, in the framework of a sustainable agriculture.

A pile of 25 m^3 was prepared respecting the microbial requirements and its temperature was kept $\geqslant$55 °C for at least three days by turning and irrigating periodically the windrow in order to obtain the hygienization of the biomasses. The curing phase was characterized by less frequent turning and continued till the ninetieth day in order to achieve further stabilization. At the end of the composting, five samples were collected randomly spanning the whole compost pile. Table 1 reports the main features of the final compost.

2.2. Compost tea production and characterization

The compost was thoroughly mixed to insure physical/chemical uniformity of the sample before the extraction of CT. The CT was obtained suspending the final compost in the irrigation water obtained from the artesian well at CIHEAM-IAM. The main characteristics of the irrigation water are reported in Table 2.

The bucket-bubbler method was used for compost tea extraction. This is a simple and feasible method in which the mixture is deliberately aerated, allowing large numbers of beneficial organisms to populate this mixture (Scheuerell, 2003; Kelley, 2004; Ingham, 2005).

Each extraction unit consisted of a plastic container open at top and with a tap at bottom, a 6 W pump with two outlets, two plastic pipes with two control valves and two bubblers. For CT extraction, ten liters of water were added in each extraction unit. Two bubblers were immerged and placed at the bottom of the bucket and the pumps were put on to start bubbling. After a while, compost was added slowly at different rates per treatment.

Treatments consisted of three levels of compost/water ratio (CWR: 1/2.5, 1/5 and 1/10) replicated three times: therefore, the extraction units were nine. Further treatments were: three levels of extraction time (ET: 2 days, 4 days and 6 days); five levels of storage duration (SD: 0 week, 1 week, 2 weeks, 3 weeks and 4 weeks); and two levels of storage temperature [ST: room temperature and cool temperature (4 °C)].

Eighteen samples of CT were collected from each extraction unit at the end of each extraction time (54 samples from a set of compost/water ratio replicates) using a plastic beaker and then filtered by a strainer. Six samples of 54 were immediately analyzed (time 0), whereas 48 were stored in 100 mL sterile plastic bottles for different duration (from one to four weeks). Twenty four samples were preserved at room temperature (24–28 °C) and twenty four at cool temperature (4 °C). CT samples were characterized for their main physical and chemical properties according to the Italian Official Methods of Fertilizers Analyses (Trinchera et al., 2006).

Table 1
Chemical properties of compost used for compost tea extraction.

Compost parameters	Unit	Value
pH (H_2O) (3:50, w/v)		9.5 ± 0.13
Electrical conductivity (1:10, w/v)	dS m^{-1}	2.1 ± 0.36
Organic carbon	g kg^{-1}	158.9 ± 12.5
Organic matter	g kg^{-1}	274.0 ± 21.6
Total nitrogen	g kg^{-1}	16.7 ± 0.12
C:N ratio	g kg^{-1}	9.5
Total P (as P)	g kg^{-1}	5.6 ± 0.35
Total Ca	g kg^{-1}	103.4 ± 12.3
Total K (as K)	g kg^{-1}	78.4 ± 9.6
Total Mg	g kg^{-1}	75.6 ± 9.0
Total Na	g kg^{-1}	56.6 ± 6.7
Total Fe	g kg^{-1}	14.7 ± 2.1
Total Cd	mg kg^{-1}	2.0 ± 0.2
Total Cr	mg kg^{-1}	22.4 ± 3.3
Total Cu	mg kg^{-1}	65.0 ± 7.6
Total Mn	mg kg^{-1}	625.9 ± 32.4
Total Ni	mg kg^{-1}	17.8 ± 2.6
Total Pb	mg kg^{-1}	24.7 ± 1.7
Total Zn	mg kg^{-1}	160.4 ± 24.7
Total Hg	mg kg^{-1}	<0.4

Table 2
Chemical properties of water used for compost tea extraction.

Water parameters	Unit	Value
pH		7.4
Electrical conductivity	dS m^{-1}	1.05
Cl^-	mg L^{-1}	113.4
HCO_3^-	mg L^{-1}	457.5
Ca^{++}	mg L^{-1}	162.2
Mg^{++}	mg L^{-1}	18.2
K^+	mg L^{-1}	7.8
Na^+	mg L^{-1}	50.6