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Compost suppressiveness against *Fusarium oxysporum* was not reduced after one-year storage under various moisture and temperature conditions

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ABSTRACT

The effect of storage conditions on compost suppressiveness against fusarium wilt of melon, caused by *Fusarium oxysporum* f. sp. *melonis* (FOM) was studied in relation to the dynamics of compost microbial activity and biodegradability. For this purpose, mature suppressive compost, prepared from tomato plants and separated cow manure, was divided into four portions and stored for one year under cool/warm (12 or 28 °C) or dry/wet (15–35 or 55–65% moisture content) conditions, in four different combinations: cool-dry, warm-dry, cool-wet and warm-wet. All composts retained and even enhanced their suppressive capacity during storage, with no significant differences among them by the end of the storage period. However, significant differences were found in the dynamics of some of the measured chemical and microbial properties. The microbial activity of composts stored under wet conditions was higher than that of those stored under dry condition, which resulted in a substantial decrease in dissolved organic matter content (expressed as dissolved organic carbon; DOC) and increase in its recalcitrance to biological degradation, decrease in basal heat emission, slower response to added glucose or citric acid, and higher NO_3 concentration, indicating increased nitrification under wet conditions. The DOC significantly correlated with several microbial properties as well as with compost suppressiveness of fusarium wilt of melon seedlings, and may be regarded as a most suitable general index for compost maturity. A best-subset multiple linear regression analysis revealed that the three best predictors, namely dissolved organic carbon (DOC), basal heat, and mesophilic bacterial counts, could explain as much as 83% of the total variance in compost suppressiveness. The generally agreed association between compost maturity and suppressiveness was verified in this case. It appears that compost microbial populations might compete and interfere with the saprophytic stage of FOM conidia, between germination and host invasion. In conclusion, it was demonstrated that compost suppressiveness against fusarium wilt of melon can be maintained for at least one year under a wide range of storage conditions, without any loss of suppressive capacity. This fact has positive logistical implications for the use of suppressive composts against FOM.

1. Introduction

Root diseases cause significant economic damage to many plant species. In the past, fumigation with methyl bromide (MeBr) was used for soil sterilization, and it resulted in practically pest-free soils. Although MeBr caused a biological vacuum which presented many horticultural disadvantages, it was only the finding that MeBr contributed to depletion of the stratospheric ozone layer that resulted in an international agreement for complete phase-out of MeBr (with the exception of quarantine and other critical use exemptions) from 1 January 2005 under the Montreal Protocol.

The use of disease suppressive composts has been proposed as an environmentally-friendly substitute for soil fumigation. During the composting process, organic matter undergoes fundamental biological, chemical and physical changes; and conspicuous among these is the development of suppressiveness against several soil-borne fungal diseases (Hoitink et al., 1977; Nelson and Hoitink, 1982). Various types of composts have been shown to provide some level of pathogen and disease suppression (Bulluck et al., 2002; Benitez et al., 2007; Wu et al., 2007) in several production systems, including growing media (Hoitink and Fahy, 1986) and soil (Perez-Piqueres et al., 2006). The term "pathogen suppression" refers to the ability of the soil (or other media) to limit the inzoculum

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density of a pathogen, whereas "disease suppression" refers to the capacity of a soil to limit disease development in the presence of both the host and the pathogen when ambient conditions are conducive to the development of the disease. In addition to a substantial body of reports of suppression of fungal diseases, there are also reports of inhibition of disease-causing nematodes (Oka and Yermiyahu, 2002; Raviv et al., 2005) and bacteria (Schonfeld et al., 2003; Yogev et al., 2009). The suppressiveness phenomenon has been attributed to several mechanisms, including: competition for nutrients (especially organic compounds and iron) during the saprophytic stage in the life-cycle of some pathogens (Hoitink and Boehm, 1999); competition for penetration sites (Takenaka et al., 2008); hyperparasitism (Danon et al., 2007); antibiosis (Craft and Nelson, 1996); and induction of plant systemic resistance (Kavroulakis et al., 2005). At least several of these mechanisms should be intimately linked to the microbial status of the compost, whereas some, e.g., competition for nutrients, would be more generally related to the active microbial biomass, and others would involve specific species, e.g., fungal and bacterial species that are antagonistic against certain pathogens.

Except for a few cases (Danon et al., 2007; Zmora-Nahum et al., 2008), the suppressiveness level of composts is positively related to their degree of maturity (Hadar and Mandelbaum, 1986; Diab et al., 2003; Trillas et al., 2006). Since the disease suppression properties of composts are, at least in part, driven by their microbial activity and composition, the question arises as to what extent prolonged storage may affect disease suppression. Widmer et al. (1998) showed that when composted municipal waste was stored for more than 3 months, its suppressive capacity against *Phytophthora nicotianae* was reduced, possibly because of the disappearance of the hyperparasitic *Acremonium* spp. In a few studies of long-term microbial changes during prolonged maturation it was found that distinct microbial changes occurred long after the composts might be considered stable on the basis of general physical and chemical indicators (Boulter et al., 2002a; Levanon and Pluda, 2002). However, there is little information regarding the effects of storage conditions and duration on the suppressive capacity of composts (Boulter et al., 2002b; Boulter-Bitzer et al., 2006; van Rijn et al., 2007) and additional information is needed. Regardless of the mechanisms responsible for compost suppressiveness, from the practical point of view, a long "shelf life" of the suppressiveness property is desired, for both logistic reasons and horticultural practice.

The objective of the present study was to evaluate the effect of prolonged (>1 year) storage under various temperature and moisture-content conditions, on compost suppressiveness against *Fusarium oxysporum* f. sp. *melonis* (FOM), in relation to the dynamics of compost microbial activity and biodegradability. For this purpose, mature suppressive compost, prepared from tomato plants and separated cow manure, was separated into four portions and stored under cool or warm temperatures (12 or 28 °C) and dry or wet conditions (15–35 or 55–65%, moisture content; MC) in four combinations: cool-dry, warm-dry, cool-wet, and warm-wet. Compost's suppressiveness level and other biological parameters were assessed along the storage period.

2. Materials and methods

2.1. Composting

Separated cow manure and ground, dried tomato plants were mixed (1:1 v:v), and placed in a 6-m^3 composting bin on Sept. 27, 2006. The bin was equipped with temperature- and time-controlled forced aeration, with air supplied at a rate of 80 m^3 m^{-3} compost h^{-1} (Raviv et al., 1998). The set-point thermophilic temperature was 60 °C. When there was no temperature-driven requirement for aeration, the blowers were operated for 1 min h^{-1}, in order to maintain aerobic conditions. The temperature was measured by two sensors located at depths of 40 and 80 cm, and was recorded every 5 min. Water was added to the pile according to (MC) measurements, conducted three times a week. During the thermophilic stage the desired MC was 50 ± 5%, and during the mesophilic stage it was lowered to 40 ± 5%. The compost was mixed monthly with a front-end loader, to ensure homogeneity.

As typically observed with this type of raw materials (Raviv et al., 2004), the pile temperature reached thermophilic levels in a few days. The first two turnings, at 34 and 62 days from starting, resulted in short-term (2–4 days) cooling, but the pile soon returned to the cooling set-point of 60 °C, which was maintained for ~70 days. The third turning, on day 89, resulted in an irreversible temperature drop. The compost was considered stable after 3 months (on Dec 25, 2006) and was left in the bin for one additional month (until Jan 31, 2007) for curing under ambient conditions, at an average temperature of 12 °C. Basal heat emission, as measured by microcalorimetry, and the dissolved organic carbon (DOC) concentrations of the compost extract, decreased rapidly during the active composting period and then stabilized. A further slight decrease was observed during the curing period (Fig. 1).

2.2. Compost storage

After the end of the curing period, part of the compost was dried at 30 °C for an additional 3 days, to a MC of 34% (w/w), and was designated as "dry"; another part was moistened to a MC of 57% and was designated as "wet". Half of each part was stored at 12 °C and the other half at 28 °C, designated as cool and warm conditions, respectively. The wet samples tended to dry over time, and were moistened as necessary, whereas the dry samples were stored without further moisture control. The MC of wet-stored composts remained stable during the storage period, at 59.7 ± 3.4% and 58.9 ± 3.2% for cool-wet and warm-wet storage, respectively. Dry-stored composts dried steadily over time, from an initial MC of 34% to 27.7 ± 0.85% and 15.5 ± 0.35%, in the cool-dry and warm-dry composts, respectively.

2.3. Fusarium wilt suppression assay

The stored composts were sampled at 11, 116, 270 and 403 days from the start of storage for suppressiveness tests. Melon seeds (cv. "Ofir", Zeraim, Gedera, Israel) were germinated in sand in a growth chamber under day/night temperatures of 28/25 °C, and day length of 12 h. Five-day-old plantlets were used for the assay. Their roots were washed, cut to 2-cm length, and dipped for 2 min in

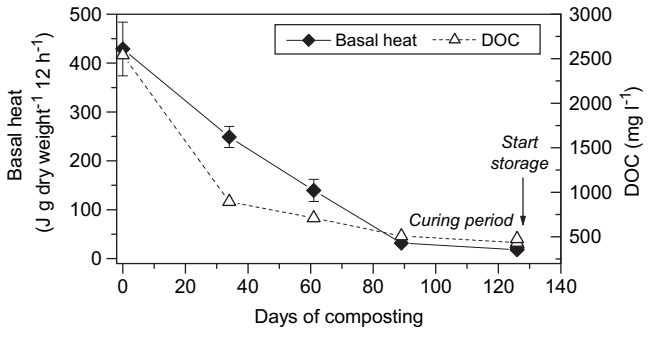

Fig. 1. Basal heat evolution and DOC in compost extracts during composting and after 1 mo of curing.