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Citrus Waste Compost for Control of Root-infecting *Phytophthora* Species

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ABSTRACT

Control of soilborne pathogens by organic amendments is a well-known phenomenon, with most consistent disease suppression being obtained with composted material. Composting of citrus waste produced by fruit-processing plants is a viable option for transforming it into a value-added product. Composting of citrus waste was attempted on a pilot-scale in bins with forced and natural aeration and in crates and piles, with the latter producing the most acceptable product. Composted citrus waste (CWC) inhibited cress seed germination to a greater extent than two commercial composts but was equally or less inhibitory to sunflower seedlings. In the greenhouse, CWC suppressed Phytophthora nicotianae and Phytophthora cinnamomi when evaluated according to the lupin seedling bio-assay. Suppression appeared to be of a "general" nature, thus indicating that augmentation with additional introduced antagonists is not required.

INTRODUCTION

Various reports refer to the control of *Phytophthora* diseases with organic amendments (Vaughn *et al,* 1954; Gilpatrick, 1969; Hoitink *et al,* 1977; Nesbitt *et al.,* 1979; Spencer & Benson, 1982; Hardy & Sivasithamparam, 1991; Tsao & Oster, 1981). Organic materials which can be used for this purpose include hardwood and pine bark, municipal sludge, licorice roots, grape marc, cattle manure, poultry litter, cotton waste and other crop residues (Zentmyer, 1963; Huber & Watson, 1974; Daft *et al,* 1979; Lumsden *et al.,* 1983; Nelson *et al,* 1983; Hadar & Mandelbaum, 1986; Hoitink & Fahy, 1986; Chen *et al,* 1988; Kuter et *al,* 1988; Mandelbaum *et al,* 1988; Mandelbaum & Hadar, 1990; Gorodecki & Hadar, 1991). However, when applying green manures for controlling soilborne pathogens, results are often inconsistent (Zentmyer, 1963; Kuter *et al,* 1983; Ramirez-Villapudua & Munnecke, 1988) because effects of age and quality of the substance have been overlooked (Nelson *et al,* 1983). Furthermore, many green manures result in side-effects due to phytotoxicity, nitrogen immobilisation, high salt content and structural incompatibility (Verdonck, 1988). It is thus feasible to convert the raw material to a more stable product by composting.

In Japan and other parts of the Orient, compost has been used for centuries with beneficial effects in agriculture (Kelman & Cook, 1977), but the concept is relatively new to Western countries. Nevertheless, an environmental problem associated with the disposal of organic wastes as landfills and in streams or by incineration has compelled man to investigate composting as a less objectable alternative for waste-disposal.

Modern composting entails the thermophilic decomposition of organic waste materials by mixed populations of indigenous micro-organisms under controlled conditions (Parr & Willson, 1980). The main application of the resultant product is in agriculture where it is utilized for improving soil structure and moisture retention, and as biofertiliser and biological control substance (Hadar & Mandelbaum, 1992). By using compost, it is thus possible to cut back on pesticides and inorganic fertilisers and to reduce soil deterioration and erosion associated with intensive farming systems (Parr & Willson, 1980).

Suppression of soilborne plant pathogens by compost is the result of microbial activity developing subsequent to the thermophilic phase of composting (Hadar & Mandelbaum, 1992). Nutrientindependent pathogens like *Rhizoctonia solani* Kühn are suppressed by a narrow group of micro-organisms, and this suppression is referred to as "specific suppression". On the other hand, nutrient depended pathogens such as *Phytophthora* are suppressed by "general suppression", i.e. where many kinds of micro-organisms present in compost function as biocontrol agents (Cook & Baker, 1983; Chen *et al,* 1988; Mandel-baum & Hadar, 1990; Hardy & Sivasithamparam, 1991). For the latter purpose, compost must be adequately stabilised and analysed for maturity to assess the carrying capacity or the potential of a soil mix to support sustained microbial activity, and hence "general suppression" (Hoitink *et al,* 1991).

Composts produced in the open near a forest — an environment with many microbial species -are more consistently suppressive than those produced from the same materials in partially enclosed facilities where microbial species are fewer (Hoitink & Fahy, 1986). The latter composts are also normally recolonised by a less diverse microflora than compost produced in windrows (Nelson *et al,* 1983). As a result, there is no way of predicting whether antagonistic microorganisms would reach high enough population densities to render the resulting compost suppressive to a specific plant pathogen. To solve the problem of variability in suppressiveness, specific microbial inoculants can be introduced into the compost after peak heating, but before recolonisation has reached significant levels (Hoitink, 1990).

COMPOST FROM CITRUS WASTE

Raw material

Citrus waste is produced in enormous quantities by fruit processing plants. The waste, consisting mainly of peel, contains soluble and insoluble carbohydrates, as well as digestible crude fibre and protein, thus making it suitable as feedstuff. However, due to the high water content of citrus waste (80-92%) it is subjected to spoilage and has to be preserved by drying or ensilage. Since the cost of drying is exorbitant and the practicability of ensiling remains questionable (Ashbell & Lisker, 1987) the utilisation of citrus waste as fodder seems economically unfeasible. Braddock & Graumlich (1981) proposed the exploitation of citrus waste as fibre source, binding agent in food technology, and fermentation substrate for production of single cell protein. Although these technologies may yield interesting results it is doubtful whether they would find industrial application. Composting therefore appears to be a viable option for transforming citrus waste to a value added product.

The composting process

Citrus residue remaining after juice extraction was obtained from Letaba Citrus Processors. The raw material comprised citrus peel, membranes, juice vesicles and seed. Composting was first attempted on a pilot-scale in bins with forced and natural aeration (Streichbier *et al,* 1982) and in crates and piles, with the latter producing the most acceptable product. Compost was subsequently prepared from *ca* 5 000 kg citrus waste materials piled in a heap under shelter, and aerated by mechanical mixing once a week. The composting process could be completed within 6 weeks provided that limestone was added beforehand to the waste at 15 kg t^{-1}, temperature exceeded 50°C during the thermophilic phase, and moisture content remained between 55 and 65%. C/N ratio of the raw material was 28:1, which falls within the optimum range for composting (Verdonck, 1988), and thus required no adjusting. The final product consisted of a medium-textured, dark-coloured, aromatic, humus-like substance, hereafter referred to as citrus CWC.

Effect of CWC on plant growth

Organic matter, irrespective of origin, is inclined to cause some phytotoxicity in plants (Zucconi *et al.,* 1981). CWC was therefore compared with commercial composts for inhibition of seed germination and plant growth according to standard screening procedures described by Zucconi *et al.* (1981), viz. effect on cress *(Lepidium sativum* L.) seed germination by water extracts of composts, and growth response of sunflower *(Helianthus annuus* L.) seedlings to different compost concentrations. CWC inhibited cress seed germination to a greater extent than commercial composts, but was equally or less inhibitory to sunflower seedlings.

Suppression of *Phytophthora* spp by CWC

The ability of CWC to suppress *Phytophthora nicotianae* B de Haan and *Phytophthora cinnamomi* Rands was evaluated in the greenhouse by the blue lupin *(Lupinus angustifolius* L.) bioassay (Darvas, 1979). Unsterilised CWC, presterilised CWC, or presterilised CWC amended with 0.4 % (m/v) mycelial inoculum of the antagonistic fungi *Trichodenna hamatum* (Bonard.) Bain, or *T. harzianum* Rifai, was incorporated in seed germination sand at a rate of 25% (v/v). The various sand/CWC mixes were or were not artificially infested with mycelial inoculum of *P. nicotianae* or *P. cinnamomi* at 0.1% (m/v). Each mix was dispensed into six 250 ml polystyrene cups, and five aseptically pregerminated blue lupin seeds were planted in each cup. Cups were arranged randomly in a greenhouse at 25-32°C, and each cup received 30 ml of sterile distilled water three times a week. Lupin seedlings which capsized within 3 weeks were recorded and their crowns plated on PARPH medium (Solel & Pinkas, 1984) for recovery of *P. nicotianae* and *P. cinnamomi.*

Unsterilised CWC significantly reduced lupin mortality in comparison with presterilised CWC and presterilised CWC amended with *T. hamatum* or *T. harzianum* (Figure 1), thus indicating that CWC harbours an antagonistic microbial population highly suppressive to disease.

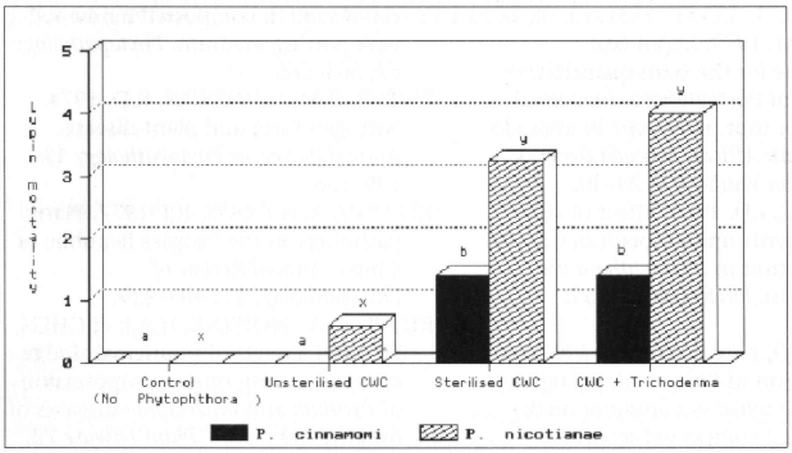

Figure 1
Disease incidence in lupin seedlings planted in CWC-amended medium artificially infested with *Phytophthora cinnamomi* and *Phytophthora nicotianae*.
Bars with the same letter do not differ significantly according to Duncan's multiple range test (P = 0.05)

DISCUSSION

Suppression of *P. nicotianae* and *P. cinnamomi* by CWC-amended substrates appears to be due to indigenous microbial antagonists in the compost, analogous to the situation with other disease-suppressive organic amendments (Chef *et al,* 1983; Cook & Baker, 1983; Hoitink & Fahy, 1986; Hoitink *et al,* 1991). Results furthermore indicated that suppression by CWC is of a "general" nature, i.e. not requiring further augmentation with an introduced antagonist (Hoitink *et al.,* 1991), but the actual mode of action and organisms involved still need to be elucidated. Once this has been done, quality control criteria should be established to produce a consistent commodity with persistent performance.

It is also not known what the effect of CWC would be on the development of target crops. Chemical analysis and greenhouse and field evaluations are therefore in progress to determine the biofertilising capacity of the product.

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