Eur J Plant Pathol (2007) 117:393–402
DOI 10.1007/s10658-007-9108-x

FULL RESEARCH PAPER

The suppressive effects of composts used as growth media against *Botrytis cinerea* in cucumber plants

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Received: 6 June 2006 / Accepted: 29 January 2007 / Published online: 28 February 2007

Abstract The incidence/severity of soil-borne plant diseases is often reduced when composts are used as growth media. However, much less information is available about the effects of composts on the development of foliar diseases. Here we studied the suppressive capacity of five composts (from olive marc-cotton gin trash, grape marc, cork, spent mushroom and municipal organic and yard wastes) as growth media against *Botrytis cinerea* disease in cucumber plants. We also examined the putative correlations of several biotic and abiotic factors involved in disease suppression. The suppressive capacity of the growth media was studied by comparing disease incidence/severity in plants grown in composts with that occurring in plants grown in commercial peats, which are conducive to most soilborne diseases. Correlations were made between the occurrence of disease and leaf nutrient status, as well as electrical conductivity (EC) and microbial activity (measured as β-glucosidase activity) in the growth media. Cucumber plants grown in the peats showed greater severity of *B. cinerea* during the bioassay than those grown in composts. Mo, Ca and Si content in leaves showed negative correlations with this disease. A negative correlation with disease severity was observed for EC and microbial activity in the growth media. The noticeable reduction in *B. cinerea* in plants grown in composts was related to the supply of specific chemical elements, a certain degree of salt stress, and the high microbial activity of composts.

Keywords Calcium · Compost · Gray mold · Molybdenum · Nutrient status · Silicon

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Introduction

Botrytis cinerea produces a gray mold that threatens the productivity of tomatoes and cucumbers grown in greenhouses worldwide. This mold affects leaves, stems and fruit (Dik & Elad, 1999). Greenhouse growers use various fungicides (e.g., diethofencarb and carbendazim) against this fungus; however, due to the emergence of resistant strains, results are poor (Elad, Yunis, & Katan, 1992). Azole and strobilurine fungicides show limited effectiveness (Vermeulen, Schoonbeek, & De Waard, 2001). Gray mold development on leaves can be reduced by lowering the relative water content of air by means of heating

and ventilation; however, this is a costly procedure. It is also ineffective against direct infections produced by mechanical wounds (Shtienberg, Elad, Ariela, Nitzani, & Kirshner, 1998). Moreover, for health and environmental reasons, there is increasing legislative pressure to reduce reliance on pesticides. Consequently, organic amendments are the focus of renewed interest in terms of their potential for improving soil health and preventing, suppressing, or controlling pests and diseases (Litterick, Harrier, Wallace, Watson, & Wood, 2004).

Composts suppress soilborne diseases (Hoitink, Schmitthener, & Herr, 1975). This suppression has been widely reported for *Pythium* spp. (Pascual, Hernandez, Garcia, De Leij, & Lynch, 2000), *Phytophthora* spp. (Khan, Ooka, Miller, Madden, & Hoitink, 2004); *Rhizoctonia* spp. (Trillas et al., 2006), and *Fusarium* spp. (Borrero, Trillas, Ordovas, Tello, & Aviles, 2004). Although Tränkner (1992) proposed that compost amendments also contribute to controlling foliar diseases, support for this hypothesis has been provided only recently for diseases such as *Puccinia* spp. (Loschinkohl & Boehm, 2001), *Alternaria solani* (Mills, Coffman, Teasdale, Everts, & Anderson, 2002) and *Pseudomonas syringae* pv. *syringae* (Stone et al., 2003). However, the use of composts as growth media to control *B. cinerea* has been reported only once in a pot mix containing 10% composted cow manure and the parameters involved in disease suppression were not discussed (Horst et al., 2005).

Disease suppression by composts has been explained mainly by biotic mechanisms (Hoitink & Boehm, 1999). Microorganisms in composts make a significant and direct contribution to the control of soilborne pathogens (Hoitink et al., 1975). Currently, research focuses on the induction of systemic resistance in plants by microorganisms from composts, which would explain protection against soilborne and foliar diseases (Krause et al., 2003). Less research effort has been devoted to the nutrient/salt effect of composts on the occurrence of plant diseases (Borrero et al., 2004).

Here we report a short-lived bioassay (14 days) to evaluate the capacity of two commercial peats and five composts from municipal and agricultural wastes to suppress *B. cinerea* disease in cucumber plants. We also assessed the nutrient status of the plant and the microbial activity and electrical conductivity (EC) of the growth media, in order to correlate these parameters with disease suppression.

Materials and methods

Bioassay

We developed a bioassay to assess the effect of composts on the development of *B. cinerea*. Seeds of the cucumber plant (*Cucumis sativus* cv. Negrito) were placed in 35 ml multipots in the growth media described in the section below. The plants were grown in a chamber at 25 ± 1°C, with a 16 h light photoperiod at 200 μmol m^{-2} s^{-1}. Plants were irrigated with the following nutrient solution: 0.5 g l^{-1} Peter's foliar feed 27-15-12 (Scotts, Heerlen, Netherlands), 0.22 g l^{-1} $CaCl_2$ and 0.25 g l^{-1} $MgSO_4 \cdot 7H_2O$. Two-week-old plants (with only one fully expanded leaf) were transplanted to 300 ml pots in the same growth media in which they had been germinated. They were then inoculated with the pathogen, as described in the following section. Inoculated plants were kept in a growth chamber for 2 weeks at 18°C, 100% relative humidity and an 8 h light photoperiod at 85 μmol m^{-2} s^{-1}. One bioassay consisted of 10 pots per treatment (growth media) with one plant per pot; the pots were fully randomized; the bioassay was performed four times.

Inoculation with *Botrytis cinerea*

We used the isolate CECT 2850 of *B. cinerea*, obtained from the Spanish Type Culture Collection (University of Valencia, Spain). Four silica gel crystals, which held the strain, were plated on Petri dishes with 39 g l^{-1} potato dextrose agar (Scharlau Chemie S.A., Spain). Plates were kept at 25°C for 3 weeks. Conidia were collected from the plates in an inoculation buffer containing 0.5 mg ml^{-1} glucose and 0.5 mg ml^{-1} KH_2PO_4 (De Meyer, Bigirimana, Elad, & Höfte, 1998). Ten ml of the buffer was used per plate. The

resulting suspension was filtered through two cotton gauzes. The concentration of *B. cinerea* was adjusted to 5×10^5 conidia ml^{-1} by counting using a hemocytometer. Finally, a drop of Tween 20 was added. The only fully expanded leaf from each plant was inoculated with 3 ml of the suspension using a low-pressure hand sprayer.

Disease evaluation

The severity and incidence of disease was examined 7, 10 and 14 days post-inoculation (dpi). Severity (Fig. 1) was evaluated using the following scores for each inoculated leaf: 0 (healthy leaf); 1 (<25% of the leaf surface infected); 2 (26–50% of the leaf surface infected); 3 (51–75% of the leaf surface infected); and 4 (>75% of the leaf surface infected). Disease incidence was calculated as % of diseased plants over the total number of plants.

Growth media

Composts from a range of raw materials were used as growth media. Two commercial peats: peat A (Klasmann, Valimex, Spain) and peat B (Mikskaar, Burés, Spain) were used as reference media. In addition, a set of peat A was heated at 60°C for 1 week to reduce microbial populations (peat A 60). All peats were neutralized with 4 g l^{-1} $CaCO_3$. Grape marc compost (GMC), olive marc-cotton gin trash (1:1, v:v) compost (OMC) and cork compost (CC) were produced at the Universidad de Sevilla (Escuela Universitaria de Ingeniería Técnica Agrícola), Spain, in 40–100 m^3-piles (Trillas, Aviles, Ordovas, Bello, & Tello, 2002). All these composts were used as growth media. Two commercially available composts: spent mushroom compost (SMC) from RECOMSA S.C.L. (Cuenca, Spain) and a compost made with municipal organic and yard wastes Metrocompost S.A., (Castelldefels, Spain) were also used. Several composts were formulated to attain favourable physicochemical properties for plant growth. OMC and SMC were washed to reduce salinity and were formulated (1:1, v:v) with rice hulls and peat, respectively. Compost from Metrocompost was formulated (MPV) with peat and vermiculite (2:1:1, v:v:v, respectively). The EC and pH of all the materials were determined in a water extract (2:1, v/v). The mixture was shaken for 5 min and left to stand for 30 min; pH was then measured and, after filtration, EC was determined.

Microbial activity of the growth media

The microbial activity of the growth media at the start of the bioassays was estimated by measuring β-glucosidase activity (Bandick & Dick, 1999). This method is based on the colorimetric determination of *p*-nitrophenol released by β-glucosidase when media are incubated for 1 h at 37°C in the presence of p-nitrophenil-β-glucoside. The *p*-nitrophenol released is extracted by filtration and determined colorimetrically at 410 nm.

Nutrient analyses of cucumber leaves

In the fourth bioassay, ten 2-week-old plants per treatment were used in the bioassay and four plants (one leaf per plant) for nutrient analyses. Leaves were dried at 60°C until constant weight was reached. They were then ground separately with an agate mortar and pestle. B, Mn, Zn, Cu, Mo and Ni analyses were performed by inductively coupled plasma mass spectrometry

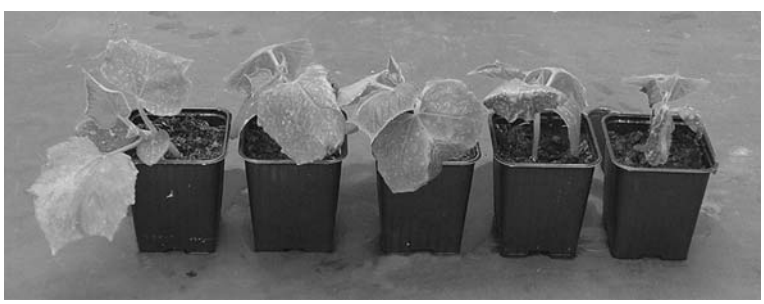

Fig. 1 Cucumber plants showing five disease scores, from left to right: 0 (healthy leaf); 1 (<25% of the leaf surface infected); 2 (26–50% of the leaf surface infected); 3 (51–75% of the leaf surface infected); and 4 (>75% of the leaf surface infected)

(ICP-MS) using a Perkin–Elmer apparatus, model Elan-6000. Ca, Fe, K, Mg, P, S and Si analyses were performed by inductively coupled plasma optical emission spectrometry (ICP-OES), using a Perkin–Elmer apparatus, model Optima-3200RL. In both cases, 45 mg of sample was attacked overnight in teflon reactors with 1 ml HNO_3 and 0.5 ml H_2O_2 at 90°C. N analyses were carried out by gas chromatography coupled with a thermal conductivity detector (TCD), after sample combustion at 1,000°C with an EA 1108 CHNS-O apparatus (Carlo Erba Instruments). In this case, 1,000–1,500 μg of the sample, containing a similar amount of V_2O_5, was used. Two analytical replicates were performed per sample.

Statistical treatment

The severity and incidence of disease for each of the three periods (7, 10 and 14 dpi), and the nutrient composition of the leaves were analyzed by one-way ANOVA. When significant differences were observed ($P = 0.05$), Tukey's multiple range test was performed. The results of the nutrient analyses (fourth bioassay) were studied using standardized principal component analysis (PCA). Values of the first and second components were subjected to ANOVA. Moreover, linear regressions were performed between: disease severity and the first component; disease severity and the second component itself; and disease severity and elements showing importance in the second component. We also studied the correlation between β-glucosidase activity and EC with disease severity 14 dpi. Data was analyzed by SPSS 11.5 and Statgraphics 5.0 software.

Results

At the end of the experiment, 14 dpi, plants grown in the composts showed a lower severity of *B. cinerea* than those grown in the peats. Moreover, those grown in peat B showed higher severity than peat A and A 60 (Fig. 2). The greatest reduction in severity was observed in the CC treatment, which showed about a 90% decrease compared to peat B 14 dpi. Similar results were obtained at

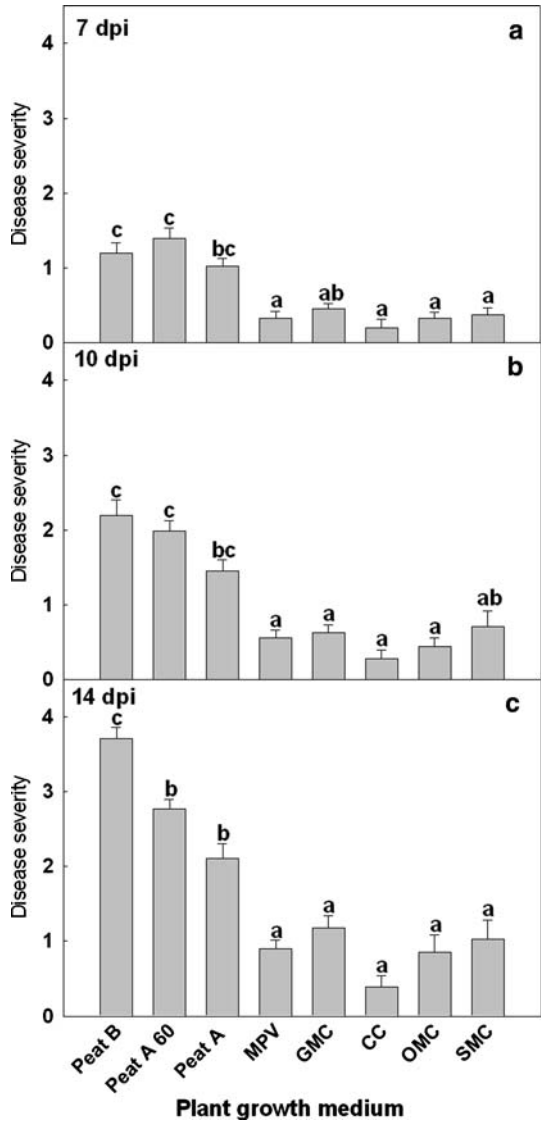

Fig. 2 Disease severity of *Botrytis cinerea*-inoculated cucumber leaves at three time points of evaluation: (**a**) 7, (**b**) 10 and (**c**) 14 days post-inoculation (dpi) for cucumber plants grown in eight growth media: Peat B, Minskaar peat; Peat A 60, Klasmann peat heated at 60°C for 1 week; Peat A, Klasmann peat; MPV, municipal organic and yard wastes compost; GMC, grape marc compost; CC, cork compost; OMC, olive marc-cotton gin trash compost; SMC, spent mushroom compost. The disease severity scale was: 0 = healthy leaf; 1 = <25% of the leaf surface infected; 2 = 26–50% of the leaf surface infected; 3 = 51–75% of the leaf surface infected; and 4 = >75% of the leaf surface infected. Different letters show significant differences ($P < 0.05$) in a Tukey's multiple range test. Data ± SE are means of four independent bioassays with 10 plants each

7 dpi and 10 dpi, with the exception of plants grown in GMC and SMC, which showed similar disease severity to those grown in peat A (at 7 dpi and 10 dpi, respectively).

Calculations of disease incidence—% of diseased plants—showed similar results to those of disease severity. In general, plants grown in composts had a lower incidence of *B. cinerea* than those grown in the peats (90–100% disease incidence at 14 dpi). Plants grown on CC, OMC and SMC showed the lowest incidence of disease and values remained stable throughout the bioassay (32% for OMC and from 32% to 34% for SMC). The greatest decrease in disease incidence was recorded in the CC treatment, which showed 11–19% disease incidence (7 dpi and 14 dpi, respectively), which represents a reduction of about 80% compared with peat B at 14 dpi. However, the MPV and GMC groups (31 dpi and 45% at 7 dpi, respectively) showed an increase in disease incidence as the bioassay progressed, and reached similar levels to plants grown in peats at 14 dpi (72% and 68%, respectively).

All the nutrients analyzed from 14-day-old cucumber leaves prior to pathogen inoculation showed significant differences between treatments (Table 1). Leaves from plants grown in composts tended to have higher concentrations of Mo, Ca, K and Si than those from peat treatments. Mo was significantly higher in plants grown in all composts except GMC, compared to plants grown in peat treatments; Ca was significantly higher in OMC and SMC; K was significantly higher in MPV, GMC and CC; and Si was significantly higher in CC. Plants grown in peat A had significantly higher Mg and lower Zn, Cu and N concentrations than those grown in peat A 60. The N concentration was highly variable among the plants grown in the growth media and did not depend on the kind of media (compost or peat). The leaf water content at the beginning of the bioassay ranged from 89.2% to 90.7% and did not differ between treatments.

The results of the PCA for leaf nutrient status are shown graphically (Fig. 3). The first two principal components (PCs) accounted for 52.6% of the variance in the data. PC 1 did not correlate with disease severity. Leaf samples from peat and compost treatments differed significantly in their PC 2 values ($P = 0.000$). Moreover, there was a negative correlation between PC 2 and disease severity 14 dpi for all growth media ($P = 0.000$; $r^2 = 89.19$). The variables Mo, Ca and Si were the most important in the PC 2

Table 1 Nutrient status of leaves from 14 day-old cucumber plants grown in eight plant growth media[a]

Plant growth medium[b]	B[c]	Mn[c]	Zn[c]	Cu[c]	Mo[c]	Ca[d]	Fe[d]	K[d]	Mg[d]	P[d]	S[d]	Si[d]	N[e]
Peat B	60.0 bc	63.0 b	88.3 ab	11.3 bc	0.09 a	14.1 ab	0.20 bc	22.5 a	4.9 a	9.9 ab	6.6 b	0.08 a	6.6 de
Peat A60	52.9 b	50.5 ab	128.7 c	13.4 cd	0.11 a	15.1 abc	0.14 abc	26.3 ab	4.3 a	12.6 b	7.2 bc	0.12 a	6.9 ef
Peat A	59.8 bc	59.4 b	104.7 ab	6.9 a	0.13 a	11.0 a	0.15 abc	26.4 ab	7.7 b	9.7 ab	7.0 bc	0.07 a	5.3 a
MPV	63.5 bc	65.0 b	112.0 bc	14.3 d	1.06 cd	18.3 bc	0.22 c	42.3 d	8.5 b	10.0 ab	7.8 bc	0.18 a	7.2 f
GMC	41.5 ab	65.0 b	114.3 bc	9.4 ab	0.36 a	18.9 bc	0.13 ab	39.3 d	5.3 a	9.8 ab	8.2 c	0.12 a	6.3 bcd
CC	25.0 a	26.9 a	74.2 a	9.2 ab	0.73 b	21.3 cd	0.10 a	35.2 cd	4.2 a	11.0 ab	5.2 a	0.34 b	6.0 bc
OMC	81.5 c	107.3 c	102.1 ab	12.1 bcd	1.20 d	26.8 d	0.14 abc	29.4 abc	8.9 b	8.0 a	7.8 bc	0.17 a	5.9 ab
SMC	47.3 ab	31.4 a	106.1 ab	13.7 cd	0.86 bc	27.2 d	0.14 abc	31.3 bc	5.6 a	10.4 ab	8.0b c	0.16 a	6.5 cde

[a] Within each column, values with different letters are significantly different ($P < 0.05$) according to Tukey's test. Data presented are means of four leaves from different plants per treatment collected from one of the bioassays

[b] Peat B, Minskaar peat; Peat A 60, Klasmann peat heated at 60°C for 1 week; Peat A, Klasmann peat; MPV, municipal organic and yard wastes compost; GMC, grape marc compost; CC, cork compost; OMC, olive marc-cotton gin trash compost; SMC, spent mushroom compost

[c] Expressed as μg g^{-1} of dry weight of leaves

[d] Expressed as mg g^{-1} of dry weight of leaves

[e] Expressed as a %

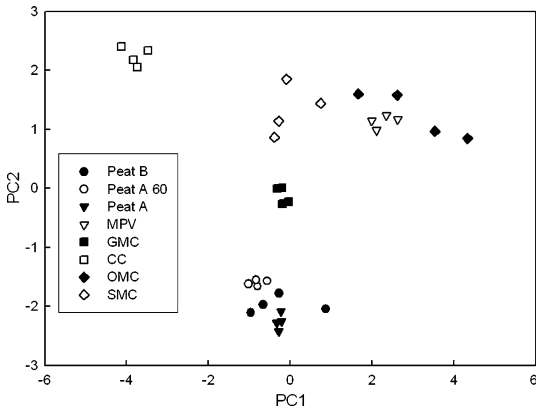

Fig. 3 Ordinate plot of the principal components (PC1 and PC2) of the nutrient status of cucumber leaves grown in eight growth media: Peat B, Minskaar peat; Peat A 60, Klasmann peat heated at 60°C for 1 week; Peat A, Klasmann peat; MPV, municipal organic and yard wastes compost; GMC, grape marc compost; CC, cork compost; OMC, olive marc-cotton gin trash compost; SMC, spent mushroom compost. Nutrient analysis and principal component analysis were performed in one of the four bioassays

Table 3 Physicochemical and biological properties of growth media at the beginning of the bioassays[a]

Plant growth medium[b]	pH	Electrical conductivity[c]	β-glucosidase activity[d]
Peat B	5.81 a	0.05 a	71.26 b
Peat A 60	6.32 b	0.06 a	7.89 a
Peat A	6.36 bc	0.06 a	98.98 cd
MPV	8.13 e	1.59 e	133.17 e
GMC	8.31 e	0.79 b	110.47 d
CC	7.65 d	0.97 c	148.33 e
OMC	7.61 d	1.31 d	261.81 f
SMC	6.59 c	3.60 f	81.73 bc

[a] Within each column, values with different letters are significantly different ($P < 0.05$) according to Tukey's test. Data presented are means of four pots per treatment

[b] Peat B, Minskaar peat; Peat A 60, Klasmann peat heated at 60°C for 1 week; Peat A, Klasmann peat; MPV, municipal organic and yard wastes compost; GMC, grape marc compost; CC, cork compost; OMC, olive marc-cotton gin trash compost; SMC, spent mushroom compost

[c] mS cm^{-1}

[d] µg hydrolyzed *p*-nitrophenol cm^{-3} growth medium

weighting and showed individual negative correlations with the severity of *B. cinerea* 14 dpi (Table 2).

The pHs of compost-based growth media were higher than those of peat, except for SMC, which did not differ from that of peat A (Table 3). EC was at least ten fold higher in compost-based growth media than in peat. For SMC, EC was 60-fold higher (Table 3). Element contents (mg l^{-1}) of compost-based growth media were higher than those of peat except for P, and among the composts the abundance of a particular element was not related to an increase of that element in the leaf. Mn concentration in the peats was around 0.02, while in the composts it ranged from 0.04 to 0.34 (in SMC and OMC, respectively); Zn was around 0.02 in the peats, while in the composts it ranged from 0.06 to 0.18 (in SMC and GMC, respectively); Cu was around 0.02 in the peats while in the composts it ranged from 0.06 to 0.14 (CC and OMC, respectively); Ca was around 16 in the peats, while in the composts it ranged from 80 to 526 (in OMC and SMC, respectively); Fe was around 0.14 in the peats, while in the composts it ranged from 0.16 to 6.76

Table 2 Significant correlations between *Botrytis cinerea* disease severity (ds) 14 days post-inoculation and the leaf nutrient status and physical and biochemical parameters of the growth media

Element	r^2	P	Equation
Mo[a]	63.77	0.0175	ds = 3.00768 – 2.222555 × Mo
Ca[b]	67.87	0.0119	ds = 5.12837 – 0.177021 × Ca
Si[b]	54.83	0.0356	ds = 3.43299 – 10.9204 × Si
Electrical conductivity[c]	56.37	0.0318	ds = 2,58348 – 0.000790984 × electrical conductivity
β-glucosidase activity[d]	47.11	0.0498	ds = 2,86962 – 0.0105096 × β-glucosidase activity

[a] Expressed as µg g^{-1} of dry weight of leaves

[b] Expressed as mg g^{-1} of dry weight of leaves

[c] Expressed as mS cm^{-1}

[d] Expressed as µg hydrolyzed *p*-nitrophenol cm^{-3} growth medium

(GMC and OMC, respectively); K was around 0.16 in the peats, while in the composts it ranged from 432 to 3,204 (in CC and SMC, respectively); Mg was around four in the peats while in the composts it ranged from 26 to 176 (OMC and SMC, respectively); P was around 0.2 in the peats and ranged from 0.2 in SMC to 8.2 in GMC while in OMC was 0.0. β-glucosidase activity in composts was greater than in peat, except for SMC, in which the activity was the same as that of peats A and B; and GMC, in which the activity was the same as that of peat A. Heat treatment of peat A (peat A 60) resulted in 12-fold lower β-glucosidase activity (Table 3). EC and β-glucosidase activity correlated negatively with disease severity 14 dpi (Table 2).

Discussion

Cucumber plants grown in peat showed greater severity of *B. cinerea* disease as the bioassay progressed than those grown in compost. Moreover, disease incidence, which is a different way to evaluate disease, allowed us to define two groups of compost growth media: the most suppressive ones (CC, OMC and SMC) and those which sometimes did not differ from peat (MPV and GMC). These results support the notion that the use of composts as growth media reduces disease intensity (severity and incidence) in aerial parts of plants attacked by foliar pathogens (Abbasi, Al-Dahmani, Sahin, Hoitink, & Miller, 2002; Miller et al., 1997; Tränkner, 1992). However, Krause et al. (2003) reported that the suppression of *Xanthomonas campestris* foliar disease in radish by use of compost growth media is a rare phenomenon: only one of the 79 composts they assayed decreased the severity of lesions. In contrast, all five composts assayed in our study reduced *B. cinerea* disease (at 14 dpi) compared to the peat growth media. The beneficial effect of using composts as growth media to reduce this disease has recently been reported in begonia plants grown in a pot mix containing 10% composted cow manure (Horst et al., 2005).

Our results show that the nutritional status of cucumber leaves is related to the severity of gray mold caused by *B. cinerea*. Ca, Mo and Si content in the leaves showed negative correlations with disease severity 14 dpi. Ca involvement in disease resistance has been widely reported. According to Wojcik and Lewandowski (2003), foliar treatment with $CaCl_2$ led to foliar Ca increases and was effective against *Botrytis* strawberry leaves and fruit. Moreover, Elad, Yunis, and Volpin (1993), reported that *Botrytis* incidence in cucumber was reduced to 50% when Ca supplements were applied to the growth media. Similar disease control was obtained with diethofencarb and carbendazim. Ca ions are key elements in salicylic acid production; salicylic acid is a molecular signal related to systemic acquired resistance (Schneidermuller, Kurosaki, & Nishi, 1994). Ca ions are also involved in the production of callose (Trillas, Cotxarrera, Casanova, & Cortadellas, 2000) and phytoalexin (Vogeli, Vogelilange, & Chappell, 1992). These ions act as binding elements between pectin molecules, which may produce cellular wall reinforcement (Carpita & McCann, 2000). Several reports have associated Mo with disease resistance in plants (De Jesus et al., 2004; Graham, 1983). However, the way in which Mo affects plant protection remains unclear. However, this element is required to enhance N metabolism (Marschner, 1995). The negative correlation between Si leaf content and disease severity could be related to Si deposition on the surface cell layers, thus reinforcing cell walls (Epstein, 1999). Alternatively, Fawe, bou-Zaid, Menzies, & Belanger, (1998) reported that Si treatment leads to the production of a phytoalexin in cucumber after *Sphaerotheca fuliginia* inoculation. They proposed that Si is related to systemic acquired resistance.

Although significant differences were observed in the nutrient status of cucumber leaves, most elements fell within the optimal levels proposed by Fox and Valenzuela (1992), with the exception of K and Ca in the plants grown in the peats, which were below optimal levels, even though the peat media were amended with 4 g l^{-1} $CaCO_3$. The relatively high pH of the composts could have interfered with nutrient uptake. Nevertheless, plants grown in compost had an adequate nutrient status, probably due to the abundance of macro and micro elements and the selective absorption ability of plants.

The differences observed in the nutrient status of plants grown in peats A and A 60 are consistent with previous studies (Borrero et al., 2004). In that study, tomato plants grown in heated growth media (1 week at 60°C) also showed higher levels of Cu and N, and lower Mg than those grown in non-heated growth media. However, none of these elements was found to correlate with the severity of *B. cinerea* in cucumber plants.

In the four trials the same lots of growth media were used consecutively; although the nutrient status of leaves was only studied in one of the trials, it is reasonable to expect similar results from the other. Several studies report the importance of specific elements in the occurrence of plant diseases. However, the improvement of plant nutrient status by composts is usually omitted in studies of disease suppression. Moreover, it is not clear whether the activation of the protective mechanism is associated with improved plant nutrition (Murray & Walters, 1992) or salt stress (Mucharromah & Kuc, 1991). On the basis of the levels proposed by Warncke and Krauskopf (1983), our results on EC show that: peat growth media had very low salt levels; GMC and CC had desirable levels; OMC, MPV and SMC salt content was slightly high, high and severely high, respectively. However, plants from all treatments looked healthy and no wilting or marginal leaf burn was observed. Furthermore, there was no significant difference between the water content of cucumber leaves in the distinct treatments. The EC of the growth media correlated negatively with disease severity 14 dpi. Our results suggest that a low level of persistent stress leads to an induced state of resistance, as proposed by Mucharromah and Kuc (1991).

The negative correlation between microbial activity and disease severity observed in our study suggests that microorganisms in the growth media participate in the process resulting in disease reduction, as proposed by Krause et al. (2003). Biotic (i.e., pathogen, elicitors) and abiotic stresses (i.e., salt stress) may be linked to reactive oxygen intermediates which induce the same transcription factors (Mengiste, Chen, Salmeron, & Dietrich, 2003), thereby leading to a similar pattern of mRNA expression in Arabidopsis (Cheong et al., 2002) and rice (Agrawal, Tamogami, Iwahashi, Agrawal, & Rakwal, 2003).

In conclusion, on the basis of our results, we propose that the marked reduction of *B. cinerea* severity/incidence in cucumber plants grown in the composts tested is related to the following: the supply of specific elements; a certain degree of salt stress; and the high microbial activity of the composts, all of which reinforce plant tissues and/or enhance other plant defenses. The relative significance of these parameters may differ for each of the composts studied.

Acknowledgements We thank the *Departament d'Universitats, Recerca i Societat de la Informació* of the Government of Catalonia and the European Social Fund for funding Guillem Segarra's Ph.D. studentship. This study was supported by the *Ministerio de Educación y Ciencia* (AGL2005-08137-C03-01), Spain.

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