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Bioresource Technology 97 (2006) 123–130

BIORESOURCE TECHNOLOGY

Use of composted sewage sludge in growth media for broccoli

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Received 8 April 2004; received in revised form 20 January 2005; accepted 10 February 2005
Available online 29 March 2005

Abstract

In this study, the use of composted sewage sludge (CSS) as a binary component with peat (P) in growth media for a horticultural crop, broccoli (*Brassica oleracea* var. *Botryti* cv. Marathon), was evaluated. Four treatments were established, based on the addition of increasing quantities of composted sewage sludge to peat (0%, 15%, 30% and 50%, v/v). Physical, physico-chemical and chemical analyses of the different mixtures of CSS and P were made. Plant growth, biomass production and macronutrient (N, P, K, Ca, Mg), micronutrient (Fe, Cu, Mn, Zn) and heavy metal (Pb, Ni, Cd, Cr) contents of plants were determined.

The addition of CSS to P increased plant nutrient and heavy metal contents of plants and electrical conductivity (EC) and bulk density values of the substrates. The use of CSS did not affect the germination rate, even at 50% compost. For broccoli growth, the highest yield was obtained with the medium prepared by mixing the peat with 30% of compost; however, the mixture with the most sewage sludge compost (50%) had the greatest contents of macro and micronutrients.

Keywords: Sewage sludge; Compost; Propagation; Growth media; Broccoli; Potentially toxic elements

1. Introduction

In recent decades, the use of soil-less substrates in horticulture has become common, not only for growing seedlings and propagation of plants but also for vegetable production. The cost and the declining availability of peat in high-demand Mediterranean countries make it necessary to look for alternative materials (Abad et al., 2001). Composted organic wastes used as substrates could be a feasible option, especially sewage sludge due to its high production (Terés et al., 1997). In the EU, more than 10 million tonnes will be generated in 2005.

Composts used as components of substrates could modify the properties of peat, due to provision of nutrients, growth regulators, etc. (Bragg et al., 1993; Nappi and Barberis, 1993). When composted materials are used as fertilisers in substrates, it is of great importance that the material is sufficiently stabilised, in order to avoid negative growth effects due to N mineralisation, oxygen depletion or the presence of phytotoxic compounds (Iglesias-Jimenez and Perez-Garcia, 1989). The proportion of compost in the final substrate is also very important, in order to minimise potential hazards, especially salinity. Raviv et al. (1986) reported that combinations of peat with sewage sludge and other residual materials can minimise the negative properties of single materials (high salinity, heterogeneity, high content of contaminants), thus obtaining a sound and cheap substrate. Other researchers (Pinamonti et al., 1997; Eklind et al., 2001; Perez-Murcia et al., in press) have reported that the presence of compost tends to reduce concentrations of heavy metals in plants, due to the higher pH values that usually result. Pinamonti et al. (1997) found significant increases in the N, P and K contents in cucumber, tomato and strawberry plants grown in

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doi:10.1016/j.biortech.2005.02.005

peat–sewage sludge compost media. So, the integrated evaluation of the beneficial (nutrient input) and non-beneficial effects (salinity, heavy metals) associated with the use of sewage sludge compost–peat combinations for broccoli germination and growth media must be considered, in order to optimise their general application.

In this study, the use of sewage sludge compost in the preparation of substrates for broccoli cultivation in pots was evaluated in order to determine any limitation to their use. In addition, nutrient dynamics and heavy metal concentrations were evaluated.

2. Methods

2.1. Materials

Four composted sewage sludge (CSS)/peat (P) mixtures were made: P (100% peat), P + CSS1 (85% P + 15% CSS), P + CSS2 (70% P + 30% CSS) and P + CSS3 (50% P + 50% CSS), on a volume basis. The mature compost used in this experiment was produced in a turned-pile system, in a pilot plant, using 30% sewage sludge and 70% chopped straw (volume basis). The pile was turned every two days during the first week of composting, twice during the second week and once a week during the rest of the bio-oxidative phase. The bio-oxidative phase of composting was considered finished when the temperature of the pile was stable and near to that of the surrounding atmosphere. This stage was reached after 70 days of composting and then the turnings were stopped to allow the compost to mature over a period of one month. The temperature increased quickly at the beginning of the process to high thermophilic values (70 °C), which contribute to the hygiene of the end-product due to pathogen, weed and seed reduction. A commercial Sphagnum peat (P) from Germany was used. In Table 1, physico-chemical and chemical characteristics of the peat and sewage sludge compost are shown. The compost used reached a good degree of maturity according to its carbon to nitrogen ratio (C/N < 12) (Bernal et al., 1998). In accordance with the ideal substrate (Raviv et al., 1986; ADAS, 1988; Bunt, 1988; Abad et al., 2001), the commercial peat had more adequate values of pH, EC and organic matter than the compost.

Table 1
Physical–chemical and chemical properties of the growing media components, peat (P) and composted sewage sludge (CSS), on a dry matter basis

Parameter	Peat (P)	Compost (CSS)
EC (dS m^{-1})	0.26	2.04
pH	6.22	6.83
Total organic matter (%)	94.2	58.3
Total N (%)	0.96	2.67
C/N	27.2	9.1
P (g kg^{-1})	0.53	28.9
K (g kg^{-1})	1.02	2.78
Na (g kg^{-1})	1.35	2.49
Fe (mg kg^{-1})	798	21,442
Cu (mg kg^{-1})	20	139
Mn (mg kg^{-1})	22	173
Zn (mg kg^{-1})	23	634
Pb (mg kg^{-1})	2.0	80
Ni (mg kg^{-1})	3.0	19.2
Cd (mg kg^{-1})	0.26	3.6
Cr (mg kg^{-1})	1.4	30.4
Co (mg kg^{-1})	3.0	15.0

EC: electrical conductivity.

2.2. Setting up the experiment

The experiment was carried out in a greenhouse with temperature control (20 °C). A germination assay was carried out prior to use of the mixtures for growth purposes, in order to estimate the phytotoxicity of the increasing presence of CSS in the media. In this assay, broccoli (*Brassica oleracea* var. *Botryti* cv. Marathon) was sown in trays (with 64 plants in each tray and 50 ml volume per plug). Seedling conditions in the growth chamber were 27 °C for 36 h. The germination rate was evaluated for each mixture. Of the 64 plants in each tray, 24 were used for the growth experiment. The treatments of this experiment, in a fully-randomised design with six replicates per treatment, were established in pots of 10 dm^3. The plants were irrigated, in accordance with their water demand, with distilled water during the growing period, the irrigation scheduling and water quantity being equal for all treatments. No additional fertilisation was used in the experiment. At the end of the experiment, on day 110, all the plants ($n = 6$ per treatment) were harvested and analysed separately, according to their commercial size, and the leaves, shoots and edible parts were washed and then dried at 60 °C, in an air-forced oven, for 72 h. Fresh and dry weights of aerial biomass were determined.

2.3. Plant and growth media analysis

The pH, electrical conductivity (EC), and water-soluble Na^+, K^+ and Cl^- were determined in the mixtures. Total contents of macronutrients (N, P, K, Ca, Mg), micronutrients (Fe, Cu, Mn, Zn, B), Na and heavy metals (Pb, Cd, Ni, Cr) in the initial mixtures and plants (total aerial parts) were determined. Growing media pH, EC and soluble Na^+, K^+ and Cl^- were determined in water extracts (1:6 v/v) (ADAS, 1988). Bulk density of substrates was determined according to the methods of De Boodt (1975). Dry matter was calculated by drying at 105 °C for 12 h and at 60 °C for 72 h, for substrate and plant samples, respectively. Plant samples and substrates were mineralised by microwave acid-digestion, using HNO_3/H_2O_2 at a ratio of 4:1 (v/v) (Moral et al., 1996; Kalra et al., 1988). Total contents of Ca, Mg, Fe, Mn, Cu, Zn, Pb, Ni, Cd and Cr were determined