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The effect of salinity and porosity of sewage sludge compost on the growth of vegetable seedlings

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ABSTRACT

Salinity and porosity of composted sewage sludge (CSS) were studied to evaluate their effect on vegetable seedlings, specifically on vegetable seedling performance and toxicity threshold of soluble salts. For the evaluation, CSS was mixed with different proportions of leached CSS to control the salinity. Soluble salt content of 1.45% or higher in growth media inhibited the growth of cucumber, tomato, and pepper seedlings, while that of 1.1% was relatively safe. Different porosities of CSS media were prepared by mixing CSS (<10 mm) with ground CSS (<1 mm) in different proportions (CSS and ground CSS were leached beforehand to prevent salt stress). The vegetable seedlings grew well in CSS media without showing symptoms of growth inhibition if the total porosity ranged from 66% to 81% and the water holding porosity ranged from 48% to 59%. However, the best seedling performances were achieved with the coarser media with high total porosities. The study indicated that when salt content was appropriate, CSS can be used alone as a vegetable seedling growth medium without the need for grinding or blending with other materials.

1. Introduction

Composted sewage sludge (CSS) or municipal solid wastes in growth media as a substitute for peat to nurse vegetable or horticultural crops has been frequently reported to present better performances based on plant morphology, biomass, and yield (Herrera et al., 2008; Grigatti et al., 2007; Perez-Murcia et al., 2006). However, negative factors such as organic contaminants, heavy metals, and pathogens normally exist in sewage sludge, and their presence often raises concern because of environmental risks from ill-considered waste disposal and reclamation (Kidd et al., 2007; Sahlström et al., 2004; Petersen et al., 2003; Schnaak et al., 1997; Alloway and Jackson, 1991). If a successful composting procedure is conducted by degrading organic contaminants, stabilizing heavy metals, and killing pathogens these risks could be reduced effectively (Oleszczuk, 2007; Zheng et al., 2007; Noble and Roberts, 2004). Concentrated salts such as sodium chloride in CSS could also be disastrous for establishing vegetable seedlings due to salt stress (Gasco and Lobo, 2007; Al-Khateeb, 2006; Bani-Aameur and Sipple-Michmerhuizen, 2001; Fostad and Pedersen, 2000; Masataka and Tetsuo, 2000). This should be an important concern along with the environmental risks if CSS is used as growth media. A common solution is blending composts with other materials such as soil, vermiculite, peat, or agricultural wastes (Zaller, 2007; Tsakaldimi, 2006; Atiyeh et al., 2001), or by soaking seeds in saline water for a short period prior to sowing to enhance seedling tolerance to high salinity (Gómez et al., 1998). However, no paper has as yet proposed solutions for fixing the threshold of salt content adequate for CSS media. Similarly, physical properties of CSS media such as porosity were neglected in previous studies. It is well known that CSS has heavier bulk density and lower air-filled porosity compared with peat or sphagnum, which are widely used on bedding plants (Agnew and Leonard, 2003), and this raises the issue of oxygen deficiency in growth media. This study is meant to quantify the total soluble salts in growth media made from CSS adequate for nursing several common vegetable species, and to evaluate the effect of porosity on seedling performances.

2. Materials and methods

2.1. Salinity

Sewage sludge was taken from a municipal wastewater treatment plant in Beijing and mixed with sawdust in a 1:1 ratio by volume in wet base. The resulting mixture was then fermented in a static forced-aeration composting device (Composoft®V 2.0). After 35 days, the finished compost was placed in a storehouse and allowed to age for 5 months. The mature compost was air dried and passed through a 10 mm sieve.

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The compost was soaked with deionized water (water/compost equal to 3:1 in volume) for 12 h and leached on nylon gauze with a mesh screen of 50 μm to remove gravitational water. The soaking and leaching process was repeated three times. The leached compost was air dried and used as a low salinity sample.

To determine the total water soluble salts in the compost, 50 g of the compost sample was soaked in 250 ml deionized water, surged for 4 h at room temperature, and then filtered through quantitative filter paper. Next, 50 ml of the filtrate in a 100 ml beaker was evaporated at 100 °C in a water bath. During the evaporation, 10 ml of 30% H_2O_2 was added to eliminate organic matter. The residue in the beaker was oven dried at 105 °C for 4 h and weighed. The resulting figure was multiplied by 5 to determine the soluble salt content in the 50 g compost sample (Lu, 1999). The leached compost (low salinity) had a salt content of 0.21%, while the non-leached compost (high salinity) had 2.4% (in dry base).

Mixing the CSS with the leached CSS (LCSS) in different proportions resulted in a salinity series of 1.8%, 1.45%, 1.1%, 0.75%, and 0.4% (content of water soluble salts, %, dry base) in the growth medium. The CSS/LCSS (w:w) ratios were 2.65, 1.31, 0.68, 0.33, and 0.1, respectively.

Five seeds each of cucumber (*Cucumis sativus* L.), tomato (*Lycopersicum esculentum* Mill.), and pepper (*Capsicum frutescens* L.) were sowed respectively in pots containing 120 cm^3 of the medium. For each vegetable and medium, six replicates and a control made from a commercial peat were prepared. The control was mixed with peat and perlite at the ratio of 3:1 by volume. The soluble salt content of the peat was 0.6%.

The pots were irrigated with deionized water (about 40 ml per pot, the media were in adequate humidity without leaching or water logging) and placed randomly in a greenhouse. The seeds were allowed to germinate and grow at 18 °C minimum night temperature, 30 °C maximum day temperature, and 35–60% relative humidity. The illumination intensity was not controlled and the photoperiod was natural (the day/night rhythm in 24 h was about 14 h). After emergence, only one seedling in each pot was left while all the others were cut off. Thus, six seedlings from each treatment were used in this study.

Before seedling emergence, the pots were irrigated with deionized water followed by irrigation with a 1/4 concentration of Hoagland solution (Hoagland and Arnon, 1938). To avoid salt accumulation and water logging, no nutrient solution was added until the media was dry. To avoid draining (which would change the salinity of the growth medium), a 20 ml beaker was used for irrigation, and only 30–40 ml of the nutrient solution per pot was added every 3 or 4 days. Using this frequency, the media had adequate humidity for seedling growth without water logging or leaching. The peat–perlite control was irrigated with less nutrient solution (about 20–30 ml per pot each time) to avoid water logging because peat has higher water holding capacity.

On days 26, 28, and 37, respectively, cucumber, tomato, and pepper seedlings were harvested to determine biomass (aboveground, oven dried), shoot length, stem diameter, and seedling index (seedling index = (stem diameter/shoot height) × biomass × 1000) in order to evaluate the effect of salinity on seedling growth. For determining biomass, each aboveground seedling was oven dried at 70 °C for 48 h and weighed. The shoot height was defined as the distance from medium surface to stem tip and was measured using a meter stick. The stem diameter taken below the cotyledon of each seedling was measured with a vernier caliper.

Table 1
Physical and chemical properties of sewage sludge compost, peat and a sandy loam soil, on dry base.

Parameter	Sewage sludge compost	Peat	Soil
pH	7.39	4.70	7.82
EC (dS m^{-1})	5.01	0.52	0.20
Org (%)	33.4	37.3	1.25
P (mg kg^{-1})	11.4	7.24	0.35
K (mg kg^{-1})	833.9	136	25.0
Ca (mg kg^{-1})	4080	280	135
Mg (mg kg^{-1})	728.1	55	30.8
Fe (mg kg^{-1})	0.46	0.22	1.31
Mn (mg kg^{-1})	0.35	0.13	0.04
Cu (mg kg^{-1})	0.27	0.25	0.30
Zn (mg kg^{-1})	0.21	0.17	0.15
Mo (mg kg^{-1})	0.53	0.09	0.01
Cl (mg kg^{-1})	1199	87.7	54.8
Na (mg kg^{-1})	1035	19.5	12.6

To determine the physical and chemical properties of the sewage sludge compost, an air dried sample equal to 10 g of the oven dried sample was soaked with 50 ml distilled water and surged for 4 h at room temperature. It was then filtered to allow for measuring pH, electrical conductivity (EC), and salt or nutrient content in the extract. For comparison, sandy loam soil taken from an agricultural field in Beijing and peat purchased from a flower market were tested as well.

The methods used to analyze chemical characteristics are as follows. The pH was determined using an ORION 310P-02 pH meter (Chapman and Pratt, 1961), and EC was determined using an ORION 310C-01 conductimeter (Bower and Wilcox, 1965). The P, Na, K, Ca, Mg, Fe, Mn, Cu, Zn, and Mo in the extract were diluted 10 times and determined by inductively coupled plasma optical emission spectrometer (ICP-OES), and Cl^- was determined via the precipitation titration method (Mohr's method, ISO 9297-1989). Organic matter content (Org) was determined by potassium dichromate wet digestion method (Schnitzer, 1982). Results are shown in Table 1.

2.2. Porosity

Mature compost (see Section 2.1) was leached with deionized water to reach a safe salt content of 0.30% and oven dried at 105 °C (the leaching process and the method for testing the salt content of

Table 2
Composition and porosity of growth media made from sewage sludge compost.

Treatment	Composition of growth media		Bulk density (g cm^{-3})	Total porosity (%)	Water holding porosity (%)
	Sewage sludge compost (<10 mm; g)	Grinded sewage sludge compost (<1 mm; g)			
T1	–	45.00	0.88 a	66 d	59 ab
T2	7.00	36.00	0.84 a	68 d	58 ab
T3	14.00	27.00	0.78 a	72 cd	55 ab
T4	21.00	18.00	0.76 a	74 bcd	54 ab
T5	28.00	9.00	0.63 b	78 bc	50 ab
T6	35.00	–	0.60 b	81 b	48 b
CK	Peat/perlite = 3:1 (v:v)		0.43 c	91 a	60 a

Values in each index followed by the same letter are not statistically different at $p < 0.05$ according to LSD.