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Bioresource Technology 93 (2004) 139–144
BIORESOURCE TECHNOLOGY

Effects of vermicomposts produced from food waste on the growth and yields of greenhouse peppers

Norman Q. Arancon [a,*], Clive A. Edwards [a], Rola Atiyeh [a], James D. Metzger

[a] *Soil Ecology Laboratory, The Ohio State University, 400 Aronoff Laboratory, 318 W 12th Avenue, Columbus, OH 43210, USA*

Abstract

Vermicomposts, produced commercially from food wastes, were substituted at a range of different concentrations into a soil-less commercial bedding plant container medium, Metro-Mix 360 (MM360), to evaluate their effects on the growth and yields of peppers in the greenhouse. Six-week-old peppers (*Capsicum annum* L. var. California) were transplanted into 100%, 80%, 60%, 40%, 20% or 10% MM360 substituted with 0%, 10%, 20%, 40%, 60%, 80% and 100% vermicompost. All plants were watered three times weekly with 200 ppm Peter's Nutrient Solution from the time of transplanting up to 107 days. Peppers grown in potting mixtures containing 40% food waste vermicomposts and 60% MM360 yielded 45% more fruit weights and had 17% greater mean number of fruits than those grown in MM360 only. The mean heights, numbers of buds and numbers of flowers of peppers grown in potting mixtures containing 10–80% vermicompost although greater did not differ significantly from those of peppers grown in MM360. There were no positive correlations between the increases in pepper yields, and the amounts of mineral-N and microbial biomass-N in the potting mixtures, or the concentrations of nitrogen in the shoot tissues of peppers. Factors such as: an improvement of the physical structure of the potting medium, increases in populations of beneficial microorganisms and the potential availability of plant growth-influencing-substances produced by microorganisms in vermicomposts, could have contributed to the increased pepper yields obtained.

Keywords: Food waste; Vermicomposts; Pepper; Plant growth; Yield

1. Introduction

Peppers (*Capsicum annum* L.), which belong to the family Solanaceae, are known for their versatility as a vegetable crop and are consumed both as fresh vegetables or dehydrated for spices. As with other vegetable crops, peppers are still usually grown using conventional applications of inorganic fertilizers and pesticides (Bosland and Vostava, 2000). However a growing awareness of some of the adverse economic and environmental impacts of agrochemicals in crop production, has stimulated greater interest in the utilization of organic amendments such as composts or vermicomposts for crop production (Follet et al., 1981).

The use of organic amendments, such as traditional thermophilic composts, has been used to increase crop productivity and yields (Bwamiki et al., 1998; Johnston et al., 1995; Maynard, 1993), and their use is usually associated with improved soil structure and enhanced soil fertility (Follet et al., 1981), increased soil microbial populations (Barakan et al., 1995) and activity (Zink and Allen, 1998; Pascual et al., 1997), and an improved moisture-holding capacity of the soil. Recently, there is increasing interest in the potential of vermicomposts, which are products of a non-thermophilic biodegradation of organic materials through interactions between earthworms and microorganisms, as plant growth media and soil amendments. Vermicomposts are finely divided peat-like materials with high porosity, aeration, drainage, water-holding capacity and microbial activity, which make them excellent soil amendments or conditioners (Edwards and Burrows, 1988; Atiyeh et al., 1999, 2000d; Edwards, 1998). Metro-Mix 360 is a soil-less medium prepared from vermiculite, Canadian sphagnum

* Corresponding author. Tel.: +1-614-292-5483; fax: +1-614-292-2180.
E-mail address: arancon.1@osu.edu (N.Q. Arancon).

peat moss, ash from bark and sand, and contains a starter nutrient fertilizer in its formulation. Substitution of different proportions of vermicomposts produced from cattle manure, pig manure or food wastes, into a commercial soil-less bedding plant growth medium (Metro-Mix 360), increased the rates of germination, growth, and flowering of a range of ornamental and vegetable seedlings including tomatoes, even when all necessary mineral nutrients were supplied in greenhouse experiments (Atiyeh et al., 2000a,b,c). Recent greenhouse experiments in our laboratory have demonstrated that vermicomposts contain plant growth-regulating materials, such as plant growth hormones and humic acids, which are probably responsible, at least in part, for the increased germination, growth, and yields of plants in response to vermicompost application or substitution (Atiyeh et al., 2002). The objectives of the research reported here was to assess the effects of a commercial vermicompost on the growth and yields of greenhouse peppers.

2. Methods

The experiment was conducted in a Horticulture Department greenhouse at the Ohio State University, Columbus, OH. Peppers were grown in a standard soilless commercial greenhouse container medium (Metro-Mix 360) (Scotts, Marysville, OH), with a range of concentrations of a commercially produced food waste vermicompost substituted into corresponding concentrations of Metro-Mix 360. The commercial food waste vermicompost, from Oregon Soil Corporation (Oregon City, OR), consisted of supermarket vegetable wastes, processed by earthworms (*Eisenia fetida*), in indoor automated continuous flow vermicomposting reactors (Edwards and Burrows, 1988; 2003). The basic chemical properties of Metro-Mix 360 and the food waste vermicompost are summarized in Table 1.

Six-week old pepper seedlings var. 'California' were germinated in Metro-Mix 360 (MM360), and transplanted into 30 l polystyrene pots, containing 100%, 80%, 60%, 40%, 20%, 10%, or 0% Metro-Mix 360 substituted with 0% (control/100% MM360), 20%, 40%, 60%, 80%, or 100% (by volume) of food waste vermicompost, respectively. There were seven replicate pots, each containing one pepper plant, for each MM360/vermicompost mixture. Pots were moved into a greenhouse, watered regularly with tap water and fertilized three times a week with 20–10–20 (200 ppm N) Peters Professional plant nutrient solution. This is a water-soluble fertilizer, recommended for continuous liquid feed programs of bedding plants, and contains 7.77% NH_4-N, 12.23% NO_3-N, 10% P_2O_5, 20% K_2O, 0.15% Mg, 0.02% B, 0.01% Cu, 0.1% Fe, 0.056% Mn, 0.01% Mo, and 0.0162% Zn. Heights of pepper plants were measured, and the numbers of buds and flowers counted, 21, 32, and 41 days after transplanting. Pepper fruits were harvested at the green mature stage and weighed. Fresh whole plants were harvested 107 days after transplanting, all leaves were removed from the stems, oven-dried at 60 °C for 3 days; dry shoots were weighed, ground in a ball mill and analyzed for tissue N concentration on a Carlo Erba NA 1500 C/N analyzer.

Samples of the potting mixtures (5 g) were taken from each pot (bulked for each mixture), for nitrate-nitrogen analysis, prior to transplanting and 107 days after transplanting. The nitrate-nitrogen concentrations in each of the potting mixtures were determined colorimetrically in 0.5 M K_2SO_4 extracts using a modified indophenol blue technique (Sims et al., 1995) with a Bio-Tek EL 311sx automated microplate reader (Bio-Tek® Instruments, Inc., Winooski, Vermont).

Data were analyzed statistically by one-way ANOVA in a general linear model using SAS (SAS Institute, 2001). For each sampling date and for each measured parameter, the means were separated statistically using least significant difference (LSD). Statistical significance was defined as $P \leqslant 0.05$.

3. Results

Heights of pepper plants did not differ significantly between treatments and sampling dates (Table 2). Pepper plants grown in MM360 produced most buds but the numbers of buds did not differ significantly from those in pots substituted with up to 80% of food waste vermicomposts, 21 and 41 days after transplanting (Table 2). The numbers of flowers did not differ significantly between treatments, 41 days after transplanting, although the pepper plants grown in the 80% vermi-

Table 1
Chemical properties of the commercial potting medium (Metro-Mix 360) and the vermicompost

Medium	pH	Conductivity (mmhos/cm)	Total N (%)	Organic C (%)	Total P (%)	Total K (%)
Commercial medium						
Metro-Mix 360	5.9	1.35	0.43	31.78	0.15	1.59
Vermicompost						
Food waste	7.4	16.9	1.3	19.5	2.7	9.2

Table 2
Mean heights, numbers of buds, numbers of flowers and dry shoot weights of peppers grown in (Metro-Mix 360) substituted with different concentrations of food waste vermicompost

Percentage of vermicompost in Metro-Mix 360	Height (cm) Days after transplanting			Number of buds Days after transplanting			Number of flowers Days after transplanting		Dry shoot weights Days after transplanting
	21	32	41	21	32	41	32	41	107
Control	69.4 ± 5.7a	143.0 ± 10.9a	308.1 ± 36.6a	16.4 ± 1.3a	45.4 ± 4.3a	76.3 ± 3.8a	0.4 ± 0.4ab	7.3 ± 0.9a	320.7 ± 13.4a
10	76.3 ± 6.9a	144.3 ± 14.1a	309.2 ± 26.2a	14.4 ± 1.5ab	41.6 ± 2.1a	67.3 ± 4.6ab	0.3 ± 0.2b	6.7 ± 0.8a	218.0 ± 14.8abc
20	84.5 ± 7.1a	168.6 ± 19.1a	366.6 ± 30.6a	12.9 ± 1.1b	44.0 ± 3.7a	70.1 ± 8.1ab	0.4 ± 0.2ab	8.6 ± 1.3a	281.8 ± 16.4abc
40	74.5 ± 11.8a	143.9 ± 18.7a	303.9 ± 39.2a	13.9 ± 1.2ab	35.0 ± 4.6a	66.1 ± 3.5ab	0.3 ± 0.3b	8.3 ± 0.9a	296.4 ± 11.0ab
60	70.9 ± 5.0a	132.1 ± 14.5a	299.0 ± 30.2a	13.9 ± 1.2ab	44.3 ± 4.4a	62.9 ± 8.1ab	0.7 ± 0.3ab	7.9 ± 1.5a	295.7 ± 14.6ab
80	74.2 ± 4.4a	155.3 ± 9.5a	302.4 ± 20.7a	12.4 ± 0.8b	38.7 ± 3.3a	67.6 ± 10.7ab	1.3 ± 0.6a	6.1 ± 0.9a	262.7 ± 6.9bc
100	77.8 ± 11.1a	141.4 ± 17.4a	286.6 ± 24.0a	11.6 ± 1.1b	38.3 ± 3.8a	54.9 ± 5.2b	1.1 ± 0.4ab	7.1 ± 0.8a	253.9 ± 17.7c
LSD ($\alpha = 0.05$)	22.6	43.7	86.4	3.4	10.9	19.3	0.9	3.1	39.9

Means followed by the same letters do not significantly differ ($P < 0.05$).

compost/20% MM360 had most flowers, 32 days after transplanting. Pepper plants in 0%, 10%, 20%, 40%, and 60% vermicomposts substituted with 100%, 90%, 80%, 60%, and 40% MM360 mixtures had significantly larger dry shoot weights ($P \leqslant 0.05$) than those grown in 80% and 100% vermicompost 20% and 0% MM360 mixtures.

The concentrations of mineral-N increased significantly, with increasing concentrations of vermicomposts in the mixtures, but leveled out after 107 days (Table 3). The concentrations of microbial biomass N did not differ significantly between treatments at transplanting, but growth media with a 20% vermicompost substitution had significantly more microbial biomass ($P \leqslant 0.05$) than those from the MM360 control, 107 days after transplanting (Table 3). Concentrations of total N in pepper shoot tissues were significantly greater ($P \leqslant 0.05$) in pots containing MM360 only compared to those in plants from pots substituted with more than 60% vermicomposts (Table 3).

Peppers grown in pots containing 40% vermicomposts/60% MM360 had significantly larger mean marketable fruit yields (Fig. 1a) and larger mean fruit weights (Fig. 1b) ($P \leqslant 0.05$) than those grown in pots with any other MM360/vermicomposts mixtures.

4. Discussion

A number of workers have shown that substitutions of vermicomposts into commercial growth media for bedding plants, increased plant growth and yields. Subler et al. (1998) reported significantly increased weights of tomato seedlings after substitution of 10% and 20% pig manure vermicomposts into Metro-Mix 360. Atiyeh et al. (2000a) reported that the substitution of Metro-Mix 360 with 10% or 50% pig manure vermicompost increased the dry weights of tomato seedlings significantly, compared to those grown in the 100% Metro-Mix 360 alone. However, in our current experiments the dry shoot weights of peppers grown in potting mixtures that had been substituted with 10%, 20%, 40% or 60% food waste vermicompost did not differ significantly from those of plants grown in Metro-Mix 360 only. Such non-significant effects of vermicompost on heights, numbers of buds, and numbers of flowers of peppers might have been because the pepper seedlings used in this experiment were germinated and grown in Metro-Mix 360, during their first six weeks of seedling growth, before transplanting them into the vermicompost MM360 mixtures.

The largest increase of 45% in fruit yield was from peppers grown pots with 40% vermicomposts/60% MM360 with 17% greater mean number of fruits. These results are similar to those obtained by Atiyeh et al. (2000a) who reported that lower concentrations of vermicomposts (<50%) into potting mixtures, usually

Table 3
The concentrations of mineral nitrogen, microbial biomass (Metro-Mix 360) substituted with different concentrations of food waste vermicompost at transplanting and 107 days after transplanting and organic nitrogen in shoot tissues 107 days after transplanting

Percentage vermicompost in Metro-Mix 360	Mineral N (mg/g)		Microbial biomass-N (mg/g)		Tissue-N (mg/g)
	At transplanting	107 days after transplanting	At transplanting	107 days after transplanting	107 days after transplanting
Control	153.8 ± 8.2f	215.9 ± 28.3d	66.9 ± 25.8a	82.6 ± 15.7b	53.7 ± 2.0a
10	388.7 ± 15.8e	172.8 ± 35.0bcd	85.0 ± 15.2a	93.7 ± 11.5b	50.7 ± 1.6ab
20	457.9 ± 29.8d	149.4 ± 25.7cd	69.2 ± 12.7a	167.9 ± 58.0a	50.9 ± 0.8ab
40	706.1 ± 21.7c	155.1 ± 12.3ab	116.1 ± 9.7a	66.14 ± 6.4b	49.7 ± 1.8ab
60	719.9 ± 22.4c	216.15 ± 33.7abc	111.9 ± 15.43a	62.6 ± 11.9b	48.6 ± 1.4b
80	930.4 ± 26.6b	224.72 ± 29.3ab	121.5 ± 3.5a	96.4 ± 23.5b	48.6 ± 0.8b
100	1005.9 ± 9.2a	181.2 ± 33.6a	132.2 ± 2.9a	75.4 ± 9.2b	47.9 ± 0.9b
LSD (α = 0.05)	59.7	43.1	83.3	69.72	4.1

Means followed by the same letters do not significantly differ ($P < 0.05$).

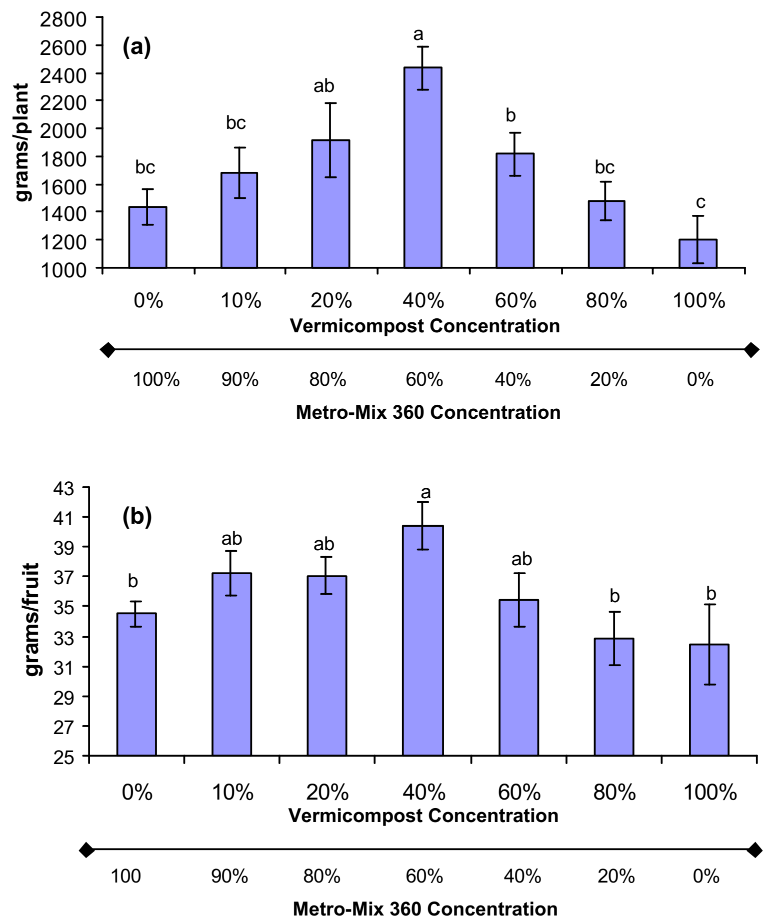

Fig. 1. Mean yields and mean fruit weights of peppers produced in standard commercial medium (Metro-Mix 360) substituted with different concentrations of food waste vermicompost. Columns followed by the same letter(s) do not differ significantly ($P < 0.05$); (a) mean marketable pepper yields, (b) mean pepper fruit weights.

produced greater tomato plant growth and yield effects than the higher concentrations. They reported that the largest marketable tomato fruit yields resulted from the substitution of 20% vermicompost into 80% Metro-Mix 360. Atiyeh et al. (2000a) also reported that tomatoes grown in vermicompost with concentrations below 50% usually produced more fruits which were classified 'large' in size. Wilson and Carlile (1989) reported increases in the growth rates, of tomatoes, lettuces, and peppers, in response to much lower substitutions of 8–10%, 8%, and 6%, respectively, of a duck waste vermicompost into 90–92%, 92%, and 94% peat mixtures.

Increases in yields of plants grown in vermicompost-substituted media, has consistently been correlated positively with increases in proportions of marketable fruits and decreased proportion of non-marketable fruits (Atiyeh et al., 2000a). In our experiment, yields of peppers were also greater due mainly to the larger fruit sizes. The proportions of marketable fruits also tended to be larger on peppers grown in potting mixtures with 40% food waste vermicomposts and 60% MM360 (Fig. 1a), compared to those of peppers grown MM360 only. However, although there was an obvious trend, the proportions of marketable and non-marketable fruits (data not shown) did not differ significantly in response to vermicompost substituted, as did the data on tomato yields reported by Atiyeh et al. (2000a).

The increased yields of peppers that we observed could be influenced by the greater availability of plant nutrients in the growth media. However, this is unlikely because in our experiment all treatments were watered regularly with complete nutrient solutions regularly, which virtually eliminated nutrients as major contributing factor in increasing yields of tomatoes or peppers. The total amounts of mineral-N and microbial biomass-N, in the growth mixtures increased significantly ($P < 0.05$) in response to increasing substitution rates of food waste vermicompost into the potting mixtures on all sampling dates (Table 3). However, increases in mineral-N, in the mixtures, were not correlated with increases in pepper yields. The concentrations of microbial biomass-N did not differ significantly between any treatment, either at transplanting or after transplanting. However, there was a significant increase in microbial biomass-N in the potting mixture substituted with 20% vermicomposts, 107 days after transplanting, but this increase was not correlated with any increase in pepper yields. Similarly, the assimilation of nitrogen into the shoot tissues of peppers was not correlated with increases in yields of peppers.

High rates of vermicompost substitution may cause adverse effects on plant growth and yield. This was obvious in Atiyeh et al. (2000a) experiments showing tomato plants with decreased growth and yields at substitution rates of pig manure vermicomposts greater than 60% into MM360. In our current experiment, yields from plants grown in pots with 60% and 80% vermicomposts decreased significantly ($P \leqslant 0.05$) which could have been due to either high soluble salt concentrations, poor aeration, heavy metal toxicity, and/or plant phytotoxicity in the undiluted vermicompost.

It is possible that other growth-enhancing factors, resulting from mixing smaller concentrations of food waste vermicompost into Metro-Mix 360 may have been responsible for the growth changes of peppers and other crops. Such factors could include improvements of the physical structure of the container medium, increases in enzymatic activities, increased numbers of beneficial microorganisms or biologically active plant growth-influencing substances, (Grappelli et al., 1987; Tomati and Galli, 1995; Subler et al., 1998; Arancon et al., in press) such as plant growth regulators and humic acids. For instance, applications of humic acids that had been extracted from vermicomposts increased the overall growth of tomatoes and cucumbers significantly (Atiyeh et al., 2002; Arancon et al., in press). It has been reported that humic fractions obtained from earthworm casts can mimic the modes of action of plant growth regulators or hormones. Applications of humic acids to soils increased the dry matter yields of corn and oat seedlings (Lee and Bartlett, 1976; Albuzio et al., 1994), numbers and lengths of tobacco roots (Mylonas and Mccants, 1980), vegetative growth of chicory plants (Valdrighi et al., 1996) and induced shoot and root formation in tropical plants. The stimulatory effects of humic acids that have been hypothesized as "direct" action, are probably more hormonal in nature, together with an "indirect action" on increased activity and metabolism of soil microorganisms, the dynamics of the uptake of soil nutrients, and soil physical conditions (Cacco and Dell' Agnola, 1984; Nardi et al., 1988; Muscolo et al., 1993, 1999). Atiyeh et al. (2002) postulated, that although plant hormones are quite transient in soil, they may become adsorbed onto the complex structure of humic acids and have acted in conjunction with them to influence plant growth. In support of this hypothesis Canellas et al. (2000) identified exchangeable auxin groups from humic acids extracted from cattle manure, following a structural analysis, which enhanced root elongation, lateral root emergence and plasma membrane H^+-ATPase activity of maize roots.

The overall effects of the applications of food waste vermicompost in this experiment, in terms of vegetative growth was not very pronounced but were significant in terms of yield increases of peppers, particularly in potting mixtures substituted with 40% food waste vermicompost. Since the contributions of nutrients from the mixtures on the growth and yield of peppers could be eliminated as a possibility, it seems likely that other plant growth-influencing materials such as humic acids and/or plant growth regulators, improvement of physical structure of potting medium and the presence of beneficial microorganisms increase the yields of peppers as recorded.

Acknowledgements

The funding that supported the research was from a USDA/NRI grant no. 2001–01332. This research was possible with the support of the staff of The Ohio State University Howlett Greenhouse especially Jim Vent and Dave Snodgrass.

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