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Effects of vermicomposts on growth and marketable fruits of field-grown tomatoes, peppers and strawberries

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Summary

Vermicomposts, produced commercially from cattle manure, market food waste and recycled paper waste, were applied to small replicated field plots planted with tomatoes (*Lycopersicon esculentum*) and bell peppers (*Capsicum anuum grossum*) at rates of 10 t ha^{-1} or 20 t ha^{-1} in 1999 and at rates of 5 t ha^{-1} or 10 t ha^{-1} in 2000. Food waste and recycled paper vermicomposts were applied at the rates of 5 t ha^{-1} or 10 t ha^{-1} in 2000 to replicated plots planted with strawberries (*Fragaria* spp.). Inorganic control plots were treated with recommended rates of fertilizers only and all of the vermicompost-treated plots were supplemented with amounts of inorganic fertilizers to equalize the initial N levels available to plants in all plots at transplanting. The marketable tomato yields in all vermicompost-treated plots were consistently greater than yields from the inorganic fertilizer-treated plots. There were significant increases in shoot weights, leaf areas and total and marketable fruit yields of pepper plants from plots treated with vermicomposts compared to those from plots treated with inorganic fertilizer only. Leaf areas, numbers of strawberry suckers, numbers of flowers, shoot weights, and total marketable strawberry yields increased significantly in plots treated with vermicompost compared to those that received inorganic fertilizers only. The improvements in plant growth and increases in fruit yields could be due partially to large increases in soil microbial biomass after vermicompost applications, leading to production of hormones or humates in the vermicomposts acting as plant-growth regulators independent of nutrient supply.

Key words: Vermicomposts, field crops, microbial biomass, humates

Introduction

Vermicomposts are products of a non-thermophilic biodegradation and stabilization of organic materials, by interactions between earthworms and microorganisms. They are finely-divided, peat-like materials, with high porosity, aeration, drainage, water-holding capacity and microbial activity which make them excellent

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soil conditioners (Edwards & Burrows 1988; Edwards 1998). Substitution of a range of vermicomposts, produced from cattle manure, pig manure, food wastes, into a commercial soil-less bedding plant growth medium (Metro-Mix 360) in greenhouse experiments, increased the rates of germination, growth and yields of ornamentals, tomatoes and peppers even when all necessary mineral nutrients were supplied (Atiyeh et al. 2000 a,b, 2001, 2002). Recently, our laboratory and greenhouse experiments have shown that vermicomposts contain plant growth regulating materials such as humic acids and plant growth hormones which may be responsible in part for the increased germination, growth and yield of plants (Atiyeh et al. 2002). Moreover, our experiments have demonstrated that vermicomposts can suppress *Pythium*, *Rhizoctonia* and *Verticillium* plant diseases (Chaoui et al. 2002) and plant parasitic nematodes (Arancon et al. 2002). However, experimental investigations into the effects of vermicompost applications on field crop production, have been very few. Our main objective was to investigate the effects of different rates of vermicompost applications on the growth and yield of tomatoes, peppers and strawberries in the field.

Materials and Methods

Experimental Treatments

The tomato, pepper and strawberry field experiments were at South Research Centers, Piketon, Ohio on a soil type of a DoA- Dole Silt Loam. Commercially produced vermicomposts from dairy cow manure, supermarket food wastes and recycled paper wastes were applied at rates of 10 or 20 t ha^{-1} (d.w.) to tomatoes and peppers. Food waste and paper waste-based vermicomposts were applied at 5 or 10 t ha^{-1} (d.w.) to strawberries and grapes. One replicate set of plots received full recommended rates of inorganic fertilizer: 130–95–95 kg NPK ha^{-1} for peppers; 80–75–75 kg NPK ha^{-1} for tomatoes; and 85–155–125 kg NPK ha^{-1} for strawberries. Seventy-five percent of the nitrogen was applied as pre-plant fertilizers and the rest were applied after a month. A second set of plots received recommended rates of thermophilic leaf composts only in the tomato and pepper experiments. All vermicompost- and compost-treated plots were supplemented with inorganic fertilizers, to balance the initial available N supply with that in the inorganic fertilizer. Nutrient contents of vermicomposts are summarized in Table 1. Vermicomposts, composts and inorganic fertilizers were incorporated into the top 15 cm of the tomato, pepper and strawberry plots with a roto-tiller. Twelve 4-week-old tomato seedlings (var. BHN 543 F1) were transplanted into each bed measuring 1.5 × 5.5 m (8.25 m^2 per plot) with 38 cm between plants. Guard rows measuring 1.5 × 5.5 m (8.25 m^2 per plot) were set between each block. Plastic mulch and drip irrigation systems were constructed over beds after vermicompost and fertilizer applications. All treatments were replicated four times in a randomized complete block design.

Twenty-four 4-week-old pepper seedlings (var. 'King Arthur') were transplanted into two rows in each raised 1.5 × 5.5 m (8.25 m^2) bed. Guard rows measuring 1.5 × 5.5 m (8.25 m^2 per plot) were set between each block. Seedlings were planted in a staggered pattern relative to plants in the other row spaced 38 cm between plants and 38 cm between rows. Treatments were replicated four times in a randomized complete block design.

Twenty-four 4-week-old strawberry seedlings (var. 'Chandler') were transplanted into plots (4.5 m^2) spaced 38 cm between plants with three rows spaced 38 cm between rows, under a high plastic tunnel hoop house (9.14 × 14.6 × 3.6 m). Plants in the middle row were planted in a staggered design with respect to the outer rows to maximize distances between plants. Treatments were replicated four times in a completely randomized design. There were guard rows (1.5 wide × 12 m) around the perimeter of the experiment.

Plant sampling

Whole plant samples were harvested for assessment of leaf area, shoot dry weights, numbers of suckers and numbers of flowers. Leaves were removed from each sample plant and passed through a portable leaf area measuring machine (LI 3100, LI-COR Inc., Lincoln, Nebraska, USA). All leaves and stems of plants were weighed to determine fresh shoot weights, placed into

Table 1. Composition of nutrient elements of vermicomposts

Vermicomposts/ Composts Used	N gkg^{-1}	P gkg^{-1}	K gkg^{-1}	B gkg^{-1}	Ca gkg^{-1}	Fe gkg^{-1}	Mg gkg^{-1}	Mn gkg^{-1}	Na gkg^{-1}	S gkg^{-1}	Zn gkg^{-1}
Food Waste	13	2.7	9.2	23.3	18.6	23.3	4.3	0.6	0.8	2.6	0.2
Cow Manure	19	4.7	14.0	57.7	23.2	34.5	5.8	0.1	3.3	5.5	0.5
Paper Waste	10	1.4	6.2	31.4	9.2	17.8	7.6	0.4	0.6	1.9	0.1

paper bags, oven-dried at 60 °C for 92 hours and weighed again for dry shoot weights. Fruits were harvested and graded as marketable and non-marketable and weighed for yields. Fruits were classified as non-marketable when signs of rots, insect feedings and malformations were present on the fruit surface.

Soil sampling and analyses

Eight 2.5 cm diameter × 20 cm deep soil samples were taken with a corer from the plant root zones in each plot. Moist soil samples were passed through a 2 mm-sieve and stored at 4 °C until chemical analyses. Extractable N (NO_3-N and NH_4-N) was determined using a modified indophenol blue technique (Sims et al. 1995). Five-gram soil samples were extracted with 0.5M K_2SO_4 for 1 h and filtered through Whatman no. 42 filter paper. Filtrates were collected and stored into scintillation vials. NO_3-N and NH_4-N were determined by color development after adding citrate, salicylate and hypochlorite reagents to the samples. Absorbance was measured in a Bio-Tek EL211sx automated microplate reader. Soluble phosphorus was assessed using NH_4-HCl reagent. Microbial biomass nitrogen was measured in chloroform-fumigated soil samples (Brookes et al. 1985) which were extracted and digested using potassium sulfate and potassium persulfate. Nitrate-N was measured colorimetrically in a modified indophenol blue technique (Sims et al. 1995) with a Bio-Tek EL211sx automated microplate reader.

Statistical analyses

Data were analyzed using one-way ANOVA. The means of parameters measured were grouped for comparisons and differences were separated by orthogonal contrasts with single degree of freedom using SAS (SAS Inc., 1990).

Results and Discussion

The amounts of total extractable N, orthophosphates, dehydrogenase enzyme activity, and the microbial biomass were usually greater ($P \leq 0.05$) in the soils from the vermicompost-treated tomato plots on certain sampling dates (Fig. 1a). Tomato shoot dry weights increased significantly ($P \leq 0.05$) in vermicompost-treated plots over those in tomato plants treated with inorganic fertilizers only (Fig. 1b). Marketable tomato yields in vermicompost-treated plots were consistently greater, but not statistically different from yields in inorganic fertilizer-treated plots (Fig. 1c).

There was significantly more microbial biomass N, ($P \leq 0.05$; Fig. 2a) and orthophosphates in soils from pepper plots treated with vermicomposts than in those from the inorganic fertilizer-treated plots. There were significant increases ($P \leq 0.05$) in pepper shoot dry weights (Fig. 2b), leaf areas and marketable fruit yields (Fig. 2c) in plots treated with vermicomposts, compared to those from the inorganic fertilizer-treated plants. There were no significant differences in pepper yields between the vermicompost application rates of 5 t ha^{-1} or 10 t ha^{-1}.

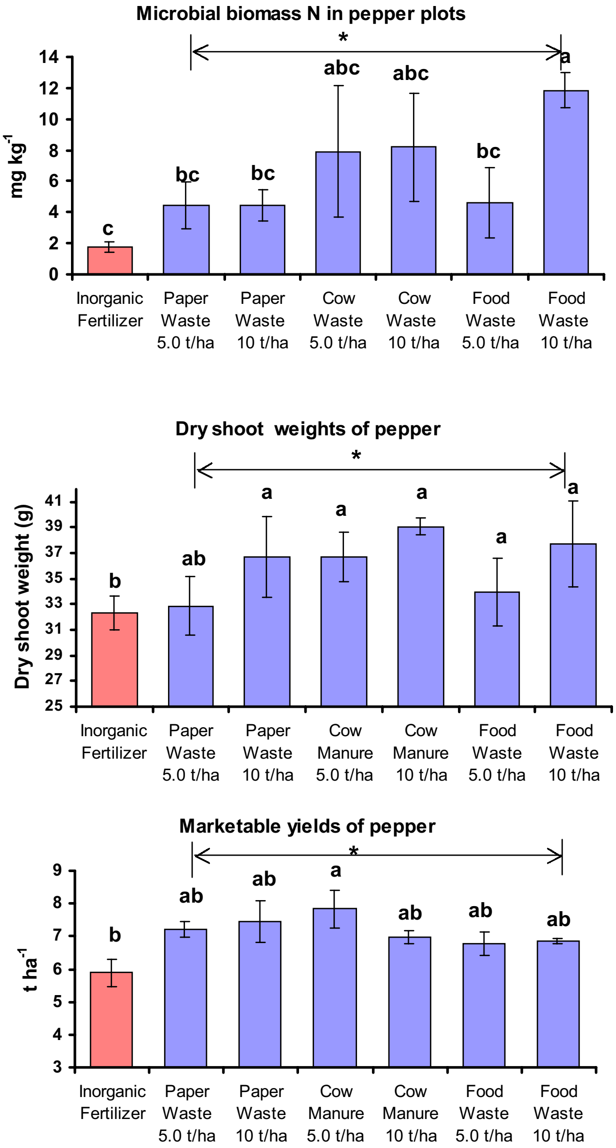

Fig. 1. Effects of vermicomposts produced from cattle manure, food waste and paper wastes on (a) microbial biomass N, (b) shoot dry weights and (c) marketable yields of tomatoes in soils planted with tomatoes (Means ± SE). Grouped means designated by an inclusion line and an asterisk (*) are significantly different from control (inorganic fertilizer) by orthogonal contrast at $P < 0.05$

The total extractable N, or microbial biomass N did not differ statistically ($P \leq 0.05$) between treatments at the end of the strawberries growth cycle (Fig. 3a). There were more orthophosphates ($P \leq 0.05$) in those soils with vermicompost treatments than in those from the inorganic control plots. Strawberries leaf areas, numbers of suckers, numbers of flowers, shoot dry weights (Fig. 3b), and marketable fruit yields (Fig. 3c) were all significantly greater ($P \leq 0.05$) in plots that received vermicompost treatments than in those that received inorganic fertilizers only. Food waste vermicomposts had greater effects on growth and yields of strawberries ($P \leq 0.05$) than paper waste vermicomposts.

The improvements in plant growth and increases in yields could not be explained by the availability of macronutrients, because all vermicompost treatments were supplemented with inorganic fertilizers, to equalize macronutrient availability at transplanting time. Some of the increases in growth may have been due to increases in microbial biomass in soils receiving vermi-

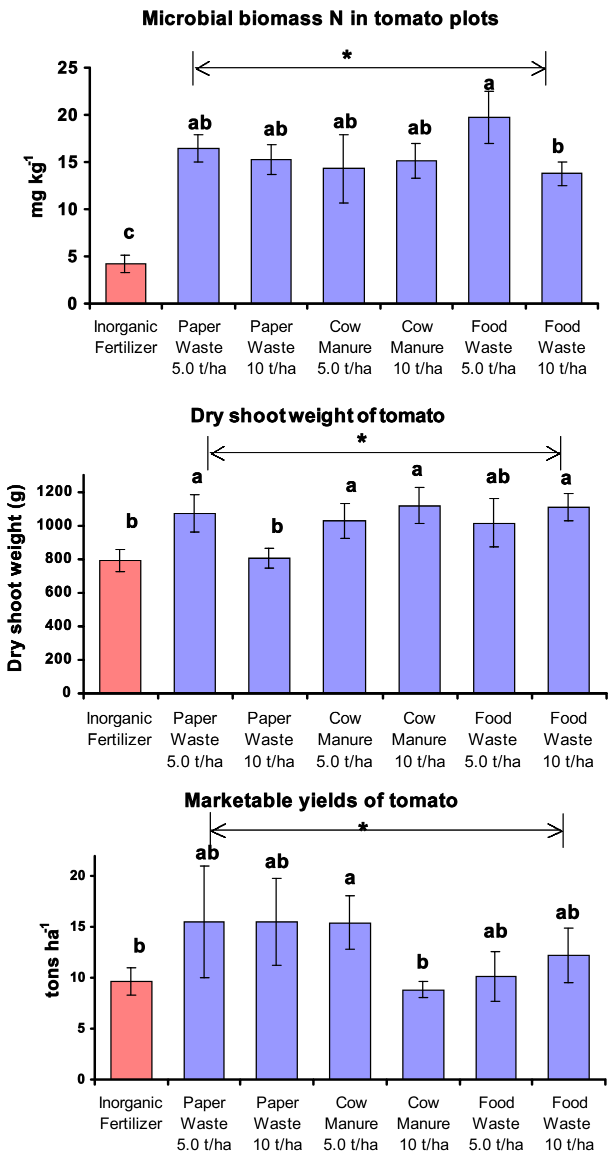

Fig. 2. Effects of vermicomposts produced from cattle manure, food waste and paper wastes on (a) microbial biomass, (b) shoot dry weights and (c) marketable yields of peppers in soils planted with peppers (Means ± SE). Grouped means designated by an inclusion line and an asterisk (*) are significantly different from control (inorganic fertilizer) by orthogonal contrast at $P < 0.05$

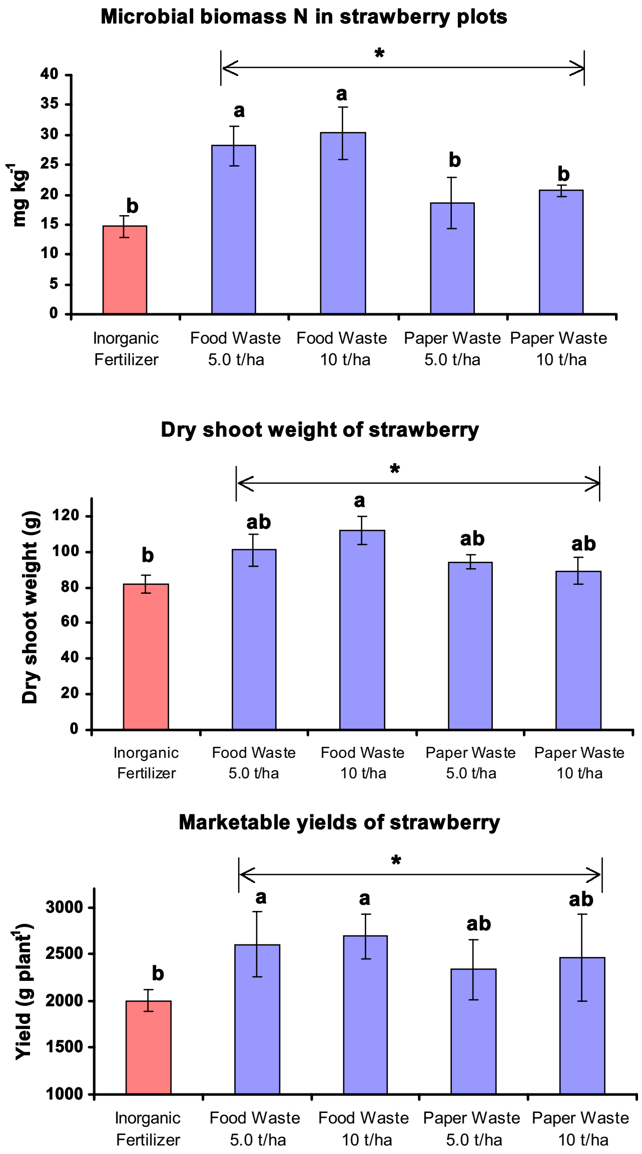

Fig. 3. Effects of vermicomposts produced from cattle manure, food waste and paper wastes on (a) microbial biomass, (b) shoot dry weights and (c) marketable yields of strawberries in soils planted with strawberries (Means ± SE). Grouped means designated by an inclusion line and an asterisk (*) are significantly different from control (inorganic fertilizer) by orthogonal contrast at $P < 0.05$

composts which increased nutrient mineralization. Moreover, increases in microbial biomass could have enhanced microbial competition which suppressed plant parasitic nematodes (Arancon et al. 2002) and plant diseases (Chaoui et al. 2002). Based on other research in our laboratory (Atiyeh et al. 2002) we conclude that the increases in growth and yields were more probably due to the production of plant growth regulators by microorganisms or to the effects of humates (Canellas et al. 2000) in the vermicomposts since we have clear evidence from greenhouse trials that these can produce significant growth effects independent of nutrients.

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