Journal of Plant Nutrition
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597277

Fruit Characteristics of Bell Pepper Cultivated in Sheep Manure Vermicompost Substituted Soil

María Angela Oliva Llaven [a]; Jose Luis Guzman Jimenez [b]; Blanca Irene Cabrera Coro [b]; Reiner Rincón-Rosales [b]; Joaquín Montes Molina [b]; Luc Dendooven [c]; Federico A. Gutiérrez-Miceli [b]
[a] Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Chiapas, Chiapas, México [b] Instituto Tecnológico de Tuxtla Gutiérrez, Chiapas, México [c] Cinvestav, Dept. Biotechnology and Bioengineering, Av. Instituto Politécnico Nacional, México City, México

Online Publication Date: 01 September 2008

To cite this Article Llaven, María Angela Oliva, Jimenez, Jose Luis Guzman, Coro, Blanca Irene Cabrera, Rincón-Rosales, Reiner, Molina, Joaquín Montes, Dendooven, Luc and Gutiérrez-Miceli, Federico A.(2008)'Fruit Characteristics of Bell Pepper Cultivated in Sheep Manure Vermicompost Substituted Soil',Journal of Plant Nutrition,31:9,1585 — 1598

To link to this Article: DOI: 10.1080/01904160802244738

URL: http://dx.doi.org/10.1080/01904160802244738

Journal of Plant Nutrition, 31: 1585–1598, 2008

ISSN: 0190-4167 print / 1532-4087 online
DOI: 10.1080/01904160802244738

Fruit Characteristics of Bell Pepper Cultivated in Sheep Manure Vermicompost Substituted Soil

María Angela Oliva Llaven,[1] Jose Luis Guzman Jimenez,[2] Blanca Irene Cabrera Coro,[2] Reiner Rincón-Rosales,[2] Joaquín Montes Molina,[2] Luc Dendooven,[3] and Federico A. Gutiérrez-Miceli[2]

[1]Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Chiapas, Chiapas, México
[2]Instituto Tecnológico de Tuxtla Gutiérrez, Chiapas, México
[3]Cinvestav, Dept. Biotechnology and Bioengineering, Av. Instituto Politécnico Nacional México City, México

ABSTRACT

The effects of earthworm-processed sheep manure (vermicompost) on growth, productivity, and characteristics of bell pepper fruits (*Capsicum annum*) (cv 'Ancho supremo') were investigated in a greenhouse experiment. Six treatments were applied combining vermicompost and soil in 0:1, 1:1, 1:2, 1:3, 1:4, and 1:5 (v/v) ratios. Plant characteristics were measured 21 and 90 days after transplanting. Addition of vermicompost increased plant size significantly with 8 cm in the 1:3 vermicompost: soil treatment compared to the unamended soil after 21 days, but no significant differences were found after 90 days. Seven more flowers were found in the 1:2 vermicompost: soil treatment and four in the 1:3 vermicompost: soil treatment compared to the unamended soil after 90 days. The number of marketable fruits per plant was significantly 1.5 and 1.9 times greater in the 1:2 and 1:3 vermicompost: soil treatments compared to plants cultivated in unamended soil after 90 days. The addition of vermicompost to soil increased soluble solids in pepper fruits > 2 Brix compared to fruits from plants cultivated in unamended soil while their pH was significantly lower. The nitrogen (N) content of the pepper fruits was significantly higher in the 1:4 vermicompost: soil mixture compared to the other treatments, whereas the fruits obtained from plants cultivated in the 1:3 and 1:4 vermicompost: soil treatments had higher titratable acidity values than in those from other treatments. It was found that amounts and characteristics of pepper fruits from plants cultivated in soil

Received 2 June 2006; accepted 16 March 2007.
Address correspondence to Luc Dendooven, Cinvestav, Department of Biotechnology and Bioengineering, Av. Instituto Politécnico Nacional 2508, C.P. 07360 México D. F., México. E-mail: dendoove@cinvestav.mx

supplemented with vermicompost were generally better than those from plants grown in soil only.

Keywords: chemical composition; soil supplement

INTRODUCTION

Peppers (*Capsicum annum* L) belong to the family Solanaceae and there are many varieties that form part of the Mexican diet. Bell pepper cultivars are consumed as fresh vegetables, dehydrated for spices and from some cultivars ascorbic acid and provitamin A are obtained (Simonne et al., 1997). The vegetable needs good light conditions, temperatures, high humidity, and minerals for cultivation (Maroto, 1989).

Large amounts of organic wastes, such as biosolids, animal manures, and household wastes, are produced in Mexico. These organic wastes could easily be used in horticulture, the production of vegetables, in agriculture or to restore soil fertility (Krogman et al., 1997; Benton and Wester, 1998). They have a large nutrient value, mainly as nitrogen (N), phosphorous (P), and potassium (K) (Elliot and Dempsey, 1991). However, organic wastes in Mexico often contain pathogens so they are incinerated or dumped in landfills (Franco-Hernández et al., 2003), which can cause air-pollution and contaminate surface and ground water (Cardoso and Ramírez, 2002).

Thermophilic composting is a biological aerobic decomposition of organic residues in which labile organic matter is degraded to carbon dioxide (CO_2), H_2O, ammonia (NH_3), inorganic nutrients, and stable organic material containing humic-like substances is formed (Senesi, 1989). Compost is homogenous, retains most of the original nutrients, and has reduced amounts of pathogens and organic contaminants with respect to the starting material (Ndegwa et al., 2000). However, thermophilic composting is generally a time-consuming process, which requires frequent mixing with possible losses of nutrients, i.e., NH_3. There is increasing interest to vermicompost organic wastes. Vermicompost is the product of a non-thermophilic biodegradation of organic materials through interactions between earthworms and microorganisms (Arancon et al., 2004). Certain species of earthworms fragment organic material residuals rapidly into much finer particles by passing them through a grinding gizzard (Ndegwa and Thompson, 2001). Additionally, earthworms reduce numbers of human pathogens, an effect obtained in traditional composting by increases in temperature (Contreras-Ramos et al., 2004), but vermicomposting is generally faster.

There is a growing tendency to use vermicompost in the production of diverse vegetables (Atiyeh et al., 1999; Arancon et al., 2004). Vermicomposting is increasingly being applied to organic wastes in Mexico, but little is known how this product could be used in agriculture practices and how it might affect plant growth and fruit characteristics. Therefore, we investigated how supplementing soil with vermicomposted sheep manure affected growth of bell pepper plants, soluble and insoluble solids, and carbohydrate concentration in the fruit and yield characteristics in a greenhouse experiment. The objective of the study was to investigate the effect of different application rates of sheep manure derived vermicompost on characteristics of pepper plants and their fruits.

MATERIALS AND METHODS

Raw Materials and Treatments

Sheep manure was composted thermophilically for two months while mechanically turning it over every 15 days. The composted sheep manure, adjusted to 80% moisture content, was placed in indoor beds. Earthworms (*Eisenia fetida*) were added (25 g earthworms kg^{-1} of sheep manure or 2.5 kg earthworms m^{-2} for bed) and left to vermicompost for two months. The obtained vermicompost was then characterized.

Six vermicompost: soil mixtures with ratios of 0:1, 1:1, 1:2, 1:3, 1:4, and 1:5 were prepared (Table 1). The 0:1 vermicompost: soil mixture served as control. The soil used in this experiment was classified as a well-drained calcareous silt loam with total nitrogen (N) content 3.1 g kg^{-1} and concentrations of 35.4 mg nitrate (NO_3^-)-N kg^{-1} and 2.50 mg ammonium (NH_4^+)-N kg^{-1}.

Table 1
Chemical characteristics of different mixture in which soil was substituted with different amounts of sheep manure vermicompost.

Treatment (vermicompost:soil)	pH	WHC[a] ($g\ kg^{-1}$)	Organic C ($g\ kg^{-1}$)	EC[b] ($dS\ m^{-1}$)
1:0	8.6 A[c]	723 A	233 A	2.8 A
1:1	8.3 A	709 A	180 B	2.2 B
1:2	8.4 A	667 B	167 C	2.0 BC
1:3	8.4 A	634 BC	145 D	1.8 CD
1:4	8.3 A	646 B	138 D	1.8 CD
1:5	8.4 A	602 C	128 E	1.6 D
0:1	8.4 A	501 D	124 E	1.3 E
LSD ($P<0.05$)[d]	0.3	41	7	0.2

[a]WHC: Water holding capacity.
[b]EC: Electrolytic conductivity.
[c]Values with a different letter are significantly different ($P < 0.05$).
[d]LSD: Least Significant Difference ($P < 0.05$).

Chemical, Biological, and Physical Characterization of the Soil: Vermicompost Mixtures

The water holding capacity (WHC) of the vermicompost: soil mixtures were determined by adding nine 100 g sub-samples from each of the mixtures to PVC-columns fitted with fine mesh cloth at the bottom. The samples were water logged for 48 h and allowed to drain. The samples were weighed before and after drying in an oven at 60°C for four days (Atiyeh et al., 2001). The water holding capacity (WHC) (% volume) was calculated as: [(wet weight – dry weight)/volume] × 100 (Inbar et al., 1993).

The germination index for cress (*Lepidium sativum*) was determined by placing a layer of vermicompost in a Petri dish and covering it with a filter paper. Water was added until the filter paper was completely submerged and seeds of cress were placed on the filter paper. The number of seeds germinating was measured after incubating the covered Petri dishes in the dark at 28°C for 4 days (Mathur et al., 1993a; 1993b).

The pH was measured in 1:2.5 (v/v) soil-H_2O suspension of each of the soil:vermicompost mixtures (n = 9) using a 716 DMS Titrino pH meter (Metrohm Ltd.CH.-9101 Herisau, Switzerland) fitted with a glass electrode (Thomas, 1996). Total carbon (C) was determined by oxidation with potassium dichromate and titration of excess dichromate with ammonium ferrosulfate (Kalembasa and Jenkinson, 1973). Total N was measured by the Kjeldhal method using concentrated sulfuric acid (H_2SO_4), potassium sulfate (K_2SO_4), and mercury oxide (HgO) to digest the sample (Bremner, 1996) and soil particle size distribution by the hydrometer method as described by Gee and Bauder (1986). The concentration of NH_4^+ was determined by distillation with magnesium oxide (MgO) (Bremner and Keeney, 1966) and nitrite (NO_2^-) and NO_3^- colorimetrically (APHA AWWA WPCF, 1989).

Cation exchange capacity (CEC) was measured with the barium acetate method (pH 8.1) (Sumner and Miller, 1996). Production of CO_2 was determined over a four-day period (Bartha and Pramer, 1965) by trapping evolved CO_2 in 1M sodium hydroxide (NaOH) and determining the residual NaOH by titration with 0.1 M hydrochloric acid (HCl) (Jenkinson and Powlson, 1976). Electrolytic conductivity (EC) was determined in the effluent and in a saturated solution extract of the vermicompost (Rhoades et al., 1989).

A dry sub-sample of 1 g was treated with 20 mL 0.1 M NaOH (1:20 w/v), shaken for 4 h, centrifuged at 8000 × g for 15 min, and the supernatants divided into two equal parts. An aliquot of supernatant was analyzed for oxidizable total C and this part was considered as the total extractable C (EXC); the other aliquot was adjusted to pH 2 by adding 95% H_2SO_4, incubated at 4°C for 24 h and then centrifuged at 8000 × g for 15 min. The supernatant was considered the fulvic (FA) fraction and the coagulated precipitate the humic (HA) fraction. The former was analyzed for total C subtracted from the C content of EXC fraction to calculate the C content of the HA fraction (García et al., 1993; Sánchez-Monedero et al., 1996).

The sheep manure and sheep manure vermicompost were analyzed for total and fecal coliforms (*Escherichia coli, Salmonella sp*., and *Shigella spp*.) (Appendix F, G, I; USEPA, 1999). *Salmonella* and *Shigella* were determined by serial dilution. A sub-sample of 10 g biosolid was added to 90 mL 1% peptone solution under sterile conditions and 10^{-1}, 10^{-2}, and 10^{-3} dilutions were made with sterile 0.8% sodium chloride (NaCl) solution. A 100 μL aliquot was plated on two selective media *Salmonella*-*Shigella* agar and sulfite-bismuth agar. The second medium is highly specific for *Salmonella*. The colonies were identified by form and color (Appendix G; USEPA, 1999). For the measurement of total and fecal coliforms (*E. coli*), a 100 μL aliquot of each serial dilution was incubated in lactose broth at 35°C for 24 h and total coliforms were counted. The fecal coliforms were differentiated from the rest of the coliforms by incubating a 100 μL aliquot of each serial dilution in E. coli medium at 44°C. Gas production in each assay was considered as positive after 48 h. Results were confirmed by plating on eosin methylene blue (EMB) agar, incubating for 24 h, and examining for typical coliform colonies (Appendix F, G, I; USEPA, 1999).

Cultivation of Pepper Plants and Growth Parameters

Pepper seeds (*C. annum* cv. 'Ancho supremo') were sown in plastic pots (7.5 cm diameter, three per pot), each containing 50 g Canadian sphagnum peat moss potting material. After sowing, the pots were placed in a greenhouse until the seeds germinated. The 180 pepper plantlets were transplanted to cylindrical black plastic bags (length 35 cm, diameter 25 cm, one plantlet per bag) filled with the different vermicompost: soil mixtures. Six treatments with different mixtures of vermicompost and soil were used (Table 1). Plants were grown under black knitted shade cloth (60%) without temperature control and grouped in plots 7 m long and 2.1 m wide each containing 30 plants spaced at a distance of 70 cm. The plots were separated 1.8 m from each other. The center eight plants were analyzed for growth and sampled for fruits to determine yields. The plots were arranged in a randomized complete block design in triplicate. All treatments were drip irrigated with tap water ranging from 1 to 2 dm^3 per plant per day depending of soil conditions and crop maturity.

Height and stem diameter of pepper plants were measured and the numbers of leaves and flowers counted 21 and 90 days after transplanting. After 90 days, pepper fruits were harvested at the green mature stage and weighed (Arancon et al., 2004). Fruits were separated into marketable and non-marketable (cracked, damaged, and infected) and only marketable ones were used to calculate yields (Atiyeh et al., 1999).

The results reported here were the mean of measurements of eight plants in triplicate at day 21 and/or day 90.

Chemical Analyses of Pepper Fruits

All marketable pepper fruits from each treatment were cut into small slices and pooled. A 10 g sub-sample was pressed through cheese cloth to extract the juice, which was analyzed for pH, soluble solids and titratable acidity. A 5 mL pepper juice aliquot was added to 100 mL distilled water and pH was measured. The soluble solids were determined on a portable refractometer 300003 (Sper Scientific Ltd., Scottsdale, Arizona, USA) standardized with distilled water. The titratable acidity was determined by adding a 5 mL pepper juice aliquot to 100 mL distilled water and adjusting pH to 8.2 using 0.1 N NaOH. Acidity was expressed as mg citric acid 100 mL^{-1} juice (Wang and Lin, 2002). Total N was determined in 0.1 g (dry weight) sub-samples by the Kjeldhal method using concentrated H_2SO_4, K_2SO_4, and HgO to digest the sample.

Statistical Analyses

Pepper growth, yield data, and pepper fruit characteristics were subjected to a one-way analysis of variance to test for significant difference between the treatments using PROC GLM (SAS statistical package, SAS Institute, 1989).

RESULTS AND DISCUSSION

Characteristics of Vermicompost and Planting Media

The pH of the sheep-manure vermicompost was 8.6 and greater than values reported for vermicompost derived from other organic sources (Table 1). Vermicompost derived from cattle manure had pH 6.0 (Jordao et al., 2002) and 6.7 (Alves et al., 2001), whereas that derived from pig manure had pH 5.3 (Atiyeh et al., 2002a) and 5.7 (Atiyeh et al., 2001). Vermicompost derived from sewage sludge had pH 7.2 (Masciandaro et al., 2000). These differences in pH are presumably related to difference in the raw material used for vermicomposting (Alves et al., 2001).

The vermicompost had an organic C content of 233 g kg^{-1}, an electrical conductivity (EC) of 8 mS cm^{-1}, a 1.7 humic-to-fulvic acid ratio (HA/FA), total N content 11.8 g kg^{-1}, cation exchange capacity 43 $cmol_c$ kg^{-1}, a respiration rate of 152 mg CO_2-C kg^{-1} compost-C day^{-1}, a NO_3^- content of 234 mg N kg^{-1} , a NO_2^- content of 2.17 mg N kg^{-1}, and a NH_4^+content of 9.14 mg N kg^{-1}. The vermicompost gave a germination index for cress (*L. sativum*) of 95%.

Concentrations of NH_4^+ and NO_2^- were low whereas NO_3^- concentrations were high indicating that ammonification and nitrification were not inhibited. These values also indicated that stable compost was obtained, because NH_4^+ concentration has to be lower than 0.04% in mature compost (Bernal et al., 1998). In addition, the NH_4^+/NO_3^- ratio of the vermicompost was 0.04 and lower than the 0.16 recommended for mature compost (Bernal et al., 1998).

The sheep manure had large amounts of *Escherichia coli* (9.5×10^{7} CFU kg^{-1} dry manure), *Salmonella* plus *Shigella* (2.3×10^{7} CFU kg^{-1} dry manure), and total coliforms (7.6×10^{8} CFU kg^{-1} dry manure). After 60 days of vermicomposting, no *E. coli*, *Shigella, Salmonella*, or total coliforms were detectable. Similar results were reported for vermicomposting of biosolids supplemented with cow manure and oat straw (Contreras-Ramos et al., 2004). The reduction of the number of the human pathogens might be related to the activity of the haemolytic system from earthworms, which has antibacterial properties and has been reported to kill pathogens (Pierre et al., 1982).

Addition of sheep manure vermicompost to soil did not change the pH of the mixtures (Table 1). Atiyeh et al. (2001), however, reported that addition of pig manure vermicompost with pH 5.7 to Metro-Mix 360 progressively decreased pH with increased application rates of vermicompost. The stability of the pH in our mixtures could be due to the buffer capacity of the soil used (Goh and Haynes, 1977) and more importantly the pH values of vermicompost and soil were similar, 8.6 and 8.4.

The WHC of sheep manure vermicompost was similar to that of pig manure vermicompost (Atiyeh et al., 2001). The WHC of the vermicompost-soil mixtures increased with increased application of vermicompost and was significantly greater than in the unamended soil. The WHC in the 1:1 mixture was 1.4-times greater than in the control soil. These differences could be related to a higher proportion of hydrophilic/hydrophobic groups of the humic substances in the sheep manure vermicompost compared to those found in soil (Jordao et al., 2002).

Total C in the vermicompost was 233 g kg^{-1} dry matter (Table 1). This was lower than the 310 g kg^{-1} dry matter reported elsewhere for sewage sludge vermicompost (Masciandaro et al., 2000) and the 273.8 g kg^{-1} for pig manure vermicompost (Atiyeh et al., 2001), although it was greater than 199 g kg^{-1} reported for compost of sewage sludge (Masciandaro et al., 2002).

The EC of the vermicompost was only 2.8 dS m^{-1}(Table 1) and lower than values generally reported. Masciandaro et al. (2000) reported an EC of 4.7 dS m^{-1} for vermicompost derived from sewage sludge and Atiyeh et al. (2001) a value of 3.2 dS m^{-1} for pig manure vermicompost. The EC of the vermicompost depends on the raw materials used for vermicomposting and is related to their ion concentration (Atiyeh et al., 2002b). The EC in vermicompost: soil mixtures were significantly greater than in the unamended soil and increased with increasing application rates of vermicompost. Atiyeh et al. (2001) reported the same for pig manure-vermicompost substituted into Metro-Mix 360.

Growth and Yield Parameters

The addition of vermicompost increased plant sizes significantly in the 1:3 vermicompost: soil mixture after 21 days, but not after 90 days ($P < 0.05$)

(Tables 2 and 3). After 21 days, plants were 6 cm taller in the 1:3 vermicompost: soil treatment compared to the other mixtures and 8 cm compared to the unamended soil. The stems were 0.2 cm thicker in the 1:3 vermicompost: soil treatment compared to the other treatments. After 90 days, plants were 0.23 cm thicker in the 1:3 vermicompost: soil treatment compared to the control treatment.

Arancon et al. (2004) reported that height of pepper plants var. California did not differ significantly when cultivated in potting mixtures containing 100%, 80%, 60%, 40%, 20%, 10%, or 0% Metro-Mix 360 substituted with 0%, 20%, 40%, 60%, 80%, or 100% (by volume) of food waste vermicompost 21 and 41 days after transplanting. The differences between the results in this study and the ones reported by Arancon et al. (2004) might be due to the pepper variety (Martínez et al., 1999) and/or the composition and nutritional value of the vermicompost. Arancon et al. (2005) reported that soils amended with cattle manure vermicompost at a rate of 10000 kg ha^{-1}, produced pepper plants with significantly larger shoot dry weights than those in soils treated with inorganic fertilizers. However, they did not find differences between food waste vermicompost, cow manure vermicompost, paper waste vermicompost, biosolids vermicompost, and yard waste compost.

The number of leaves and flowers was not affected by addition of vermicompost compared to the unamended soil after 21 days (Table 2). However after 90 days, the pepper plants grown in the 1:1, 1:2, and 1:3 vermicompost: soil mixtures produced more flowers compared to the other treatments with most found in the 1:3 treatment, i.e., seven more flowers compared to the unamended soil (Table 3). Arancon et al. (2004) found no significant effect on the number of flowers in pepper plants cv 'California 41' days after transplanting.

Table 2
Growth characteristics of bell pepper (*Capsicum annum*) cv. 'Ancho supremo' plants cultivated in different mixtures of soil and sheep manure vermicompost obtained 21 days after transplanting.

Treatment (vermicompost:soil)	Plant height	Stem diameter (cm)	Number of leaves	Number of flowers
1:1	39 B[a]	0.6 B	48 A	14 A
1:2	39 B	0.6 B	48 A	14 A
1:3	45 A	0.8 A	40 AB	9 B
1:4	39 B	0.6 B	35 B	11 AB
1:5	39 B	0.6 B	38 AB	11 AB
0:1	37 B	0.6 B	40 AB	12 AB
LSD ($P<0.05$)[b]	4	0.1	10	3

[a]Values with a different letter are significantly different ($P < 0.05$).
[b]LSD : Least significant difference at $P < 0.05$.

Table 3
Growth characteristics of bell pepper (*Capsicum annum*) cv. 'Ancho supremo' plants cultivated in different mixtures of soil and sheep manure vermicompost obtained 90 days after transplanting

Treatment (vermicompost:soil)	Plant height (cm)	Stem diameter (cm)	Number of flowers	Number of fruits
1:1	64 A[a]	0.8 B	2.5 C	2.5 DE
1:2	69 A	0.8 B	5.8 B	4.6 B
1:3	71 A	1.1 A	9.3 A	5.7 A
1:4	67 A	0.8 B	2.0 C	2.3 E
1:5	65 A	0.8 B	2.0 C	3.2 C
0:1	65 A	0.9 B	2.0 C	3.0 CD
LSD ($P<0.05$)[b]	7	0.1	0.5	0.5

[a]Values with a different letter are significantly different ($P<0.05$).
[b]LSD: Least significant difference at $P<0.05$.

However, 32 days after transplanting, the pepper plants grown in the 80% vermicompost/20% Metro Mix 360 had more flowers than those cultivated in 100% Metro Mix 360.

The number of fruits was significantly larger in the 1:2 and 1:3 vermicompost: soil treatment compared to the unamended soil after 90 days (Table 3). Arancon et al. (2005) reported positive effects of vermicompost on the yield of peppers in field experiments and attributed this partly to an increased microbial biomass and activity, and the addition of macronutrients such as phosphorus. However, they suggested that the major contribution might have been the addition of plant growth regulators, such as humic acids and plant growth hormones adsorbed onto the humic acids. Plant growth regulators, such as auxins, gibberellins, cytokinins, abscisic acid, and ethylene, are signal molecules that regulate many processes of plant development including fruit development, i.e., formation of mature fruit or viable mature seeds (Ozga and Reinecke, 2003).

Chemical Analysis of Bell Pepper Fruits

The addition of vermicompost increased soluble solids in pepper fruits compared to those in the control treatment (Table 4). Soluble solids and carbohydrate content in strawberry fruits were positively correlated and sugar and organic acids are important for the sensory quality of fruits, i.e., fruits with low sugar and acid content taste flat (Wang and Lin, 2002). Additionally, for post-harvest purposes, pepper fruits with higher soluble solids content are more suitable in the drying process (Adegoke et al., 1996). The N content of the pepper fruits

Table 4
Chemical characterization of bell pepper (*Capsicum annum*) cv. 'Ancho supremo' fruits from plants cultivated in different mixtures of soil and sheep manure vermicompost

Treatment (vermicompost:soil)	pH	Solids Soluble (°Brix)	Solids Insoluble (°Brix)	Titratable acidity (μg citric acid 100 g^{-1})	Total N (g kg^{-1})
1:1	6.2 B[a]	8.5 A	5.8 A	1.4 C	17.4 B
1:2	6.1 B	8.1 A	5.5 A	1.2 C	17.4 B
1:3	6.2 B	8.2 A	6.3 A	6.4 A	17.3 B
1:4	6.1 B	8.4 A	5.5 A	7.0 A	19.6 A
1:5	6.1 B	8.6 A	5.6 A	3.9 B	16.8 B
0:1	7.1 A	6.1 B	5.6 A	4.0 B	16.9 B
LSD (P<0.05)[b]	0.5	1.0	1.1	0.8	1.9

[a]Values with a different letter are significantly different ($P < 0.05$).
[b]LSD: Least significant difference at $P < 0.05$.

significantly increased in the 1.4 vermicompost: soil treatment compared to the other treatments. Increases in N content are normally related to increased protein content (Bajaj et al., 1979).

The pH of the fruits was significantly lower when cultivated in vermicompost: soil mixtures compared to the unamended soil. Citric acid is the primary organic acid found in most fruits (Wang and Lin, 2002). Pepper fruits with low pH value indicate more citric acid, which is beneficial for human consumption (Wang and Lin, 2002). Additionally, fruit with low pH is more suitable for ripening while it also improves shelf life (Hernández-Pérez et al., 2005). The 1:3 and 1:4 vermicompost: soil treatments induced a significant increase in titratable acidity compared to the control treatment and an increase in titratable acidity is positively correlated to organic acid level (malic + citric) in fruits (Wang and Lin, 2002).

The positive effect of vermicompost on growth, yield, and characteristics of peppers, tomatoes, and strawberries might be related to humic acids and other plant growth regulators, improvement of physical structure of soil and the presence of microorganisms (Arancon et al., 2003a; 2003b). Pepper fruits from plants grown in soil mixed with sheep manure vermicompost gave better post harvest conservation characteristics as they contained more soluble solids, pH was lower and the titratable acidity was higher (Villareal, 1982).

CONCLUSIONS

It was found that development and number of flowers and fruits of pepper plants grown in soil supplemented with sheep manure vermicompost increased, confirming the positive effects obtained with other soil supplements, such as food waste vermicompost, cow manure vermicompost, paper waste vermicompost, biosolids vermicompost, and yard waste compost. Fruit characteristics were also better so the utilization of vermicompost as soil supplement might be promoted as an alternative to the use of agrochemicals to increase crop production.

ACKNOWLEDGEMENT

The research was funded by Fundación Produce Chiapas, A.C.

REFERENCES

Adegoke, G. O., A. E. Allamu, J. O. Akingbala, and A. O. Akanni. 1996. Influence of sundrying on the chemical composition, aflatoxin content and fungal counts of two pepper varieties—*Capsicum annum* and *Capsicum frutescens*. *Plant Food Hum. Nutr*. 49: 113–117.

Alves, M. R., M. D. Landgraf, and M. O. O. Resende. 2001. Absorption and desorption of herbicide alaclor on humic acid fractions obtained from two vermicompost. *J. Environ. Sci. Heal. B* 36: 797–808.

APHA, AWWA, and WPCF. 1989. *Standard Methods for the Examination of Water and Wastewater. Published jointly by American Public Health Association, American Water Works Association and Water Environment Federation*. Washington, DC: American Public Health Association.

Arancon, N. Q., C. A. Edwards, P. Bierman, J. D. Metzger, and C. Lucht. 2005. Effects of vermicomposts produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. *Pedobiologia* 49: 297–306.

Arancon, N.Q., C. A. Edwards, R. Atiyeh, and J. D. Metzger. 2004. Effects of vermicomposts produced from food waste on the growth and yields of greenhouse peppers. *Bioresource Technol*. 93: 139–144.

Arancon, N. Q., C. A. Edwards, P. Bierman, J. D. Metzger, S. Lee, and C. Welch. 2003a. Effects of vermicompost on growth and marketable fruits of field-grown tomatoes, peppers and strawberries. *Pedobiologia* 47: 731–735.

Arancon, N. Q., S. Lee, C. A. Edwards, and R. Atiyeh. 2003b. Effects of humic acids derived from cattle, food and paper-waste vermicomposts on growth of greenhouse plants. *Pedobiologia* 47: 741–744.

Atiyeh, R. M., N. Q. Arancon, C. A. Edwards, and J. D. Metzger. 2002a. The influence of earthworm-processed pig manure on the growth and productivity of marigolds. *Bioresource Technol*. 81: 103–108.

Atiyeh, R. M., C. A. Edwards, S. Subler, and J. Metzger. 2001. Pig manure vermicompost as a component of a horticultural bedding plant medium: effects on physicochemical properties and plant growth. *Bioresource Technol*. 78: 11–20.

Atiyeh, R. M., S. Lee, C. A. Edwards, N. Q. Arancon, and J. D. Metzger. 2002b. The influence of humic acids derived from earthworm-processed organic wastes on plant growth. *Bioresource Technol*. 84: 7–14.

Atiyeh, R. M., S. Subler, C. A. Edwards, and J. Metzger. 1999. Growth of bell pepper plants in horticultural potting media amended with vermicompost. *Pedobiologia* 43: 724–728.

Bajaj, K. L., G. Kaur, J. Singh, and J. S. Brar. 1979. Effect of nitrogen and phosphorus levels on nutritive values of sweet peppers (*Capsicum annum* L.) fruits. *Plant Food Hum. Nutr*. 28: 287–292.

Bartha, R., and D. Pramer. 1965. Features of a flask method for measuring the persistence and biological effects of pesticides in the soil. *Soil Sci.* 100:68–70.

Benton, M. W., and D. B. Wester. 1998. Biosolids effects on tobosograss and alkali sacatonin a chihuahuan desert grassland. *J. Environ. Qual*. 27: 199–208.

Bernal, M. P., C. Paredes. M. A. Sánchez-Monedero, and J. Cegarra. 1998. Maturity and stability parameters of composts prepared with a wide range of organic waste. *Bioresource Technol*. 63: 91–99.

Bremner, J. M., 1996. Nitrogen-total. In: *Methods of Soils Analysis, Part 3. Chemical Methods*, ed. D. L. Sparks, pp. 1085–1122. Madison, WI: Soil Science Society of America Inc, American Society of Agronomy.

Bremner, J. M., and D. R. Keeney. 1966. Determination and isotope-ratio analysis of different forms of nitrogen in soils: 3. Exchangeable 'ammonium, nitrate, and nitrite' by extraction distillation methods. *Soil Sci. Soc. Am. Proc*. 30: 577–582.

Cardoso, L., and E. Ramírez. 2002. Vermicomposting of sewage sludge: a new technology for Mexico. *Water Sci. Technol*. 46: 153–158.

Contreras-Ramos, S. M., E. M. Escamilla-Silva, and L. Dendooven. 2004. Vermicomposting of biosolids with cow manure and oat straw. *Biol. Fert. Soils* 41: 190–198.

Elliot, H. A., and B. A. Dempsey. 1991. Agronomic effects of land application of water treatment sludge. *J. AWWA* 83: 126–131.

Franco-Hernández, O., A. N. Mckelligan-González, A. M. Lopez-Olguin, F. Espinosa-Ceron, E. Escamilla-Silva, and L. Dendooven. 2003. Dynamics of carbon, nitrogen and phosphorus in soil amended with irradiated, pasteurized and limed biosolids. *Bioresource Technol*. 87: 93–102.

García, D., J. Cegarra, M. P. Bernal, and A. F. Navarro. 1993. Comparative evaluation of methods employing alkali and sodium pyrophosphate to extract humic substances from peat. Commun. *Soil Sci. Plan*. 24: 1481–1494.

Gee, G. W., and J. W. Bauder. 1986. Particle size analysis. In: *Methods of Soil Analysis Vol I: Physical and Mineralogical Methods*, ed. A. Klute, pp. 383–411. Madison, WI: American Society of Agronomy.

Goh, K. M., and R. J. Haynes. 1977. Evaluation of potting media for commercial nursery production of container grown plants. *New Zeal. J. Agr. Res.* 20: 363–370.

Hernández-Pérez, T., A. Carrillo-López, F. Guevara-Lara, A. Cruz-Hernández, and O. Paredes-López. 2005. Biochemical and nutritional characterization of three prickly pear species with different ripening behavior. *Plant Food Hum. Nutr.* 60: 195–200.

Inbar, Y., Y. Hadar, and Y. Chen. 1993. Recycling of cattle manure: the composting process and characterization of maturity. *J. Environ. Qual.* 22: 857–863.

Jenkinson, D. S., and D. S. Powlson. 1976. The effects of biocidal treatments on metabolism in soil I. Fumigation with chloroform. *Soil Biol. Biochem.* 8: 167–177.

Jordao, C. P., M. G. Pereira, R. Einloft, M. B. Santana, C. R. Bellato, and J. W. Vargas de Mello. 2002. Removal of Cu, Cr, Ni, Zn, and Cd from electroplating wastes and synthetic solutions by vermicompost of cattle manure. *J. Environ. Sci. Health A* 37: 875–892.

Kalembasa, S. J., and D. S. Jenkinson. 1973. A comparative study of titrimetric and gravimetric methods for the determination of organic carbon in soil. *J. Sci. Food Agric.* 24: 1085–1090.

Krogman, U., L. S. Boyles, C. J. Martel, and K. A. McComas. 1997. Biosolids and sludge management. *Water Environ. Res.* 69: 534–549.

Martínez, M. J. M., R. F. Cerrato, and M. C. G. Chávez. 1999. Effect of vermicompost and mycorrhizal fungi on growth and photosynthetic rate of chili. *Terra* 17: 9–15.

Maroto, B. J. V. 1989. *Horticultura Herbacea Especial*. [Special Horticulture Herbacea]. Madrid: Ediciones Mundi-Prensa.

Masciandaro, G., B. Ceccanti, V. Ronchi, and C. Bauer. 2000. Kinetic parameters of dehydrogenase in the assessment of the response of soil to vermicompost and inorganic fertilisers. *Biol. Fert. Soils* 32: 479–483.

Masciandaro, G., B. Ceccanti, V. Ronchi, S. Benedicto, and L. Howard. 2002. Humic substances to reduce salt effect on plant germination and growth. *Commun. Soil Sci. Plan.* 33: 365–378.

Mathur, S. P., H. Dinel, G. Owen, M. Schnitzer, and J. Dugan. 1993a. Determination of compost maturity. II. Optical density of water extracts of compost as a reflection of their maturity. *Biol. Agric. Hortic.* 10: 87–108.

Mathur, S. P., G. Owen, H. Dinel, and M. Schnitzer. 1993b. Determination of compost maturity. I. Literature review. *Biol. Agric. Hortic.* 10: 65–86.

Ndegwa, P. M., and S. A. Thompson. 2001. Integrating composting and vermicomposting in the treatment and bioconversion of biosolids. *Bioresource Technol.* 76: 107–112.

Ndegwa, P. M., S. A. Thompson, and K. C. Das. 2000. Effects of stocking density and feeding rate on vermicomposting of biosolids. *Bioresource Technol.* 71: 5–12.

Ozga, J. A., and D. M. Reinecke. 2003. Hormonal interactions in fruit development. *J. Plant Growth Regul.* 22: 73–81.

Pierre, V., R. Phillip, L. Margnerite, and C. Pierrette. 1982. Anti-bacterial activity of the haemolytic system from the earthworms *Eisenia foetida andrei. Invertebr. Pathol.* 40: 21–27.

Rhoades, J. D., N. A. Mantghi, P. J. Shause, and W. Alves. 1989. Estimating soil salinity from saturate soil-paste electrical conductivity. *Soil Sci. Soc. Am. J.* 53: 428–433.

Sánchez-Monedero, M. A., A. Roig, C. Martínez-Pardo, J. Cegarra, and C. Paredes. 1996. A microanalysis method for determining total organic carbon in extracts of humic substances. Relationships between total organic carbon and oxidable carbon. *Bioresource Technol.* 57: 291–295.

SAS Institute Inc. 1989. *Statistic Guide for Personal Computers.Version 6.04* Cary, NC: SAS Institute.

Senesi, N. 1989. Composted materials as organic fertilizers. *Sci Total Environ.* 81: 521–542.

Simonne, A. H., E. H. Simonne, R. R. Eitenmiller, H. A. Mills, and N. R. Green. 1997. Ascorbic acid and provitamin A contents in unusually colored bell peppers (*Capsicum annuum* L.). *J. Food Compos. Anal.* 10: 299–311.

Sumner, M. E., and W. P. Miller. 1996. Cation exchange capacity and exchange coefficients. In: *Methods of Soil Analysis, Part 3, Chemical Methods*, ed. D. L. Sparks, pp 1201–1229. Madison, WI: Soil Science Society of America Inc, American Society of Agronomy, Inc.

Thomas, G. W. 1996. Soil pH and soil acidity. In: *Methods of Soil Analysis, Part 3, Chemical Methods.*, ed. D. L. Sparks, pp 475–490. Madison, WI: Soil Science Society of America Inc., American Society of Agronomy, Inc.

USEPA. 1999. *Environmental Regulations and Technology. Control of Pathogens and Vector Attraction in Sewage Sludge (Including Domestic Septage). Under 40 CFR Part 503. Appendix F, G and I. EPA/625/R-92–013*. Cincinnati, OH: US. Environmental Protection Agency Office of Research an Development, National Risk Management Research Laboratory, Centre for Environmental Research Information.

Villareal, R. D. 1982. *Jitomates* [Tomatoes]. San José, Costa Rica: Instituto Interamericano de Cooperación para la Agricultura.

Wang, S. Y., and S. S. Lin, S. S. 2002. Compost as soil supplement enhanced plant growth and fruit quality of strawberry. *J. Plant Nutr.* 25: 2243–2259.