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Differential Effects of a Vermicompost Fertilizer on Emergence and Seedling Growth of Tomato Plants

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A R T I C L E I N F O

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A B S T R A C T

Vermicompost products have gained a great importance in plant nutrition over the years. They are reported to have plant growth promoting effects both in horticulture and field crops. The nutritional value and chemical properties of vermicomposts highly depend on the feedstock used in their production. The aim of this study was to evaluate vermicompost manure, derived from the mixture of cattle manure and kitchen scraps, on seed germination and growth of tomato seedlings (*Lycopersicon lycopersicum* Mill.). Four solid vermicompost amendment rates of 0, 10, 20, and 30% were applied in plastic trays. Vermicompost application delayed and reduced seed emergence in all application rates, while in general, vermicompost substitution promoted growth tomato seedlings up to 20% of application rate. The results showed that vermicompost substitutions greater than 20% had adverse effects on seedling emergence and seedling growth parameters, which was attributed to high EC of vermicompost induced by cattle manure. Results suggest that both physical and chemical properties of the feedstock used for vermicompost production should be taken into consideration in order to sustain high vermicompost quality to ensure targeted plant growth for horticultural and agricultural purposes.

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Introduction

Vermicomposting has long been recognized as a low cost and environmentally sound process for treatment of many organic wastes such as animal manures, sewage-sludge, crop residues, and industrial wastes (Albanell et al., 1988; Edwards and Burrows, 1988; Atiyeh et al., 2001; Edwards et al., 2004; Arancon et al., 2008; Lazcano and Dominquez, 2011).Vermicomposts are derived from the accelerated biological degradation of organic wastes by earthworms and microorganisms living in the vermicompost mixture. Vermicomposts are peat-like materials with excellent physical, chemical, and biological properties (Dominquez et al., 2010). There are numerous studies confirming that earthworm-processed organic wastes have growth promoting effects on a variety of crops in sgriculture, horticulture, and forestry (Edwards and Burrows, 1988; Edwards et al., 2004; Lazcano and Dominquez, 2011). Vermicompost promotes plant growth, enhances germination and increase yield in various vegetables, field crops, forest nursery plants and ornamentals.

Increased cost of environmentally safely managing of animal manures and increased prices of peat moss induced public to develop alternative ways, to process those wastes in a cost effective and environmentally sound way, and to gain materials to be used effectively in plant production. However, the side effect of these new alternative products should be assessed to ensure their beneficial use. Physical, chemical, and microbiological properties of end products in vermicomposting highly depend on many factors, including the type and properties of the initial waste materials used as feed stocks for vermicompost production. The objective of this study was to evaluate efficacy of vermicompost, produced from the mixture of cattle manure and kitchen scraps, in germination and growth of tomato seedlings (*Lycopersicon lycopersicum* Mill.) grown in plastic trays in greenhouse conditions.

Materials and Methods

Preparation of Vermicompost

Vermicomposting feed stocks material was consisted of cattle manure, kitchen scraps, and card board. Separated cow manure was obtained from a local dairy operation farm (Cankiri, Turkey) where the barn is cleaned weekly by shovels. Manure was kept without treatment at least two months before its use for vermicomposting. Kitchen scraps (potato, green vegetables, cucumber, fruits, etc.) were provided by a local restaurant. Corrugated card board were shredded and used as the bedding material for the earthworms. The worm composting materials with the top layer (wetted shreds of card board) were mixed thoroughly by hand then earthworms *Eisenia fetida* (Savingy) were introduced.

The carbon to nitrogen (C:N) ratios of all worm composting materials were maintained between 20:1 to 25:1. Vermicomposting was carried out in a 1-m long by 1-m wide worm bed on a concrete floor at temperature varying between 20 and 30°C. Initial stocking density for each batch was maintained between 2 and 3 kg m^{-2}. Each worm bed was covered by a thick black plastic to protect worms from light and preserve the moisture inside. The worm bed was mixed manually every week throughout vermicomposting processes and watered with tap water as needed. The moisture content of the vermicomposting material was kept around field capacity to prevent nutrient loses by leaching. After 14 to 16 weeks of vermicomposting period, Vermicompost was made free of worms by inducing the worms to migrate to fresh waste material after 14 to 16 weeks of vermicomposting period. The vermicomposted material was left partially open at room temperature until to dry enough to be sieved using a chrome plated metal screen with 3 mm openings.

Determination of The Vermicompost Properties

Organic matter (OM) content was determined in a combustion oven (550°C) as described by Nelson and Sommers (1982). Water content of vermicompost was determined by drying a five gram of fresh vermicompost in 105°C constant oven temperature. EC and pH were determined in one hour shaken slurries using a portable EC and pH-meter in 1:5(v:v) and (1:2.5) vermicompost to 1 N KCl mixtures, respectively. Total N content was determined by Kjeldahl method (Bremner and Mulvaney, 1982). Combustion at 550°C was performed to determine C:N ratio of the vermicompost.

Cation exchange capacity of vermicompost was measured using ammonium acetate procedure as described by (Rhoades, 1982). Five grams of oven dry vermicompost was saturated with 1 N sodium acetate (pH7) then 1 M ammonium acetate used to cast out sodium. The filtrates obtained from three repeats of the procedure described above were accumulated and analyzed for Na with a Flame Photometer. Micronutrient analysis of water extract of the vermicompost (vermicompost: distilled water (1:2, v/v)), was carried out by Atomic Absorption Emission Spectrophotometer (Model: Varian Vista). The number of bacteria, actinomycetes and fungi in vermicompost were determined by plate count technique with application of selective media as described by Szczech (1999). The results were expressed as number of colony-forming units (cfu) per 1 g of vermicompost dried at 105°C.

Experimental Setup

Tomato seeds (*Lycopersicon lycopersicum* Mill.) were obtained from a local market. Vermicompost was substituted for sphagnum peat in seed beds at rates of 0, 10, 20, and 30% by volume. Individual seeds of tomatoes were sown as one seed per cell into each 85 cells of Styrofoam seedling trays filled with the corresponding vermicompost substitution rate. Seedling emergence was observed on all the cells of a tray. Thereafter, seedling emergence and seedling growth and development parameters were evaluated using fifteen randomly tagged seedlings from each of three replicates per treatment. In total, 45 samples/seedlings were examined for each treatment at the end of the sixth week after sowing. Seedlings were watered equally as needed. None of the chemical nutrients were used through the experiments. Trials were repeated two times (in 2013 and 2014). Seedling emergence time (ET; the time needed for the germination of 50% of the seeds) and seedling emergence rate (ER; the ratio of emerged seedlings over the total number of seeds sown) were observed. Shoot height (mm), root length (mm), shoot diameter (mm), fresh and dry weights (g), and leaf number were measured as seedling growth variables.

Plant analysis

The seedling samples were oven dried to constant weight at 65°C using a hot air oven (Scientific Series 2000). Total N content was measured according to Bremner and Mulvaney, (1982); total K content was measured according to Jones et al. (1956). For determination of micro-element content of the plant samples, 0.5 gr of the plant sample was digested with the nitric acid (10 N) solution by boiling on a hot plate, which was then diluted to 50 ml with distilled water and filtered through Whatman No.1. Samples were analyzed with an Atomic Absorption Emission Spectrophotometer (Model: Varian Vista)

Statistical analysis

Tray trials were repeated twice. The data were analyzed by one-way ANOVA to evaluate effect of vermicompost application rates on tomato seedling emergence and growth variables of root length, shoot height, number of leaves and shoot diameter. When the “zero hypothesis” was rejected in ANOVA, means for treatments were grouped by LSD procedure. Significance level of 5% was considered in rejecting all zero hypothesis.

Results and Discussion

Characteristics of The Vermicompost

pH and EC of the vermicompost, derived from the mixture of cattle manure and kitchen scraps, were high (Table 1), which could be attributed to the use of salt rocks as cattle feedstock by the local cattle hoarders. In this region, use of salt rocks as cattle feedstock is a common practice of growers. Total N and P contents of the vermicompost are quite low to support a vigorous plant development, while K and Ca contents are high, which would be derived from cattle manure (Table 1). Among the micronutrients, Zn, and B contents of vermicompost are adequate and Fe, Mn, and Cu contents are not adequate (Table 2) to support plant growth.

Increased vermicompost application rates did not show a consistent positive effect across plant growth variables (Table 3). Greatest shoot height (SH) occurred at no vermicompost application, while greatest root length (RL) occurred at 20% vermicompost. In general, 30% vermicompost resulted in decreased plant growth than 20% application rate, and this could be attributed to increased osmotic effect that influenced seedling growth adversely due to high electrical conductivity (EC) of the vermicompost (Table 2). Twenty percent vermicompost substitution provided the greatest values of RL, leaf number (LN), shoot diameter (SD), and dry weight (DW); while 30% vermicompost substitution resulted in the lowest growth parameters except in LN (Table 3). The highest vermicompost substitution decreased emergence rate (ER) as well.

Plant Chemical Analyses

Total N content of the seedlings were low in all treatments as expected because of the low N content of the vermicompost (Table 4). Similarly, K contents in seedlings were high in all rates of vermicompost applications as K content of the vermicompost was high. Adequate contents of Fe and Zn in seedlings revealed that plants could absorb these elements from the growth media in spite of high pH. However, Ca content in seedlings showed that plants could not absorb this element even though Ca was present at adequate level in the vermicompost. On the other hand, accelerated contents of the P, Zn, and Fe in seedlings at 20% and %30 vermicompost indicated that vermicompost' chemical structure could support bioavailability of these nutrients even though their contents (Zn and Fe) were not high enough in the vermicompost (Table 4). Mn and Mg contents of the seedlings were insufficient as their amounts were inadequate in both of vermicompost and the sphagnum peat.

Table 1 Some physical, chemical, and biological characteristics of the vermicompost used in experiments.

Characteristics of the vermicompost	Value
Organic matter content (%)	45.0
Total N content (%)	1.72
EC (dS cm^{-1})	6.0
pH	8.3
CEC ($cmol_c$ kg^{-1})	52.35
Moisture content (%) at saturation	105.0
C/N ratio	15
Total fungal colony (CFU $gdwt^{-1}$)	1.5×10^5
Total bacterial colony (CFU $gdwt^{-1}$)	2.0×10^6
Total actinomycetes colony (CFU $gdwt^{-1}$)	0.7×10^4

Table 2 Micro element and heavy metal contents of the vermicompost used in experiments.

Macro elements (%)	N: 1.72	K: 2.90	S: 0.006	Ca: 7.24	Mg: 1.15	P: 0.8
Micro elements (mg kg^{-1})	Fe: 0.76	Mn: 0.06	B: 0.005	Cu: 0.003	Zn: 0.15	Mo: 0.002
Heavy metals (mg kg^{-1})	Pb: 0.004	Cd: 0.003	Co: 0.002	Ni: 0.004	Cr: 0.003	Al: 0.015

Table 3 Seedling emergence and growth parameters as affected by vermicompost substitution rates in six week-old tomato seedlings.

VR	Vermicompost substitution rates			
	0	10	20	30
SH (mm)	24.88$^{\&}$(4.23)^a	20.64 (3.37)^a	24.08 (2.41)^b	19.68 (3.30)^b
RL (mm)	15.48 (3.46)^{ab}	14.37 (2.91)^{bc}	16.77 (4.01)^a	13.31 (2.74)^c
SD (mm)	3.20 (0.30)^a	3.19 (0.55)^b	3.58 (0.39)^b	3.19 (0.37)^b
LN	3.33 (0.67)^a	3.04 (0.56)^a	3.97 (0.62)^b	3.95 (0.67)^c
FW (gr)	58.38 (5.32)^a	67.97 (8.99)^a	66.51 (11.66)^a	60.52 (15.82)^a
DW (gr)	7.34 (0.32)^a	8.27 (0.93)^a	8.51 (2.01)^a	5.98 (1.69)^a
ET (day)	8 (0.36)^a	10 (0.23)^b	11 (0.15)^b	11 (0.24)^b
ER (%)	95 (0.14)^a	95 (0.18)^a	95 (0.12)^a	92 (0.15)^b

VR: Vermicompost ratio used for germination media. SH: Shoot height. RL: Root length. SD: Shoot diameter. LN: Leaf number. FW: Fresh weight. DW: Dry weight. ET: Time period as day that 50% of the seeds were germinated and seedling were emerged (day). ER: the ratio of emerged seedlings to the total number of seeds sown (%). &: Means with different letters in the same Colum are different at the significance level of 0.05. Numbers in parentheses are standard deviations of the means.

Table 4 Chemical nutrient contents of six week-old tomatoe seedlings.

VR	N	P	K	Ca	Mg	Zn	Fe	Mn	Cu	B
	(%)					(mg kg^{-1})				
0	1.54D	0.35D	5.32A	0.66D	0.6D	45.5A	184.3A	26.6D	11.9A	31.9A
0	1.68D	0.34D	4.97A	0.74D	0.59D	34.4A	219.9A	18.2D	18.9H	26.6A
10	1.68D	0.35D	6.07A	0.71D	0.55D	43.4A	161.4A	24.2D	19.5H	30A
10	1.4D	0.38D	6.31A	0.12D	0.4D	74.6A	194.9A	29.4D	28.8H	26.7A
10	1.4D	0.38	6.49A	0.14D	0.33D	90.2H	215.7H	21.4D	15.8H	30.2A
20	1.4D	0.38D	6A	0.1D	0.3D	90.9H	209.1H	16.1D	12.1H	36.8A
20	1.75D	0.4A	8.23A	0.12D	0.28D	96.7H	282.2H	24.4D	12.4H	36.5A
20	1.75D	0.41A	7.61A	0.14D	0.3D	98.2H	304.6H	22.7D	14.2H	38.4A
30	1.61D	0.4A	7.17A	0.13D	0.25D	101.2H	282.3H	21.2D	8.2A	31.8A
30	2.1D	0.39	7.52A	0.09D	0.23D	113.2H	185.5H	19.5D	14.4H	33.4A
30	1.96D	0.42A	7.86A	0.09D	0.24D	139.8H	235.2H	22D	7.9A	42.9A
30	2.17D	0.42A	7.78A	0.07D	0.23D	100.5H	238.7H	29.9D	22.8H	39.2A

VR: Vermicompost rate used for germination media. A: Adequate, D: Deficient, H: High

Numerous studies have been conducted for evaluating plant growth promoting effect of vermicompost in ornamentals and horticultural and field crops (Arancon et al., 2006; 2005; 2004; Atiyeh et al., 2001; 2000; 1999; Lazcano and Dominquez, 2011). Most of these studies showed that vermicompost products have great potential in plant propagation and organic plant production. The plant growth promoting effect of vermicompost was suggested to be derived from its unique microbiological, chemical, and physical properties, resulting in increased enzymatic activities, increased numbers of beneficial microorganisms or biologically-active plant growth-influencing substances such as plant growth regulators and humic acids, and improved physical structure of the container medium (Edwards et al., 2004; Lazcano and Dominquez, 2011).

In contrast to many literatures cited (Edwards and Burrows, 1988; Donald and Visser, 1989; Arancon et al., 2004; Edwards et al., 2004; Atiyeh et al., 2000; 1999; Lazcano and Dominquez, 2011), we observed differential effects of the vermicompost substitution on tomato seedlings. Emergence time (ET) and emergence ratio (ER) were affected adversely by the vermicompost, which would be resulted from its high EC and pH (Table 1). High pH inhibits uptake of many plant nutrients such as P, Mn, Zn, Cu, Fe, and B (Diaz-Perez and Camacho-Ferre, 2010). In addition, P content of the vermicompost was very low that would aggravate P deficiency in plants, reducing vermicompost utility for plant growth (Table 3). Plant growth is controlled by the most deficient nutrient in growth medium; therefore, we believe that P deficiency was the major growth limiting factor in our study besides high pH and EC (Sanchez, 2007). Even though vermicompost seemed to promote P bioavailability for seedlings grown 20% and %30 vermicompost (Table 4) (Arancon et al. 2004; Atiyeh et al., 2002) compared with the control, this increase in P content was not sufficient for an adequate seedling growth overall.

Vermicompost products are rich in humic acids compounds. Humic acids form complexes (chelates) with Fe, Al, and other cations which may explain the highest Fe contents in seedlings at 20% vermicompost rate, compared to the control (Table 4). High pH is known to inhibit Fe and Cu absorption in plants, however, seedlings grown in 20% vermicompost had greater Fe and Zn contents compared to the control, and this was attributed to complexation effect of humic acids that increased availability of Fe and Zn to tomato seedlings (Atiyeh et al., 2002b; Römheld and Nikolic, 2007).

Although concentrations of Ca and Mg in the vermicompost were adequate, their concentrations in plants were quite low, which would be resulted from high K concentration in vermicompost. K competes with Ca and Mg for plant uptake, known as ion antagonism or cation competition and it usually inhibits Ca and Mg uptake when its concentration is high enough in the solution (Carvajal et al., 1999).

Mn contents of tomato seedlings were low and this was attributed to its low concentration in vermicompost. In addition, high pH of the vermicompost could aggravate Mn deficiency of plants since manganese deficiency is most prevalent in calcareous soils, the pH of which varies from 7.3 to 8.5 (Humphries et al., 2007). On the other hand, elevated Zn contents of seedlings observed with increasing vermicompost substitutions might be due to high Ca concentration of vermicompost since it forms complexes with $CaCO_3$ in alkaline soils with pH 8.2 that promotes plant uptake of Zn (Storey and Anderson, 1970).

Our results revealed that quality of the vermicompost as affected by many factors including type and physical and chemical properties of the feed stocks used for vermicompost production is vital to sustain its plant growth promoting effect. Therefore, it is imperative that properties of feed stocks material must be reviewed carefully before their use in vermicompost production.

Conclusion

We evaluated plant nutritional value of a vermicompost produced from mixture of cattle manure and kitchen scraps (potato, green vegetables, cucumber, fruits, etc.). The vermicompost was highly affected by the feed stocks used in its production. High pH and EC were the principal determinants for its effects on emergence and growth parameters of the seedlings (*Lycopersicon* *lycopersicum* Mill.). In addition, the low P contents in tomato seedlings and vermicompost was also a major growth limiting factor in our study. Response of tomato seedlings to increasing vermicompost rates was inconsistent. In general, greatest growth promoting effect of vermicompost occurred with its 20% application rate. Further increases in vermicompost application rates resulted in reduced values of growth variables of root length, leaf number, and shoot diameter due to its high pH and EC.

Our results suggest that feed stocks materials used in vermicompost production should be selected properly to obtain a vermicompost with balanced nutrients and proper pH and EC needed for a vigorous plant growth. Therefore, future studies should proceed revealing the physical and chemical properties of the initial wastes (feed stocks) before vermicompost production to avoid a possible detrimental effect derived from high pH and EC of the final vermicompost product.

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