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Vermicompost as Substrate Amendment for Tomato Transplant Production

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Abstract

Vermicompost may be a promising substitute for peat especially in transplant production. Vermicomposting is a sustainable solution for management of organic wastes. However, due to variability of organic wastes, vermicomposts might have varying nutrient content levels. The study compared vermicomposts from different sources on growth and nutrition of tomato (*Solanum lycopersicum* L.) transplants. Chemical composition of vermicomposts differed. Common characteristics were high pH and very high electrical conductivity. All vermicomposts stimulated growth of tomato transplants, with up to a 2.2-fold increase occurring in shoot biomass. Differences in growth were attributed mainly to differences in nutrient content of the potting mixtures, but some changes in physical and biological properties of the substrate could also be responsible.

Keywords: *Solanum lycopersicum*, Bulgaria, cow manure, plant nursery, vermicompost

1. Introduction

Profitability of high-value crops, such as tomato (*Solanum lycopersicum* L.) necessitates detail cultural management to ensure crop required growing conditions. Production of high quality transplants is a key factor for success. Adequate root and aerial biomass of tomato transplants assure an improved ability to exploit soil resources and higher photosynthetic capacity. Potential consequences are enhanced crop yield and improved fruit quality (Zaller, 2007; Lazcano, Arnold, Tato, Zaller, & Domíngues, 2009).

The choice of growing media is considered a challenge for production of seedlings for transplanting. The medium nutritional quality, structure and stability are of primary importance. Peat is widely used as a component of potting mixes in conventional and organic production but increased concern has risen due to exploitation of these slowly renewable natural resources and degradation of valuable peatland ecosystems (Lappalainen, 1996; Carlile, 2004). Increasing pressure against peat extraction and the demand for low cost substrates leads to an increasing interest on substituting peat with other materials.

Compost appears to be a promising substitute for peat. It is also a sustainable solution for management of organic wastes which are major source of environmental pollution (Atiyeh, Subler, Edwards, Bachman, Metzger, & Shuster 2000b; Hashemimajd, Kalbasi, Golchin, & Shariatmadari, 2004; Lazcano et al., 2009). Recycling organic wastes could be done by thermophylic composting or mesophilic biodegradation. Recycling of organic wastes by earthworms and microorganisms, i.e., vermicomposting, is the subject of scientific investigation (Arancon, Edwards, Bierman, Metzger, & Lucht, 2005; Gutiérrez-Miceli et al., 2007; Azarmi, Sharifi Ziveh, & Reza Satari., 2008; Warman & AngLopez, 2010). Possibly due to better physical properties, higher microbial and enzymatic activity, and higher content of available nutrients (Krishnamoorthy & Vajrabhiah, 1986; Edwards & Burrows, 1988; Tomati & Galli, 1995) producer acceptance of vermicompost is greater than that of compost (Atiyeh et al., 2000b; Tognetti, Laos, Mazzarino, & Hernandez, 2005). Vermicompost could be used as a natural fertilizer having a number of advantages over chemical fertilizers (Venugopal, Chandrasekhar, Naidu, & Raju, 2010). Substituting peat with vermicompost in potting mixes improved seedling quality of tomato (Atiyeh, Arancon, Edwards, & Metzger, 2000a; Bachman & Metzger, 2008; Lazcano et al., 2009), green and chili pepper (both *Capsicum annuum* L.) and eggplant (*Solanum melongena* L.) (Bachman & Metzger, 2008; Prasanna Kumar, & Raheman, 2010).

Ample availability of vermicomposts in Bulgaria, and their competitive price, could make their application as peat substitutes a widely used and attractive technology, especially in transplant production. But due to variability of organic wastes the produced vermicomposts might have completely different features. The objective of this study was to compare the quality of vermicomposts on growth and nutrition of tomato transplants.

2. Material and Methods

The experiment was conducted during 2010 in a growth chamber (22-25^{o}C; 14/10 hrs day/night; maximum light intensity 400 $\mu mol \cdot m^{-2} \cdot s^{-1}$ supplied by 36W fluorescent tubes) at the Maritsa Vegetable Crops Research Institute, Plovdiv, Bulgaria. Tomato seed, cv. Miliana, were sown, one seed per cell, in foamed polystyrene plug trays with 198 inverted pyramid cells, filled with peat moss and perlite in the ratio of 1:1 (v/v). Fertilized milled peat (Rekyva AB, Šiauliai, Lithuania), containing 1.0 $kg \cdot m^{-3}$ of complex *PG-Mix*™ 14·16·18 fertilizer (*Hydro* Agri, Yara International ASA, Norway) was used. At the first true leaf stage seedlings were transplanted into plastic pots containing 0.5 L of a mix of peat moss and perlite (1:1 v/v) to which 10% vermicompost was added to all treatments but the control.

2.1 Vermicompost Sources

Mature vermicomposts, obtained from five commercial farms located in Bulgaria, were used. All vermicomposts were produced with the "bed" method, which involves applying thin layers of partially matured manure to the surface of beds made up of porous sheets and containing high densities of earthworms (*Lumbricus rubellus* Hoffmeister, 1843). The commercial products tested were: 1) Biohumus MM (Ecofarm Marinov ECO, Kujlevcha, Bulgaria) produced in northeastern Bulgaria in which fresh manure was settled for 3-4 months under anaerobic conditions, then 80% cow dung and 20% horse dung were added to beds (1-2 m W×0.4-0.5 m H×varying L). Earthworms had been active at least one year and the final product was sieved through 5 mm mesh; 2) Biohumus NN (Ecofarm Nikolova, Panayot Volov, Bulgaria) produced in northeastern Bulgaria in which 4-5 month old cattle dung was placed in beds (2×0.4-0.5×up to 25 m, W×H×L) - earthworms had been active for approximately one year, and the final product sieved through 5 mm mesh; 3) Chirpan vermicompost (Ecofarm Velkov, Chirpan, Bulgaria) was produced in southcentral Bulgaria in which partially decomposed cattle manure (settled for 2-3 months under anaerobic conditions) was applied to beds (1×1×up to 20 m, W×L×H) - the earthworms had been active from April to the end of November and the final product was not sieved; 4) Lumbrical (Ecofarm T. Prazova, Kostievo, Bulgaria) produced in southern Bulgaria was made from cow, pig and horse dung, partially decomposed under anaerobic conditions (settled for 2-3 months to decrease NH_3 content) and mixed so that final product contained 95% cow and 5% pig + horse dung, with the mix placed in beds (1.2-1.5×0.4-0.5×up to 20 m, W×H×L)-earthworms had been active for approximately one year, and he final product sieved through 5-10 mm mesh, and 5) WasteNoMore (Waste No More Farm, Kazanlak, Bulgaria) produced in southcentral Bulgaria made from cattle dung stored for 2-3 years under anaerobic conditions and placed in vermi beds of varying dimensions - earthworms had been active for approximately one year, and the final product sieved through 3 mm mesh.

2.2 Experimental Design

The experiment was repeated twice; each lasting 40 days. Treatments were: 1. Control-mixture of peat and perlite 1:1 (v/v), no verimcompost; 2. Biohumus MM; 3. Biohumus NN; 4. Chirpan vermicompost; 5. Lumbrical and 6. Waste no more. Each treatment was replicated three times and each replication was composed of 10 plants. All pots were set in the same growth chamber, arranged in a randomized complete block design. Plants were irrigated with 100 mL non-chlorinated water twice a week.

2.3 Analysis

2.3.1 Compost/Substrate Analysis

Vermicompost samples were analyzed to characterize chemical and physico-chemical properties. Samples from each treatment were analyzed before planting, to determine initial nutrient content. Analysis were performed as follows: plant available P and K-in Ca-lactate extract followed by colorimetric (P) and flame photometric (K) determination; pH, electrical conductivity (EC) and water soluble nutrients were determined in aqueous extracts 1:1.5 (v/v) (Soneveld, van den Ende, & van Dijk, 1974). The following were quantified: NO_3^--ion-selective analysis; P-colorimetric Mo blue reaction; K-flame photometery; Ca and Mg-complexometrically with EDTA;

and organic matter content determined by dry combustion at 550°C.

2.3.2 Plant Analysis

N, P and K were quantified in dried shoots at the end of the experiment by: N-Kjeldahl method; P and K-colorimetry and flamephotometry, respectively, after dry ashing and subsequent extraction with 2 M HCl.

2.3.3 Microbiological Analysis

Total microbial populations of bacteria and fungi from vermicomposts were enumerated using dilution plates on appropriate medium to support growth of microorganisms; Potato Dextrose Agar for fungi and Nutrient Agar for bacteria.

2.3.4 Plant Growth Analysis

At the end of the experiment shoot fresh weight, shoot length (distance from the substrate level to the top node), leaf number (excluding cotyledons), and leaf area were determined.

2.3.5 Statistical analysis

All results are means of three replicates. Data were subjected to Duncan's Multiple Range Test to separate means. Regression analysis was used to determine relationships between growth parameters and amounts of nutrients supplied by vermicomposts as well as between amounts of nutrients supplied by vermicomposts and nutrient concentrations in plant tissues.

3. Results and Discussion

3.1 Comparison of Physicochemical, Chemical and Biological Properties of Vermicomposts

The vermicomposts differed in amounts of macronutrients (Table 1). The pH of vermicomposts was not different (avg. pH 7.62) but higher than optimal for growing tomato transplants (Shulgina et al., 1990). The EC was also high, except in WasteNoMore. The most nutrient rich vermicomposts were Biohumus MM and Lumbrical. The latter also contains the highest amount of P. The lowest EC and lowest nutrient content in WasteNoMore could be explained with the used production technology which involves composting and subsequent vermicomposting.

Table 1. Chemical and physicochemical properties of vermicomposts

Properties	Biohumus MM		Biohumus NN		Chirpan vermicompost		Lumbrical		WasteNoMore	
Organic matter, %	73.5	b*	79.2	a	81.8	a	77.5	ab	73.8	b
Ca-lactate extractable										
P_2O_5, mg/100g	289.8	c	649.9	b	175.5	c	2191.7	a	245.8	c
K_2O, mg/100g	11500.0	a	11125.0	a	7500.0	b	10500.0	ab	4500.0	c
Water extractable										
NO_3^-, $mg \cdot L^{-1}$	754.8	a	754.8	a	344.6	ab	742.4	a	236.3	b
P, $mg \cdot L^{-1}$	33.4	b	33.4	b	34.6	b	141.4	a	24.0	b
K, $mg \cdot L^{-1}$	1718.1	a	1718.1	a	610.1	b	1360.0	a	356.5	c
Ca, $mg \cdot L^{-1}$	216.0	a	216.0	a	168.0	a	72.0	ab	36.0	b
Mg, $mg \cdot L^{-1}$	172.8	b	172.8	b	129.6	b	302.4	a	14.4	c
EC, $mS \cdot cm^{-1}$	5.62	a	5.62	a	3.03	b	4.96	a	1.42	c
pH	7.78	ns	7.78	ns	7.49	ns	7.38	ns	7.68	ns

*Values in rows followed by different letter are significantly different at $P<0.05$, Duncan's Multiple Range Test.

High bacterial counts were observed in all vermicomposts (Table 2). Durán and Henríquez (2007) reported bacterial population values of vermicompost produced from cow manure were similar to those reported here. In Lumbrical, WasteNoMore and Biohumus NN fungal loads were higher than those reported by Anastasi, Varese, Voyron, Scannerini, & Marchisio (2004) and Durán and Henríquez (2007).

Table 2. Total amount of bacteria and fungi in vermicompost ± Standard deviation

Sample	Bacteria, $CFU \cdot g^{-1}$	Fungi, $CFU \cdot g^{-1}$
WasteNoMore	$4.1 \pm 0.21 \times 10^7$	$2.4 \pm 0.15 \times 10^6$
Biohumus NN	$3.7 \pm 0.18 \times 10^7$	$1.5 \pm 0.15 \times 10^6$
Chirpan vermicompost	$3.0 \pm 0.15 \times 10^7$	$1.0 \pm 0.12 \times 10^4$
Biohumus MM	$1.4 \pm 0.15 \times 10^7$	$1.0 \pm 0.10 \times 10^4$
Lumbrical	$0.4 \pm 0.02 \times 10^7$	$0.1 \pm 0.02 \times 10^6$

The production technologies used to develop vermicomposts were similar. Differences in their properties could be explained by differences in starting raw material. In all cases the predominant raw material was cow dung from animals that were treated differently, which probably influences vermicompost contents. Based solely on these analyses it is hard to predict how each vermicompost could influence plant growth, since factors, other than nutrient availability influence plant response (Atiyeh, Edwards, Subler, & Metzger, 2000c; Atiyeh, Edwards, Subler, & Metzger, 2001; Hidalgo & Harkess, 2002a; Arancon, Lee, Edwards, & Atiyeh, 2003; Arancon, Edwards, Atiyeh, & Metzger, 2004; Bachman & Metzger, 2008; Yasir, Aslam, Won Kim, Lee, Jeon, & Chung, 2009; Robledo, Grosso, Zoppolo, Lercari, & Etchebehere, 2010).

3.2 Chemical and Physicochemical Properties of Potting Mixtures Containing 10% Vermicomposts

Chemical and physicochemical properties of potting mixtures before planting were within acceptable ranges for growing tomato transplants (Shulgina, Simidchiev, Cekleev, & Kanazirska, 1990) (Table 3). Most vermicomposts increased nitrate and soluble P levels in the potting mixtures, compared to the control, the exception was Biohumus NN. The K amount increased only in Biohumus MM treated mixes; while the Ca amount increased only in Chirpan vermicompost treated mixes. Vermicomposts did not affect Mg content in potting mixes. Biohumus MM was the only vermicompost that had a higher EC value than the control, which is attributed to the highest concentration of K. Biohumus MM, Biohumus NN and WasteNoMore, which had comparatively high pH increased pH of mixtures compared to the control. Atiyeh et al. (2000c) observed increased pH in peat-perlite based substrate after application of 10-20% pig manure vermicompost. Chirpan vermicompost and Lumbrical, with comparatively lower pH does not modify mixture pH. These observations suggest that vermicompost could be an important source of nutrients. Hence, it could be also assumed that application of vermicompost will reduce the use of mineral fertilizers or even will replace them.

Table 3. Content of water soluble nutrients ($mg \cdot L^{-1}$), EC ($mS \cdot cm^{-1}$) and pH of the growing media before planting

Treatment	NO_3^-	P	K	Ca	Mg	EC	pH
Control	110 b*	42.2 c	103.3 b	30.0 b	14.4 ns	0.71 b	5.82 b
Biohumus MM	415 a	79.0 b	532.3 a	51.0 ab	30.6 ns	2.19 a	6.89 a
Biohumus NN	355 a	49.9 c	351.7 ab	54.0 ab	28.8 ns	1.59 ab	7.04 a
Chirpan vermicompost	365 a	126.7 a	312.5 ab	78.0 a	37.8 ns	1.44 ab	6.12 b
Lumbrical	455 a	92.2 ab	348.7 ab	51.0 ab	54.0 ns	1.68 ab	6.45 ab
WasteNoMore	425 a	77.4 b	186.8 b	54.0 ab	43.2 ns	1.30 ab	6.68 a

*Values in columns followed by different letter are significantly different at P<0.05, Duncan's Multiple Range Test.

3.3 Effect on Plant Growth

Addition of vermicompost to the potting mixture stimulated plant growth (Table 4). The best shoot fresh weights and lengths were due to amending the medium with Biohumus MM. All vermicomposts caused greater production of leaves than the control. The best leaf area was on plants treated with Biohumus MM and leaf area produced with Lumbrical was similar to the control. The correlation coefficient between shoot fresh weight and electrical conductivity (EC) of the mixtures before planting was r = 0.85* (asterisk indicate that correlation is significant at 0.05 level). This suggests that differences in EC of the potting mixtures, derived by vermicomposts which consequently affect nutrient availability could explain observed differences in growth response. Promotion of plant growth by vermicompost is attributed mostly to amounts of available nutrients (Atiyeh, Subler, Edwards, & Metzger, 1999; Atiyeh et al., 2001; Paul & Metzger, 2005; McGinnis, Wagger, Warren, & Bilderback, 2010; Theunissen, Ndakidemi, & Laubscher, 2010).

Table 4. Comparative effect of vermicomposts on some plant growth indices

Treatment	Shoot fresh weight, g		Shoot length, cm		Leaf numbers		Leaf area, cm^2	
Control	7.4	e*	12.5	d	5.3	d	7.8	d
Biohumus MM	16.1	a	19.8	a	6.1	ab	10.9	a
Biohumus NN	12.8	b	17.8	b	6.0	b	10.2	b
Chirpan vermicompost	10.6	c	16.9	bc	5.6	c	9.0	c
Lumbrical	9.0	d	17.6	b	6.3	a	8.2	d
WasteNoMore	10.4	c	16.2	c	5.5	c	8.8	cd

*Values in columns followed by different letter are significantly different at P<0.05, Duncan's Multiple Range Test.

However, nutrient content may not be the major factor influencing plant growth. WasteNoMore and Chirpan vermicompost differ in initial nutrient content (Table 1) but both had similar effects on plant growth. WasteNoMore is comparatively poor in nutrients, but it had the highest amount of microorganisms, while Chirpan vermicompost possess the highest organic matter content. Lumbrical is rich in nutrients, similar to Biohumus MM, but the effect on plant growth was not as evident. The observed differences might be due to physical properties of the substrate (Atiyeh et al., 2001; Hidalgo & Harkess, 2002a), and other biological factors including enhanced microbial and enzyme activity and presence of plant growth-promoting substances such as hormones and humates (Atiyeh et al., 2000c; Arancon et al., 2003; Bachman & Metzger, 2008; Yasir et al., 2009; Robledo et al., 2010).

3.4 Effect on Nutrients Concentrations in Shoots

Higher than control N, P, K concentrations were found in transplants grown in media supplemented with Lumbrical and WasteNoMore (Table 5). Higher N, K concentrations occurred in transplants treated with Biohumus MM, but P concentration was similar to controls. The N, P, K concentrations in plants treated with Chirpan vermicompost and Biohumus NN, were not different from controls. The P concentration was lower than in the control.

Table 5. N, P, K concentrations in tomato shoots, $mg \cdot g^{-1}$

Treatment	N		P		K	
Control	35.1	b*	75.4	c	207.1	b
Biohumus MM	40.4	a	68.0	c	270.8	a
Biohumus NN	36.7	b	57.0	d	260.4	ab
Chirpan vermicompost	38.8	ab	56.2	d	217.6	b
Lumbrical	43.2	a	97.6	a	302.0	a
WasteNoMore	40.8	a	88.0	b	258.4	ab

*Values in columns followed by different letter are significantly different at P<0.05, Duncan's Multiple Range Test

A moderate correlation (r = 0.61*) occurred between N concentration in plant tissues and nitrate level in potting mixtures before planting. This indicates that vermicomposts contribute to the plant N supply. This agrees with Hashemimajd et al. (2004) who also found a moderate correlation ($r = 0.42^{**}$) between total N content of composts and N in plant tissues.

The study was undertaken to analyze vermicomposts to determine their quality and potential use in transplant production. The chemical composition differed among vermicomposts regardless of similarity in production technologies and raw materials. The general characteristic of the vermicomposts was that they have high pH and electrical conductivity, indicating that they can not be used individually as a substrate for growing tomato transplants, but as a component of the potting mixture. When mixing vermicomposts with peat and perlite nutrient content decreased, due to the dilution, and kept nutrients within acceptable, or optimal, ranges for growing tomato transplants. Differences in growth responses were attributed to differences in nutrient content of potting mixes. Although the present study was focused more on effects of vermicomposts on plant growth rather than on causes leading to these effects, the results indicated that availability of nutrients is an important factor influencing plant growth. But changes in physical and biological properties of the substrate could also be responsible for observed differences.

Vermicomposts can be used in sustainable culture practices in horticulture, but their widespread use depends on economic benefits and farmer awareness about environmental issues. The optimal use rate for transplant production needs to be determined. Nutrient management guidelines for vermicompost application need to be developed, considering that vermicompost composition might vary even between different batches in one farm and is exclusively dependent on the parent material used.

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