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Characterization and use of a vegetable waste vermicompost as an alternative component in substrates for horticultural seedbeds

R. Melgar-Ramirez* and M. I. Pascual-Alex

Natural Resource Area. IFAPA «La Mojonera-La Cañada». Ctra. de La Playa. 04120 Almería. Spain

Abstract

This experiment was designed to characterize the physical and chemical properties of six crop's media obtained by mixing different percentages (v/v) of peat, perlite, coconut coir dust, and vermicompost (end-product of the breakdown of organic matter of crop residues mixed with re-used coconut coir dust by *Eisenia fetida*) and to evaluate the tomato (*Solanum lycopersicum* cv. cumquat) seedling growth in this media. The treatments were: T1 (75% peat and 25% perlite), T2 (25% peat, 25% coconut coir dust, 25% vermicompost and 25% perlite), T3 (50% peat, 25% vermicompost and 25% perlite), T4 (25% peat, 50% vermicompost and 25% perlite), T5 (50% coconut coir dust, 25% vermicompost and 25% perlite), T6 (25% coconut coir dust, 50% vermicompost and 25% perlite). The electrical conductivity, pH, bulk density and water-soluble elements, contained in the substrate, increased with increasing amounts of vermicompost in the substrate, whereas the total porosity, easily available water and total water holding capacity decreased significantly with increasing amounts of vermicompost. Stem length and leaf area of tomato seedlings were higher in the substrate without vermicompost (T1) but no significant differences were found between substrates with vermicompost. No significant difference was found in the production of roots dry weight in all treatments; this is a very important result, because good quality of root system is the main goal in seedbeds. There are not clear relationships between the increase of vermicompost in mixtures and nutrient contents in stems and leaves.

Additional key words: bioproductive variables; *Eisenia fetida*; seedling; *Solanum lycopersicum*; vegetable crop waste; water:air relationships.

Resumen

Caracterización y empleo de un vermicompost de residuos vegetales como componente alternativo de sustratos en semilleros hortícolas

Este experimento se diseñó para caracterizar las propiedades físicas y químicas de seis medios de cultivo diferentes, obtenidos por la mezcla, en diferentes proporciones (v:v), de turba, perlita, fibra de coco y vermicompost (producto final obtenido de la degradación de restos hortícolas mezclado con fibra de coco reutilizada a través de la acción de *Eisenia fetida*) y evaluar el crecimiento de plántulas de tomate (*Solanum lycopersicum* cv. cumquat) en estos sustratos. Los tratamientos fueron: T1 (75% turba y 25% perlita), T2 (25% turba, 25% fibra de coco, 25% vermicompost y 25% perlita), T3 (50% turba, 25% vermicompost y 25% perlita), T4 (25% turba, 50% vermicompost y 25% perlita), T5 (50% fibra de coco, 25% vermicompost y 25% perlita), T6 (25% fibra de coco, 50% vermicompost y 25% perlita). La conductividad eléctrica, pH, densidad aparente y los elementos solubles contenidos en los sustratos aumentaron a medida que se aumentó la cantidad de vermicompost, mientras que la porosidad total y la cantidad de agua total y fácilmente asimilable, decreció significativamente al incrementar la cantidad de vermicompost. La longitud del tallo y el área foliar fueron mayores en el sustrato que no contenía vermicompost (T1), pero no se observaron diferencias significativas en la producción de peso seco de la raíz en todos los tratamientos. Este es un resultado importante, ya que el desarrollo de un buen sistema radicular es el objetivo principal en la producción de plántulas para trasplante. Finalmente no se observó una relación clara entre el incremento de vermicompost en las mezclas y el contenido en nutrientes en tallos y hojas.

Palabras clave adicionales: *Eisenia fetida*; parámetros bioproductivos; plántulas; restos de cultivos; relaciones aire:agua; *Solanum lycopersicum*.

* Corresponding author: raquel.melgar@juntadeandalucia.es
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Raquel Melgar Ramírez is member of the SECH.

Abbreviations used: BD (bulk density), CEC (cation exchange capacity), EC (electrical conductivity), OM (organic matter), PD (particle density), TN (total nitrogen).

Introduction

In recent years, due to limiting factors in intensive farming using natural soil, such as salinity, diseases, depletion of nutrients and contamination of aquifers, there has been a gradual shift away from traditional cultivation in soil, to cultivation in other growing mediums. The most commonly used alternative substrates for this type of cultivation are: perlite, peat, rock wool and coconut coir dust. Besides the intensive farming sector, another agricultural sector dependent on the use of substrates is made up of companies dedicated to the propagation of plants. These companies usually use peat as a base, and mix this with perlite or vermiculite in order to modify the properties of aeration and water retention. Given the present day economic situation, the price of the most commonly used substrates is increasing. This is mainly due to the increase in transportation costs, and, in the case of peat, due to it being a natural resource with limited long term availability. Therefore, at present, new alternative materials are being studied and developed which may replace traditional substrates (Raviv *et al*., 1986; Abad *et al*., 1997, 2001; Pérez-Murcia *et al.,* 2006; Bustamante *et al.,* 2008; Warman and Anglopez, 2010).

With this in mind, the use of waste materials, such as almond shell, pine bark compost, or solid urban refuse, etc, are being looked at as a proven alternative. These materials supply nutrients, increase the cation exchange capacity (CEC) and increase the water retention capacity (Tomati *et al*., 1990). Beginning with this idea, and given that agricultural activity in the west of Almería generates a large amount of organic waste (1 million tonnes per year) (Cara and Ribera, 1998; Miguéiz and Añó, 2002), which has a serious environmental impact when it is dumped and accumulates. That waste materials, once processed, could be transformed into a valid resource for use as a substrate.

A material which is gaining importance in the agricultural sector is the vermicompost. Vermicomposting —the transformation of organic waste by means of the combined action of earthworms and micro organisms— is seen as a clean, low cost alternative for the transformation of these waste materials. The products obtained from this technique have the same benefits as traditional compost — high levels of macro and micro nutrients in a form which is easy to assimilate for cultivation (García *et al*., 1990), and an improvement in the physical— chemical and biological properties of soil, as well as other growing mediums. Furthermore, the use of vermicomposts appears to favour vegetal development in a way that is not directly related to physical or chemical properties (Dash and Petra, 1979), but through a phytohormonal activity related to the microflora associated with vermicomposting, and to the metabolites produced as a consequence of secondary metabolism (Parle, 1963; Tomati *et al*., 1987; Atiyeh *et al*., 2002). Therefore, these products can be used as substrates in seedbeds or in soilless cultivation without any risk of biological or chemical contamination (Atiyeh *et al.*, 2000b; Brown *et al*., 2000), reducing the amount of fertilizer, soil additives and substrates needed (Costa *et al*., 1991; Climent *et al*., 1996; Abad and Puchades, 2002).

Previous studies have concluded that mixtures made with different proportions of vermicompost could be suitable for use as alternative substrates for seedbeds for aromatic plants, provided that no more than 50% of vermicompost is used (Pascual *et al*., 2006).

The main objective of this study has been to characterize five different mixtures of a vermicompost (prepared using the remains of peppers originating from intensive farming under plastic sheeting and recycled coconut coir dust) with substrates commonly used in seedbeds, and to evaluate their possible use as an alternative substrate.

Material and methods

Six mixtures (v/v) of commercial blonde *Sphagnum* peat (Kekkilä-C1), coconut coir dust (Cocopeat®), perlite (B12) and vermicompost were studied, in order to evaluate the agronomic potential of a vermicompost obtained by the action of the *Eisenia fetida* worm on a mixture of vegetable waste from pepper crops and recycled coconut coir dust in the proportion 3:1 (v/v). Vermicomposting wastes were carried out by *Eisenia fetida* over four months on a pilot scale. Chemical properties of vermicompost were: pH 8.4; EC 3.5 dS m^{-1}; TN 2.48%; OM 29.9%.

The treatments evaluated were: a control T1 (75% peat and 25% perlite), T2 (25% peat, 25% coconut coir dust, 25% vermicompost and 25% perlite), T3 (50% peat, 25% vermicompost and 25% perlite), T4 (25% peat, 50% vermicompost and 25% perlite), T5 (50% coconut coir dust, 25% vermicompost and 25% perlite), T6 (25% coconut coir dust, 50% vermicompost and 25% perlite). Based on the work of Atiyeh *et al.* (2001); Arancon *et al.* (2004); Bustamante *et al.* (2008), the content of vermicompost in the mixture did not exceed 50%.

Characterization of the substrates used

Previous to transplant, the following variables were evaluated: the particle density (PD), bulk density (BD), porosity, granulometry, organic matter (OM), total nitrogen (TN), cation exchange capacity (CEC), electrical conductivity (EC) and pH, assimilable nitrogen, soluble elements in water (P, Na, K, Ca, Mg and S).

The PD was estimated from the ashes (Martínez, 1992); the BD by determining dry material at 105°C contained within a known volume; porosity, calculated from the two previous variables; the granulometric analysis described in Ansorena (1994); OM was determinate by loss on ignition for 4 h at 540°C; TN was determined by the Kjeldahl method; CEC by titration with NaOH 0,1N (AOAC, 1990); EC and pH in water extract 1:5 (v:v) (obtained according to Norm UNE-EN 13040) in accordance with the MAPA (1986) method for organic material.

The assimilable N (nitric and ammoniacal) determination was carried out in accordance with the procedure set out by Purchades *et al.* (1985), in which the concentrations of nitric N and ammoniacal N are determined by the NH_3 levels obtained from two successive distillations of the extracts 1:5 (v/v) with anhydric magnesium oxide and Devarda's alloy respectively. The determination of water soluble elements (Na, K, Ca, Mg, Fe, Cu, Zn, Mn) was carried out on the extract 1:5 (v:v) (Norm UNE-EN 13652) using atomic absorption spectrophotometry (UNICAM 969). Phosphorous was determined by colorimetry method (molybdenum blue method) at 650 nm in spectrophotometer (Nicolet evolution 300-Thermo), Cl^- and SO_4^{2-} with ionic chromatography (Metrohm 790).

The hydrophysical properties of the treatments evaluated, such as the air capacity (AC), easily available water (EAW), water buffering capacity (WBC), total water holding capacity (TWHC) and unavailable water (UW) were obtained through the water release curve in glass funnel as described by De Boodt *et al*. (1974).

Growth, development and the nutritional state of seedbed tomato seedlings

Seedbed tomato seedlings (*Solanum lycopersicum* cv. cumquat) grown in the six mixtures of substrate under consideration were evaluated agronomically. The trial lasted 38 days and took place in a growth chamber where an average temperature of 23°C and a relative humidity of 85% were maintained. All treatments were fertilized daily with a standard nutritive solution (11.6 mmol L^{-1} N (NO_3^-+ NH_4^+); 1.4 mmol L^{-1} $H^2PO_4^-$; 5 mmol L^{-1} SO_4^{2-}; 4 mmol L^{-1} K^+; 5 mmol L^{-1} Ca^{2+} and 1.6 mmol L^{-1} Mg^{2+}; pH: 6.5; E.C: 2.29 dS m^{-1}). The «Latin square» experimental design was followed, with 6 repetitions per treatment and 16 cells per repetition. The variables studied were germination percentage, stem height, leaf area and seedling dry weight.

At the end of the experiment, a chemical analysis was carried out on the vegetal material separated into limbs, stems, petioles and roots. As there was not sufficient vegetal material for the analysis, the 6 repetitions of each treatment were mixed, so 3 repetitions for each treatment were analyzed.

The vegetal material was burnt in a muffle furnace at 540°C in order to obtain ashes which were re-suspended in an acid medium (6 M HCl). The Na, K, Ca and Mg of this extract were measured by atomic absorption spectrophotometry (UNICAM 969) and phosphorous was determined by colorimetric method (molybdenum blue method) at 650 nm in Spectrophotometer (Nicolet evolution 300-Thermo). Additionally, the TN was determined by the Kjeldahl method.

Statistical analysis

All the data is based on an average of 3 repetitions, except those of the development and vegetal growth which is based on an average of 6 repetitions. The results have been statistically interpreted by variance analysis ($p < 0.05$) using the STATGRAPHICS Plus 5.1 program.

Results and discussion

Characterization of the substrates

Table 1 shows the chemical and physical properties of the six treatments. In general, all the substrates, except control (T1), showed pH and EC values higher than those established in optimal range (5.2-6.3 and < 0.5 dS m^{-1}, respectively; Abad *et al.*, 2001; Noguera *et al*., 2003; Sánchez-Monedero *et al.,* 2004). The increase in EC could be due to a greater concentration of soluble salts and nutrients, as shown in Table 3.

Table 1. Chemical and physical properties of six treatments

	T1	T2	T3	T4	T5	T6
Chemical properties						
pH	5.62[d 1]	8.01[c]	7.93[c]	8.71[b]	8.63[b]	8.95[a]
EC (dS m^{-1}) (25°C)	0.19[e]	0.76[b]	0.61[d]	0.96[a]	0.72[c]	0.99[a]
CEC ($cmol_+$ kg^{-1})	94.69[a]	59.24[c]	67.61[b]	56.15[c]	55.57[c]	55.37[c]
N (%)	0.81[c]	1.19[a]	1.29[a]	1.32[a]	0.99[b]	1.26[a]
OM (%)	61.78[a]	46.14[c]	49.04[b]	37.01[d]	45.91[c]	37.97[c]
C/N	45.59[a]	22.64[bc]	22.14[bc]	16.35[c]	26.95[b]	17.55[c]
Physical properties						
Particle density (g cm^{-3})	1.80[f]	1.96[c]	1.93[d]	2.06[a]	1.96[c]	2.05[b]
Bulk density (g cm^{-3})	0.12[f]	0.18[c]	0.18[c]	0.24[a]	0.15[d]	0.21[b]
Granulometry (%)						
> 10 mm	0.74[a]	0.04[b]	0.01[b]	0.03[b]	0.05[b]	0.03[b]
> 5 mm	4.91[a]	0.64[c]	0.85[b]	0.59[cd]	0.51[cd]	0.48[d]
> 2 mm	39.26[a]	21.87[b]	22.47[b]	17.78[b]	20.24[b]	19.21[b]
> 1 mm	15.79[d]	26.45[c]	26.87[bc]	28.67[ab]	27.06[bc]	29.69[a]
> 0.5 mm	13.84[d]	22.82[bc]	21.57[c]	24.40[a]	23.67[ab]	24.04[ab]
< 0.5 mm	25.11[a]	28.06[a]	28.1[a]	28.43[a]	28.31[a]	26.46[a]

[1] Means within the same row followed by the same letter are not significantly different at $p < 0.05$.

These results concur with those observed by Atiyeh *et al.* (2000a, 2001) on work carried out on mixtures of a manure based vermicompost and a commercial substrate.

The CEC was significantly lower in the treatments containing vermicompost, although the levels observed in all of the treatments were high (Table 1), which ensures a reserve deposit of available nutrients and guarantees a high buffering capacity when faced with changes in pH (Abad *et al.*, 1993).

The C/N relationship of the control treatment T1 (perlite and peat) slightly exceeded the recommended level (< 40) given by Bunt (1988) and Abad *et al.* (1993) for cultivation substrates, whilst the rest of the treatments which included vermicompost showed a C/N relationship within the optimum range. This variable is related to the stability of the material, and optimum C/N relationship levels show that the material is chemically stable over time, and consequently, does not easily degrade.

The PD and BD levels remained within the range recommended by Abad *et al.* (1993), although they were greater in T4.

As far as the granulometry is concerned, no significant differences were seen in the distribution of particles smaller than 0.5 mm between treatments. What was observed was that the control had a greater proportion of particles between 2 and 10 mm compared to the other treatments which included vermicompost, whilst the treatments containing vermicompost had a greater percentage of particles measuring between 0.5 and 2 mm, a percentage which increased as the amount of vermicompost increased.

Table 2 shows the hydrophysical properties of the mixtures. There were significant differences between the six treatments with regard to total porosity, which reduced slightly as the amount of vermicompost increased, although all the treatments were within the optimum limits (> 85) recommended by Abad *et al.* (1993, 2001). This reduction is in line with the increase in BD observed in the samples containing vermicompost (Table 1). However, the levels of easily obtainable water and totally available water for all the substrates containing vermicompost were below the optimum range established by De Boodt and Verdonck (1972) and Abad *et al.* (1993, 2001), especially in mixtures T4, T5, and T6, which contained coconut coir dust and 50% vermicompost. As long as there is adequate irrigation, then these relatively low water retention characteristics in the mixtures containing vermicompost should not be seen as implying an agronomic limitation. Finally, the mixture of vermicompost and coconut coir dust (T5 and T6) increased the aeration capacity of the substrates, showing very high, unrestricted levels for all of the mixtures of substrate evaluated.

Table 2. Hidrophysical properties of the mixtures (%)

	Aceptable range[1]	T1	T2	T3	T4	T5	T6
TP[2]	> 85	93.3[a 3]	90.8[d]	90.9[c]	88.3[f]	92.3[b]	89.8[e]
AC	20-30	36.9[c]	41.5[b]	42.4[b]	41.7[b]	50.4[a]	47.8[a]
EAW	20-30	21.3[a]	16.7[b]	17.2[b]	12.9[c]	12.9[c]	12.3[c]
WBC	4-10	5.5[a]	4.2[b]	4.3[b]	3.6[bc]	2.6[d]	2.9[cd]
TWHC	55-80	26.8[a]	21.0[b]	21.5[b]	16.6[c]	15.4[c]	15.1[c]
UW	—	29.6[a]	28.4[ab]	27.0[b]	30.1[a]	26.5[b]	26.8[b]

[1] According to Abad *et al.* (2001) and Noguera *et al.* (2003). [2] TP: total porosity; AC: air capacity; EAW: easily available water; WBC: water buffering capacity; TWHC: total water holding capacity; UW: unavailable water. [3] In each row different letters indicate statistically different values ($p < 0.05$).

The chemical composition of the extract in water of the six substrate mixtures is shown in Table 3. The addition of vermicompost to the mixture significantly increased the content of the majority of nutrients, the increase being greater as the proportion of vermicompost increased. For K^+, Ca^{2+}, Mg^{2+}, NH_4^+, SO_4^{-2} and HCO_3^- the greatest concentrations were found in treatments T4 and T6 (treatments in which the proportion of vermicompost was 50%) and the lowest concentration was found in the control mixture (T1). With regard to P, the greatest concentration occurred in treatments T2 and T6, these were significantly different from the rest of the treatments. To summarize, and taking into account these results, there could be a reduction in the amount of mineral fertilizer applied during cultivation for the mixtures of substrate in which vermicompost has been substituted for part of the peat, since the vermicompost can be regarded as an important source of essential nutrients for the plants.

Growth, development and the nutritional state of tomato seedlings

Figure 1 shows the measured bioproductive data of the seedbed seedlings. Vermicompost did not induce any reduction in the germination rate, according to statistical analysis.

Different investigations have shown that vermicompost increases the germination of the seeds (Alves and Passoni, 1997) possibly due to phytohormonal activity found in different vermicomposts (Edwards and Burrows, 1988). In our case, the germination index was similar in the six treatments (> 85%); there were no significant differences in the number of germinated seedlings in the different substrate mixtures. The fact that we did not find that the vermicompost affected germination could be due to the fact that the seeds used in our experiment were supplied by a commercial seed company which guaranteed a high germination

Table 3. Water soluble element of six substrate mixtures [mg $L^{-1}{}_{(substrate)}$]

	T1	T2	T3	T4	T5	T6
NO_3^-	146[f 1]	201[e]	224[d]	336[c]	377[b]	510[a]
K^+	25.05[f]	838[c]	608[e]	1,098[b]	456[d]	1,162[a]
Ca^{2+}	130[c]	125[c]	159[b]	201[a]	146[b]	200[a]
Mg^{2+}	1.75[f]	26.90[e]	41.20[c]	81.95[a]	37.55[d]	53.55[b]
Na^+	9.98[e]	165b[c]	82.85[d]	148[c]	200[a]	189[ab]
NH_4^+	81.60[d]	157[c]	183[c]	360[a]	141[cd]	264[b]
Cl^-	16.30[a]	8.00[e]	9.40[d]	16.30[a]	15.55[b]	13.80[c]
SO_4^{2-}	53.75[f]	157[d]	176[c]	425[a]	77.76[e]	306[b]
HCO_3^-	5.00[f]	9.00[c]	8.00[d]	13.50[b]	7.00[e]	15.00[a]
P	31.05[d]	84.75[a]	52.15[c]	55.22[c]	71.82[b]	78.48[ab]
Fe	0.48[bc]	1.01[a]	0.16[d]	0.65[b]	0.51[bc]	0.42[c]
Cu	nd[2]	0.21[a]	0.19[a]	0.25[a]	0.10[b]	nd
Zn	nd	nd	nd	nd	nd	nd
Mn	0.23[a]	0.16[c]	0.16[c]	0.18[bc]	0.17[bc]	0.20[ab]

[1] In each row different letters indicate statistically different values ($p < 0.05$). [2] nd: not detected.

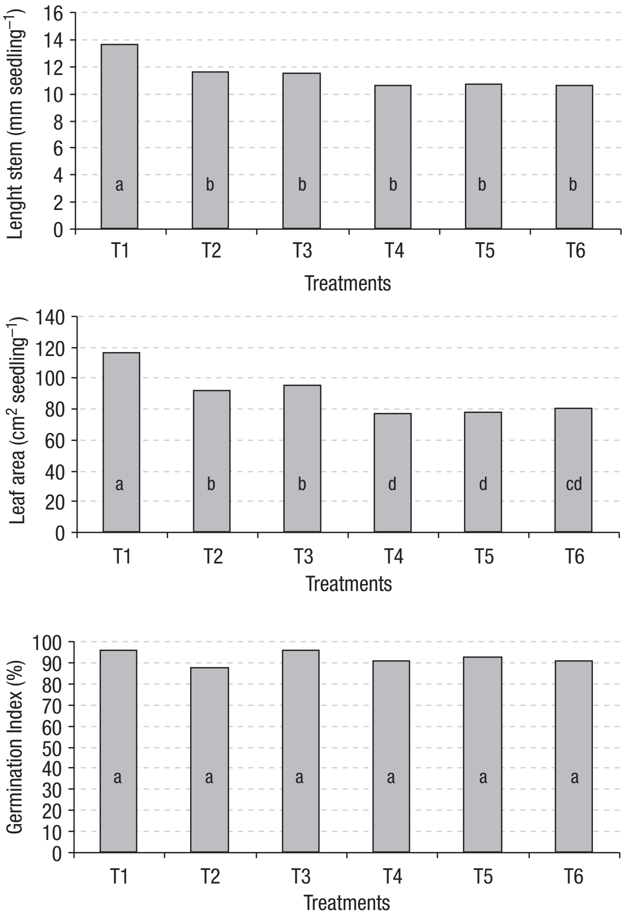

Figure 1. Effects of the treatments on tomato length stem, leaf area and germination index. Treatments with the same letter are not significantly different ($p < 0.05$).

percentage, so we cannot rule out the possibility that our vermicompost may have a positive effect on germination.

It was noted that the stem height and the leaf area of the seedbed seedlings grown in the control substrate were significantly greater than in the rest of the substrates (Fig. 1). Also, the leaf area was smaller in the treatments which included more 50% vermicompost (T4-T6) and 50% coconut coir dust (T5).

Table 4 shows the production of dry weight and its distribution. The production of aerial dry weight was lower for the tomato seedlings grown in mixtures of substrates containing vermicompost 50% and vermicomposts mixed with coconut coir dust. The production of limb and petiole dry weight was significantly higher in treatments T1, T2 and T1, T2, T3 respectively, whilst that stem was greater in the seedlings in treatment T1, there being no significant differences between the seedlings in T2 and T3, which at the same time were greater than in seedlings from T4, T5 and T6. This could be related with the different hydrophysical properties of treatment T2 and T3. No significant differences were found in the production roots dry weight in all treatments. This is an important result, because a good quality root system is the main goal in seedbeds.

Figure 2 shows the distribution of dry weight in the seedling. For all of the treatments, the percentage of dry weight assigned to the root of the seedling was

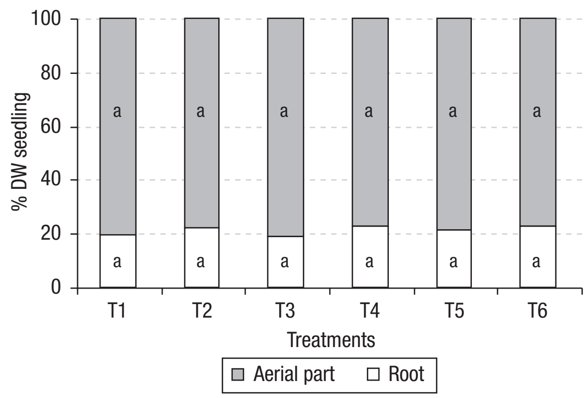

Figure 2. Distribution of dry material in the seedling. Treatments with the same letter are not significantly different ($p < 0.05$).

Table 4. Production of dry weight and distribution (mg seedling^{-1})

	T1	T2	T3	T4	T5	T6
Limbs	189.74^{a} [1]	159.66^{bc}	173.36^{ab}	134.44^{cd}	132.27^{d}	137.01^{cd}
Stems	64.62^{a}	50.29^{b}	52.63^{b}	38.33^{c}	38.66^{c}	39.14^{c}
Petioles	52.30^{a}	46.12^{ab}	49.01^{a}	37.79^{bc}	34.35^{c}	38.59^{bc}
Roots	73.58^{a}	72.27^{a}	66.92^{a}	61.07^{a}	61.46^{a}	63.65^{a}
Aerial part	306^{a}	256^{b}	275^{ab}	210^{c}	205c	214^{c}
Total	380^{a}	328^{b}	342^{ab}	272^{c}	267^{c}	278^{c}

[1] In each row different letters indicate statistically different values ($p < 0.05$).

Table 5. Extraction of nutrients by tomato seedling (mg seedling^{-1})

	T1	T2	T3	T4	T5	T6
N	15.32^{a} [1]	12.75^{b}	13.30^{b}	10.78^{c}	10.71^{c}	10.68^{c}
P	2.96^{a}	2.38^{ab}	2.16^{ab}	1.83^{b}	1.57^{b}	1.77^{b}
K	20.55^{ab}	22.74^{a}	20.43^{ab}	18.27^{b}	19.91^{ab}	18.69^{b}
Ca	6.61^{a}	4.34^{b}	4.29^{b}	3.53^{b}	2.91^{b}	3.77^{b}
Mg	3.48^{ab}	3.43^{ab}	3.69^{a}	3.17^{ab}	2.97^{b}	3.38^{ab}
Na	2.56^{a}	2.32^{ab}	1.76^{bc}	1.38^{c}	2.00^{abc}	1.68^{bc}

[1] In each row different letters indicate statistically different values ($p < 0.05$).

around 20% of the total biomass, there were no significant differences between treatments. The same thing occurred with aerial part of the plant, the percentage in the seedling being around 80%.

Table 5 shows the values which correspond to the extraction of nutrients by the tomato seedlings. Generally, seedlings grown in the control mixture extracted a greater quantity of nutrients (N, P, Ca and Na). Those results are related with pH conditions, the values of pH in T1 were much better for nutrient availability than obtained in the others treatments. The seedlings grown in mixtures containing peat also had the highest levels of N, P, Ca and Na. There were no significant differences in the extraction of nutrients between treatments T3 and T4, or between T5 and T6, except for N which had the highest levels in T3.

Table 6. Effects of the treatments on the nutrient content of tomato seedling's limbs, stems, petioles and roots (% dw)

	N	P	K	Ca	Mg	Na
Limb						
T1	4.82^{a} [1]	1.16^{a}	3.69^{c}	2.41^{a}	1.03^{c}	0.38^{a}
T2	4.4^{c}	0.78^{a}	5.04^{a}	1.85^{b}	1.18^{b}	0.49^{a}
T3	4.69^{ab}	0.81^{a}	4.11^{bc}	2.15^{ab}	1.14^{bc}	0.35^{a}
T4	4.67^{ab}	0.85^{a}	4.62^{ab}	1.8^{b}	1.22^{ab}	0.28^{a}
T5	4.42^{c}	0.77^{a}	4.5^{abc}	1.8^{b}	1.24^{ab}	0.46^{a}
T6	4.54^{bc}	0.88^{a}	4.95^{a}	2.04^{ab}	1.35^{a}	0.54^{a}
Stems						
T1	3.14^{e}	0.50^{d}	9.42^{c}	0.58^{a}	0.71^{bc}	1.05^{a}
T2	3.56^{a}	1.04^{ab}	11.45^{a}	0.46^{b}	0.70^{bc}	1.03^{a}
T3	3.47^{b}	0.71^{c}	10.37^{b}	0.58^{a}	0.85^{ab}	0.85^{ab}
T4	3.24^{d}	0.94^{b}	11.62^{a}	0.47^{b}	0.84^{ab}	0.81^{ab}
T5	3.34^{c}	1.04^{ab}	11.78^{a}	0.42^{b}	0.64^{c}	1.02^{a}
T6	3.38^{c}	1.06^{a}	11.46^{a}	0.45^{b}	0.90^{a}	0.69^{b}
Petiole						
T1	3.45^{a}	0.26^{d}	7.91^{c}	1.37^{a}	0.87^{bc}	1.39^{a}
T2	3.35^{a}	0.27^{cd}	10.01^{a}	0.85^{bc}	0.88^{bc}	1.39^{a}
T3	2.81^{a}	0.39^{ab}	8.57^{b}	0.97^{b}	0.97^{ab}	1.03^{b}
T4	3.30^{a}	0.43^{a}	9.93^{a}	0.78^{bc}	1.07^{a}	1.06^{b}
T5	3.16^{a}	0.38a^{bc}	9.90^{a}	0.67^{c}	0.80^{c}	1.29^{a}
T6	3.26^{a}	0.30^{bcd}	9.83^{a}	0.68^{c}	1.09^{a}	0.97^{b}
Root						
T1	2.88^{c}	0.30^{c}	4.48^{b}	1.20^{a}	0.82^{d}	0.56^{a}
T2	3.26^{ab}	0.19^{d}	5.87^{a}	1.05^{a}	1.09^{c}	0.51^{abc}
T3	3.06^{bc}	0.22^{cd}	5.59^{a}	0.98^{a}	1.24^{ab}	0.48^{bc}
T4	3.34^{a}	0.71^{a}	6.43^{a}	1.03^{a}	1.30^{a}	0.47^{bc}
T5	2.83^{c}	0.57^{b}	5.76^{a}	1.00^{a}	1.02^{c}	0.53^{ab}
T6	3.00^{bc}	0.52^{b}	5.80^{a}	1.15^{a}	1.22^{b}	0.45^{c}

[1] In each column different letters indicate statistically different values ($p < 0.05$).

Table 6 shows the main effects of the treatments studied on the nutrient content of the tomato seedlings' limbs, stems, petioles and roots. In general terms, the concentrations of N, P and K in the treatments containing vermicompost were greater than in the control treatment. There were no significant differences in the concentrations of these elements (in limb, stem, petiole and root) between treatments T5 y T6.

In general terms, no significant differences were observed between treatments with the same substrates but with different doses of these in limbs, stems and petioles. In other words, the increase in the dose of vermicompost did not have an effect on the nutrient content, but this result is normal, because all treatments were irrigated with the same nutrient solution. In the case of the roots, a slight increase in nutrient concentration was noted as the dose of vermicompost increased in the mixtures used.

Conclusions

The use of vermicompost as part of the mixture of substrates for the production of seedbed tomato seedlings increased EC, the pH value and the nutrient content of the substrate solution, but reduced the CEC. Substrates containing vermicompost provided the plants with significant quantities of essential nutrients, which should be taken into account in fertirrigation.

The addition of waste vegetable vermicompost to the substrate mixture reduced total porosity and the amount of easily available water, and increased the aeration capacity of the substrate. However, different doses of vermicompost did not affect the germination of the tomato seeds. This is an important result, in economic terms, because the efficiency of seedbeds is one of the main factors determining the costs in seedling production, moreover, the use of these vermicompost can minimize two problems: the environmental impact that these wastes can cause and the peat extraction.

From the obtained data, it can be concluded that, in general, the substrates elaborated with waste vegetable vermicomposts needs a pre-treatment (*e.g.,* make a sieving at the beginning of the experiment to obtain particle distribution similar with control. Changes the pH to increase nutrient availability and therefore, reduce the use of fertilizer).

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