SEMICOMPOST AND VERMICOMPOST MIXED WITH PEAT MOSS ENHANCE SEED GERMINATION AND DEVELOPMENT OF LETTUCE AND TOMATO SEEDLINGS

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SUMMARY

Peat moss is one the most popular organic substrates used for the production of plantlets in greenhouse; however, this material is imported, expensive and non-renewable. In this study, we evaluated the effect of different ratios of vermicompost (V) and semicompost (S) of cattle manure and pine sawdust, mixed with peat poss (PM), on seed germination and seedling development of lettuce and tomato under greenhouse conditions. Five treatments, including the proportions 1V:2PM, 2V:1PM, 1S:2PM, 2S:1PM, and PM as control, were established under a completely randomized design with four replicates, each represented by a tray with 100 seedlings. Results showed statistical differences among treatments (P≤0.05). In lettuce, 2V:1PM was greater than the control in germination (12.5%), leaf area (94.5%) and number of leaves (54.3%); in tomato 1S:2PM was superior than the control in germination (16.8%), leaf area (80.2%), number of leaves (46.6%) and seedling height (66.3%). In root development of lettuce, 2V:1PM was higher than control with 74.1% and 44.4% in root length and in root volume, respectively. In tomato, 1S:2PM increased by 53.0% and 89.3% root length and root volume, respectively, compared to the control. These results show that the mixtures of vermicompost and semicompost with peat moss, in different proportions, improved the germination and development of lettuce and tomato seedlings, which makes them appropriate for use in agriculture.

Introduction

The growth substrate is an important component in seedling production. The commercial production of vegetable seedlings for transplant requires large volumes of substrates. The term substrate refers to any material, natural or synthetic, organic or inert, in pure form or mixed, whose main function is to serve as a medium for growth and development of plants by providing anchorage, support, water and oxygen to the root system (Rojas *et al*., 2007). Good germination rates for different substrates can be attributed, among other factors, to high biological stability and low salt levels (Zapata *et al*., 2005). In Mexico, the primary substrates used to produce seedlings are coconut coir and peat moss (Muratalla-Lua *et al*., 2006). Peat moss is noted for its qualities to retain moisture, good structure, and sterility (De Grazia *et al*., 2007; Schmilewski, 2008), but it is a non-renewable and very expensive substrate. In addition, it has an acid pH (4-6; Brown *et al*., 2000) and low nutrient content in comparison with other substrates.

On the other hand, improperly handled organic waste can cause serious environmental problems. In the State of Chihuahua, Mexico, dairy cattle generate on a dry matter basis a total of 312,609t/year of manure, causing soil and groundwater contamination (NRAES, 1999; Jurado, 2004). The timber forestry sector, achieves only 19.2% efficiency in the wood transformation sawmilling process, and sawdust becomes the primary generated sub product (Zaragoza, 2004).

Traditionally, organic waste has been considered as an important source of contamination. Semicompost and vermicompost from this organic waste need to be assessed as substrates and organic fertilizers. The main purpose of composting is to reach a stable product with high contents of essential elements, which are readily available to plants (Mondini *et al*., 2003). In this regard, Avilés and Tello (2001) found that the stability of composts has a great effect on the germination, growth, and development of seedlings. Nonetheless, there is a need for more specific research related to compost composition and its effect on seed germination, and plant growth and development (Giulietti *et al.,* 2008; Oberpaur *et al*., 2012).

KEYWORDS / Cattle Manure / Germination / *Lactuca sativa* L. / Root-Bulk Soil / Sawdust / *Solanum lycopersicon* L. /

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SEMICOMPOSTA Y VERMICOMPOSTA MEZCLADA CON TURBA DE MUSGO INCREMENTA LA GERMINACIÓN DE SEMILLA Y DESARROLLO DE PLÁNTULAS DE TOMATE Y LECHUGA

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RESUMEN

La turba de musgo es uno de los sustratos orgánicos más utilizados para la producción de plántulas en invernadero; sin embargo, es un producto importado, costoso y no renovable. En este estudio se evaluó el efecto de diferentes proporciones de vermicomposta (V) y semicomposta (S) mezcladas con turba de musgo (PM) sobre la germinación y desarrollo de plántulas de lechuga y tomate en invernadero. Se evaluaron cinco tratamientos, incluyendo las proporciones 1V:2PM, 2V:1PM, 1S:2PM, 2S:1PM y el PM como control, establecidos bajo un diseño completamente al azar con cuatro repeticiones, cada una representada por una charola con 100 plántulas. Los resultados mostraron diferencias estadísticas entre tratamientos (P≤0,05). En lechuga 2V:1PM fue superior al control en germinación (12,5%), área foliar (94,5%) y número de hojas (54,3%); en tomate, 1S:2PM superó al control en germinación (16,6%), en área foliar (80,2%), número de hojas (46,3%) y altura de la plántula (66,3%). En el desarrollo radicular de lechuga, 2V:1PM fue superior que el control en 74,1% y 44,4% en longitud y volumen de raíz, respectivamente. En tomate, 1S:2PM incrementó un 53,0% y 89,3% la longitud y el volumen de raíz, respectivamente, comparado con el control. 2S:1PM destacó en la calidad de cepellón. Estos resultados muestran que las mezclas de vermicomposta y semicomposta, con turba de musgo en diferentes proporciones, mejoraron la germinación y desarrollo de las plántulas de lechuga y tomate, lo cual las hace adecuadas para su utilización en agricultura

SEMICOMPOSTAGEM E VERMICOMPOSTAGEM MESCLADA COM TURFA DE MUSGO INCREMENTA A GERMINAÇÃO DE SEMENTE E DESENVOLVIMENTO DE PLÂNTULAS DE TOMATE E ALFACE

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RESUMO

A turfa de musgo é um dos substratos orgânicos mais utilizados na produção de plântulas em estufa; no entanto, é um produto importado, custoso e não renovável. Neste estudo foi avaliado o efeito de diferentes proporções de vermicompostagem (V) e semicompostagem (S) mescladas com turfa de musgo (PM) sobre a germinação e desenvolvimento de plântulas de alface e tomate em estufa. Avaliaram-se cinco tratamentos, incluindo as proporções 1V:2PM, 2V:1PM, 1S:2PM, 2S:1PM e o PM como controle, estabelecidos sob um desenho completamente aleatório com quatro repetições, cada uma representada por uma bandeja com 100 plântulas. Os resultados mostraram diferenças estatísticas entre tratamentos (P≤0,05). Em alface 2V:1PM foi superior ao controle em germinação (12,5%), área foliar (94,5%) e número de folhas (54,3%); em tomate, 1S:2PM superou ao controle em germinação (16,6%), em área foliar (80,2%), número de folhas (46,3%) e altura da plântula (66,3%). No desenvolvimento radicular de alface, 2V:1PM foi superior que o controle em 74,1% e 44,4% em longitude e volume de raiz, respectivamente. No tomate, 1S:2PM incrementou 53,0% e 89,3% o comprimento e o volume de raiz, respectivamente, comparado com o controle. 2S:1PM destacou na qualidade de bola de raízes. Estes resultados mostram que as mesclas de vermicompostagem e semicompostagem, com turfa de musgo em diferentes proporções, melhoraram a germinação e desenvolvimento das plântulas de alface e tomate, o que faz com que sejam adequadas para sua utilização na agricultura.

In addition, Richmond (2010) found that the application of organic fertilizers to mixtures of substrates significantly improved substrate chemical properties, resulting in a better plant performance. Thus, the goal of this study was to evaluate the effectiveness of vermicompost and semicmpost made of cattle manure and pine sawdust mixed in different ratios with peat moss on seed germination and seedling development of lettuce (*Lactuca sativa* L.) and tomato (*Solanum lycopersicon* L.) under greenhouse conditions. With this study, we expect to reduce the use of peat moss by including vermicompost and semicompost as novel substrates in the production of lettuce and tomato seedlings. These substrates, cheaper than peat moss, are available in the local market.

Materials and Methods

Study location

The study was conducted at the Facultad de Ciencias Agrotecnológicas, Universidad Autónoma de Chihuahua, México, located at 31º47”N and 109º 07”O, and altitude of 1292 masl, with a temperate climate classified as BS1K (INEGI, 2015), 403mm average pluvial precipitation, and a 18.2ºC annual average temperature.

Semicompost and vermicompost production

Two organic fertilizers, obtained from semicomposting and vermicomposting of cattle manure and pine sawdust were selected. Raw manure of cattle was obtained from 2 to 5 years old Holstein cows of a dairy farm, confined in a 50×40m^2 area and fed with rolled corn, wheat bran, ground cotton seed, soy paste, alfalfa and corn silage. Cattle manure, as a source of nitrogen (N), was mixed with fine-particle (<2mm) of pine (*Pinus* sp.) sawdust as a source of carbon (C), for the preparation of the initial composting mixture with a 25/1 C/N ratio, which is expected to be within the optimal range suggested for the composting and vermicomposting processes (Hernandez-Rodriguez *et al.* 2010). To ensure the quality of these substrates, total nitrogen was determined by the Micro-Kjeldahl method (TASAR, 2006), organic carbon by the Garcia and Ballesteros (2005) method, and humidity by the drying method (ASTM, 2000).

The initial mixture was deposited in eight thick plastic containers with dimensions of 36×58×28cm^3 (58 L) (Nogales *et al.*, 2005); four containers were assigned to semicomposting, and four to vermicomposting systems. In the containers used for semicomposting, the mixture was rotated each week to increase air circulation and to reduce formation of anaerobic spot zones. During the composting process, humidity ranged from 50 to 60% (NRAES, 1999). The mixture did not reach the temperature of the thermophilic phase; hence, the resulting product is considered a semicomposted substrate (Hernandez-Rodriguez *et al.*, 2013). In the vermicomposting system, the composites were subjected to a pre-composting process for 15 days. At the end of this period, seeding of the California red worms (*Eisenia foetida*) was carried out at a density of 580 adult worms per experimental unit, with an average of 10 worms/L. Watering was done every other day to maintain a 70-80% moisture (NRAES, 1999). After 24 weeks of decomposition, the vermicompost and semicompost had a C/N ratio of 12.4 and 9.8, respectively. A C/N ratio <12 has been suggested as an indicator of maturity of the products obtained by composting (Mondini *et al.* 2003; Flavel and Murphy (2006). Vermicompost and semicompost were sieved through a 0.5cm mesh to ensure uniform particle size and to remove the worms. Sieved composts were maintained for 52 weeks in storage between 14º and 20.7ºC, recorded using a maximum/minimum thermometer (Fisher Scientific, Pittsburgh, PA, USA), and humidity between 40 and 45%. To know the nutritional composition of the composts used in this study, several characteristics were determined, including total N by the Micro-Kjeldahl method (Fernandez *et al.*, 2006); organic-C with the Walkley-Black dichromate oxidation method (ASTM, 2010); N-NO_3^- by Brucine and spectrophotometry UV-visible method (Bono and Romano, 2007); Ca^{++}, Mg^{++}, K^+, Na^+, Cu^{++}, Fe^{++}, Mn^{++} and Zn^{++} by digestion with *aqua regia* (nitric and perchloric acids in 3:1 ratio) method (Chen and Ma (2001) and an atomic absorption spectrophotometer (Perkin Elmer Analyst 100, USA); total P by the method of ammonium molybdenum-vanadate and analysis by UV-visible spectrophotometry; and pH by means of a potentiometer (Fisher Scientific Accumet AB15, USA) in a 1:5 (w/v) water dilution.

Study establishment

To evaluate the effect of different ratios of vermicompost and semicompost mixed with peat moss (packed and distributed by Premier Tech Horticulture, under the trade mark "Premier") on seed germination and development of lettuce and tomato, a completely randomized design was used. The five treatments applied, according to the proportions of vermicompost (V) semicompost (S) and peat moss (PM) were: 1V:2PM, 2V:1PM, 1S:2PM, 2S:1PM and PM as control. Each treatment was replicated four times, with an experimental unit of 100 seeds. The study began on June 6, 2011 in a type-chapel greenhouse mesuring 16×45m, with a galvanized iron frame and covered with fiberglass. Temperatures during the experiment were between 21.7 and 32.3±1ºC. Lettuce seeds cultivar Great Lakes, which is highly sensitivity to substrate quality (Celis *et al.*, 2006), and tomato seeds cultivar Floradade were used. Sowing was performed in expanded polystyrene trays with 100 cavities of 25ml, each filled with the corresponding mixture of substrate.

Data collection

The experiment lasted 21 days after sowing. The variables evaluated were: days to germination; germination percentage; seedling height, leaf area, determined with a laptop CI-202 Area Meter from Cid Bio-Science (Camas, WA, USA); chlorophyll index, measured using a Minolta SPAD 502 unit; number of leaves; root length and; root volume expressed in cc of water displaced in a graduated cylinder. The quality of root-bulk soil in the substrate was determined by pulling up the stem carefully to remove the seedling from the tray cavity, and the integrity of the root-bulk soil was determined using the following arbitrary scale: 1) 100% of the root ball stays intact when the plant is extracted from the tray cavity, 2) 90% of the root ball is removed from the tray cavity, 3) 75% of the root ball is removed from the tray cavity, 4) 50% of the root ball is removed from the tray cavity and 5) <50% of the root ball is removed or the roots contain no substrate at all (Quesada and Mendez, 2005).

Data analysis

A linear model that included as fixed effect the type of substrate used was adjusted. For the two variables, days to initiation of germination and germination percentage, all the seeds used in each treatment were considered. For the other variables, the average of 25 randomly selected seedlings per replicate was recorded. Analysis of variance was performed using Proc GLM of SAS ver. 8.2 and the mean comparison was performed using the Tukey's test ($P \leq 0.05$).

Results

Days to germination and germination percentage

Lettuce seedlings grown on the substrate 2V:1PM showed the highest rate of emergence (93.5%) on day 7, reaching the maximum values of emergence on day 14 in comparison with all treatments. Regarding to the tomato seedlings, germination was observed already from day 4, reaching the values of 78 and 83% with substrates 2V:1PM and 2S:1PM, respectively. Substrate PM had the lowest germination levels in both tomato and lettuce seedlings (Figure 1).

Leaf measurements

The results for leaf area and number of leaves (Table I) showed significant differences among all treatments; however, no differences were found in the chlorophyll index ($P \leq 0.05$). Lettuce seedlings with the largest leaf area 1V:2PM, 2V:1PM, 1S:2PM, and 2S:1PM showed values of 17.96, 23.19, 19.29, and 13.98cm^2, respectively. The highest average in leaf number was observed in 2V:1PM with 4.09cm^2 per plant, while the tallest seedling height was obtained in 1S:2PM with 7.99cm. The lowest values (1.87 and 1.52cm) for these parameters were observed with PM. On the other hand, in the tomato seedlings, plants with the highest leaf area were obtained with treatments 2V:1PM and 1S:2PM, with values of 18.07 and 20.14cm^2, respectively. These treatments also had the tallest plants with a height of 8.90 and 10.45cm, respectively.

Root features

Results for root length and volume for both lettuce and tomato are shown in Table II. Lettuce seedlings with better root system characteristics were observed on treatments 1V:2PM, 2V:1PM, 1S:2PM, and 2S:1PM, while in the case of tomato, the largest root lengths were obtained in 1V:2PM and 1S:2PM with values of 9.97 and 10.23cm, respectively. The highest root volume was found in treatments 1V:2PM, 2V:1PM, 1S:2PM, and 2S:1PM. For both variables, PM had the lowest mean values with 2.11cm and 0.10cm^2 for lettuce, and 4.81cm and 0.03cm^2 for tomato, respectively.

Root-bulk soil quality

The results for root-bulk soil quality showed significant differences among all treatments (Table II). The treatments with the highest quality for growing lettuce were 1V:2PM and 2S:1PM, while for the tomato

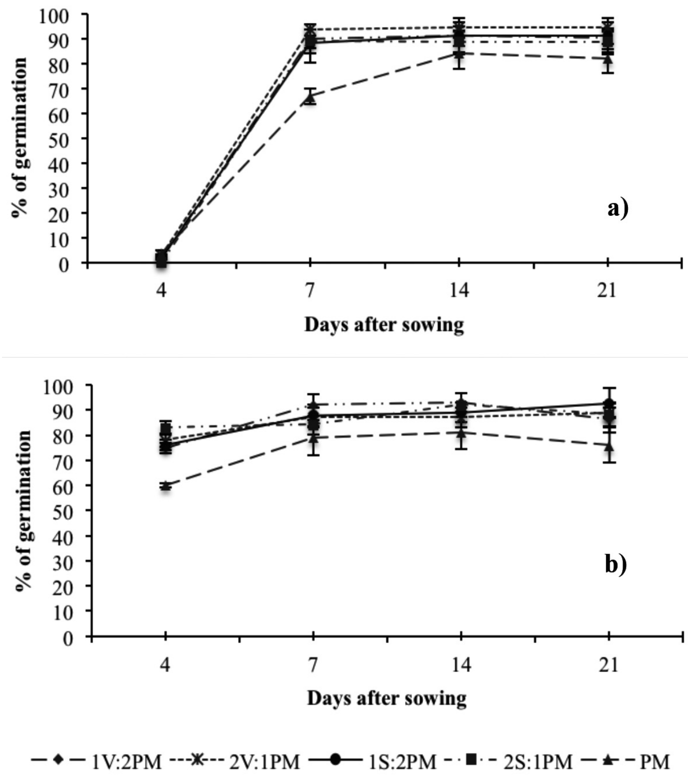

Figure 1. Days to germination and germination percentage of seedlings of a) lettuce (*Lactuca sativa* L.), and b) tomato (*Solanum lycopersicon* L.), in different organic substrate proportions from vermicompost (V), semicompost (S) and peat moss (PM). Bars are the standard deviation of four replications.

TABLE II
ROOT LENGTH, ROOT VOLUME AND ROOT-BULK SOIL QUALITY IN LETTUCE AND TOMATO SEEDLINGS IN DIFFERENT GERMINATION SUBSTRATE PROPORTIONS AT 21 DAYS AFTER SOWING

Crop	Treatment	Root length (cm)	Root volume (cm-3)	Root-bulk soil quality
Lettuce	1V:2PM	7.02 ±1.36 a	0.15 ±0.0 a	2.70 ±0.53 bc
	2V:1PM	8.15 ±0.25 a	0.18 ±0.12 a	1.93 ±0.31 c
	1S:2PM	7.35 ±0.82 a	0.15 ±0.005 a	3.01 ±0.50 b
	2S:1PM	8.12 ±1.31 a	0.16 ±0.02 a	1.74 ±0.64 c
	PM	2.11 ±0.22 b	0.10 ±0 b	4.97 ±0.06 a
	R^2	0.88	0.89	0.46
	CV	14.27	10.41	16.11
Tomato	1V:2PM	9.97 ±0.13 a	0.25 ±0.01 a	1.75 ±0.42 b
	2V:1PM	8.95 ±1.46 ab	0.22 ±0.05 a	2.04 ±0.73 b
	1S:2PM	10.23 ±0.92 a	0.28 ±0.04 a	1.96 ±0.34 b
	2S:1PM	8.08 ±0.54 b	0.26 ±0.02 a	1.26 ±0.20 b
	PM	4.81 ±0.46 c	0.03 ±0.02 b	5.00 ±0.00 a
	R^2	0.87	0.90	0.93
	CV	9.99	15.97	17.48

a, b: Means with the same letter in the same column and crop do not differ statistically according to the Tukey's test ($P \leq 0.05$). R^2: coefficient of determination. CV: coefficient of variation.

seedlings treatments 1V:2PM, 2V:1PM, 1S:2PM, and 2S:1PM were the best. These results were related with those observed in root development, where a greater development was found in mixtures containing vermicompost and semicompost, which is associated with root-bulk soil quality. The root-bulk soil observed in the control PM treatment was more loose and disintegrated at the bottom. Vermicompost and semicompost substrates produced from cattle manure and sawdust mixed with PM had an important beneficial effect on root development of lettuce and tomato seedlings.

Discussion

Although the characteristics of the mixtures were not determined in this study, it can be seen that they behaved differently. Composted materials generally vary greatly in their characteristics, and may be influenced by a diverse number of factors such as geography, management, time of year, and others (Carlile, 2008). The most important compost characteristics that affect its use in agriculture are the degree of maturity and the stability. Maturity refers to the degree of decomposition of organic substances that will not cause adverse effects on crop plants (Bernal *et al*., 2009). Stability is related to the levels of activity of the microbial biomass (Fuente *et al*., 2006). According to Prat (1999), substrates with a high organic content and low biological stability are more exposed to microbial degradation, which may increase the release of CO_2 and affect the absorption of water and nutrients by the roots. Even after a short period of use as a substrate, peat moss can become a major carbon emitter (Gaudig, 2008). Our results suggest that the preparation and preservation of vermicompost and semicompost used in this study had an appropriate reduction in C/N ratio, suitable for mixing with PM as substrates for germination, improving the development of root and leaf growth in seedlings. Different results were reported in a study using composted

TABLE I
SEED GERMINATION, AND SEEDLING GROWTH OF LETTUCE AND TOMATO IN VARIOUS ORGANIC SUBSTRATE PROPORTIONS AT 21 DAYS AFTER SOWING

Crop	Treatment	Seed germination (%)	Leaf area (cm2)	Chlorophyll index SPAD	Number of leaves	Seedling height (cm)
Lettuce	1V:2PM	90.00 ±4.08 ab	17.96 ±8.46 a	27.00 ±0.35 a	3.54 ±0.27 b	5.59 ±0.39 b
	2V:1PM	94.50 ±1.91 a	23.19 ±8.47 a	26.05 ±0.88 a	4.09 ±0.43 a	7.50 ±1.82 ab
	1S:2PM	91.00 ±7.25 ab	19.29 ±2.16 a	27.81 ±1.51 a	3.90 ±0.24 ab	7.99 ±1.82 a
	2S:1PM	88.75 ±4.42 ab	13.98 ±0.73 a	25.54 ±1.25 a	3.77 ±0.06 ab	7.32 ±0.78 ab
	PM	82.00 ±5.78 b	1.27 ±0.27 b	27.59 ±0.88 a	1.87 ±0.12 c	1.52 ±0.21 c
	R^2	0.46	0.71	0.47	0.93	0.89
	CV	5.65	36.02	3.93	7.33	15.42
Tomato	1V:2PM	86.50 ±6.1 ab	11.40 ±1.29 b	34.11 ±1.00 a	9.43 ±0.53 a	7.77 ±0.93 b
	2V:1PM	88.75 ±2.06 a	18.07 ±3.04 a	34.33 ±1.83 a	10.35 ±0.77 a	8.90 ±1.05 ab
	1S:2PM	92.75 ±2.99 a	20.14 ±3.23 a	34.37 ±1.49 a	10.67 ±0.74 a	10.45 ±1.36 a
	2S:1PM	88.25 ±4.50 a	13.11 ±1.52 b	35.72 ±1.05 a	9.82 ±0.73 a	7.68 ±0.57 b
	PM	76.00 ±7.07 b	3.99 ±0.31 c	33.69 ±1.00 a	5.70 ±0.25 b	3.52 ±0.13 c
	R^2	0.60	0.89	0.26	0.91	0.89
	CV	6.05	16.35	3.84	6.94	11.94

a, b: Means with the same letter in the same column and crop do not differ statistically according to the Tukey's test ($P \leq 0.05$). R^2: coefficient of determination. CV: coefficient of variation.

pine bark as germination substrates, which were found to reduce the number of leaves in lettuce plants (Oberpaur *et al*., 2010). Additionally, the availability of N in organic substrates is influenced by its stability, which affects plant leaf development. The peat moss, vermicompost and semicompost used in this study had N contents of 1.80, 2.28 and 2.83%, respectively; thus, the substrate mixtures provide the seedlings of lettuce and tomato with adequate N for cell multiplication and development of plant organs during the third stage of germination, in which seedlings stop making use of reserve substances and begin depending on other exogenous nutrients (Castellanos *et al*., 2000).

The optimum pH for plant growth has been found to be between 5.3 y 6.8 (Argo, 1998). The pH values of vermicompost and semicompost evaluated in this study were outside of the optimal range, with pH values above 8.5, in agreement with Schmilewski (2008), who states that composts should always be mixed with a material with a lower pH, resulting in a pH close to 7. The pH values determined in the mixtures used in this study were 6.1, 7.04, 7.19, and 7.9 for treatments 1V:2PM, 2V:1PM, 1S:2PM, and 2S:1PM, respectively, allowing their use in greenhouse conditions, and reducing the risks of its use as the sole constituent of a culture medium. According to Sobrino and Sobrino (1994) lettuce grows at pH levels between 5.5 and 7.0, but its growth and development is best at pH between 6.0 and 6.8. Oberpaur (2010) found that the substrate composed by a 40% PM and 60% compost mix reached this range of pH. In addition, Varela *et al.* (2005) reported that the use of vermicompost for seedling growth has better conditions when it is mixed with PM, because vermicompost could have a high salt content that might inhibit seed germination.

The results observed in days to initiation of germination and germination percentage are very important for the production of lettuce seedlings, as this crop is difficult to germinate because of its seeds low reserves, high demand for oxygen, moisture and temperature. Treatments 1V:2PM, 2V:1PM, 1S:2PM, and 2S:1PM provided a good germination environment for lettuce, which is also important for plant growth and development. Quesada and Méndez (2005) reported that in compact substrates with low oxygen concentration, lettuce usually does not reach even a 50% germination. Giulietti *et al.* (2008) indicated that the bovine vermicompost showed beneficial effects on germination percentage of *Digitaria eriantha* when mixed with sandy soil in a proportion of 50%.

Lettuce seedlings with the highest leaf development also had the greatest root development. Quesada and Méndez (2005) reported that plant growth and root development is associated to the quality of the root-bulk soil, specifically by two physical properties, total porosity, and bulk soil density. In our study, substrate mixtures of vermicompost and semicompost improved growth and development of the root system. The most suitable proportion for lettuce seedlings was 2V:1PM, while 1S:2PM was the best for tomato seedlings. Moreover, different doses and types of semicompost and vermicompost should still be further evaluated to expand the possibilities of their use in the production of high quality lettuce and tomato seedlings.

Conclusions

Our results show that semicompost, vermicompost mixed in different proportions with peat moss significantly improved seed germination, as well as the development of lettuce and tomato seedlings, emphasizing the poor performance of peat moss alone. Thus, these organic fertilizers are appropriate for their use in the production of lettuce and tomato seedlings under greenhouse conditions.

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