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MILLICOMPOSTING: COMPOSTING BASED ON THE USE OF DIPLOPODS AIMING AT THE PRODUCTION OF ORGANIC SUBSTRATES

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ABSTRACT: Millicomposting, a not so well-known biotechnology, involves the biotransformation of vegetable residues into stable organic matter, promoted by the activity of diplopods, popularly known as millipedes. Considering the importance of the substrate in the production of vegetable seedlings, the aim of the present work was to assess the millicomposting technique and evaluate the efficiency of millicompost in the production of seedlings of the American lettuce cultivar Angelina. The millicompost consisted of *Bauhinia sp.* (cow's foot leaves), *Paspalum notatum* (grass clippings), *Musa sp.* (banana leaves), and cardboard. Physical, physicochemical, and chemical analyses of the obtained millicompost were performed 180 days into the experiment. The lettuce seedlings were grown in expanded polystyrene trays of 200 cells and the evaluations occurred 30 days after sowing. The evaluated phytotechnical characteristics were fresh and dry shoot mass, fresh and dry root mass, plant height, number of leaves, seedling vigor, and clod stability. The millicompost had a higher total nutrient content and lower volume density than the Biomix® organic substrate. All of the developmental parameters of the lettuce seedlings differed between the millicompost and the Biomix® organic substrate; all of the mean values were higher for the millicompost, except for the number of leaves, which did not differ from the Biomix® organic substrate. The millicomposting process facilitated the reuse of organic waste by converting it into

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quality organic compost and resulted in the efficient production of excellent quality lettuce seedlings.

KEY WORDS: Horticulture; Millipedes; Organic compounds; Quality seedlings.

GONGOCOMPOSTAGEM: A COMPOSTAGEM BASEADA NA UTILIZAÇÃO DE DIPLÓPODES VISANDO A PRODUÇÃO DE SUBSTRATOS ORGÂNICOS

RESUMO: A gongocompostagem é uma biotecnologia ainda pouco conhecida, consistindo na biotransformação dos resíduos vegetais em matéria orgânica estável, promovida pela atividade de diplópodes, popularmente conhecidos como gongolos ou piolhos-de-cobra. Considerando a importância do substrato na produção de mudas de hortaliças, o presente trabalho teve como objetivos difundir a técnica da gongocompostagem e avaliar a eficiência do gongocomposto na produção de mudas de alface americana cultivar Angelina. A gongocompostagem foi estabelecida a partir da mistura de resíduos de *Bauhinia sp.* (folhas de pata-de-vaca), *Paspalum notatum* (aparas de grama), *Musa sp.* (folhas de bananeira) e papelão picado. Foram realizadas análises físicas, físico-químicas e químicas do gongocomposto obtido aos 180 dias. As mudas de alface foram produzidas em bandejas de poliestireno expandido de 200 células e as avaliações ocorreram 30 dias após a semeadura e as características fitotécnicas avaliadas foram: massas fresca e seca de parte aérea, massas fresca e seca de raízes, altura de plantas, número de folhas, vigor de mudas e estabilidade do torrão. O gongocomposto apresentou teores de nutrientes totais superiores aos do substrato orgânico Biomix®, bem como a menor densidade volumétrica em relação ao substrato Biomix®. No desenvolvimento das mudas de alface, todas os parâmetros diferiram, com valores médios superiores para o gongocomposto, com exceção do número de folhas, o qual não diferiu do substrato orgânico Biomix®. O processo de gongocompostagem proporciona o reaproveitamento de resíduos orgânicos convertendo-os em composto orgânico de qualidade e com eficiência na produção de mudas de alface, proporcionando a obtenção de mudas de excelente qualidade.

PALAVRAS-CHAVE: Compostos orgânicos; Gongolos; Mudas de qualidade; Olericultura.

INTRODUCTION

Organic waste has become a focus of research owing to the threat it poses to the environment and human health in modern society. The global agricultural waste production is more than hundreds of megatons per year and a large part of this agricultural waste is disposed of inappropriately or burned directly, further intensifying global warming and air pollution (ZHANG *et al*., 2016).

Composting is a biological process that facilitates the transformation of the organic matter present in plant residues to humidified material; the compost generated can be used as an organic fertilizer in agriculture, vegetable gardens, and gardens in general (ANTUNES, 2017). In addition, composting is an environmentally friendly technique, as waste is processed sustainably and has low production cost (LÓPEZ-GONZÁLEZ *et al*., 2015).

From traditional composting, in which microbial activity is of decisive importance, to composting mediated by soil invertebrates, such as vermicomposting and millicomposting, different mixtures, practices, and management regimes have been proposed with the aim of improving the efficiency of composting and the quality of the produced compost. In the case of millicomposting, a diplopod species with particular composting potential is *Trigoniulus corallinus*, as it has a pantropical distribution, occurs widely in different agricultural environments, and is easily recognized by its distinct red color (ANTUNES, 2017).

Diplopods are widely distributed in tropical, subtropical, and temperate regions and play an important role in improving soil fertility, as they are able to mobilize nutrients trapped in litter and enrich the soil with N, C, Ca, Mg, P, and K in microcosm conditions (ANTUNES *et al*., 2019). This nutrient enrichment results from a high litter consumption capacity that is associated with a high microbial activity present in the feces of diplopods. When the litter passes through the digestive tract, it is crushed; this process increases its specific surface, it moistens it, and it enriches it with microorganisms (CORREIA; AQUINO, 2005). Diplopods can metabolize up to 0.3% to 7% of the ingested material and the microbial activity continues taking place in their fecal pellets, which increases the bioconversion of plant residues (AMBARISH; SRIDHAR, 2013).

Millicomposting is a new, little known, and environmentally friendly biotechnology, which facilitates the biotransformation of plant residues into stable organic matter; this process is aided by the activity of diplopods, commonly known as millipedes, which act directly on the fragmentation of plant residues, thus accelerating the decomposition rates of various residues whose C/N ratios are out of reach for traditional composting. The final product of millicomposting is millipede humus, which has been called millicompost (ANTUNES *et al*., 2018).

The use of organic compounds to supply nutrients and support substrate compost may be a viable alternative in the effort to reduce the cost of vegetable seedling production (SILVA JÚNIOR *et al*., 2014). The substrate is essential for the production of vegetable seedlings and its physical, physicochemical, and chemical properties are indicative of seedling quality to the producer. Based on the above, this study aimed to disseminate the millicomposting technique and evaluate the millicompost efficiency in the production of seedlings of the lettuce cultivar Angelina (*Lactuca sativa* L.), in order to provide family producers with a new option of organic substrate from renewable sources.

2 MATERIALS AND METHODS

2.1 THE MILLICOMPOSTING PROCESS

The millicomposting process was carried out in the experimental area of the Integrated System of Agroecological Production - SIPA, located at Fazendinha km 47, Seropédica, RJ, Brazil. The region's climate is hot and humid, classified as Aw, with rainfall concentrated from November to March, and an average annual rainfall of 1213 mm (CRUZ, 2005).

We used concrete rings that were 0.5 m high and 1 m wide, with a capacity to receive 500 L of waste (Figure 1-A). In the first stage, the residues were quantified and deposited inside the three rings, at an approximate 40 cm height. Millicomposting was established from the mixture of 200 L, 150 L, 100 L, and 50 L of *Bauhinia sp.* (cow's foot leaves), *Paspalum notatum* (grass clippings), and *Musa sp.* (banana leaves) residues as well as chopped cardboard, respectively. The materials were wetted in order to create a homogeneous mixture (Figure 1-B).

In the second stage, each ring received approximately 2.2 L of millipedes, which is equivalent to a population of approximately 3,960 adult individuals (Figure 1-C), collected manually from vermicomposting beds, from compost areas, and from lawn containing fresh cuttings. These rings remained covered with sombrite, whose function was to prevent the millipedes in the ring from escaping when climbing the wall of the ring or to prevent the entry of anything undesired in the rings during the millicomposting process (Figure 1-D).

Figure 1. A) Concrete ring with the addition of 500 L of waste. B) Waste properly prepared for millicomposting. C) Quantification and addition of millipedes in the rings containing the residues. D) Beginning of the millicomposting process and protection of the rings.

Throughout the entire millicomposting process, it was necessary to monitor the moisture content of the material contained in the rings. The maintenance of a certain humidity level was achieved by adding approximately 4 L of water per concrete ring with a watering can. Water was added to the rings either weekly or when it was necessary, in order to maintain humidity at approximately 50-60%.

This humidity level would provide a favorable environment for the survival of the millipedes and the continuity of the composting process.

The millicompost was obtained 180 days after the beginning of the experiment. The residues were removed, sieved through a 2 mm mesh (Figure 2), stored in plastic bags, subjected to physical, physicochemical, and chemical analysis, and later used in the production of vegetable seedlings.

Figure 2. The removal and sieving process of millicompost produced from cow's foot leaves, grass clippings, banana leaves, and chopped cardboard 180 days after the beginning of the experiment.

2.2 CHARACTERIZATION OF THE PHYSICAL, PHYSICOCHEMICAL, AND CHEMICAL PROPERTIES OF THE MILLICOMPOST

The physical properties of the millicompost and the commercial organic substrate Biomix® (used as the control) evaluated by the adapted methodology of Silva (1998) and MAPA (2008), were the following: macroporosity, microporosity, total porosity, water retention capacity, and volumetric density.

To characterize the millicompost and the commercial organic substrate Biomix® in terms of their chemical properties, samples of each treatment were sent to the Agricultural Chemistry Laboratory of Embrapa Agrobiologia, to determine the P, K, Ca, and Mg contents, according to the methodology described by Embrapa (2005). The N and C contents were determined in an elemental analyzer (CHN), also known as the Dumas method (NELSON; SOMMERS, 1996).

The pH analyses were performed in a distilled water solution (5:1 v/v); the same aqueous extract was used to determine the electrical conductivity (EC), according to the method described by MAPA (2008). All the analyses were performed in triplicates.

2.3 PRODUCTION OF LETTUCE SEEDLINGS

The experiment was conducted in a greenhouse of the Integrated System of Agroecological Production - SIPA, located at Fazendinha Km 47, Seropédica, RJ, Brazil, from August 21 to September 20, 2017.

The production of the seedlings of the lettuce cultivar Angelina took place in 200-cell expanded polystyrene trays. The treatments consisted of two organic substrates; millicompost, which was produced as described in section 2.1, and organic Biomix®, consisting of coconut fiber powder, crushed and composted pine bark, bokashi (organic additive with macro and micronutrients), and the Biomix® organic compound formula.

Thirty days after sowing, ten lettuce seedlings per experimental unit were collected at random and the following parameters were evaluated: fresh shoot weight (FSW), dry shoot weight (DSW), fresh root weight (FRW), dry root weight (DRW), number of leaves (NL), plant height (PHE), which was measured from the point of root insertion up to the leaf apex, seedling vigor (SV), and clod stability (CS). To evaluate the plants' dry masses, aerial parts, and roots they were packed separately in paper bags and kept in a forced air circulation oven at 65 °C for 72 h.

The methodology used to determine the SV was adapted from Franzin et al. (2005). According to this methodology, we classified SV into four categories: Note 1: excellent vigor (number of leaves ≥ 4, height greater than 5 cm, and visual absence of nutritional deficiency), Note 2: good vigor (number of leaves ≥ 4, height ≥ 5 cm, and non-prominent yellowish basal leaves), Note 3: regular vigor (number of leaves ≥ 4, height ≥ 5 cm, and nutritional deficiency expressed by a prominent yellowing that extended beyond the basal leaves or other intrinsic symptoms), Note 4: poor vigor (well-defined nutritional deficiency expressed by height problems (≤ 5 cm), reduced number of leaves (≤ 4 leaves), and intense yellowing or other intrinsic symptoms).

The methodology used to determine the CS was adapted from Gruszynski (2002). According to this methodology, we classified ECL into four categories: Note 1: low stability (50% or more of the clod was retained in the container when the seedling was removed and the clod did not remain cohesive), Note 2: average stability (between 30% and 50% of the clod was retained in the container when the seedling was removed, but the clod did not remain cohesive), Note 3: regular stability (between 15% and 30% of the clod was retained in the container when the seedling was removed, but it did not remain cohesive), and Note 4: good stability (the clod was completely detached from the container with up to 90% cohesion and maximum loss of up to 10% of the substrate).

The experimental design used was completely randomized, with 4 repetitions (trays) for each treatment (substrate). The data were submitted to analysis of variance by the F test ($p \leq 0.05$), using the statistical program SISVAR (FERREIRA, 2014).

3 RESULTS AND DISCUSSION

3.1 CHEMICAL PROPERTIES OF WASTE USED IN MILLICOMPOSTING

The residues used in the millicomposting process that had the highest nutritional contents in terms of N, P, and K were grass clippings, followed by cow's foot leaves, and banana leaves (Table 1). Cardboard was the residue that had the lowest nutrient levels and the highest C/N ratio, thus justifying its use in lower proportions in millicomposting.

Table 1. C/N ratio and macronutrient contents of the residues used in millicomposting

Wastes	C/N ratio	N	P	K	Ca	Mg
		g kg^{-1}				
Cow's foot leaves	39.62 c	12.80 b	0.90 b	2.75 c	34.52 a	3.59 a
Grass	25.22 d	20.20 a	3.49 a	19.84 a	4.17 d	3.12 b
Banana	56.02 b	9.40 c	0.65 c	13.21 b	11.62 b	2.89 c
Cardboard	291.04 a	1.90 d	0.20 d	0.52 d	5.89 c	0.50 d

The same letters in the column do not differ by the Scott-Knott test ($p \leq 0.05$).

Although there were nutritional differences among the residues analyzed, we can infer that the rate by which *T. corallinus* diplopods consumed them proved to be efficient. The performance of the millipedes in the decomposition process and transformation of waste into millicompost for ready use as a substrate for plants was facilitated by the initial mixing of the residues in different proportions.

The importance of the diplopod activity regarding waste with a high C/N ratio is also worth highlighting, as in the traditional composting processes C/N ratios between 30 and 40 are recommended (INÁCIO; MILLER, 2009). According to Corrêa (2015), residues with a C/N ratio above 50, as is the case with banana leaves and cardboard (C/N ratios of 56 and 291, respectively), promote a decrease in the speed of decomposition by microorganisms because they are low in nitrogen.

3.2 PHYSICAL AND CHEMICAL PROPERTIES OF SUBSTRATES

The parameters of the physical analysis of the substrates are shown in Table 2. The macropore percentages differed between the substrates, with this percentage being higher for the organic substrate Biomix®. As for microporosity, the millicompost had higher percentages compared with the commercial substrate. The total porosity was similar between the substrates. The millicompost was able to retain 9.96% more water than the commercial substrate. The volumetric density was higher in the Biomix® organic substrate compared with the millicompost, which was 37.97% less dense.

Gonçalves and Poggiani (1996) consider a macroporosity range of 35-45% to be appropriate. However, in our study, the macroporosity of both substrates ranged from 12.50% to 18.34% (Table 2); these levels are considered low by the same authors. The lower percentage of macropores in the millicompost resulted from the biological activity that took place during the millicomposting process (from isopods, collembola, and microorganisms), which promoted the fragmentation of these structures. In turn, this resulted in a more pulverized millicompost and led to lower macropore levels compared with the commercial substrate the macropore level of which was at a percentage below the recommended range even when it was combined with other raw material types.

Table 2. Physical analysis of the evaluated substrates: macroporosity (MAC), microporosity (MIC), and total porosity (TP) percentages, water retention capacity at 10 cm tension (WRC), and volumetric density (VC)

Substrates	MAC	MIC	TP	WRC (mL 50 cm^{-3})	VC (kg m^{-3})
	--------------	(%)	--------------		
Biomix$^{®}_{organic}$	18.34 a	60.46 b	78.80 a	30.23 b	400 a
Millicompost	12.50 b	66.47 a	78.97 a	33.24 a	290 b
CV (%)	5.37	1.80	1.83	1.80	1.18

Means followed by the same letter in the column do not differ by the F test ($p<0.05$).

The microporosity recorded for the substrates ranged from 60.46% to 66.47% (Table 2). The range considered adequate according to the recommendation of Gonçalves and Poggiani (1996) is between 45-55%. Although the millicompost was above the range considered adequate, this excess did not cause problems in the development of lettuce seedlings.

The total porosity levels considered as adequate by Gonçalves and Poggiani (1996), range between 75% and 85%. In the present study, the millicompost and the Biomix® substrate met the recommendation established by the aforementioned authors (Table 2). Drzal *et al*. (1999) and Schmitz *et al*. (2002) affirm that the water content retained in the substrate is directly correlated with the size distribution of the pores as the macropores do not retain water under gravitational force but are responsible for the aeration of the roots.

The water retention capacity of a substrate plays a fundamental role in supplying water to plants and intercepting nutrients. Gonçalves and Poggiani (1996) consider a water retention capacity of 20-30 mL 50 cm^{-3} to be adequate. In the present study, the water retention capacity of the Biomix® substrate fitted into the range described by these authors (Table 2), while that of the millicompost exceeded the value established by 9.96%, owing to its greater microporosity (Table 2).

The density of a substrate is important in assisting in the interpretation of other characteristics, such as porosity, aeration space, and water availability (FERMINO, 2014). Volumetric density values ranging from 100 to 300 kg m^{-3}, 250 to 400 kg m^{-3}, 300 to 500 kg m^{-3}, 500 to 800 kg m^{-3}, are considered as reference values for substrates used in trays and for pots up to 15 cm, 20 to 30 cm, and higher than 30 cm, respectively (FERMINO, 2014). In our study, the millicompost met the standard for use in trays. However, the Biomix® substrate had a volumetric density above the proposed reference values (Table 2), possibly owing to its formulation and granulometry. Density is an important property for management as it facilitates root development and allows greater ergonomic efficiency when handling trays, which are lighter when transferred to the production field.

The pH and EC values of the evaluated substrates (Table 3) were statistically different ($p<0.05$), being slightly higher for Biomix®. The levels of all the nutrients contained in the substrates differed significantly ($p<0.05$) from each other, while millicompost had the highest mean values.

Table 3. Physicochemical and chemical analyses of the evaluated substrates: hydrogen potential (pH), electrical conductivity (EC), C/N ratio, total carbon content, and total macronutrient contents of the substrates evaluated in the production of lettuce seedlings

Substrates	pH	EC	C/N	C	N	P	K	Ca	Mg
		dS m^{-1}	ratio	------------------------- g kg^{-1}----------------------					
Biomix® organic	6.69 a	0.48 b	41.93 a	325 a	7.70 b	1.53 b	2.39 b	9.03 b	2.73 b
Millicompost	6.17 b	3.32 a	11.00 b	240 b	21.90 a	2.52 a	6.00 a	14.96 a	3.78 a
CV (%)	0.96	5.27	2.15	1.70	2.83	6.04	11.56	11.09	8.33

Means followed by the same letter in the column do not differ by the F test ($p<0.05$).

According to Gonçalves and Poggiani (1996), the ideal pH range is between 5.5 and 6.5. The Biomix® substrate's pH was 0.19 points above the ideal range. However, the lower development of lettuce seedlings in the Biomix® substrate compared with that of the millicompost substrate could probably be attributed to the low amount of nutrients contained in the substrate. It should be noted that, according to Costa (2014), lettuce is a species adapted to more alkaline soil levels, tolerating a pH of 6.5 to 7.5.

Araújo Neto *et al*. (2009) established value ranges for the EC of substrates. EC values between 2.0 and 4.0 dS m^{-1} are considered high for substrates, values from 1.0 to 2.0 dS m^{-1} are normal, and values less than 1.0 dS m^{-1} are considered low. The EC value of the millicompost was 6.9 times higher than that of the commercial substrate Biomix®. Although considered high by the aforementioned authors, this value resulted from the higher nutrient supply in the millicompost compared with the nutrient supply of the commercial substrate (Table 3).

The nitrogen content of the millicompost substrate was 2.8 times higher than that of the commercial Biomix® substrate (Table 3). Nitrogen is an essential element for plants and its lack affects directly the formation of roots, the process of photosynthesis, the production and translocation of photosynthates, and the growth rate of leaves and roots, with leaf growth being primarily affected (TAÍZ; ZIEGER, 2004).

The C/N ratio is an important parameter for substrate characterization, as it indicates how much organic material remains at the end of the composting process (DA ROS *et al*., 2015). Normative instruction number 25 of the Ministério da Agricultura, Pecuária e Abastecimento (2009) highlights that the C/N ratio cannot exceed 20 and the total nitrogen content must be at least 5.0 g kg^{-1} for mixed fertilizers and compound organics. In our study, the millicompost substrate met the requirements of this normative instruction, as it was an organic compound.

Stevenson (1986) reported that a C/N ratio higher than 30 leads to nitrogen immobilization; mineralization that ranges between 20 and 30 is the same as immobilization and with a C/N ratio less than 20, mineralization prevails. As is shown in Table 3, the C/N ratio of the Biomix® substrate (41.93) is considered very high for the adequate mineralization of the nutrients and this may result, at least initially, to the immobilization of the mineralized nitrogen. The millicompost substrate had a C/N ratio of 11, which was in the range in which the mineralization of nutrients prevails, as it is more stabilized.

Gonçalves and Poggiani (1996) established value scales for the interpretation of the chemical properties of plant substrates, such as adequate levels of macronutrients. The phosphorus concentration that is considered adequate by these authors varies from 0.40 to 0.80 g kg^{-1}; in our study, both substrates had phosphorus concentration levels higher than the recommended range (these were 1.53 g kg^{-1} and 2.52 g kg^{-1} for the Biomix® and the millicompost, respectively).

Gonçalves and Poggiani (1996) consider potassium to be adequate when it ranges from 1.17 to 3.91 g kg^{-1}. In our study, only the potassium in the Biomix® substrate remained within the established range (Table 3). The millicompost had 2.5 times more potassium compared with the commercial substrate, thus being above the range established by the aforementioned authors.

According to Gonçalves and Poggiani (1996), calcium levels ranging from 2.00 to 4.00 g kg^{-1} are considered adequate. In our study, both substrates had calcium levels above the recommended range. The calcium levels in the millicompost substrate in particular, were well above the recommended calcium range (14.96 g kg^{-1}) (Table 3). This significantly higher calcium content in the millicompost could be attributed to two factors. The first factor is that cow's foot leaves are rich in calcium (Table 1) and constituted 40% of the initial mixture for the millicomposting process of waste containing calcium. The second factor is that throughout the millicomposting process, there was a decrease in the survival of the millipedes, thus promoting the incorporation of the calcium from their exoskeletons into the compound.

Magnesium levels established as adequate, according to Gonçalves and Poggiani (1996), vary from 6.07 to 12.16 g kg^{-1}. As is shown in Table 3, the magnesium contents of both substrates were below the recommended range; however, the magnesium content of the millicompost was 38.46% higher than that of the Biomix® commercial substrate.

3.3 MILLICOMPOST EFFICIENCY IN THE PRODUCTION OF LETTUCE SEEDLINGS

There were significant differences ($p<0.05$) between the two substrates for all the parameters evaluated in the development phase of the seedlings of the lettuce cultivar Angelina, except for the NL, which remained the same (Table 4).

Table 4. Average values of phytotechnical parameters evaluated in lettuce seedlings: fresh shoot weight (FSW), dry shoot weight (DSW), fresh root weight (FRW), dry root weight (DRW), plant height (PHE), number of leaves (NL), clod stability (ECL), and seedling vigor (SV)

Substrates	FSW	DSW	FRW	DRW	PHE	NL	ECL	SV
	g plant $^{-1}$				(cm)			
Biomix$_{®organi}$c	0.18 b	0.02 b	0.12 b	0.02 b	2.50 b	4.25 a	3.05 b	3.68 a
Millicompost	1.12 a	0.13 a	0.54 a	0.05 a	6.60 a	4.38 a	3.75 a	1.85 b
CV (%)	23.60	135.66	23.94	19.59	14.90	13.09	11.24	15.27

Means followed by the same letter in the column do not differ by the F test ($p<0.05$).

The lettuce seedlings grown in the millicompost substrate had a superior development pattern than those grown in the Biomix® organic substrate (Figure 3); in the millicompost substrate, the average values of the fresh masses of the aerial parts and roots were 522% and 350% higher, respectively, than in the Biomix® organic substrate (Table 4).

The average values of the dry masses of the aerial parts and of the roots of the seedlings grown in the millicompost were 550% and 150% higher, respectively, than of those grown in the organic substrate Biomix® (Table 4). According to Costa *et al.* (2013), the average values obtained from the dry matter mass facilitate our understanding of which substrate provided the seedlings with higher nutrient amounts. Based on this, we can confirm the efficiency of the millicompost in providing adequate nutrients to the lettuce seedlings.

Figure 3. Seedlings of the American lettuce cultivar Angelina grown in the millicompost (A) and Biomix® (B) organic substrates, 30 days after sowing.

Antunes *et al*. (2016) found that the presence of nutrients such as calcium, magnesium, and phosphorus, as well as the physicochemical and physical characteristics of the compound generated by diplopods, resulted in a substrate that was efficient in the growth of the seedlings of lettuce cultivar Regina 2000, thus corroborating the results obtained in this work.

Potassium is a fundamental element in the development of vegetables, as it increases the translocation of carbohydrates in plants and improves their water usage. In addition, in the presence of potassium, the use of nitrogen is enhanced (FOLONI *et al*., 2013). The potassium contents of the millicompost along with the higher levels of nitrogen (Table 3) resulted in the best development in the seedling phase of American lettuce.

Rezende *et al*. (2013) evaluated the growth of watercress in response to the earthworm activity of *Chibuibari* and *T. corallinus* in soil-based substrate and organic compost; they verified that the compost produced by *T. corallinus* resulted in higher fresh and dry watercress mass, which corroborates the results of the present work with regard to fresh and dry mass parameters.

Freitas *et al*. (2013) evaluated the production of seedlings of the lettuce cultivar Elba based on different substrates and carbonized rice husk combinations. They registered the highest average height and number of leaves (4.1 cm and 6 leaves, respectively) for the substrate Plant Hort III. The millicompost resulted in seedlings with higher height compared with the Biomix® substrate (Table 4) and the Plant Hort III heights, which was documented by the aforementioned authors. Regarding the number of leaves, although there were no statistical differences between the substrates, this parameter was lower than that recorded by Freitas *et al*. (2013); this result could be attributed to the cultivar type, as the authors of the aforementioned study used curly-type lettuce and in the present work we used American type lettuce.

According to Menegaes *et al*. (2017), the substrate used for the production of seedlings has a direct relationship with the formation and stability of the clod, providing ideal conditions for root development. The average values of clod stability and seedling vigor were 3.75 and 1.85, respectively (Table 4); these values were similar to those recorded by Antunes *et al.* (2018) who, when evaluating the agronomic performance of curly lettuce, confirmed that the quality of the transplanted seedlings in the field is able to influence the final productivity of the lettuce culture, providing greater gains in tons per hectare for treatments with better stability and seedling vigor.

4 FINAL CONSIDERATIONS

The millicomposting process facilitated the reuse of locally available agricultural and urban waste, converting it into organic compost, the millicompost, which combined the physical, physicochemical, and chemical characteristics desirable for a good substrate.

The millicompost was efficient in the production of quality lettuce seedlings. In addition, this compound may represent a viable production alternative for the small producer when used as an organic substrate, as it as it was more cost effective than commercial substrates and encouraged the reuse of organic waste from the property and the region.

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