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ORIGINAL RESEARCH

Quality of seedlings of different pepper genotypes grown in millicompost: An organic substrate generated by millipedes' activity

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Abstract

Purpose To evaluate the production and the quality of seedlings of different pepper genotypes produced on millicompost as an organic substrate.

Method Three experiments were carried out, one for each pepper genotype (ENAS-5007, ENAS-5031 and ENAS-5032) in which three substrates were evaluated: 100% Millicompost (S1); Millicompost MIX (50% millicompost + 50% powdered coconut fiber) (S2) and Carolina organic® commercial substrate (S3). Variables evaluated: shoot and root dry mass (SDM and RDM), number of leaves (NL), plant height (PH), seedling vigor (SV) and clod stability (CS). The data were subjected to the analysis of variance and the means were compared by the Tukey's test at 5% probability level.

Results For the ENAS-5007 and ENAS-5032 genotypes, there was a significant difference in all the variables analyzed, being S1 and S3 the substrates with the highest and the lowest performances, respectively. In the ENAS-5031 genotype, SDM and RDM did not differ between S1 and S2. For ENAS-5031, there were significant differences in PH, NL and SV, in which S1 promoted the best results; however, no significant difference was observed for CS.

Conclusion The 100% millicompost substrate promoted the best development of pepper seedlings in all the three genotypes evaluated. However, the combination of the millicompost MIX has the potential to be used, as it promotes seedlings of superior quality in comparison to the commercial substrate, maximizing the use of millicompost as a substrate for the production of organic pepper seedlings.

Keywords *Capsicum* spp, Millicomposting, Plug seedlings, Coconut fiber

Introduction

Pepper (*Capsicum* spp.) is a vegetable that belongs to the Solanaceae family, native to the tropical region of the Americas, which is composed of a diverse group of sweet and spicy peppers. Within the genus *Capsicum*, the species *C. annuum*, *C. baccatum*, *C. chinense*, *C. frutescens* and *C. pubescens* are the ones that are domesticated and cultivated worldwide (Dagnoko et al. 2013). Peppers play an important role in the fresh vegetable market in Brazil, due to their nutritional richness and medicinal properties, being increasingly present on the table of Brazilians, and their use is mainly in the condiments, seasonings and preserves segment (Ferraz et al. 2016).

Within the production chain of good quality vegetables, the production of seedlings is one of the most important phases, because it directly influences the final performance of the plant, both from a nutritional and productive standpoint (Frazão et al. 2018). Good quality seedlings develop better and have a greater capacity to adapt to the new location after transplanting, enhancing the crop development and enabling early harvest,

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while poorly formed seedlings extend the crop cycle, tending to compromise the production and the final quality of the product, causing losses to the producer (Oliveira Junior 2016).

In the nursery phase, the substrate is an important factor to obtain seedlings with high quality, and, it must have physical and chemical characteristics that provide ideal conditions for the good development of the seedlings. Substrates are often prepared by the producers or purchased from specialized companies, and they can consist of just one type of material or a mixture of different types of materials (Araújo Neto et al. 2009).

The selection of the substrate for the production of vegetable seedlings must be based on two essential criteria: the cost of acquisition and the availability of the material for its production (Steffen et al. 2010). The use of organic waste in the formulation of substrates contributes to reduce their impact on the environment and the costs of the producer, resulted from the acquisition of commercial substrates (Costa et al. 2013). Thus, it is possible for the producers to develop their own substrates at a lower cost, using available organic waste from their properties or places near them (Araújo Neto et al. 2009; Ardisana et al. 2020).

The millicompost, also known as millipede humus, is a new source of organic material to be used as a substrate and it is the result of the fragmentation of plant residues by the millipedes' species. Current studies have shown that millicompost is an environmentally friendly technology due to promising results when it is used as a substrate, because it contains the appropriate chemical and physical properties to grow organic seedlings (Antunes et al. 2020a; Antunes et al. 2021). The millicompost generates a substrate capable of providing the necessary nutrients for the growth of many vegetables (Antunes et al. 2016).

The production time of the millicompost is approximately 100 to 180 days and the materials used for its production can come from pruning of organic agricultural systems; these sources can be crushed tree branches and leaves obtained from grass shavings (*Paspalum notatum*) and leguminous trees (*Gliricidia sepium*, *Flemingia macrophylla*), for example (Antunes et al. 2016; Antunes et al. 2019b). Crushed leaves and branches (3 cm long) from leguminous urban trees (*Albizia lebbeck* and *Senna siamea*) and non-leguminous trees (*Licania tomentosa* (Benth) and *Terminalia catappa*) have also been used, besides other residues such as paperboard, coconut husks (*Cocos nucifera* L.) and corn cobs (Bugni et al. 2019. Antunes et al. 2020b).

Research in millicompost production is still very specific to some places in the world, being it mainly developed in India and Brazil. The Indians observed that the millicompost provided better performances in the production of red pepper, and this substrate has also been shown to be adequate to promote the seeds germination and growth of seedlings of five different forest species (Ramanathan and Alagesan 2012; Senthilkumar et al. 2018). In Brazil, the results also confirm the quality of millicompost as an organic substrate, making it possible to obtain vegetables of quality and ornamental seedlings (Antunes et al. 2018 and 2019a).

There is no commercialization of millicompost, as it is a new product and its production process is still in the experimental stages. The production time, equivalent to the millipede's waste processing, is still considered relatively long and its yielding is only 30% (Antunes et al. 2016; Antunes et al. 2019b). Therefore, scientific studies must be carried out to optimize its production, and because of that, it is important to test mixtures with other sources of substrates to optimize the use of millicompost. One of the alternatives of easily accessible substrates is coconut fiber, which makes it a potential material to be used with millicompost.

Few studies approach the theme of organic substrates in the production of peppers, and considering that the substrate is essential for the production of vegetable seedlings and that their physical, physical-chemical and chemical properties are capable of reflecting on the acquirement of high-quality seedlings for the producer. This work aimed to evaluate the production and the quality of pepper seedlings of different genotypes produced on millicompost as an organic substrate.

Material and methods

The experiment was conducted in a greenhouse located on the premises of Embrapa Agrobiologia, in the municipality of Seropédica-Rio de Janeiro (Brazil), from June 24th to August 5th of 2019.

Characterization of the physical, physical-chemical and chemical properties of the substrates

For the physical characterization of the substrates, the following properties were evaluated: macroporosity, microporosity, total porosity, water retention capacity and volumetric density, which were obtained through the tension table method, using 100 mL metal rings and tension of 10 cm (Teixeira et al. 2017). The pH analyzes were performed in a distilled water solution (5:1 v/v) and the electrical conductivity was determined in the same aqueous extract obtained for the pH measurement, according to the method described by Brasil (2008), being the procedures repeated three times for all the evaluated parameters. The total contents of N, P, K, Ca, and Mg were analyzed through sample digestion. The elementary analyzes were carried out in dry substrate at 65 ° C for 48 hours, in a forced air circulation oven. The total nitrogen (N) levels were determined by distillation, after acid digestion (Kjedahl method). The total P, K, C and Mg levels were determined in aqueous acid extract after their own nitric-perchloric digestion, as described by Teixeira et al. (2017). The available levels of these elements were determined after extraction with KCl 1.0 mol L^{-1} (N, Ca and Mg) and HCl 0.05 mol L^{-1} + H_2SO_4 0.0125 mol L^{-1} (P and K) solutions, as described by Teixeira et al. (2017).

Experimental conduction and experimental design

For the production of the pepper seedlings, sowing was carried out in expanded polystyrene trays with 128 cells (36 cm^3 $cell^{-1}$), using two seeds per cell, and the thinning was performed ten days later, leaving only one plant per cell. Three experiments were carried out, one for each genotype. The experimental design adopted was completely randomized, using one genotype and three substrates, with four replications for each treatment and 10 plants per plot. The treatments consisted of the individual evaluation of three pepper genotypes that belong to the Federal Rural University of Rio de Janeiro (ENAS-5007, ENAS-5031 and ENAS-5032) grown on organic substrates: 100% Millicompost (S1), Millicompost MIX (50% millicompost + 50% powdered coconut fiber) (S2) and Carolina organic® commercial substrate (S3). The Carolina organic® substrate was chosen due to its easy access by organic farmers and because its chemical and physical properties, provided by the company, are in accordance with the Brazilian legislation for substrates sales.

Each tray was sown with only one genotype and was divided into three equal parts, being each part corresponded to a type of substrate. Each experimental plot was composed of 40 plants, in which the useful area was represented by 18 seedlings, 10 of which were chosen at random to be evaluated. Approximately 6 dm^{-3} of substrate per treatment was used. The volumetric density (dry basis) of the substrates were 145 kg m^{-3} (S1), 137 kg m^{-3} (S2) and 141 kg m^{-3} (S3), which were obtained according to the methodology proposed by Teixeira et al. (2017).

The millicompost used was supplied by Embrapa Agrobiologia, located in Seropédica-Rio de Janeiro (Brazil) and it was composed of dry leaves of *Bauhinia* sp. (40%), *Paspalum notatum* (30%), *Musa* sp. (20%) and chopped cardboard (10%), based in volume / volume (Antunes et al. 2020a). The commercial substrate Carolina Soil organic® is composed of *Sphagnum* peat, expanded perlite, limestone, expanded vermiculite and carbonized rice husk.

Seedling's evaluation and statistical analysis

At 43 days after sowing, when the seedlings had three to four pairs of true leaves, the following parameters were evaluated: seedling vigor (SV), clod stability (CS), shoot dry mass (SDM), root dry mass (RDM), number of true leaves (NL) and plant height (PH), which comprised the point of insertion of the root up to the leaf apex. To determine the dry masses, the shoot and the roots of the plants were packed separately in paper bags and kept in a forced air circulation oven at 65 °C for 72 hours.

The seedling vigor (Table 1) and the clod stability (Table 2) were evaluated according to the adapted methodology of Antunes et al. (2018). Due to the different types of development, a rating scale was established by genotype for the assessment of the seedling vigor (Table 1).

The analysis of variance (ANOVA) was performed after verifying the normality and homogeneity of the residues using the Shapiro-Wilk's and Bartlett's tests, respectively, at 5% probability level. When data were significant according to the F test at 5% probability level, the means were subsequently subjected to the Tukey's test ($p \leq 0.05$), using the statistical program Sisvar (Ferreira 2019).

Results and discussion

Physical, physical-chemical and chemical properties of the substrates

Regarding the macroporosity, the substrates showed values of 31.24% (S1), 10.11% (S2) and 51.01% (S3)

(Table 3). Gonçalves and Poggiani (1996) consider the range of 35-45% of macroporosity to be adequate. The microporosity values obtained were 60.45% (S1), 61.16% (S2) and 32.13% (S3) (Table 3). For micropores, the range from 45 to 55% in substrates for plant cultivation is considered to be optimal (Lopes et al. 2008). Thus, all substrates were outside the range considered adequate for the percentage of macropores and micropores, however, this fact did not cause any problems in the development of pepper seedlings.

Table 1 Rating scale proposed to assess the seedling vigor (SV) of the three pepper genotypes developed on organic substrates

Genotype	Vigor	Rating	Number of leaves	Height (cm)	Observed symptoms
ENAS-5007	High	1	≥ 4	≥ 8	Presence of cotyledonal leaves and visual absence of nutritional deficiency.
	Good	2	≥ 4	≥ 8	Beginning of non-prominent yellowing of cotyledonal or basal leaves.
	Regular	3	≥ 4	≥ 5	Nutritional deficiency expressed by prominent yellowing that extends beyond cotyledonal or basal leaves and/or other intrinsic symptoms.
	Low	4	< 4	< 5	Well-defined nutritional deficiency expressed by problems at the seedling height, reduced number of leaves and intense yellowing and/or other intrinsic symptoms.
ENAS-5031 and ENAS-5032	High	1	≥ 4	≥ 6	Presence of cotyledonal leaves and visual absence of nutritional deficiency.
	Good	2	≥ 4	≥ 6	Beginning of non-prominent yellowing of cotyledonal or basal leaves.
	Regular	3	≥ 4	≥ 4	Nutritional deficiency expressed by prominent yellowing that extends beyond cotyledonal or basal leaves and/or other intrinsic symptoms.
	Low	4	< 4	< 4	Well-defined nutritional deficiency expressed by problems at the seedling height, reduced number of leaves and intense yellowing and/or other intrinsic symptoms.

Table 2 Rating scale proposed to assess the clod stability (CS) of the three pepper genotypes developed on organic substrates

Clod stability	Rating	Observed symptoms
Very low	1	50% or more of the clod gets retained in the container when the seedling is removed and it does not remain cohesive.
Low	2	Between 30 to 50% of the clod gets retained in the container when the seedling is removed and it does not remain cohesive.
Regular	3	Between 15 to 30% of the clod gets retained in the container when the seedling is removed and it does not remain cohesive.
Good	4	The clod is completely detached from the container with up to 90% of cohesion and maximum loss of 10% of the substrate.
High	5	The clod is completely detached from the container and more than 90% of it remains cohesive, with losses of less than 10% of the substrate.

Pascual et al. (2018) consider the total porosity levels that vary from 50 to 80% as adequate; therefore, only S2 fits the recommendation established by these authors. The water content retained in the substrate is directly correlated to the distribution of the pores by size, in which the macropores are responsible for the aeration of the roots and not for the retention of water under gravitational force (Schmitz et al. 2002). Thus, the adequate proportion of macropores and micropores contributes to the maintenance of moisture as well as the necessary aeration for the good development of the seedling.

The substrates showed water retention capacity values that varied from 30.23 to 34.85 mL 50 cm^{-3} (Table 3). Levels of water retention capacity between 20 - 30 mL 50 cm^{-3} are considered appropriate (Gonçalves and Poggiani 1996). Thus, substrates S1 and S2 approach the levels of water retention described by the authors and the substrate S3 exceeded the appropriate range by 10.45%. The micropores are those responsible for the water retention (Reinert and Reichert 2006). The water retention capacity of a substrate plays a fundamental role in the water supply to plants and in the interception of nutrients; therefore, substrates that have good water retention can favor germination and, consequently, the establishment of the seedling.

The tested substrates showed volumetric density between 122 and 200 (kg m^{-3}) (Table 3), thus, all of them presented adequate values for the cultivation of seedlings in trays, which should be in the range that varies from 100 to 300 kg m^{-3} (Fermino 2014). Clearly, the substrates have different volumetric densities. Considering that the cell trays used had the same volume for all evaluated treatments, it was found that the equivalent mass of each one was 0.288 kg, 0.264 kg, and 0.176 kg for the 100% Millicompost, 50% Millicompost + 50% powdered coconut fiber and Carolina organic commercial substrates, respectively. The density of a substrate is important to assist in the interpretation of other characteristics, such as porosity, aeration space and water availability (Fermino 2014). Density is an important property, because when it is adequate, it facilitates the root development and improves ergonomics while handling trays, which are lighter to be taken to the production areas. It is important to consider that, in addition to affecting plant growth, lower density substrates have great advantages in horticulture and in marketing logistics, reducing transport weight and increasing ergonomics for workers (Tereso et al. 2014).

When the physical-chemical characteristics of the substrates were determined (Table 4), it was observed that the pH of all the evaluated substrates presented values within the appropriate range for the cultivation of plants, from 5.0 to 6.0 (Fermino 2014), and it allows the greater absorption of nutrients by the plants and less susceptibility of the seedlings to toxicity caused by salts and chemical elements such as aluminum, which negatively affects the plants' root system.

All the substrates showed low electrical conductivity (EC) values (Table 3) and only the average value of S1 was close to the adequate range for the seedling development, which is from 1 to 2.0 dS m^{-1}; it is noteworthy that EC values above 2.0 dS m^{-1} or below 1.0 dS m^{-1} are considered very high and very low for the production of seedlings, respectively (Araújo Neto et al. 2009).

Substrate S1 showed a value of 15.24 for the C/N ratio and 23.25 g kg^{-1} of N (Table 3), thus, it satisfied the requirements of the normative instruction No. 25 of Ministério da Agricultura, Pecuária e Abastecimento (MAPA 2008), which highlights that the C/N ratio cannot be higher than 20 and the total nitrogen content must be at least 5.0 g kg^{-1} for mixed organic fertilizers and composts. Substrate S2 had a C/N ratio of 23.78, being it close to the recommended value and it had an N content equal to 13.15 g kg^{-1}, which was better in comparison to the commercial substrate (S3), which presented very high C/N ratio (61.03) and very low N content (3.90 g kg^{-1}).

The ideal levels of organic carbon should be above 25% for substrates used in containers (Schmitz et al. 2002). Substrates S1 and S2 satisfied this criterion, with contents of 35 and 31%, respectively, while substrate S3 presented only 23%, being it below the recommended value (Table 3).

Nitrogen is an essential element for plants and its absence directly affects the formation of roots, the photosynthetic process and the growth rate of leaves and roots, being the leaf growth the first one to be affected (Castro et al. 2016). The nitrogen content present in the 100% millicompost substrate (S1) was 5.96 times higher in comparison to the commercial substrate (S3) (Table 3), which promoted better development of the pepper seedlings. Substrates composed of millicompost positively influenced the growth of ornamental sunflower seedlings, as they had higher nitrogen contents when compared to the organic commercial substrate (Antunes et al. 2019b).

Gonçalves and Poggiani (1996) established scales for the interpretation of the chemical properties of plant substrates, such as adequate levels of macronutrients. The concentration of phosphorus that is considered adequate varies from 0.40 to 0.80 g kg^{-1}, and, in the present work, all substrates showed values above the adequate levels, with 2.96 g kg^{-1}, 1.71 g kg^{-1} and 2.05 g kg^{-1} in S1, S2 and S3, respectively (Table 3).

Potassium levels from 1.17 to 3.91 g kg^{-1} are considered appropriate (Gonçalves and Poggiani 1996), therefore, none of the substrates had content within the established range (Table 3). Substrates S1 and S2 showed higher potassium values (4.78 and 7.09 g kg^{-1}, respectively), while S3 presented a value that was well below the optimal range (0.46 g kg^{-1}).

Calcium levels considered adequate vary from 2.00 to 4.00 g kg^{-1} (Gonçalves and Poggiani 1996). Evaluating the three substrates studied in this work, none of them fit within the ideal range, and the millicompost ones presented values which were above those recommended (Table 3). This can be justified due to the occurrence of two factors: the leaves of *Bauhinia* sp. used in its composition, which are rich in calcium and constituted 40% of the initial mixture for the millicomposting process, and also because that during the process of millicomposting, there is a decrease in the survival of millipedes until the end of the process, promoting the incorporation of the calcium that constitutes their exoskeletons into the compound (Correia and Aquino 2005). Substrate S2 also had a high calcium content, because it contained 50% of millicompost in its mixture.

The magnesium levels established as adequate vary from 6.07 to 12.16 g kg^{-1} according to Gonçalves and Poggiani (1996). Thus, these were below the recommended range in the substrates S1 and S2 (4.48 and 2.92 g kg^{-1}, respectively), and S3 had a magnesium content which is well above the recommended range (41.56 g kg^{-1}) (Table 3).

Table 3 Characteristics of the organic substrates used in the production of pepper seedlings

Physical proprieties					
Substrates	Macropores	Micropores	Total porosity	$WRC_{10\ cm}$	Volumetric density
	%	%	%	mL 50 cm^{-3}	(kg m^{-3})
Millicompost	31.24	60.45	91.70	30.23	200
Mix	10.11	61.16	71.27	30.83	183
Commercial	51.01	32.13	83.63	34.85	122

Chemical proprieties									
Substrates	pH	EC (dS m^{-1})	C/N ratio	C	N	P	K	Ca	Mg
				g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}
Millicompost	5.87	0.95	15.24	354.34	23.25	2.96	4.78	31.69	4.48
Mix	6.50	0.65	23.78	312.00	13.15	1.71	7.09	19.42	2.92
Commercial	5.44	0.30	61.03	238.00	3.90	2.05	0.46	11.81	41.56

Physical proprieties: Macroporosity, microporosity, total porosity, water retention capacity at a tension of 10 cm ($WRC_{10\ cm}$) and volumetric density.

Chemical proprieties: Potential of hydrogen (pH), electrical conductivity (EC), C/N ratio, total carbon content and total macronutrient content.

Evaluation of the pepper seedlings produced on the different substrates

The effect of the substrates on the seedlings' quality of each genotype studied was evaluated in isolation. There were significant differences ($p<0.05$) for all the parameters of the seedling development phase in all three pepper genotypes, except for the clod stability (CS) in the ENAS-5031 genotype, which remained the same (Table 4).

The pepper seedlings of the three genotypes developed on the 100% millicompost substrate (S1) stood out, presenting a superior development pattern when compared to the seedlings developed on the substrates S2 and S3 (Fig. 1).

Among the possible causes for the lower height development of the seedlings in the substrate S2, which is a combination of 50% of millicompost and 50% of powdered coconut fiber, is the low availability of some nutrients in relation to the substrate S1, which is composed of 100% of millicompost. Beside that, the low percentage of macropores and the high percentage of micropores may have contributed to the lower development of the seedlings, since these factors are directly related to the water retention and the aeration of the roots. Similar results were found by Oliveira et al. (2006) while working with substrates formulated with coconut powder and humus in the production of pepper seedlings. Campanharo et al. (2006) and Pragana (1998) also observed similar results. According to these

Table 4 Average values of shoot dry mass (SDM), root dry mass (RDM), plant height (PH), number of leaves (NL), seedling vigor (SV) and clod stability (CS) obtained from seedlings of the three pepper genotypes developed on organic substrates

Substrates	SDM	RDM	PH	NL	SV	CS
	(mg plant^{-1})		(cm)			
	ENAS-5007					
100% Millicompost	273.6 ^{a}	73.1 ^{a}	23.1 ^{a}	8.4 ^{a}	1.0 ^{a}	4.6 ^{a}
50% Millicompost + 50% Coconut fiber	102.3 ^{b}	38.0 ^{b}	13.9 ^{b}	6.1 ^{b}	2.0 ^{b}	4.1 ^{b}
Carolina organic commercial	17.2 ^{c}	10.1 ^{c}	6.3 ^{c}	3.3 ^{c}	3.3 ^{c}	3.6 ^{c}
CV (%)	29.98	24.4	15.88	15.7	15.49	16.55
	ENAS-5031					
100% Millicompost	^{a} 94.8	21.9 ^{a}	8.2 ^{a}	7.7 ^{a}	1.0 ^{a}	3.0 ^{a}
50% Millicompost + 50% Coconut fiber	^{a} 71.5	21.4 ^{a}	4.7 ^{b}	6.0 ^{b}	2.8 ^{b}	3.0 ^{a}
Carolina organic commercial	^{b} 14.4	7.5 ^{b}	2.7 ^{c}	3.3 ^{c}	3.9 ^{c}	3.0 ^{a}
CV (%)	88.1	40.91	17.57	17.69	15.5	28.64
	ENAS-5032					
100% Millicompost	^{a} 175.3	38.1 ^{a}	13.8 ^{a}	8.0 ^{a}	1.0 ^{a}	4.3 ^{a}
50% Millicompost + 50% Coconut fiber	^{b} 64.3	22.1 ^{b}	5.1 ^{b}	4.6 ^{b}	2.4 ^{b}	4.0 ^{b}
Carolina organic commercial	^{c} 17.0	8.3 ^{c}	2.9 ^{c}	3.3 ^{c}	4.0 ^{c}	3.6 ^{b}
CV (%)	50.73	53.63	11.77	12.95	10.14	18.09

Means followed by the same letter in the column do not differ by the Tukey's test at 5% probability level.

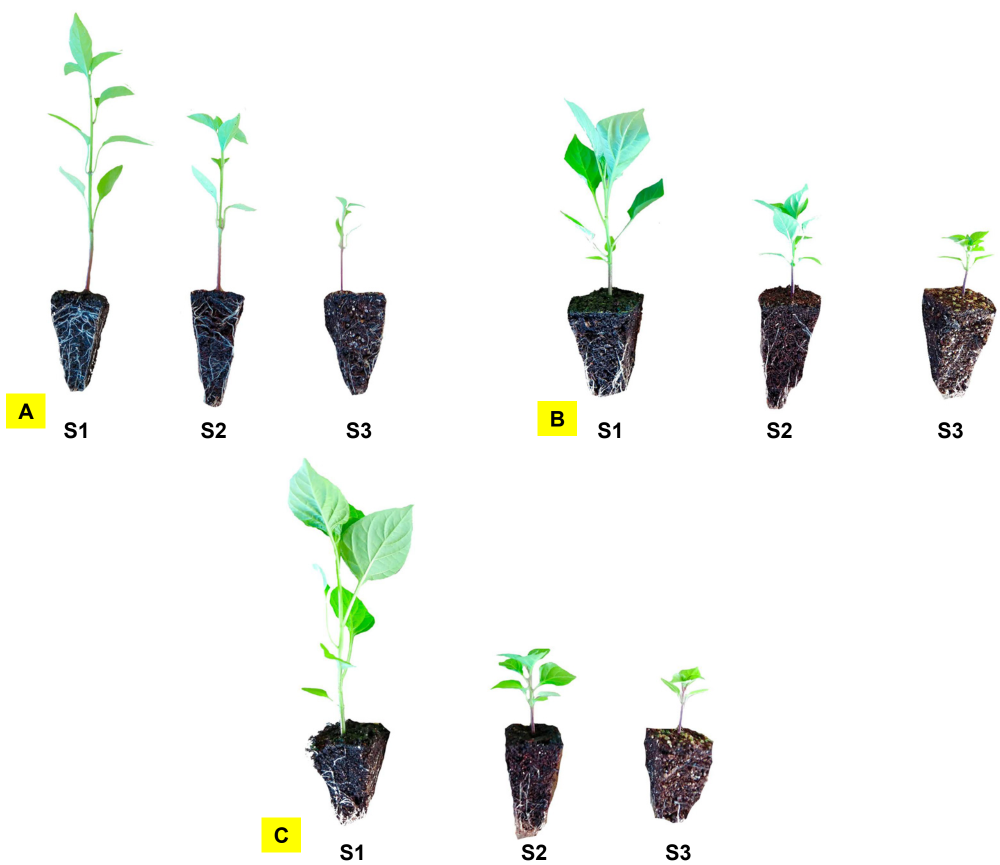

Fig. 1 Pepper seedlings of the ENAS-5007 (A), ENAS-5031 (B) and ENAS-5032 (C) genotypes at 43 days after sowing in 100% Millicompost (S1), 50% Millicompost + 50% Coconut fiber (S2) and Carolina Organic commercial substrate (S3)

authors, the smaller number of leaves, height and dry mass of the seedlings occurs because the powdered coconut fiber does not have the enough amount of nutrients suitable for the plants. Freitas et al. (2013) state that the coconut fiber should be mixed with other nutrient-rich materials, as it has a low amount of nutrients.

Substrate S3 provided the lowest quality seedlings, and this may have happened because it did not have adequate physical and chemical characteristics for the development of pepper seedlings (Tables 3 and 4). These results corroborate with Motta et al. (2018), who evaluated different substrates in the production of broccoli seedlings and observed that the Carolina organic commercial substrate did not provide seedling with high quality, and they also stated that this substrate needs mineral complementation to the obtaining of satisfactory seedling development.

For the shoot dry mass and root dry mass, there was a statistical difference among the substrates in the ENAS-5007 and ENAS-5032 genotypes, with the highest values found in the seedlings produced in the substrate S1. For the ENAS-5007 genotype, S1 presented average values of SDM 15.9 times greater than the ones obtained in the commercial substrate (S3). Besides, in the ENAS-5007 genotype, S1 showed mean values of RDM 7.23 times higher than in S3 (Table 4). For the ENAS-5031 genotype, there was no significant difference between substrates S1 and S2, and the substrate S3 was the one that differed, showing the lowest values. It is possible to know which substrate provided greater amounts of nutrients to the seedlings from the average values obtained of dry matter mass (Costa et al. 2013). Thus, it is possible to confirm the efficiency of the millicompost in the adequate supply of nutrients to the pepper seedlings.

The substrate that provided the highest seedling height in all genotypes was S1, while the lowest results were found in the seedlings obtained in the substrate S3 (Table 4). When comparing the height values of S1 and S3, it can be noticed that S1 reaches, on average, values three times higher than S3.

The number of leaves varied among substrates in all three genotypes, being S1 the one with the highest values, differing statistically from the other substrates. The lowest number of leaves was observed in the substrate S3, which presented an average of 3.3 leaves in all genotypes (Table 4).

For all three genotypes, substrate S1 provided pepper seedlings with high vigor. The substrate S2 allowed the acquirement of seedlings with good vigor, and substrate S3 resulted in seedlings with regular vigor for the genotypes ENAS-5007 and ENAS-5031 and low vigor for the genotype ENAS-5032 (Table 4).

In the clod stability (CS), there was also a significant difference among substrates in the genotypes ENAS-5007 and ENAS-5032, being S1 and S2 the substrates that promoted good CS, and the substrate S3 showed regular stability (Table 4). For the ENAS-5031 genotype, there was no statistical difference among substrates and all of them showed regular clod stability (Table 4). The clod stability is an important factor, as it is desired that when the plant is removed from the seedling production container, the substrate remains adhered to the root of the plant, providing support for it and allowing its normal development. This cohesion of the substrate is desirable, because it prevents the seedling and, in particular, the root system, from suffering stresses when transplanted to the final area.

The millicompost has enabled the best plant development in all the parameters evaluated, showing that its chemical and physical properties are adequate for the production of seedlings, especially in agricultural systems of organic production, in addition to being an environmentally correct technology, since it is produced from plant residues of many species. However, it is important to highlight some aspects of the production of the millicompost. This substrate in its composting process due to the use of senescent plant residues (pruning of leguminous and non-leguminous plants from organic system agriculture, urban trees, dry grass clippings, banana leaves, cultural remains, etc.) is reduced by up to 70%, and the process can last from 100 to 180 days, because when combined with each other, these residues constitute a large volume, and after the composting period, its final yield is only 30%, approximately (Antunes 2016).

Considering that the quantity of millicompost produced may sometimes not be sufficient to the demand of the seedling producer, the use of coconut fiber combined with the millicompost, in the ratio of 1: 1 (v: v), may be an option for the producer, as it provided better quality seedlings when compared to those produced on the commercial substrate. Therefore, the producer could reduce costs with the acquisition of the commercial substrate and would also be able to maximize the use of millicompost.

Conclusion

The pepper genotypes ENAS-5007, ENAS-5031 and ENAS-5032 grown on 100% millicompost substrate had the highest quality and the best performance in all evaluated parameters, producing plants with higher vigor and greater clod stability.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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