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Formation of pepper seedlings on a substrate formulated by carnauba (*Copernicia prunifera* Mill.) residue

Kleber Veras Cordeiro[1], Paula Sara Teixeira de Oliveira[2], Ramon Yuri Ferreira Pereira[3], João Pedro Santos Cardoso[1], Marcos de Oliveira Sousa[1], Geisiane Silva Sousa[1], Rafael Silva Marchão[1], Raissa Rachel Salustriano Da Silva Matos[1], Edmilson Igor Bernardo Almeida[1]

[1]Universidade Federal do Maranhão, Brazil
[2]Universidade Estadual do Maranhão, Brazil
[3]Universidade Federal do Piauí, Brazil

Corresponding author: paulasara1997@gmail.com

Abstract

The consumption of pepper in Brazil stands out in several sectors of the economy, either *in natura* or processed form, due to its characteristics of profitability and added value. Thus, the objective was to evaluate the biometric characteristics of gold pepper seedlings produced on substrates containing different proportions of carnauba (*Copernicia prunifera* Mill.) bagana. The proportions of the substrates were: 0%, 20%, 40%, 60%, 80% and 100% carnauba bagana, plus soil. The following were evaluated: percentage of emergence, number of leaves; leaf area; plant height; stem diameter; root length; root volume; fresh and dry root mass and dry and fresh shoot mass. The effect of bagana on the pepper plant was observed and the variables studied showed responses mainly with the substrates containing 80% and 100% bagana, including the percentage of emergence, plant height, stem diameter, leaf area, root volume, mass fresh shoot and root, dry shoot weight and Dickson's quality index. The substrate with 100% bagana provided a higher leaf area of 85%, expressive growth in height, diameter and root length, compared to control. The ability of the substrate to retain water and the availability of nutrients may be the main factor, while the contents of organic matter and other nutrients available in the carnauba bagana may have been fundamental in the performance of both the aerial part and the root system. Thus, it is concluded that the use of carnauba bagana can be indicated as a substrate in the formation of gold pepper seedlings. Hence, application of of 100% carnauba bagana is recommended for the production of pepper cultivar gold.

Keywords: *Copernicia prunifera* Mill.; seedling production; alternative substrates; agroecology; family farming.
Abbreviations: E%_Percentage of seedling emergence; PH_plant height; NL_number of leaves; LA_leaf area; SD_stem diameter; RL_root length; RV_root volume; FMAP_fresh mass of the aerial part; FMRS_fresh mass of the root system; DMAP_dry mass of the aerial part; DMRS_dry mass of the root system; DQI_Dickson's quality index, CB_carnauba bagana.

Introduction

The pepper belongs to the family of *Solanaceae* and to the genus *Capsicum*. It is considered an important product of Brazilian agribusiness, in the states of Minas Gerais, Goiás and São Paulo, Ceará and Rio Grande do Sul as the main producers and the Northeast region presenting significant potential for the production of this vegetable due to its edaphoclimatic condition (Alves et al., 2017). The consumption of pepper is highlighted in several sectors of the Brazilian economy, both in the “in natura” and processed form (EMBRAPA Hortaliças, 2012).
In the pepper production process, the formation and performance of the seedling is very important (Maggioni et al. 2014). In this way, the technology used with the genetic material and the quality of the seed, the irrigation techniques, the cultural treatments and the substrates used can culminate in better productive yields in the field.
The choice of substrate for the conduction of plants is one of the factors that interfere in the entire crop cycle, as it serves as a support for root fixation, nutrient availability, water retention and aeration. The substrate is indispensable in the healthy and vigorous formation of seedlings, and its choice depends on the cost of production and regional availability (Delarmelina et al., 2014). As a search strategy to reduce costs, the producer has adopted the use of alternative substrates (Nadai et al., 2015).
Among the options of regional substrates, in some northeastern states, the potential of carnauba biomass compounds stands out. The carnauba (*Copernicia prunifera* Mill.) is a native Brazilian palm, found mainly in areas close to rivers and lakes. According to Araújo et al. (2017), the reuse of residues in the formation of substrates has often been the subject of studies aimed at reusing the nutrients contained in these materials, reducing the cost of production, in addition to mitigating the negative environmental impacts generated. The carnauba residue has been used empirically in agriculture and its effect on the production of seedlings is still little addressed in the scientific literature (Brito et al., 2017).
However, the effects and the appropriate proportion for the formation of pepper seedlings remain unknown, although both the culture and the raw material (carnauba) have the potential to strengthen the economy of the north and

Table 1. Analysis of variance of emergence percentage (E%), leaf area (LA), number of leaves (NL), plant height (PH), stem diameter (SD), root length (RL), root volume (RV), fresh shoot weight (FMAP), fresh shoot weight (FMRS), dry shoot weight (MSPA), dry shoot weight (DMRS) and Dickson quality index (DQI), parameters evaluated in pepper seedlings, submitted to different concentrations of the carnauba bagana substrates, plus soil.

VS	DF	---------------------- F. CAL ------------------------						
		E%	LA	NL	PH	SD	RL	F TAB
Substrate	5	3.02^{**}	29.14^{**}	85.52^{**}	58.69^{**}	83.55^{**}	40.08^{**}	2.57
Residue	18	-	-	-	-	-	-	
C.V.		13.91	23.60	6.27	7.81	3.53	7.58	
VS	DF	---------------------------------F. CAL ------------------------						
		RV	FMAP	FMRS	DMAP	DMRS	DQI	F TAB
Substrate	5	11.55^{**}	131.15^{**}	53.77^{**}	136.20^{**}	0.73^{ns}	21.34^{**}	2.57
Residue	18	-	-	-	-	-	-	
CV		38.57	12.57	22.40	10.06	84.05	28.53	

VS - variation source; DF - Degree of freedom; CV - Coefficient of variation;
** - significant at the 1% probability level (p<0.01); ns - not significant (p>= 0.05).

Table 2. Values of pH, organic matter (OM) and contents of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) of the carnauba bagana (CB) substrates plus soil.

Substrates	pH	OM	N	P	K	Ca	Mg	S
		$g\ kg^{-1}$	$g\ kg^{-1}$	$mg\ kg^{-1}$		$cmol_c\ kg^{-1}$		
0% CB	4.00	22.80	1.14	3.50	0.14	0.69	0.53	2.82
20% CB	5.1	60.67	3.92	6.00	0.63	35.19	0.50	4.30
40% CB	4.9	73.82	5.36	12.00	0.72	4.50	1.30	6.80
60% CB	5.0	95.22	6.89	23.00	1.28	5.80	1.40	8.90
80% CB	5.1	114.26	9.28	42.00	2.21	7.00	3.10	12.70
100% CB	5.3	598.86	4.02	89.00	3.88	19.80	10.40	34.60

Table 3. Global density (GD), particle density (PD) and porosity (P) of carnauba bagana (CB) substrates, plus soil.

Substrates	Density ($g\ cm^{-3}$)		Porosity (%)
	GD	PD	
0% CB	1.44	2.67	45.99
20% CB	1.17	2.61	55.33
40% CB	0.99	2.42	59.26
60% CB	0.78	1.98	60.78
80% CB	0.56	1.77	68.53
100% CB	0.27	0.90	70.20

northeast of Brazil, especially Maranhão. Therefore, the objective was to evaluate the biometric characteristics of gold pepper seedlings, produced in substrates formulated with carnauba bagana.

Results and discussion

Analysis of variance

The results of the analysis of variance are shown in Table 1. Significant values were observed for all treatments, except for the dry mass variable of the root system.

Similar positive outcomes were observed in other studies evaluating the use of carnauba residue as a substrate for pepper seedling production, which also reported significant improvements in germination, biometry, biomass, and DQI variables, e.g. Mendonça et al. (2021), evaluated the morphophysiology and nutrition of yellow passion fruit seedlings grown on carnauba bagana-based substrates. Sousa et al. (2020), studied the effect of substrates on the production of açaí seedlings cultivar BRS-Pará. Both studies corroborate and highlight the quality of this residue and its efficiency for use as a substrate.

Emergency

Figure 1A shows the E% and the influence of CB on this variable, in which the highest value (48.6%) observed, which reveals a significant difference between treatments, with 100% CB and 80% CB standing out with the best averages. One of the main causes of the influence is associated with the increase in capacity provided by the substrate, with lower density (0.90 g cm-3) and higher porosity (70.2%). This allowed better water retention and aeration for plant development (Souza et al., 2011).

It is an important result, as the carnauba bagana proved to be a more viable alternative compared to substrates composed only of soil or most of the soil. However, other works reported in the literature have reached higher values of E%, with the use of other residues that are more advantageous in this phase of the plant. For example, Gonçalves et al., 2014, evaluated substrates composed of a commercial material, Plantmax® and earthworm vermicompost, and obtained values very close to 100% emergence.

Aerial and root growth of plants

The LA was also influenced by the use of 100% CB (Figure 1B), which presented an average result of 153.9 cm^2 and 85% higher than the use of soil alone (0% CB), which presented 14.4 cm^2. This result may be related to the physical conditions and the proper concentration of nutrients in the 100% CB substrate. According to Jakelaitis et al. (2005), the leaf growth rate, is directly related to the nitrogen supply to the plant. For these nutrients, it was

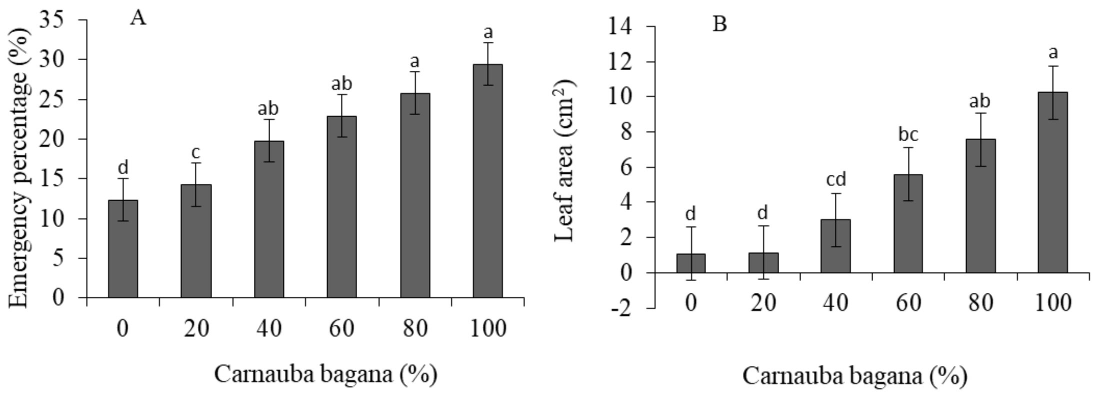

Fig 1. Percentage of emergence (A) and leaf area (B) of pepper seedlings in substrate formulated based on carnauba residue. Means with equal letters do not differ statistically from each other by Tukey's test at 1% significance.

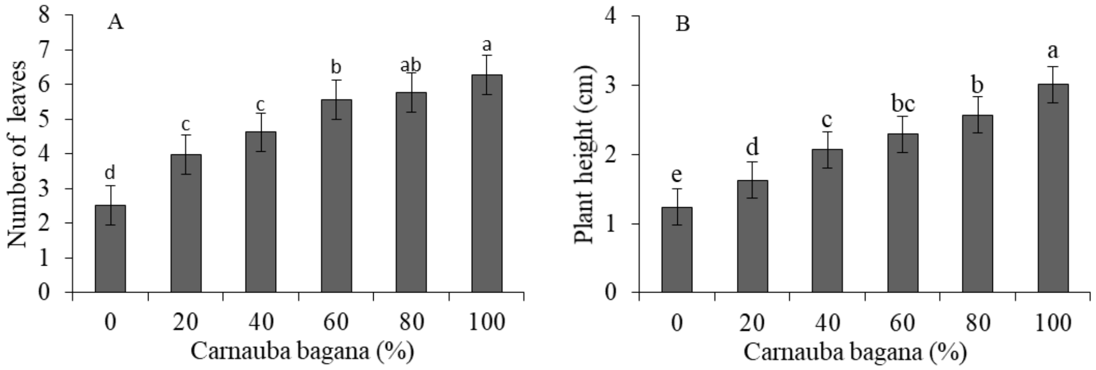

Fig 2. Number of leaves (A) and plant height (B) of pepper seedlings on substrate formulated based on carnauba residue. Means with equal letters do not differ statistically from each other by Tukey's test at 1% significance.

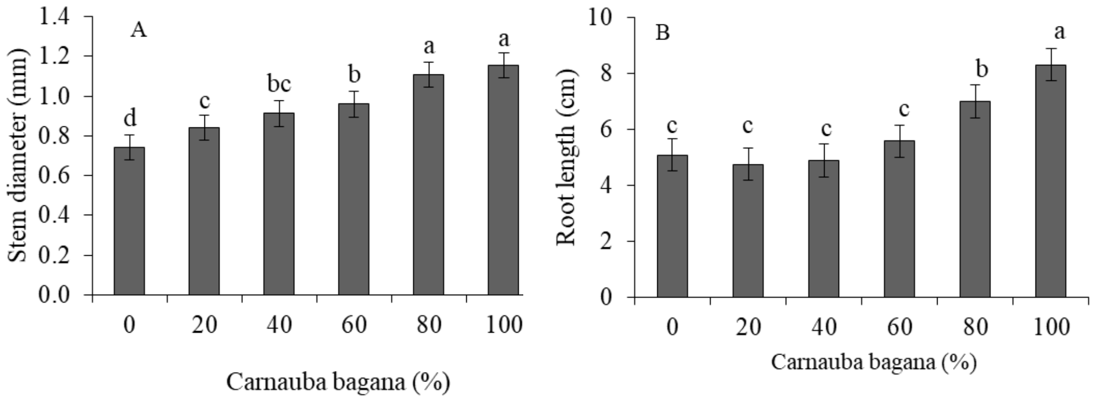

Fig 3. Stem diameter (A) and root length (B) of pepper seedlings on substrate formulated based on carnauba residue. Means with equal letters do not differ statistically from each other by Tukey's test at 1% significance.

observed that the carnauba bagana presented four times greater concentration, which can culminate in greater effects on LA and corroborate with the aforementioned author.

There was an increase in the variable NL (Figure 2A), in response to the increase in concentrations of bagana highlighting a significant difference in the variable, where the 100% CB treatment had the highest average (6.2 units) and the lowest was observed in the 0% CB treatment com (2.5 units). This result is possibly associated with the deficit of soil nutrients compared to the other treatments.

The PH variable (Figure 2B), showed better performance with the use of 100% CB, compared to the others. It is likely that the physical-chemical characteristics of the substrate containing 100% CB have provided adequate conditions for the growth of pepper seedlings, in strategic aspects such as water retention, ease of root penetration, absorption of nutrients by the roots and availability of nutrients, such as nitrogen, phosphorus and potassium, which play important roles in the initial growth of plants. This corroborates with Saraiva et al. (2011), who observed better yields in papaya seedlings, when in adequate nutritional conditions.

The SD response (Figure 3A), showed a behavior similar to that observed in the PH. The best yields were obtained using 80% CB + 20% soil and 100% CB. As the concentrations of carnauba bagana decreased, there was a decrease in the SD means. This increase was possibly due to the concentration of potassium in the substrate of carnauba (Table 1). Souza et al. (2013) stated that the length of the aerial part, combined with the diameter of the stem, constitutes an important morphological characteristic for estimating performance after transplanting into the field.

For the RL (Figure 3B), the highest values among the formulations of the substrate bagana of carnauba were with

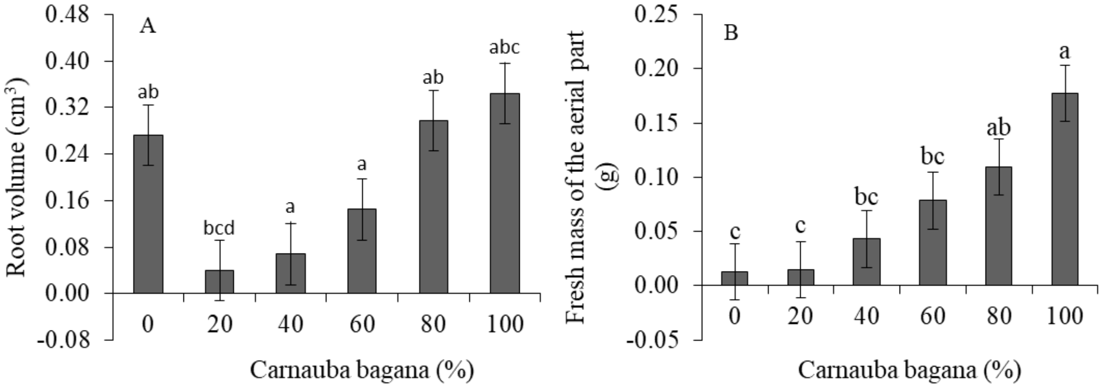

Fig 4. Root volume (A) and fresh weight of the aerial part (B) of pepper seedlings on substrate formulated based on carnauba residue. Means with equal letters do not differ statistically from each other by Tukey's test at 1% significance.

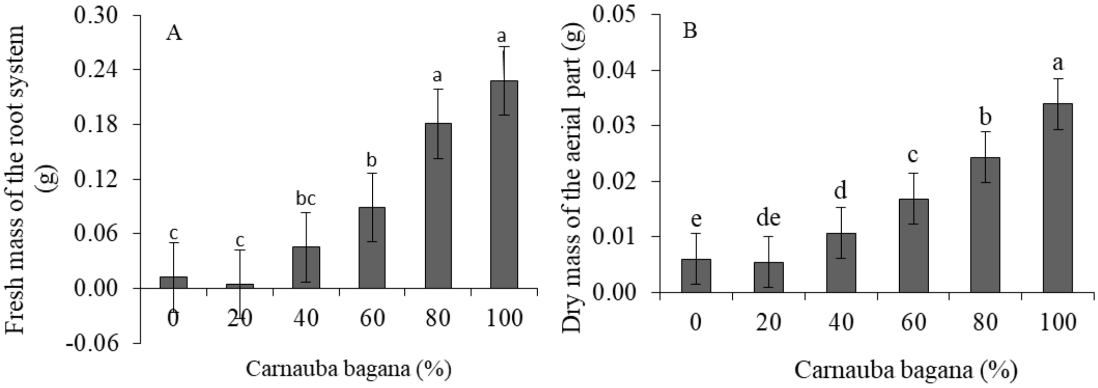

Fig 5. Fresh mass of the root system (A) and dry mass of the aerial part (B) of pepper seedlings on substrate formulated based on carnauba residue. Means with equal letters do not differ statistically from each other by Tukey's test at 1% significance.

100%, 80% and 60% CB with 8.29 cm; 6.99 cm and 5.56 cm respectively, providing greater growth of the roots in relation to the others, thus revealing the superiority in these formulations.

With regard to RV (Figure 4A), the analysis expressed that the best yields occurred with the use of 100% CB and 80% CB + 20% of soil. This result suggests that these formulations may have provided an environment without impediments or physical barriers for pepper roots. According to Alvares (2011), the presence of organic matter in the substrate improves the chemical, physical and biological characteristics, creating an environment suitable for the root development of the plant.

Plant biomass and DQI

The fresh mass of the aerial part (FMAP) content (Figure 4B), was influenced by the presence of the substrate combinations, presenting higher average values with the use of 100% CB, which was already expected by the beneficial effects of this substrate on the different variables of the aerial part analyzed. The ability of the substrate to retain water and availability of nutrients may be the main factor for this result, which was approximately four times that obtained for the control (100% soil). The hypotheses about the benefits of these formulations, may be related to nutritional, mainly phosphorus and calcium.

For FMRS (Figure 5A), possibly the average proportions of 60% CB + 40% soil; 80% CB + 20% soil and 100% CB compared to the others, provided better conditions of fixation and growth in volume, guaranteeing a better biomass and highlighting 100% CB with the best average presented (0.228 g) and the worst presented by control 0% CB (0.012 g). Another hypothesis is that the amount of organic matter available in the carnauba bagana may be related to 598.86 g kg^{-1} in 100% CB. Lima (2016), used babassu fiber, carbonized rice husk and goat manure in the proportions of (80-10-10) while evaluating alternative substrates for the production of ornamental pepper, and noticed 194.42 g kg^{-1} of organic matter in the composition.

In general, production of DMAP (Figure 5B) responded in a similar way with the composition of 100% CB, presenting higher averages due to the increase in the proportion of carnauba bagana. Bezerra et al. (2010), used agro-industrial and agricultural waste as substrates, including carnauba bagana for the production of ornamental pepper seedlings, and found good performance of carnauba bagana in the production of dry pasta.

Regarding the effect of formulations of the carnauba bagana substrates on the DMRS (Figure 6A), there was no significant difference. However the highest value observed was with the proportion of 80% with 0.0126 g. Araújo et al. (2017) evaluated the growth and quality of paricá seedlings produced on substrates based on organic residues, including the carnauba bagana, while did not obtain any influence with the use of this substrate for the same variable.

As highlighted by Gomes (2001), the morphological parameters of height, diameter and biomass determine the DQI, the higher the index, the higher the seedling quality standard. Posse et al. (2018) stated that DQI cannot be the only parameter to determine the quality of a seedling, with the number of leaves, height and diameter being relevant characteristics for survival in the field.

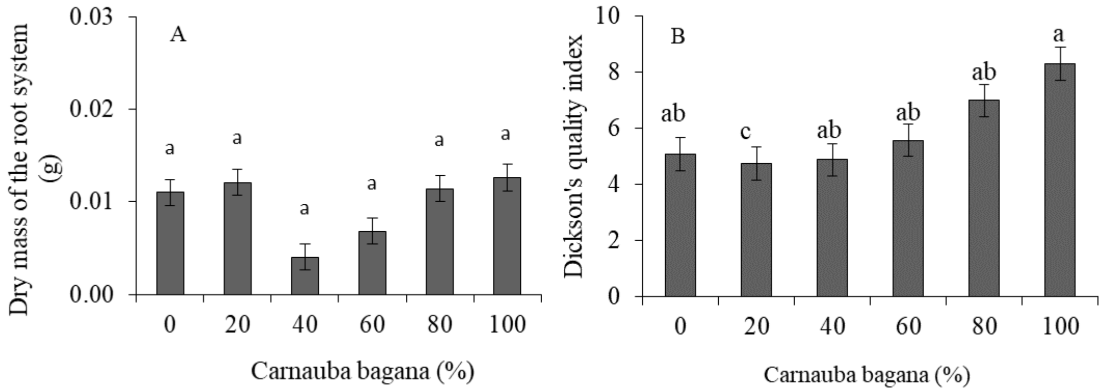

Fig 6. Dry mass of the root system (A) and Dickson's quality index (B) of pepper seedlings in substrate formulated based on carnauba residue. Means with equal letters do not differ statistically from each other by Tukey's test at 1% significance.

In our evaluation of gold pepper seedlings, we observed that the largest seedlings with the best biomass and the best development indexes were deduced with the proportions of 100% CB and 80% CB observed in this variable (Figure 6B). Possibly the chemical and physical conditions of the substrates (Tables 2 and 3) were favorable, allowing greater availability of nutrients, good aeration with porous spaces and water retention, thus the root system had better rooting and the plants had a better accumulation of biomass and development.

Materials and methods

Location and climate

The experiment was carried out from September to November 2018, in a greenhouse with 50% interception of solar radiation, at the Center for Agricultural and Environmental Sciences of the Federal University of Maranhão, Chapadinha (MA), under the following geographical coordinates: 03º44'17 ” S and 43º20'29 ”O. The municipality is located 100 m above sea level and 252 km from the capital São Luís. The climate, according to Thornthwaite (1995), is of the type C2s2A'a ', that is, subhumid, megathermic with severe water deficiency in summer, average annual temperature of 27.9 ° C and average annual rainfall of 1613 mm obtained by the city's weather station. de Chapadinha, Maranhão (Passos et al., 2016).

Preparation of substitutes and plant material

Carnauba bagana is generally collected in very large pieces. Therefore, this material had to pass through a mechanical crusher, and then through a No. 3 sieve to homogenize the particle sizes.

The soil used was collected near the experimental area. It is classified as Dystrophic Yellow Latosol. This material was also sieved with a No. 2 sieve.

As for the physical characteristics, the soil used in the formulation of the substrates has the following attributes: 384 g kg^{-1} of coarse sand; 336 g kg^{-1} of fine sand; 112 g kg^{-1} of silt; 168 g kg^{-1} of total clay; 38 g kg^{-1} of natural clay; flocculation degree of 77 g g^{-1}. As for texture, the soil was classified as sandy frank.

For the formation of the seedlings, pepper seeds were used to cultivate 'Topseed' gold, with 99.9% purity and minimum germination guarantee of 85%. Sowing was carried out in a polystyrene tray with 128 cells, with two seeds per cell being placed one centimeter deep. The thinning of the seedlings was done when they had two definitive leaves, leaving the most vigorous.

Experiment design and evaluation

The experiment was conducted in a completely randomized design, with six treatments, four replications and 16 plants per plot, totaling 384 experimental units. The treatments consisted of different proportions of carnauba bagana (CB): 0%, 20%, 40%, 60%, 80% and 100% CB, plus soil.

The chemical characteristics of the substrate formulation are shown in Table 2. For physical characterization (Table 3), analyzes of global density, particle density and porosity were performed and determined according to procedures described by Schmitz et al. (2002).

At 65 days after sowing, to understand the effects of treatments on the formation of sweet pepper seedlings, the following variables were evaluated: percentage of seedling emergence (%), by counting the number of seedlings emerged daily until stabilization; plant height (cm) measured with the aid of a millimeter ruler; number of sheets, determined by the count of sheets issued; leaf area (cm^2), measured with the computer program 'ImageJ'; stem diameter (mm), measured by using a digital caliper; root length (cm), measured with the aid of a millimeter ruler; root volume (cm^3), measured according to the methodology described by Basso (1999); fresh mass of the aerial part (g) and fresh mass of the root system (g); dry mass of the aerial part (g) and dry mass of the root system (g), obtained by drying in an oven with forced air circulation, at a temperature of 65ºC, until reaching constant mass. Dickson's quality index (DQI) was also determined using the formula (Dickson et al., 1960): in which: TDM: total dry mass; PH: plant height; SD: stem diameter; DMAP: dry mass of the aerial part; DMRS: dry mass of the root system.

Statistical analysis

The data were submitted to analysis of variance by the "F" test, to diagnose the effect of the treatments. When there was a significant effect, the treatments were compared with the Tukey test, using the Software Assistat® V 7.7 program (Silva and Azevedo, 2016).

Conclusion

The use of carnauba bagana as a substrate in the formation of gold pepper seedlings provides good formula according to the organic matter content and nutrient availability of this substrate. Therefore, the use of 100% carnauba bagana is recommended for the production of pepper seedlings.

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