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Development of papaya tree in organic substrates

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Abstract

Papaya is a tropical fruit of great importance in the international and national market. For crop success, the use of quality seedlings is of paramount importance and substrates formulated from organic sources may be a viable alternative. In this context, the objective of this study was to evaluate the initial development of papaya seedlings in different formulations and levels of organic substrates. A completely randomized design was used in a 4x4+1 factorial scheme, corresponding to four substrate formulations, containing decomposed buriti stem (CDB). The treatments included of the following: (CDB, ½ CDB + ½ poultry manure, ½ CDB + ½ cattle manure and ½ CDB + ½ gray with plant origin sourced from materials resulting from the burning of plant material (stem, branches); four proportion levels of the formulations of the substrates mixed to the soil (25; 50; 75 and 100%) and the additional control (100% soil). The following variables were measured: plant height, leaf area, number of leaves, shoot dry matter, root length and root dry matter at 42 days of seedling cultivation. The results showed that use of an ideal source of organic matter is feasible in the production of papaya seedlings. The substrate consisting of CBD + poultry manure had great potential to be used in the production of papaya seedlings.

Keywords: *Carica papaya* L., seedling production, organic fertilization.
Abbreviations: CBD_Decomposed buriti stem; AP_Plant height; AF_Leaf area; NF_Number of leaves; CR_Root length; MSPA_Shoot dry matter; MSR_Root dry matter; CPCE_Cinobelina Elvas Campus; UFPI_Federal University of Piaui; DAS_Days after sowing; pH_ In water; P_Phosphorus; S_Sulfur; H + Al_Hydrogen + Aluminum; Al_Aluminum; Ca_Calcium; Mg_Magnesium; K_Potassium; SB_Sum of Exchangeable Bases; T_CTC effective; m_Aluminum Saturation Index; V_Base Saturation Index; MO_Organic matter.

Introduction

Papaya (*Carica papaya* L.) is a tropical species belonging to the Caricaceae family. It is believed that papaya is native to tropical America, its region of origin being southern Mexico and neighbouring Central America (Cotruţ et al., 2017). It is a crop of socioeconomic importance for Brazilian fruit growing, with Brazil as the second largest producer in the world, with a share of 12.6% of production, being the second largest exporter with 9.6% of the world exportation, mainly exporting to Europe and North America (FAO, 2015).

Due to the importance of this fruit in the national scenario the constant development of research is necessary, especially in relation to seedling production (Deb et al., 2010; Saran et al., 2015), since the use of quality and vigorous seedlings is a fundamental factor for the success of transplanting and establishment in the field (Oliveira et al., 2016).

Many factors can affect seedling quality especially the conditions under which they are produced and the substrate source (Santos et al., 2018). According to Terra et al. (2011) and Santos et al., (2016), the ideal substrate for seedling production must have a good structure, allowing aeration, water availability and nutrient retention, adequate pH, pathogens free and stimulation of the high dry weight content production in both the aerial and root parts.

Besides the physical, chemical and sanitary characteristics of substrates, cost/benefit ratio, availability in the market and handling must be taken into account (Silva et al., 2011; Ahmed et al., 2013; Dahmardeh, 2013). With the increase in costs of mineral fertilization and the awareness of the problem generated by the accumulation of residues from anthropic activities in the urban and rural environment, organic waste has become more important. They are usually recyclable and usable materials to improve the physical conditions of the soil and increase fertility of soil and plant, plus contributing to the sustainability of the planet (Cui et al., 2007; Hafle et al., 2011; Silva et al., 2012).

The use of organic waste in agriculture has increased exponentially in recent years. The organic fertilizer stands out in relation to the application of mineral fertilizers, mainly due to the gradual release of nutrients, reducing losses by volatilization, fixation or leaching (Machado et al., 2011). Besides, the addition of organic matter to the soil contributes to increase the water absorption capacity for the plants, enabling the increase in seedling and food production and quality.

For the production of papaya seedlings some mixtures have been suggested for the formulation of the substrates such as tanned manure + charcoal + soil + sand at a ratio (Mendonça et al., 2003); bovine manure + soil + sand + vermiculite (Negreiros et al., 2005) plantmax + humus + cattle manure (Góes et al., 2010); plant soil + sand + cattle manure (Lima et al., 2011); agro-industrial residue of carnauba wax semi-decomposed (Albano et al., 2017), bovine manure + sugarcane residue + cotton residue (Costa and Martins, 2018). Alternatively, chicken manure may be employed in the ratio 1:4 (Costa and Martins, 2018). Other organic sources are also suggested, such as poultry manure, sheep manure (Sá et al., 2016) and earthworm humus (Hafle et al., 2011).

The organic sources for the formulation of substrates are many and vary between regions. The buriti decomposed stem (CDB), poultry and bovine manure, as well as plant ashes, are easily found in the southwestern region of Piauí and can be easily accessible and affordable for producers (Oliveira et al., 2016). In this context, the objective of this study was to evaluate the initial development of papaya seedlings in different formulations and levels of formulations of organic substrates.

Results and Discussion

Effect of treatments on shoot development

For the variables AP, AF and NF, there was a significant interaction (F test, p <0.01) between the substrate formulations and levels of substrate formulations. In general, for these variables, the formulation with organic source CBD + poultry manure, at all proportion levels, contributed with a significant increase in relation to the additional control (soil only), being superior to the other formulations (Table 2). The formulations CBD and CBD + cattle manure, although inferior to CBD + poultry manure, also yielded significantly higher results than the additional control, mainly at higher concentrations. For CDB + cattle manure there was an increase in AP and NF at the formulation level of 25% and AF at the formulation level of 25 and 50%. Application of CDB influenced AP and AF by formulation levels of 75 and 100%, while only the 100% level (Table 2) influenced NF. These results emphasize the potential of CBD mixed with other organic sources in the composition of horticultural substrates, already successfully tested for fruit species such as “castanheira-do-gurgueia” (Cavalcante et al., 2011), passion fruit (Silva, 2012) and papaya (Albano et al., 2014). These organic sources have also shown satisfactory results for other tree species such as monkfish (*Enterolobium contortsiliquum*) (Sousa et al., 2013), neem (*Azadirachta indica*) (Oliveira et al., 2016) and *Heliconia* (Beckmann-Cavalcante et al., 2011).

The benefits of the use of the substrate formulation CBD + poultry manure in the shoot development of papaya seedlings found in this research corroborates with other studies. Oliveira et al. (2016) verified that the organic formulations of CBD stem and poultry manure yielded better results in the initial shoot development of *Azadirachta indica* seedlings.

The use of CBD has already shown promising results in several plants especially in tree species cultivation (Sousa et al., 2010). According to Albano et al. (2014), the CBD presents 597.85 g dm^{-3} of organic matter, 21.18 g kg^{-1} of N, 8.8 cmolc dm^{-3} of Ca^{2+} (extractor KCl 1 M), 7.9 cmolc dm^{-3} of Mg (1 M KCl extractor), 0.03 mol cm^{-1} of Al^{3+} (1 M extractor KCl), 0.95 cmolc dm^{-3} Na^{+} (Melich extractor 1) (Melich 1 extractor), 404.00 mg dm^{-3} of K^{+} (Melich extractor 1) and 2.03 mg dm^{-3} of B. Furthermore, Avelino et al. (2010) characterized the physical properties of CBD, containing 625 Kg m^{-3} wet density (DU), dry density (DS) 124 Kg m^{-3}, water retention capacity (ARC) 57%, aeration space EA) 35% and total porosity (PT) 93%. Its combination with poultry manure increased its potential for papaya seedling production. According to Rogeri et al. (2016), poultry manure is a source of organic matter. It is a suitable substrate that can improve the physical characteristics of the soil. Poultry manure that contains only feces are considered rich in essential plant nutrients (Rogeri et al., 2016). According to Gianello and Ernani (1983) and Ernani (1984), these substrates frequently have high levels of nitrogen (2.6-3.0%), phosphorus (3.9-4.5%) and potassium (1.0-3.0%). In addition, the poultry bed increases pH and macronutrient contents (Rogeri et al., 2016).

The use of the CBD formulation alone showed a linear behavior for the variables AP, AF and NF (Figure 1). The results of the maximum levels (100%) of the CBD formulation led to a greater shoot development of the seedlings. These results contradict those found by Silva (2012) and Albano et al. (2014), who observed a reduction in papaya seedlings with formulation levels of 100% CBD.

Analysis of regression equations for AP, AF and NF (Figure 1A, B, C, respectively) showed that except for the CBD formulation, the data conformed to the quadratic model. We found that regardless of the formulation level substrate ratio, the CBD + poultry manure formulation had higher values in these characteristics. For the variable AP the use of the formulation of CBD + poultry manure from the formulation level of 25%, already yielded superior results in relation to the other treatments, with maximum increase in the proportion of approximately 56%, corresponding to an increase of 66.38%.

There was a decrease in AP with increasing levels of the substrate formulation CDB + poultry manure to 100%. However, this formulation yielded higher seedlings in relation to the other substrates and 38.25% higher than the control. This reduction can be attributed to the excess amount of ammonia present in poultry manure. Miranda et al. (1998)

Table 1. Chemical characterization of an Oxisol, in the layer from 0 – 0.20 m.

pH	P	K	S	H+Al	Al	Ca	Mg	K	SB	T	m	V	MO
H_2O	-- mg dm^{-3} –			-------------------------- cmol$_c$ dm^{-3} --------------							------ % ----		g/kg
5.4	14.19	192.5	-	4.95	0.00	2.24	0.86	0.49	3.59	8.54	0.00	42.1	20.9

pH in water; P=phosphorus; S=sulfur; H + Al=hydrogen + aluminum; Al=aluminum; Ca=calcium; Mg=magnesium; K=potassium; SB= Sum of Exchangeable Bases; T=CTC effective; m=Aluminum Saturation Index; V=Base Saturation Index; and MO=Organic matter.

Table 2. Mean plant height, leaf area and number of leaves of papaya seedlings produced with different formulations and levels of organic substrates.

Substrate formulations	Levels of source proportions (%)			
	25	50	75	100
	Plant height (cm)			
CDB	6.50 b	6.55 b	6.94 b*	7.15 b*
CDB + Poultry manure	9.07 a*	9.42 a*	9.18 a*	8.06 a*
CDB + Cattle manure	7.17 b*	6.56 b	6.36 b	5.95 c
CDB + Plant ash	6.55 b	5.98 b	6.30 b	5.95 c
Control	5.83			
CV %	7.32			
	Leaf area (cm^2)			
CDB	9.82 b	14.28 bc*	16.32 b*	18.41 b*
CDB + Poultry manure	37.71 a*	38.67 a*	49.50 a*	43.08 a*
CDB + Cattle manure	14.64 b*	15.64 b*	9.62 c	8.13 c
CDB + Plant ash	13.03 b	9.92 c	11.77 bc	6.30 c
Control	8.55			
CV %	17.64			
	Number of leaves (unit $plant^{-1}$)			
CDB	6.17 b	6.17 b	6.40 b	7.00 a*
CDB + Poultry manure	8.00 a*	8.33 a*	8.60 a*	7.80 a*
CDB + Cattle manure	6.83 b*	6.60 b	6.50 b	6.00 b
CDB + Plant ash	6.50 b	6.20 b	6.33 b	6.00 b
Control	5.67			
CV %	8.91			

CDB: Buriti decomposed stem. Means followed by the same letter in the column, for the same variable and the same formulation level do not differ by the Tukey test at 5% probability. Means containing * differ from the additional treatment (control) at 5% of probability, by the Dunnett test.

Table 3. Mean shoot dry matter, length and root dry matter of papaya seedlings produced with different formulations and levels of organic substrates.

Substrate formulations	Levels of source proportions (%)				
	25	50	75	100	Média
	Shoot dry matter (g)				
CDB	191.67	193.33	200.00	202.67	196.92 b
CDB + Poultry manure	212.00*	222.33*	244.00*	216.00*	223.58 a
CDB + Cattle manure	195.00	190.00	194.00	180.00	189.75 bc
CDB + Plant ash	185.00	177.50	179.00	171.00	178.12 c
Control	170.00				
CV %	11.82				
	Root length (cm)				
CDB	10.02	10.22	10.90	11.97*	10.77 b
CDB + Poultry manure	12.58*	12.87*	12.40*	11.44	12.32 a
CDB + Cattle manure	11.07	10.72	10.24	9.05	10.27 b
CDB + Plant ash	10.07	9.72	9.78	8.80	9.59 b
Control	8.70				
CV %	18.33				
	Root dry matter (g)				
CDB	153.33	148.33	160.00	170.00	157.92 b
CDB + Poultry manure	215.00*	223.33*	222.00*	184.00	211.08 a
CDB + Cattle manure	158.33	150.00	132.00	120.00	140.08 bc
CDB + Plant ash	135.00	134.00	126.67	114.17	127.46 c
Control	125.00				
CV %	24.05				

CDB: Buriti decomposed stem. Means followed by the same letter in the column, for the same variable and the same formulation level do not differ by the Tukey test at 5% probability. Means containing * differ from the additional treatment (control) at 5% of probability, by the Dunnett test.

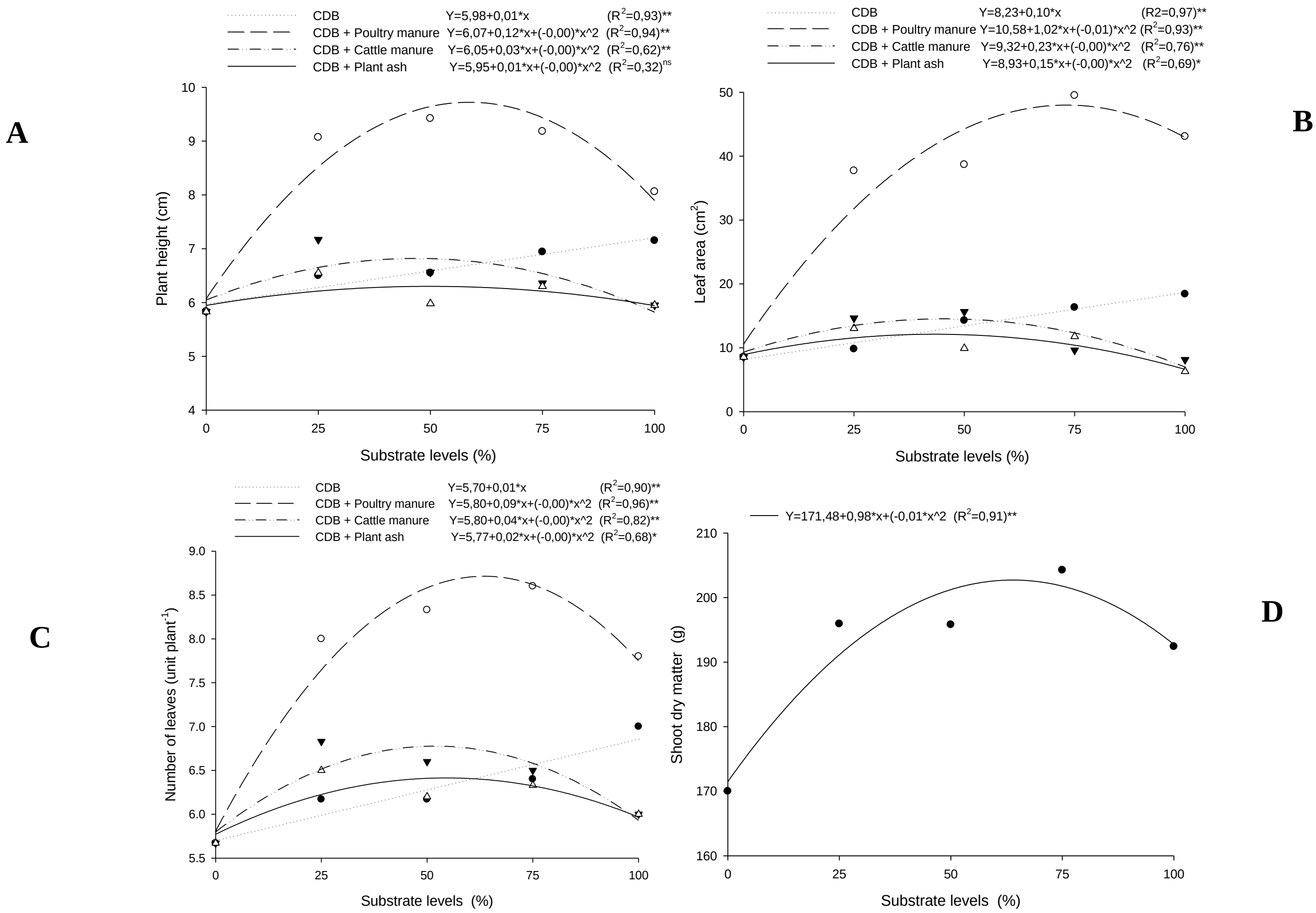

Fig 1. Plant height (A), leaf area (B), number of leaves (C) and shoot dry matter (D) of papaya seedlings as a function of different formulations and organic substrate levels. * and **: significant at 5% and 1%, respectively; ns Not significant.

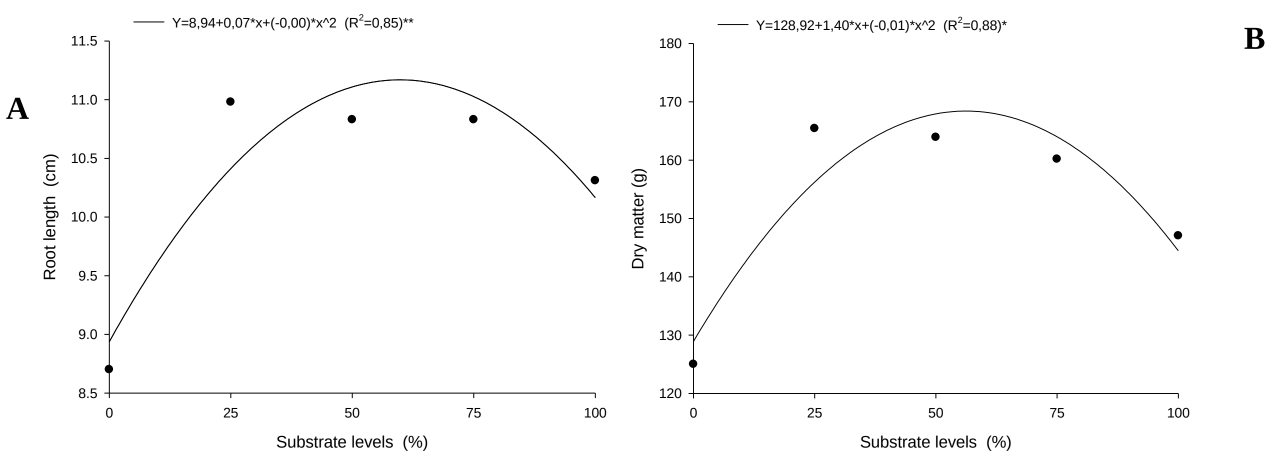

Fig 2. Root length (A), and dry matter (B) of papaya seedlings as a function of different formulations and organic substrate levels. * and **: significant at 5% and 1%, respectively.

recommend not to exceed 30% poultry manure in the total formulation, otherwise seedling growth could be impaired. On the other hand, they recommend adding 50% organic material for substrate aeration.
For the variable AF, all levels of CBD + poultry manure formulations were increased more than 341%, compared to the control. For the variable NF a superiority above 37% was observed (Table 2). For higher shoot AF, the maximum level of the CBD + poultry manure formulation was approximately 73%, leading to an increase of 461.17% (Figure 1B). For the variable NF the maximum level of the CBD + poultry manure formulation was 65.5%, with an increase of 53.61% for this characteristic (Figure 1C). Although the seedlings showed better shoot development with increasing levels of CBD + poultry manure formulations, the volume of 25% showed promising results. Therefore, it can potentially be recommended for the seedling production, which may present a reduction in the final production cost, besides maintaining desirable characteristics for planting.
The seedlings with higher AF and NF amplify the light-trapping surface, photosynthetic rates, and consequently, greater yield and plant growth, directly influencing shoot dry matter (MSPA). For seedling MSPA, CR and MSR there was no significant interaction (F test, $p<0.05$) between the formulations and their levels (Table 3). However, for MSPA there was an isolated effect of the substrate formulation factor and the formulation consisting of CBD + poultry manure, which was superior to the other treatments and also the control. This behavior may represent the accumulation of nutrients in the plant constituting a greater seedling growth and development over time.

Effect of treatments on shoot dry matter and root system

According to the levels of substrate formulations, the mean MSPA, CR and MSR showed a quadratic tendency (Figure 1D; 2A:B). For MSPA, best response of the formulations tested was the formulation level of approximately 64%. Higher formulations led to a decrease for this variable. The reductions in growth parameters upon the increase in formulation levels can be attributed to the fact that organic compounds in the formulations alter some characteristics such as pH and electrical conductivity (Albano et al., 2014) or, in some cases, the excess of N provided (Oliveira et al., 2016).
The CR formulations with organic sources of CBD at the level of 100%; and CBD + poultry manure at 25, 50 and 75% levels were significantly higher, compared to control. There was a significant increase in MSR, only for the formulation CBD + poultry manure at the levels of 25, 50 and 75%, compared to the control. For the root system variables, the use of the CBD + poultry manure formulation better responses were observed, compared to the other treatments. This fact can be justified by the higher nutrient content, mainly supplied by poultry manure, as well as the physical characteristics of the substrate, as provided by CBD, such as aeration space (35%), wet density (625 kg m^{-3}), water retention capacity (57%) and pore volume (93%) (Silva Júnior et al., 2014).
The formulations tested at levels between 25% and 75% were those that showed the greatest response regarding the development of the root system (Figure 2). The highest CR was obtained at the formulation level of 62%, while MSR was 56%. This increase in CR and MSR indicates greater soil exploration with increased water and nutrient uptake, providing greater root development of the seedlings. This fact may have occurred due to the greater soil aeration, as a function of the addition of organic fertilizers. The use of organic substrate sources has the advantage of adding organic matter and, consequently, improve the chemical and physical characteristics of the soil. The substrates with high contents of organic matter ensure a high number of porous spaces, in addition to low apparent density, favoring root development (Rasmussen et al., 2005; Moni et al., 2010; Sanaullah et al., 2010; Rumpel et al., 2012; Tuzel et al., 2016). As these materials are easy to acquire and available in the southwest region of Piauí, they are presented as an alternative in the formulation of substrates for the production of papaya seedlings.
In general, the results of this research corroborate other studies, which affirm the advantages of applying organic fertilizers in papaya, since it provides an excellent response in seedling development. These formulations based on organic substrates also improve the soil physical, chemical and biological conditions, increasing water retention, aggregation and soil porosity. The increase in cation exchange capacity, fertility and soil microbia can potentiate the production of quality papaya seedlings. The use of vigorous quality seedlings leads to rapid early papaya development and greater tolerance to pest and disease attack, increasing the benefit-cost ratio (Natale et al., 2018).

Materials and Methods

Location of the experiment

The experiment was carried out in a greenhouse with 50% shade in October and November 2015, at Federal University of Piauí-UFPI, Campus Professora Cinobelina Elvas-CPCE, in the municipality of Bom Jesus-PI, located at geographic coordinates 09º04'28''S and 44º21'31''W, with average altitude of 277 m and average temperature of 26.5ºC.

Conducting the experiment

A completely randomized design was used in a 4x4+1 factorial scheme in six replicates, whereas organic formulations x proportion levels of the formulations + additional control were treatments. The organic sources were previously formulated from four materials (CBD, ½ CDB + ½ poultry manure, ½ CDB + ½ cattle manure and ½ CDB + ½ ash of plant origin). They manually mixed with the soil. The ratio factor consisted of four proportion levels of the formulations (25, 50, 75 and 100%); and the control, as a control treatment (100% soil), totaling 102 experimental plots. The soil used in substrate formulations was characterized as an Oxisol, with chemical composition presented in Table 1. The CDB (decomposed buriti stem), process occurs after the death of the plant (Araújo, 2015). The poultry manure were obtained from Assentamento Agrovila Formosa, in Redenção do Gurguéia-PI, cattle manure on the

UFPI/CPCE farm, and plant ash was obtained from Cachoeira village, in Currais-PI.

The different formulations and ratios of the organic substrates were packed in plastic bags (12.5 cm length x 3.0 cm diameter) and subsequently, 5 seeds of Papaya ‘Hawaii’ were sown. This variety has a smooth, yellow and firm peel, the pulp has a strong orange color, indicated for warm and mild climates (Feltrin, 2005).

After sowing and throughout the experimental period, manual and daily watering were performed twice a day (morning and late afternoon), with the aid of a watering can. At 12 days after sowing (DAS), plant thinning was carried out, taking into account the vigor and sanity characteristics of the plants, leaving a single plant with plastic bags.

Variables analyzed

Seedling development was evaluated 30 days after emergence. At 42 DAS the following variables were evaluated: Plant height (AP): with a ruler graduated in cm; Leaf area (AF): using the LI-3100 Area Meter equipment (LI-COR, Inc. Lincoln, NE, USA); Number of leaves (NF): total number of leaves/seedlings; Root length (CR): using a ruler graduated in centimeters; Shoot (MSPA) and root (MSR) dry matter: After drying in a greenhouse at 65 ºC, a semi-analytical scale was used to weigh the material.

Statistical analysis

Data were subjected to analysis of variance by the SISVAR software (Ferreira, 2011) and the means were compared by the Tukey test ($p \leq 0.05$). The regression analysis was used for the responses of the variables to different levels of substrate formulations with the aid of the SigmaPlot 10.0 software. The mean values between the treatments with the additional control were compared by the Dunnett test at 5% probability.

Conclusion

The use of substrate formulated with decomposed buriti stem + poultry manure is recommended for production of papaya seedlings, where they showed positive effects on seedling growth and development, presenting a maximum between the proportional levels of 50% to 75%.

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