ISSN 0104-7760
v.25 n.2 2019

Ayrton Senna da Silva Damasceno[1a], Cácio Luiz Boechat[1b+], Joacir Morais[1c], Breendon Patrick da Silva Gonçalves[1d], Adriana Miranda de Santana Arauco[1e]

SOIL CLASSES AND REGIONAL ORGANIC RESIDUES AFFECT NUTRITION, MORPHO-PHYSIOLOGY AND QUALITY OF COPAIBA SEEDLINGS

DAMASCENO, A. S. S.; BOECHAT, C. L.; MORAIS, J.; GONÇALVES, B. P. S.; ARAUCO, A. M.S. Soil classes and regional organic residues affect nutrition, morpho-physiology and quality of copaiba seedlings. **CERNE**, v. 25, n. 2, p. 131-139, 2019.

HIGHLIGHTS

Copaiba seedlings show better growth response on substrate with carnauba residue.

Higher volume of *in natura* or carbonized rice husks and goat manure such as seedlings.

The classes of soils Gleissolo and Latossolo are more indicated in the formulation of the substrate.

The mix of organic residues and soil classes increase the amounts of P, K, Ca and Mg in the aerial part.

Keywords:
Copaifera langsdorffii Desf.
Oxisol
Entisol Quartzipsamment
Entisol Aquent
Ultisol

ABSTRACT

Besides being used in the wood industry, copaiba has medicinal properties. However, continuous and excessive extraction both of wood and of oil may impair the regeneration and make the product scarce. It is very important to produce quality seedlings, both for sustainable exploitation and for the recovery of degraded and disturbed areas. The purpose of the present study was to evaluate the initial growth and nutrition of Copaiba seedlings, incorporating organic residues into different classes of soils. The treatments were disposed in a design of entirely randomized blocks using the 5x4 factorial scheme, with four organic residues (rice husks in natura, carbonized rice husks, goat manure, carnauba residue), plus a treatment with soil only and four classes of soil (Latossolo Vermelho-Amarelo, Neossolo Quartzarênio, Gleissolo Háplico e Argissolo Vermelho-Amarelo), with four repetitions. At 90 days, the morpho-physiological variables of the seedling and macronutrient contents of the aerial part were evaluated. As to the morpho-physiological variables, the carnauba residue was outstanding among the residues tested in the present study. There was an increase in the quantities of P, K, Ca and Mg in the aerial part of copaiba seedlings resulting in the combination between the organic residues and the soil classes.

Historic:
Received 11/12/2018
Accepted 02/04/2019

+Correspondence:
cacioboechat@gmail.com

DOI:
10.1590/01047760201925022624

[1] Federal University of Piauí,Bom Jesus, Piauí, Brazil - ORCID: 0000-0002-3337-7125[a], 0000-0002-5086-9156[b], 0000-0002-7025-1767[c], 0000-0001-8399-9929[d], 0000-0002-2538-777X[e]

INTRODUCTION

Non-Wood Forest Products (NWFP) have been sought increasingly for the production of foods, pharmaceuticals and other products. The extraction of these products has been intensified, especially by marketing raw materials from forests (Imperador and Wadt, 2014). Among the NWFPs copaiba oil, for instance, has been outstanding as an alternative product for medicinal purposes with anti-inflammatory properties (Yasojima et al., 2018); it is also used as an antibacterial agent in biopackaging (Morelli et al., 2015). In 2016 alone, about 175 t of copaiba oil were produced, with a recorded increase of production of 7.8% from 2015 to 2016 (IBGE, 2016).

However, the continuous and excessive exploitation of NWFP, including copaiba oil, may compromise the regeneration of the species in forestry. There is a risk that the products will become scarce, since the extraction process uses non-sustainable practices (Imperador and Wadt, 2014) provoking the susceptibility of individuals of the species to the attack of pests and diseases, thus causing the species population to diminish.

In order to ensure the forest succession of the species, the recomposition of degraded and disturbed areas, as well as forestry compensation by inserting copaiba seedlings (*Copaifera langsdorffii* Desf.) into the forest, may be practical solutions for extractivist communities. Success in forming populations of native arboreal species for conservation purposes depends on the production of seedlings, with adequate quality and morphological characteristics (Dutra et al., 2012), and it is essential to use substrates that will supply an adequate amount of nutrients to the seedlings.

An economically feasible alternative for extractivist family farmers is to use materials from the property as a substrate to produce seedlings of native forest essences. Among the materials available, the organic residues present desirable characteristics as components in substrates because they improve fertility and contribute the physical attributes of the substrates, besides being low priced and cheap to transport (Rocha et al., 2013).

Most organic wastes present unbalanced proportions of nutrients (Rocha et al., 2013), and thus need complementary material to formulate substrates. Soil can be an excellent option for the purpose of producing native cerrado plant seedlings, besides being easy to acquire and low cost. It is a source of nutrients and support to the plants. However, it is necessary to be careful in choosing the soil to be used, because each class of soil presents its own physical and chemical characteristics and may benefit or even impair seedling quality. In the literature, few studies discuss and compare classes of soil in the composition of substrates for the production of forest species seedlings.

Although they mostly present low nutrient contents and high acidity, many arboreal species manage to develop adequately. Jeromini et al. (2017) found higher values in the growth of *Copaifera langsdorffii* Desf. seedlings in the substrate composed only with soil and Gonçalves et al. (2014), testing substrate composed with Argissolo Vermelho-Amarelo, observed that the quantities of nutrients present were sufficient to supply the needs of the jacaranda-da-bahia (Brazilian Rosewood) seedlings.

Therefore, the present study aimed at evaluating the initial growth and nutritional status of Copaiba (*Copaifera langsdorffii* Desf.) seedlings, grown in substrates with low cost organic residues and the main classes of soils from the north and northeast regions.

MATERIAL AND METHODS

The experiment was performed in a seedling production nursery covered with screened with 50% shade in the municipality of Bom Jesus – PI, located at the geographical coordinates: 9º04'59.07" S Latitude and 44º19'35.31" W Longitude. The climate of the region is classified as Cwa, which corresponds to a temperate and humid climate with a dry winter and warm summer, according to the Köppen classification.

The organic residues used were goat manure, rice husks *in natura*, carbonized rice husks and carnauba residue. The goat manure was collected and composted for 15 days in order to diminish the levels of urea in the residue and seeking to stabilize it. The carbonized rice husks were obtained by carbonizing rice husks *in natura* for 2 hours. The carnauba residue is the agroindustry residue of the carnauba tree *Copernicia prunifera* (Mill.) H.E. Moore after wax is extracted from its leaves. It is sold for pharmaceutical, automobilist and other purposes, and was acquired from extractivist farmers. The chemical characteristics of the residues are shown in Table1.

The soils used were chosen for their abundance in the region and classified as Latossolo Vermelho-Amarelo, Neossolo Quartzarênio, Gleissolo Háplico e Argissolo Vermelho-Amarelo, according to the Brazilian System of Soil Classification (Santos et al., 2018) or according to Soil Survey Staff (2014) as Oxisol, Entisol Quartzipsamment, Entisol Aquent and Ultisol, respectively. The soil samples

TABLE 1 Chemical characteristics of organic residues used in the composition of substrates for the production of copaiba seedlings.

Organic residue[1]	N	P	K	Ca	Mg	Zn	C	C:N ratio
	%	_ g·kg⁻¹ _		__ mg·kg⁻¹ __			%	-
Agroindustry carnauba residue	4.9	3.0	1.5	202.8	9.8	18.0	79.8	16.3
Goat manure	3.0	0.0	7.6	204.6	21.5	4.5	70.1	23.5
Rice husks in natura	0.4	1.5	0.6	28.6	6.4	15.2	90.9	259.7
Carbonized rice husks	0.8	1.0	0.4	27.7	4.9	14.8	62.2	78.7

[1]Chemical characterization according to the methodology described by Empresa Brasileira de Pesquisa Agropecuária (Teixeira et al., 2017).

were collected at a depth of 0.0 – 0.20 m after the removal of the organic layer present on the surface. Sub-samples were air-dried, homogenized, passed through a sieve with a 2 mm mesh opening and then, physical and chemical characterization was performed according to the methodology described in Tedesco et al. (1995). Table 3 shows the results of the soil analysis.

TABLE 2 Chemical and physical characteristics of samples of four classes of soil used in the composition of substrate for the production of Copaiba seedlings.

Class[1]	O.M.	pH	K	P	Ca	Mg	Al	H+Al	SB	V	Clay	Silt	Sand
	$g \cdot kg^{-1}$	H_2O	_mg·kg⁻¹_		___ cmolc·kg⁻¹ ____					______ % _____			
Argissolo[1]	10.0	5.1	74.0	2.0	0.2	0.2	0.4	2.3	0.6	20.3	12	8	80
Gleissolo	19.7	5.9	192.0	65.4	3.0	1.1	0.0	3.6	4.5	55.6	14	6	80
Latossolo	10.0	4.8	10.0	0.8	0.1	0.1	0.9	4.0	0.2	5.3	24	1	75
Neossolo	10.7	5.2	16.0	1.4	0.4	0.4	0.5	2.3	0.8	26.0	7	1	92

[1]Argissolo Vermelho-Amarelo; Gleissolo Háplico; Latossolo Vermelho-Amarelo; Neossolo Quartzarênio or as Ultisol, Entisol Aquent, Oxisol and Entisol Quartzipsamment, respectively, according to Soil Survey Staff (2014); pH in water (1:2,5); O.M. - organic matter, SB - sum of exchangeable bases, V – base saturation index.

The treatments were disposed in a randomized block design with a factorial scheme of 5 x 4, with four organic residues, rice husks *in natura* (RHI), carbonized rice husks (CRH), goat manure (GM), agroindustry carnauba residue (CR) and a control treatment without the incorporation of organic residues, and four classes of soils: Latossolo Vermelho-Amarelo (Oxisol), Neossolo Quartzarênio (Entisol Quartzipsamment), Gleissolo Háplico (Entisol Aquent) e Argissolo Vermelho-Amarelo (Ultisol), with four repetitions. The soil samples and organic residues were mixed at a proportion of 1:1 (v:v).

The experimental units (EU) were composed of tubes with a volume of 100 mL filled with the respective treatments after complete homogenization. They were moistened at close to 70% of the water retention capacity for each treatment during 15 days for full re-establishment of the microbial population.

The copaiba seeds were collected from a matrix tree and the break of dormancy was performed by mechanical scarification, using sandpaper for wood. Before sowing, pre-germinative treatment was performed, disinfection in a solution of 5% hypochlorite sodium, which was done for 5 minutes in order to eliminate pathogens, and later sowing was performed using three seeds per EU.

At 30 days, after complete germination of the seeds, the seedlings were thinned out, leaving the visually most vigorous ones per EU. The irrigations were performed periodically during the time the experiment was conducted, in order to maintain the substrates with a humidity close to 70% of the water retention capacity. At 90 days after thinning out, the seedlings were collected, separating the aerial part of the root. The roots were washed in running water to remove the adhered material.

The response variables evaluated were: length of the aerial part (LAP), taking as a standard the terminal apical meristem, root length (RL) , diameter of the root collar (RC)), measured with a pachymetry, with a precision of 0.05 cm, number of leaves (NL), number of folioles (FOL), fresh mass of aerial part (FMAP), fresh root mass (FRM), dry mass of aerial part (DMAP), dry root mass (DRM), and quantification of dry matter was performed by weighing after drying in an oven at 65°C for a period of approximately 72 hours; height/diameter ratio of root collar (H/DR/RC), dry mass of aerial part/ dry mass of root (DMAP/DMR) and Dickson Quality Index (DQI), and physiological parameters: Chlorophyll a and Chlorophyll b, measured using a Falker portable chlorophyll meter (ChrolophylLOG), model CFL1030.

The concentrations of macronutrients P, K, Ca and Mg in the dry mass of the aerial part were determined after grinding in a Wiley type mill, weighing and digestion with a nitro perchloric acid solution according to a methodology described in Tedesco et al. (1995). The P contents were determined by colorimetry, those of K by flame photometry, Ca and Mg by atomic absorption spectrophotometry using certified plant material as standard sample.

The data were submitted to the F test, by analysis of variance (ANOVA), with a 1% probability and the means when significant submitted to Tukey's test ($p<0.05$) using the Sisvar statistical program (Ferreira, 2011).

RESULTS AND DISCUSSION

Interaction between the classes of soils and organic residues (C x R) was significant only for the variables chlorophyll a (QCA), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg), and isolated effects are observed for each source of variation. The variables length of the aerial part (LAP), diameter of the root collar (RC), dry mass of the aerial part (DMAP), number of leaves (NL), and quantity of folioles (FOL) were affected by the classes of soil and the effect of residues was significant for all variables studied (Table 3).

TABLE 3 Chemical and physical characteristics of samples of four classes of soil used in the composition of substrate for the production of Copaiba seedlings.

SV[1]	DF	Mean Square					
		LAP	RC	LAP/RC	DMAP	LAP/DMAP	RL
Class	3	54.14**	0.43**	2.94ns	0.13*	74.39ns	6.04ns
Residue	4	242.60**	0.88**	19.59**	0.95**	599.33**	145.05**
C x R	12	6.45ns	0.09ns	1.19ns	0.03ns	112.72ns	5.19ns
C.V. (%)[2]		17.33	11.85	20.35	31.19	30.39	14.44
		FRM	DRM	DMAP/DRM	FOL	NL	DQI
Class	3	0.15ns	0.02ns	1.11ns	50.04*	2.77*	0.002ns
Residue	4	1.78**	0.46**	7.16**	353.82**	17.01**	0.01**
C x R	12	0.08ns	0.01ns	0.80ns	20.23ns	0.86ns	0.001ns
C.V. (%)		31.39	28.78	53.02	32.26	27.69	29.46
		QCA	QCB	P	K	Ca	Mg
Class	3	31.61ns	8.40*	97.46**	9.29**	422.18**	10.78**
Resídue	4	155.64**	17.72**	12.18**	26.64**	51.32**	80.13**
C x R	12	26.97ns	7.03*	510.30**	18.05**	91.81**	7.36**
C.V. (%)		17.08	29.11	39.94	15.85	20.75	18.31

[1]SV – Source of variation; DF – Degree of Freedom; LAP – Length of the aerial part; RC – root collar diameter; LAP/RC – Ratio of Length of Aerial part to root collar; DMAP – Dry mass of the aerial part; LAP/DMAP – Ratio of length of aerial part to dry mass of the aerial part; RL – Root length; FRM – Fresh root mass ; DMR – Dry root mass; DMAP/DRM – Ratio of dry mass of aerial part to dry root mass. s; FOL – Folioles; NL – Number of leaves; DQI – Dickson quality index; QCA Amount of chlorophyll a; QCB – Amount of chlorophyll b; 2C.V. – Coefficient of variation; ** - significant to 1%; * - significant to 5%; ns – non-significant to 5%.

There was a significant difference among the residues evaluated for the variable LAP, and the highest average was observed in carnauba agroindustry residues (22.73 cm), a result that may be related to the greater amount of nitrogen (Tables 1 and 4). This macronutrient is among the most sought after, and it is the one that most limits plant growth (Souza and Fernandes, 2006). In addition, it has a high P content and C: N ratio lower than other residues. Lower values were observed by Dutra et al. (2015), in which copaiba seedlings did not surpass 11.4 cm, 90 days after transplanting, when produced using the Bioplant commercial substrate and different compositions of vermiculite, carbonized rice husks and coconut fiber.

TABLE 4 Length of the aerial part (LAP), root collar (RC), ratio of length of aerial part and root collar diameter (LAP/RC), ratio of length of the aerial part and dry mass of the aerial part (LAP/DMAP), dry mass of the aerial part (DMAP), number of leaves (NL) and number of folioles (FOL) of copaiba seedlings grown in different substrates.

Treatment[1]	LAP	RC	LAP/RC	LAP/D/DMAP	DMAP	NL	FOL
	cm	mm	_	_	g	units	
RHI	13.55c	2.46b	5.50c	36.96a	0.39c	2.53c	9.31b
GM	13.61c	2.65b	5.20c	40.38a	0.37c	2.50c	9.25b
CRH	14.56c	2.40b	6.02bc	37.56a	0.40c	2.81bc	10.12b
CR	22.73a	2.97a	7.79a	24.61b	0.95a	4.93a	20.37a
Control	17.57b	2.46b	7.17ab	33.07ab	0.57b	3.62b	12.87b
C.V. (%)[2]	17.33	11.85	20.35	31.19	31.19	27.69	32.26

[1]RHI – Rice husk in natura; GM – Goat manure; CRH – Carbonized rice husks; CR – Agroindustry carnauba residue; Control – soil without the incorporation of residue; 2C.V. – coefficient of variation; Means followed by the same letter are not different from each other according to Tukey's test at 5%.

Using carbonized rice husks and rice husks *in natura* the same means, being lower than in the control treatment as observed in Table 4 for LAP (13.56 and 13.55 cm, respectively), a result that can be explained due to the excess of rice husks in the composition of the substrate and the lower chemical quality presented by these residues (Table 1). Further tests are needed with smaller volumes of these residues in the substrate to produce copaiba seedlings.

When they refer to rice husks, Delarmelina et al. (2014) do not recommend using them to produce seedlings since, according to the authors, the result is inadequate values of total porosity of the substrate. In this sense, substrates with a higher macroporosity retain less water and, consequently, less nutrients (Wendling et al., 2006).

The growth of the root collar (RC) diameter of copaiba seedlings was also greater in the treatment with carnauba residue (2.97 mm), as seen in Table 4. The same value was found by Vieira and Weber (2015) in copaiba seedlings 120 days after transplanting to tubes with 60% Basaplant® and 40% soil. Taking into account the values of the root collar diameter recommended by Xavier et al. (2009), above 2 mm for forest species seedlings, all treatments resulted in seedlings that were appropriate to plant in the field.

For variable LAP/RC, there was a variation of 5.20 to 7.79 (Table 4), and these values agreed with those advocated by Carneiro (1995) for forest species seedlings (4.4 to 8.1). Lower values were found by Dutra et al. (2015) when they produced copaiba seedlings using different substrate compositions, including carbonized rice husks, vermiculite, coconut fiber, sand and Bioplant®.

As to the variable LAP/DMAP, Gomes and Paiva (2012) say that the smaller the resulting quotient the higher the chances of survival after definitive planting, since it is related to the rusticity of the seedling. Table 4 showed that the lower quotient was the result of applying carnauba residue (24.61), and that the other treatments were statistically equal. The carnauba residue, besides physically improving the substrate, presents a high amount of N and P (Table 1), which are the macronutrients most required by the plants, in general.

Gomes and Paiva (2012) say that DMAP reflects sample rusticity where, according to the authors, the higher the DMAP, the more lignified, with a greater capacity to develop in inadequate environments. In the present work, the highest DMAP referred to treatment with carnauba residue (0.95 g), as well as the variable LAP. The higher DMAP can be explained by the greater amount of nitrogen and phosphorus present in the carnauba residue (Table 1). Nitrogen is one of the most important nutrients, since it is directly related to photosynthesis and respiration, besides being part of the structure of aminoacids, proteins, cell multiplication and differentiation and phosphorus plays an important role in photosynthesis, respiration, energy storage and transfer, cell division, cell growth and various other processes in plants (Malavolta et al., 1997).

Both the variable number of leaves (NL) and the amount of folioles (FOL) are related to the production of photoassimilates. In this sense, Reis et al. (2013) say that the higher the NL, the greater the photosynthetic conversion, and consequently the greater the growth of the seedlings. In this study, there was a significant difference between the treatments for the two variables, the highest values (4.93 and 20.37 units) being obtained applying carnauba residue (Table 4). Carnauba residue is a plant residue and it presents adequate physical and chemical characteristics for the composition of substrates (Araújo et al., 2016).

For the variable root length (RL), the lowest mean (7.23 cm) resulted from applying goat manure (GM), and the other treatments were not statistically different from each other (Table 5). This result may be related to the excess of goat manure in the composition of the substrate which may have altered the physical characteristics of the substrate. Besides, goat manure has a good C: N ratio and a higher amount of N, K, Ca and Mg (Table 1), this requiring less root growth because, according to Caldeira et al. (1998) the plants have larger roots in environments with less nutrients.

TABLE 5 Root length (RL), fresh root mass (FRM), dry root mass (DRM), ratio of dry mass of the aerial part to dry root mass (DMAP/DRM) quantity of chlorophyll (QC), and Dickson quality index (DQI) of copaiba seedlings grown in different substrates.

Treatment[1]	RL	FRM	DRM	DMAP/DRM	QC	DQI
	cm	g	g	-	-	-
RHI	14.90a	0.83b	0.40b	1.06b	23.90c	0.12b
GM	7.23b	0.37c	0.18c	2.59a	30.42a	0.08c
CRH	13.55a	0.89b	0.44b	0.92b	23.89c	0.12b
CR	13.55a	1.28a	0.65a	1.52b	29.26ab	0.17a
Control	13.25a	1.02ab	0.48b	1.24b	24.98bc	0.12b
C.V. (%)[2]	14.44	31.39	28.78	53.02	17.08	28.46

[1]RHI – Rice husk in natura GM – Goat manure; CRH – Carbonized rice husks; CR – Agroindustry carnauba residue; Control - soil without the incorporation of residue; 2C.V. – coefficient of variation; Means followed by the same letter are not different from each other according to Tukey's test at 5%.

Table 5 shows that the higher means of variables fresh root mass and dry root mass (FRM and DRM) were in the substrate constituted by carnauba residue (1.28 and 0.65 g, respectively). On the other hand, the lowest means refer to the substrate with goat manure (0.37 and 0.18 g, respectively) corroborating the suspicion that the amount of goat manure in the composition of the substrate impaired the development of the root system. In this sense, Caldeira et al. (1998) state that the high proportion of organic compound in constituting substrate may be harmful, both for the root length and for the production of dry biomass of the root.

The highest mean of variable DMAP/DRM was observed in treatment with goat manure (Table 5), and the other treatments were statistically equal. However, according to Pinto et al. (2011) ideally the aerial part/root ratio should be low, since it is beneficial at sites with low fertility, enabling the roots to better explore the soil in search of nutrients to supply the needs of the seedlings in the field.

Goat manure (GM) and carnauba residue (CR) were the residues that resulted in the highest means (30.42 and 29.26, respectively) for the chlorophyll an index (QCA) (Table 5). Table 1 shows that carnauba residue presents the highest quantity of nitrogen and phosphorus and goat manure high amount of nitrogen, potassium, calcium and magnesium. According to Bonamigo et al. (2016) these nutrients are closely related to chlorophyll production in plants.

As to the Dickson Quality Index (DQI), none of the treatments evaluated resulted in values equal to the minimum mean (0.20), being the highest DQI referring to the substrate constituted by carnauba residue (0.17). However, it should be emphasized that this minimum mean refers to the *Pseudotsuga menziessi* and *Picea abies* species and may not be appropriate to the species in the present study, according to Tsukamoto Filho et al. (2013) information in the literature on an adequate DQI related to most forest species is scarce.

There was a significant different between the classes of soils for all variables shown in Table 6. The highest mean of the LAP variable was the result of the substrate constituted by Gleissolo Háplico (18.49 cm), reflecting on the variable DMAP that obtained the highest mean (0.65 g), a result that may be related to the chemical characteristics of the soil in this class (Table 2).

TABLE 6 Length of the aerial part (LAP), dry mass of the aerial part (DMAP), root collar diameter (RC), number of leaves (NL) and quantity of folioles (FOL) of copaiba seedlings in different classes of soil.

Treatment	LAP	DMAP	RC	NF	FOL
	cm	g	mm	____ unit ____	
Argissolo Vermelho-Amarelo[1]	14.99b	0.50b	2.48b	3.30ab	11.65ab
Gleissolo Háplico	18.49a	0.65a	2.67ab	3.80a	14.75a
Latossolo Vermelho-Amarelo	16.95ab	0.55ab	2.76a	3.05ab	11.75ab
Neossolo Quartzarênio	15.20b	0.45b	2.45b	2.97b	11.40b
C.V. (%)[2]	17.33	31.19	11.85	27.69	32.26

[1]Ultisol, Entisol Aquent, Oxisol and Entisol Quartzipsamment, respectively, according to Soil Survey Staff (2014); [2]C.V. – coeffiecient of variation. Means followed by the same letter are not different from each other according to Tukey's test at 5%.

For the variable root collar diameter (RC) there was a significant difference among the soil classes, the highest mean being observed in Latossolo Vermelho-Amarelo. However, the values are below the range considered adequate for the forest species seedlings as suggested by Scremin-Dias et al. (2006). Different results were observed by Nóbrega et al. (2008) in a study of sesbania seedlings. When they evaluated seedlings produced with Latossolo Vermelho-Amarelo and Neossolo Quartzarênio, the authors obtained higher RC values in a substrate constituted with Neossolo Quartzarênio.

As with the variables LAP and DMAP, variables NL and FOL presented higher means (3.80 and 14.75 units, respectively) using Gleissolo Háplico (Table 6). Gleissolo Háplico presents a greater amount of organic matter, potassium, calcium, phosphorus and magnesium (Table 1), which may explain the result observed. Both Ca, Mg and P are essential in the photosynthetic processes, cell division, cytoplasmic movements and increase of cell volume (Malavolta et al., 1997).

For variable QCB (quantity of chlorophyll b), there was a significant difference among the residues only within Argissolo Vermelho-Amarelo and Latossolo Vermelho-Amarelo. In both classes of soils, both goat manure and carnauba residue presented the highest means. On the other hand, regarding the classes of soils there was no significant difference among the carbonized rice husks and the rice husks *in natura* residues. However, both within the carnauba residue and in the control the highest means were for Latossolo Vermelho-Amarelo and also goat manure (Table 7).

Although it has a lower quantity of nutrients, the Latossolo Vermelho-Amarelo used in the present study presents a higher quantity of clay thus better retaining the nutrients and preventing them from leaching, which may explain the better result for QCB (Table 2). High concentrations of chlorophyll result in high rates of photosynthesis, enabling a greater adaptive capacity after planting (Afonso et al., 2017). Chlorophyll b is considered an accessory pigment that helps the chlorophyll a (Taiz and Zieger, 2013).

TABLE 7 Quantity of chlorophyll b (QCB) and contents of phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) in the aerial part of copaiba seedlings grown in different residues and classes of soil.

Treatment[1]	QCB	P	K	Ca	Mg
	-	____ g·kg⁻¹ ____		____ mg·kg⁻¹ ____	
Argissolo Vermelho-Amarelo (Ultisol)[2]					
RHI	4.37bA	0.12aB	7.73bAB	5.59abB	2.63bA
GM	8.10aA	0.32aB	12.51aA	4.39bB	3.55abC
CRH	4.52bA	0.16aAB	8.88bA	5.31abB	3.35bAB
CR	6.32abAB	0.11aB	3.86cC	9.45aB	4.95aA
Control	3.85bB	0.14aA	6.61bA	6.78abBC	2.41bA
Gleissolo Háplico (Entisol Aquent)					
RHI	5.20aA	0.18aB	8.16aA	4.30dB	2.49cA
GM	4.27aB	0.34aB	9.87aB	16.09aA	8.57aA
CRH	4.12aA	0.18aB	5.67bB	7.94cdB	3.95bcA
CR	6.40aAB	0.11aB	4.99bBC	14.12abA	5.30bA
Control	5.37aAB	0.09aA	3.88bB	9.95bcB	3.68cA
Latossolo Vermelho-Amarelo (Oxisol)					
RHI	4.12bcA	4.02bA	7.25aAB	7.31bB	2.59cA
GM	7.55aA	9.37aA	7.67aBC	16.78aA	6.90aB
CRH	3.80cA	2.27bA	8.92aA	4.45bB	2.21cB
CR	8.37aA	4.98bA	6.55aAB	7.86bB	4.57bA
Control	7.10bcA	0.16cA	8.35aA	5.48bC	2.67cA
Neossolo Quartzarênio (Entisol Quartzipsamment)					
RHI	3.28aA	0.16aB	5.57cB	19.60bA	3.73bcA
GM	6.27aAB	0.36aB	6.80bcC	16.90bcA	8.66aA
CRH	5.45aA	0.20aB	10.31aA	24.33aA	3.83bcA
CR	4.20aB	0.10aB	8.57abA	9.32dB	4.81bA
Control	4.10aB	0.20aA	8.43abA	14.44cA	3.19cA
C.V. (%)[3]	22.11	39.94	15.85	20.75	18.31

[1]RHI – Rice husks in natura; GM – Goat manure; CRH – Carbonized rice husks; CR – Agroindustry carnauba residue; Control – soil without the incorporation of the residue; 2 Soil Survey Staff (2014); 3C.V. – Coefficient of variation; Lower case letters compare residues within each class of soil and upper-case letters the classes within each residue; Means followed by the same letter are not different from each other according to Tukey's Test at 5%.

Among the residues studied, there was a significant difference only within Latossolo Vermelho-Amarelo for the phosphorus (P) contents in the aerial part, since the highest mean (9.37 g·kg^{-1}) refers to the substrate with goat manure (Table 7). However, goat manure presented the lowest quantity of phosphorus among the residues evaluated (Table 1). Much lower values were found by Vieira and Weber (2015), where the highest mean of P in copaiba seedlings at 120 days was 0.47 g·kg^{-1} when testing substrates constituted by different proportions of soil and commercial substrate Basaplant®.

On the other hand, regarding soil classes, there was a significant difference in all four residues evaluated. The P contents in the aerial part of plants cultivated in Latossolo Vermelho-Amarelo, stood out from the others with the four residues (Table 7). Besides being important for photosynthesis and respiration, phosphorus plays a major role in radial and tangential contraction of wood (Moya et al., 2010).

As to potassium (K), there was no significant difference among the treatments in Latossolo Vermelho-Amarelo. However, in Argissolo Vermelho-Amarelo the highest concentration of K was found in treatment with goat manure, while in Gleissolo Háplico it was goat manure and rice husks *in natura* and in Neossolo Quartzarênio the highest concentration was in the treatment with carbonized rice husks (Table 7).

Among the classes of soil studied, there was a significant difference from all residues, where the highest concentration of K was greater in Neossolo Quartzarênio both in the carnauba residue, and for the carbonized rice husks and the control. However, in Gleissolo Háplico, the highest K content was observed with *in natura* rice husk residue and in Argissolo Vermelho-Amarelo with goat manure (Table 7). Potassium (K) was the second nutrient most absorbed by the copaiba seedlings. Differently, Vieira and Weber (2015) observed that K was the nutrient most required by the copaiba seedlings. According to Gondim et al. (2016), the plants at an initial phase of development present intense metabolic activity, thus requiring a higher amount of K.

The magnesium (Mg) content in the aerial part of the copaiba was higher in the treatment of carnauba residue in the Argissolo Vermelho-Amarelo class (9.45 mg·kg^{-1}), goat manure in Gleissolo Háplico and Latossolo Vermelho-Amarelo (16.09 and 16.78 mg·kg^{-1}, respectively), and it was higher in the treatment with carbonized rice husks in Neossolo Quartzarênio (24.33 mg·kg^{-1}).

Except for Gleissolo Háplico, which presented a higher concentration of Ca with the treatment constituted with carnauba residue (14.12 mg·kg^{-1}), the highest Ca contents were observed in Neossolo Quartzarênio, referring to the carbonized rice husks substrates (24.33 mg·kg^{-1}) and the *in natura* ones (19.60 mg·kg^{-1}) as well as goat manure (16.90 mg·kg^{-1}) and in the control (14.44 mg·kg^{-1}), as can be seen in Table 7.

The better response of Neossolo Quartzarênio can be explained by the fact that this class of soil presents a higher amount of Ca and sand (Table 2), allowing a better development of the root system favoring absorption of the nutrients. According to Brandão et al. (2006) the difference between the Latossolo Vermelho-Amarelo and Neossolo Quartzarênio is due to less compaction and greater porosity of the substrates, and Neossolo Quartzarênio is characterized by a sandier texture than Latossolo Vermelho-Amarelo.

The Mg content in the aerial part of the copaiba seedlings was higher in the treatment with goat manure in the soil classes of Gleissolo Háplico (8.57 mg·kg^{-1}), Latossolo Vermelho-Amarelo (6.90 mg·kg^{-1}) and Neossolo Quartzarênio (8.66 mg·kg^{-1}), but in Argissolo Vermelho-Amarelo they were higher in the treatments with goat manure and carnauba residue (3.55 and 4.95 mg·kg^{-1}, respectively). Among the soil classes, there was a significant difference only in the treatments with carbonized rice husks (CRH) and goat manure (GM), with the lowest concentrations of Mg in the aerial part of plants in Argissolo Vermelho-Amarelo (3.35 and 3.55 mg·kg^{-1}, respectively) and in Latossolo Vermelho-Amarelo (6.90 and 2.21 mg·kg^{-1}, respectively), and is related to the amount of Mg in the two classes of soil (Table 2).

All contents are adequate, according to Malavolta et al. (1997), who presented as reference for forest species values between 1.5–5.0 g·kg^{-1} for Mg. Vieira and Weber et al. (2015) found, 120 days after transplantation, values between 1.07–1.97 g·kg^{-1} of Mg in the aerial part of copaiba seedlings cultivated in a substrate with different percentages of Basaplant®.

CONCLUSIONS

The morpho-physiological variables of the copaiba seedlings present a better response when grown in a substrate with carnauba residue. The volume of carbonized rice husks, rice husks *in natura*, and goat manure used to formulate the substrate harm the copaiba seedlings. Seedlings grown in Gleissolo Háplico and Latossolo Vermelho-Amarelo are outstanding compared to those grown in the other classes. The values found for the morphological variables of the copaiba seedlings that grow in the soil classes evaluated are outstanding in relation to those in the literature. The combinations between the organic residues and soil classes increase the amounts of P, K, Ca and Mg in the aerial part of copaiba seedlings.

ACKNOWLEDGMENTS

The authors would like to thank National Council for Scientific and Technological Development (CNPq) and Federal University of Piauí (UFPI) for financial support and collaborating in this study.

REFERENCES

AFONSO, M. V.; MARTINAZZO, E. G.; AUMONDE, T. Z.; VILLELA, F. A. Parâmetros fisiológicos de mudas de *Albizia niopoides* produzidas em diferentes composições de substrato. **Ciência Florestal**, v.27, n.4, p.1395-1402, 2017.

ARAÚJO, E. F.; ARAUCO, A. M. S.; LACERDA, J. J. J.; RATKE, R. F.; MEDEIROS, J. C. Crescimento e balanço nutricional de mudas de *Enterrolobium contortsiliquum* com aplicação de substratos orgânicos e água residuária. **Pesquisa Florestal Brasileira**, v.36, n.86, p.169-177, 2016.

BRANDÃO, V. S.; CECÍLIO, R. A.; PRUSKI, F. F.; SILVA, D. D. **Infiltração da água no solo**. Viçosa: Editora UFV. 3ª ed. 2006. 120p.

BONAMIGO, T.; SCALON, P. Q.; PEREIRA, Z. V. Substratos e níveis de luminosidade no crescimento inicial de mudas de *Tocoyena formosa* (Cham. & Schltdl.) K. Schum. (Rubiaceae). **Ciência Florestal**, v.26, n.1, p.501-511, 2016.

CALDEIRA, M. V. W.; SCHUMACHER, M. V; BARICHELLO, L. R.; VOGEL, H. L. M.; OLIVEIRA, L. S. Crescimento de mudas de *Eucalyptus saligna* Smith em função de diferentes doses de vermicomposto. **Revista Floresta**, v.28, p.19-30, 1998.

CARNEIRO, J.G. de A. **Produção e controle de qualidade de mudas florestais**. Curitiba: UFPR/FUPEF; Campos: UENF, 1995. 451p.

DELARMELINA, W. M.; CALDEIRA, M. V. W.; FARIA, J. C. T.; GONÇALVES, E. O.; ROCHA, R. L. F. Diferentes substratos para a produção de mudas de *Sesbania virgata*. **Floresta e Ambiente**, v.21, n.2, p.224-233, 2014.

DUTRA, T. R.; GRAZZIOTTI, P. H.; SANTANA, R. CA.; MASSAD, M. D. Qualidade de mudas de copaíba produzidas em diferentes substratos e níveis de sombreamento. **Floresta**, v.45, n.3, p.635 - 644, 2015.

DUTRA, T. R.; MASSAD, M. D.; SARMENTO, M. F. Q.; OLIVEIRA, J. C. Emergência e crescimento inicial da canafístula em diferentes substratos e métodos de superação de dormência. **Revista Caatinga**, v.25, n.2, p. 65-71, 2012.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, v.35, n.6, p.1039-1042, 2011.

GOMES, J. M.; PAIVA, H. N. **Viveiros florestais: propagação sexuada**. Viçosa: Editora UFV, 2012. 116p.

GONDIM, A. R. O.; PRADO, R. M.; FONSECA, I. M.; ALVES, A. U. Crescimento inicial do milho cultivar BRS 1030 sob omissão de nutrientes em solução nutritiva. **Revista Ceres**, v.63, n.5, p.706-714, 2016.

GONÇALVES, E. O.; PAIVA, H. P; NEVES, J. C. L.; KLIPPEL, V. H.; CALDEIRA, V. W. Crescimento de Jacarandá-da-Bahia [*Dalbergia Nigra* (Vell.) Fr. All. Ex Benth] sob diferentes doses de NPK. **Cerne**, v. 20, n. 3, p. 493-500, 2014.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE. **Produção da extração vegetal e da silvicultura. Rio de Janeiro**, v. 31, p.1-54, 2016.

IMPERADOR, A. M.; WADT, L. H. O. Certificação de produtos florestais não madeireiros na perspectiva mercadológica de associações extrativistas no estado do acre. **Holos**, v.01, p.126-135, 2014.

JEROMINI, T. S.; FACHINELLI, R.; SILVA, G. Z.; PEREIRA, S. T. S.; SCALON, S. P. Q. Emergência de plântulas e crescimento inicial de copaíba sob diferentes substratos. **Pesquisa Florestal Brasileira**, v.37, n.90, p.219-223, 2017.

MALAVOLTA, E.; VITTI, G. C.; OLIVEIRA, S. A. **Avaliação do estado nutricional das plantas, princípios e aplicações**. 2ª ed. Piracicaba: POTAFOS, 1997. 319p.

MORELLI, C. L.; MAHROUS, M.; BELGACEM, M. N.; BRANCIFORTI, M. C.; BRETAS, R. E. S.; BRAS, J. Natural copaiba oil as antibacterial agent for bio-based active packaging. **Industrial crops and products**, v.70, p.134-141, 2015.

MOYA, L.; VICTOR A.; Gonzalez, P.; ERNESTO, O. G.; CARLOS, R. G.; VINICIO. Efecto de las propiedades fìsicas y quìmicas del suelo en algunas propiedades de la madera de teca (*Tectona grandis*). **Revista Árvore**, v.34, n.6, p.1109-1118, 2010.

NÓBREGA, R. S. A.; PAULA, A. M. D.; VILAS BOAS, R. C.; NÓBREGA, J. C. A.; MOREIRA, F. M. D. S. Parâmetros morfológicos de mudas de *Sesbania virgata* (Caz.) Pers e de *Anadenanthera peregrina* (L.) cultivadas em substrato fertilizado com composto de lixo urbano. **Revista Árvore**, v.32, n.3, p.597-607, 2008.

PINTO, S. I. C.; FURTINI NETO, A. E.; NEVES, J. C. L.; FAQUIN, V.; MORETTI, B. S. Eficiência nutricional de clones de eucalipto na fase de mudas cultivados em solução nutritiva. **Revista Brasileira de Ciência do Solo**, v.35, n.2, p.523-533, 2011.

REIS, L. S.; AZEVEDO, C. V. A.; ALBUQUERQUE, A. W.; SILVA JÚNIOR, J. F. Índice de área foliar e produtividade do tomate sob condições de ambiente protegido. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.17, n.4, p.386-391, 2013.

ROCHA, I. T. M.; SILVA, A. V.; SOUZA, R. F.; FERREIRA, J. T. P. Uso de resíduos como fonte de nutrientes na agricultura. **Revista Verde**, v. 8, n. 5, p. 47 - 52, 2013.

SANTOS, H. G.; JACOMINE, P. K. T.; ANJOS, L. H. C.; OLIVEIRA, V. A.; LUMBRELAS, J. F.; COELHO, M. R.; ALMEIDA, J. A.; ARAÚJO FILHO, J. C.; OLIVEIRA, J. B.; CUNHA, T. J. F. **Sistema Brasileiro de Classificação de Solos**. 5.ed. rev.amp. Embrapa: Brasília, 2018. E-book.

SCREMIN-DIAS, E.; KALIFE, C.; MENEGUCCI, Z. D. R. H.; SOUZ, P. R. D. **Produção de mudas de espécie florestais nativas**: manual. Campo Grande: Editora UFMS, 2006. 59 p.

SOIL SURVEY STAFF. **Keys to Soil Taxonomy**. 12th ed. Washington: USDA - Natural Resources Conservation Service, 2014.

SOUZA, S. R.; FERNANDES, M. S. Nitrogênio. In: FERNANDES, M. S. (Ed.) **Nutrição mineral de plantas**. Viçosa: SBCS, 2006. p.215-252.

TAIZ, L.; ZEIGER, E. **Fisiologia Vegetal**. 5ª ed. Porto Alegre: Artmed, 2013. 848p.

TEDESCO, M. J.; GIANELLO, C.; BISSANI, C. A.; BOHNEN, H.; VOLKWEISS, S. J. **Análises de solos, plantas e outros materiais**. 2ª ed. Porto Alegre: UFRGS, 1995. 147p.

TEIXEIRA, P. C.; DONAGEMMA, G. K.; FONTANA, A.; TEIXEIRA, W. G. (Ed.). **Manual de métodos de análise de solos**. 3ª ed. Rio de Janeiro: Embrapa Solos, 2017. 573p.

TSUKAMOTO FILHO, A. A.; CARVALHO, J. L. O.; COSTA, R. B.; DALMOLIN, A. C.; BRONDANI, G. E. Regime de Regas e Cobertura de Substrato Afetam o Crescimento Inicial de Mudas de *Myracrodruon urundeuva*. **Floresta e Ambiente**, v.20, p.521-529, 2013.

VIEIRA, C. R.; WEBER, O. L. S. Influência do substrato na produção de mudas de espécies medicinais. **Nativa**, v.03, n.02, p.135-142, 2015.

XAVIER, A.; WENDLING, I.; SILVA, R.L. **Silvicultura clonal**: princípios e técnicas. 2ª ed. Viçosa: editora UFV, 2009. 272 p.

WENDLING, I.; DUTRA, L. F.; GROSSI, F. **Produção de mudas de espécies lenhosas**. Colombo: Embrapa Florestas, 2006. 1 CD-ROM. (Embrapa Florestas. Documentos, 130).

YASOJIMA, E. Y.; TEIXEIRA, R. K. C.; HOUAT, A. P.; COSTA, F. L. S.; YAMAKI, V. N.; FEITOSA-JUNIOR, D. J. S.; SILVA, C. A. M.; BRITO, M. V. H. Copaiba oil influences ventral hernoa repair with vicryl mesh. **Arquivos Brasileiros de Cirurgia Digestiva**, v.28, n.3, p.186–189, 2015.