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Phytotechnical and nutritional parameters of fig tree seedlings grown in different proportions of decomposed stem of the buriti palm

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Abstract: Plant and fruit quality is a reflection of several factors, one of which is the way the seedlings were produced. The aim of this study was to analyse the phytotechnical and nutritional characteristics of fig tree seedlings (*Ficus carica* L.) produced in a substrate comprising decomposed stems of the buriti palm (*Mauritia flexuosa* L.). A randomised block design was used, with treatments distributed in a 5x6 factorial scheme with one additional treatment, arranged in five blocks. The substrates included the following levels of decomposed buriti stems: 20%, 40%, 60%, 80% and 100%, with a different decomposition time (0; 15; 30; 45; 60 and 75 days) for each treatment. There was one additional treatment comprising 100% soil. The following variables were evaluated to determine the effects of the treatments: number of leaves (NL), number of branches (NB), leaf chlorophyll index, diameter of the largest shoot (DLS), length of the largest shoot (LLS), leaf area (LA), root length (RL), root volume (RV), shoot fresh matter (SFM), root fresh matter (RFM), shoot dry matter (SDM) and root dry matter (RDM), with a chemical analysis of the shoots and soil before and after setting up the experiment. The proportion of decomposed buriti palm stem in the substrate yielded significant results for the morphological variables, including the number of leaves, shoot fresh matter, root fresh matter and root volume. For the nutritional variables relating to the aerial part of the seedlings, the proportion of substrate yielded significant results for the levels of calcium, magnesium, iron and zinc. There were no significant results from the decomposition time; however, multivariate analysis showed that by the end of the experiment the nutrient concentration in the soil was higher than before the experiment.

Index terms: Organic substrate, Proportions, Cuttings, *Ficus Carica L.*

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Parâmetros fitotécnicos e nutricionais de mudas de figueira sobre diferentes proporções de caule decomposto de buriti

Resumo: A qualidade da planta e dos frutos é reflexo de vários fatores, sendo um deles a forma como foi produzida a muda. Objetivou-se analisar as características fitotécnicas e nutricionais da muda de figueira (*Ficus carica* L.) produzida com substrato de caule decomposto de buriti (*Mauritia flexuosa* L.). Utilizou-se o delineamento em blocos casualizados, com tratamentos distribuídos em sistema fatorial 5x6 mais um adicional, dispostos em 5 blocos. Os substratos foram formados nas seguintes proporções de caule decomposto de buriti: 20%, 40%, 60%, 80% e 100%, e cada proporção, oriunda de diferentes tempos de decomposição: 0; 15; 30; 45; 60 e 75 dias, além do adicional composto por 100% de solo. Para a determinação dos efeitos dos tratamentos, foram avaliadas as seguintes variáveis: Número de folhas (NF), Número de ramos (NR), índice de clorofila foliar, diâmetro do maior broto (DMB), Comprimento do maior broto (CMB), Área foliar (AF), Comprimento da raiz (CRZ), Volume radicular (VRZ), Massa fresca da parte aérea (MFPA), Massa fresca da raiz (MFRZ), Matéria seca da parte aérea (MSPA), Matéria seca da raiz (MSRZ) e análise química da parte aérea e do solo, antes e após a montagem do experimento. As proporções de caule decomposto de buriti no substrato proporcionaram resultados significativos para as variáveis morfológicas, número de folhas, massa fresca da parte aérea, massa fresca da raiz e volume radicular. Para as variáveis nutricionais referentes à parte aérea das mudas, as proporções de substrato também favoreceram resultados significativos para os teores de cálcio, magnésio, ferro e zinco. Os tempos de decomposição não proporcionaram resultados significativos; mas, através da análise multivariada, pôde-se observar que, ao final do experimento, havia maior concentração de nutrientes no solo em relação ao mesmo antes da montagem.

Termos para indexação: Substrato orgânico, Proporções, Estacas, *Ficus Carica* L.

Introduction

The fig tree (*Ficus carica* L.) is one of the earliest fruit trees to be cultivated and commercialised. It originated in Western Asia and, through human action, spread throughout the Mediterranean area (CANDOLLE, 1885). Although considered exotic and typical of tropical climates, it is produced in several countries due to its adaptability as a crop (BISI et al., 2016).

Brazil is the largest fig producer in South America, however, the state of Piauí (PI) is not even listed in the statistics of top producers (FAO, 2018). There is therefore a need for research that would help introduce fig cultivation to Piauí, with emphasis on the production of quality seedlings.

Plant productivity depends on several stages of cultivation. Seedling production is considered one of the most important, as final performance depends on the phytotechnical and nutritional parameters of the plants during the initial growth phase. Choosing the ideal substrate, whether commercial or organic, can mean a substantial increase in seedling quality. However, it is difficult to find a material with all the desirable characteristics to meet the conditions for optimal plant growth and development (KLEIN, 2015). In this respect, research has evaluated different proportions of substrate in order to meet plant requirements.

Preparing the substrate is of fundamental importance for obtaining quality seedlings. Substrates should be easy to obtain, have good chemical and physical characteristics, and a reasonable decomposition time, so that they contribute to crop productivity and are easy to manage (KLEIN, 2015).

Decomposed buriti stems (*Mauritia flexuosa* L.), a material that originates from the natural decomposition of the strain following the death of the plant (Fonseca et al., 2019), can be a viable alternative for producing fig seedlings since, due to the scarcity of natural resources, the demand for alternative materials is growing.

From an economic point of view, organic buriti palm substrate is one option, as it is abundant in the south of Piauí, easy to acquire, and contains suitable quantities of nutrients that are essential for plant development, such as nitrogen, potassium, phosphorus, calcium, magnesium and others (COSTA JUNIOR et al., 2017; FONSECA et al., 2019; MATIAS et al., 2019a and 2019b).

The quality of this organic compost is seen in other crops, such as shoot development in the cauliflower (CUNHA et al., 2014), or development of the leaf area in tomato seedlings (EVANGELISTA et al., 2014). The search for alternative substrates that facilitate the economically viable production of quality seedlings represents a challenge to any significant introduction of fig cultivation in the state of Piauí.

As such, the aim of this study was to evaluate different proportions and decomposition times of decomposed buriti stems (*Mauritia flexuosa* L.) on the phytotechnical and nutritional parameters of fig tree seedlings in order to improve seedling quality.

Material and Methods

Description of the area

The experiment was carried out in an area screened with 50% sombrite on the Professora Cinobelina Elvas Campus of the Federal University of Piauí in Bom Jesus, located at 09º04’28” S, 44º21’31” W at an altitude of 277m. According to Köppen (1948), the climate in the region is classified as Aw, tropical hot and semi-humid, with less rainfall during the winter than the summer, an average temperature of 26.7°C and an average annual rainfall of 1.200 mm.

Cropping conditions, treatments and experimental design

The first stage of the experiment began in June 2019 with collection of the decomposed buriti stems (*Mauritia flexuosa* L.) at the Brejo do Altos settlement, located approximately 20 km from Bom Jesus, PI. The stems were crushed in order to prepare the substrate.

Before setting up the experiment in September 2019, the collected material was left to decompose for six different periods (0, 15, 30, 45, 60 and 75 days), irrigated daily, in order to determine the best decomposition time for the fig tree cuttings to develop. A randomised block design was used in a 6x5+1 factorial scheme, with five replications, including six decomposition times (0, 15, 30, 45, 60 and 75 days) and five proportions by volume of buriti stems (20%, 40%, 60%, 80% and 100%) for each period, for a total of 30 treatments, plus one additional treatment of 100% soil taken from a gully. These were used to plant the fig tree cuttings, giving a total of 355 seedlings.

Polythene bags, each of 750 ml, were used to plant the fig tree cuttings that were taken from plants grown for three years in the teaching orchard at the Professor Cinobelina Elvas Campus of the Federal University of Piauí. The cuttings were standardised to a length of 25 cm and planted in each of the different proportions of substrate. They were then kept under a screened area on a bench covered with plastic to form a moist chamber that was irrigated five times a day, at 06:00, 10:00, 12:00, 16:00 and 18:00 for a period of four minutes each time, with the aim of maintaining field capacity.

Table 1 shows the chemical attributes of the soil and decomposed buriti stems that were used in the experiment, with the different decomposition times, as per the methodology of Donagemma et al. (2011).

Table 1. Results of the analyses of the soil and of the organic substrate of decomposed buriti stems for the different decomposition times.

Treatment	pH H_2O	H+Al	Al^{3+}	Ca^{3+}	Mg^{2+}	K^+	SB	T	P mg dm^{-3}	V %	m %	OM g/kg
		-------------- cmol$_c$ dm^{-3} --------------------										
Soil	4.51	5.52	2.65	0.24	0.11	0.12	0.46	5.98	1.36	7.75	85.1	7.75
0 days	6.75	2.30	0.00	3.05	2.04	5.17	10.26	12.55	1.02	81.70	0	81.6
15 days	6.77	2.43	0.00	3.00	1.77	5.65	10.42	12.85	5.78	81.07	0	81.0
30 days	6.64	2.87	0.00	3.31	1.71	0.63	5.65	8.52	1.75	66.36	0	66.36
45 days	6.25	3.52	0.00	3.01	1.58	0.29	4.87	8.39	0.78	58.06	0	58.06
60 days	5.99	3.35	0.00	2.92	1.41	0.02	4.34	7.69	0.97	56.47	0	56.46
75 days	5.58	3.52	0.00	2.93	1.47	0.08	4.48	8.00	0.78	55.99	0	55.99

pH in water, Hydrogen + aluminium (H+Al); Aluminium (Al^{3+}); Calcium (Ca^{3+}); Magnesium (Mg^{2+}); Potassium (K^+); Sum of bases (SB); cation exchange capacity (T); Phosphorus (P); Base saturation (V); Aluminium saturation (m); Organic matter (OM).

Morphological variables

The collections and evaluations were carried out 60 days after planting, when the following parameters were evaluated: number of leaves - determined by counting all the fully expanded or opened leaves on the plant; number of branches - determined by counting all the main branches on the plant; SPAD index for chlorophyll a and b - determined using a model CFL 1030 portable chlorophyll meter (ClorofiLOG); diameter and length of the largest shoot (mm) - measured using the Panec 300 mm digital calliper; total leaf area (mm^2) – determined by collecting all the leaves of the plant and using the LI-3100 UV-VIS Spectrophotometer area integration device; root length (cm) - measured from the root collar to the apex of the root using a ruler graduated in cm; root volume (cm^3) – by displacement of the water column, using a 100ml test tube (Silva et al., 2018); shoot and root fresh matter (g) - determined by weighing on an analytical balance; shoot and root dry matter (g) – determined by drying in a forced air circulation oven at 65ºC for 72 hours and then weighing on an analytical balance.

Chemical analysis of the substrates and nutrient analysis of the seedlings

The following chemical attributes were analysed in the substrate: pH, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), Aluminium (Al^{3+}), Hydrogen + Aluminum (H + Al), copper (Cu), iron (Fe), zinc (Zn) and manganese (Mn). The nutrient analysis of the soil was carried out in two stages: before setting up the experiment, to determine the nutrient content up to that moment, as well as to evaluate whether the decomposition times afforded any increase in nutrients in the organic substrates of decomposed buriti stems; after setting up the experiment, to determine whether the nutrient content increased or decreased while the cuttings were planted. The macro- and micronutrient content was also analysed via leaf analysis, as per Donagemma et al. (2011).

The leaves were removed, and after measuring the leaf area, were washed with distilled water and placed in an oven to constant weight. A nutrient analysis of the shoots was then carried out to determine the nutrient content of the seedlings.

Statistical analysis

The data were submitted to analysis of variance for the morphological and chemical responses of the plant using the F-test at a level of $p<0.05$. The normality of the residuals was checked using the Shapiro-Wilk test at p<0.05; when significant, the effect of each concentration was described using polynomial regressions including parameters that were significant by t-test.

The effect of the soil nutrient content before and after seedling development was evaluated on a biplot showing the scattering of the treatments and considering the first two principal components. Each of the analyses was carried out using the R Software v 4.0 (R CRAN, 2020).

To analyse the correlation between the phytotechnical and nutritional parameters, a correlation analysis was carried out between the variables, resulting in the Pearson coefficient.

Results and Discussion

It can be seen that the substrate decomposition times had no significant effect on the variables under analysis (Table 2); however, the levels of decomposed buriti stems did have a significant effect on the morphological variables: number of leaves (NL), shoot fresh matter (SFM), root fresh matter (RFM), root volume (RV), and the levels of calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn) and manganese (Mn) in the leaves of the fig plants.

Table 2. Analysis of variance of the phytotechnical variables of fig tree seedlings for the decomposed buriti stems and decomposition time.

SV	DF	NL	NB	CLA	CLB	DLS	LLS	SFM	RFM
Stem	4	2.67**	1.35ns	1.81ns	2.43ns	0.40ns	0.62ns	2.57**	9.29**
Time	5	0.38ns	1.27ns	2.25ns	0.24ns	0.09ns	0.72ns	0.56ns	1.03ns
Stem x Time	20	0.83ns	1.64ns	0.19ns	1.13ns	0.73ns	0.65ns	0.79ns	0.82ns
factor x additional	1	0.31ns	0.12ns	1.04*	6.82**	0.03ns	3.19ns	0.35ns	1.98ns
Block	4	4.15*	17.42*	7.81ns	1.99ns	2.88**	12.24*	19.00**	16.92**
CV%		24.81	27.84	20.93	21.45	14.82	39.75	32.39	32.02
SV	**DF**	**LA**	**RL**	**RV**	**SDM**	**RDM**			
Stem	4	0.86ns	1.25ns	5.88*	1.35ns	2.14ns			
Time	5	0.57ns	0.83ns	2.10ns	0.61ns	0.89ns			
Stem x Time	20	0.86ns	1.00ns	0.73ns	1.20ns	0.74ns			
factor x additional	1	0.02ns	0.41ns	1.32ns	0.05ns	2.53ns			
Block	4	21.82*	9.84*	14.60*	19.92**	26.27**			
CV%		30.68	16.68	32.39	31.19	32.45			

NL= number of leaves; NB= number of branches; CLA= Chlorophyll a content; CLB= Chlorophyll b content; DLS= diameter of the largest shoot; LLS= Length of the largest shoot; SFM= shoot fresh matter; RFM= root fresh matter; LA= leaf area; SDM= shoot dry matter; RDM= root dry matter; RL= root length; RV= root volume.

It can be seen from Figure 1 that the different proportions of organic substrate had a significant effect on NL, showing a quantitative drop in the number of leaves for the substrate with 80% decomposed buriti stems. This result was similar to that of Fernandes and Pasin (2019), which showed a progression in the number of leaves when adding an organic compost, affording the plant a higher rate of light assimilation, with a consequent increase in photosynthesis due to the increase in the number of leaves.

This result is in line with that of Silva et al. (2016), who found an increase in NL as the concentration of decomposed buriti stems increased (Figure 1). The increase in NL may be related to the amount of calcium (Ca) made available by the organic substrate (Table 1). Miranda et al. (2019) point out that calcium is responsible for the emission of new leaves in plants, and that the significant presence of leaves on the cuttings helps in forming the root system, since the phenolic compounds produced in the shoots interact with auxins and induce root formation.

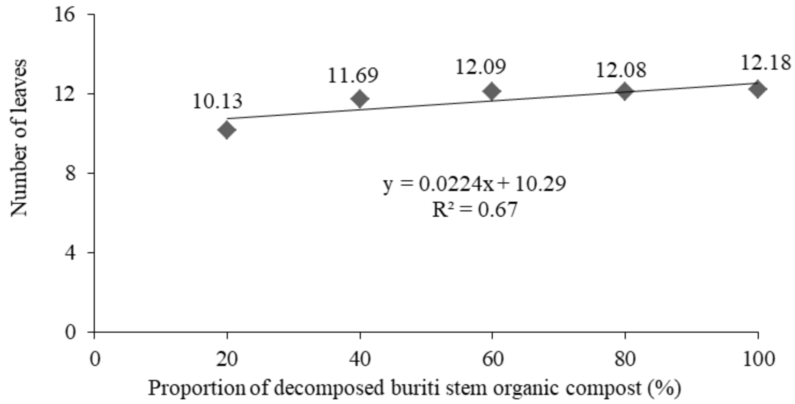

Figure 1. Number of emerged leaves (units) on fig tree cuttings for different proportions of substrate based on decomposed buriti stems.

Therefore, in addition to contributing to a higher rate of light assimilation, the number of leaves is essential for the development of vigorous roots, which is directly related to plant development, since the leaf area is the main site of photosynthesis (COSTA JUNIOR et al., 2017; MATIAS et al., 2019a).

Linear growth was observed in both the shoot (SFM) and root (RFM) fresh matter (Figure 2), showing that it is not possible to identify the point of stability or maximum return for these characteristics, but that the addition of decomposed buriti stems affords an increase in both variables.

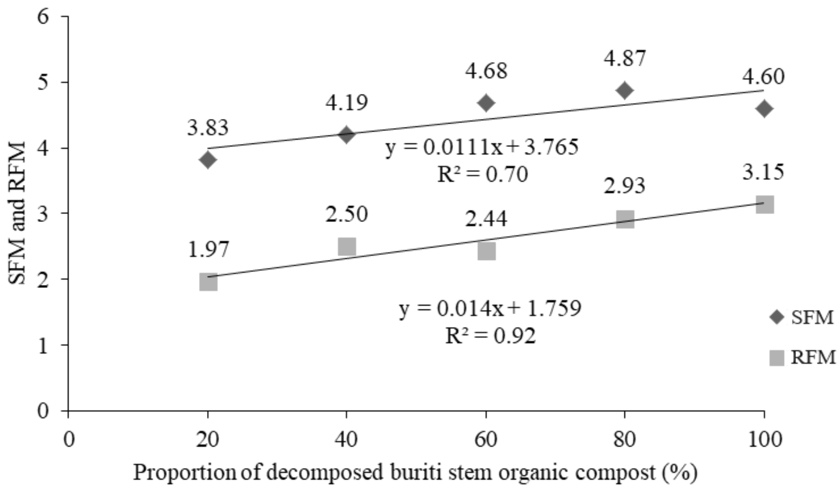

Figure 2. Shoot fresh matter and root fresh matter (grams) in fig tree cuttings for different proportions of substrate based on decomposed buriti stems.

Silva et al. (2016) showed that the addition of organic compounds contributed to shoot development in the cauliflower. The same result was found in this study, where, according to the correlation analysis (Figure 3), the increase in SFM is related to the levels of Ca, Mg, Mn and Zn that were made available by the organic substrate, in addition to the number of leaves and root length of the cutting itself.

These results corroborate those of Martins et al. (2018), who analysed the development of pepper seedlings in decomposed buriti stems and found that the presence of organic matter favoured development of the shoots and roots. Evangelista et al. (2014) also point out that the root system only develops satisfactorily when the substrate combines good aeration with high water retention capacity, good drainage and a lack of contaminating agents.

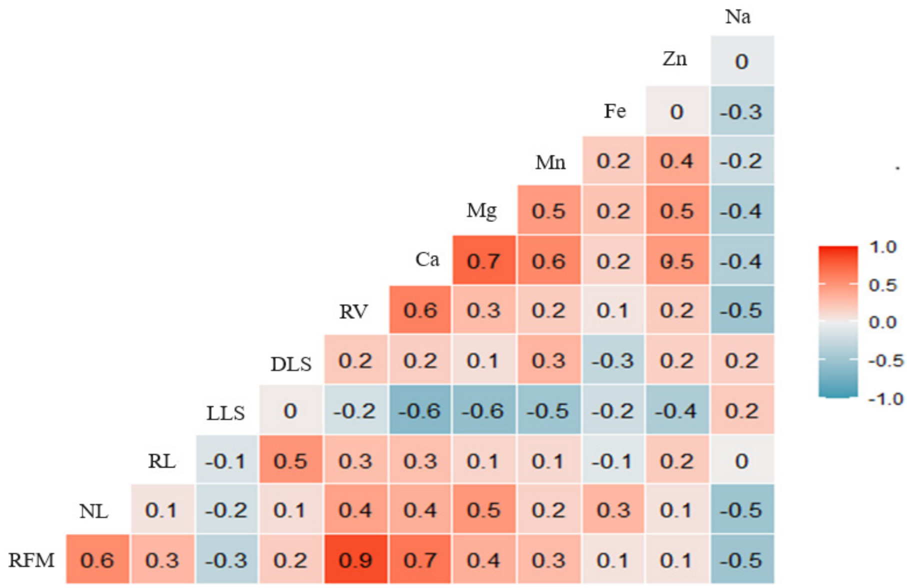

Figure 3. Correlation between the morphological and nutritional variables in fig tree cuttings for different proportions of substrate based on decomposed buriti stems.

The correlation analysis (Figure 3) shows that RFM is correlated with the number of leaves on the cuttings, the length and volume of the roots, and with the nutrient content of the leaves (Ca, Mg, Mn, Fe and Zn), demonstrating the importance of these elements in substrates for the production of fig tree seedlings.

Similarly, the root volume increased (Figure 4) in response to the addition of decomposed buriti stems to the substrate. It was found that the substrate of 100% decomposed buriti stems obtained the best results with a linear increase. This may be related to the positive characteristics of the organic residue (Table 1), showing that the chemical composition of the substrate has significant levels of nutrients that are essential to the plants (P, K, Ca, Mg) and a high organic matter content, as well as an increase in pH compared to the soil.

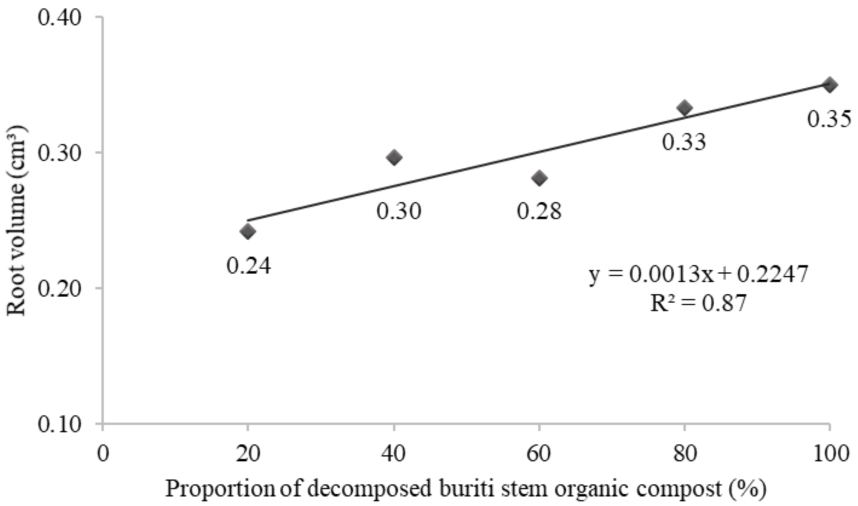

Figure 4. Root volume of fig tree cuttings for different proportions of substrate based on decomposed buriti stems.

According to Santos et al. (2018), the organic matter in the substrate helps to retain greater amounts of water and nutrients that can be released gradually to meet the needs of the plant. This may have contributed significantly to the good development of the roots. Furthermore, given its absorption area, the root system is responsible for the development and productivity of the plant, which is why root volume is important.

The results show that the levels of calcium in the plant increased linearly, with no point of maximum concentration (Figure 5). The increase in calcium in the leaves of the plant can be explained by the presence of organic matter in the substrate. According to Miranda et al. (2019), organic matter, as well as retaining moisture, provides the seedlings with nutrients (Ca, Mg, P and K). Furthermore, as shown in Table 1, decomposed buriti stems already contain calcium.

It can be seen that with each increase in the level of decomposed there was an increase in the accumulation of Mg in the leaves of the plant (Figure 6). This result confirms the positive correlation between calcium and magnesium, as can be seen in Figure 4.

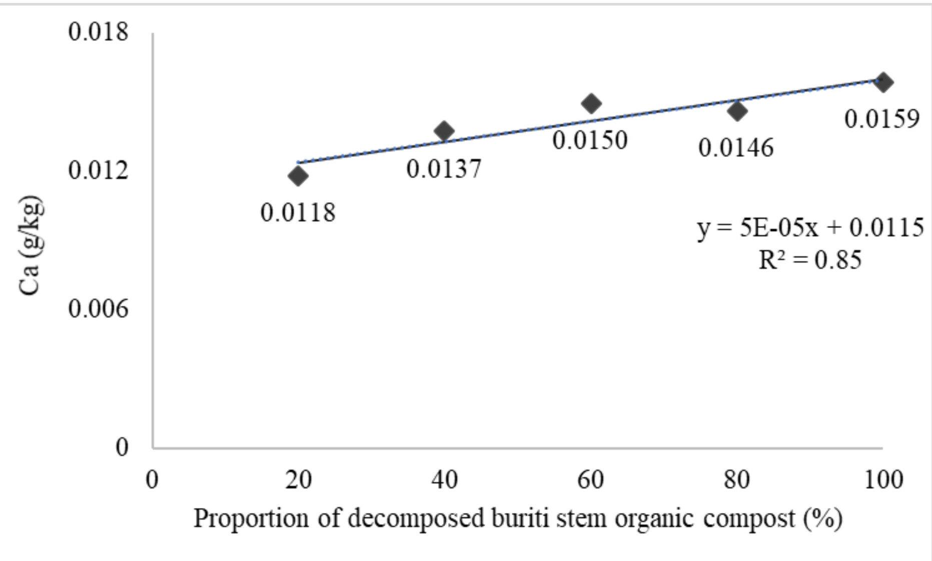

Figure 5. Calcium accumulation (Ca g kg^{-1}) in the shoots of fig tree cuttings for different proportions of substrate based on decomposed buriti stems.

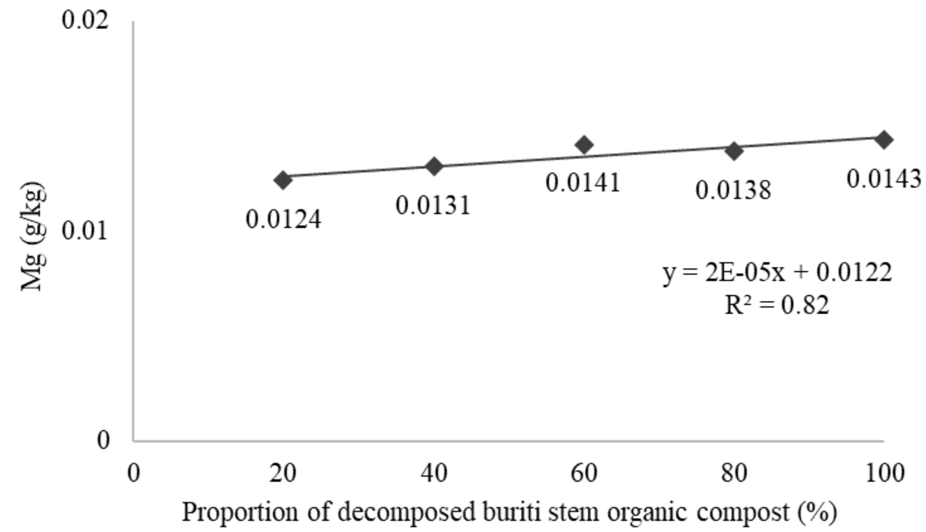

Figure 6. Accumulation of magnesium (Mg g kg^{-1}) in the shoots of fig tree cuttings for different proportions of substrate based on decomposed buriti stems.

Martins et al. (2018) found that the addition of organic compost to the substrate afforded a significant linear increase in the Mg content of the shoots of maize plants, as was seen in the present study in the leaves of the fig tree (Figure 6). According to the authors, this result was due to the contribution of the existing chemical characteristics of the organic substrate which included these nutrients.

By analysing Figure 7, it can be seen that the compost of buriti stems had a significant effect on Zn and Fe in the plant, where a level of 60% resulted in a higher accumulation of these micronutrients, with a reduction for the level of 100%. Cavichioli (2019) found that Zn and Fe also increased significantly due to the presence of organic matter in the substrate where the plants were found. It can be seen that the buriti stems must have provided the nutrients, affording an increase in the accumulation of Zn and Fe; however, there may be a reduction in the accumulation of these nutrients at higher proportions.

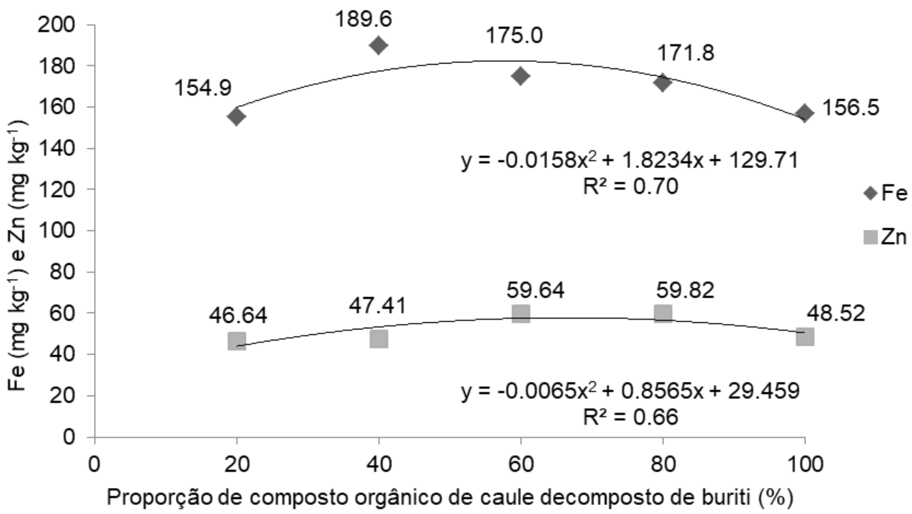

Figure 7. Accumulation of zinc and iron (Zn and Fe mg kg^{-1}) in the shoots of fig tree cuttings for different proportions of substrate based on decomposed buriti stems.

The decomposition of the buriti stems contributed to the greater availability of organic matter and, consequently, of nutrients. Cabreira et al. (2017) found that adding organic matter to the substrate resulted in better nutritional balance as well as a well-formed root system, as shown by the results of the present study.

For the micronutrients Fe and Zn, the proportion of substrate gave significant results, with a proportion of only 20% contributing to the best result for Fe, while a proportion of 80% gave the highest index for Zn (Figure 7).

The substrate composed of decomposed buriti stems gave a positive result for manganese in the leaves of the plants (Figure 8). According to Cruz et al. (2017), between 50 and 200 mg is considered to be an adequate level of Mn in the leaves. It can be seen that even the smallest proportion of decomposed buriti stems afforded an increase in Mn in the plants.

From the principal component analysis of the substrate parameters before and after the experiment, it can be seen that the nutrients P and K are correlated (Figure 9), as are the values of H+Al and Al, and organic matter and the Ca and Mg content. It can be seen that OM in the substrate may contribute to an increase in the levels of Ca and Mg as well as to a reduction in the concentration of available Al and an increase in the pH of the soil.

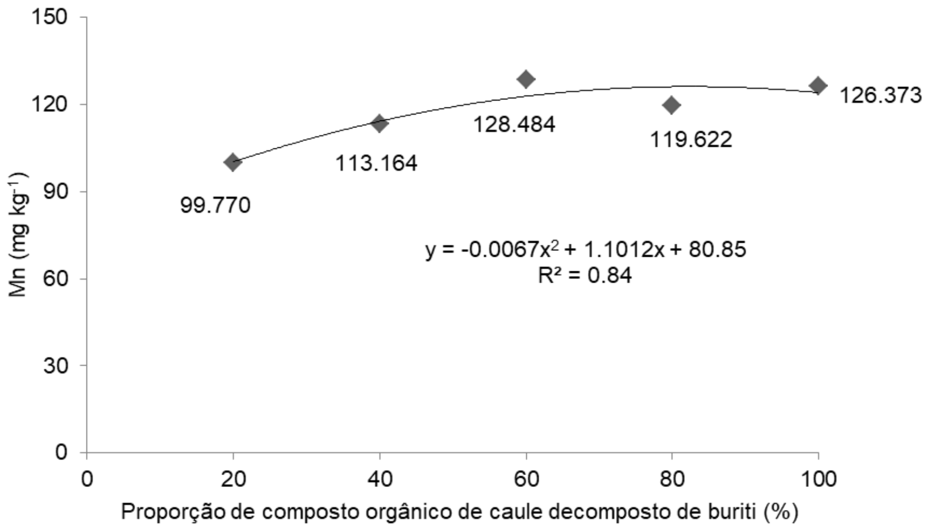

Figure 8. Accumulation of manganese (Mn mg kg^{-1}) in the shoots of fig tree cuttings for different proportions of substrate based on decomposed buriti stems.

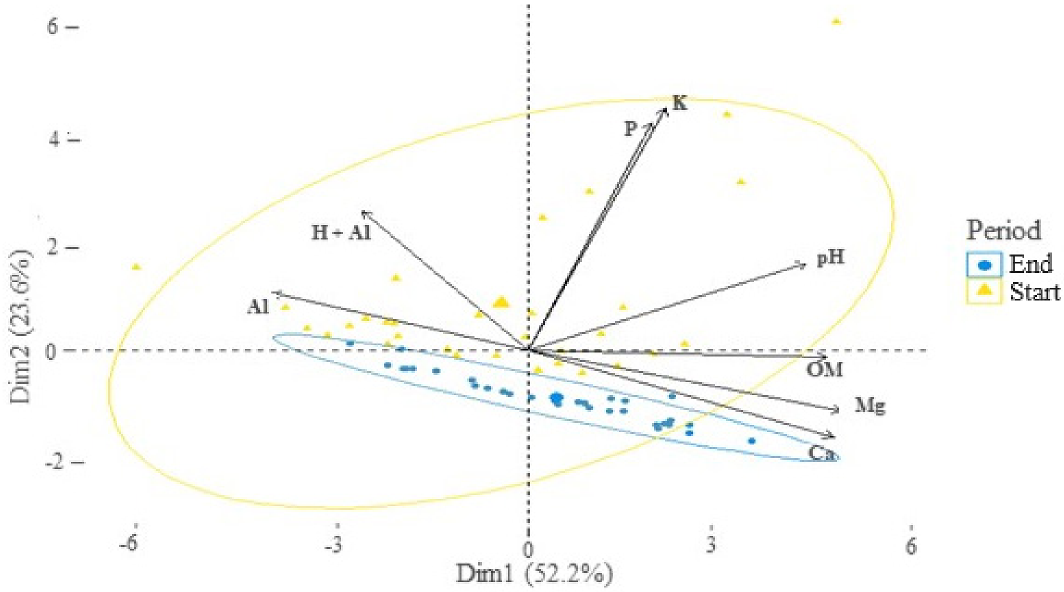

Figure 9. Principal component analysis of the chemical attributes of the substrates based on decomposed buriti stems and soil before and after setting up the experiment.

In contrast, P is a nutrient with low mobility in the soil, but accompanies the increase in organic matter, whose slow and gradual mineralisation leads to the emergence of forms of P that are released by the decomposition of plant residue (SILVA et al., 2016), as seen in the present study.

Furthermore, the nutrient concentration was higher after the experiment. This is because the organic compost improves the characteristics of the substrate, but releases nutrients gradually, unlike commercial chemical substrates, which readily release nutrients, especially during the early stages of plant development (Silva et al., 2018).

Conclusions

The nutrient analysis of the leaves showed that the proportion of decomposed buriti stems (20%, 40%, 60%, 80% and 100%) gave significant results for the nutrients: calcium, magnesium, iron and zinc; significant results were also seen for the morphological variables: shoot fresh matter (SFM), root fresh matter (RFM) and root volume (RV). The use of buriti stems in the above proportions is therefore an economically viable alternative substrate for the production of fig seedlings, and can be recommended from both an environmental and technical point of view. In addition, it can serve as an incentive for fruit farming in Piauí due to the availability of the residue.

The decomposition times had no significant effects on the variables under analysis, showing that for this substrate and this crop decomposition is unnecessary, as it does not increase the production parameters considered important in producing fig tree seedlings, neither does it cause any damage.

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