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Research Article

Production of pre-sprouted sugarcane seedlings using carnauba bagana as substrate[1]

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ABSTRACT

Sugarcane seedling quality is strongly influenced by the substrate used. Currently, alternative substrate sources from the sugarcane industry itself have been used; however, there is no specific substrate to produce pre-sprouted seedlings. This study aimed to evaluate the quality of pre-sprouted sugarcane using substrates with different proportions of carnauba bagana (0, 20, 40, 60, 80 and 100 %) plus soil. The experimental design was completely randomized, with six treatments and five replicates. Pre-sprouted seedlings cultivated using substrate composed by 80 % of carnauba bagana showed the best response for number of leaves, diameter, shoot length, shoot, root and total dry mass, and Dickson Quality Index, owing to the improvement in the substrate physical and chemical characteristics.

PALAVRAS-CHAVE: *Saccharum* spp., *Copernicia prunifera* (Mill.) H. E. Moore, alternative substrate.

RESUMO

Produção de mudas pré-brotadas de cana-de-açúcar utilizando-se bagana de carnaúba como substrato

A qualidade de mudas de cana-de-açúcar é fortemente influenciada pelo substrato utilizado. Atualmente, fontes alternativas de substrato oriundas da própria indústria canavieira têm sido empregadas; no entanto, não existe substrato específico para produção de mudas pré-brotadas. Objetivou-se avaliar a qualidade de mudas pré-brotadas de cana-de-açúcar cultivadas em substratos com diferentes proporções de bagana de carnaúba (0, 20, 40, 60, 80 e 100 %) acrescida de solo. O delineamento experimental foi inteiramente casualizado, com seis tratamentos e cinco repetições. As mudas pré-brotadas cultivadas em substrato composto por 80 % de bagana de carnaúba obtiveram melhor resposta para número de folhas, diâmetro, comprimento do broto, massa seca da parte aérea, radicular e total, e Índice de Qualidade de Dickson, em decorrência da melhoria nas características físicas e químicas do substrato.

PALAVRAS-CHAVE: *Saccharum* spp., *Copernicia prunifera* (Mill.) H. E. Moore, substrato alternativo.

INTRODUCTION

The growing demand for renewable energy has driven the sugarcane (*Saccharum* spp.) sector to search for new cultivation and management techniques to increase yield. In conventional production systems, whole stalks are used in sugarcane planting, and it is common that failures occur in the planting rows.

In recent years, the use of pre-sprouted seedlings has been introduced into the production system, which consists of individualizing the buds for emergence before transplanting (Martins et al. 2015). The pre-sprouted seedlings system has certain advantages over the conventional one, such as a reduction of up to 90 % in the volume of stalks used per hectare, in addition to increased plant vigor, higher phytosanitary quality and more uniform stands (Landell et al. 2013, Santos et al. 2020).

The use of pre-sprouted seedlings can be a promising alternative in the sugarcane production system, which can boost yield in cultivated areas and minimize the opening of new areas, allowing a greater conservation of natural resources in vegetation areas (Santos et al. 2020). The pre-sprouted seedlings system allows for a reduction in the number of seed stalks, when compared to conventional planting, which uses approximately 20 t ha^{-1} (Landell et al. 2013), and its cultivation takes place using individual buds, what may promote a greater material viability,

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higher sprouting rate and better rooting (Jain et al. 2010).

However, the quality of seedlings is strongly influenced by the substrate used, which must have adequate physical and chemical characteristics (Bezerra 2003). The use of commercial substrates, in general, manages to meet the seedling demands in the formation stage until installation in the field; however, they are expensive and not economically feasible. As a strategy to reduce pre-sprouted seedlings production costs, alternative substrate sources have been sought, such as sugarcane bagasse and filter cake from the sugarcane industry itself (Braga et al. 2019, Santos et al. 2020). However, there is no specific substrate for pre-sprouted seedlings production, and it is possible to use other agro-industrial residues (Boene et al. 2013).

Carnauba bagana is an agro-industrial waste derived from the straw of the palm tree *Copernicia prunifera* (Mill.) H. E. Moore, which is generated after removing dust from the leaves to extract wax (Ferreira et al. 2013). It is an abundant residue in rural properties that produce carnauba wax for different purposes, such as the manufacture of handcrafted pieces, mulch of cultivated soils, and even as a component in animal feed (Moreira 2022).

The use of carnauba bagana has been reported in the literature as an alternative substrate source and has shown satisfactory results in the production of seedlings of various species (Lustosa Filho et al. 2015, Sousa et al. 2020, Mendonça et al. 2021). However, no study has evaluated the potential of carnauba bagana as a substrate for producing pre-sprouted sugarcane seedlings. Thus, this study aimed to evaluate the quality of pre-sprouted sugarcane seedlings grown in substrates with different carnauba bagana proportions.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse at the Universidade Federal do Maranhão, in Chapadinha, Maranhão state, Brazil (3º44'12.62"S, 43º19'03.51"W and altitude of 105 m), from September to November 2018.

The experimental design was completely randomized and consisted of six treatments and five replicates. The substrates were formulated with different proportions of carnauba bagana (0, 20, 40, 60, 80 and 100 %) and soil [Dystrophic Yellow Latosol - LAd (Santos et al. 2013), equivalent to Oxisol (USDA 1996)], on a volumetric basis (v/v). The soil was collected from the 0-20 cm layer and contained 820 g kg^{-1} of sand, 40 g kg^{-1} of silt and 140 g kg^{-1} of clay.

Samples of the formulated substrates were collected, and physical and chemical characterizations performed. For the physical characterization, the overall density, particle density and total porosity were determined (Teixeira et al. 2017). For the chemical characterization, the pH of the substrate/water suspension (1:5; v/v) was determined according to Brasil (2007). The organic matter (OM), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) contents were determined according to Teixeira et al. (2017). For K and P, the Mehlich 1 extract solution was used, and KCl (1.0) was used for Ca and Mg.

The sugarcane cultivar used was RB863129, harvested from an experimental area at eight months after emergence, in its first cycle (cane-plant). The stem segments (mini-cuttings) were cut to an approximate size of 4 cm, containing a single bud, and removed from the central part of the stem. Next, mini-cutting stones with viable buds (healthy and with no injuries) were selected. Each replication consisted of 10 mini-cuttings, that is, 50 mini-cuttings per treatment, totaling 300 samples.

Sowing was performed in polyethylene bags (12 × 20 cm) containing one mini-cutting wheel per bag, with the buds facing upward and half-covered by a thin layer of substrate. Subsequently, the bags were placed in an area covered by black sombrite with 60 % shade. During the experiment, daily irrigation was performed, keeping the substrates close to the bag capacity.

Emergence evaluations were performed at 7, 14, 21, 28 and 35 days after sowing. At the end of the experiment, the sprouting percentage was calculated according to Brasil (2009): B = (NE * 100)/NT, where: NE is number of emerged buds; and NT the number of buds placed to germinate.

At the end of the experiment (40 days after sowing), a destructive analysis of the seedlings was performed, and the following variables were determined: number of leaves; sprout diameter, with readings at 1 cm from the base of the plant, with the aid of a digital caliper; sprout length, measured from the base of the substrate to the tip of the flag leaf; root length; shoot (SDM) and root dry mass (RDM). The seedlings were sectioned, placed in paper envelopes, dried in an oven with forced air circulation at 60 ºC, for 72 h, and then weighed on a precision scale. The total dry mass was obtained by adding the SDM and RDM, and the Dickson Quality Index (DQI) (Dickson et al. 1960) as DQI = TDM/[(PH/SD) + (SDM/RDM)], where: TDM is the total dry matter (g); PH the plant height (cm); SD the stem diameter (mm); SDM the shoot dry matter (g); and RDM the root dry matter (g).

The data were subjected to analysis of variance and the F test used to detect significant effects ($p < 0.05$) in the substrates. When there was a significant effect, the means were compared using the Tukey test ($p < 0.05$), with the InfoStat 2018® statistical software (Di Rienzo et al. 2018); while the graphs were plotted in the SigmaPlot 14.0 software.

RESULTS AND DISCUSSION

The addition of carnauba bagana to the soil improved the physical characteristics of the formulated substrates, as well as reduced density and increased porosity (Table 1). Schmitz et al. (2002) suggested that substrates should contain densities in the range of 400-500 kg m^{-3}. The substrate composed of 80 % of carnauba bagana had a density of 560 kg m^{-3}, close to the range considered ideal. As for porosity, another important indicator of the physical quality of the substrate, the value recommended by Verdonck & Gabriels (1988) is 85 %. Substrates with higher proportions of carnauba bagana had the highest porosity; however, their values were lower than the recommended ones.

Table 1. Initial physical characterization of the substrates based on carnauba bagana (CB).

Substrates	Density (g cm^{-3})		Porosity (%)
	Global density	Particle density	
0 % CB (soil)	1.3	2.6	51.5
20 % CB	1.2	2.6	55.3
40 % CB	1.0	2.4	59.3
60 % CB	0.8	2.0	60.8
80 % CB	0.6	1.8	68.5
100 % CB	0.3	0.9	70.2

The formulated substrates had pH values ranging from 4.5 to 5.3 (Table 2). Most of the evaluated substrates showed pH values below the ideal (5.1 to 6.3) for seedling production, according to Abad et al. (1993). Thus, the substrates containing 80 and 100 % of carnauba bagana were the only ones that were within the range recommended by the aforementioned authors. Carnauba bagana, when added to the soil, caused an increase in the pH values, making it less acidic, when compared to the soil.

Maintaining the pH within the ideal range is one of the crucial factors in the formulation of substrates, as it enables a greater solubility and availability of nutrients and ensures a good growth and development of seedlings (Antunes et al. 2022). According to these authors, a low pH may lead to toxicity, given the increased availability of toxic elements, in addition to reducing the availability of nutrients such as nitrogen, potassium, calcium and magnesium, whereas a high pH may cause deficiencies in phosphorus and micronutrients (e.g., iron, manganese, zinc and copper).

The carnauba bagana increments in the substrates also increased the levels of organic matter and macronutrients (N, P, K, Ca, Mg and S) (Table 2). This result is consistent with those of previous studies (Costa et al. 2021, Mendonça et al. 2021), which found that an increase in the proportion of organic residues in the substrate increases the levels of macronutrients. For cultivation in containers, a high organic matter content is desirable, considering the sporadic supply of water and nutrients (Schmitz et al.

Table 2. Initial chemical characterization of the substrates formulated with carnauba bagana (CB).

Substrates	pH	OM	N	P	K	Ca	Mg	S
		g kg^{-1}		mg kg^{-1}	cmol$_c$ kg^{-1}			
0 % CB (soil)	4.0	0.6	1.2	14.0	0.7	1.6	1.0	3.8
20 % CB	4.5	60.7	3.9	6.0	0.6	2.9	0.5	4.3
40 % CB	4.9	73.8	5.4	12.0	0.7	4.5	1.3	6.8
60 % CB	5.0	95.2	6.9	23.0	1.3	5.9	1.4	8.9
80 % CB	5.1	114.3	9.3	42.0	2.2	7.0	3.1	12.7
100 % CB	5.3	598.9	4.0	89.0	3.9	19.8	10.4	34.6

pH: hydrogen potential; OM: organic matter; N: nitrogen; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; S: sulfur.

2002). The minimum organic matter value considered by Schmitz et al. (2002) for substrates is 50 %. For nutrient content, although there is no current information on adequate ranges in substrates, higher contents are expected to guarantee quality seedlings (Antunes et al. 2022).

The sprouting time ranged from 7 to 28 days after sowing (Figure 1A). The substrate with 20 and 40 % of carnauba bagana had emergence peaks at 7 days after sowing, with about 60 and 40 % of emerged buds, respectively, which gradually reduced by 28 days after sowing. Substrates with 0, 60, 80 and 100 % of carnauba bagana showed emergence peaks at 14 days after sowing, which ranged from 50 to 60 % of emergence.

Even noticing differences in the emergence peaks among the substrates during the sprouting time, no statistical differences were detected for the sprouting percentage, which varied between 90 and 94 % (Figure 1B). The high sprouting rate may indicate that the amount of energy reserves (sugars) and nutrients present in the mini-cuttings were sufficient to support this first stage, because sprouting depends mainly on this source for activating enzymes, synthesis of hormones that promote division and cell elongation, and consequently for the survival of new plants in the first 60 days, and decreasing this dependence according to the development of shoots and roots (Landell et al. 2013, Manhães et al. 2015, Thomas 2016).

Pre-sprouted sugarcane seedlings cultivated in a substrate composed of 80 % of carnauba bagana showed a better response for the following parameters: number of leaves, diameter and shoot length, with increases of approximately 26, 24 and 21 %, respectively, in relation to the seedlings grown in the soil (Figures 2A, 2B and 2C).

Soils from the Cerrado (Brazilian Savanna) region, mostly classified as Latosols, have reduced nutrient and organic matter contents as their main characteristic, what contributes less to support plants nutritionally (Severiano et al. 2013) and demands a greater input of fertilizers. The addition of carnauba bagana to the substrate promoted a greater emission of leaves in the sugarcane seedlings, suggesting that this result is due to the addition of macronutrients present in the agro-industrial residue (Table 2). Additionally, this may ensure a greater competitive advantage for seedlings in the field, because, by emitting a greater number of leaves, they may have a greater photosynthetic capacity and, consequently, a greater production of photoassimilates directed to plant growth (Pessarakli 2014).

The increase in the proportion of carnauba bagana in the substrate composition contributed to the availability of P and N (Table 2). Specifically, P, which is an essential element in the biosynthesis of carbohydrates (Khavari-Nejad et al. 2009), indicates that seedlings well-nourished of this element have a higher rate of carbohydrate production that can be used to increase length and diameter from the bud. N, in turn, occupies a prominent place in the metabolic system of plants, because it is the constituent element of proteins and chlorophyll, the latter being responsible for the photosynthetic process, which promotes length (Leghari et al. 2016) and bud diameter of sugarcane seedlings (Gírio et al. 2015). It is evident that seedlings require N to maintain a satisfactory photosynthetic rate and, consequently, to produce photoassimilates, which are essential for growth (Kanai et al. 2008).

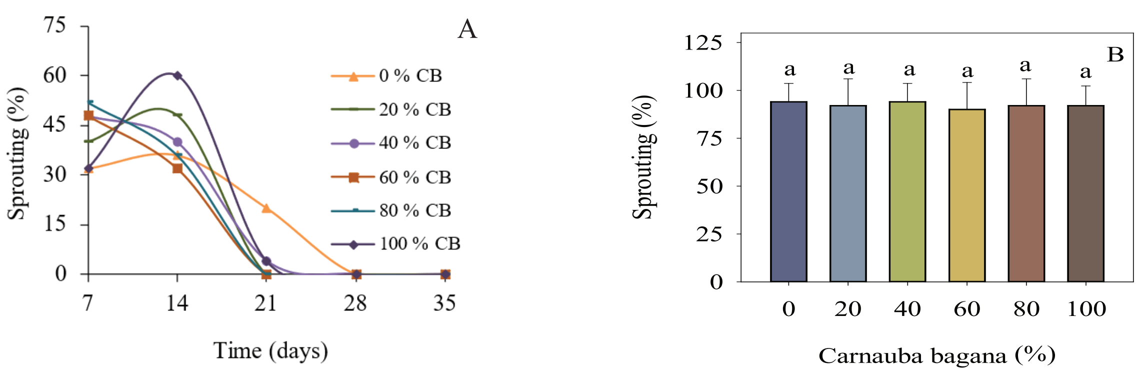

Figure 1. Sprouting percentage at 7, 14, 21, 28 and 35 days after sowing (A) and total sprouting (B) of pre-sprouted sugarcane seedlings, as a function of different substrates based on carnauba bagana. Means followed by the same letter in the bars do not differ according to the Tukey test ($p < 0.05$). Means with standard deviation.

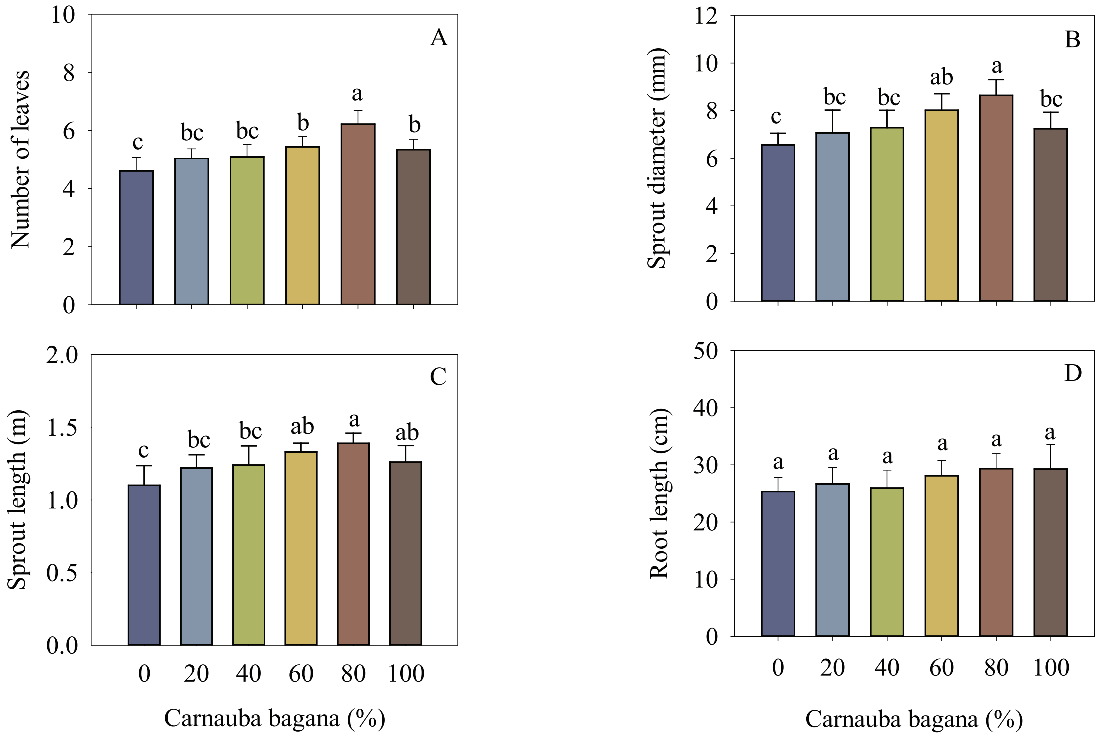

Figure 2. Number of leaves (A), shoot diameter (B), shoot (C) and root length (D) of pre-sprouted sugarcane seedlings grown in substrate with different percentages of carnauba bagana. Means followed by the same letter in the bars do not differ according to the Tukey test ($p < 0.05$). Means with standard deviation.

Even when a growth trend was observed when carnauba bagana was added to the substrate, no differences in root length were detected among the substrates (Figure 2D). One of the objectives of increasing the carnauba bagana proportion in the substrate is that this residue can promote an increase in the total pore volume and, therefore, improve the root growth by improving the water retention capacity and water/air ratio after drainage (Delarmelina et al. 2015, Meng et al. 2018). Such morphological alterations allow seedlings to better explore the substrate in a way that they increase the the contact between roots and nutrients, possibly contributing to a greater absorption of these (Souza et al. 2013), thus increasing nutritional efficiency (Du Jardin 2015).

For the shoot and total dry mass of pre-sprouted seedlings, the percentage of 80 % of carnauba husk had the best effect, differing statically from the other substrates (Figures 3A and 3C). These results indicate that this percentage can meet the plant chemical needs, providing nutrients such as K and N (Table 2), which are absorbed in greater quantities by sugarcane. K plays an important role in the osmotic regulation of plant cells, in the activation of many enzymes involved in respiration and photosynthesis, in addition to playing an important role in the transport of sucrose and photoassimilates (Meyer & Wood 2001, Taiz et al. 2017), thereby contributing to the accumulation of masses. N is another important macronutrient for shoot growth and total plant dry mass, and it mainly affects cell division, differentiation and elongation (Taiz et al. 2017).

The root dry mass of sugarcane seedlings in the substrate composed of 80 % of carnauba bagana was statistically superior to the treatments with 20 and 40 % of carnauba bagana (Figure 3B). This result indicates that a higher proportion of organic waste improves the chemical and physical characteristics (porosity and density), thus contributing to the accumulation of mass in pre-sprouted seedlings. The positive result of increasing bagana addition may have occurred because of the physical nature of the organic particles, which have low density and are positively correlated with porosity (Santos et al. 2020).

The Dickson Quality Index is an important indicator of seedling quality, as it considers

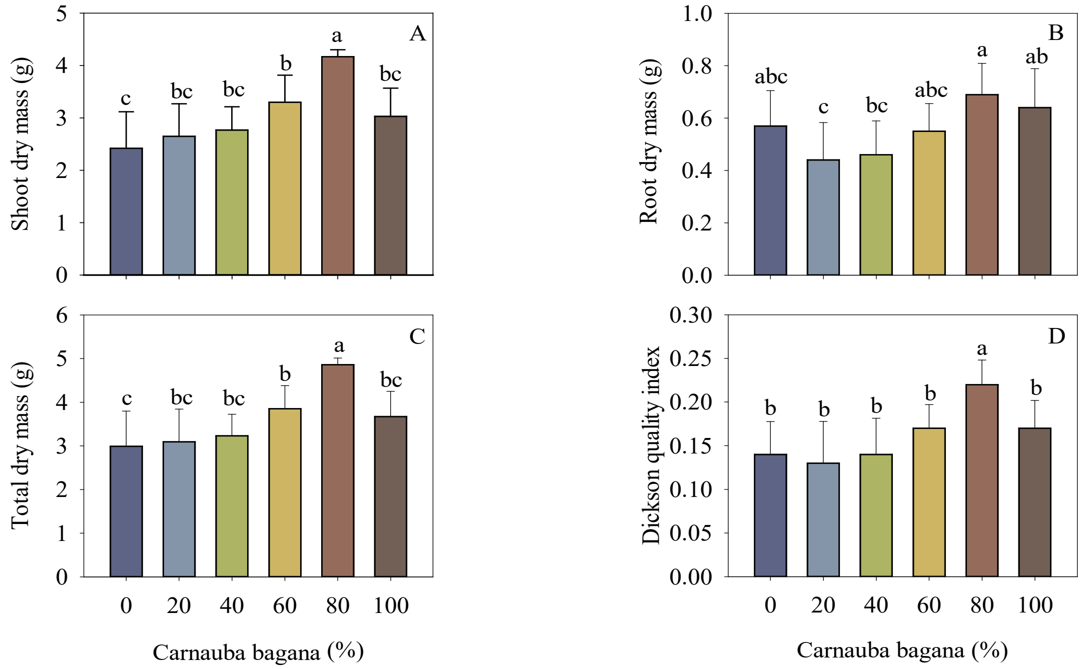

Figure 3. Shoot (A), root (B) and total dry mass (C) and Dickson Quality Index (D) of pre-sprouted sugarcane seedlings grown in substrate with different percentages of carnauba bagana. Means followed by the same letter in the bars do not differ according to the Tukey test ($p < 0.05$). Means with standard deviation.

morphological characteristics and calculates robustness and biomass distribution by considering several important parameters (Johnson & Cline 1991, Fonseca et al. 2002). According to Hunt (1990), the minimum recommended value for this index is 0.20. The substrate composed of 80 % of carnauba bagana was the only one that presented a value above the recommended value for this index (Figure 3D). This result suggests that the addition of carnauba bagana in this proportion promoted improvements in the quality parameters of the seedlings through chemical (increase in nutrients) and physical changes in the substrates. Pre-sprouted sugarcane seedlings, as well as plants in general, require balanced amounts of nutrients to ensure their structural and physiological quality, that is, amounts that do not conjecture deficiency or excess.

CONCLUSIONS

1. The use of carnauba bagana is recommended as a substrate formulation in the production of pre-sprouted sugarcane seedlings;
2. The substrate formulation composed of 80 % of carnauba bagana promoted high-quality pre-sprouted sugarcane seedlings.

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