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Research Article

Initial growth of *Syagrus romanzoffiana* seedlings in biosolid-based substrate[1]

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ABSTRACT

Substrate composition is a major factor influencing seedling quality. This study aimed to evaluate the potential of biosolid as a substrate component in the initial growth of *Syagrus romanzoffiana* (Cham.) Glassman seedlings. The experimental design was completely randomized, with six treatments, five replicates and seven plants per plot. The treatments consisted of substrates resulting from the mixture of subsoil (SS) and biosolid (BIO) at different proportions: 100 % SS; 20 % BIO + 80 % SS; 40 % BIO + 60 % SS; 60 % BIO + 40 % SS; 80 % BIO + 20 % SS; 100 % BIO. The seedling quality and morphological characteristics were evaluated. There was an increase up to the proportion of 60 % of biosolid for shoot height, stem diameter, number of leaves, leaf area, total chlorophyll content, root length, shoot dry matter and Dickson's quality index. For the root and total dry matter, increases occurred up to the proportion of 40 % of biosolid. Therefore, the use of biosolid in the proportions of 40 and 60 % in the substrate composition proved to be efficient, as they promoted a satisfactory initial growth (all seedlings presented shoot height between 30 and 40 cm and stem diameter of 5 mm) and quality of the evaluated seedlings.

KEYWORDS: Arecaceae, organic compost, jerivá, sewage sludge.

RESUMO

Crescimento inicial de mudas de *Syagrus romanzoffiana* em substrato à base de biossólido

A composição do substrato é fator de grande influência na qualidade das mudas. Objetivou-se avaliar o potencial de biossólido como componente de substrato, no crescimento inicial de mudas de *Syagrus romanzoffiana* (Cham.) Glassman. O delineamento experimental foi inteiramente casualizado, com seis tratamentos, cinco repetições e sete plantas por parcela. Os tratamentos foram constituídos por substratos resultantes da mistura de terra de subsolo (TS) e biossólido (BIO) em diferentes proporções: 100 % TS; 20 % BIO + 80 % TS; 40 % BIO + 60 % TS; 60 % BIO + 40 % TS; 80 % BIO + 20 % TS; 100 % BIO. Avaliaram-se as características morfológicas e de qualidade das mudas. Houve incremento até a proporção de 60 % de biossólido para altura da parte aérea, diâmetro do coleto, número de folhas, área foliar, clorofila total, comprimento da raiz, massa seca da parte aérea e índice de qualidade de Dickson. Para a massa seca da raiz e total, o incremento se deu até a proporção de 40 % de biossólido. Portanto, o uso do biossólido nas proporções de 40 e 60 % na composição do substrato mostrou-se eficiente por promover satisfatório crescimento inicial (todas as mudas apresentaram altura entre 30 e 40 cm e diâmetro do coleto de 5 mm) e qualidade das mudas avaliadas.

PALAVRAS-CHAVE: Arecaceae, composto orgânico, jerivá, lodo de esgoto.

INTRODUCTION

Palm trees are present in all tropical and subtropical regions of the world for being adapted to a variety of climates and soils (Eiserhardt et al. 2011). Brazil stands out as the third country with the greatest diversity of native palm trees, presenting approximately 270 species distributed in 38 native genera (Leitman et al. 2015, Valois 2016).

The *Syagrus* genus is native from South America, consisting of approximately 42 species, with *Syagrus romanzoffiana* (Cham.) Glassman, popularly known as jerivá, among them. It is a native species from Brazil with great potential for use, as it produces oil, fiber and hearts of palm, besides being considered ornamental, reaching heights of approximately 20 m. It also has ecological importance for its sweet-tasting fruits, being consumed by parrots and other wild animals. It is widely distributed mainly in the southeastern and southern regions of Brazil (Bernacci et al. 2008, Laindorf et al. 2018, Weirich Neto et al. 2020).

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Although it has potential, there is a lack of basic studies in the literature on the production of high-quality seedlings. In general, for the production of palm seedlings, it is common to use organic materials, especially cattle manure and poultry litter, which can be mixed at different proportions with the soil. However, there are no reports on substrates that can specifically contribute to the production of palm seedlings, mainly regarding the *Syagrus romanzoffiana* species (Costa et al. 2021). In the substrate composition, the organic part is responsible for retaining moisture and providing nutrients, presenting the best results in seedling production, as it helps to maintain the physical, chemical and biological characteristics of substrates (Cordeiro et al. 2020, Oliveira et al. al. 2020).

The substrate has the function of sustaining and providing adequate conditions for seedlings, contributing to their initial growth. Its composition is a factor of great influence on seedlings that may be offered to the market, as it should provide high-quality seedlings, facilitating planting operations and ensuring a good post-planting performance, greater field survival and resistance to environmental stresses (Kratz & Wendling 2016, Siqueira et al. 2019). Obtaining high-quality seedlings requires substrates with good physical, chemical, biological and sanitary characteristics. In addition, the substrate must be easy to handle, presenting low cost and high availability (Krause et al. 2017).

Research related to the effect of different substrate compositions on seedling quality, seeking to integrate the precepts of sustainability and reduce the time and costs of the production process, as well as to provide options for nurserymen (Siqueira et al. 2019), is constant and current. The use of organic waste as an alternative substrate for seedling production is directly related to regional availability, making it more affordable than other organic substrates found in the market (Krause et al. 2017). Thus, industrial or urban waste may be used, culminating in the minimization of the environmental impact that would be caused by the inadequate disposal of this waste.

Among the urban waste generated in large quantities, sewage sludge stands out. When properly treated, it is called biosolid and acquires characteristics that allow its use in agriculture. It is a material rich in organic matter and nutrients that can be used as a conditioner of the soil physical, chemical and biological properties. It also has a good capacity to partially or totally replace the use of commercial substrates and fertilizers by meeting the nutritional needs of plants (Prates et al. 2011, Ferraz et al. 2016, Souza et al. 2019, Djandja et al. 2020).

Some studies show that biosolids have a great potential for use as a substrate component in the production of seedlings of several forest species (Prates et al. 2011, Rocha et al. 2013, Trigueiro & Guerrini 2014, Ferraz et al. 2016, Bortolini et al. 2017, Abreu et al. 2019, Siqueira et al. 2019, Souza et al. 2019) and also in the production of seedlings of some palm species (Silva et al. 2015, Berilli et al. 2018, Ferreira et al. 2021).

Therefore, this study aimed to evaluate the potential of biosolid as a substrate component in the initial growth of *Syagrus romanzoffiana* seedlings.

MATERIAL AND METHODS

The experiment was conducted from November 2020 to April 2021, in a greenhouse covered with a 50 % black shading screen (Sombrite®), in the Universidade Estadual Paulista, Jaboticabal, São Paulo State, Brazil (21º15’2”S, 48º16’47”W and 600 m of altitude). The climate in the region is Cw (humid subtropical, with dry winters and rainy summers), according to Köppen classification, with minimum, average and maximum temperatures of 19.8 ºC, 24.5 ºC and 32.5 ºC, respectively.

The experimental design was completely randomized, with six treatments, five replicates and seven plants per plot. The treatments consisted of substrates resulting from the mixture of subsoil (SS) and biosolid (BIO) at different proportions: 100 % SS; 20 % BIO + 80 % SS; 40 % BIO + 60 % SS; 60 % BIO + 40 % SS; 80 % BIO + 20 % SS; 100 % BIO. To obtain the mixtures, both the biosolid and the subsoil were sieved through a 3-mm steel mesh sieve and subsequently homogenized.

The biosolid was obtained from the wastewater treatment plant of the municipality of Botucatu, São Paulo State, with this material already being suitable for use in agriculture. The biosolid met the requirements of the Conama resolution 375/2006 (Conama 2006), being classified as belonging to Class A, whose chemical composition was determined with the following results: organic carbon = 21.7 % (m m^{-1}); total cobalt = < 0.001^2 % (m m^{-1}); CEC = 500 mmol kg^{-1}; S = 3.3 % (m m^{-1}); Fe = 4.4 % (m m^{-1}); P = 3.4 % P_2O_5 (m m^{-1}); Mg = 0.22 % (m m^{-1}); N =

3.7 % (m m^{-1}); pH ($CaCl_2$) = 5.3; K = 0.12 % K_2O (m m^{-1}); C/N = 5.86; and with the following heavy metals: As = 3.9 mg kg^{-1}; Cd = 1.6 mg kg^{-1}; Pb = 24.6 mg kg^{-1}; Cr = 96.8 mg kg^{-1}; Hg = < 1.0 ² mg kg^{-1}; Ni = 28.5 mg kg^{-1}; Se = < 1.0 ² mg kg^{-1}; Ba = 296 mg kg^{-1}; Na = 678 mg kg^{-1}.

The subsoil was collected at a depth of 20-40 cm. The soil in the area corresponds to a Latossolo Vermelho Distrófico típico with clayey texture (Santos et al. 2018), or clayey Oxisol (Eutrustox) (USDA 1999). Its chemical characteristics showed the following results: P_{resin} = 1 mg dm^{-3}; K^+ = 7 mmol dm^{-3}; Ca^{2+} = 21 $mmol_c$ dm^{-3}; Mg^{2+} = 6 $mmol_c$ dm^{-3}; H + Al = 20 $mmol_c$ dm^{-3}; SB = 28 $mmol_c$ dm^{-3}; CEC = 48 $mmol_c$ dm^{-3}; V = 58 %; OM = 9 g dm^{-3}; pH ($CaCl_2$) = 6.3 $mmol_c$ dm^{-3}.

Syagrus romanzoffiana (Cham.) Glassman fruits were harvested from matrices belonging to the Universidade Estadual Paulista, with the pulp being removed by using a 3-mm steel mesh sieve. The seeds were subsequently placed to germinate at a depth of 2 cm, in a plastic box (17 × 22 × 50 cm) containing medium-grained expanded vermiculite as substrate. When the seedlings presented a shoot height of approximately 5 cm, they were transplanted into plastic pots (20 × 12 × 10 cm) with volumetric capacity of 1.7 L (1,700 cm^3) containing the substrates (treatments), which were previously moistened in order to avoid stress to the seedlings. The pots were suspended on metal mesh benches at 70 cm from the ground.

The seedlings were irrigated by micro-sprinklers activated automatically at one-hour intervals, with the first irrigation at 6:00 a.m. and the last at 6:00 p.m., lasting one minute each. The total daily water flow released by the sprinklers in the greenhouse was 12.6 L. The substrates were maintained at 100 % of their field capacity and each formulation presented different values regarding their water holding capacity. The maximum water holding capacity for the treatments with 100, 80, 60, 40, 20 and 0 % BIO was reached when 225, 552.5, 637.5, 850, 327.5 and 225 mL of water were applied to the substrate. The maximum water holding capacity of the substrate was determined by the difference between the mass of the saturated substrate and the mass of the dry substrate, discounting the weight of each pot (Tatagiba et al. 2015).

At 159 days after transplanting, the following characteristics were evaluated: shoot height (cm), measured at the substrate level to the tip of the last leaf, and root length (cm), both measured using a ruler in centimeters; stem diameter (mm), determined at the substrate level, using a digital caliper accurate to 0.01 mm; number of leaves, verified by the visual counting of fully expanded leaves; leaf area (cm^2), measured using an electronic leaf area meter (Li-3100C, LI-COR®, Lincoln, Nebraska, USA); and chlorophyll content, measured using a ClorofiLOG portable chlorophyll meter (model CFL1030, brand FALKER®). The Falker Chlorophyll Index (FCI) was determined through absorption ratios at different frequencies. This index is highly correlated with laboratory measurements and takes into consideration the presence of chlorophyll *a* and *b* (data provided by the manufacturer). The shoot (SDM) and root dry matter (RDM) were obtained after drying the shoots and roots in a forced air circulation oven at 70 ºC, until reaching constant weight, and weighing them on a precision scale (0.001 g) (SHIMADZU®, model AY220). The total dry matter (TDM) was obtained by the sum of the SDM and RDM, with results expressed in g $plant^{-1}$.

From these measurements, the following seedling quality variables were determined: height/diameter ratio (H/D) and Dickson's quality index, obtained by the formula: DQI = [total dry matter/(H/D + SDM/RDM)].

The seedlings were considered as satisfactory when presenting the "standard" based on the commercialization of seedlings of the juçara palm (*Euterpe edulis*), which must present a height of 30-40 cm and stem diameter of 5 mm (Silva et al. 2015). In addition, this standard was also selected due to the fact that these characteristics are easy to measure and non-destructive.

The obtained data were submitted to tests for normality of residuals and homogeneity of variances and, when normal, to analysis of variance (Anova). When significant, polynomial regression analysis was performed at 1 % ($p < 0.01$), in which the significant equations with the highest coefficient of determination (R^2) were selected using the AgroEstat® statistical software, version 1.1.0.711 (Barbosa & Maldonado Junior 2015). The Pearson's correlation coefficient (r) ($p < 0.05$) was also calculated among the studied characteristics using the R® software, version 4.0.4 (R Core Team 2021). The graphs were drawn using the Excel® software, version 2019.

The maximum point of increase of each evaluated characteristic was calculated according to the vertex of the parabola of the quadratic equation, using the formula X = - b/2a.

RESULTS AND DISCUSSION

There was a significant effect of the different substrates on practically all the evaluated characteristics of the *Syagrus romanzoffiana* seedlings, with no significance being only observed for the height/diameter ratio ($p > 0.05$). It was possible to calculate the proportion of biosolid at which the maximum point of increase of each of the evaluated characteristics was reached.

The shoot height showed a quadratic trend, with a maximum increase obtained at the proportion of 62.17 % of biosolid in the substrate composition, presenting a decrease after this value (Figure 1A). It was also noted that treatments consisting of different proportions of biosolid stood out in comparison to the control treatment (subsoil). Silva et al. (2015) reported that, in many conventional nurseries, the seedling production is generally carried out using only subsoil as a substrate, whose low fertility and frequent high acidity may compromise the plant development, thus justifying the obtained results. A similar result was obtained by Berilli et al. (2018) in *Hyophorb lagenicaulis* seedlings and by Ferreira et al. (2021) in *Archontophoenix alexandrae* seedlings, in which the highest concentrations of biosolid (40 % for *Hyophorb lagenicaulis* and 80 and 100 % for *Archontophoenix alexandrae*) in the substrate composition with soil classified as a Dystrophic Red Latosol, similarly to this research, reduced the shoot height of seedlings. A result inferior to that of this paper was obtained with juçara palm seedlings produced in substrates with different proportions of biosolid and residues from the heart of palm agroindustry (peach palm peel) (Silva et al. 2015). This difference may be associated with factors such as the size of the container used, as, in the present study, the *Syagrus romanzoffiana* seedlings were produced in pots with volumetric capacity of 1.7 L, while *Euterpe edulis* seedlings were produced in 110 mL tubes. In addition, it may be associated with the fact that peach palm sheath is a light material, increasing the substrate porosity as the percentage of sheath in the substrate increases and reducing the water holding capacity, unlike subsoil, which is a denser material. However, in the present study, the physical and chemical characterizations of the substrate mixtures were not carried out, precluding a more accurate comparison between the results.

The stem diameter showed a quadratic trend (Figure 1B). The growth in diameter of the seedlings was positively influenced up to the maximum proportion of 63.70 % of biosolid. Stem diameter is one of the most observed characteristics when evaluating seedling quality in a nursery, as it indicates the ability of survival and, consequently, the establishment of seedlings in the field (Grossnickle & MacDonald 2018); however, there are no reference values in the literature regarding this characteristic for *Syagrus romanzoffiana* seedlings.

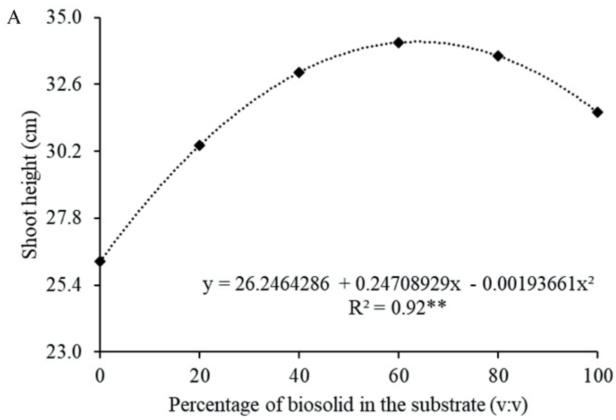
Based on the standard for seedlings of native forest species, whose minimum diameter value for seedlings to be considered adequate to be planted in the field is 3 mm (Davide et al. 2015), all treatments presented higher values in this study, ranging between 4.8 and 7.9 mm. Similar results were reported by Ferreira et al. (2021), when producing *Archontophoenix alexandrae* in a biosolid-based substrate associated with the commercial substrate Carolina Soil®, observing an increase in stem diameter as the biosolid concentrations increased, corroborating Silva et al. (2015), who reported that substrates that have high amounts of organic compounds in their composition positively influence the stem development in seedlings. In the substrate composition, the organic part is responsible for retaining moisture and providing nutrients, presenting the best results in seedling production, as it helps to maintain the physical, chemical and biological characteristics of the substrates (Cordeiro et al. 2020, Oliveira et al. 2020).

The regression for number of leaves showed a quadratic fit, with increases up to the concentration of 62.50 % of biosolid and the lowest average being obtained in the control treatment (Figure 1C). Thus, it can be said that the formulations used in this study significantly contributed to increase the number of leaves of the seedlings.

Regarding the leaf area (Figure 1D) and chlorophyll content (Figure 1E), the regression showed a quadratic trend for both characteristics, with increases up to the proportions of 59.92 and 67.34 % of biosolid, respectively. The leaf area is of great importance in the evaluation of seedling quality, since the amount of photoassimilates in the plant is generally proportional to its leaf area, and plants that present a high concentration of chlorophyll are potentially capable of reaching higher photosynthetic rates for their good capacity of capturing light energy per unit of time, consequently better adapting during the field planting phase (Cavalcante et al. 2016, Taiz et al. 2017). It is possible to observe that all the proportions of biosolid used influenced in a significant increase, in relation to the control treatment, for leaf area and chlorophyll content. Such results may be related to the nutritional richness present in the biosolid, especially a high nitrogen content, as shown in the literature (Conama 2006, Prates et al. 2011, Trigueiro & Guerrini 2014, Ferraz et al. 2016, Bortolini et al. 2017, Abreu et al. 2019, Siqueira et al. 2019, Souza et al. 2019, Djandja et al. 2020), whose availability can directly influence the photosynthetic capacity (Taiz et al. 2017).

The root length showed a non-significant result ($p < 0.01$) with increases in the percentage of biosolid in the substrate (Figure 2A). A similar result was reported by Ferreira et al. (2021), when producing *Archontophoenix alexandrae* seedlings in a biosolid-based substrate associated with the commercial substrate Carolina Soil®.

When the shoot dry matter was evaluated, the highest averages were obtained in treatments that



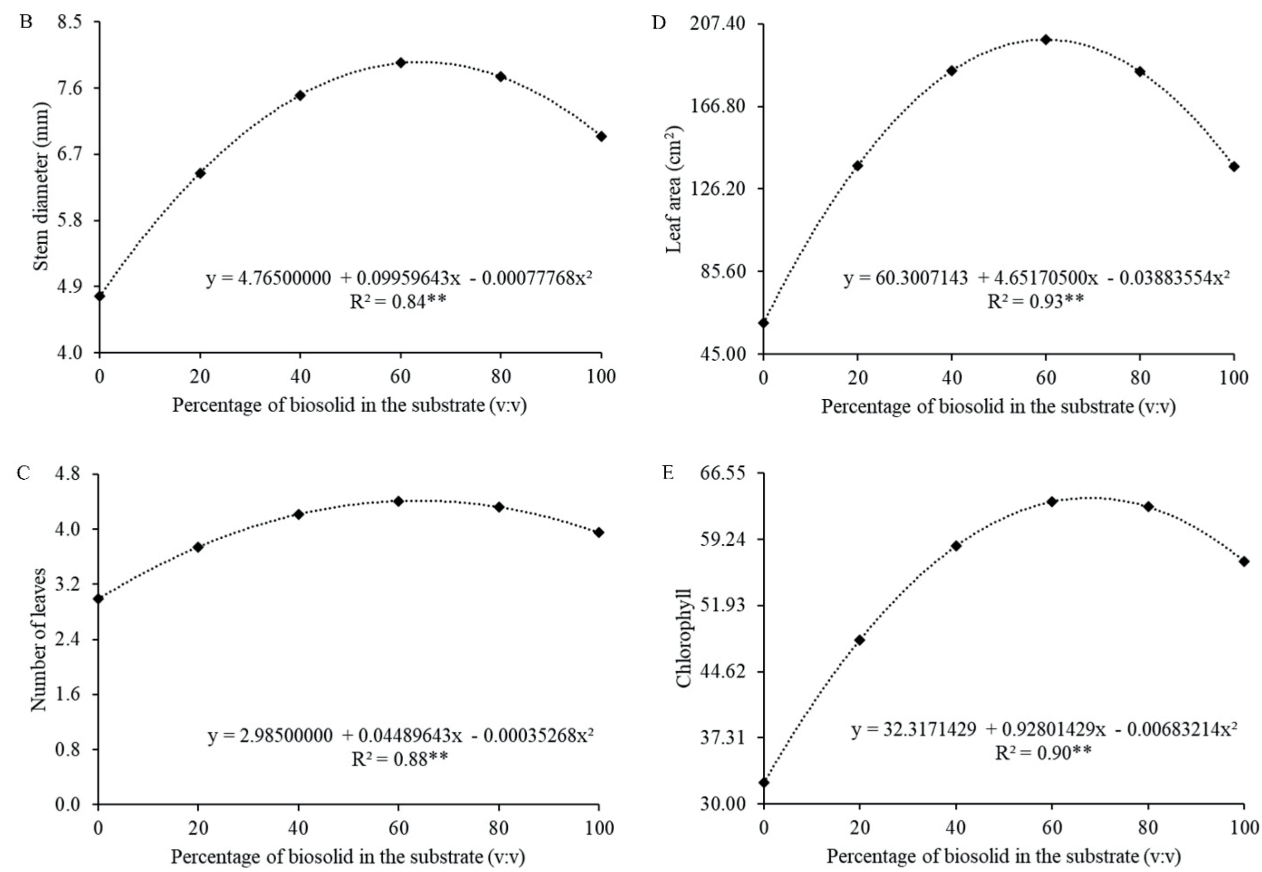
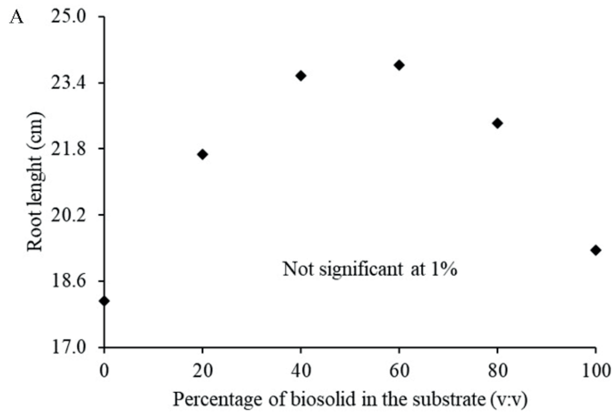


Figure 1. Shoot height (A), stem diameter (B), number of leaves (C), leaf area (D) and total chlorophyll content (E) of *Syagrus romanzoffiana* seedlings produced in substrates with different percentages of biosolid. ** Significant at 1 % of probability by the F test.

contained biosolid, with the maximum average being observed in the treatment with 50.34 % of biosolid (1.911 g plant^{-1}) (Figure 2B). For root dry matter, there was an increase up to the proportion of 46.57 %, which presented the highest average (2.209 g plant^{-1}), while lower and higher concentrations reduced the averages of this characteristic (Figure 2C). According to Afonso et al. (2012), roots with a greater amount of dry matter tend to have a greater number of root apices and are more efficient in the absorption and transport of water and nutrients, especially in the production of phytohormones. Regarding total dry matter, the increase occurred up to 49.30 % of biosolid (4.087 g plant^{-1}) (Figure 2D). High percentages of biosolid in the substrate tend to increase the dry biomass produced by seedlings in the nursery, as observed by Ferreira et al. (2021) when growing *Archontophoenix alexandrae* seedlings in a substrate formulated with different concentrations of biosolid and commercial substrate. The authors observed an increase in total dry biomass from the percentage of 20 % of biosolid.

In the evaluation of the Dickson's quality index (DQI) of the seedlings, there was an increase up the concentration of 51.38 % of biosolid, with an average value of 0.78 (Figure 2E). Substrates containing biosolid in their composition were



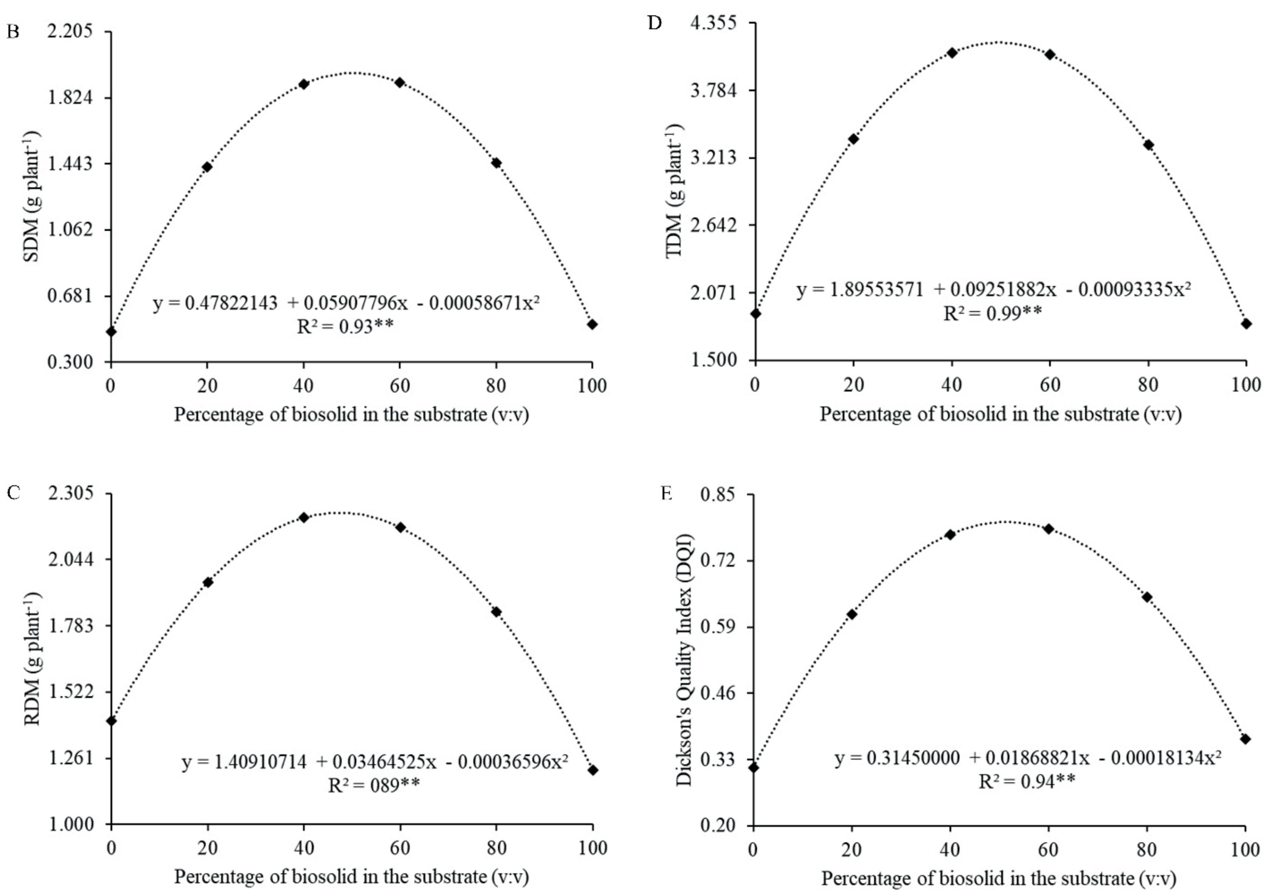


Figure 2. Root length (A), shoot dry matter (SDM; B), root dry matter (RDM; C), total dry mass (TDM; D) and Dickson's quality index (E) of *Syagrus romanzoffiana* seedlings produced on substrates with different percentages of biosolid. ** Significant at 1 % of probability by the F test.

superior when compared to the control treatment, showing that this compost was effective for the growth and quality of seedlings of this species, except when the substrate was formed only with biosolid, which presented a similar behavior to that of the control treatment. The DQI is considered as a good indicator of seedling quality for being a weighted morphological measurement that takes into consideration the robustness and balance of the dry biomass distribution of seedlings (Abreu et al. 2019). Araújo et al. (2020) suggested a minimum value of 0.2 for high-quality seedlings, which may vary according to the species, seedling age and treatment to which it was submitted. Thus, it is understood that seedlings produced in all substrates presented a good quality, especially in the treatments formulated with 40 and 60 % of biosolid, in which higher results were observed for this variable, probably being better adaptable when planted in the field, as higher values may theoretically indicate seedlings of better quality for a same species (Davide et al. 2015). However, more research is needed so that the DQI can be used reliably in seedlings of palm species of the *Syagrus* genus in general, given the lack of information in the literature. There is only one previous research by Beltrame (2018) with the *Syagrus schizophylla* species, who obtained DQI values for seedlings produced under different light gradients ranging from 4 to 10, which were higher than those of this study. It should be noted that the discrepancy between the obtained values may be associated with the evaluation period between the studies, since *Syagrus schizophylla* was evaluated at eight months after planting and *Syagrus romanzoffiana* at five months after planting.

For the production of seedlings of different species of palm trees in alternative substrates, especially with the use of residues of organic origin, different values are reported in the literature regarding the DQI, whose average values ranged from 0.12 to 2.24 (Silva et al. 2015, Araújo et al. 2020, Ferreira et al. 2021), reinforcing the comment made by Araújo et al. (2020), who reported that this value may vary according to the species, seedling age and treatment to which it was submitted.

According to the Pearson's correlation matrix (r), it was observed that significant positive correlations were found for practically all the analyzed variables, except for the height/diameter ratio, which was negatively correlated with all other characteristics, and root dry matter, which was only correlated with total dry matter and DQI (Figure 3). The highest correlation indices were observed for number of leaves and chlorophyll content (0.93) and total dry matter and DQI (0.90).

For the variable DQI, there was a negative correlation with the height/diameter ratio, thus allowing to infer that as one increases, the other decreases (Figure 3). There was also a significant positive correlation between the DQI and the other characteristics, with the highest indices observed for total dry matter (0.90), root dry matter (0.81), shoot dry matter (0.74) and stem diameter (0.75), making it possible to understand that these are the characteristics that most influenced the seedling quality for the species of the present study. It is also emphasized that no studies addressing the correlation between the growth characteristics of seedlings of palm species were found in the literature, especially when using the biosolid compound in the substrate composition. Therefore, these results serve as a basis for future research.

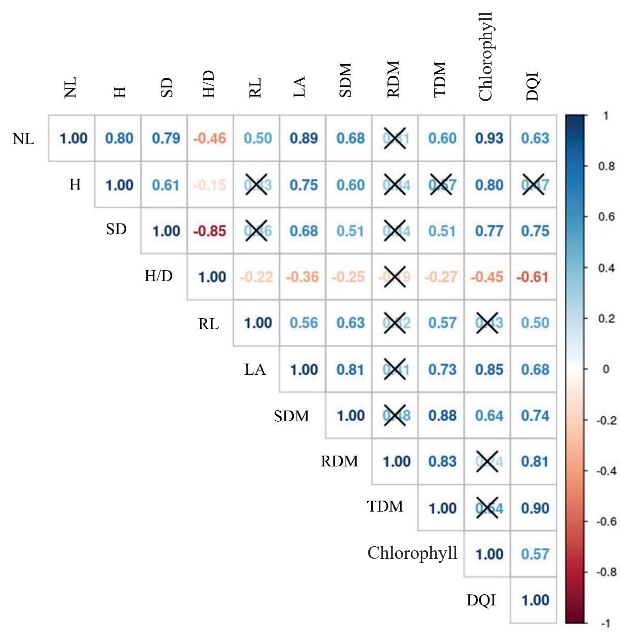


Figure 3. Pearson's correlation between the analyzed characteristics of *Syagrus romanzoffiana* seedlings produced in substrates with different percentages of biosolid. Significant at 5 % of probability. The X over the numbers indicates that there is no significant correlation among the variables. NL: number of leaves; H: shoot height; SD: stem diameter; H/D: height/diameter ratio; RL: root length; LA: leaf area; SDM: shoot dry matter; RDM: root dry matter; TDM: total dry matter; DQI: Dickson's quality index.

In general, the *Syagrus romanzoffiana* seedlings produced in substrates with different percentages of biosolid showed a satisfactory growth, being considered as adequate for use in the field, with excellent results also for the other morphological variables evaluated. Thus, the biosolid presented potential to be used in the formulation of substrates for the improvements obtained in the quality of the seedlings analyzed in this study, becoming a viable alternative to be used as a constituent of substrate in the production of seedlings of this species.

CONCLUSION

The use of biosolids with percentages ranging from 40 to 60 % in the substrate composition proved to be efficient, as they promoted a satisfactory initial growth (all seedlings presented shoot height of 30-40 cm and stem diameter of 5 mm) and quality of *Syagrus romanzoffiana* seedlings.

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