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Influence of organic substrates on growth and nutrient contents of jatobá (*Hymenaea stigonocarpa*)

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The use of native forests for the purpose of agricultural and livestock occupation have caused the degradation of native ecosystems of caatinga and cerrado. The negative impact of these activities can be minimized with the revegetation of degraded areas. With that comes the need to produce seedlings of native forest species of quality. The objective of this study was to evaluate how the addition of bagana of carnaúba, compost, and cattle manure to Quartzarenic Neosol soil affects the percentage and rate of emergence, growth, and macronutrient contents of *Hymenaea stigonocarpa* Mart (Jatobá) seedlings. The treatments consisted of the following proportions (v/v) of bagana of carnaúba, compost, and cattle manure to the soil: 0:100, 20:80, 40:60, 60:40, 80:20, and 100:0, being in a factorial (3:6), with 10 replications, and standard chemical fertilizers were used as the control. The addition of bagana of carnaúba increased height, ratio of height to diameter, aerial part dry weight, root dry weight, total dry weight, ratio of aerial part height to aerial part dry weight, and Dickson quality index of *H. stigonocarpa* seedlings, in the estimated proportion of 48:52 (bagana of carnaúba: soil), which is the most suitable substrate composition for the cultivation of this species. The substrate containing compost enabled a greater accumulation of N, P, and Ca in the shoots of the jatoba seedlings, due to increased availability of these nutrients in the substrate containing organic compost.

Key words: Bagana of carnauba, compost organic, cattle manure, macronutrients.

INTRODUCTION

The disorderly exploitation of native forests in Brazil for agriculture and livestock farming has caused disturbances in the ecosystems of Cerrado and Caatinga. To reduce the negative impact of these activities,

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introduction of strategies such as the recovery of degraded areas have been emphasized. In this context, the demand for seedlings of native tree species to restore the degraded areas has increased (Saidellis et al., 2009), mainly in the state of Piauí. Here, a significant increase in agricultural activities in Cerrado has been observed in recent years, with intensive substitution of native vegetation by cultivated crops, mainly *Glycine max* and *Zea mays*.

Obtaining quality seedlings for reforestation is essential for the recuperation of degraded areas. The development of seedlings is influenced by the substrate and several other materials that can be used alone or in combination. Traditionally, the subsoil is a widely used substrate in the region, because of the low technological level and socioeconomic status of farmers; however, it is deficient in nutrients and contains toxic levels of aluminum (Nóbrega et al., 2008). Hence, the use of substrates made from wastes of animal and/or plant origin has become an alternative for increasing the nutrient content; they also have the advantages of low cost and easy acquisition. Addition of organic matter sources contributes not only to the supply of nutrients but also to the physical characteristics of substrates, mainly to increase the water-holding capacity of soil (Caldeira et al., 2008).

Carvalho Filho et al. (2003) evaluated the production of seedlings of jatobá (*Hymenaea courbaril*) in different environments, containers, and substrate compositions, and they found that the best results were obtained using substrates containing soil, sand, and cattle manure in the ratio of 1:2:1. The authors affirm that adding cattle manure not only increases the supply of nutrients, but also improves soil fertility, aeration conditions, and water availability. Costa et al. (2005) combined vermiculite with bagana of carnaúba, a straw-like waste product generated by the extraction of wax from the film of powder that coats the leaves of the carnauba wax palm (*Copernicia cerifera* Miller). They found that substrates were formed with greater ease by the removal of soursop (*Annona muricata* L.) rootstock from the containers, probably because of the good capacity of aggregates obtained by the combination of bagana and vermiculite and the appropriate moisture retention of the components.

Hymenaea stigonocarpa Mart. ex. Hayne (Fabaceae-Caesalpinioideae), commonly known as the jatobá of Cerrado and found in the southwestern State of Piauí, Brazil, is an ornamental hermaphrodite tree that grows up to 10 m in height. The farinaceous pulp of the jatobá fruit is much sought after by many animal species that disperse the seeds, making the plant very useful for reforestation in degraded areas and restoration of arboreal vegetation (Lorenzi, 1998). To the best of our knowledge, there are no studies on the nutrition of this species when grown on organic substrates, although there are studies on the nutrient content of the foliage of native species grown on substrates containing organic compounds. Therefore, studies aimed at analyzing the seedling tissue could contribute significantly to the production system of this species.

The objective of this study was to evaluate how the addition of cattle manure, bagana of carnaúba, and organic compost to Quartzarenic Neosol soil affects the percentage and rate of emergence, growth, and macronutrient content of *H. stigonocarpa*.

MATERIALS AND METHODS

The experiment was conducted under greenhouse conditions by using a screen with 50% shade at the Universidade Federal do Piauí, Bom Jesus city, State of Piauí, Brazil (09°04′28″S and 44°21′ 31″W, with a mean altitude of 277 m).

For the composition of the substrates, we used three organic wastes—bagana of carnaúba (BC), which consists of compost produced from a mixture of tree pruning residues (mainly (fig (*Ficus* sp.), Acacia (*Acacia* sp)., *Licania tomentosa*, and *Cenostigma macrophyllum*); Cocos nucifera husk fiber (OC); and cattle manure (CM)—together with Quartzarenic Neosol soil samples sieved through a 2-mm mesh sieve with the following chemical and physical characteristics: pH (H_2O): 6.30; Soil organic matter: 6.0 g kg^{-1}; P (Mehlich): 5.10 mg dm^{-3}; K^+: 1.3 $mmol_c$ dm^{-3}; Ca^{2+}: 11.0 $mmol_c$ dm^{-3}; Mg^{2+}: 4.0 $mmol_c$ dm^{-3}; Al^{3+}: 1.0 $mmol_c$ dm^{-3}; H+Al: 18.0 $mmol_c$ dm^{-3}; Base sum: 16.3 $mmol_c$ dm^{-3}; Cation exchange capacity: 34.3 $mmol_c$ dm^{-3}; Base saturation: 48.0%; Al^{3+} saturation: 6.1%, B: 0.19 mg dm^{-3}, Cu^{2+}: 0.20 mg dm^{-3}; Fe^{2+}: 15.0 mg dm^{-3}:Mn^{2+}: 4.20 mg dm^{-3}; Zn^{2+}: 0.70 mg dm^{-3}; Sand: 92.9 dag kg^{-1}; Silt: 3.5 dag kg^{-1}; Clay 3.6: dag kg^{-1}; Bulk density: 1.45 g cm^{-3}; Particle density: 2.66 g cm^{-3} and Total porosity: 0.45.

Organic wastes were mixed with soil after drying in the sun, in proportions (v/v, waste:soil) such as 0:100; 20:80; 40:60; 60:40; 80:20, and 100:0. The experiment was conducted as factorial arranged in a completely randomized design with 10 replications. We also used an additional treatment consisting of the following composition: 700 L of subsurface soil corrected with 300 L of cattle manure, 5 kg of superphosphate, and 0.5 kg of potassium chloride (Carvalho et al., 1978).

Jatobá seeds were collected from different indigenous matrices located in the city of Bom Jesus. Before sowing, seeds were kept in sulfuric acid (95–97%) for 1 h (chemical scarification) to break dormancy, and they were washed for 10 min under running tap water (Dechoum, 2004). Three seeds each were seeded in perforated plastic bags with a capacity of 1 kg.

The emergence percentage (E%) was calculated according to Labouriau and Valadares (1976), the formula below is used, %E = (N/A) x 100; where: N is the total number of emerged seeds and A is the total number of seeds germinated. The emergence rate index (ERI) was calculated using the formula (Maguire, 1962), ERI = åNi/Di, wherein Ni is the number of germinated seeds, and Di is days after planting

After 108 days of seeding, the following parameters in the seedlings were evaluated: the height (SH) of a ruler, considering as standard yolk terminal (apical meristem), stem diameter (SD) measured with a precision caliper (± 0.05 cm), and the relationship between seedling height and stem diameter (SH/SD). Subsequently, the aerial part dry weight (ADW) and root dry weight (RDW), being evaluated 5 randomly selected seedlings from each treatment. Samples were dried at 60°C for 72 h by using a forced air circulation drier. ADW and RDW were added to obtain the total dry weight (TDW). The shoot samples were ground in a Willey TE-650 mill to determine the macronutrient content in the plants (Malavolta, 1997): (i) N, determined by the Kjeldahl method in which

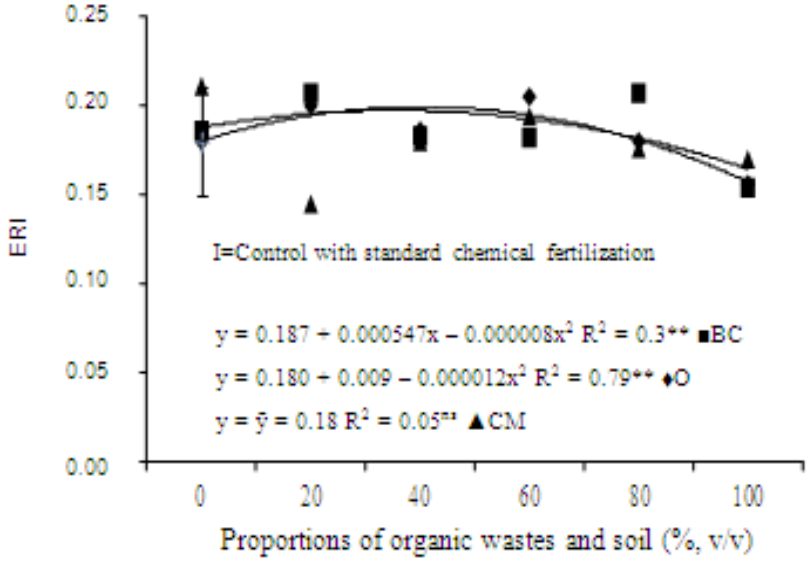


Figure 1. Emergence rate index (ERI) of seedlings of *Hymenaea stigonocarpa* Mart with different compositions of substrate (■ BC: bagana of carnaúba; ♦ O: compost; ▲ CM: cattle manure). I: standard error.

the extracts were prepared from solutions by digestion with sulfuric acid; (ii) P, determined by colorimetry; (iii) K, determined by flame emission photometry; (iv) Ca, determined by EDTA titration. The accumulation of each element in the shoots of seedlings was calculated as the product of dry weight and the content of nutrients. We calculated the relationships between seedling height and aerial part dry weight (SH / ADW) and aerial part dry weight and root dry weight (ADW / RDW). Dickson's quality index (DQI) was calculated using the following formula: DQI = TDW (g) / [SH (cm) / SD (mm) + ADW (g) / RDW (g)] (Dickson et al., 1960).

The results were subjected to analysis of variance Scott-Knott test mean 5% for the sources of organic waste that characterized the qualitative treatments and regression polynomial with respect to the proportions of bagana of carnaúba, cattle manure, and compost (quantitative treatments). The interaction between the sources of organic waste in the different proportions of bagana of carnaúba, cattle manure, and organic compost were determined. The statistical program SISVAR 4.2 was used to analyze the data (Ferreira, 2011).

RESULTS AND DISCUSSION

The addition of organic residues in different proportions of soil did not affect the E% of jatobá seedlings. On the basis of ERI, it was observed that there was an interaction between the sources of organic waste and the proportions of soil wherein the estimated highest was obtained in the organic compound at a ratio of 40:60 (organic compost: soil), with a quadratic response (Figure 1). The substrates composed of organic compounds probably have adequate hydric availability, thus providing the conditions necessary to maximize seed germination and subsequent seedling emergence. The effect of adding organic compost to jatobá seedlings was also observed by Santos et al. (2011) in their study, in which seedlings were grown in a greenhouse by using a commercially made 100% organic compost. They obtained an ERI of 0.89, which was equivalent to the substrates with a higher index. Araújo and Sobrinho (2011) evaluated the germination and seedling production of *Enterolobium contortisiliquum* on different substrates; they found better performance in the ERI of the substrate containing soil, cattle manure, and carbonized rice hull. According to the authors, the ERI may have been influenced by the materials that retain water in adequate quantity, thereby suggesting that the reference substrates promoting seedling emergence, probably due to the less physical impediment to emergence, may have also occurred in this study.

There was an interaction between the sources of organic waste and soil ratios for the following variables: SH, SD, SH/SD, ADW, RDW, TDW, SH/ADW, ADW/RDW, and DQI. The highest SH (31.04 cm plant^{-1}) was obtained for seedlings grown on substrates with bagana of carnaúba in the estimated proportion of 56:44 (bagana:soil), which was higher than the seedling grown with a standard fertilizer (24.2 cm·plant^{-1}). Seedlings grown in soil with compost showed an increasing linear effect, while those grown in soil with manure exhibited a decreasing linear effect (Figure 2a). Costa et al. (2005) also investigated the effect of bagana of carnaúba (50% bagana of carnaúba + 50% commercial vermiculite) on the SH of *A. muricata* seedlings and obtained a mean of 27.7 cm·plant^{-1}. This positive influence of bagana can be attributed to the greater availability of nutrients provided by it, which can be explained on the basis of the

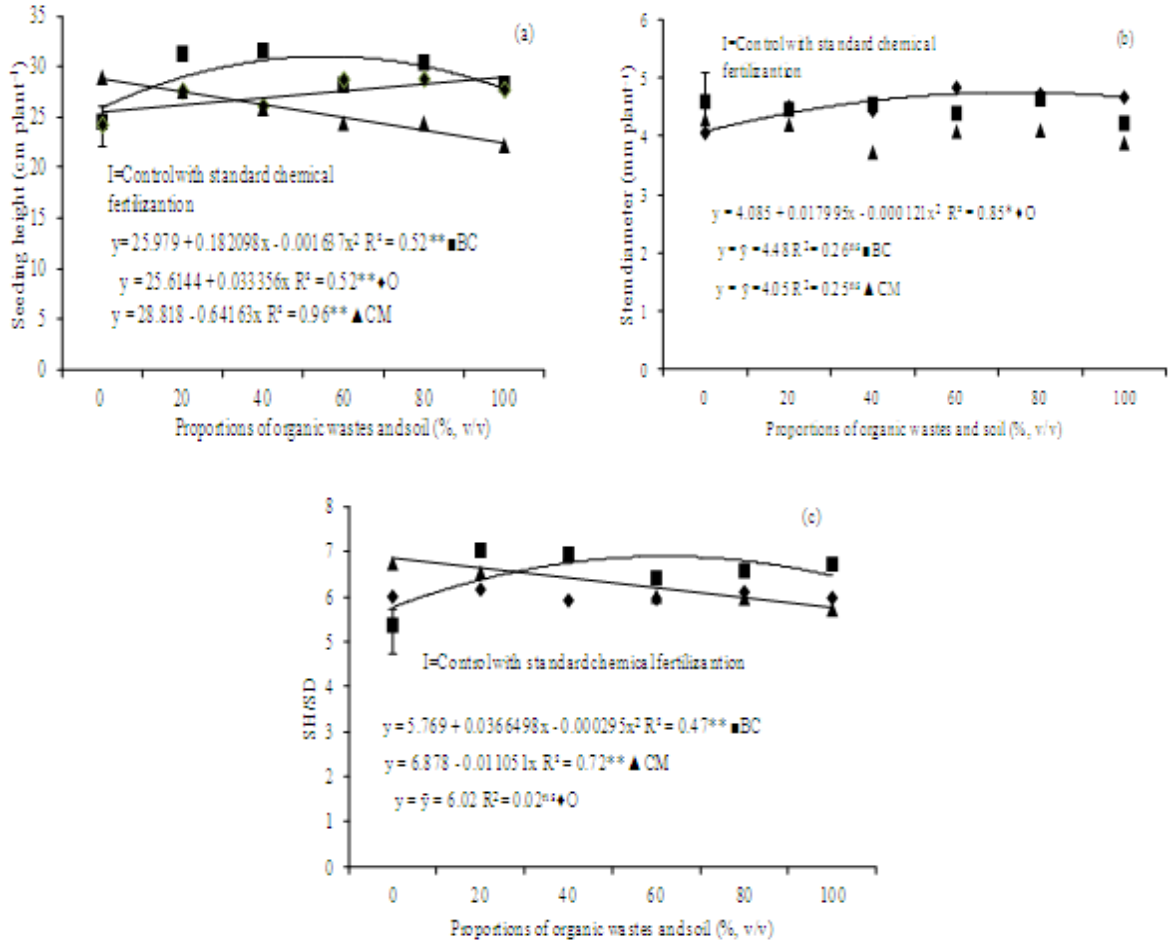


Figure 2. Seeding height (SH) - (a), stem diameter (SD) - (b) and relationship between seeding height and stem diameter (SH/SD) - (c) of seedlings of *Hymenaea stigonocarpa* Mart with different compositions of substrate (■ BC: bagana of carnaúba; ♦ O: compost; ▲ CM: cattle manure). I: standard error.

observation that seedlings grown on a substrate with a dose of 0:100 (bagana:soil) showed the lowest SH (24.56 cm·plant^{-1}).

However, the seedlings grown on a substrate containing organic compounds in the ratio 75:25 (compost:soil) showed the highest (4.75 mm·plant^{-1}) SD value. The seedlings grown with a standard fertilizer showed an SD (4.61 mm plant^{-1}) within the confidence interval, while those grown with substrates containing an increased proportion of bagana of carnaúba and cattle manure had no significant effects (Figure 2b). Santos et al. (2011) cultivated seedlings of the same species in a greenhouse using 70% commercial organic manure; they obtained an SD value higher than that observed in this study (5.90 mm), but measurements were taken 120 days after sowing. Carvalho Filho et al. (2003) found a better SD in the seedlings cultivated in substrate mixtures containing sand and manure, suggesting the requirement of the species by mixing lighter.

The highest mean SH/SD ratio (6.89) was obtained for the seedlings grown with the estimated proportion of 62:38 (bagana:soil), which was also higher than the seedlings grown with a standard fertilizer (5.26 plant^{-1}). This ratio was within the limit (the highest ratio of 10) obtained by Birchler et al. (1998). Seedlings grown in substrates containing organic compounds had no significant effects, while those grown in substrates containing manure showed a decreasing linear effect (Figure 2c). According to Silva et al. (2007), this is an important feature for the successful adaptation of plants in the fields, because the lower the ratio, the more the plants are resistant to environmental conditions because of the greater balance between the aboveground biomass and roots.

Biomass, ADW, RDW, and TDW showed a quadratic effect with respect to the proportions of bagana and compost, while the seedlings grown with manure showed a negative linear effect (Figure 3a-c). The ADW production was 4.11 and 3.94 g·plant^{-1} for the estimated proportions of 49:51 (bagana:soil) and 53:47 (organic

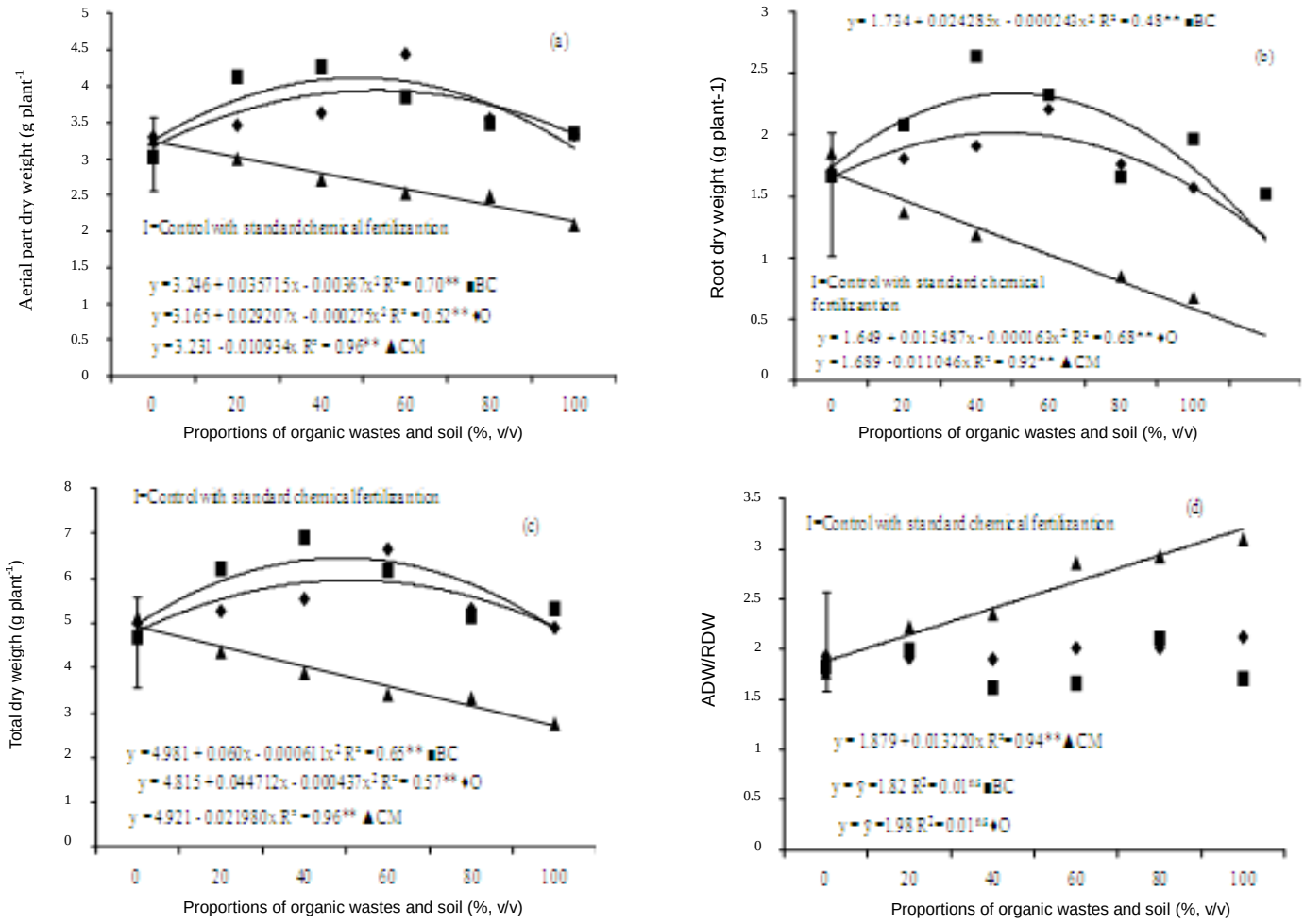


Figure 3. Aerial part dry weight (ADW) - (a), root dry weight (RDW) - (b), total dry weigth (TDW) - (c) and relationship between the aerial part dry weight and the root dry weight (ADW/RDW) - (d) of seedlings of *Hymenaea stigonocarpa* Mart with different compositions of substrate (■ BC: bagana of carnaúba; ♦ O: compost; ▲ CM: cattle manure). I: standard error.

compost:soil), respectively. These values were higher than those for the seedlings grown with a standard fertilizer (3.26 g·plant^{-1}) (Figure 3a). Costa et al. (2005) also indicated an increase in this variable in 25% of *A. muricata* seedlings with the addition of bagana, obtaining a highest yield (3.79 g·plant^{-1}) after 140 days of sowing. Arthur et al. (2007) evaluated the effect of cattle manure on the seedling formation of *Calophyllum brasiliense* Cambess; they found a reduction in this variable with an increase in the proportion of manure. According to them, manure is an important component of the substrate because it increases the organic matter content and cation exchange capacity of the substrate, and therefore, its use cannot be discontinued (although the dose can be adjusted).

The highest yields of RDW (2.34 and 2.04 g·plant^{-1}) were obtained in the substrates with the proportions of 50:50 (bagana:soil) and 48:52 (organic compost:soil), respectively, while the RDW yield of superior seedlings grown with a standard fertilizer was 1.52 g·plant^{-1} (Figure 3b). Costa et al. (2005) described the effect of bagana of carnaúba on this variable in their study on the seedlings of *A. muricata* using 33% bagana. The increase in RDW on basis of the doses of bagana and organic compost can be attributed not only to the improved chemical properties but also to the physical properties that probably allowed better root development.

The highest values of TDW (6.45 and 5.95 g·plant^{-1}) were obtained in the substrates with the estimated proportions of 49:51 (bagana:soil) and 51:49 (organic compost:soil), respectively, while the seedlings grown with a standard fertilizer yielded 4.59 g·plant^{-1} (Figure 3c). The substrates containing bagana of carnaúba significantly influence TDW, as well as SH, and SH/SD (Figure 2a and c), ADW, and RDW (Figure 2a and b, respectively). The estimated dose of 49:51 (bagana:soil) promoted an increase in TDW (29.31%) compared to the dose of 0:100 (bagana:soil). The decreasing trend in the

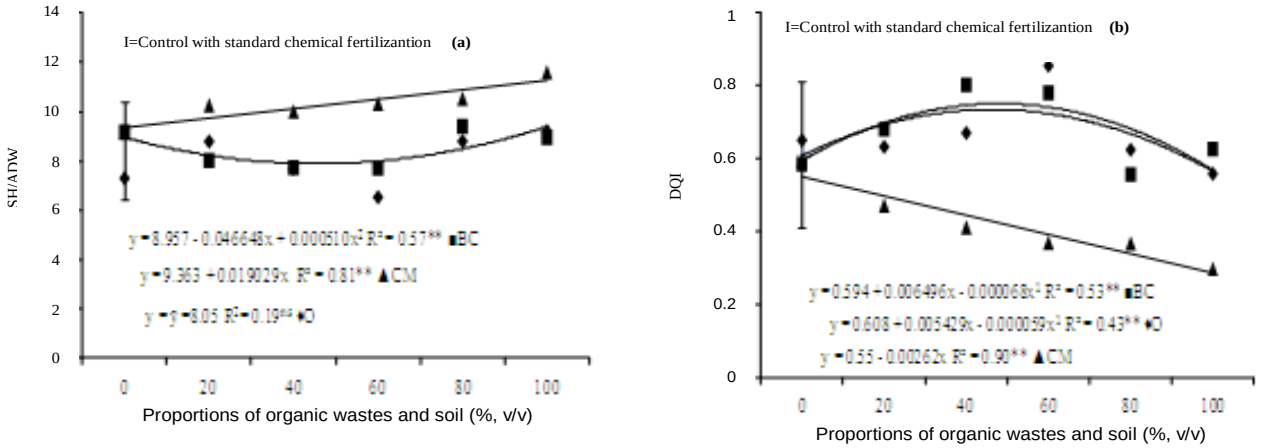


Figure 4. Relationship between seedlings height and aerial part dry weight (SH/ADW) - (a) and e Dickson quality index (DQI) - (b) of seedlings of *Hymenaea stigonocarpa* Mart with different compositions of substrate (■ BC: bagana of carnaúba; ♦ O: compost; ▲ CM: cattle manure). I: standard error.

function of different doses of manure on TDW was also confirmed by Arthur et al. (2007), who obtained the highest yield (17.13 g·plant^{-1}) in the absence of manure in the seedlings of *C. brasiliense*. Since mineralization of the manure added to the soil may probably not be adequate, the organic acids derived from decomposition might have caused a detrimental effect on the seedling biomass production.

The ADW/RDW relationship was influenced by the addition of cattle manure, which increased linearly. Seedlings cultivated in the ratio of 100:0 (manure: soil) showed a higher mean value (3.09 plant^{-1}) than the seedlings grown with a standard fertilizer (2.08 plant^{-1}). The seedlings cultivated with organic compost and bagana showed no significant effects (Figure 3d). Caldeira et al. (2008) found the ADW/RDW relationship in seedlings to be 2:1. According to these authors, it is important to analyze this relationship when the seedlings are in the field, because SH should be lower than the root length, as a function of possible problems regarding water uptake to the shoot. In this study, only the previously cited dose was higher than this ratio, with the others being below 3:1.

SH/ADW showed a quadratic effect in relation to the proportion of bagana and soil, with the lower mean (7.89) for the seedlings cultivated in the estimated proportion of 46:54 (bagana:soil). The substrates containing compost showed no significant effects in the SH/ADW relationship, while those containing manure showed a linear increase in SH/ADW values with the highest mean (9.24), compared to the seedlings grown with a standard fertilizer (8.42) (Figure 4a). Gomes et al. (2002) assessed the morphological parameters of the seedlings of *Eucalyptus grandis* and found that the SH/ADW ratio showed the greatest relative contribution, indicating its importance despite taking into account a destructive parameter, the weight of dry matter. In this study, all mean values were higher than the mean recommended by Brissete and Barnett (1991), which is too independent of the species.

DQI showed a quadratic effect in relation to the dose of bagana of carnaúba and organic compost, with the highest values (0.75 and 0.73) obtained in the seedlings cultivated in the estimated proportions of 46:54 (bagana:soil) and 48:52 (organic material: soil), respectively, compared to the seedlings cultivated with a standard fertilizer (0.61). With the increase in the proportion of manure in the substrate, a linear decreasing effect was observed in DQI (Figure 4b).

Seedlings cultivated with bagana showed higher values of DQI and also exhibited higher levels of SH, SH/SD, ADW, RDW, and TDW. According to Bernardino et al. (2005), the higher these values, the better the quality of the seedlings. The decrease in SH, SH/SD, ADW, RDW, TDW, and DQI in the seedlings of *H. stigonocarpa* with the addition of cattle manure to the substrate contradicts the observations found in other forest species. This may have occurred because the manure may not have fully decomposed, and consequently the nutrients may not have been readily available to the seedlings, because of the presence of organic acids present in plant materials that comprise the organic compost.

Several authors recommend the DQI as an index to determine the quality of seedlings (Fonseca et al., 2002; Nóbrega et al., 2008; Costa et al., 2011). In this study, we observed that a higher DQI (0.75) was obtained for the estimated dose of 48:52 (bagana:soil), which is the most recommended dose for the production of seedlings of *H. stigonocarpa*.

The addition of organic compost, mainly bagana, promoted an increase in the growth variables in relation to the dose of 0:100 (organic waste: soil). This can be observed with the increments of 27.12 and 12.3% in the estimated proportions of DQI 48:52 (bagana:soil) and

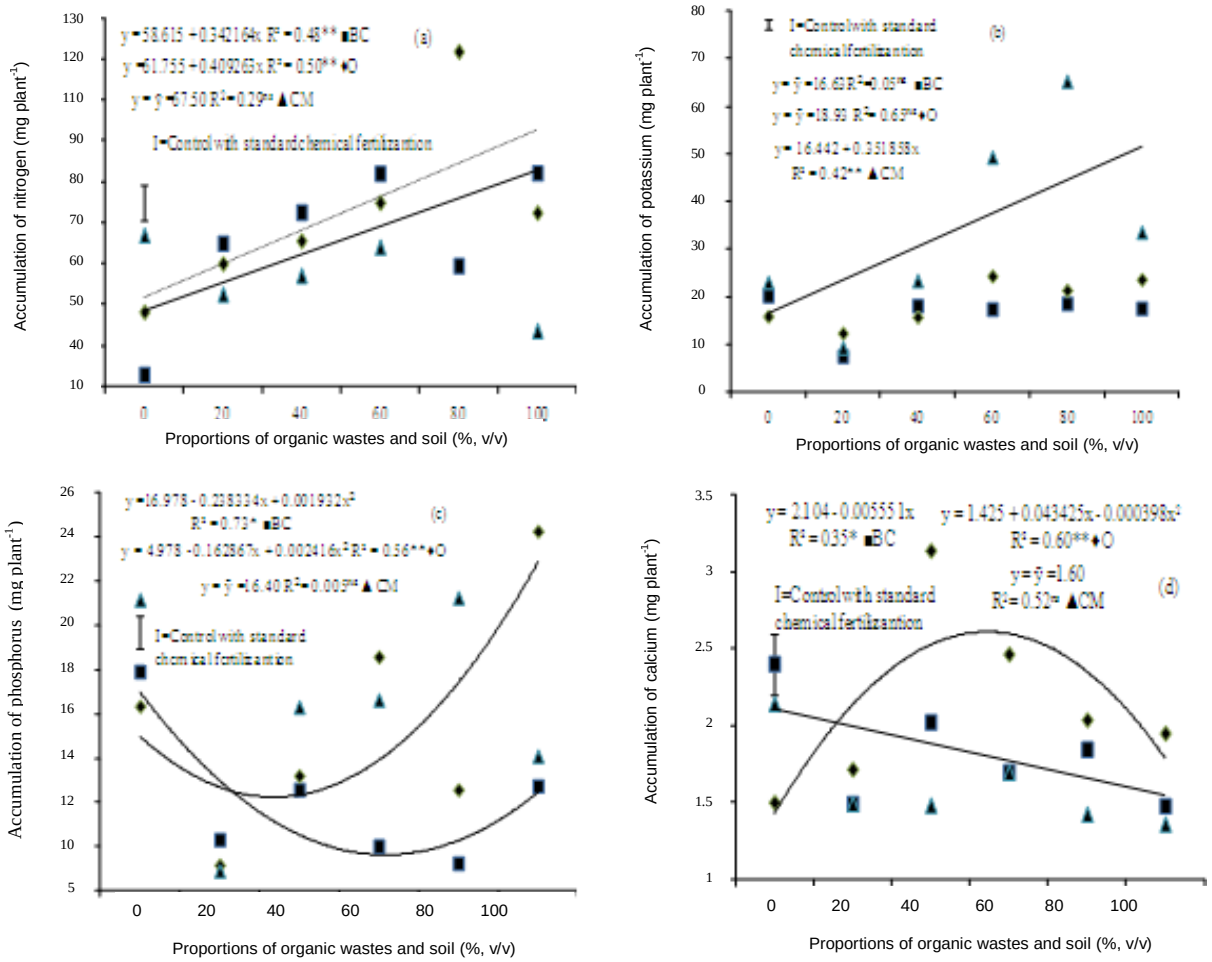


Figure 5. Accumulation of nitrogen (N) - (a), potassium (K) (b), phosphorus (P) - (c) e calcium (Ca) - (d) in aerial part dry weight of seedlings of *Hymenaea stigonocarpa* Mart with different compositions of substrate (■ BC: bagana of carnaúba; ♦ O: compost; ▲ CM: cattle manure). I: standard error.

46:54 (organic compost: soil), respectively, indicating that *H. stigonocarpa* is responsive to the nutrients added to the soil. The response of *H. stigonocarpa* to the addition of organic residues to the soil was also observed by Costa et al. (2011); they observed that the seedlings grown in a greenhouse substrate with coconut fiber had a greater DQI.

There was an interaction between the sources of organic waste and soil ratios caused by the accumulation of N, K, P, and Ca in the ADW of seedlings, excluding Mg. The accumulation of N in the ADW of seedlings was influenced by the quantity of organic compost and bagana of carnaúba added to the substrate, which showed an increasing linear effect. Seedlings cultivated in the ratio of 100:0 (organic compost: soil) showed a higher mean (102.68 mg·plant^{-1}), compared to the seedlings cultivated with a standard fertilizer (84.84 mg·plant^{-1}). The seedlings cultivated with cattle manure showed no significant effects (Figure 5a). The addition of organic compost increased the accumulation of N in the ADW with respect to the dose of 0:100 (organic compost: soil). This can be observed in the increase (66.27%) in N content at a dose of 100:0 (organic compost:soil). Souza et al. (2005) evaluated the effect of different substrates on the production of ipê amarelo [*Tabebuia serratifolia* (Vahl.) Nich.] seedlings for 270 days and found that, compared to the level of N in the shoots of seedlings cultivated in the substrate subsoil, the level of N was higher in those cultivated in the substrate containing organic compost (plant remains, 70%; cattle manure, 25%; and chicken manure, 5%).

The accumulation of K in the ADW of seedlings increased linearly when cattle manure doses were added to the substrate, with the highest mean (51.63 mg plant^{-1}) obtained in the ratio of 100:0 (manure:soil). The seedlings grown using a standard fertilizer showed greater accumulation of K (77.31 mg·plant^{-1}), while those grown in substrates with a higher dose of bagana and organic compost showed no significant effects (Figure 5b). Severino et al. (2008) evaluated the macronutrient

content in castor seedlings cultivated in five organic substrates and found that seedlings grown in substrates containing cattle manure showed the highest levels of K. According to Duboc et al. (1996), among the macronutrients, K is the least required element by jatobá.

The accumulation of P in the ADW of seedlings showed a quadratic effect in relation to the levels of organic compost and bagana, with the highest accumulation (12.23 and 9.63 mg·plant^{-1}) in the estimated proportions of 34:66 (bagana:soil) and 62:38 (organic waste:soil); however, seedlings grown with fertilizers were inferior (19.7 mg·plant^{-1}). The substrates with increased manure content showed no significant effects (Figure 5c). Trindade et al. (2001) evaluated the nutrition of *E. grandis* seedlings in response to organic compost; they reported that P uptake was always a function of increasing doses of compost-based manure and straw grass, with the largest increase occurring between doses of 0 and 5%. According to these authors, P is a very important nutrient for plant growth even in low doses; however, the availability of this nutrient is limited in the soil under natural conditions and needs to be supplied externally.

The accumulation of Ca in the seedlings cultivated with substrates containing organic compost showed a higher mean (2.61 mg·plant^{-1}) in the estimated proportion of 54:46 (organic compost:soil), which was within the confidence interval of seedlings grown with a standard fertilizer (2.4 mg·plant^{-1}). Seedlings grown in substrates containing bagana of carnaúba showed a decreasing linear effect, while those containing cattle manure showed no significant effects (Figure 5d). Trindade et al. (2001) conducted nutrition studies on *E. grandis* seedlings in response to organic compost, and they reported that the absorption of Ca was always a function of increasing doses of compost-based manure and straw grass, with the largest increase occurring between doses of 0 and 5%. Duboc et al. (1996) evaluated the nutrition of jatobá and observed that the Ca content in ADW of the treatment without Ca did not differ from the Ca content in the treatment with Ca; this suggests that jatobá has a high capacity to extract calcium from the substrate, even under limited availability or low physiological requirement for this nutrient.

Conclusions

The addition of bagana of carnaúba, organic compost, and cattle manure in soil samples did not influence the emergence of *H. stigonocarpa* seedlings. The estimated proportion of 40:60 (organic compost:soil) allows a greater speed of emergence of seedlings. The addition of bagana of carnaúba promotes increase in height, ratio of height by diameter, aerial part dry weight, root dry weight, total dry weight, ratio of aerial part height by aerial part dry weight, and the Dickson quality index of *H. stigonocarpa* seedlings, in the estimated proportion of 48:52 (bagana of carnaúba:soil), which is the most suitable substrate composition for the cultivation of this species. Seedlings cultivated with 100% cattle manure had higher K accumulation in the shoots. The substrate containing organic compost enabled a greater increase in the accumulation of N, P, and Ca in the shoots of jatobá seedlings, possibly because of the greater availability of these nutrients.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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