PRODUCTIVITY OF AÇAI EUTERPE PRECATORIA AND PRODUCTION SYSTEM MANAGEMENT RECOMMENDATIONS IN THE SOUTH OF THE AMAZONAS

Gisely da Silva Melo¹  
Francimara Souza da Costa²  
Luiz Carlos da Silva³

ABSTRACT

Objective: To investigate the productivity of the Amazon açaí Euterpe precatoria Mart in order to support recommendations for adapting management to increase productivity in the production system in southern Amazonas.

Theoretical Framework: The demand for açaí justifies its domestication to increase productivity in addition to extractive production. In this context, difficulties arise due to the lack of knowledge about managing the species, which is required along with its domestication. Thus, knowledge that supports the supply of soil and nutritional conditions is required for E. precatoria, which is still little studied in terms of management.

Method: The productivity assessment was carried out in an experiment whose ages of açaí groves planted side by side, 8, 9, 10 and 12 years old, constituted treatments. For each açaí grove age, randomized by the producer in the planning, 4 experimental plots were designed containing 3 trees spaced 3.0 m x 3.0 m, with 4 replications, totaling 16 experimental plots in randomized blocks.

Results and Discussion: The results indicate the need to manage soil fertility to increase the productivity of açaí groves, which are obtained in conditions of low soil fertility, even for the 12-year-old açaí grove, selected as the most productive.

Research Implications: This study presents practical and theoretical implications for the açaí palm in Amazonas, whose management is still in its infancy. It identifies low productivity of açaí groves and the need to insert nutrients not only through alternative practices with low economic and environmental impact.

Originality/Value: This study contributes to the basis of future studies on the agricultural management of the Amazon açaí tree as a cultivable species.

Keywords: Amazon, Family Farming, Extractivism, Technical-Scientific Indicators.

PRODUTIVIDADE DO AÇAÍ EUTERPE PRECATORIA E RECOMENDAÇÕES DE MANEJO DO SISTEMA DE PRODUÇÃO NO SUL DO AMAZONAS

RESUMO

Objetivo: Investigar a produtividade do açaizeiro Euterpe precatoria Mart a fim de embasar recomendações de adequação do manejo para aumento da produtividade no sistema de produção do sul do Amazonas.

¹ Universidade Federal do Amazonas (IEAA), Humaitá, Amazonas, Brazil. E-mail: giselyvidam@gmail.com  
Orcid: https://orcid.org/0000-0002-1824-4201

² Universidade Federal do Amazonas (FCA), Manaus, Amazonas, Brazil. E-mail: francimara@ufam.edu.br  
Orcid: https://orcid.org/0000-0003-4352-0826

³ Universidade Federal do Amazonas (FCA), Manaus, Amazonas, Brazil. E-mail: luiz_silva@ufam.edu.br  
Orcid: https://orcid.org/0000-0002-4604-9358
Referencial Teórico: A demanda pelo açaí justifica sua domesticação para aumento da produtividade em complemento à produção extrativista. Nesse contexto, as dificuldades emergem pela falta de conhecimento sobre o manejo da espécie, demandado juntamente com sua domesticação. Assim, conhecimentos que embasam o suprimento das condições edafológicas e nutricionais são demandados para o E. precatoria, que ainda é pouco estudado em termos de manejo.

Método: A avaliação da produtividade foi feita num experimento cujas idades de açaizais plantados, lado a lado, de 8, 9, 10 e 12 anos, constituíram os tratamentos. Para cada idade de açaizal, aleatorizada pelo produtor no plantio, foram delineadas 4 parcelas experimentais contendo 3 árvores, em espaçamento 3,0 m x 3,0 m, com 4 repetições, totalizando 16 parcelas experimentais em blocos casualizados.

Resultados e Discussão: Os resultados indicam a necessidade de manejo da fertilidade do solo para aumento das produtividades dos açaizais, que são obtidas em condições de baixa fertilidade, mesmo para o açaizal com 12 anos, verificado ser o mais produtivo.

Implicações da Pesquisa: Este estudo apresenta implicações práticas e teóricas sobre o açaiaqueiro do Amazonas, cujo manejo ainda está incipiente. Nele identifica-se baixa produtividade dos açaizais, em espacamento 3,0 m x 3,0 m, com 4 repetições, totalizando 16 parcelas experimentais em blocos casualizados.

Originalidade/Valor: Este estudo apresenta informações sobre a espécie de açaizeiro do Amazonas, com poucos estudos realizados, e contribui com o embasamento de trabalhos sobre o manejo cultivado dessa espécie.


PRODUCTIVIDAD DO AÇAÍ EUTERPE PRECATORIA Y RECOMENDACIONES PARA LA GESTIÓN DEL SISTEMA DE PRODUCCIÓN EN EL SUR DEL DE AMAZONAS

RESUMEN

Objetivo: Investigar la productividad del árbol de açaí Euterpe precatoria Mart con el fin de sustentar recomendaciones de adaptación del manejo para aumentar la productividad en el sistema de producción en el sur de Amazonas.

Marco Teórico: La demanda de açaí justifica su domestación para aumentar la productividad más allá de la producción extractiva. En este contexto, surgen dificultades por el desconocimiento sobre el manejo de la especie, necesario junto con su domestación. Por lo tanto, se necesita conocimiento para apoyar la provisión de suelos y condiciones nutricionales para E. precatoria, que aún está poco estudiada en términos de manejo.

Método: La evaluación de la productividad se realizó en un experimento cuyas edades de huertos de açaí plantados uno al lado del otro, 8, 9, 10 y 12 años, constituírion tratamientos. Para cada edad de bosquete de açaí, aleatorizada por el productor en la planificación, se diseñaron 4 parcelas experimentales con 3 árboles espaciados 3,0 m x 3,0 m, con 4 repeticiones, totalizando 16 parcelas experimentales en bloques al azar.

Resultados y Discusión: Los resultados indican la necesidad de gestionar la fertilidad del suelo para aumentar la productividad de los huertos de açaí, que se obtienen en condiciones de baja fertilidad del suelo, incluso para el huerto de açaí de 12 años, seleccionado como el más productivo.

Implicaciones de la Investigación: Este estudio presenta implicaciones prácticas y teóricas para la palma de açaí en Amazonas, cuyo manejo aún está en su infancia. Identifica la baja productividad de los huertos de açaí y la necesidad de inserir nutrientes no sólo a través de prácticas alternativas de bajo impacto económico y ambiental.

Originalidad/Valor: Este estudio contribuye a la base de futuros estudios sobre el manejo agrícola del árbol de açaí amazónico como especie cultivable.

Palabras clave: Amazonía, Agricultura Familiar, Extractivismo, Indicadores Técnico-Científicos.

RGSA adopts Creative Commons CC BY Attribution Licence (https://creativecommons.org/licenses/by/4.0/).
1 INTRODUCTION

It has been observed recently the growth of importance and commercial space for the Amazon assaizeiro (Euterpe precatoria Mart), in the national and international markets (Melo et al., 2021; Martinot et al., 2013). Its fruit is a traditional food in the Amazon and its commercialisation increases income to the family producer, with economic, social and environmental importance (Costa; Melo; Silva, 2023), arousing the interest of small producers.

However, the production of assai in the Amazon is seasonal, predominantly done in extractive moulds (Lopes et al., 2022; Cartaxo et al., 2020; Amazonas, 2005). For this reason, there are gaps in the techniques of managing the soil and the nutrition of the plants, for an increase in productivity, in the face of the demands for the fruit. The lack of productivity indicators and technologies applicable to the species has limited the use of sustainable techniques for conducting the crops, either due to lack of knowledge or lack of resources for investment in the productive process.

This context of a lack of scientific information about productivity and management of the species has stimulated the development of this study, which started from the following questions: i) how does the productivity of the açai behavior? ii) what are the recommendations for the adequacy of the management of the açai for an increase in productivity and sustainability of production? Therefore, the objective was to investigate the productivity of the Amazon basin (Euterpe precatoria Mart), in order to base recommendations of adequacy of handling for increased productivity in the production system in the southern region of the state of Amazonas.

2 THEORETICAL FRAME

According to Homma (2012), from the emergence of demand for assai by non-regional markets began the planting and domestication of the Amazon assaizeiro (E. precatoria Mart). Thus, an increase in the planted area was encouraged as a complement to the production obtained through extraction (Bents et al., 2017). However, the domestication of this species to plantations in small areas, in a consortium with other species, represents a strategy of increasing production without necessarily completely replacing extractivism (Martinot et al., 2013). This change generated the demand for basic knowledge for the generation of crop technologies, in order to associate it with extractivism and to enrich the natural environments and agroenvironments.
Farmers in the southern part of the state of Amazonas, based on the knowledge transmitted between generations of the families, have been cultivating the Amazon basin in low environmental impact systems (Costa et al., 2023), which are similar to agroforestry systems (SAF), considered more sustainable in relation to conventional production systems. These production systems are formed by germplasms of native plants (Homma, 2006), and contribute to the maintenance of local biodiversity (Konagano, 2011). On the other hand, farmers face difficulties in relation to access to technical assistance and lack of knowledge about adequate ways of managing the species, which make it possible for them to obtain satisfactory agronomic productivity, within their technical and economic conditions of production.

For Homma (2006), mixed production systems, such as STLs and the like, cause lower environmental impacts, reduce harmful changes to the soil, deforestation and burning. From the economic point of view, these systems make it possible to make more products and services available in the cultivated area unit and guarantee the food security of the families, generating and/or increasing income by marketing the surplus produced.

In this context, knowledge that underpins the supply of soil conditions (physical, chemical and biological) and nutritional conditions for satisfactory development, growth and productivity is done by the proper management of soil fertility and nutrition of cultivated species (Fernandes, 2018; Gonçalves, 2015), improving the sustainability indicators of agro-ecosystems. Such basic foundations are exceptionally applicable to those plant species that are still being domesticated, such as E. precatoria, which is still little studied in terms of species management.

3 METHODOLOGY

An experiment was installed on a property of the Alto Crato Community, municipality of Humaitá, south of Amazonas (07º 28' 11,16" S 63º 02' 14,41" W), with predominantly soft-wavy relief.

The climate of the region is tropical rainy, with small dry season in the months of June, July and August (Vidotto et al., 2007). The maximum rainfall is 2,500 mm in summer, between the months of October and March, and the average temperature is 25°C. The soil of the experimental area is a Plintosolo, of medium texture (Santos et al., 2018), containing 250.0 g kg⁻¹ of clay, 595.0 g kg⁻¹ of silt and 155.0 g kg⁻¹ of sand. The mean soil density, determined for 12 simple trench soil samples in the experimental area, was 1.34 g cm⁻³ (Embrapa, 2017).
The characteristic vegetation of the area is undergrowth, but in small areas primary forest occurs. In the area of the açaizais, at least 10 different fruit and forest species with different ages occur in a dispersed manner, planted over the years. This conformation gives the E. precatoria production system characteristics similar to those of agroforestry systems (SAF).

The total area of the experiment was 4.0 ha, delimited with the use of GPS (Marca Garmin GPSMAP 78s, Brazil). The ages of the açaizais were 8, 9, 10 and 12 years, planted in the east-west direction, and were considered treatments. Four experimental blocks were delineated in a north-south direction, each block consisting of four (4) ages of assaizal, subdivided into individual experimental parcels, containing 3 trees, with an average spacing of 3.0 m x 3.0 m, with extreme spacing of 2.0 to 4.0 m between trees, selected by random walking. Thus, 4 treatments (ages) were constituted with 4 repetitions, totalling 16 experimental plots, in design in casualised blocks. The assaizal at the age of 8 years was taken as control.

The experimental blocks were randomised considering the randomised planting procedure done by the producer (non-planning). In order to confer a greater probabilistic nature on the data collected in the experimental plots, the order and location of the blocks were chosen. The açaizais were located and distinguished among themselves due to the presence of diverse fruit trees, located among the assaizeiros in each year of planting and that divide the 4 açaizais.

The productivity of the springs was represented by the components: number of traces per bunch (NR C-1), number of fruits per trache (NF R-1), number of fruits per bunch (NF C-1), number of fruits per tree (NF A-1), mass of fruit with stone per bunch (MF C-1) and mass of fruit with stone per tree (MF A-1). These quantifications were carried out in the annual harvest period from November to March 2020. To do so, all the bunches with the fruit of the assailant were picked at intervals of 5 to 7 days from each experimental parcel, by hand cutting with a machete and with the help of peconha, as they reached the point of ripening. The soil around the trees was covered with a canvas at the time of cutting the bunches, in order to avoid losses of fruit on the descent of the bunch. The transport of the collected bunches was done with a wheelbarrow to the area covered in the property, reserved for collecting quantitative data.

Data from NR C-1, NF R-1, NF C-1, NF A-1 were quantified by simple accounting, with later tabulation in Excel spreadsheet, at each collection step. The MF C-1, in kg bunch-1, was made at each stage of collection by weighing the fruits with common balance (Balances de Prato, Marca Cauduro, Brazil). In order to quantify the mass of stone fruit per tree (MF A-1), the masses, in kg, of the bunches belonging to the 3 trees of each experimental plot were added, generating an average value.
For chemical fertility analyses, a representative soil sample from each plot was prepared from three simple samples, collected at a depth of 0.20 m in a radius of 1.0 m in the projection of the crown of the trees, with the aid of a Dutch tow. A mass of 600 g of each soil sample was air dried and packed for the following soil fertility analyses (Silva, 2009): (i) soil acidity attributes (active acidity = pH CaCl2 0.01 M), exchangeable aluminium (Al³+, cmolc dm⁻³), potential acidity (H+Al, cmolc dm⁻³); (ii) organic matter (MO, g kg⁻¹), cation exchange capacity (CTC pH 7.0) and saturation by bases (V%, cmolc dm⁻³), e; iii) exchangeable Mehlich-1 (P, mg dm⁻³) phosphorus, potassium (K⁺), calcium (Ca²⁺) and magnesium (Mg²⁺) (cmolc dm⁻³), as well as copper (Cu²⁺), iron (Fe²⁺), manganese (Mn²⁺) and zinc (Zn²⁺). Available sulphur (SO₄²⁻ calcium phosphate) and boron (B hot water) were determined according to Van Raij et al. (1996).

The result of the analysis of the remaining phosphorus (P-rem, mg L⁻¹) allowed the identification of the fertility class as to the available sulphur (SO₄²⁻) according to Alvarez et al. (1999). The result of the soil particle size analysis (Embrapa, 2017) allowed the classification of soil chemical fertility attributes according to Alvarez et al. (1999).

The normality of soil fertility data as well as the productivity components of the acazals was verified by applying the Shapiro-Wilk test (p≥0.05) in the PAST software of the University of Oslo (Norway). The homocedasticity of the data was verified by Cochran's test (p≤0.05), in Excel spreadsheet. The significance of the means was identified by the F test (p≤0.05), and the comparison of means was made by applying the Tukey test (p≤0.05) in the MStatC software, from Michigan State University (USA). Both the statistically significant and non-significant data in the analysis of variances had the overall averages classified as to their specific soil fertility class according to Alvarez et al. (1999). Pearson's linear correlation analysis was enrolled in Excel spreadsheet in order to determine the joint behaviour of soil fertility data with productivity components. The significance of the values of the correlation coefficient (r) was determined by the t-test (p = 0.05).

4 RESULTS AND DISCUSSIONS

Higher values of Al³+, H+Al and CTC (pH 7.0) were observed in the soil of the 8- and 12-year-old Acaizals (Table 1). The toxic effects of high concentrations of Al³+ can lead to thickening and even prevent the release of roots by plants and therefore reduce the absorption of nutrients and water and finally plant growth and production (Sade et al., 2016; Kopittke et al., 2015).
Table 1

Averages of active acidity (pH), exchangeable aluminium (Al\(^{3+}\)), potential acidity (H\(^+\)Al), phosphorus (P), potassium (K\(^+\)), exchangeable calcium (Ca\(^{2+}\)), available sulphur (SO\(_{4}^{2-}\)) and boron (B hot water) in the soil of areas of acacia (E. precatória Mart) with different ages in the Alto Crato, Humaitá, Amazonas Community.

<table>
<thead>
<tr>
<th>Age</th>
<th>pH</th>
<th>Al(^{3+})</th>
<th>H(^+)Al</th>
<th>CTC (pH 7.0)</th>
<th>P</th>
<th>K(^+)</th>
<th>Ca(^{2+})</th>
<th>SO(_{4}^{2-})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>— cmolc dm(^{-3}) —</td>
<td>— mg dm(^{-3}) —</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 years</td>
<td>3.800 to 5.400 to</td>
<td>12.81 to 13.03 a</td>
<td>1.690 to 29.00 b</td>
<td>0.1000 b</td>
<td>3.750 b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 years</td>
<td>3.830 to 3.900 b</td>
<td>9.840 b</td>
<td>10.39 b</td>
<td>2.280 to 31.50 b</td>
<td>0.1000 b</td>
<td>3.000 b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3.900 to 3.900 b</td>
<td>9.570 b</td>
<td>10.02 b</td>
<td>2.100 to 28.50 b</td>
<td>0.1000 b</td>
<td>4.000 b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 years</td>
<td>4.880 ab</td>
<td>12.17a</td>
<td>12.17 ab</td>
<td>1.540 to 47.00 to</td>
<td>0.3000 to 5.750 to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMS</td>
<td>0.069</td>
<td>1.095</td>
<td>2.396</td>
<td>2.297</td>
<td>1.559</td>
<td>33.81</td>
<td>0.069</td>
<td>1.480</td>
</tr>
<tr>
<td>Block</td>
<td>0.001NS</td>
<td>0.029NS</td>
<td>1.205NS</td>
<td>0.06 NS</td>
<td>0.667NS</td>
<td>46.0NS</td>
<td>0.001NS</td>
<td>0.063NS</td>
</tr>
<tr>
<td>Age</td>
<td>0.009**</td>
<td>2.226**</td>
<td>10.718**</td>
<td>8.231**</td>
<td>5.500**</td>
<td>307.3**</td>
<td>0.006**</td>
<td>5.563**</td>
</tr>
<tr>
<td>Error</td>
<td>0.001</td>
<td>0.247</td>
<td>1.181</td>
<td>1.106</td>
<td>0.500</td>
<td>30.667</td>
<td>0.001</td>
<td>0.451</td>
</tr>
<tr>
<td>CV(%)</td>
<td>0.65</td>
<td>10.99</td>
<td>9.79</td>
<td>9.23</td>
<td>14.89</td>
<td>16.29</td>
<td>209.52</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>0.998</td>
<td>0.8612</td>
<td>0.8694</td>
<td>0.8038</td>
<td>0.6794</td>
<td>0.6794</td>
<td>0.9084</td>
<td>0.990</td>
</tr>
<tr>
<td>C</td>
<td>0.5909</td>
<td>0.497</td>
<td>0.456</td>
<td>0.474</td>
<td>0.769</td>
<td>0.769</td>
<td>0.529</td>
<td>0.3416</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2024). DMS: minimum significant difference from Tukey test (p≤0.05).
Averages followed by the same letter in the column do not differ from each other by the Tukey test (p≤0.05).

It was expected that the greater the age of the assayal the greater would be the influence of organic materials produced by the species upon the above-mentioned attributes, after their decomposition on the surface of the soil. However, recent results indicate that Amazonian soils cultivated with SAF are acidic and of low fertility and that, despite their greater availability of nutrients that in primary forests, for their maintenance depend on organic cover materials deposited on the soil surface (Soares et al., 2021). The soil attributes under discussion are influenced by pH values below 5.5 of soils that have not received liming, which may negatively interfere with the activity of the microorganisms and consequently the availability of nutrients (Troeh; Thompson, 2007), which explains the low MO value added to the soil in the different ages of assaults studied.

This level of acidity in the soil also explains the high values of Al\(^{3+}\), since this form of the element, when undergoing hydrolysis, releases H\(^+\) and contributes to the increase in the acidity of the soil (Troeh; Thompson, 2007). In contrast, the results of the 6- and 13-year SAF study by Iwata et al. (2012) indicated that in the older production system a higher MO content occurred, which had an influence on the acidity attributes of the soil. As a result, they also observed a reduction in CTC saturation by Al\(^{3+}\) (m%), increased pH and nutrient availability. According to Troeh; Thompson (2007), the high concentration of Al\(^{3+}\) in the soil solution is closely related to pH and implies high saturation by Al\(^{3+}\) (m%) in CTC (pH 7.0). Thus, the
toxic action of high levels of Al\textsuperscript{3+} is reflected on the productivity of the açaí implanted in soils with pH values below 5.5. The predominance of acidity and high Al\textsuperscript{3+} toxicity are the most common problems of soil fertility in the Amazon region (Moreira et al., 2005). For this reason, liming and surface gessage can be cited among the ways of adapting the soil conditions for the cultivation of E. precatoria.

Greater availability of K\textsuperscript{+}, Ca\textsuperscript{2+} and SO\textsubscript{4}\textsuperscript{2-} were verified in this Plintosolo covered with the 12-year-old asbestos (Table 1), even with unchanged MO values as well as in the soil of the other asbestos. The present discussion is limited, given the lack of information on the general fertility of the managed soil without soil improvers and fertilisers related to the age of cultivation of the assailant or other fruit species. The highest levels of nutrients available in the most aged sable are due to the action of environmental factors, such as temperature, luminosity, wind, sectional stage, water availability, which provide greater decomposition of the leaf litter in a specific surface area of the soil, altering the cycles of these nutrients (Zhu et al., 2019; Silva et al., 2018; Holanda et al., 2017; Lorenzo et al., 2014). Age and species are potential differentiators of biomass production and the availability of N, P, K\textsuperscript{+}, Ca\textsuperscript{2+} and SO\textsubscript{4}\textsuperscript{2-} in soil. Higher fertility in P and K\textsuperscript{+} were found by Croda (2019) in soils covered by SAF cultivated for a longer time.

It has also been found that in soils under different tree compositions, including the assayer, there is possible interference of organisms in the decomposition and restoration of the fertility of these agroecosystems, by the supply of nutrients to the soil (Castro et al., 2016; Brancher et al., 2011; Sanches et al., 2009). The composition and diversity of species determine the variation of the decomposition of the leaf litter in the specific environment in which it appears (Gessner et al., 2010). The accumulated burlap and its decomposing fauna, in turn, have specific functions of moisture control, nutrient retention, soil restoration and plant growth (Mateus et al., 2013).

In this way it becomes possible to state that the fruit species existing in the areas of the açaí makes it possible to deposition biomass. This biomass, added to the greater quantity of biomass produced by the older saddle, makes it possible, already in the initial stage of decomposition, to release K\textsuperscript{+} rapidly into the soil (Scheer, 2008), at the beginning of the rainiest period. Then, Ca\textsuperscript{2+} and SO\textsubscript{4}\textsuperscript{2-} are released as the decomposition of the deposited materials on the soil surface progresses, increasing the availability of these cations.

Fertility classes of soil chemical attributes are shown in Table 2. The Plintosol of the experimental area falls into a class of low natural fertility, according to Alvarez et al. (1999). It resembles soil covered by primary forest whose fertility was compared by Soares et al. (2021)
Productivity of Açai Euterpe Precatoria and Production System Management Recommendations in the South Of The Amazonas

to soil considered fertile, covered by SAF in the state of Pará. The forest soil studied by these authors also presents the low fertility and high acidity now found, and which is also corroborated by the verifications made for land in the Brazilian Amazon (Fearnside et al., 2009). These soil conditions cause damage to plant growth due to high levels of toxic Al3+, Mn2+ and Fe2+ at low pH, which are the main limitations of plant productivity due to low soil fertility (Moreira et al., 2005b).

Table 2

Global average and fertility class of the soil attributes of the area of açai (E. precatória Mart) with different ages in the community of Alto Crato, Humaitá, Amazonas.

<table>
<thead>
<tr>
<th>Attribute1</th>
<th>pH</th>
<th>Al3+</th>
<th>H+Al</th>
<th>CTC (pH 7.0)</th>
<th>P</th>
<th>K+</th>
<th>Ca2+</th>
<th>SO42-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall average</td>
<td>3.8</td>
<td>4.5</td>
<td>11.</td>
<td>11.4</td>
<td>1.9</td>
<td>34.0</td>
<td>0.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Class</td>
<td>MB4</td>
<td>MA4</td>
<td>MA</td>
<td>B4</td>
<td>MB</td>
<td>B4</td>
<td>MB</td>
<td>B</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute4</th>
<th>V%</th>
<th>Mg2+</th>
<th>MO</th>
<th>m</th>
<th>B</th>
<th>Cu2+</th>
<th>Fe2+</th>
<th>Mn2+</th>
<th>Zn2+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall average</td>
<td>1.</td>
<td>0.08</td>
<td>1.62</td>
<td>93.69</td>
<td>0.38</td>
<td>3.93</td>
<td>61.13</td>
<td>6.74</td>
<td>2.41</td>
</tr>
<tr>
<td>Class</td>
<td>MB</td>
<td>MB</td>
<td>B</td>
<td>MA</td>
<td>MB</td>
<td>A4</td>
<td>A</td>
<td>M</td>
<td>B</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2024). 1. Significant soil fertility attribute in test F (p≤0.05). 2. Classification based on P-remnant between 0 and 4 mg L-1. 3. Soil fertility class of each attribute according to Alvarez et al. (1999). 4. A: high. M: medium. B: low (or good, according to fertility attribute). MA: very high. MB: very low (or very good according to fertility attribute). 5. Soil fertility attribute not significant in test F (p≤0.05).

The low levels of P and K+ may be due to losses by the assayers and other fruiting species of the area. However, they deserve to be highlighted because even at low levels of availability, they are responsible for the biomass that plants produce in systems such as this one under study. The very low fertility class of P (< 10 mg dm-3) limits species productivity (Schlindwein et al., 2012).
Table 2

Global average and fertility class of the soil attributes of the area of açai (E. precatoria Mart) with different ages in the community of Alto Crato, Humaitá, Amazonas.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>pH</th>
<th>Al3+ H+Al CTC (pH 7.0)</th>
<th>K+</th>
<th>Ca2+</th>
<th>SO42-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall average</td>
<td>3.8</td>
<td>4.5</td>
<td>11</td>
<td>11.4</td>
<td>1.9</td>
</tr>
<tr>
<td>Class</td>
<td>MB</td>
<td>MA</td>
<td>MA</td>
<td>B</td>
<td>MB</td>
</tr>
<tr>
<td>Attribute4</td>
<td>V%</td>
<td>Mg2+</td>
<td>MO</td>
<td>m</td>
<td>B</td>
</tr>
<tr>
<td>Overall average</td>
<td>1.0</td>
<td>0.08</td>
<td>1.62</td>
<td>93.69</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2024). 1significant soil fertility attribute in test F (p≤0.05). 2classification based on P-remnant between 0 and 4 mg L-1. 3soil fertility class of each attribute according to Alvarez et al. (1999). 4A: high. M: medium. B: low (or good, according to fertility attribute), MA: very high. MB: very low (or very good according to fertility attribute). 5 soil fertility attribute not significant in test F (p≥0.05).

The low availability of Ca2+ and Mg2+ (Table 2), according to Alvarez et al. (1999), limit the productivity of cultivated tree species (Gonçalves & Benedetti, 2015) and crop production in general (Epstein & Bloom, 2006). In turn, the low saturation by bases (V%) serves as an indicator of the dystrophic character of the Plintosolo under the açai (V < 50%) (Santos et al., 2018). The high saturation by Al (m%) in the CTC ratifies its high acidity and higher content of Al3+ which, in turn, explains the lower values of Ca2+, Mg2+ and K+ and of V% (Lopes; Guilherme, 2004).

In general terms, the high acidity and low natural fertility of the Amazon soils are due to their low to medium levels of MO (Fearnside, 2009), which are generally associated with mineralisation and consequent release of nutrients to the soil solution. Thus, the conditions of high precipitation and low MO levels become conditions of reduction of cation levels, caused by leaching from the Plintosolo under study, being the main reason of its low natural fertility.

Regarding productivity, the 12-year-old açaizal is more productive (Table 3). Higher NR C-1, NF R-1, NF C-1, NF A-1 and higher MF C-1 and MF A1 yields were observed, respectively, being 42.3; 195.4; 307.7; 489.6; 129.8 and 171.1% higher than those verified in the acyclic-control at the age of 8 years. These higher yields are due to the higher availability of K+, Ca2+, SO42- in the soil (p≤0.05). The global averages of Cu2+, Fe2+ and Mn2+ (FNS, p≤0.05) may have contributed to the higher productivity of the saddle of 12 years, despite occurring below the appropriate classes of availability proposed by Alvarez et al. (1999). Under a different experimental condition, Neves (1999) found that tree species with lower age showed greater production in the 12th month of observation. The result was attributed to lower
availability and nutrient absorption by the indicator species, which produced less under similar soil fertility conditions (Fernandes et al., 2018).

Table 3

Average number of bunches per tree (NC A-1), number of stalks per bunch (NR C-1), number of fruits per stalk (NF R-1), number of fruits per bunch (NC C-1), mass of fruits per bunch (MF C-1), number of fruits per tree (NF A-1) and mass of fruits per tree (MF A-1) of the Euterpe precatoria mussel in the Alto Crato community.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>NR C-1</th>
<th>NF R-1</th>
<th>NF C-1</th>
<th>NF A-1</th>
<th>MF C-1 (kg bunch-1)</th>
<th>MF A-1 (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>101.4 c</td>
<td>15.68 b</td>
<td>1.631 c</td>
<td>2.983 b</td>
<td>3.480 c</td>
<td>7.790 b</td>
</tr>
<tr>
<td>9</td>
<td>131.0 ab</td>
<td>34.08 ab</td>
<td>4.543 ab</td>
<td>14.750 ab</td>
<td>6.850 ab</td>
<td>25.08 to 20.85 a</td>
</tr>
<tr>
<td>10</td>
<td>115.0 bc</td>
<td>28.72 ab</td>
<td>3.295 bc</td>
<td>11.600 ab</td>
<td>4.950 bc</td>
<td>19.85 a</td>
</tr>
<tr>
<td>12</td>
<td>144.3 to</td>
<td>46.33 a</td>
<td>6.650 to</td>
<td>17.590 to</td>
<td>8.000 to</td>
<td>21.12 a</td>
</tr>
<tr>
<td>DMS</td>
<td>20.249</td>
<td>21.341</td>
<td>2.647.336</td>
<td>411.919</td>
<td>2.559</td>
<td>10.450</td>
</tr>
<tr>
<td>Block</td>
<td>389.500 NS</td>
<td>80.047 NS</td>
<td>1609475.5 NS</td>
<td>49615943.0 NS</td>
<td>2.236 NS</td>
<td>26.787 NS</td>
</tr>
<tr>
<td>Age</td>
<td>1374.8 ***</td>
<td>645.984 ***</td>
<td>17894470.3 ***</td>
<td>160069809.0 ***</td>
<td>16.534 ***</td>
<td>222.365 ***</td>
</tr>
<tr>
<td>Error</td>
<td>84.333</td>
<td>93.674</td>
<td>1441488.896</td>
<td>34898629.36</td>
<td>1.347</td>
<td>22.464</td>
</tr>
<tr>
<td>CV (%)</td>
<td>7.47</td>
<td>31.02</td>
<td>29.80</td>
<td>50.35</td>
<td>19.89</td>
<td>25.68</td>
</tr>
<tr>
<td>W</td>
<td>0.9302</td>
<td>0.976</td>
<td>0.286</td>
<td>0.9244</td>
<td>0.9188</td>
<td>0.9465</td>
</tr>
<tr>
<td>C</td>
<td>0.625</td>
<td>0.330</td>
<td>0.360</td>
<td>0.471</td>
<td>0.316</td>
<td>0.491</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2024). Averages followed by the same letter in the column do not differ from each other by the Tukey test (p≤0.05). DMS: minimum significant difference from Tukey test. CV (%): coefficient of variation, in percent; W: Shapiro-Wilk statistics (p≥0.05); C: Cochran statistics (p≤0.05); DMS: minimum significant difference from Tukey test (p≤0.05). *: significant value by F test (p≤0.05); **: significant value by F test (p≤0.01); NS: non-significant value.

The productivity now verified is below the genetic potential of the species, which is due to the low availability and absorption of nutrients, leading the plants to the need for maximisation of their internal use to provide the highest productivity due, also, the higher incidence of light in the spawning plots at the age of 12 years (Isaac et al., 2011) and the absence of interspecific competition. According to Barros et al. (2021), the presence of crop residues decreases the acquisition of macro- and micronutrients by tree plants, which can be compensated by the efficient internal use of the absorbed nutrients. Thus, there is an important gap in knowledge about the internal use of nutrients by E. precatoria in the phase of adaptation to the technificated cultivation.

The Amazon basin is a forest species supported by acidic and low fertility soils (Viégas, 2004), which should justify its survival in the Plintosoil of low fertility of the experimental area. The maintenance of forest species occurs according to the efficiency in the deposition and decomposition of the sawdust and the availability and reabsorption of nutrients by the surface roots (Sanes et al., 2013; Klinge, 1977).
These results, therefore, indicate that acylazales of E. precatoria increase productivity from 9 years in relation to the acylazal of 8 years of age, even vegetating in low fertility soil (Table 2). Considering that E. precatoria is a species still little studied, it is not possible to conclude categorically about this increase, or, that the productivities of acaizales at the age of 8 years are influenced by the soil conditions and, or, handling of the acaizal of this species. However, Carvalho (2011) indicates that the species begins to produce fruits between 7 and 8 years old. In fact, several factors can influence its productivity, citing the water regime and climate changes, given the seasonal climate (Dias et al., 2019).

According to Homma (2006), the productivity under these conditions must be taken into account in a joint way when analysing the management and production of the açai in terms of sustainability. Altieri (2012) reports that the ecological balance can be verified by the use of agriculture and forest planting and management together in areas of low productivity. For him, sustainable management maintains the productive potential, the vegetal succession, the cycling of nutrients, and the diversity and equilibrium between species, bringing about a reduction in production costs with external inputs and making the property more productive. According to Silva et al. (2020), low yields are obtained when soil management is inadequate or neglected in planting the assaizal. The conduction of the dams on the studied property is similar to the STLs. Based on these accounts by Homma et al. (2006) and Silva et al. (2020), these acyshais meet certain sustainability requirements, even without the use of external inputs and inadequate handling for plant growth.

From this, there is a demand for alternatives to reconcile productivity and sustainability in productive property, such as the SAF sugarcane mill, whose objective is to increase the sustainability of production by the spatial and temporal arrangement of the plants (Abdo et al., 2008). This results in greater sustainability through increased productivity, soil fertility levels and biological diversity, and fewer handling operations (Marchini et al., 2015) with less soil degradation (Barros et al., 2009).

At this moment, it is conjectured that the assaizals studied produce below their genetic potential due to the conditions of pH and Al3+ and H+Al (Troeh; Thompson, 2007). However, the joint behaviour (0.54* < r < 0.68**) verified for P, Ca2+, Mg2+, K+ and SO42- in soil indicates that, although below adequate levels of fertility (Table 3), they jointly contribute to the maintenance of productivity, even without inserting the required nutrients. In turn, the increase of one unit in the value of a certain productivity component is simultaneous to the increase in the other components (0.67** < r < 0.98**), which allows us to conjecture that they influence decisively and jointly the total productivity of the açai.
5 CONCLUSION

The area of the açaizais studied in this work has never received management of chemical fertility such as the practice of liming and fertilising. There was a general level of soil fertility inadequate for the satisfactory agronomic production of the açaizais. However, it is clear that even the low availability of phosphorus, calcium, magnesium and sulphur in the soil makes it possible to cultivate E. precatoria in a system similar to the agroforestry system, and that these nutrients contribute jointly to maintaining the annual productivity of the açaizais. In these conditions of soil fertility similar to that of a primary forest, the 12-year-old savanna is the most productive, which is evidenced by the highest productivity observed for all the components studied.

This low availability of cationic nutrients, phosphorus and sulphur, coupled with the potential suppressive effect of the attributes of acidity in the soil on the productivity of the açaizais, indicates the need for soil management in the studied area. Thus, under these conditions, it becomes possible to increase the productivity of the E. precatoria mill and the sustainability of the production system if the following practices are adopted: (i) liming, gypsum and surface phosphating added to the insertion of organic waste to supply nutrients and reduce the toxic effects of exchangeable aluminium on the productivity of the açaizais; (ii) suitability of the areas by the seasonal implantation of different cultivated annual and perennial species; and (iii) maintenance of the soil cover throughout the agricultural year in order to protect it from the impacts of rainfall and improve the cycling of nutrients in the agro-ecosystem. However, specific research is necessary in order to qualify and quantify recommendations for handling with liming and fertilising the crop of the Amazon basin.

THANKS

To the Federal University of Amazonas/UFAM; To the Coordination for the Perfection of Higher Level Personnel/CAPES; Pro-Rectory of Research and Postgraduate Studies/PROPESP/ PPGCA/UFAM; To the Amazonas State Research Support Foundation/FAPEAM; To the National Council for Scientific and Technological Development/CNPq, and; To the participating Farmers.
REFERENCES


