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Articles

Influence of early cattle entry on the development of eucalyptus clones in a silvopastoral in the Amazon

Influência da entrada precoce do gado sob o desenvolvimento de clones de eucalipto em sistema silvipastoril na Amazônia

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ABSTRACT

This study aimed to compare the development of two eucalyptus clones under the influence or not of the early animal entry into a silvopastoral system in Capixaba, Acre. The region's climate is AWI, with annual rainfall between 1,680 and 2,580 mm and a dry season between May and September. The design was entirely randomized in a 2 x 2 factorial scheme with six replications and four treatments: a) Clone I144 with cattle access at nine months (TR1); b) Clone I144 without cattle access at nine months (TR2); c) Clone VM01 with cattle access at nine months (TR3); and d) Clone VM01 without cattle access at nine months (TR4). Data was collected from the 16 central trees of each plot at 9, 12, 19, 24, 32, and 36 months of age. Total height (TH) and diameter at breast height (DBH) were measured, and the individual volume with bark from each stem per clone was obtained by rigorous cubing. Growth curves were generated as a function of age for HT, DBH, and Volume per ha using the Logistic model. Clone VM01 displayed higher survival, diameter, and volume per ha than clone I144, with higher values for these variables for the treatment without early animal entry. Clone VM01 demonstrated estimates of maximum production volume per hectare 83.8% higher than clone I144. The early animal entry into the silvopastoral system negatively influenced the growth and survival of the eucalyptus clones.

Keywords: Agroforestry Systems; SSP; IPF; *Eucalyptus* spp.

RESUMO

O objetivo deste estudo foi comparar o desenvolvimento de dois clones de eucalipto sob a influência ou não da entrada precoce dos animais em sistema silvipastoril em Capixaba, Acre. O clima da região é AWI, com precipitação anual entre 1.680 a 2.580 mm, com estação seca entre maio e setembro. O delineamento foi inteiramente casualizado em esquema fatorial 2 x 2 com seis repetições e quatro tratamentos: a) Clone I144 com acesso do gado aos 9 meses (TR1); b) Clone I144 sem acesso do gado aos 9 meses (TR2); c) Clone VM01 com acesso do gado aos 9 meses (TR3); e d) Clone VM01 sem acesso do gado aos 9 meses (TR4). Os dados foram coletados das 16 árvores centrais de cada parcela, aos 9, 12, 19, 24, 32 e 36 meses de idade. Realizou-se a medição de altura total (HT), diâmetro à altura do peito (DAP) e o volume individual com casca de cada fuste para cada clone foi obtido por meio de cubagem rigorosa. Foram geradas curvas de crescimento em função da idade para HT, DAP e Volume por ha, utilizando o modelo Logístico. O clone VM01 apresentou maior sobrevivência, diâmetro e volume por ha em comparação ao clone I144, com maiores valores destas variáveis para o tratamento que não teve a entrada precoce dos animais. O Clone VM01 apresentou estimativas de produção máxima de volume por hectare 83,8% superior ao do clone I144. A entrada precoce dos animais no sistema silvipastoril influenciou negativamente o crescimento e a sobrevivência dos clones de eucalipto.

Palavras-chave: Sistemas Agroflorestais; SSP; IPF; *Eucalyptus* spp.

1 INTRODUCTION

Agroforestry systems encompass agricultural, livestock, and forestry activities in different spatial arrangements and insertion times of the system components to achieve sustainability in the production area with environmental compatibility and income generation (Vasconcellos; Beltrão, 2018). Among the various types of agroforestry systems, the silvopastoral system can be highlighted due to its potential to increase net income with diversification of products per area and in a sustainable way (Martínez; Silva; Azevedo; Botelho; Oliveira; Godinho, 2019).

The silvopastoral system or SPS is a land-use practice where tree species are integrated simultaneously with livestock (Bento; Schmitt Filho; Faita, 2020), with different spatial arrangements and pasture implementations (Peri; Dube; Varella, 2016). The trees introduced into the system generate the characteristics of soil and water conservation, pasture nutrition, and an increase in the development capacity and supply of wood-based products to society (Torralba; Fagerholm; Burgess; Moreno; Plieninger, 2016). In addition to increased animal performance and weight gain (Santos; Grzebieluckas, 2014), tree shading leads to an increase in animal grazing time, a decrease in water consumption, and an increase in meat and milk production (Valderrama, 2019). In this system, fast-growing species with economic value, such as eucalyptus, have been the most widely used (Falesi; Galeão, 2020).

Species of the Eucalyptus genus are capable of providing ecosystem services ranging from water supply to carbon sequestration and storage and mitigation of greenhouse gas emissions (GHGs) (Parron; Garcia; Moreira; Porfírio-Da-Silva, 2019), as well as having good adaptability to different soil and climate conditions, rapid growth and a canopy compatible with integration systems (Aranha; Andrighetto; Lupatini; Bueno; Trivelin; Mateus; Luz; Santos; Sekiya; Vaz, 2019). These species have been used in SPS in various parts of Brazil. Nonetheless, eucalyptus cultivation is not yet well developed in the northern region of the country due to the limited knowledge of which species have the potential to be used in silvopastoral systems according to the region’s soil and climate conditions (Garcia; Tonucci; Gobbi, 2010). In this region, most SPSs are established based on empirical knowledge, with a low level of technical expertise (Rego; Kato, 2017). Farmers seek to give access to the animal component into the system early, aiming for a rapid economic return, which can cause damage of different intensities to the forest species (Triches; Moraes; Porfírio-Da-Silva; Lang; Lustosa; Bonatto, 2020), from the foliage consumption to breaking of the main trunk, causing reduced growth and even the tree death (Brun; Dalposso; Sartor; Kuss, Brun; Peretiatko, 2017).

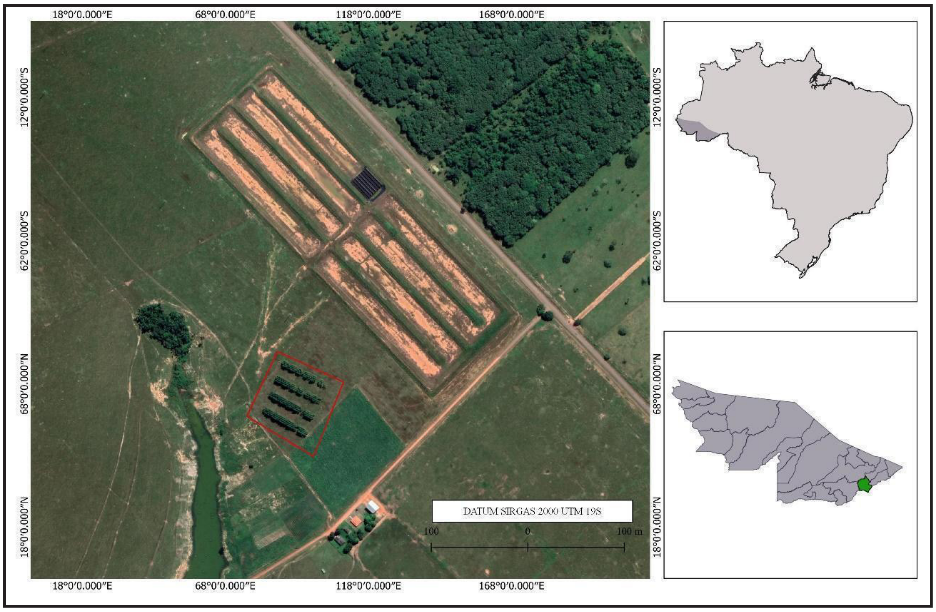
More precisely, in the southwest of the Amazon, few SPSs have been implemented, with no conclusive studies to indicate eucalyptus species or clones for the region or research that considers the possible effects of the interactions between the animal/tree/pasture components of the SPS allowing it to remain sustainable from an economic and socio-environmental point of view.

However, this research aims to compare the development of two eucalyptus clones under the influence of early animal entry or not into a silvopastoral system in Capixaba, Acre.

2 MATERIALS AND METHODS

The experimental planting was conducted at Fazenda Colorado, located at km 33 of the BR-317 highway, in Capixaba, the lower Acre region (Figure 1). It is bordered to the north by Rio Branco and Senador Guiomard counties, to the west by Xapuri, to the east by Plácido de Castro, and south by Bolivia, with an altitude of 196 meters and geographical coordinates of 10° 33′ 39″ South latitude and 67° 41′ 25″ West longitude (Brasil, 2021).

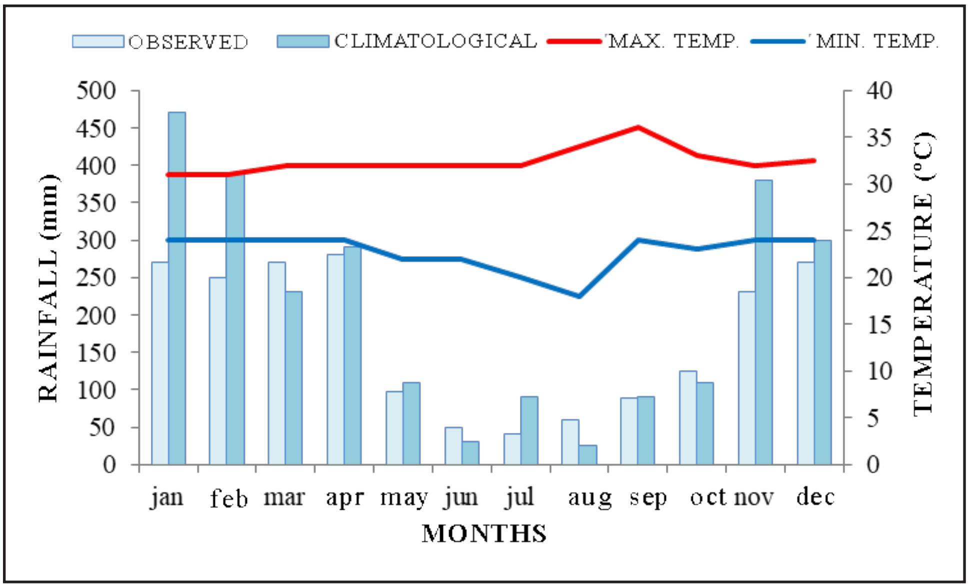
Figure 1 – Location of the area where the silvopastoral system was implemented in Capixaba, Acre



Source: Authors (2022)

The region's climate is AWI (hot and humid), according to the Koppen classification, with a maximum temperature of 31.7ºC and a minimum of 19.5ºC, with an annual rainfall of between 1,680 and 2,580 mm, with a dry season between May and September and relative humidity of around 79% (Rodrigues; Andrade Neto; Lessa; Girardi; Soares Filho, 2018). Rainfall and temperature data for 2019 can be seen in Figure 2.

Figure 2 – Rainfall and maximum and minimum monthly air temperature in 2019 in the municipality of Capixaba, Acre

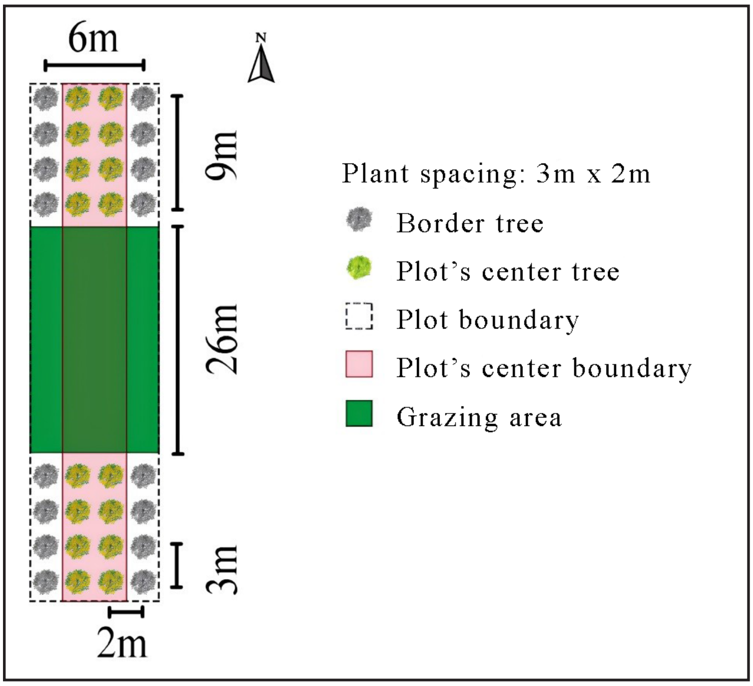


Source: ANA and INMET (2019)

The soils in the Capixaba region belong to the dystrophic yellow-red Latosol + dystrophic yellow-red Oxisol, with a percentage of texture varying from 15<clay<60, considered well-drained and deep, (>100 cm deep) with less than 10% of concretions (Bardales; Pereira; Duarte; Araújo; Oliveira; Lani, 2011). The area where the system was implemented consisted of 2.7 hectares of flat terrain with a pasture of *Brachiaria brizantha* cv. *Xaraés* (MG5).

This study is the continuation of the research by Gonçalves, Cruz, Sales, Souza, Gomes e Gonçalves (2022) in which the silvopastoral system was implemented in December 2018, characterized by having four rows of trees arranged in an east-west direction, with a spatial arrangement (3 x 2) + 26 meters (Figure 3), totaling four plots, with 571 plants per hectare and a tree occupancy rate in the silvopastoral of 31.4%. The eucalyptus clones used were VM01 (Eucalyptus camaldulensis Dehnh x Eucalyptus urophylla S.T. Blake) - recommended for energy purposes, and I144 (AEC 0144) (Eucalyptus urophylla S.T. Blake) - also recommended for energy purposes. The clonal seedlings, propagated by cutting method, were obtained from the Vale Verde nursery, located in Vilhena - RO.

Figure 3 – Spatial arrangement of the forest stand in a silvopastoral system in Capixaba, Acre



Source: Authors (2022)

The minimum cultivation method was used to plant the eucalyptus seedlings, after mowing the rows and digging the holes with a hand digger. Post-emergent herbicides were only applied in the forest interspaces. The holes were 30 cm deep, and the seedlings were approximately 20 cm high. Planting was carried out manually.

The starter fertilizer was applied to the bottom of the hole, with 150g of NPK 03-30-10 and micronutrients such as copper, boron, and zinc. The planting fertilizer was laid in the side holes after the seedlings had been planted, using the same formulation and amount of fertilizer as mentioned above. After three, six and twelve months of planting, the trees were fertilized with NPK 20-00-20 plus micronutrients (copper, boron, and zinc).

At the beginning of the forest stand's development, mowing and chemical weeding were performed in the planting rows and between the rows before fertilizing, with crowning being carried out to avoid weed competition in the first few months when needed.

The entire experimental area was insulated with an electric fence after planting the trees. After nine months, the animal component was given access, and only the control treatments were kept insulated. The electric barrier isolating the control trees was removed two years after planting.

Six Aberdeen Angus and Nelore industrial crossbred animals weighing 300 kg were placed on 1 hectare, with the forage component reaching 45 cm in height (initial) up to a minimum residual height of 20 cm, being kept in rotation for three months (Gonçalves; Cruz; Sales; Souza; Gomes; Gonçalves, 2022).

The paddock area was determined by the number of UA (animal unit) x area/UA x grazing time, corresponding to 1 ha; area/UA is the area available per day in the paddock for the animals to graze (150 m²); the grazing time, until the forage reaches a minimum height, corresponds to approximately 14 days (Gonçalves; Cruz; Sales; Souza; Gomes; Gonçalves, 2022).

Two paddocks of approximately 0.7 ha were separated so that the forage could recover and reach a height of 45 cm. The rotation took place over three months (September, October, and November) with three animal entries that remained in the experimental area for an average of 14 days at each access (Gonçalves; Cruz; Sales; Souza; Gomes; Gonçalves, 2022).

The experiment was set up in a completely randomized design in a 2 (clones) x 2 (with and without livestock access) factorial scheme with six replications and four treatments: a) Clone I144 with livestock access at nine months (TR1); b) Clone I144 without livestock access at nine months (TR2); c) Clone VM 01 with livestock access at nine months (TR3); and d) Clone VM 01 without livestock access at nine months (TR4). To assess the clones' growth in height, diameter at breast height (DBH), and volume, only the 16 central trees (plot center) of the 32 plants that occupied each plot (Figure 2) from a total of 24 plots, summing up, thus, 384 trees from a total of 768 of the entire experiment.

In addition, plant survival, total height, and DBH growth were assessed using a digital clinometer and measuring tape, respectively, at 9, 12, 19, 24, 32, and 36 months after planting.

Rigorous cubing was carried out using the Smalian method 36 months after planting the seedlings. Based on the inventory data, three trees were cubed for each diametric class observed in the diametric distribution of trees of each clone. The total individual bark volume of each stem was obtained using volumetric equations generated from the Schumacker and Hall model (LnV = β0 + β1lnDap+ β2lnHt + e) for each clone.

For each treatment, using all the measurements since the age of nine months, growth curves based on age were generated using non-linear regression analysis for Total Height, DBH, and Volume per ha using the Logistic model. The growth curves were generated using CurveExpert software, as following in Equation (1):

$$Yi = \left(\frac{\propto}{[1+e^{(\beta-\gamma x)}]}\right) + \varepsilon i \qquad (1)$$

where: Yi: dependent variable (DBH, in cm; total height, in m; volume in m^3ha^{-1}); α, β and y: model parameters; x: stand age, in months; εi = random error ~ NID (0, σ^2).

The model was selected based on the usual criteria for evaluating models, such as correlation between observed and estimated values, distribution of residuals, and biological realism.

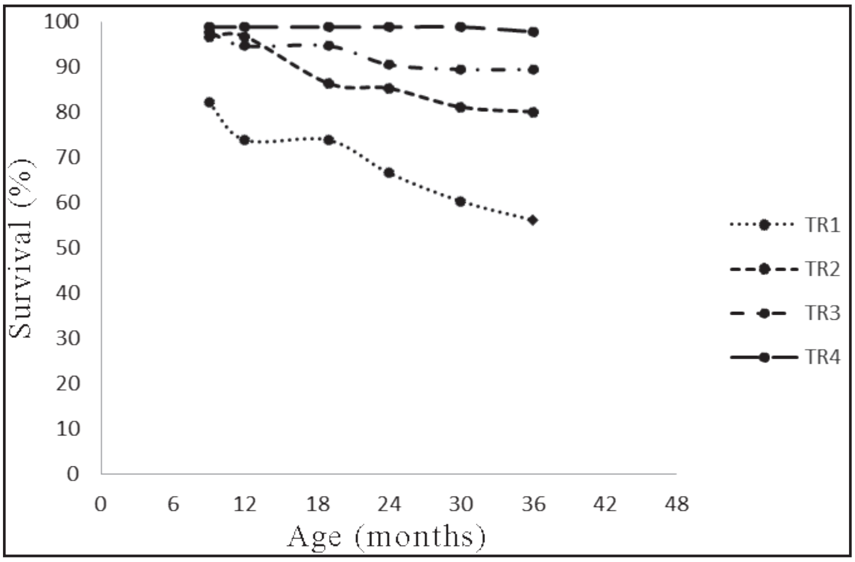
The model identity test was used to assess the statistical equality between the growth curves of each treatment. When there was no significant difference at 5% probability by the F test, a single model was fitted for similar treatments. This analysis was carried out for all variables.

3 RESULTS

Survival ranged from 56 to 98% between the four treatments up to 36 months after planting (Figure 4). Concerning the clones' survival in the planting area, the treatments without cattle access (TR2 and TR4), clone VM01 showed higher survival than clone I144 (Figure 4), with values around 98% and 80%, respectively, at 36 months after planting.

There was a survival reduction for each clone when comparing treatments with and without cattle access. This was very evident for clone I144, in which the treatment with cattle access (TR1) showed approximately 30% lower survival compared to the treatment without cattle access (TR3) in the last evaluation period.

Figure 4 – Survival of eucalyptus clones in a silvopastoral system up to 36 months after planting in Capixaba, Acre

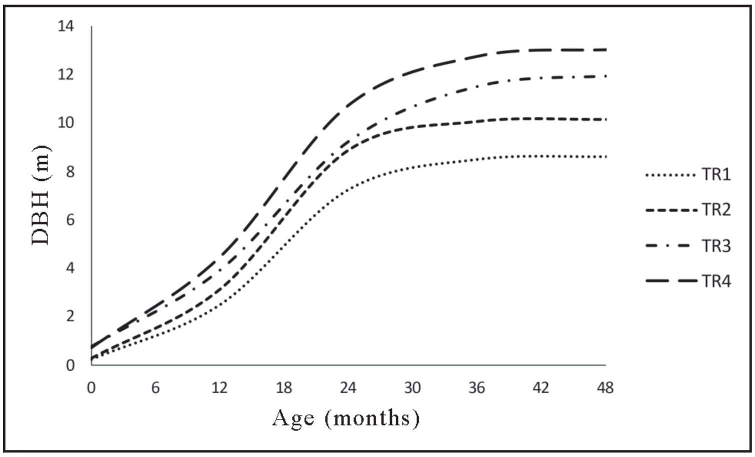


Source: Authors (2022)

In where: TR1 = clone I144 with cattle access at 9 months; TR2 = clone I144 without cattle access at 9 months; TR3 = clone VM 01 with cattle access at 9 months (TR3); TR4 = clone VM 01 without cattle access at 9 months.

The asymptotic values (α parameter) and diameter growth trends varied ($p \leq 0.05$) between all the treatments (Figure 5, Table 1). Clone VM01 showed higher ($p \leq 0.05$) growth in diameter than I144. When the analysis was carried out within each clone, the treatments without livestock access showed higher ($p \leq 0.05$) diameter growth than those with livestock access. The maximum diameters projected for the VM01 and I144 clones with livestock access represented 85% and 92%, respectively, of the highest value estimated for the clones without livestock access (Figure 5, Table 1).

Figure 5 – Diameter growth curves (DBH) of eucalyptus clones in a silvopastoral system in Capixaba, Acre



Source: Authors (2022)

In where: TR1 = clone I144 with cattle access at 9 months; TR2 = clone I144 without cattle access at 9 months; TR3 = clone VM 01 with cattle access at 9 months (TR3); TR4 = clone VM 01 without cattle access at 9 months.

Table 1 – Adjusted equations of diameter (DBH), total height, and volume (m^3 ha -1) as a function of age (I) for eucalyptus clones in a silvopastoral system in Capixaba, Acre

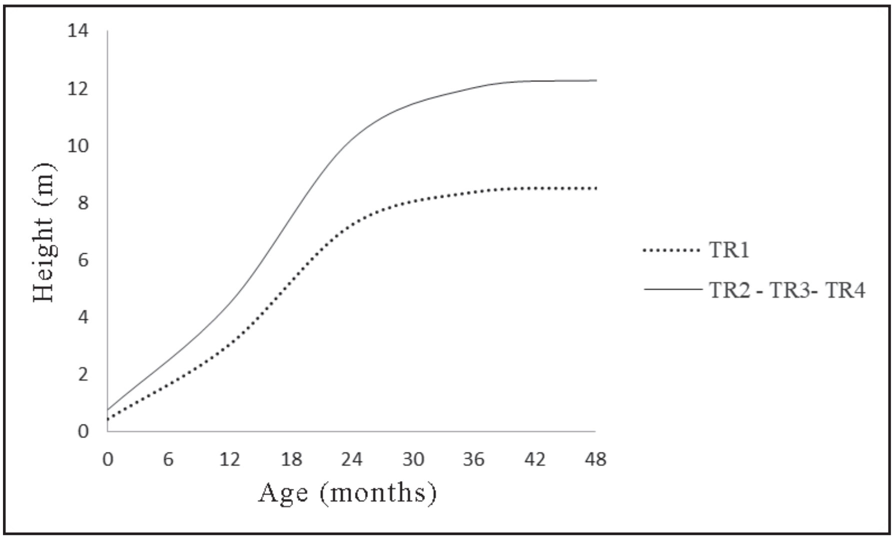
Treatments	Parameters α	β	γ	rŷy	Syx
			DBH (cm)		
TR1	8.64149	31.2032	0.21287	0.9456	0.9483
TR2	10.1740	35.1192	0.2292	0.9611	0.9969
TR3	12.0092	13.9376	0.1600	0.9651	0.9608
TR4	13.0632	17.0525	0.1818	0.9670	1.0470
			Total height (m)		
TR1	8.5312	17.8240	0.1915	0.9449	0.8889
TR2	12.3159	14.7280	0.1779	0.9595	1.1196
TR3	12.3159	14.7280	0.1779	0.9595	1.1196
TR4	12.3159	14.7280	0.1779	0.9595	1.1196
			Volume (m^3 ha-1)		
TR1	7.5314	90.8457	0.2271	0.9424	1.0424
TR2	32.5010	73.6108	0.1596	0.9549	3.4424
TR3	32.5010	73.6108	0.1596	0.9549	3.4424
TR4	60.7891	83.4241	0.1573	0.9747	4.1203

Source: Authors (2022)

In where: α, β, and γ = Parameters of the Logistic model in the form Y = α (1- βe-γx)-1; rŷy = Correlation Coefficient; Syx= Standard error of the residuals. TR1 = clone I144 with cattle access at nine months; TR2 = clone I144 without cattle access at nine months; TR3 = clone VM01 with cattle access at nine months (TR3); TR4 = clone VM01 without cattle access at nine months.

There was no difference (p>0.05) between the treatments for height growth, except for TR1, which had the lowest estimate for this variable (Figure 6, Table 1). The maximum height (parameter α) estimated for TR1 was around 69.3% of the highest plant height of the other treatments. For the VM01 clone, the early entry of animals did not interfere with tree height growth.

Figure 6 – Total height growth curves of eucalyptus clones in a silvopastoral system in Capixaba, Acre



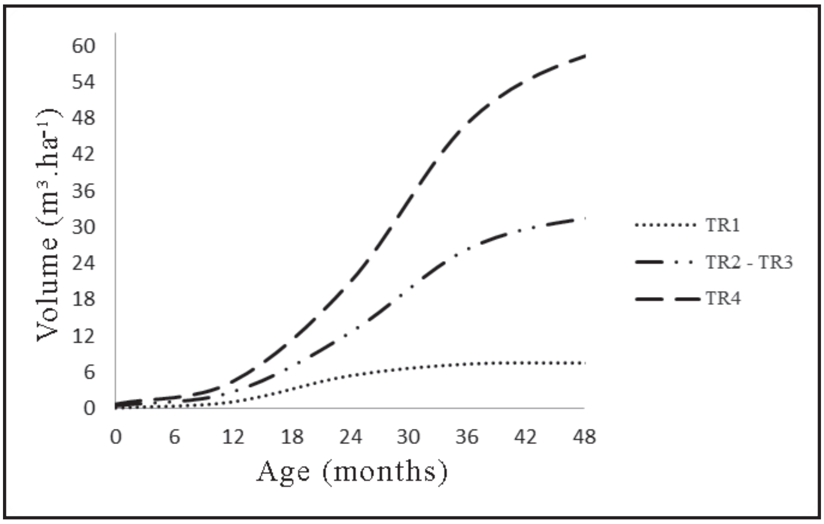
Source: Authors (2022)

In where: TR1 = clone I144 with cattle access at 9 months; TR2 = clone I144 without cattle access at 9 months; TR3 = clone VM 01 with cattle access at 9 months (TR3); TR4 = clone VM 01 without cattle access at 9 months.

The asymptotic values and growth trends in volume per ha varied (p≤0.05) between treatments (Figure 7, Table 1). Clone VM01 showed maximum production estimates 83.8% higher than clone I144. Although clone VM01 showed lower production in the area with animal access (TR3), the growth in volume per ha of this treatment was similar (p>0.05) to that of clone I144 without animal access (TR2) (Figure 7), which again demonstrates the greater development capacity of clone VM01 in the planting area than I144.

When analyzing the influence of early livestock access to the planting area on the clones, there was higher ($p \leq 0.05$) growth in volume per hectare in the treatments with no livestock access (Figure 7, Table 1).

Figure 7 – Volume growth curves (m³ ha^{-1}) of eucalyptus clones in a silvopastoral system in Capixaba, Acre

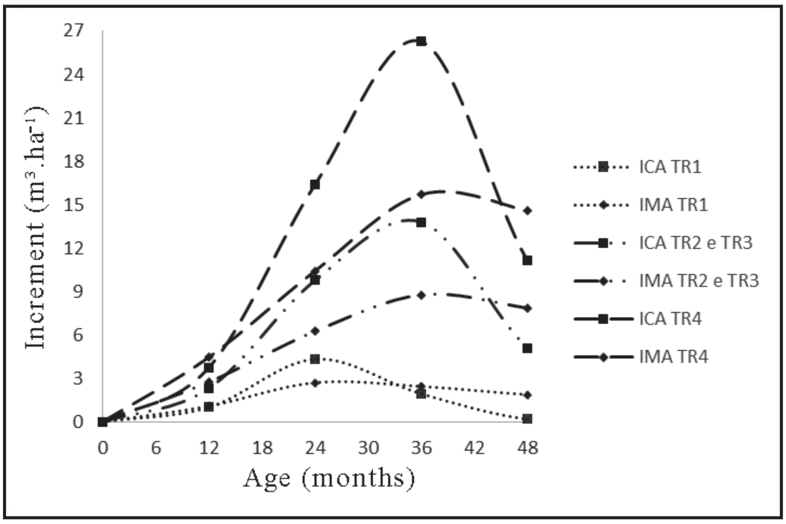


Source: Authors (2022)

In where: TR1 = clone I144 with cattle access at 9 months; TR2 = clone I144 without cattle access at 9 months; TR3 = clone VM 01 with cattle access at 9 months (TR3); TR4 = clone VM 01 without cattle access at 9 months.

Growth stagnation in volume per hectare occurred around 38 months after planting, with a maximum *IMA* of 15.8 m³ ha-1 year -1 for clone VM01 in treatment TR4. For treatments TR2 and TR3, growth stagnation occurred at 37 months, while for treatment TR1 (clone I144), it was seen at 27 months and with the lowest maximum *IMA* value (2.8 m³ ha-1 year -1) (Figure 8).

Figure 8 – Annual Current Increment (ICA) and Average Annual Increment (IMA) (m³ ha-1) of eucalyptus clones in a silvopastoral system in Capixaba, Acre



Source: Authors (2022)

In where: TR1 = clone I144 with cattle access at 9 months; TR2 = clone I144 without cattle access at 9 months; TR3 = clone VM 01 with cattle access at 9 months (TR3); TR4 = clone VM 01 without cattle access at 9 months.

4 DISCUSSIONS

There are still no commercial eucalyptus plantations in the southwestern Amazon region and no eucalyptus species/clones suitable for the area in question, making it harder to analyze the experimental plantations that have been conducted due to the lack of published works in the literature to serve as a basis for correlation. Therefore, in this study, when possible, comparisons were made with research carried out in other regions of Brazil.

The clones evaluated in this study have distinct morphological characteristics that may or may not be a factor in their adaptation to the soil and climate conditions of the study site. Therefore, in addition to the effect of early cattle access on the growth and survival of the trees, a comparison can be made between the development of the two clones under the environmental conditions in the treatments in which the clones were not exposed to early grazing by animals.

The satisfactory survival rate for commercial eucalyptus plantations should be at least 90% (FAO, 1979), and replanting should be carried out when the mortality rate exceeds 5%. In this way, the survival rate of clone VM01 in the plantation region is within the standards considered adequate, differently from for clone I144, which may indicate difficulty adapting to the region's environmental conditions.

Hybrids of *E. urophylla* x *E. camaldulensis*, such as the VM01 clone, have favorable characteristics for better performance in the field due to the adaptation plasticity to different locations and the water absorption by the roots in deeper layers of the soil with resistance to drought periods, a typical characteristic of plants of the *E. camaldulensis* species, maintaining favorable performance in survival, height and DAP under adverse conditions (Costa; Almeida; Martinez; Silva, 2015). We should not forget that the planting region has a very pronounced dry period from June to September (Figure 2). The ability to develop during water deficit periods, with less disease vulnerability, and an increased capacity for mechanical resistance are fundamental aspects of obtaining satisfactory survival results.

In addition, the soil was only prepared for planting this forest stand by digging holes. The smaller area of prepared soil combined with the differences in the root architecture of the two clones may have contributed to the difference in the survival of these genetic materials. Rocha, Reinert, Fleig and Prevedello (2015) observed significant differences in eucalyptus survival according to soil preparation methods, with worse growth results for trees planted only employing manual digging, without turning the soil, compared to scarification, harrowing, and rotary hoeing.

Bringing the animals into the system earlier reduced the clone's survival, as observed for treatments TR1 and TR3 (Figure 4). Survival was higher for treatments without early animal access. Gonçalves, Cruz, Sales, Souza, Gomes and Gonçalves (2022) showed different intensities of damage caused by cattle entering the system at nine months, such as branches and trunks breaking and trees falling over. These authors also observed a slight reduction in survival at 12 months after planting. Brun et al. (2017) found eucalyptus stand damage ranging from leaf consumption to wood exposure, which also affected the survival of the forest species.

The significant growth discrepancy of clone I144 concerning DBH compared to clone VM01 may again indicate the difficulty this genetic material has in adapting to the environmental conditions of the planting site since clone I144 stands out in terms of production in other regions of Brazil (Reis; Santos; Pacheco; Moraes, 2021).

The negative influence of the tree/animal interaction was also seen concerning DBH for the treatments with early animal access to the system. This lower growth in diameter had already been observed in these clones' initial growth analyses (Gonçalves; Cruz; Sales; Souza; Gomes; Gonçalves, 2022) and persisted over time. These results indicate that the possible damage caused by early cattle entry affected the diameter growth of the trees.

The damage caused to trees ranges in intensity from pruned branches to broken branches and broken trunks (Porfirio-Da-Silva; Moraes; Moletta; Pontes; Olivera; Pelissari; Carvalho, 2012). Damage, when severe, contributes to an increase in the mortality rate and growth reduction in height, DBH, and volume. When they don't cause mortality, there can be a loss of commercial value due to the defects found in the trunk. Trees that have been established for longer are usually less affected by cattle entering the system (Rondon Neto; Kruger; Rodrigues, 2021).

Brun, Dalposso, Sartor, Kuss, Brun and Peretiatko (2017) found, in SPS, where animals entered between seven and ten months after planting, lower DBH for trees nearby where the animals grazed (0 to 25 meters) than for trees further away (0 to 75 m). When assessing the damage caused by cattle, Porfirio-da-silva, Moraes, Moletta, Pontes, Olivera, Pelissari and Carvalho (2012) observed that all the trees with broken trunks had DBHs below 6 cm when animals entered them three years after the system was set up. Porfirio-Da-Silva, Utima, Franco, Triches and Kruchelski (2018) found no harmful effect on tree diameter when animals entered the area 24 months after planting.

Porfirio-da-silva, Moraes, Moletta, Pontes, Olivera, Pelissari and Carvalho (2012) verified that the greater the damage incidence caused by animals, the lower the DBH value, and to minimize the damage caused to trees in SPS, the DBH values should be 6 cm to 8 cm in diameter when the animals enter. These minimum DBH values for releasing animals recommended in the literature are well above those observed in this study, in which for both clones, the DBH was less than 2.50 cm when cattle entered at nine months after planting (Gonçalves; Cruz; Sales; Souza; Gomes; Gonçalves, 2022).

When analyzing the results regarding tree height, the harmful influence of animal entry was only seen for treatment TR1 (Figure 6). This may be due to the lower tree height in this treatment by the time the animals were released (Gonçalves; Cruz; Sales; Souza; Gomes; Gonçalves, 2022). At that time, the trees of clone I144 were less than 2.5m tall, i.e., the minimum height recommended in the literature for releasing animals (Garcia; Tonucci; Gobbi, 2010). Porfirio-Da-Silva, Moraes, Moletta, Pontes, Olivera, Pelissari and Carvalho (2012), in an SPS with the implantation of three forest species, observed more damage to trees that were shorter in height. Barbosa, Flávio, Freitas, Lima, Silva, Ensinas and Marques Filho (2019), when evaluating the performance of eucalyptus clones in an SPS with cattle entry when the trees were seven meters high, observed that the presence of the animal component did not interfere with the silvicultural development of the plants. According to Gonçalves, Cruz, Sales, Souza, Gomes and Gonçalves (2022), the age of the trees should not be the basis for placing animals in an SPS, but rather the dimensions, such as their height and DBH.

Both clones have not been evaluated in clonal tests for the Amazon region or spatial arrangements and spacing typical of silvopastoral systems. As such, the performance of these materials may be very different from the locality where they were tested. This may justify the lower volumetric performance exhibited by I144 in the site of this study, while other regions stand out in this regard (Behling; Martinez; Silva; Oliveira; Cipriani, 2021).

As animal damage to trees can reduce their growth in DBH and height, it is to be expected that these effects are responsible for volumetric growth reductions of the forest species. Clone I144 in treatment TR1 had the lowest estimated growth in volume per ha, demonstrating the harmful effects of bringing animals into the system earlier on volume production. It is important to note that the lower survival rate in this treatment (Figure 4) was also a determining factor in the lower estimated volume.

Gonçalves, Cruz, Sales, Souza, Gomes and Gonçalves (2022), in a previous study, had already found lower initial growth in volume per ha for the VM01 and I144 clones in an area where cattle were brought in early. This shows that the trees could not recover from the damage caused by the animals. These authors observed damage of various classes and intensities (low, high, and extreme), such as toppling (extreme), trunk breakage (high), and branch breakage (low). Clone I144 had the highest incidence of extreme damage precisely because it displayed the lowest initial growth.

The premature animal entry into the system caused the technical harvest age to be brought forward, besides drastically reducing the maximum IMA of the TR1 and TR3 treatments. This indicates that the trees whose understory was grazed could not express their peak growth potential. The factors that lead to the anticipation of the technical harvesting age are associated with the productive capacity of the site, given the changes that can occur in a stand, the type of soil, species, genetic material, water and nutrient availability, spacing, light and temperature, production costs, the market for timber and by-products, fires, damage caused by pests and diseases or natural events (Roveda; Dias; Figueiredo Filho; Scavinski; Castro, 2016), and, as seen in this study, damage caused by animals in integration systems when they are not released at the right time.

Bringing animals earlier into integration systems to optimize animal production gains can damage the development of the tree component. Therefore, for the SPS to be able to confirm their potential, it is necessary to observe the optimum time for animals to enter the system, always based on tree size, to reduce possible harmful interactions between the tree/animal interface.

5 CONCLUSIONS

The early animal entry into the silvopastoral system negatively influenced the growth and survival of the eucalyptus clones.

Eucalyptus clone VM01 displayed better development than clone I144 when planted in a silvopastoral system in the southwestern Amazon region.

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