v. 5, n. 4, 2025

Journal of
Agricultural
Sciences
Research

Acceptance date: 25/04/2025

INITIAL ESTABLISHMENT OF THREE TREE SPECIES IN THE AFFORESTATION OF A DEGRADED AREA ON THE BANKS OF THE RIBEIRÃO DO GAMA DAM IN THE FEDERAL DISTRICT[1]

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Abstract: The study was conducted at Fazenda Água Limpa, owned by the University of Brasilia (15º55'S and 47º53'W). The experiment was set up during the rainy season in the Central Brazil region, with the aim of monitoring the initial establishment of forest species when used in the afforestation of a stretch on the right bank of the Gama stream dam. 552 seedlings of three species were used: *Tapirira guianensis* Aublet, *Hymenaea courbaril* Linnaeus and *Crtptocarya aschersoniana* Mezzidem. 369 individuals were planted in one area (area 1) and 183 in another (area 2). Survival rate and biometric development (height and collar diameter) were assessed. In areas 1 and 2, the seedlings showed 74 % and 57 % survival rates respectively, with the highest rates in both areas being achieved by the following species: *T. guianensis* (88 % and 90 %), *H. courbaril* (66 % and 46 %) and *C. aschersoniana* (67 % and 39 %). Considering the biometric evaluation, the species had the following height and diameter measurements, respectively: *T. guianensis* (72.4 cm and 15.6 mm), *H. courbaril* (49.4 cm and 8.1 mm) and *C. aschersoniana* (54.3 cm and 6.3 mm). The higher survival rate and higher biometric averages of the *T. guianensis* species can be attributed to its good adaptation to hydraulically saturated soils with a high aluminum saturation content.
Keywords: Tapirira guianensis, Hymenaea courbaril and Cryptocarya aschersoniana

INTRODUCTION

Afforestation of degraded environments consists of trying to provide forest cover to the altered area, and differs from rehabilitation, which aims to restore characteristics similar to the original ones. In general, consortium plantings of native species already adapted to the conditions of the natural environment should be adopted, with the aim of creating a microclimate and supply of resources similar to the conditions previously found (Felfili *et al.* 2000).

Kageyama *et al.* (1992) state that advances in technology have brought marked improvements to revegetation projects, bringing them ever closer to restoring ecosystems. However, the term recovery is still widely used to refer to any action that makes it possible to revert a degraded area to a non-degraded condition. The subject of recovering degraded areas has been the subject of numerous studies over the last few decades, and is already a consolidated line of research. The recent theoretical and methodological advances in this area have been fundamentally due to the application of accumulated knowledge in the field of ecology, especially the dynamics of forest communities (Rodrigues and Gandolfi, 2000). There is almost a consensus among researchers working in the field of environmental recovery that creating a forest similar to the original, with all its peculiarities in terms of diversity, regeneration and interaction, is an almost utopian ideal (Kageyama and Gandara, 2000).

Thus, rebuilding or reorganizing a forest ecosystem implies knowledge of the complexity of the phenomena that develop in these environments (Rodrigues and Gandolfi, 2000).

According to Duringan and Silveira (1999), the purpose of recovering degraded areas is to restore ecological functionality to the ecosystem. In this context, environmental recovery has not been restricted to tree planting, but to the development of research and environmental recovery programs that take into account the strategies or disputes of species within the dynamics of forests.

Thus, environmental recovery based on forest succession has been the most successful system, due to the fact that it favors the rapid re-covering of the soil and consequently the self-renewal of the forest (Botelho *et al.* 1995). It is estimated that there are more than 100 million hectares of degraded soil in Brazil. Actions such as mining, road building, dams and industrial areas have an immediate impact on the soil. There are various techniques for revegetating degraded areas, including using fertile soil layers from other locations as a way of allowing vegetation to establish itself (Castro and Kluge, 1998)

The aim of this study is to evaluate the initial development of three native gallery forest species in the afforestation of a degraded area, characterized by its allochthonous soil, which was landfilled and terraced in the 1960s during the construction of the Gama stream dam and is currently located within the Gama and Cabeça-de-Veado Environmental Protection Area in the Federal District.

MATERIAL AND METHODS

The study was carried out at Fazenda Água Limpa/FAL, owned by the University of Brasília/UnB (15^0 55'S and $47^{(0)}$ 53'W), in an area located on the right bank of the Gama stream dam. According to current legislation, the study area is a Permanent Preservation Area and wildlife zone of the APA - Gama and Cabeça de Veado (Felfilli *et al.* 2000).

The forest species used to set up the experiment were: *Tapirira guianensis* Aublet, *Hymenaea courbaril* Linnaeus and *Cryptocarya aschersoniana* Mezzidem. The seedlings used in the study were grown in plastic bags with a substrate made up of 75% black soil and 25% sand.

To carry out the study, two neighboring areas were selected, separated by a fence, located on a stretch of the right bank of the Gama stream dam, with visibly different characteristics in terms of the type of substrate. The difference in the physical characteristics of the two areas was visibly identified and confirmed after physical and chemical analysis of the soils. The larger area (300 m by 40 m) was called "Area 1" and the smaller area (100 m by 40 m) was called "Area 2"

When the seedlings were 18 months old, they were planted in the experimental areas. The individuals chosen for planting met the following criteria: homogeneity in terms of height, good plant health and phenotypic characteristics such as stiffness, color and structure. In Area 1, 360 individuals were planted (123 individuals of each species studied). Area 2 had dimensions of (100 m by 40 m) and 180 individuals (61 individuals of each species studied) were planted in area 2. Both areas were spaced 4 m by 3 m between plants and were monitored for 1 year in order to assess the initial development and survival of seedlings of the 3 species selected for the study.

Measurements and topographical analysis were carried out using a 100 m long tape measure. Soil was collected from both areas in order to send samples for chemical and physical analysis in the laboratory. A total of 28 single samples were taken from each area.

As the areas were in an advanced state of degradation with compacted and depleted substrate, the work to prepare the area for the experiment consisted of: clearing the land; digging holes; fertilizing (200 g of N-P-K and 800 g of tanned cattle manure/hole); liming and planting. These activities were carried out in the second half of 2003. The holes, about 75 cm deep and 55 cm wide, were dug with a 1 m long auger attached to a tractor.

Biometric assessments were recorded using a ruler and tape measure graduated in millimeters (0 to 1000 mm) and a digital caliper. Height measurements were taken from the base of the stem to the center of the canopy, considering the tallest leaf, while for measurements of the collar diameter, 5 cm was taken from the base of the plants.

The statistical model used to analyze the data corresponds to the Fully Randomized Design with Factorial Arrangement, which, according to Gomes (1966) is one that includes all the combinations of the various sets of treatments or factors, thus being able to evaluate more than one factor in the same trial, in addition to the possibility of evaluating the interaction of the effects of the factors with the most rational use of the available resources, since in the absence of an interaction effect the number of repetitions is increased in the test of the main effects.

The analysis of the data relating to the development of collar diameter and height showed two factors: substrate and species. For each combination of factors, 20 individuals per treatment (area) were analyzed. One data analysis was carried out for each period monitored. Each repetition was represented by one individual.

ANOVA was used at a 5% significance level, considering the interaction of each species studied with the substrate in which the individual was established as a treatment. In this way, the analysis included 6 treatments with 20 repetitions each, allowing us to identify which species differed statistically throughout the study.

Tukey's test (5%) was used as a means comparison test for comparing more than two means The study therefore analyzed 120 individuals out of the 552 established, 60 in each area. For the physico-chemical analysis of the substrates studied and the survival assessment, statistical analysis was carried out using arithmetic means.

RESULTS AND DISCUSSIONS

During the study period, 5 (five) survival measurements (30-day interval) and 3 (three) biometric measurements (60-day interval) were taken.

In general, individuals of the *T. guianensis* species showed better survival rates, as well as better development in terms of height and diameter of the collection of individuals established in the two areas studied. The *C. aschersoniana* and *H. courbaril* species showed similar growth, with slight variations. The first species showed better growth when established in the substrate in area 1, while the second species showed better growth when established in the substrate in area 2.

Some factors, when analyzed simultaneously, explain the results obtained, such as: better adaptation of a given species to soil conditions and better adaptation in relation to climatic conditions, especially in terms of rainfall between the months of December/03 and October/04 (one of the highest levels of rainfall in central Brazil in the last 20 years).

In order to chemically and physically characterize the substrate in the areas studied, it was necessary to carry out chemical and physical analyses. Substrate profiles were studied in each area, which generally revealed greater nutrient availability for the substrate in area 1, with the exception of phosphorus (P) content and base saturation percentage (%V). The physical characterization of the soils studied shows that the areas are similar in terms of the presence of sand, silt and clay (substrates classified as medium texture). The pH found in the substrate in area 1 and in the substrate in area 2 were similar (5 and 5.1 respectively), so they can be characterized as acidic. Potassium (K) availability was considered extremely low in area 2, unlike in area 1. Calcium (Ca) and magnesium (Mg) did not vary much between the areas, nor did the Ca+Mg ratio. It should be noted that the percentage of aluminum saturation (% Al) found in the substrates studied was considered high in both areas (characteristic of cerrado soils), especially in area 1.

Excess aluminum in the soil can be toxic to plants and is a limiting factor for their development, especially since soils saturated with aluminum can make the other macro and micronutrients present in the soil solution unavailable. Therefore, the fact that the substrates in the areas studied had high values of aluminum and aluminum saturation could, in some way, compromise the initial establishment of the population in the area. However, some factors stand out in area 1, such as: organic matter (OM), organic carbon (OC), potassium (K) and cation exchange capacity (CEC), which according to the chemical analysis, are considerably higher than the values found in area 2.

The textural determination of the substrates revealed a balance in clay content in both areas. There were also slightly higher levels of sand in area 1 compared to area 2, thus demonstrating that area 1 has better drainage and aeration conditions, while area 2 had higher levels of silt compared to area 1.

As far as genesis is concerned, there is not enough evidence to confirm the origin of these substrates, mainly due to the fact that they are allochthonous, i.e. they have been earthed and terraced, therefore with a high degree of anthropogenic movement, as a result of the construction of the Gama stream dam in the 1960s.

The rainfall found the rainy season (December to April) in the Brasília/DF region normally ranges from 90 to 110 mm/month (Ribeiro and Walter, 2008), reaching an average of 153.14 mm/month.

The first height and diameter measurements and the first two survival measurements of the individuals studied were taken between January and April, when the region had the highest rainfall rates.

From May onwards, insolation and evaporation values gradually increased, while rainfall values decreased. In the months of May, June, July and September, no significant rainfall was recorded.

After five (5) measures of species survival in the areas studied, the total percentage of survival in each area studied and the percentage of survival between species in area 1 and area 2 were analyzed.

The measurements were taken taking into account the rainfall rates found during the monitoring period, and were carried out every 30 days in January, March, May, July and September. In the first two survival measurements, it was possible to detect that the individuals established in area 2 had higher survival rates when compared to the individuals established in area 1 (96.75 % and 96.21 % respectively), while the survival rate achieved by the population established in area 1 in the first two measurements was 96.86 % and 93.26 % respectively. In the third survival measurement, carried out in May, a large variation was detected in the mortality percentage of the individuals studied in relation to the first measurements. From this third measurement onwards, it was detected that the individuals established in area 2 had proportionally higher mortality rates, unlike what had happened in the first two measurements. The last two measurements (the fourth and fifth) were carried out in July and September respectively, months characterized by insignificant rainfall. From the fourth evaluation onwards, there was an increase in the mortality rate compared to the previous evaluations. After these last two measurements, the same trend as seen in the third measurement was confirmed. The individuals established in area 2 showed a large increase in the mortality rate compared to the individuals established in area 1.

In area 2, there was a high variation in mortality rates. The fact that the substrate in area 2 has a lower amount of organic matter (OM), which is a fundamental component in the fixation and initial establishment of forest species when introduced into open field areas, may explain the high mortality rates. Of the 183 individuals established in area 2, around 104 are expected to reach adulthood and adapt to the environment in which they were introduced, representing a 56.83 % survival rate.

The interspecific survival of the individuals studied was also assessed. Some preliminary data was analyzed, such as the total number of seedlings planted and the number of seedlings planted per species studied.

According to the interspecific survey, it was possible to observe that *T. guianensis* was the species that showed the best development in both areas, reaching the end of the study with the mortality of 15 (fifteen) plants in area 1 and 6 (six) plants in area 2, thus representing a mortality rate of 9.84 % in area 2 and 12.2 % in area 1. With regard to the *C.* aschersoniana seedlings established in area 2, it was possible to detect that this species did not show the best initial development. *aschersoniana seedlings* established in area 2, it was possible to detect from the survival assessments that this species did not show good initial development. This species showed the highest mortality rates, reaching 60.6% in area 2 and 32.5% in area 2, corresponding quantitatively to 40 individuals in both areas that failed to develop. The *H. courbaril* species showed mortality rates of 54.1% in area 2 (33 individuals) and 34.2% in area 1 (42 individuals).

Area 1 has higher levels of organic matter (OM), which is essential for establishing seedlings in the early stages of development, as it is a source of nutrients for plants.

According to Malavolta (1976), soil organic matter represents a large number of materials of plant and animal origin in various stages of decomposition, and is an important regulator of erosion processes and protection of the soil against the impact of raindrops, reducing disintegration and sealing of the surface, ensuring greater water infiltration and less soil drag. Soil rich in organic matter reduces soil losses by up to 90% and runoff by up to 70%, while also preventing nutrient losses, which are proportional to soil and water losses (Ramos *et al.* 2001).

Losses of P, K and Ca and Mg are greater in areas poor in organic matter, while other factors such as temperature and water retention are affected by the amount of organic matter in the soil. The main effect, however, is the increase in stored water and soil humidity, with positive effects on productivity when there are veranicos during the development of the species. Soil structure improves, biological activity increases and the availability of nutrients such as P and Ca increases. All these factors contribute to an increase in the yield of the species and, certainly, this factor, among others, made it possible to reduce the mortality rate in areas 1 and 2 (Malavolta, 1976).

In its natural state, the soil is covered by vegetation which protects it from erosion and helps to maintain a balance between the factors that form it and those that cause its degradation. Disruption of this relationship causes physical, chemical and biological changes which, if not properly monitored and controlled, lead to a drop in productivity and degradation of the ecosystem (Siqueira, 1994). Degraded soils can be recovered and, if this occurs, the impact will be reduced in various ways, such as reducing the degradation of other resources such as fauna, flora and water. Microorganisms contribute to this and are essential for rehabilitating degraded soils and re-establishing vegetation cover (Ladim and Barbosa, 1996).

According to the results obtained from the soil analysis, it should be noted that in relation to the initial development of plants, area 1 has a greater amount of organic matter (44.5 g/kg) while area 2 has almost four times less (around 13.3 g/kg). This high variation in the amount of organic matter may explain the better survival rate in area 1 and the better development of living individuals observed in this area.

According to Britez (2000), soils rich in organic matter have a higher cation exchange capacity (CEC), so it is important to note the large difference in the CEC values of area 1, which are almost three times higher than those of area 2.

Invasive plant infestation rates were not measured during the study, but the high presence of these plants certainly increased the nutritional competition between the established species, especially the exotic grasses of African origin: *Melinis minutiflora* and *Andropogon gayanus*, which are easy to establish and grow quickly in the biome studied. Area 1 had a visibly greater number of plants, which is possibly due to the higher concentration of organic matter

When it came to assessing survival among the species studied, individuals of the *T. guianensis* species achieved good survival rates, mainly due to the fact that it is a plant that adapts very well to riparian environments, is not very nutritionally demanding and is native to central Brazil, has a wide geographical distribution and can colonize areas with both well-drained soils and soils with poor drainage (Lorenzi, 1998).

According to Carvalho (1994) the *H. courbaril* species is considered to be a plant that is easily adapted to the central region of Brazil and in some cases a certain tolerance to high levels of water in the soil has been reported, but nothing compared to the establishment of the *T. guianensis* species. The physical analysis of the substrates in the areas studied is of fundamental importance, as the appropriate selection of species is, if not the main guarantee of success in recovery programs for degraded areas, where revegetation through the planting of seedlings of native species accelerates the process of natural regeneration (Rodrigues and Gandolfi, 2000). It is important to identify the species that best adapt to physically and chemically depleted soils. It should be noted that the planting areas have visibly uneven topography, making it difficult for water to drain into the areas.

After evaluating the height and collar diameter of the seedlings studied in the field, it was possible to carry out a detailed analysis of the development of the individuals using analysis of variance and a mean comparison test (5%) using the "Genes" statistical program from the Federal University of Viçosa/MG.

In general, individuals of the *T. guianensis* species showed better development in height and diameter at the end of the evaluations when compared to individuals of the other two species studied.

Analysis of variance was carried out for factorial arrangements using the height and collar diameter data of the seedlings in the three monitoring periods. Arithmetic means were used for the survival evaluations, as the data for this analysis is reduced and simplified.

It was observed that, in relation to the first evaluation of the height of the individuals studied, the substrate X species interaction was significant and, therefore, it was necessary to evaluate the substrate in area 1 and the substrate in area 2 separately, as this interaction shows that there is an influence of the type of substrate in relation to the development of plant height.

From the specific analyses, it can be seen that in relation to the first height assessment, the substrate in area 1 does not significantly influence the development of the three species studied, i.e. the same species that adapts best to the substrate in area 1 also adapts to the substrate in area 2. For the substrate in area 2, however, there is a significant difference between the three species established, which is why the mean comparison test is necessary for the analysis of variance of the substrate in area 2 as a function of the first height assessment.

With regard to the second and third height evaluations, it can be said that the interaction between substrate and species was not significant. Therefore, it can be concluded that the same species that is best adapted to the substrate in area 1 is also best adapted to the substrate in area 2, both in the second and third height evaluations.

The analysis shows that there is a significant interaction between the substrates studied (substrate in area 1 X substrate in area 2) and between the species analyzed (*T. guianensis* X *C. aschersoniana* X *H. courbaril*). In these cases (second and third height evaluations) it is necessary to carry out the mean comparison test, so that the effect of each species and each substrate is known. According to the species

Journal of Agricultural Sciences Research ISSN 2764-0973 DOI https://doi.org/10.22533/at.ed.973542512035

mean comparison test carried out in the second and third height evaluations, it can be concluded that the individuals of the *T. guianensis* species showed better average growth when compared to the other two species.

Based on the analysis of variance carried out, it can be concluded that in the first assessment of the diameter of the seedlings studied, there was no significant interaction between substrate and species, although there was a significant interaction between the species.

In this case, it is necessary to carry out the mean comparison test only for the species in relation to the first assessment of the development of the collar diameter. In relation to the second and third evaluations of the development of the diameter of the collar of the seedlings studied, it can be concluded that there was no significant interaction between substrate and species, but from the analyses, it can be detected that there is a significant interaction between the substrates studied and between the species analyzed. In these cases (second and third evaluations), it is necessary to carry out a mean comparison test for both substrate and species, so that the effect of each species and substrate is known.

According to the mean comparison test for species, it can be concluded that, in relation to the first, second and third assessments of the development of the diameter of the collection of the individuals studied, the species *T. guianensis* has a better average development of the diameter of the collection when compared to the other two species (as occurred in the height assessments). Individuals of the *H. courbaril* species showed better development in the diameter of the collar when compared to individuals of the *C. aschersoniana* species. According to the mean comparison test for substrates in relation to the second and third assessment of the diameter of the collar, the substrate in area 1 had better conditions for establishment when compared to the substrate in area 2.

Individuals of the *T. guianensis* species, from the first assessments of height and crown diameter, always showed better conditions for establishment, both in area 1 and area 2 when compared to the other two species studied.

The months of May to September are characterized by high levels of sunshine, a factor that may have limited the development of the height and diameter of the collar of the *C. aschersoniana* seedlings, since it was during this period that the development rates of these individuals practically stagnated.

The results obtained from the height and diameter assessments of the species studied show that the individuals established in the two areas reacted to the abrupt climate change in terms of rainfall, evaporation and insolation.

One factor that may explain the poor performance in relation to the initial establishment and development of *C. aschersoniana* individuals during the experiment is that recent scientific studies have shown that the species develops more quickly in partially shaded environments , without the constant presence of sunlight, as well as being a species belonging to the ecological group of shade-tolerant climax species (Almeida *et al.* 2004).

The species *C. aschersoniana* and *H. courbaril* have been recommended for mixed plantings in programs to recover degraded areas, disturbed environments, riparian forests and to restore the banks of reservoirs (Almeida *et al.* 2004).

Species that can withstand water saturation can be divided into "tolerant" species, which are those that are metabolically adapted to tolerate stress, and "apparently tolerant" species, which are those that show morphological and physiological adaptations to avoid stress.

The *T. guianensis* species is morphologically adapted, showing good establishment in areas with well-drained soils, as well as flooded soils.

Excessive rainfall also contributed to the increase and rapid development of spontaneous plants, and the fact that the study area is considered to be degraded by anthropogenic actions and has not received forestry procedures for a long time, ended up making it a favorable ecosystem for this species.

The chemical conditions found in the substrates studied, especially the levels of aluminum (Al) and aluminum saturation (% Al) can also explain the development of height and collar diameter of the seedlings monitored in the experiment areas, as an excess of this element can make the absorption of macro and micronutrients present in the soil solution unavailable.

One factor that stands out from the chemical analysis of the substrates in the areas studied is the level of aluminum saturation (% Al), which was found to be around 55% in area 1 and 43% in area 2.

According to Malavolta (1976) aluminum is the third most abundant element in the earth's crust, after oxygen and silicon. Aluminum comprises approximately 15% of the earth's surface, appearing in the soil as fragments of aluminosilicate rocks, secondary minerals of an aluminosilicate nature (clay), hydroxides, aluminum salts and in solution. The amount of aluminum in the soil solution is related to its pH. Aluminum is concentrated in the lithosphere and is practically absent in the deeper layers of the earth. The nutritional state of cerrado vegetation began to be discussed in the 1950s, and it was found that the vegetation of the cerrado region was associated with nutrient-poor soils, which resulted in the formulation of the theory of oligotrophic scleromorphism, resulting in the theory of aluminotoxic scleromorphism.

Malavolta (1977) discussed the toxic effect of aluminum on vegetation and also raised the problem of manganese toxicity. Small amounts of aluminum can indirectly benefit plant growth. Aluminum toxicity cannot be diagnosed through visual symptoms or analysis of the aerial part, but what can be seen in soils with high levels of aluminum is a reduction in plant growth.

According to Britez (2000), *T. guianensis* is not an aluminum-accumulating species, and the tolerance of this species to aluminum in its natural environment is related to the exclusion of this element in the root through biochemical and microbiological changes in the rhizosphere.

C. aschersoniana is also not an aluminum-accumulating species, but the unsatisfactory development of this species can be explained mainly by the fact that individuals of this species have shown that their best development occurs when planted in partially shaded environments, without the constant presence of sunlight (Almeida *et al.* 2004).

After surveying various forest species in four different communities in the Central Brazil region, he found that the species *T. guianensis* did not accumulate aluminum in any of the communities studied. On the other hand, the species *H. courbaril* was characterized as an aluminium-accumulating plant.

It should be noted that according to Haridasan (2000), in the early 1970s, the issue of aluminum accumulation in native cerrado plants was raised for the first time. At the time, it was suggested that the scleromorphism of native cerrado plants could be due to aluminum toxicity, since the symptoms of aluminum toxicity are similar to those of essential nutrient deficiencies.

THANKS

We would like to thank the Forest Engineering Department of the University of Brasilia, the Água Limpa Farm and the National Meteorological Institute.

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