INTERNATIONAL SEVEN JOURNAL
OF MULTIDISCIPLINARY
ISSN: 2764-9547

Practices for direct sowing in an improved cerrado area: Emergence, survival and initial growth of forest species

Práticas para semeadura direta em área de cerrado melhorado: Emergência, sobrevivência e crescimento inicial de espécies florestais

DOI: 10.56238/isevmjv2n5-003
Receipt of originals: 08/21/2023
Acceptance for publication: 11/09/2023

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ABSTRACT
Considering that research on survival and growth of forest species via no-tillage in the improved cerrado of Roraima is still scarce, this research adds information to this technique with six forest species regarding emergence, survival and increase in height and diameter of plants over 18 months. In view of the above, the objective was to indicate procedures for direct sowing of tree forest species (pau-rainha, maçaranduba, freijó, jatobá, itaúba and African mahogany) in a cerrado area of Roraima, with the use of shrubby legumes, as a way to dispense with the formation and management of seedlings in nurseries and allow the establishment of forest plantations with reduced costs. Thus, in the experimental area each species, maçaranduba, freijó, jatobá, itaúba, pau-rainha and African mahogany in July 2021 were sown every 50 cm apart, in the row and distributed two seeds at a depth of up to 1 cm according to the size of the seed. The experiment occupied a total area of 4,500 m2 and a useful area with seeds sown of 3,456 m2, totaling 648 seeds per species. The percentage of emergence was evaluated at 120 days after sowing, and seedling survival after 6, 12 and 18 months. In addition, the increments in height and diameter were evaluated from 6 to 12 months and from 12 to 18 months. Of the six forest species studied, 2% (pau-rainha), 6% (African mahogany) and 53% (jatobá) of seedling emergence presented 2% (pau-reira), with survival >80% after 18 months. In the same period, African mahogany and queen's wood had a survival rate of 50%. Direct sowing in the improved cerrado from Roraima to Jatobá is recommended. The procedure used to promote the increase in stem diameter (ΔDC) of jatobá plants from no-tillage via seeds from six to 18 months is the application of 3.0 t ha-1 of limestone and 1.8 t ha-1 of agricultural gypsum in the cerrado of Roraima, being an appropriate species for the establishment of forest plantations with costs of 1.55 reais per seedling.

Keywords: Ecological restoration, Native and exotic species, Seedling emergence, Pau-rainha, Freijó, Jatobá, African Mahogany, Itaúba, Maçaranduba.

1 INTRODUCTION

The origin of the cerrados of Roraima dates to a recent geological past: late Pleistocene and during the Holocene era, that is, from 20,000 to 10,000 years ago. The soils, in their great majority, had as source material, sandy and clayey sediments, extremely poor in minerals, resulting in soils of light texture and very poor in nutrients. On them developed a native vegetation of savannah/cerrado, whose predominant species are: *Trachipogon plumosum* (grass); and *Curatella americana* o Caimbé/lixeira (BRAZIL, 1975).

The pasture aspect given by the native vegetation motivated the first exploitation of this vegetation with cattle ranching introduced in the State in 1789 (RORAIMA, 2003). This livestock developed without removal of native vegetation, but used fire intensively so that the animals grazed the soft shoots of the native grass. These fires destroyed the entire aerial part of the native vegetation leaving the soil uncovered under the sun and intense rains giving rise to compacted soils and poor in organic matter.

We then have a landscape with: soils poor in nutrients, low levels of clay and organic matter that are reflected in the low capacity to store water and nutrients for plants. That is, to do intensive quality agriculture/livestock we had to: first, build the soil with full chemical correction on the surface and sub-surface, as well as promote the addition of large amounts of living or dead plant material to protect and incorporate organic matter into the soil.

To perform this procedure, there is a need for high investments that an annual grain harvest does not cover the cost. Thus, consortia and crop rotation with legumes, forage grasses, no-tillage, crop-livestock integration and, finally, crop-livestock-forest integration emerged, which prolong the period of exploitation and improve the economic performance of the area.

It is worth mentioning that the climate of the cerrados of Roraima is imposed with high temperatures all year round, with the average of the minimum of 23ºC and the maximum of 33ºC which gives precocity, quality and productivity to the crops exploited. The rainfall regime, however, has two well-defined periods: one dry and one rainy, both of approximately six months.

During the dry season the rains are quite scarce not allowing the cultivation of grains without irrigation and the rainy season presents quite intense rains with accentuated water surplus, requiring the use of appropriate technologies to avoid soil degradation, especially soil cover and no-tillage.

The use of the state's cerrados with agriculture and suppression of native vegetation is recent. It began in the 1970s with the cultivation of dryland rice, then came the cultivated pastures, the cultivation of soybeans in the nineties more recently, the crop-livestock integration and the crop-livestock-forest integration. There were also plantations of homogeneous forests of *Acacia mangium*, African mahogany (*Khaya* spp.) and Eucalyptus. Today it is estimated a cultivated area of approximately 300,000 hectares, approximately 30% of the cerrados available for planting.

In the research carried out with soil correction and management, since 1983, the need for total soil correction both on the surface and in the sub-surface, the permanent soil cover, no-tillage and the use of integrated production systems were revealed. For the implementation of these integrated systems we already had available the necessary technologies for the production of grains, however the forest component lacks additional technological information, especially regarding the species suitable for planting, the forms of establishment and propagation, as well as the necessary care with the soil profile.

It should be noted that the forest component, especially the native component, has the functions of participating in the integrated production systems, but also participating in the forest replacement. In turn, the restoration technique of these degraded areas can be carried out by planting seedlings with superior quality and suitable for field conditions. This technique has been used in most situations.

Moreover, the development of technologies aimed at restoring these areas, at reduced costs, is essential, considering that these areas are often in the possession of small owners, who have little or no resources available to use in reforestation (SMIDERLE et al., 2023).

It is important to consider that there are more risks for seedling survival by the no-tillage methodology in the field than in the seedling planting methodology. However, no-tillage in the field becomes a promising and inexpensive option in the process of recovering degraded areas (SMIDERLE et al., 2023).

Another major challenge for the recovery of areas is the choice of species to be used in this process. For the cerrado, the use of native leguminous species, whether forage or arboreal, has been studied (CAVA et al., 2016).

In view of the above, the objective was to determine the success of emergence, survival and increase in height and diameter of the sandpiper, freijó, jatobá, itaúba, pau-rainha and African mahogany, on different doses of limestone and gypsum applied in 2015, aiming to select the best soil procedure and the best forest species via direct sowing for this cerrado condition and as well as the use of shrubby legumes, as a way to dispense with the formation and management of seedlings in nurseries and allow the establishment of forest plantations with reduced costs.

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2 METHODOLOGY

The present study was carried out in the Experimental Field Água boa, belonging to Embrapa Roraima, in the municipality of Boa Vista-RR. The history of the improved cerrado area (Image 1) in the Água Boa Experimental Field, prior to the direct sowing of forest species (maçaranduba, freijó, jatobá, itaúba, pau-rainha and African mahogany), was occupied with annual plantations (soybean and corn) and fallow between 2017 and 2019.

2.1 HISTORY OF THE STUDY AREA

In 1983, the work of fertility and soil management began in the fields of Roraima, when the reigning idea was that in the ploughed (cerrados) nothing would be produced, only served to create "calangos and anteaters". The tests that Embrapa Roraima had carried out, until then, presented very low yields, especially grains and pastures. It was then identified, through field research, the need and/or obligation to perform total correction of the soil with liming, plastering, macro and micronutrients.

With the correction of the soil and the adjustment of fertilization, the crops responded with high yields, already in the first year of planting or opening of the area from the native vegetation. That is, all inputs had first, a nutritional role and then a role of soil corrective. With these corrections and recommended fertilizations, the yields of the experiments reached: irrigated rice, 12,000 kg ha-1: soybean, 4,000 kg ha-1; and, corn 10,000 kg ha-1, in contrast to the results without soil correction of 3.500 kg ha-1 for rice and no productivity for soybean and corn.

The correction of the soil and the adjustment of the fertilizations, therefore, solved the problems of productivity, however they required high investments that only one annual cultivation was not enough to amortize them. In addition, soils poor in organic matter and without cover brought instability in crop productivity and real risk of degradation of the soil itself. In these stages of the research it was evident that, in order to produce well and sustainably in the fields of Roraima, it was necessary to completely correct the soil and use management systems that promoted soil cover and the addition of appreciable amounts of organic matter.

We also needed high productivity and economic profitability to fund the initial investments. Then came the consortia and crop rotation with legumes, forage grasses, no-tillage, crop-livestock integration and, finally, crop-livestock-forest integration that improved the economic performance of the productive system. The exploitation of the crop and livestock components are already relatively dominated, the forest component, however, lacks additional technological information, especially regarding species suitable for planting, the forms of

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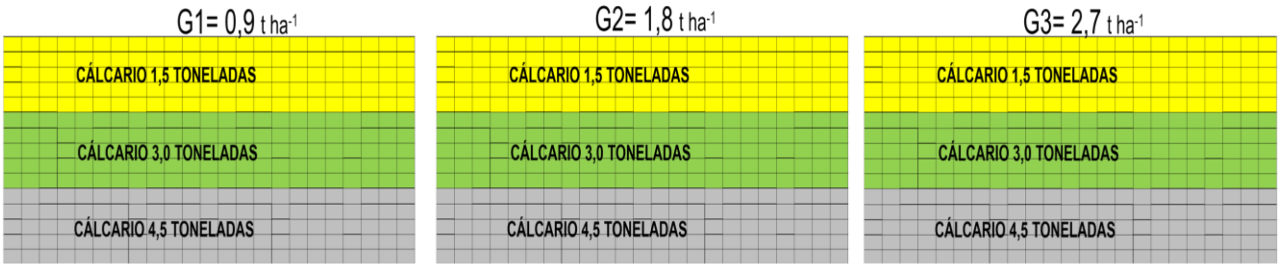
establishment and propagation, as well as the necessary care with the soil profile. The present research was designed with the perspective of removing these difficulties and bringing the missing information to the forest component.

2.2 LIMESTONE AND GYPSUM MANAGEMENT PROCEDURES FOR NO-TILLAGE IN CERRADO AREA OF RORAIMA AND AS WELL AS THE USE OF SHRUBBY LEGUMES

The present research was installed on a native vegetation of 4,500 m² that was burned and the soil systematized with a leveling grid. Immediately after, correction was applied with three doses of limestone (1,500, 3,000 and 4,500 kg ha-1) crossed with three doses of gypsum (900, 1,800 and 2,700 kg ha-1) in 2015. It is worth mentioning that corrective fertilization was also performed with 500 kg ha-1 of Triple Superphosphate (ST), 200 kg ha-1 of KCl and 50 kg ha-1 of FTE BR 12. This was followed by incorporation with a ploughing grid, a leveling grid and then sowing with a conventional fertilizer seeder.

In general, in 2015 in the experimental field Água Boa - Embrapa Roraima, soil management was carried out in an experimental area (Image 1) with the application of three doses of limestone (1.5; 3.0; and, 4.5 t ha-1) and three doses of agricultural gypsum (0.9; 1.8; 2.7 t ha-1) where the doses of limestone occupied the plots (C1, C2, C3) and gypsum doses the subplots (G1, G2, G3).

Image 1: Detailing of the distribution procedures of agricultural gypsum (G1, G2, G3) and limestone (C1, C, 2, C3) in the experimental area in the Campo do água boa, belonging to Embrapa Roraima, in the municipality of Boa Vista-RR.



Source: Smiderle e Souza, 2023

The seeds of BRS 8381 were treated and inoculated according to the soybean production system (SMIDERLE et al., 2009) and sown in a population of 400 thousand plants $^{ha-1 on 06/}$29/2015 and 05/21/2016. The basic fertilization consisted of 300 kg ha-1 of the formula 03-28-09 which also contained: 10%Ca; 8%S; 0.3%Zn; 0.3%Mn; 0.12%B; and, 0.12%Cu. Cover fertilization was performed with 100 kg $^{ha-1}$ of KCl, plus one spray with CoMo and micronutrients. Soil samples

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OF MULTIDISCIPLINARY
ISSN: 2764-9547

were also taken and analyzed for the impacts of liming and gypsum, the results of which are presented in Table 1 and Table 2.

Table 1. Impacts of liming on pH in water, base saturation (V) and aluminum saturation (m) of the soil, up to 55 cm depth, after the first harvest (2015) and second harvest (2016)

LIMESTONE	PROF	pH in H2O		V (%)		m (%)	
	(cm)	2015	2016	2015	2016	2015	2016
C11	0 - 15	5,4	5,5	46	24	6	22
	15 - 35	4.4	4,6	17	21	49	48
	35 - 55	---	4,6	---	22	---	53
C2	0 - 15	5,9	6,1	66	51	0	0
	15 - 35	4,5	4,8	18	26	47	40
	35 - 55	----	4,6	----	20	----	55
C3	0 - 15	5,9	6,3	54	56	0	0
	15 - 35	4,4	4,9	20	26	35	34
	35 - 55	---	4,6	----	23	----	49

[1] C1; C2; C3= 1.5; 3.0 and 4.5 t $^{ha-1}$ of limestone, respectively.

Data Source Provider: GIANLUPPI et al. (2017)

In the period 2017 to 2019 the experimental area was fallow and taken over by invasive plants of *Andropogon gayanus* whose aerial mass production was brushed and left on the soil surface (close to 28 t $^{ha-1}$). In 2020, on May 21, the second chemical desiccation with roundup (same dosage as the first) was performed. After four days, that is, on May 25, 2020, *Estilosantes capitata* was manually sown.It is worth mentioning, the corn was planted on May 28, 2020, in turn, for the base fertilization and cover were used the same as the experiment with soybean BRS 8381. In addition, at 30 days after the sowing of the corn in the 2020 harvest, the stylosantes were sown and, between the rows of corn, guandu beans (*Cajanus cajan*) were planted with a manual planter type matraca, that is, intercropping corn and guandu beans.

Table 2. Impacts of gypsum doses on pH, base saturation (V) and aluminum saturation (m) of the soil, up to 55cm depth (PROF. cm), after the first (2015) and second (2016) soybean harvests

		pH in H2O		V (%)		m (%)	
CHALK	PROF.	2015	2016	2015	2016	2015	2016
G11	0 - 15	5,6	5,9	59	26	2	11
	15 - 35	4,4	4,7	18	26	50	38
	35 - 55	----	4,6	---	21	---	53
G2	0 - 15	5,7	5,9	54	44	2	7
	15 - 35	4,4	4,7	19	24	49	43
	35 - 55	----	4,5	---	21	----	53
G3	0 - 15	5,8	6,1	53	47	3	4
	15 - 35	4,4	4,8	18	23	49	42
	35 - 55	---	4,6	----	23	----	51

[1] G1; G2; G3= 900, 1,800 and 2,700 kg ha-1 of gypsum, respectively.

Data Source Provider: GIANLUPPI et al. (2017)

The corn harvest was carried out with a mechanical harvester in the second half of September 2020. After collection, soil samples were taken at depths of 0-20 cm, and the physicochemical characteristics were analyzed, the results of which are presented in Table 3.

Table 3. Physicochemical characteristics of the soil of the experimental area after the cultivation of soybean, corn carried out in the years 2019/2020

Deepen. (cm)	pH	P	K+	Na+	H++H+3	Up to+3	Ca+2	Mg+2	SB	CTC	V	m	M.O.
	H2O (1:2,5)	mg/dm3		cmolc/dm³							%		g/kg
0-20	5,9	52,20	28,28	1,93		0,03	1,66	0,48	1,48	1,87	49,0	2,0	14,72

H++Al+3: Potential acidity; SB: Sum of bases; CTC: Cation exchange capacity; V: Base saturation; m: Aluminum saturation; M.O.: Organic matter.

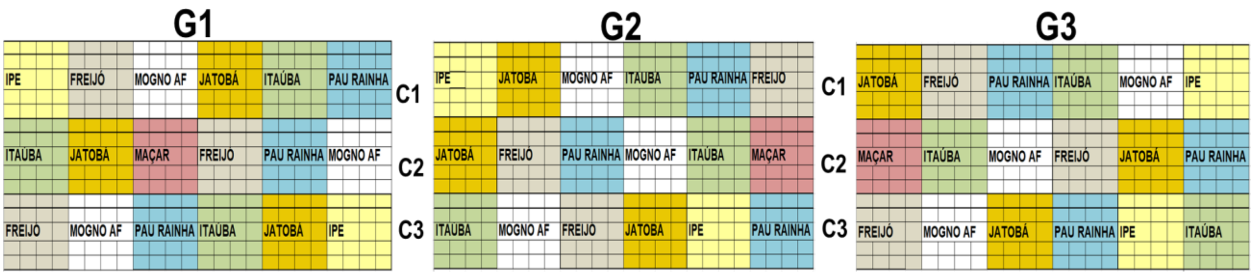
Source: GIANLUPPI et al. (2017)

2.3 PROCEDURES FOR NO-TILLAGE IN CERRADO AREA OF RORAIMA AIMING AT THE ESTABLISHMENT OF NATIVE AND EXOTIC FOREST SPECIES

The phytotechnical management of the guandu bean consisted of semiannual pruning (October 2020 to April 2021), carried out before no-tillage. These green and dried branches and leaves were distributed over the soil, in order to obtain phytomass as green manure.

The forest component was introduced, via seeds, between the rows of guandu at the beginning of the rainy season after the corn harvest, taking advantage of the shading of the legume to protect the emerging wood seedlings. The distribution of the seeds of each forest species was carried out as can be seen in the sketch of Image 2 of the area from the annual crops with three doses of limestone (1.5; 3.0; e, 4.5 t ha-1) and three doses of agricultural gypsum (0.9; 1.8; 2.7 t ha-1) where the doses of limestone occupied the plots (C1, C2, C3) and gypsum doses to subplots (G1, G2, G3), respectively.

Image 2: Schematic visualization of the distribution of seedlings of maçaranduba (MAÇAR), freijó (FREIJÓ), jatobá (JATOBÁ), itaúba (ITAÚBA), pau-rainha (PAU-RAINHA) and African mahogany (MOGNO AF).

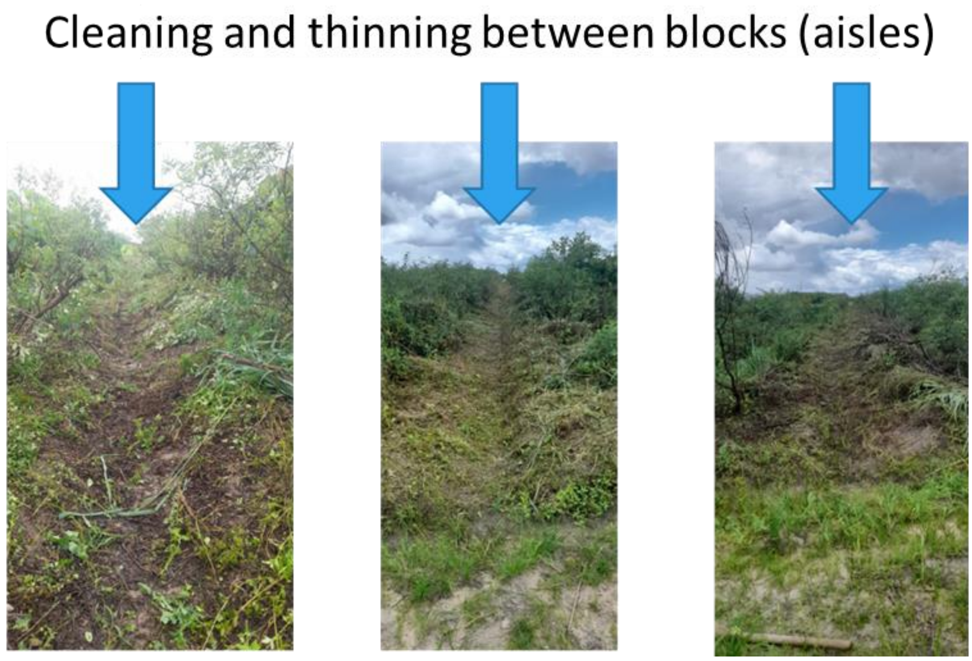


Source: Smiderle and Souza, 2023

2.4 CULTURAL TREATMENTS

Cultural treatments (weed control) were performed according to Image 3, following longitudinal lines. The control was carried out every 30 days with the aid of pruning, sickle and brushcutter in the thinning of the weeds. After implementation of the experiment, no artificial irrigation was performed, and in this period the experimental area was favored with rainfall that extended from year to year (2021-2022).

Image 3. Visualization of thinning of invasive plants in the experimental aerial



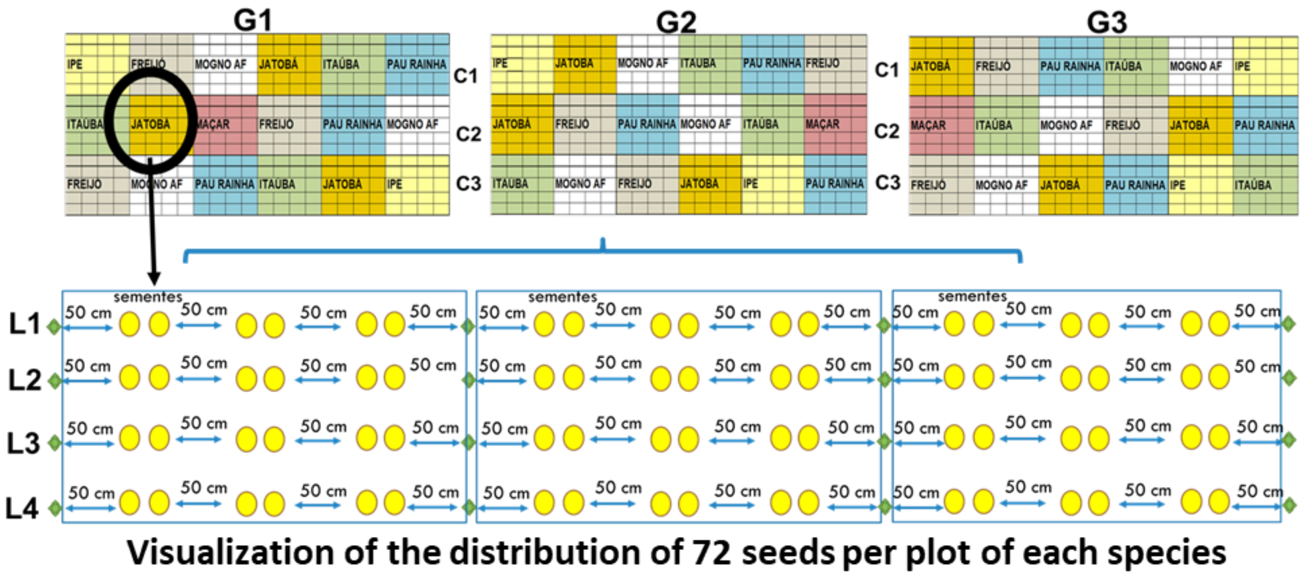
Source: Photos by Oscar Smiderle

2.5 PROCEDURES FOR NO-TILLAGE OF FOREST SPECIES

To analyze the influence of seed size on seedling emergence and initial establishment, the seeds used of (maçaranduba (MAÇAR), freijó (FREIJÓ), jatobá (JATOBÁ), itaúba (ITAÚBA), pau-rainha (PAU-RAINHA) and African mahogany (MOHOGANY AF)) were evaluated for physical characteristics, by determining the specific mass, using a precision analytical balance, and by means of their morphometric characteristics (length, width and thickness), with the aid of a digital caliper (0.05 mm).

Thus, the jatoba seeds that were classified as dormant, went through a previous treatment process to overcome dormancy, according to Smiderle and Souza (2022). The seedling emergence was also monitored in seedling at the seedling nursery of Embrapa Roraima to determine the vigor. In the field, that is, in the experimental area each forest species, maçaranduba (MAÇAR), freijó (FREIJÓ), jatobá (JATOBÁ), itaúba (ITAÚBA), pau-rainha (PAU-RAINHA) and African mahogany (MOGNO AF) in July 2021 were sown in a row spaced 2 meters apart in the bands of the guandu bean plants, every 50 cm in the line two seeds were distributed at a depth of up to 1 cm according to the size of the seed (Image 4). The experiment occupied a total area of 4500 m2 and a useful area with seeds sown of 3456 m2, totaling 648 seeds per species (Table 4). Each plot (forest species) occupied an area of 64 m2.

Image 4. Scheme of implementation of the treatments in the plots according to the experimental design, of the no-tillage activity, every 50 cm in the row were distributed two seeds, in the depth of up to 1 cm, according to the size of the seed.



Source: Smiderle and Souza, 2023

In the field, emergence (Images 5 and 6A and 6B) was defined by the number of seedlings observed 120 days after sowing divided by the number of total seeds sown. The survival rate of these emergents for the semester (six months) was calculated by comparing the number of plants that survived six months after sowing divided by the number of seedlings that emerged (Image 6A and 6B).

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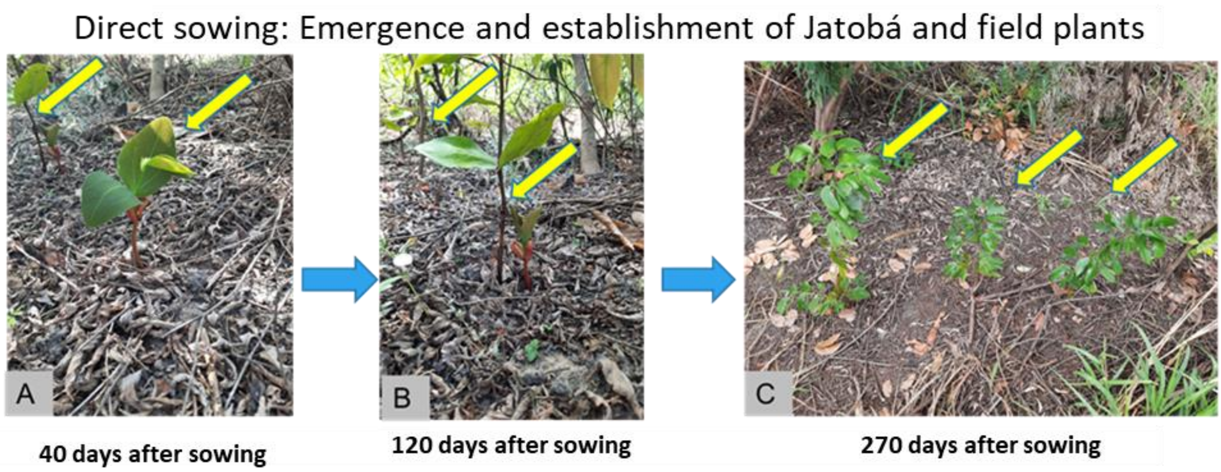
OF MULTIDISCIPLINARY
ISSN: 2764-9547

Image 5. Emergence of jatobá seedlings in no-tillage in the field.

Source: Photos by Oscar Smiderle

Survival for the first year was calculated by comparing the number of plants that were alive after 12 months divided by the number of seedlings that emerged at 120 days. Finally, the calculation of the survival rate for the 18 months was calculated by comparing the number of plants that were alive after 18 months divided by the number of seedlings that emerged at 120 days.

Image 6. Seedling emergence from no-tillage at 40 DAS (A and B) and seedling survival (C).

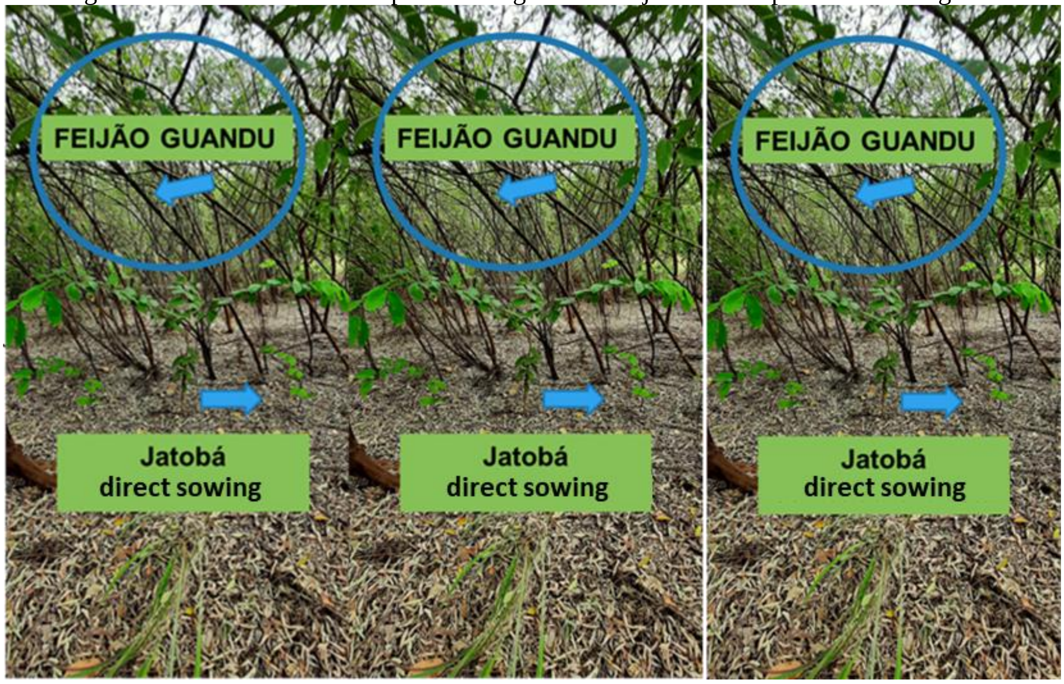


Source: Photos by Oscar Smiderle

The height of the plants (Image 7) was measured using a ruler graduated in millimeters, measuring from the base of the stem to the apical bud and the diameter of the neck (measured at the base of the stem with a digital caliper with an accuracy of 0.05 mm), these measurements were performed concomitantly with the plant survival counts performed at six, 12 and 18 months.

The mean increment of neck diameter (ΔDC) and shoot height (ΔH) were obtained from the data collected during the plant growth period until the end of the experiment (six to 18 months).

Image 7: Visualization of the disposition of guandu and jatobá bean plants in initial growth.



Source: Photos by Oscar Smiderle

2.6 DATA COLLECTION

The sense of plant emergence was made at 120 days (October/2021) after sowing (rainy season) and survival after six months (January/2022), 12 months (July/2022) and 18 months (January/2023) and growth in height and stem diameter after 18 months (January/2023).

3 RESULTS AND DISCUSSION

Of the six species studied, only one did not germinate under greenhouse conditions (Table 4). Most of the species tested showed good greenhouse emergence rates, but low seedling emergence rates in the field (Table 4).

After 120 days, of the 3,888 seeds of the six species sown at the beginning of the rainy season in the improved cerrado of Roraima (3,456 m2), 395 seedlings (10.1%) belonging to three tree species (Pau-rainha, African Mahogany and Jatobá) were recorded in the field. On the other hand, for itaúba, maçaranduba and freijó were not registered with individuals in the field, i.e. 0% and for pau-rainha and African mahogany there was 2% and 6% of emergence, respectively; and, after 6, 12 and 18 months, both had 50% survival. In turn, the Jatobá presented 53% of seedling emergence and 90% survival in the field at six months, maintaining survival of 85% at 12 and 18 months (Table 4).

Overall, the average survival rates verified at 6, 12 and 18 months for the Jatobá (90%, 85% and 85%, respectively) indicated a decrease mainly from 6 months to 12 months (Table 4), possibly due to the driest period of the year.

Table 4. Total number of seeds (N) sown, average seedling emergence values in greenhouse (ECV%) and seedlings emerged in the field, after 120 days (E %); seedling survival (%) at six, 12 and 18 months; height (cm) and stem diameter of plants (mm) after 18 months of no-tillage obtained for forest species evaluated in the improved cerrado of Roraima, regardless of the doses of limestone and agricultural gypsum;

Species	N	ECV	% E	% Survival			Height	Diameter
		%	120 DAS	6 months	12 months	18 months	cm	mm
Itaúba	648	85	0	0	0	0	0,0	0,0
Maçaranduba	648	*Yes	0	0	0	0	0,0	0,0
Freijó	648	60	0	0	0	0	0,0	0,0
Queen Stick	648	80	2	50	50	50	53,0	5,2
African mahogany	648	70	6	50	50	50	40,5	6,8
Jatoba	648	90	53	90	85	85	108,4	10,7

*si – no information

Source: Smiderle and Souza, 2023

The determination of seedling emergence in greenhouse is essential to distinguish the technique of direct seeding of low and high vigor seeds according to Silva et al. (2015).

However, Pellizzaro et al. (2017) warn that there is no direct relationship between seedling emergence in greenhouse and the establishment of seedlings in the field. This fact, also evidenced in the present research for itaúba, maçaranduba and freijó. For these aforementioned authors, some forest species exhibit good rates of establishment in the field and low percentage of emergence in the greenhouse, while others show high percentages of plant emergence in the greenhouse, but low percentages of establishment in the field.

In the present study, one (1) forest species did not emerge when sown in the medium sand substrate in a greenhouse, while in the field only for three forest species were observed live seedlings. On the other hand, only jatobá exhibited good percentages of plant emergence in the field, while African mahogany and pau-rainha showed low percentages of emergence in the field, confirming the observations of Pellizzaro et al. (2017).

Table 4 shows that plant height at 18 months was 108.4 cm for Jatobá, Pau-rainha was 53 cm and Brazilian Mahogany was 40.5 cm (mean 67.6 cm). The slow growth of forest species in savanna environments is considered one of the biggest bottlenecks in the restoration of forest stands. Pellizzaro et al. (2017) working with 75 forest species obtained an average height of 10.14 cm after 17 months.

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ISSN: 2764-9547

The increase in height (ΔH) and stem diameter (ΔDC), obtained from 6 to 18 months, from the procedures of application of correctives in the cerrado of Roraima can be observed in Table 5. The highest mean value of ΔH of jatobá plants was 86.6 cm in C2 and G3 while the highest mean value for ΔDC was in C2 and G2 (Table 5).

Table 5. Mean values of the mean increment of stem diameter (ΔDC) and plant height (ΔH) obtained from the data collected from no-tillage in the Jatobá field, from six to 18 months of growth, from the application procedures with three doses of limestone (C1= 1.5; C2= 3.0; and, C3= 4.5 t $^{ha-1}$) and three doses of agricultural gypsum (G1= 0.9; G2= 1.8; G3= 2.7 t $^{ha-1}$) in the improved cerrado of Roraima

Jatoba (*Hymenaea courbaril*)						
	Doses of Plaster					
	G1= 0.9 t $^{ha-1}$		G2= 1.8 t $^{ha-1}$		G3= 2.7 t $^{ha-1}$	
Limestone t $^{ha-1}$	(ΔH, cm)	(ΔDC, mm)	(ΔH, cm)	(ΔDC, mm)	(ΔH, cm)	(ΔDC, mm)
C1=1,5	61,9	6,1	42,0	4,3	49,7	5,4
C2=3,0	59,5	7,1	61,1	7,6	85,6	6,4
C3= 4,5	54,2	4,7	80,9	6,3	82,8	6,8

Source: Authors

In addition, the ΔH in the C2 and G3 set exhibited 28.6% more in relation to C2 and G2 in contrast to the ΔDC in C2 and G2 presented 15.7% more when compared to C2 and G3. That is, to obtain higher ΔDC in the conditions of the present research, C2 and G2 are recommended, with a reduction of 0.9 t ha-1 of agricultural gypsum and of R$ 0.04 reais in the plot of 64 m2 in relation to C2 and G3 (Table 4 and Table 5), this reduction represents R$ 6.25 reais per hectare of cultivation. This practice of soil management makes them promising for direct sowing of jatobá under the conditions of the present research. In addition, these results of the present research are of great relevance because they show that the practice of direct sowing of forest species is feasible in the improved cerrado of Roraima.

3.1 UNIT COST PER PLANT FROM SIX TO 18 MONTHS FROM NO-TILL SOWING

To obtain the unit cost per plant from six to 18 months from no-tillage (Table 6), the price for acquisition in the local market of the limestone and agricultural gypsum inputs used in this research was R$ 550 reais per ton, respectively. It was also added the cost of an employee, considered here one (01) day a week in the 12 months of monitoring and as well as for the realization of necessary cultural treatments. The cost ($) considered for 12 months was R$ 3600.

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ISSN: 2764-9547

Table 6. Cost per seedling of jatobá in no-tillage generated with the doses of limestone and agricultural gypsum from six to 18 months in the improved cerrado of Roraima

	Agricultural gypsum		
Limestone t ha-1	G1= 0,9 d a-1	G2 = 1,8t Ha-1	G3= 2,7t Ha-1
C1=1,5	0,93	0,94	0,96
C2=3,0	0,95	0,97	0,98
C3= 4,5	0,98	0,99	1,01

* Percentage representation of the cost in relation to 9 plots of 64 m2 during 12 months of monitoring. Source: Research data

The cost per seedling of jatobá emerged, from the direct sowing of each dose of limestone and agricultural gypsum is represented in table 6, ranging from R$0.93 to R$1.01. In research conducted by Smiderle and Souza (2023) in the quantification of the cost of seedlings emerged from forest species obtained from no-tillage in the improved cerrado of Roraima such as the freijó (*Cordia alliodora*); queen's wood (*Centrolobium paraense*), jatobá (*Hymenaea courbaril*), itaúba (*Mezilaurus itauba*), African mahogany (*Khaya* spp), and the curlew (*Manilkara huberi*), the cost was R$ 0.58 reais/seedling emerged up to six months after sowing.

In this case, the cost in R$ from direct sowing via jatobá seed to 18 months was R$ 0.58 x 36 plants per plot of 64 m2 = 20.88 reais. CUNHA (2005), recommends seedlings with lower heights and larger diameter of the stem for presenting fewer problems related to plant support and tipping, thus avoiding mortality or deformations that compromise the silvicultural value. In addition, using as reference jatobá plants with larger stem diameter, C2 and G2 (Table 3) from no-tillage up to 18 months after initial sowing at the final cost was R$ 0.58 + 0.97= R$ 1.55.

Smiderle and Souza (2023) quantifying the cost of jatobá seedlings obtained in plastic bags with permanence in the nursery up to six months the cost was R$ 2.79. For direct sowing of jatobá up to 18 months of growth in the field, the cost per seedling was R$1.55 in C2 and G2. Considering the cost, from 6 months to 18 months after no-tillage in the improved cerrado, the values vary (R$0.93 to R$1.01) according to the rates of limestone and agricultural gypsum applied, as shown in Table 6.

The direct sowing of jatobá via seeds in the improved cerrado of Roraima is viable for producers, nurseries and constitutes a sustainable, ecological balanced alternative for the Amazon region, since they are considered alternative species for the composition of forest plantations in Roraima.

4 CONCLUSIONS

Direct sowing via seeds in the cerrado of Roraima, independent of limestone and agricultural gypsum, is recommended for the Jatobá *(Hymenaea courbaril*) with more than 50% seedling emergence (120 days after sowing) and 85% survival at 18 months after sowing.

The procedure used to promote the increase in stem diameter (ΔDC) of jatobá plants from no-tillage via seeds from six to 18 months is the application of 3.0 t ha-1 of limestone and 1.8 t ha-1 of agricultural gypsum in the cerrado of Roraima, being an appropriate species for the establishment of forest plantations with costs of 1.55 reais per seedling.

The soil procedure of cerrado Roraima and the forest species via direct sowing with jatobá seeds in this research with the use of shrubby legumes, allow the establishment of forest plantations with costs ranging from R $ 0.93 to R $ 1.01 per seedling, according to the doses of limestone and gypsum, which can be indicated in practices of recomposition of environments in similar conditions as a way to dispense with the need for training and management of seedlings in nursery.

5 FINAL CONSIDERATIONS

Considering that studies on survival and initial growth of native and exotic forest species via no-tillage in the cerrado of Roraima are scarce. The present research adds important information regarding the emergence of plants in the field, survival and initial growth in the field in latosol-type soil under different doses of limestone and agricultural gypsum up to 18 months.

Under the conditions of the present study area, the species that stood out prominently was the Jatobá (*Hymenaea courbaril*). Followed by African Mahogany and Pau-rainha, these two species exhibited low percentages of plant emergence in the field. These two species need to use seeds of high physiological quality (>90%), in addition to providing protection to avoid the consumption of seeds deposited in the soil. Thus the jatobá can be indicated in practices of recomposition of environments in similar conditions.

In view of the satisfactory growth of jatobá in height in the improved cerrado of Roraima, it is also important to consider, in the recovery of similar areas, the planting of other forms of life such as legumes such as guandu beans (*Cajanus cajan),* stylosantes (Stylosanthes *capitata*), leucena (*Leucaena leucocephala*) among others to produce phytomass as a source of green manure.

Finally, it should be noted that these and other researches that support information for the continuous improvement of the procedure of improvements in the soil of cerrado Roraima via direct sowing of seeds, requires for the advancement in the TRL scale the monitoring of the growth and establishment of plants in field plantations in addition to wide dissemination of the indicated practices. To this end, they require incentives, investments, conceptual, managerial and technical changes for both nurseries and producers for adoption. For public agencies, the distribution of less comprehensive and contradictory information regarding native and exotic forest species are necessary for effective advances in the no-tillage system via seeds in the field in the cerrado in Roraima.

ACKNOWLEDGEMENT

The authors express their gratitude to Embrapa Roraima for providing the execution of the Research and Development Project, Type I, of SEG number: 10.19.03.005.00.00 - Technologies for the production of seedlings from seeds and plant growth, aiming at planting forest species in Roraima, led by the researcher Dr Oscar José Smiderle, in order to generate technologies for forest plantations (maçaranduba, pau-rainha, jatobá, freijó, itaúba and African mahogany) from the direct sowing in the field and as well as indicate forest species for plantations in Roraima.

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ISSN: 2764-9547

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