ESTABLISHMENT OF NATIVE FOREST SPECIES IN RECOVERY PLANTING OF RIPARIAN FOREST IN THE PIAUITINGA RIVER, SERGIPE, BRAZIL

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Resumo

Estabelecimento de espécies florestais nativas em plantio de recuperação de matas ciliares do rio Piauitinga, Sergipe, Brasil. As matas ciliares da bacia hidrográfica do rio Piauitinga, estado de Sergipe, Brasil, encontram-se bastante degradadas, necessitando, portanto, de ações urgentes visando a sua recuperação. O objetivo do trabalho foi analisar o estabelecimento de plantio de espécies florestais nativas por meio de mudas, implantadas num trecho degradado de mata ciliar do Rio Piauitinga, no município de Lagarto, no estado de Sergipe, visando à recuperação florestal dessa área. O plantio de mudas de cinco espécies florestais nativas foi realizado, incluindo espécies pioneiras e não pioneiras dispostas em delineamento em blocos casualizados, num total de 200 indivíduos, distribuídos em 10 indivíduos espaçados em 1,5m x 1,5m. A espécie *Guazuma ulmifolia* Lam. obteve os melhores resultados quanto à sobrevivência, altura (111,94 cm) e diâmetro à altura do solo (22,89 mm). *Guazuma ulmifolia* Lam.*, Tapirira guianensis* Aubl. e *Sapindus saponaria* L. mostraram-se capazes de suportar as adversidades do ambiente estudado, podendo ser recomendadas em projetos futuros de recuperação das matas ciliares nessa unidade de planejamento.
Palavras-chave: espécies arbóreas, regeneração artificial, ecossistema ripário.

Abstract

The riparian forests of the Piauitinga river Basin, Sergipe state, Brazil, are severely degraded, requiring urgent actions aimed their recovery. In this way, the present work was carried out with the objective of analyzing the establishment of native forest species, implanted in a degraded section of riparian forest of the Piauitinga river, in the municipality of Lagarto state of Sergipe, aiming the forest recovery of this area. It was performed the planting of five native forest species, including pioneers and non-pioneers specie, arranged in a randomized block design, in a total of 200 individuals, distributed in 10 individuals with spacing of 1,5m x 1,5m. The *Guazuma ulmifolia* Lam. species obtained the best results regarding survival, height (111.94 cm) and diameter at soil height (22.89 mm), *Guazuma ulmifolia* Lam., *Tapirira guianensis* Aubl. and *Sapindus saponaria* L. showed to be able to withstand the adversities of the studied environment, and can be recommended in future projects of recovery of the ciliary forests of that planning unit.
Keywords: tree species, artificial regeneration, riparian ecosystem.

INTRODUCTION

The natural ecosystems associated to the drainage network of a river basin, such as riparian forests, perform important environmental, hydrological and ecological duties, therefore being of the most necessity the adoption of actions that can facilitate the environmental recovery of these areas when degraded (FERREIRA *et al.,* 2009), since the Law n° 12.651 of May 25th of 2012 established the riparian forests as permanent preservation areas (PPA).

Thus, the reposition of the native vegetation cover, correcting the processes of degradation by the reposition of organic matter, nutrients and sources of propagating material, becomes fundamental to the stabilization of these ecosystems (CARNEVALI *et al*., 2016).

For this purpose, the use of adequate techniques, defined according to detailed evaluation of the environment and the types of disruption found, enables better chances of success in the activity of recovery of an area (FRAGOSO *et al*., 2014).

Thereon, the restoration of forestry ecosystems can be accelerated by the method of mixed planting with the native species as the most recovery technique in degraded areas that present compromised resiliency with the normal conditions of natural regeneration (CHIAMOLERA *et al*., 2011; RESENDE *et al.*, 2015; MARCUZZO *et al*., 2015).

In addition, Carnevali *et al*. (2016) emphasize that the analysis of growth and development of native forest species planted in degraded may contribute to enable species with higher growth and development potential before the environmental disturbances found. Thus, the use of environmental quality monitoring becomes fundamental to evaluate if the performed efforts are viable (ROCHA *et al*., 2015).

In this context, the sub-basin of the Piauitinga river and its feeder streams, that are part of the basin of the river Piauí in the state of Sergipe, has become a concern in the matter of environmental preservation and conservation of the riparian forests areas by the necessity of constant water provision in quantity and quality to the many users the theses planning unities (OLIVEIRA *et al*., 2012; SANTANA *et al*., 2016; JESUS *et al*., 2018).

Thus, the present work was conducted with the objective of analysing the establishment of native species planting through seedlings in a degraded part of the riparian forest of the Piauitinga river, in the municipality Lagarto, in the state of Sergipe.

MATERIAL E METHODS

Characterization of study field

The riparian forest are, to the referred study, is located in the municipality of Lagarto, South-Central region of the state of Sergipe, in a section of the sub-basin of the river Piauitinga (Piauitinga Planning Unit), between the geographic coordenates of 10º54´10´´e 11º12´12´´ S; 37º22´20´´ e 37º34´22´´ W, with an area of 418,20 km², integrated and tributary of the basin of the Piauí river (Figure 1).

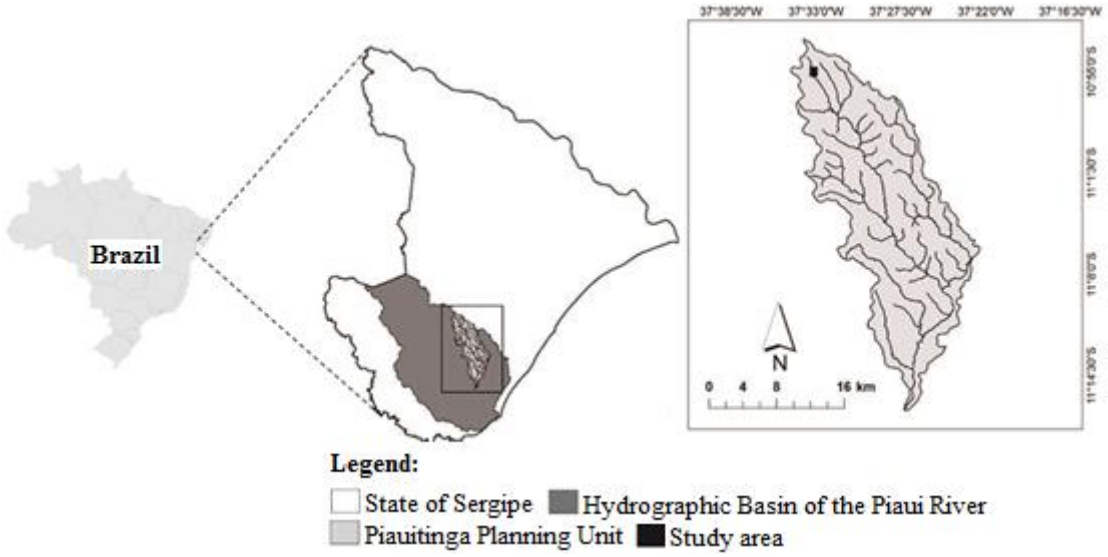

Figure 1. Geographic location of the forest recovery study area of the Piauitinga river, in the municipality of Lagarto, state of Sergipe.

Figura 1. Localização geográfica da área de estudo de recuperação de mata ciliar do Rio Piauitinga, no município de Lagarto, estado de Sergipe.

The vegetation of the region corresponds to the Tropical Semideciduous Forest and transition between Semideciduous Stationary Forest. The soil of the study area is Argisoles Red-Yellow (OLIVEIRA *et al*., 2012). The climate of the municipality is the type Aw, classified, according to Köppen, as dry tropical on winter with less pluviosity than on summer, having an annual average of rainfall of 1.020,6 mm and annual average temperature of 26,2 ºC, verying from 25,6 ºC to the more warm and rainy months (February and May) to 21,7 ºC to the more cold and dry period (July and October) (SOUSA *et al*., 2010).

Selection of the species

The process of sorting the species was carried by results obtained in floristics mapping conducted in areas of riparian forest, located in the municipality of Lagarto, Salgado, Boquim and Estância, that are part of the sub-basin of the Piauitinga river, and taking into consideration its pontencialities in relation the ecological forestry characteristics observed in works of recovery of degraded areas. The species used were classified in the ecological

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groups, as seen in Table 1, based on the strategic behavior of survival and space ocupation by the tolerance to shadow, growth rate and formation of seed bank of the species, according to Whitmore (1989).

Table 1. Species used for the study of riparian forest recovery of the Piauitinga river, in the municipality of Lagarto-SE.
Tabela 1. Espécies utilizadas para o estudo de recuperação de mata ciliar do rio Piauitinga, no município Lagarto-SE.

Botanical family	Scientific name	Popular name	Ecological group
Sterculiaceae	*Guazuma ulmifolia* Lam.	mutamba	Pioneer
Anacardiaceae	*Tapirira guianensis* Aubl.	pau-pombo	Pioneer
Rubiaceae	*Genipa americana* L.	jenipapo	Non-Pioneer
Sapindaceae	*Sapindus saponaria* L.	saboneteira	Non-Pioneer
Clusiaceae	*Kielmeyera* sp	pau-santo	Non-Pioneer

Production of seedlings

The forest species used are part of the planning unity's flora, and the seedling were produced in the Nursery Forestry Department of Forest Science of the Federal University of Sergipe, in plastic bags made of polyethylene with dimentions of 18 cm x 25 cm, applying as substrate a mixture of dark potting soil, washed sand and hardened corral manure in the proportione 3:1:1, respectively. The single siperphosphate fertilizers (1,5 $kg.m^{-3}$) and potassium chloride (120 $g.m^{-3}$) were added in the composition.

After the emergence, each seedling kept receiveng fertilization through watering in the in periods of 15 days, having 50 ml of the solution, by plant, formed by potassium chloride (60 g) and ammonium sulphate (25 g), diluted in 10 L of water. The species were kept under shadow screen of 50% in the period of 8 to 15 days after the emergence and, after being taken away of the screen, were kept in full sunlight in a period of five months in the vivarium. Before planting, to reach hardiness and morphophysiological quality needed, the seedling were kept receiving two daily irrigations (morning and afternoon) and fartilization through irrigation in the pot.

Installation of the experiment

The experiment was implanted in a degraded part of the riparian forest area, covered by intruder plants, previously, used as pasture.

The artificial method of regeneration through seedling planting was applied, using as statistical model the delineation in designed blocks (DDB). 200 individuals were used to each one of the five species tested, distributing them in 50 individual to each block, with the number of 10 individuals by line in each blocks, alternating between species.

Execution of the planting

For the deployment, the intruder plants were controlled by manual cutting and localized cleaning, conducted around each individual, in a 50 cm radius. The area did not receive any soil preparation and was surrounded by razor wire to prevent the entry of animals present in the surroundings, avoiding possibles damages to the plants due to trampling herbivory. The planting was conducted in 30 cm x 30 cm x 30 cm planting holes, in 1,5 m x 1,5 m of spacing.

During plantation, initial fertilization of 200 g by planting hole with single superphosphate was done and, after 60 day, fertilization of coverage with NPK 20:10:20 in the amount of 150 g by seedling was applied, divided in two parts distributed in two opposite planting holes 15 cm from the stem and 5 cm of depth, approximately.

Granulated ant baits were also applied to ant control in anthills located in the implanted area.

Acquisition and analysis of data

The study was conducted along 22 months (August of 2013 to May of 2015), on which a monthly monitoring of the subsistence of individuals by direct counting was done, considering as dead plants the absent individuals in the plating holes or with a dried stem and without leaves, according to what was proposed by Brancalion *et al*. (2015). Measures of the diameter to soil height diameter (DAS) were done, using pachymeters, and to total height (AT), using a scaled cane. The average increase was obtained in total height (AT) and soil

height diameter (DAS) through the absolut growth index (TCA) through the equation TCA(%) = ((Vf – Vi)/Vi), in which Vi and Vf correspond, respectively, to the values of the variable in the begging and in the end of the considered period, according to the recomendation of Benincasa (2003).

The data obtained, after the normality tests were submitted, was conducted to variance analysis (ANOVA) and, when significant difference was detected, a comparison of averages was done through the Turkey test ($p<0.05$). The analysis was done with the help of the SISVAR® software.

RESULTS

During the first six months of evaluation (August of 2013 to February of 2014), a rate of 71% of survival was noted. After the 11º monthly (July of 2014), more deaths occurred, which reduced the rate of survival to 51%. Comparing the averages of survival of each species through the Turkey test, as shown on Table 2, significant statistic differences were noted. *G. ulmifolia* presented a rate of survival of 72%, that, statiscally, is different and superior to the other, followed by *S. saponaria* (67%), althought this one has average of survival statiscally similar to the species *T. guianensis* and *G. americana*, both with 45%. *Kielmeyera* sp., with only 5%, presented the lower percentage, having, therefore, low survival. (Table 2).

Table 2. Survival rates of the selected species for the study of riparian forest recovery of the Piauitinga River, in the municipality of Lagarto-SE.
Tabela 2. Taxas de sobrevivência das espécies selecionadas para o estudo de recuperação de mata ciliar do Rio Piauitinga, no município de Lagarto-SE.

Ecological Group	Species	Survival
Pioneer	*G. ulmifolia*	72% a
Pioneer	*T. guianensis*	45% b
Non-Pioneer	*G. americana*	45% b
Non-Pioneer	*S. saponaria*	67% ab
Non-Pioneer	*Kielmeyera* sp.	5% c

Different letters indicate values that are statistically different from each other by the Tukey test ($p < 0.05$).

In relation to the growth of the species, it occurred considerably during the evaluation (Figure 2), noting peak in some of the periods, with prominence near the 285 days (between the 10º and the 11º month) and at the end of 630 days series (22º month) of study, in which was also noted the ramp of the curve to all species, but with emphasis in the responses by the *G. ulmifolia,* followed by *S. saponaria* because they had the higher values to height as well as to diameter.

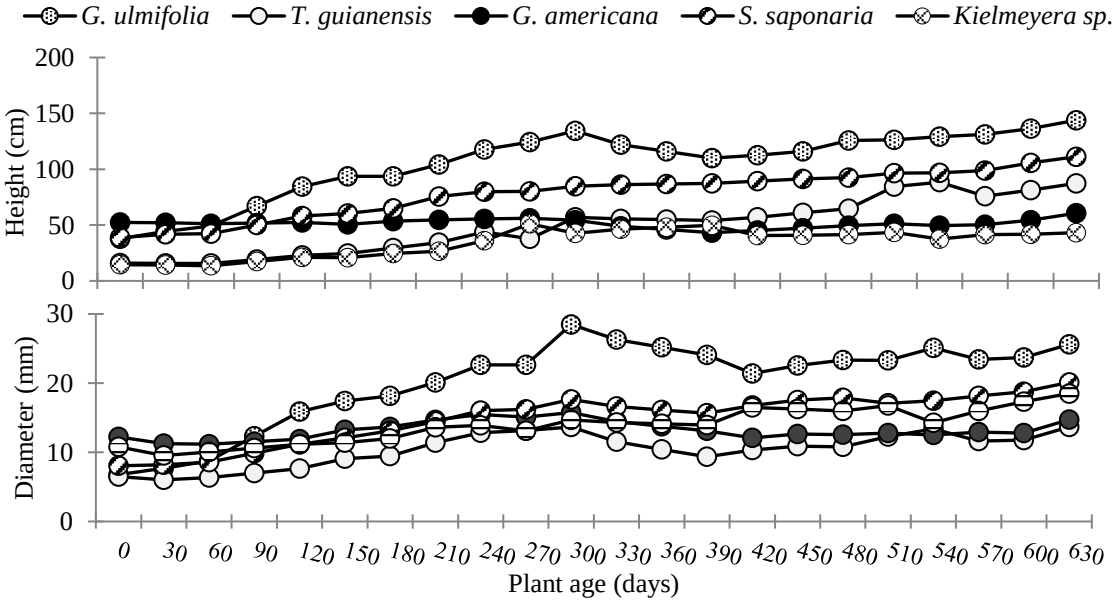

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Figure 2. Growth curve in height (cm) and diameter of soil height (mm) of pioneer and non - pioneer species at the end of 630 days of growth of the species evaluated in the study of riparian forest recovery, of the Piauitinga River, in the municipality of Lagarto-SE.

Figura 2. Curva de crescimento médio em altura (cm) e diâmetro à altura do solo (mm) de espécies pioneiras e não pioneiras avaliadas no estudo de recuperação de mata ciliar do Rio Piauitinga, no município de Lagarto-SE.

As for the growth pattern, through the monthly average increase, it was noted, between the pioneers, *T. guianensis* invested more in height, with monthly average increase 0,095 cm (9,46%); and *G. ulmifolia*, in diameter, with 0,16 mm (7,02%). And, characterizing by the investment in height, between the non-pioneers, *Kielmeyera* sp. (0,132 cm.month^{-1}).

Considering, in the same environmental conditions and time evaluated, the species presented growth with different pattern than the characteristics of it's ecological group, for example *de S. saponaria* with the diameter growth relatively superior the pioneer *T. guianensis* and in height to the *Kielmeyera* sp. (Figure 3).

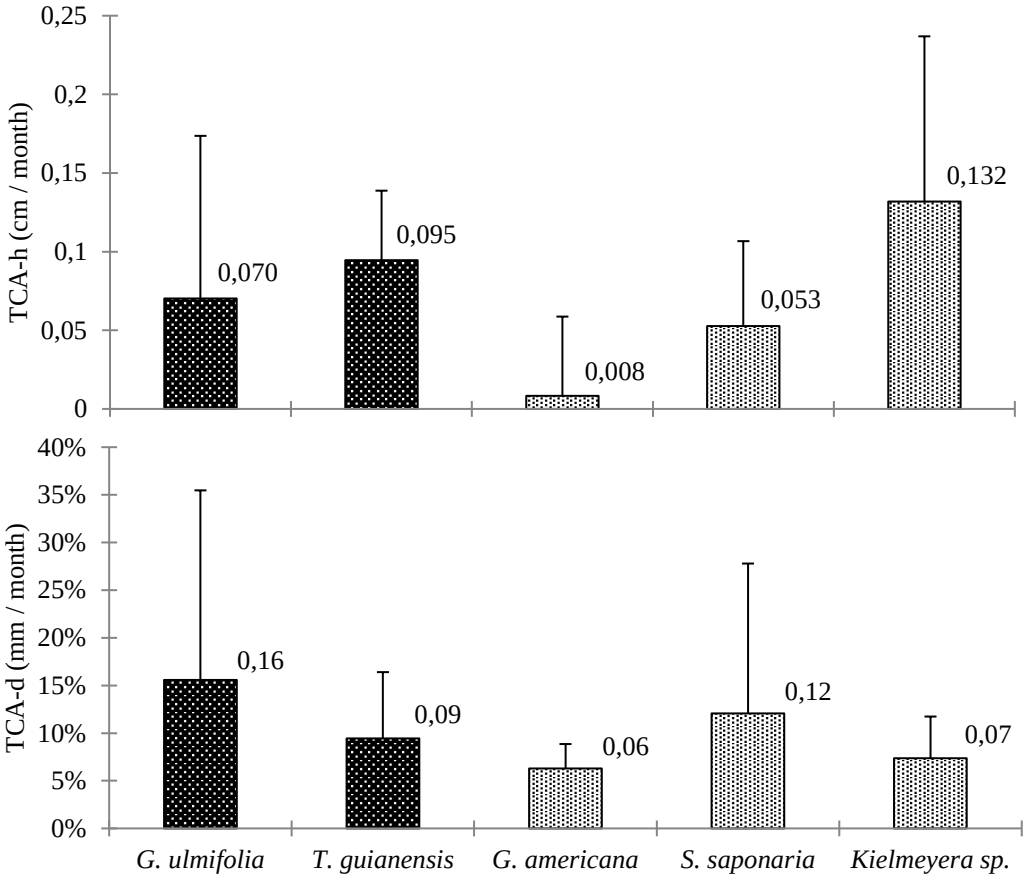

Figure 3. Monthly averages of absolute growth in height (TCA-h) and diameter (TCA-d) of pioneer and non-pioneer species at the end of 22 months of evaluation of selected species for the study of riparian forest recovery of the Piauitinga River, in the municipality of Lagarto-SE.

Figura 3. Médias mensais dos crescimentos absolutos em altura (TCA-a) e diâmetro (TCA-d), de espécies pioneiras e não pioneiras, ao final de 22 meses de avaliação das espécies selecionadas para o estudo de recuperação de mata ciliar do Rio Piauitinga, no município de Lagarto-SE.

In the final increase of growth, related to the beginning and the end of the evaluation (Table 3), *T. guianensis* presented higher increase in height (TCA = 452,1%), as well as in the monthly average increase. Next,

G. ulmifolia, with 280,6%, was the species that presented the second higher rate of growth. *G. ulmifolia* and *S. saponaria* presented final averages in height superior to the others, 111,94 cm and 60,34 cm, respectively, but with final increase rates in height (respectively, TCA = 280,6% and TCA = 187,0%) inferior to the rate presented by the *T. guianensis*, that obtained the higher value of increase (TCA = 452,1%).

In diameter above the ground, *G. ulmifolia* was superior to the other species, obtaining the higher average (22,89 mm) and the higher increase rate (315,31%), followed by the *S. saponaria* (TCA = 129,38%). On the other hand, *Kielmeyera* sp. Obtained the lower average in height (22,05 cm) and on TCA of diameter with 71,69%. Although it did not present the lower averages to both the evaluated increases, *G. americana* was the that obtained the lower percentual increases, with 15,9% and 21,83%, respectively, to the total height and soil height diameter.

Table 3. Analysis of the mean values of secondary growth (soil height diameter-DAS) and primary growth (total height-AT) by the Tukey test and its Variation Coefficients (CV%) and absolute growth rate (TCA-%) final of 22 months of evaluation of selected species for the study of recovery of riparian forest of the Piauitinga River, in the city of Lagarto-SE.

Tabela 3. Análise dos valores médios do crescimento em altura total (AT) e do diâmetro à altura do solo (DAS) pelo teste de Tukey e seus Coeficientes de Variação (CV%) e taxa de crescimento absoluto (TCA-%), ao final de 22 meses de avaliação de espécies selecionadas para o estudo de recuperação de mata ciliar do Rio Piauitinga, no município de Lagarto-SE.

Species	Total Height (AT)			Soil Height Diameter (DAS)		
	Averages (cm)	CV (%)	(TCA-%)	Averages (mm)	CV (%)	(TCA-%)
G. ulmifolia	111.94 a	39.06	280.6	22.89 a	37.18	315.31
T. guianensis	48.49 b	56.09	452.1	10.85 b	29.60	122.47
G.americana	51.69 b	14.11	15.9	13.36 b	14.05	21.83
S. saponaria	60.34 b	37.56	187.0	14.81ab	40.22	129.38
Kielmeyera sp.	22.05 c	63.46	197.0	8.28 c	16.58	71.69

Averages followed by the same letter in the same column do not differ by the Tukey test at 95% probability ($p < 0.05$).

Analysing statiscally (Table 3), it was noted that the *G. ulmifolia* presented the better average of growth in height, sigficantly unlike the other species, followed by the species *S. saponaria*, *G. americana* and *T. guianensis*, these with statiscal difference between them. *Kielmeyera* sp. differed from the others because it presented, situation also observed to the average of soil height diameter. In relation to the soil height diameter, the same responses of statiscal differences occurred, with the only difference on the *S. saponária* that did not have a different average de *G. ulmifolia*, which, in turn, presented once again superior value to all the other species. It is possible to note values of CV-% with considerable differences among species, which are associated to the rates of growth of the individuals of each species, related, in particular, possibly, to the intrinsic physiological responses of each species to the environment on its natural development.

DISCUSSION

A variation was noted in the survival rate that, in general, was inferior to 80%, lower than the critical percentage (90%) of the successful survival, such as suggested in plantings to forest restauration in the Atlantic Rainforest (RODRIGUES *et al.*, 2009). Therefore, it is understood that these variations in the survival rates indicate the potencial behaviors different of the adjustments to the environmental conditions, in which some authors, such as Lima *et al.* (2009), attach the development of the species to the local environmental conditions, in which adverse factors such as competition, herbivory, bright quality and intensity and quality of the soil can compromise the establishment as well as the survival of the species.

In the present study, the high local precipitation occurred, during the evaluations in the winter period, caused a high mortality of the species, once the excess umidity unables the soil to maintain the quantity of oxygen necessary to the plants, limiting its gas exchanges, which, associated to the relatively flat topography of the area

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and the historic of soil compaction by bovine cattle, complicates the drainage of the water volume, intensifying the fluid retention in the soil.

According to Magalhães *et al.* (2012), the sub-basin of the Piauitinga river, is characterized as lowland topography with formation of the springs with a pronounced frank sandy-clay texture associated to the hydromorphism, leading to hydric saturation of the soil. This condition, according to Scalon *et al*. (2011), tends to compromise to growth of roots and the aerial part of the plants, as well as inhibit the elongation of the internodes and the expansion of the leaves, accelerating the senescence and its natural fall, as observed by Lira *et al.* (2013), in *Lonchocarpus sericeus* (Poir.), that, undergoing water saturation in the root system, presented reduction and stagnation of growth in heights.

The higher survival rate occurred with the *G. ulmifolia* (72%) until the of the evaluation, explained by its own characteristic of resisting the adverse conditions during the development, as mentioned by Lima *et al.* (2009). To Scalon *et al*. (2011), ecophysiologically, the species tends to endure soil with hydric saturation. Melotto *et al*. (2009) also obtained a survival rate of 75% to the *G. ulmifolia* in a work of recovery of a degraded area, with pasture historic, in the municipality of Campo Grande-MS, at the end of 12 months of evaluation, In this case, it should be noted that, in the study field of theses authors, there was no historic of flooding.

S. saponaria presented survival of 67%, resisting the flooding, fact also observed by Cruz and Campos (2013), in the survival of juvinile plants of this species, in a floodplain regeneration study of the upper Paraná river. As for the *G. americana*, although it is considered a species tolerant of flooding, with adaptive characteristics to the water stress (ANDRADE, 1999), presented only 45% of survival. *Kielmeyera* sp. presented the lower rate of survival in this work (5%), similar result to the one observed by Silva & Correa (2008) to a species of the same genus, when they noted that, after 18 months of evaluation, only 6,7% of all the plants of *Kielmeyera lathrophytum* Saddi. survived in plantings to recovery of a degraded mining area in the Cerrado in Brasília-DF, even though it is a typical species of the region. Still in the same study, high survival rates were noted in *G. americana* and *T. guianensis*, respectively, 96,7% and 90%.

In a similar work, of recovery of the gallery forest in the municipality of Indianópolis-MG, Lima *et al.* (2009) noted considerable survival to the *G. ulmifolia*, with 71,4%, and *T. guianensis*, with 86,5%, followed by *G. americana* (50%) and the species genus *Kielmeyera* sp., with 44,4%, at the end of 13 months of evaluation.

On the other hand, it is presumed, in the present study, that a higher or lower survival of the species is not conditioned to the ecological group, once the higher survival rates were to the pioneer *G. ulmifolia* (72%) as well as to the non-pioneer *S. saponaria* (67%), besides the low survival rates between the pioneer (*T. guianensis*) and non-pioneer (*Kielmeyera* sp.). In general, *G. ulmifolia, S. saponaria* and *T. guianensis* responded with satisfactory establishment, noting the same behavior in works with different environmental conditions, observed previously. Probably the seasonality of flooding influenced the establishment of the species.

In regard to the analysis of increase of the studied species, *T. guianensis* stood out because it presented the higher final value to height (TCA = 452,1%), as well as the average monthly increase, once that, being a typical species of the gallery forest, has as characteristic the rapid growth, according to Silva and Correa (2008). *G. ulmifolia*, with 280,6%, was the species that presented the second higher rate of growth. Such results are similar to other studies, such as the one by Lima *et al.* (2009), in which the authors also observed to the no *G. ulmifolia* higher increases in growth, followed by *T. guianensis* and *G. americana*. Silva and Correa (2008) noted final increases in height of 492% and 464% to *G. americana* and *T. guianensis*, respectively.

In an area of riparian forest under recovery, in the municipality of Uberlância-MG, after 18 months of implementation, Pereira and Rodrigues (2012) noted higher growth in height than in diameter in the *G. ulmifolia.* In the same way, Melotto *et al.* (2009) obtained higher final increases in height (587%) and diameter (21,6%), in 12 months of evaluation.

G. americana presented low values to height and diameter, in average as well as in increase, inferior to the values found in the same species by Silva *et al*. (2016), by the end of 18 months of evaluation, in a study of recovery of a mining area in Minas Gerais. And *Kielmeyera* sp. Was the species that obtained the lower final average levels.

The results expressed of average growth of the pioneers, in the present study, are explained, according to Poggiani and Schumacher (2004), by the characteristical performance of these species to absorb more nutrients and higher efficiencies in its use than the non-pioneer species, reflecting in a greater shading area, which favours the ingress and development of the non-pioneers.

In general, the final average increase values, through the absolut growth rate (TCA) of the species, are revealed considerable, corresponding to the effect of development of the plant, because they become desirable to its purpose of forest recomposition in recovery of degraded areas, especially in the riparian forests.

CONCLUSIONS

The analysis of the establishment of the seedling allows concluding that:

- The establishment was more expressive to the group of pioneers, undergoing environmental conditions, mainly the effect of seasonal flooding in the study area.
- *Guazuma ulmifolia* and *Sapindus saponaria* presented the better results in survival, followed by *Tapirira guianensis* and *Genipa americana*, both with 45%.
- In regard to the averages of height and soil height diameter, *G. ulmifolia* and *S. saponaria* presented the higher values and absolut increases, followed by *G. americana* and *T. guianensis*. And the species *Kielmeyera* sp. Was the one that presented the lower average values.
- *G. americana* was the one that presented the lower values of increase to height and soil height diameter, although it had significant average growth.
- *G. ulmifolia, T. guianensis* and *S. saponaria* have shown to be capable of enduring the adversities of the region, potentially coming to be used in future project of recovery of the riparian forests of the sub-basin of the Piauitinga river.
- Even though *Kielmeyera* sp. presented unsatisfactory results in the present study, researchs with this species must be continued, mainly when considered inserted in another phase of recovery in which pioneers are established and favouring the development of other plants.

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