Ciência Florestal

ISSN 1980-5098
OPEN ACCESS

Ci. Fl., Santa Maria, v. 33, n. 1, e65858, p. 1-20, Jan./Mar. 2023 • https://doi.org/10.5902/1980509865858
Submitted: 19th/05/2021 • Approved: 21st/11/2022 • Published: 28th/03/2023

Artigos

Forest restoration in old pasture areas dominated by *Urochloa brizantha*

Restauração florestal em áreas de antigas pastagens dominadas por *Urochloa brizantha*

Monique Perini[I]
Matheus Lopes Souza[II]
José Pires de Lemos Filho[I]

[I]Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brazil
[II]Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Aracaú, CE, Brazil

ABSTRACT

In the present study it was evaluated the density of recruits in an area previously occupied by *Urochloa brizantha* pasture undergoing forest restoration and in a Semideciduous Forest. Was evaluated the effect of the available light on the biomass of the exotic grass, and investigated associations of recruit density with soil variables and understory light availability. The seed rain in both areas was also evaluated. The biomass of *U. brizantha* was positively associated with available light and, a negative association was found between recruit density and available light when considering the two areas together. A negative associatio between recruit density and soil pH was found. The results suggest that the low soil fertility did not limited recruitment in the semideciduos forest. The results showed that high resource availability favors the competitivity of *U. brizantha*, impairing the forest restoration in area previously used as pastures. So, pratices that result in decreasing in light availability would favors the forest restoration in areas previously used as pasture.

Keywords: *Brachiaria brizantha;* Light availability; Natural regeneration; Seed rain

RESUMO

No presente estudo foi avaliada a densidade de recrutas em uma área em restauração florestal previamente ocupada por pastagem de *Urochloa brizantha* e em uma Floresta Semidecidual. Foi avaliado o efeito da luz disponível sobre a biomassa da grama exótica e investigamos as associações da densidade de recrutamento com as variáveis do solo e a disponibilidade de luz no sub-bosque. A chuva de sementes em ambas as áreas também foi avaliada. A biomassa de *U. brizantha* foi associada positivamente com a luz disponível e, uma associação negativa foi encontrada entre a densidade de recrutamento e a luz disponível quando consideradas as duas áreas em conjunto. Foi encontrada uma associação negativa entre densidade de recrutamento e pH do solo. Os resultados sugerem que a baixa fertilidade do solo não limitou o recrutamento na Floresta Semidecidual. Os resultados mostraram que a alta disponibilidade de recursos favorece a competitividade da *U. Brizantha* com espécies nativas, dificultando a restauração florestal em áreas anteriormente utilizadas como pastagens. Assim, práticas que resultem na diminuição da disponibilidade de luz favoreceriam a restauração florestal em áreas nessas condições.

Palavras-chave: *Brachiaria brizantha*; Disponibilidade de luz; Regeneração natural; Chuva de sementes

1 INTRODUCTION

Forest restoration strategies range from low-cost spontaneous recovery of native species in abandoned sites to active processes that involve direct seeding and/ or sapling planting, the control of both invasive plants and fire, which increase the cost of restoration (REID; FAGAN; ZAHAWI RA, 2018; LOFT; GEHRIG; ROMMEL, 2019). If the recovery occurs either through a spontaneous or active process, invasion or the presence of exotic grasses, as in the case of areas previously used as pasture, can be a serious problem that affects forest restoration. The establishment and the dominance of exotic plants are often associated with low diversity of native species and the high competitive capacity of the exotic species in the utilization of available resources (MEINERS *et al*., 2012).

Abiotic factors as light and soil nutritional status can determine the competitivity of exotic species and thus interfer in the forest restoration. The opportunity to take advantage of available resources favors invasive exotic species in the process of competitive exclusion of native species (MEINERS *et al*., 2012). The competitive capacity of invasive species is commounsly favored under increased resouce availability as light and nutrients (DAWSON *et al*., 2012). The addition of nutrients results in an increase of biomass production of invasive species (LIU;

KLEUNEN, 2017) favoring the growth of grasses already established, making it difficult to restore areas previously used as pasture.

The high light availability also frequently favors exotic species due to their higher capacity of light capture and use, which result in higher growth rate in sun or partial shade as compared with native species (GAO *et al*., 2018). Thus, the low occurence of trees in areas previosly used as pastures favors a high light availability leveraging the competitive capacity of exotic grasses impacting the recruitment by forest species in areas under forest restoration. Besides having competitive advantages over native species in relation to light and water, exotic grasses can release compounds that impair or inhibit the growth of regenerating native plants in an allelopathic effect (KATO-NOGUCHIA *et al*., 2014). The fast reproductive cycle and high seed production of exotic grasses facilitate their success and promote biodiversity loss (GAO *et al*., 2018).

In addition to abiotic factors that determine the higher competitivity of exotic than native species, the arrival of forest propagules is an important factor limiting forest restoration. The seed rain is a natural process that acts in the recruitment of individuals contributing to the richness and density of species in the community by providing propagules that will recolonize areas and consequently act in the process of ecological succession (AUFFRET; COUSINS, 2011; PIOTTO *et al*., 2019). However, only the arrival of propagules in the area is not enough for the establishment of the seedlings, especially in areas dominated by exotic grasses, because they tend to cover the soil with their biomass, preventing the arrival of light for germination or even due to competition for space (KATO-NOGUCHI *et al*., 2014).

There are several strategies that favor the establishment of native species overcoming competition with grasses and, consequently, favoring forest succession, among which stand out the planting of pioneer species and direct seeding (CECCON; GONZÁLEZ; MARTORELL, 2016; SOUZA; ENGEL, 2018). Many native species, however, can overcome barriers and become established, even in pasture areas with few individuals remaining. In this case, shading tends to reduce the biomass and productivity of exotic grasses and contributes to successful forest succession (COSTA *et al*., 2012; RODRIGUES *et al*., 2012). There is also the option of controlling invasive plant species with herbicides, although this option has been generally avoided as it could potentially harm the establishment of native regenerating species (MCMANNAMEN;

NELSON; WAGNER, 2018; SOUZA; ENGEL, 2018). The management of invasive grasses in revegetation areas, independent of the control methods applied, increases costs and can limit the effectiveness of restoration efforts, as allocated financial resources are limited (SILVEIRA *et al*., 2013).

The African grass *Urochloa brizantha* (Hochst, Ex A. Rich.) RD Webster has been introduced in many tropical ecosystems to form pastures for cattle. The species has been considered an aggressive invasive in hotspots of biodiversity such as the Cerrado, and causes difficulties for biotic recovery of tropical forests as the Atlantic Forest, particularlyy in areas previosly occupied by pastures (FRAGOSO *et al*., 2017). Comparative studies in restoration areas with high densities of exotic grasses and conserved areas of the Atlantic Forest can to lead a better understanding of the environmental filters that hinder the progress of forest restoration. In the present study it was evaluated the density of forest recruits in a area under restoration dominated by *U. brizantha*, and in a semideciduous forest to verify limitant factors compromising forest restoration of mountainous areas in eastern Brazil. By meeting this objective, it is intended to collaborate by the understanding of the factors that impair the forest restoration in areas previously used as pastures.

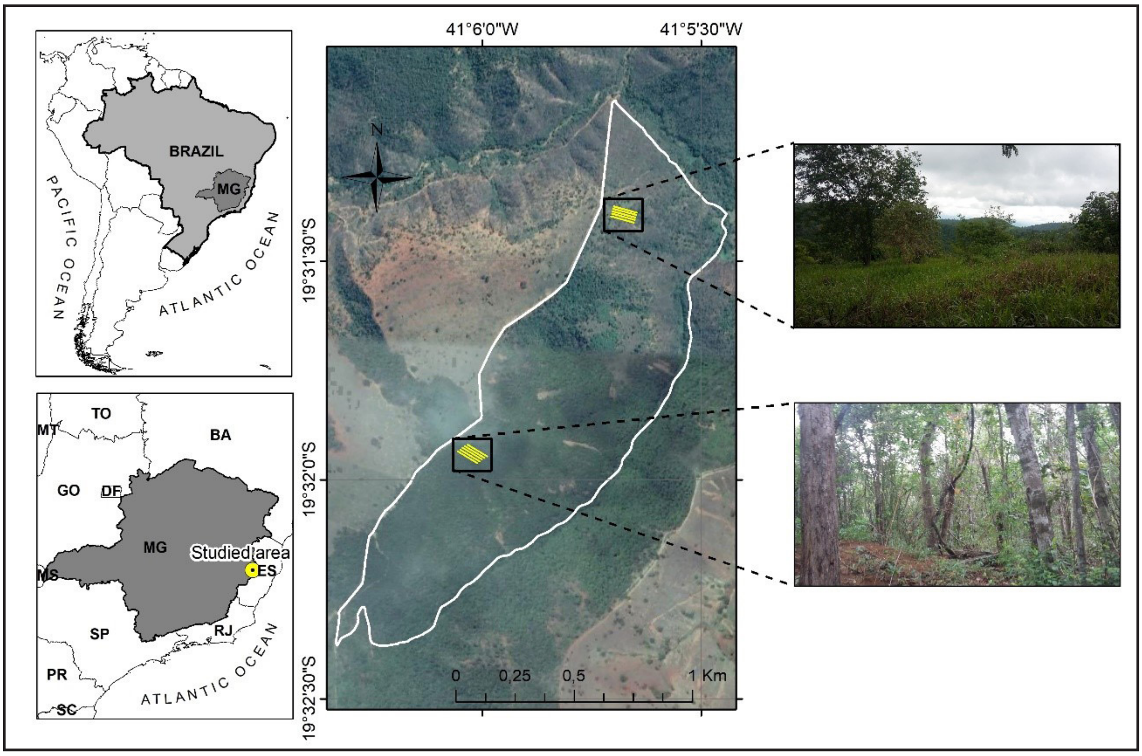
2 MATERIAL AND METHODS

2.1 Study sites

The study was conducted at the Instituto Terra (www.institutoterra.org), Aimorés, state of Minas Gerais, Southeast Brazil (19°53’S, 41°09’W, Figure 1). The climate of the Instituto Terra is tropical altitude with average temperature varying between 18 and 29ºC; December is the wettest month and August the driest with average rainfall of 1772.7 and 97.7 mm, respectively (INMET, 2018). The predominant soil in the region is classified as argisoil. The Instituto Terra encompasses 710 ha, approximately 80% of which are in different stages of forest restoration. A significant portion of the area was previously used as cattle pasture. Forest restoration on the property began in 1999, with small fragments being restored annually by the planting of woody tree species.

Data were collected at two distinct areas. The first area, here referred to as forest restoration is in an area previously occupied by *U. brizantha* pastures and where attempts at forest restoration had been performed. This area encompasses more than 44 hectares, where native species were planted at a spacing of 2x2m in 2012. The preparation of the area for planting consisted of manual cutting around the pit, and fertilizing open pits with 200 grams of simple superphosphate. Twelve months after planting, the soil was fertilized with 100 grams of NPK 20-5-20 per plant, and ant management and manual weeding were performed around each plant. The area was enriched in 2015 with replanting of native species in the lines of the first planting. There is no current management intervention in the area that is dominated by *U. brizantha*. The second area is a fragment of semideciduous forest encompassing 125 hectares. This area has been undergoing natural regeneration for approximately 40 years, and was not invaded by *U. brizantha* (Figure 1). A list of the floristic elements of both sites is provided in Supplementary Table 1.

Figure 1 – Location of the study areas being (1) forest area under restoration and (2) Semideciduous Forest fragment, located at Instituto Terra, southeast region Brazil



Source: Authors (2021)

2.2 Transmitted light, seed rain and biomass of *U. brizantha*

Five 2x110 m transects were installed at intervals of 10 m in each study areas. The transects were subdivided into 10 sampling points spaced at intervals of 10 meters. In each point, hemispheric photos taken with a Nikon Coolpix 5400 digital camera with a hemispherical fisheye-converted FC-59 lens, positioned level, facing the canopy and aligned to the north, at 1.5 m above the ground on a tripod. A total of 50 photos were taken in each area in July 2017, dry season. Photos were taken in the early hours of the day or late afternoon. The photos were analyzed to estimate the percentage of transmitted light using Gap Light Analyzer (GLA) software, version 2.0.

Five permanent 20x20m plots were installed in both study areas, which were subdivided into two subplots with a fixed collector (1x1m) in the center of each to measure seed rain. Material was collected monthly from January to December 2017, separated and quantified according to the ecological group (pioneer, non-pioneer, herbaceous or grass). The annual sum of seed density per m^2 per plot was used as a measure of seed rain.

The epigeal biomass of *U. brizantha* was sampled in July 2017 using a wood jig (0.5x0.5m). Sampling was performed randomly at 20 points at which hemisperical photos were taken along the previously installed transects in the area under restorarion. All material was cut close to the ground, oven dried for 72 hours at 65°C, and weighed.

2.3 Natural regeneration

During the wet season (January 2017), the natural regeneration in the area under restoration and in the semideciduous forest was evaluated along the five transects previously installed for estimating transmitted light. The transects were subdivided into 10 plots of 2x2m spaced 10 m from each other, for a total of 200 m^2 sampled in each area. All regenerating saplings with heights between 10 cm and 2 m, and diameter at soil height (DSH) equal to or less than 5 cm, were included. The density of forest species saplings was calculated as the number of individuals per unit area (n/m^2). Identification to family followed the classification system of the Angiosperm Phylogeny Group IV (APG IV, 2016). The species names and their respective authors followed the List of Species of Flora of Brazil (2018). The identified species were classified according to their ecological group — pioneer or climax/non-pioneer.

2.4 Soil sampling

Soil samplings at a depth of 0 – 20 cm were performed in each plot demarcated along five the transects used to evaluate recruit density. The samples were joined in pairs to form composite samples, at a total of five locations per transect and twenty-five samples per area.The soil chemical and textural analyses followed the protocols described by Embrapa (1997). The variables analyzed were: phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), aluminun (Al), and sodium (Na), pH, organic matter, and sand, silt, and clay contents.

2.5 Statistical analyses

Generalized linear models (GLMs) were initially constructed to evaluate variation in density of recruits (natural regeneration) and soil characteristics between the studied areas. Density of recruits and soil textural and chemical characteristics were used as response variables while study areas (under restoration and semideciduous forest) was the explanatory variable. Separate models were created for each response variable and models were compared using ANOVA. The average was also annual density of native seeds and *U. brizantha* per m^2 in seed rain of both studied areas by constructing models separately for each area.

Multiple regression analyses by GLM were used to investigate associations between density of recruits and soil variables and percentage of transmitted light through the canopy. Density of recruits was used as the response variable while percentage of light transmitted and soil characteristics were used as explanatory variables. Collinearity was evaluated separately between the soil predictor variables using Spearman's rank correlation coefficient ($r<0.6$) (Supplementary Table 2), and correlated variables were not used together in any of the elaborated models. To determine the most explanatory variables in the model it was used second-order Akaike Information Criterion (AIC), where the best model is indicated by the lowest AIC value. These analyses were performed using functions implemented in 'AICcmodavg' and 'psych' packages.

Multiple regression analyses by GLM were also used to verify the effect of percentage of transmitted light and soil characteristics (explanatory variables) on biomass of *U. brizantha* (response variable) initially using the same approach previously described to select the explanatory variables of the model (i.e., lowest AIC value). This was followed by analyzing the effect of biomass of *U. brizantha* (explanatory variable) on absolute density of recruits (response variable).

All data were analyzed using R v2.15.3 (R CORE TEAM, 2013). All models were built using the appropriate error distribution considering the nature of each response variable, followed by model assessment. All generated models were compared to null models.

3 RESULTS

There was a significant difference (ANOVA, $F = 102.24$, $p < 0.001$) in saplings between the study areas, with 212 recruits sampled in the semideciduous forest and 26 in the area under restoration. The saplings were distributed among 12 botanical families, with 60% being non-pioneer species, in the two study areas (Table 1).

The 17 species were recorded in the seed rain in the area under restoration, 35% of them are grasses including the *U. brizantha* seeds (Table 2). Of the 23 species of the seed rain in the semideciduous area 13% are grasses, however in this area there is no seeds of *U. brizantha*. Species with abiotic dispersion syndromes dominated in both areas, 66% in the restoration area and 70% in the semideciduous forest. Despite the difference between the number of species in the seed rain being small between the two areas studied, there was a significant difference in the amount of seeds of native species and *U. brizantha* in the forest under restoration (51.0 ± 21.51 and 405.3 ± 105.74, $P < 0.001$, respectively). *U. brizantha* seeds represented 88% of the total number of seeds that reached the collectors.

Table 1 – Regenerating species followed by their respective botanical family, ecological group (P = pioneer; NP = non-pioneer), and total number of recruits in the sampled plots of the forest restoration area and of the semideciduous forest in Instituto Terra, Southeast Brazil

Family	Species	Ecological Group	Number of Recruits	
			Restoration Forest	Semideciduous Forest
Acharieaceae	*Carpotroche brasiliensis*	NP		1
Anacardiaceae	*Astronium graveolens*	NP	1	14
Anacardiaceae	*Myracrodruon urundeuva*	NP	20	
Annonaceae	*Xylopia frutescens*	NP		9
Bignoniaceae	*Handroanthus serratifolius*	NP		4
Bignoniaceae	*Zeyheria tuberculosa*	NP	2	
Boraginaceae	*Cordia superba*	P	1	
Euphorbiaceae	*Joannesia princeps*	P		2
Fabaceae	*Anadenanthera colubrina*	P		1
Fabaceae	*Bauhinia forficata*	P		6
Fabaceae	*Dalbergia nigra*	P		66
Fabaceae	*Lonchocarpus cultratus*	NP		1
Fabaceae	*Machaerium fulvovenosum*	NP		6
Fabaceae	*Machaerium nyctitans*	P		40
Fabaceae	*Melanoxylon brauna*	NP		1
Fabaceae	*Myrocarpus fastigiatus*	NP		17
Fabaceae	*Peltophorum dubium*	P	2	14
Lecythidaceae	*Lecythis lanceolata*	NP		13
Moraceae	*Sorocea bonplandii.*	NP		2
Myrtaceae	*Plinia rivularis*	NP		1
Salicaceae	*Casearia sylvestris*	P		9
Sapindaceae	*Cupania oblongifolia*	NP		5
Total			26	212

Source: Authors (2021)

Table 2 – Relationship of species present in the seed rain in the forest restoration area and in the semideciduous forest with the ecological group

Family	Species	Ecological Group	Restoration Forest	Semideciduous Forest
Anacardiaceae	*Myracrodruon urundeuva* Allemão	NP	X	X
Asteraceae	*Bidens pilosa* L.	Herbaceous	X	
Bignoniaceae	Sp. 29	-		X
Bignoniaceae	*Zeyheria tuberculosa* (Vell.) Bureau ex Verl.	NP		X
Bignoniaceae	*Inga vera* Willd.	P	X	X
Ebenaceae	*Diospyros inconstans* Jacq.	NP	X	
Euphorbiaceae	*Croton floribundus* Spreng.	P		X
Fabaceae	Sp. 19	-		X
Fabaceae	Sp. 20	-		X
Fabaceae	Sp. 14	-	X	
Fabaceae	*Mimosa pigra L.*	NP		X
Fabaceae	*Machaerium fulvovenosum* H.C.Lima	NP		X
Fabaceae	*Pterogyne nitens* Tul.	NP		X
Fabaceae	*Myrocarpus frondosus* Allemão	NP	X	
Fabaceae	*Mimosa pudica* L.	NP	X	
Fabaceae	*Peltophorum dubium (Spreng.)* Taub.	P	X	X
Fabaceae	*Machaerium hirtum* (Vell.) Stellfeld	P		X
Fabaceae	*Dalbergia nigra* (Vell.) Allemão ex Benth.	P		X
Fabaceae	*Lonchocarpus sericeus* (Poir.) Kunth ex DC.	NP	X	
Fabaceae	*Phyllocarpus riedelii* Tul.			X
Malpighiaceae	Sp. 26	-	X	
Malvaceae	*Guazuma ulmifolia* Lam.	P	X	X
Poaceae	*Andropogon bicorni*s L.	Grass	X	X
Poaceae	*Setaria parviflora* (Poir.) Kerguélen	Grass		X
Poaceae	*Setaria* sp.	Grass	X	
Poaceae	*Cenchrus echinatus* L.	Grass	X	X
Poaceae	*Paspalum maritimum* Trin.	Grass	X	
Poaceae	*Urochloa brizantha* (Hochst. ex A. Rich.) Stapf	Grass	X	
Rutaceae	*Dictyoloma vandellianum* A.Juss.	NP		X
Sapindaceae	*Serjania salzmanniana* Schltdl.			X
Sapindaceae	*Cupania oblongifolia* Mart.	P		X
Trigoniaceae	*Trigonia* sp.	NP	X	X
-	Sp. 35	-		X

Source: Authors (2021)

In where: *(P = pioneer; NP = non-pioneer; Herbaceous)

The texture of the soils of the two studied areas differed slightly with the soil of the area under restoration consisting of sandy clay loam while that of the semideciduous forest consisted of sandy clay (Table 3). The soil of the semideciduous forest are oligotrophyc with low pH, depleted in nutrients and rich in aluminum. In contrast the soil of the area in restoration present higher nutritional status, higher pH and no detectable aluminum (Table 3).

Table 3 – Results of soil chemical and textural analysis (mean values and standard deviation along five transects) of the restoration forest area and semideciduous forest area at Instituto Terra, Southeast Brazil

Variables	**Restoration Forest**		**Semideciduous Forest**		***P***
P-Mehlich (mg/dm^3)	3.58±	0.64	4.16±	0.63	>0.05
K (mg/dm^3)	95.36±	19.13	40.56±	4.61	***
Ca (cmolc/dm^3)	2.17±	0.75	0.52±	0.12	***
Mg (cmolc/dm^3)	0.52±	0.24	0.11±	0.03	***
Al (cmolc/dm^3)	0.00±	0.00	1.26±	0.10	***
pH in H_2O	5.96±	0.18	4.56±	0.08	***
Organic matter (dag/kg^{-1})	2.28±	0.51	2.26±	0.34	>0.05
Na (cmolc/dm^3)	38.52±	8.00	17.00±	0.00	***
Base saturation (%)	58.17±	9.28	11.09±	1.26	***
Sand (g/kg)	570.32±	69.16	471.84±	52.08	***
Silt (g/kg)	108.08±	57.76	92.96±	45.89	>0.05
Clay (g/kg)	321.60±	64.63	435.20±	49.91	***

Source: Authors (2021)

In where: * P < 0.001 in GLM

Within of the analyzed variables, only P, organic matter and silt were not significantly correlated with pH, indicating that the higher the pH, the greater the nutrients available in the soil (Supplementary Table 2). Multiple regression analysis of both sites together detected variables that best explain the occurrence of recruits, namely the percentage of transmitted light and soil pH (Table 4 and Figure 2). A negative relationship between transmitted light and recruit density (Figure 2A) was found. Also, a negative association was found between soil pH and recruit density, with higher densities of recruits in the semideciduous forest where the soil is more acidic (pH ≤ 5.0) (Figure 2B).

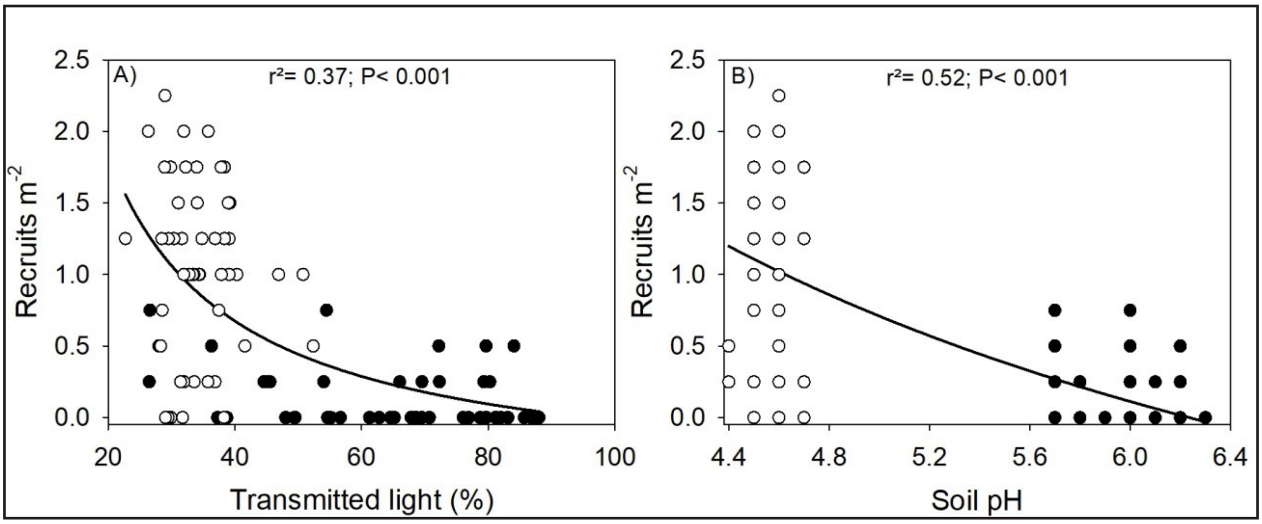
Table 4 – Results of multiple regression analyses for absolute density of recruits and total epigeal biomass of *U. brizantha* with light and soil variables

Regression	N	AIC	R^2	F	P
Absolute density of recruits					
Recruits = 3.71 - 5.05^{-3} Qi/Qo - 0.54 pH	100	131.53	0.53	53.49	<0.001
Total epigeal biomass of U. brizantha					
Biomass of *U. brizantha* = $96.572e^{0.02\ Qi/Qo\ x}$	20	248.25	0.97	30.55	<0.001

Source: Authors (2021)

In where: *Recruits = absolute density of recruits; Qi/Qo = percent of transmitted light; pH = soil pH in H_2O; biomass of *U. brizantha*= total epigeal biomass of *U. brizantha*.

Figure 2 – Relationship between percent of transmitted light and sapling density (A); and between soil pH and sapling density (B) in the Atlantic Forest Restoration area (●), and in the semideciduous forest (○) at Instituto Terra, Southeast Brazil

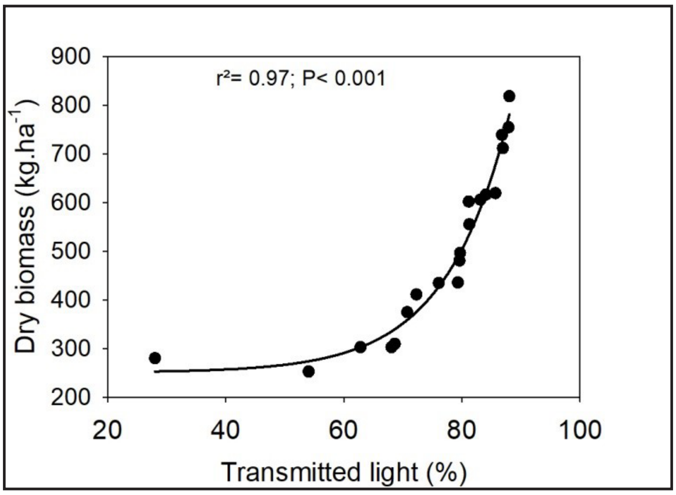


Source: Authors (2021)

Recruits of forest species were recorded in only 17 of the 50 plots evaluated in area under restoration, but recruits were recorded in most of the sampled plots of the semideciduous forest. Recruits of forest species were observed in a wide range of transmitted light levels (Figure 2A). In semidecidous forest, where *U. brizantha* was not observed, transmitted light values were always below 60% and most recruits occurred where transmited light ranged between 30 and 40% (Figure 2A).

Analysis focused only on the area dominated by *U brizantha* revealed a positive relationship between transmitted light and epigeal biomass of *U. brizantha* ($F = 30.55$, $p < 0.001$; Figure 3). No association was found between soil caracteristics and epigeal dry biomass of *U. brizantha*, or between recruit density and grass biomass ($F = 1.474$, $p = 0.24$).

Figure 3 – Effect of percent of transmitted light on total epigeal dry biomass of *U. brizantha* in the forest restoration area at Instituto Terra, Southeast Brazil



Source: Authors (2021)

4 DISCUSSION

It is a great challenge to restore degraded areas, mainly old pastures, due to the persistence of exotic species. The difficulties of restoring tropical forests in areas previously used as pasture are also related to the great capacity of grasses to compete for resources, and their production of toxins that inhibit or hinder the development of other species (MEINERS *et al*., 2012). There are records of the production of allelopathic compounds by grasses in the genus *Urochloa*, which inhibit the germination and root growth of other species. The production of toxins by *U. brizantha* can also provide competitive advantages on account of its multiple effects, such as antimicrobial and anti-herbivore activities (KATO-NOGUCHIA *et al*., 2014). Our results identified the high light availability as determinant for the expressive biomass production of *U. brizantha*. Thus it is plausible to assume that accompanying this great accumulation of biomass there is a great accumulation of allelopathic compounds impacting the success of seedlings from propagules that arrive in the area via seed rain.

The reduced density of recruits observed in the area under restoration may also be related to the limited seed bank of forest species in the area formerly occupied by pasture, and/or due to low seed deposition rates from adjacent forest fragments. The predominance of seeds of *U. brizantha* in the seed rain compared to seeds of native species as here quantified, certainly results in the maintenance of a large grass seed bank. This fact may explain the persistence of the grass even after weeding the area under restoration soon after planting the saplings of forest species. In disturbed environments, such as pasture areas, the planting of tree species can facilitate recolonization by native species by forming a canopy that provides shelter, perches and food for fauna that can contribute as seed source (HANSEN *et al*., 2013; SUGANUMA; DURIGAN, 2014). However, the observed low average seed density of native species in relation to *U. brizantha* suggests a paucity of forest seed sources near the study site, which would serve as primary seed source and support the process of ecological succession (REID; HOLL, 2012). *U. brizantha* has as main characteristics the ease of vegetative propagation and high seed production, whose fruits are dry of the cariopse type (XAVIER *et al*., 2021). Despite the high occurrence of *U. brizantha* seeds in the seed rain in the area under restoration, its absence in the reference area indicates how restricted the dispersion of the grass is.

Although seeds of forest species are present in the seed rain in the area under restoration, the establishment of seedlings in this area dominated by *U. brizantha* is limited as evidenced by the low density of recruits. The low success of the forest species seedlings in areas dominated by grasses has already been experimentally determined as in a study on direct seeding, which found low seedling survival in an area of seasonal tropical forest dominated by invasive alien grasses (SOUZA; ENGEL, 2018). High seed predation, low germination rate and competitive suppression by grasses that produce a dense layer of litter are determinant factors limiting the seedling stablisment success in areas of forest restoration dominated by grasses (MARCUZZO *et al*., 2013).

Our results indicated that the competitive advantage of *U. brizantha* is dependent on the availability of light. In sampling locations with around 60% transmitted light presented less than half the biomass of *U. brizantha* observed in more sunny locations. This result indicates that low light availability functions as a strong filter for *U. brizantha* biomass accumulation. This is in line with previous studies that have worked with grass productivity under irrigation and a light intensity of 95%, resulting in five cuts of harvest grass (JUNQUEIRA, 2015). Since invasive grasses perform better in sites with direct light, they are able to successfully invade restoring areas of Atlantic Forest as soon as their seeds reach open environments. Small openings in the forest canopy may be more favorable for the establishment of forest seedlings (ALTMAN *et al*., 2016) while large openings would favor the invasion by exotic species. However, sites with continuous canopy cover can limit invasion success by shade intolerant species as observed in the semideciduos forest in the present study. In addition to the greater canopy coverage limiting the understory light, the presence of *U. brizantha* seeds was not observed in the seed rain in the semidecidous forest. Both factors would explain the absence of exotic grass in this studied area.

It has often been reported that besides the frequency and intensity of disturbance the high resources availability favors exotic species over native species (GAO *et al*., 2018).). Here, in addition to the negative relationship between the availability of light and the density of recruits, a negative relationship was also observed in relation to soil pH. In the restoration area dominated by *U. brizantha* beyond the higher light availability, a greater availability of nutrients was observed. There are studies that report that liming and fertilization significantly increase dry mass production of pastures of *U. brizantha* (ARROYAVE *et al*., 2013), even in shaded stands (PACIULLO *et* *al*., 2011). Evaluating the nutritional limitations of growth in secondary forests, Irving (2015) observed increased total biomass in plots that received fertilization. However, this increase was accompanied by the proliferation of remaining pastures and reduced biomass of herbaceous species. In the present study, the number and diversity of recruits were higher in the semideciduous forest where the soil was more acidic and poorer in bases compared to the area under restoration. This finding indicates that low soil fertility is not necessarily a limiting factor for forest species recruitment.

In both areas of this study, the largest number of recruit species were non-pioneer species that could tolerate shade and grow, albeit more slowly, under a closed canopy. However, the largest number of individuals were of pioneer species. Pioneer species may also grow in shaded environments, but only for a limited period of time due to their greater light demand for germination and development (ALTMAN *et al*., 2016). Among the recorded forest species, saplings of *Myracrodruon urundeuva* Allem. (Anacardiaceae) and *Dalbergia nigra* (Vell.) Allemão ex Benth. (Fabaceae) had the highest number of regenerating individuals in the area under restoration and in the semideciduous forest, respectively. These species have some characteristics in common, such as capacity to germinate in the presence or absence of light and under a wide temperature range, which indicates that they can occur in both, open areas and areas under a more closed canopy (VIRGENS *et al*., 2012; MATOS; BORGES; SILVA, 2015). These characteristics can explain the common occurrence of these in pasture areas or degraded forests. Thus, these species have high potential for forest recovering since they can even occur in soils with low nutritional status and are resistant to water deficit (VIRGENS *et al*., 2012; ATAÍDE *et al*., 2013).

5 CONCLUSIONS

The data obtained here indicated that under higher canopy cover, transmited light acts as a strong filter for the productivity of the studied exotic grass. The higher imput of grass seed in areas dominated by *U. brizantha* in proportion to the arrival of propagules of forest species is another factor that can limit the success of forest restoration. The low understory light and the absence of *U. brizantha* seeds in the seed rain explain the no occurrence of the species in the semideciduous forest studied area. Considering that saplings in the semideciduous forest were present even under conditions of low light availability, procedures that limit light availability can weaken the competitiveness of the invading grass and favor recruitment in areas previously used as pasture under forest restoration. The planting of larger saplings, preferably pioneer species, that would quickly develops a dense canopy or/and the use shading screens for reducing the impact of competition between grasses and seedlings could be pratices that would favor forest restoration in sites previously used as pastures. This finding suggests that successful recruitment in areas dominated by tropical exotic grass is not necessarily related to higher soil fertility, and thus procedures such as liming and adding chemical fertilizers may be unnecessary and harmful to forest restoration, favoring invasive grasses.

REFERENCES

ARROYAVE, C. *et al*. Differential aluminum resistance in *Brachiaria* species. **Envolvonmental and Experimental Botany**, Barcelona, Espanha, v. 89, p. 11-18, 2013. DOI: 10.1016/j.envexpbot.2013.01.001.

ALTMAN, J. *et al*. Linking spatiotemporal disturbance history with tree regeneration and diversity in na old-growth forest in northern Japan. **Perspectives in Plant Ecology, Evolution and Systematics**, Pruhonice, Czech Republic, v. 21, p. 1-13, 2016. DOI: 10.1016/j.ppees.2016.04.003.

APG IV. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. **Botanical Journal of the Linnean Society**, London, v. 181, p. 1-20, 2016. DOI: 10.1111/boj.12385.

ATAÍDE, G. M. *et al.* Alterations in seed reserves of *Dalbergia nigra* (Vell.) Fr All. ex Benth.) during hydration. **Journal of Seed Science**, Londrina, Paraná, v. 35, n. 1, p. 56-63, 2013. DOI: 10.1590/S2317-15372013000100008.

AUFFRET, A. G.; COUSINS, S. A. O. Past and present management influences the seed bank and seed rain in a rural landscape mosaic. **Journal of Applied Ecology**, Stockholm, Sweden, v. 48, n. 5 p. 1278-1285, 2011. DOI:10.1111/j.1365-2664.2011.02019.x.

CECCON, E.; GONZÁLEZ, E. J.; MARTORELL, C. Is Direct Seeding a Biologically Viable Strategy for Restoring Forest Ecosystems? Evidences from a Meta analysis. **Land degradation and development**, México, v. 27, n. 3, p. 511-520, 2016. DOI: 10.1002/ldr.2421.

COSTA, H. J. U. *et al.* Forage Mass and Morphological Characteristics of Corn and *Brachiaria brizantha* cv. Piatã Cultivated in Consortium System. **ARS Veterinária**. Jaboticabal, São Paulo, v. 28, n. 2, p. 134-143, 2012.

DAWSON, W. *et al*. Alien plant species with a wider global distribution are better able to capitalize on increased resource availability. **New Phytologist**, Sevilla, Spain, v. 194, n. 3, p. 859–867, 2012. DOI:10.1111/j.1469-8137.2012.04104.x

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (EMBRAPA). Sistema brasileiro de classificação de solos (2018, January 20) Retrieved from http://www.cnps.embrapa.br/

FRAGOSO, R. O. *et al*. Forestry restoration in abandoned pastures of urochloa by different sizes of brushwood. **Cerne**, Curitiba, Paraná, v. 23, n. 1, p. 85–94, 2017. DOI: 10.1590/01047760201723012276.

GAO, L. *et al.* General laws of biological invasion based on the sampling of invasive plants in China and the United States. **Global Ecology and Conservation**, Guangdong Province, China, v. 16, p. 1-29, 2018. DOI: 10.1016/j.gecco.2018.e00448.

HANSEN, M. C. *et al.* High-resolution global maps of 21st-century forest cover change. **Science**, USA, v. 342, n. 6160, p. 850-853, 2013. DOI: 10.1126/science.1244693.

INSTITUTO NACIONAL DE METEOROLOGIA DO BRASIL (INMET). Normais Climatológicas (1972/2014). Brasília - DF, 2018. Taken from: http://www.inmet.gov.br

KATO-NOGUCHIA, H. *et al.* Physiology Phytotoxic substances with allelopathic activity may be central to the strong invasive potential of *Brachiaria brizantha*. **Journal of Plant Physiology**, Kagawa, Japans, v. 171, n. 7, p. 525-530, 2014. DOI: 10.1016/j.jplph.2013.11.010.

IRVING, L. J. Carbon Assimilation, Biomass Partitioning and Productivity in Grasses. **Agriculture**, [s.l.] v. 5, n. 4, p. 1116-1134, 2015. DOI: 0.3390/agriculture5041116.

List of Species of Flora of Brazil. Jardim Botânico do Rio de Janeiro. (2018, January 20). Retrieved from http://floradobrasil.jbrj.gov.br

LIU, Y.; KLEUNEN, M. Responses of common and rare aliens and natives to nutrient availability and fluctuations. **Journal of Ecology**, Konstanz, Germanyv, v. 105, n. 4, p. 1111–1122, 2017. DOI: 10.1111/1365-2745.12733.

LOFT, L.; GEHRIG, D. N.; ROMMEL, J. Effectiveness and equity of Payments for Ecosystem Services: Real-effort experiments with Vietnamese land users. **Land Use Policy**, Berlin, Germany, v. 86, p. 218-228, 2019. DOI: 10.1016/j.landusepol.2019.05.010.

MARCUZZO, S. B. *et al.* Comparação da eficácia de técnicas de nucleação para restauração de área degradada no sul do Brasil. **Floresta**, Santa Maria, RS, v. 43, n. 1, p. 39-48, 2013. DOI: 10.5380/rf.v43i1.28680.

MATOS, A. C. B.; BORGES, L. E. E.; SILVA, L. J. Physiology of seed germination of *Dalbergia nigra* (vell.) Allemão ex Benth. under different temperatures and exposure times. **Revista** Árvore, Viçosa, MG, v. 39, n. 1, p. 115-125, 2015. DOI: 10.1590/0100-67622015000100011.

MCMANNAMEN, C.; NELSON, C. R. C.; WAGNER, V. Timing of seeding after herbicide application influences rates of germination and seedling biomass of native plants used for grassland restoration. **Restoration Ecology**, USA, v. 26, p. 1-12, 2018. DOI: 10.1111/rec.12679.

MEINERS, S. J. *et al*. Developing anecological context for allelopathy. **Plant Ecol**, [s.l.], v. 213, p. 1861–7, 2012.

PACIULLO, D. S. C. *et al.* The growth dynamics in *Brachiaria* species according to nitrogen dose and shade. **Revista Brasileira de Zootecnia**, Rio de Janeiro, RJ, v. 40, n. 2, p. 270-276, 2011. DOI: 10.1590/s1516-35982011000200006.

PIOTTO, D. *et al.* Successional, spatial, and seasonal changes in seed rain in the Atlantic forest of southern Bahia, Brazil. **Plos One**, Ilhéus, Bahia, v. 14, n. 12, p. 1-20, 2019. DOI: 10.1371/journal.pone.0226474

R Core Team (2013) R: A Language and Environment for Statistical Computing. https://www.R-project.org/

REID, J. L.; HOLL, K. D. Arrival ≠ Survival. **Restoration Ecology**, USA, v. 21, n. 2, p. 153–155, 2012. DOI: 10.1111/j.1526-100x.2012.00922.x.

REID, J. L.; FAGAN, M. E.; ZAHAWI, R. A. Positive site selection bias in meta-analyses comparing natural regeneration to active forest restoration. **Science Advances**, USA, v. 4, n. 5, p. 01-03, 2018. DOI: 10.1126/sciadv.aas9143.

RODRIGUES, C. S. *et al*. Grupos funcionais de gramíneas forrageiras tropicais. **Revista Brasileira de Zootecnia**, Viçosa, MG, v. 41, n. 6, p. 1385-1393, 2012. DOI: 10.1590/S1516-35982012000600010.

SILVEIRA, E. R. *et al.* Controle de gramíneas exóticas em plantio de restauração do Cerrado. p. 05-09, 2013. In: DURIGAN, G.; RAMOS, V. S. **Manejo Adaptativo**: primeiras experiências na Restauração de Ecossistemas. São Paulo, SP: Páginas & Letras Editora e Gráfica, 2013.

SOUZA, D. C.; ENGEL, V. L. Direct seeding reduces costs, but it is not promising for restoring tropical seasonal forests. **Ecological Engenirin**g, São Paulo, SP, v. 116, p. 35-44, 2018. DOI: 10.1016/j.ecoleng.2018.02.019.

SUGANUMA, M. S.; DURIGAN, G. Indicators of restoration success in riparian tropical forests using multiple reference ecosystems. **Restoration Ecology**, São Carlos, SP, v. 23, n. 3, p. 238–251, 2014. DOI: 10.1111/rec.12168.

VIRGENS, I. O. *et al.* Physiologic behavior of *Myracrodruon urundeuva* (Anacardiaceae) Fr. All. SEEDS submitted to abiotic factors. **Ciência Florestal**, Santa Maria, RS, v. 22, n.4, p. 681-692, 2012. DOI: 10.5902/198050987550.

XAVIER, R. O. *et al*. Distinctive seed dispersal and seed bank patterns of invasive African grasses favour their invasion in a neotropical savanna. **Oecologia**, 2021. DOI: 10.1007/s00442-021-04904-z.

Authorship Contribution

1 Monique Perini

Biologist, PhD.

https://orcid.org/0000-0002-6532-3674 • monique.perini@gmail.com

Contribution: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Visualization, Writing – original draft, Writing – review & editing

2 Matheus Lopes Souza

Biologist, Dr.

https://orcid.org/0000-0002-9044-1883 • matheus.eco@gmail.com

Contribution: Formal Analysis, Project administration, Software, Supervision, Validation, Visualization, Writing – review & editing

3 José Pires de Lemos Filho

Agronomist, PhD.

https://orcid.org/0000-0002-1278-686X • joseplemosfilho@gmail.com

Contribution: : Conceptualization, Formal Analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing

How to quote this article

Perini, M.; Souza, M. L.; Lemos Filho, J. P. Forest restoration in old pasture areas dominated by Urochloa brizantha. Ciência Florestal, Santa Maria, v. 33, n. 1, e65858, p. 1-20, 2023. DOI 10.5902/1980509865858. Available from: https://doi.org/10.5902/1980509865858.