Tree diversity in riparian forests immersed in a pasture with *Urochloa decumbens* (Stapf) R.D. Webster (Poaceae) grass under domain of the Atlantic Forest, Brazil

Diversidade de espécies arbóreas em matas ciliares de cursos d'água imersos em uma pastagem com a gramínea *Urochloa decumbens* (Stapf) R.D. Webster (Poaceae) no domínio da Mata Atlântica, Brasil

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ABSTRACT
The riparian vegetation along water courses and the health of the river's basin, regarding the aquatic and terrestrial ecosystems associated with them, are widely discussed in literature. However, the maintenance of the services and the conservation role that riparian forests provide to flora and fauna may be affected by the regional matrix that surrounds the water course and by the length and composition of the riparian vegetation associated with them. This study aimed to evaluate the relationships among the grass cover and arboreal species diversity in three watercourses surrounded by a pasture dominated with the alien grass *Uroclhoa decumbens* (Stapf) R.D. Webster (former *Brachiaria decumbens*). Two hypotheses were tested: (i) watercourses with larger riparian forest width present higher richness and abundance of native and zoochoric tree species and those associated to late succession stages, and (ii) watercourses with larger riparian forest width present a lower grass cover on their interior. The study was conducted under domain of Semideciduous Seasonal Forest, belonging to the Atlantic Forest biome, municipality of Londrina, Paraná State, south Brazil. The regional climate is Köppen's Cfa humid subtropical. The soil is classified as a mosaic of eutroferric red nitosols and lithosols. The studied sites mostly comprise pasture with *U. decumbens* alien grass and small patches of woody vegetation amidst an open pasture dominated by species attributed to the first's stages of secondary succession. The studied site is immersed in Cambé's River watershed and contain three watercourses, Cristal River, tributary to São Lourenço River, that, in turn, is tributary to Cambé River. All watercourses are classified as small rivers

(Brazilian Forestry Code, federal law: n. 12.651/2012), with length inferior to 10 m between both riversides. The riparian vegetation shares similar characteristics and structure, encompassing woody vegetation with pioneer trees species and high canopy openness. All riparian forests are immersed in pastures with *U. decumbens* grass. Transects of 200 meters long, measuring one meter wide from the line on both sides of the transect, and one square plot (25 m^2) were allocated on the interior of each riparian forest. Transects were evaluated as arboreal species richness and the length of the riparian forest strip. In each plot, the arboreal vegetation was inventoried as species richness, abundance and density, and the *U. decumbens* cover was measured. The riparian forest width was arranged in two classes, forests with width ≤ 5 m or ≥ 10 m. The studied forests were compared as richness, abundance, density, and grass cover. The correlations among the riparian vegetation with the forest width and grass coverage (%) were evaluated. Species richness, abundance and density did not differ among the watercourses. However, species abundance and density presented positive correlations with the riparian forest width, indicating that the larger is the riparian vegetation, the higher is the species density. Grass cover presents a strong negative correlation with the riparian forest width, indicating that narrow strips of woody vegetation present higher grass cover. A high positive correlation was observed with riparian strip width and native trees, suggesting that native woody species establishment is limited by the riparian strip width and that those rustic trees species are more capable to colonize these environments. Also, the correlation found with species that present abiotic syndromes and pioneer species indicates that trees that can colonize open areas are more suitable to establish on narrow strips of vegetation amidst a pasture. The relationships observed with zoochoric trees suggests that the fauna that visits these forests are tolerant to open areas and visit these areas independently of their vegetation width. The larger riparian forests present lower grass cover and these can be related to shadow micro-sites that reduce the luminosity which can affect the permanence potential of the dominance of *U. decumbens*. In this way, the data suggests that few plants can establish in these pasture landscape, and those more rustic trees which are able to establish under open areas, high grass cover and canopy openness, and that re-sprout after a fire, became more dominant. For these watercourses, with narrow riparian vegetation strips surrounded by an *U. decumbens* pasture, the high grass cover can restrict and plant diversity, acting on the course and velocity of secondary succession in these areas.

Keywords: grass cover, natural regeneration, riparian forest width, alien grass.

RESUMO

A vegetação ciliar ao longo dos cursos d'água e a saúde da bacia hidrográfica, no que diz respeito aos ecossistemas aquáticos e terrestres a eles associados, são amplamente discutidas na literatura. No entanto, a manutenção dos serviços ambientais e das relações ecológicas que as matas ciliares conferem à flora e fauna podem ser afetados pela matriz regional que circunda os cursos d'água e pela extensão e composição das matas ciliares a eles associadas. Este trabalho teve como objetivo avaliar as relações entre a cobertura de gramíneas e a diversidade de espécies arbóreas em três cursos d'água imersos em pastagens dominadas pela gramínea exótica *Uroclhoa decumbens* (Stapf) R.D. Webster (*Brachiaria decumbens*). Duas hipóteses foram testadas: (i) cursos d'água com maior largura de mata ciliar apresentam maior riqueza e abundância de espécies arbóreas nativas e de dispersão zoocórica, assim como possuem maior número de espécies pertencentes aos estágios tardios de sucessão secundária, e (ii) cursos d'água com maior largura de mata ciliar apresentam menor cobertura de gramíneas em seu interior. O estudo foi conduzido sob o domínio da Floresta Estacional Semidecidual, pertencente ao bioma Mata Atlântica, no município de Londrina, Estado do Paraná, sul do Brasil. O clima regional é o Cfa de Köppen, subtropical úmido. O solo é classificado como um mosaico de nitossolos e litossolos vermelhos eutroférricos. Os sítios estudados compreendem, em sua maioria, pastagens com gramíneas exóticas *U. decumbens* e pequenas manchas de vegetação lenhosa em meio a uma pastagem aberta dominada por espécies atribuídas aos primeiros estágios de sucessão secundária. O local estudado está inserido na bacia do rio Cambé e contém três cursos d'água, ribeirão Cristal, afluente do ribeirão São Lourenço, que, por sua vez, é afluente do ribeirão Cambé. Todos os cursos d'água são classificados como pequenos rios (Código Florestal Brasileiro, lei federal: nº 12.651/2012), com largura entre margens inferiores a 10 m. A vegetação da área ciliar possui características e estrutura semelhantes, abrangendo vegetação lenhosa com árvores de espécies pioneiras e alta abertura do dossel. Todas as matas ciliares estão inseridas em pastagens com *U. decumbens*. Transectos de 200 metros de comprimento, avaliando um metro de largura a partir da linha em ambos os lados do transecto, e uma parcela quadrada (25 m^2) foram alocados no interior de cada mata ciliar. Os transectos foram avaliados quanto à riqueza de espécies arbóreas e ao comprimento da faixa de mata ciliar. Nas áreas das parcelas, a vegetação arbórea foi inventariada como riqueza, abundância e densidade de espécies, e a cobertura de *U. decumbens* foi mensurada. A largura da mata ciliar foi classificada em duas classes, florestas com larguras ≤ 5 m ou ≥ 10 m. As florestas estudadas foram comparadas quanto à sua riqueza, abundância, densidade e cobertura de gramíneas. Também foram avaliadas as correlações entre a vegetação ciliar, a largura da floresta ciliar e a cobertura de gramíneas (%). A riqueza, abundância e densidade de espécies não diferiram entre os cursos d'água. No entanto, a abundância e densidade total de espécies apresentaram relações positivas com a largura da mata ciliar, indicando que quanto maior a área de mata ciliar, maior a densidade de espécies. A cobertura de *U. decumbens* apresenta correlação negativa com a largura da mata ciliar, indicando que faixas estreitas de mata ciliar apresentaram no seu interior maior cobertura de gramíneas. Correlações positivas foram observadas entre a largura da faixa ripária e a abundância de árvores nativas, sugerindo que o estabelecimento de espécies lenhosas nativas é limitado pela largura da faixa de mata, e que espécies mais rústicas tem maior capacidade de colonizar esses ambientes. Além disso, a correlação encontrada com espécies que apresentam dispersão por síndromes abióticas e espécies pioneiras indica que as árvores que podem colonizar áreas abertas são mais adequadas para se estabelecer em estreitas faixas de vegetação em meio a uma pastagem. As relações observadas com as árvores zoocóricas sugerem que a fauna que visita essas florestas é tolerante a áreas abertas e visita essas áreas independentemente de sua extensão de vegetação. As matas ciliares maiores apresentam menor cobertura de gramíneas e estas podem estar relacionadas a micro-sítios mais sombreados, reduzindo a luminosidade o que é capaz de afetar o potencial de permanência de a dominância de *U. decumbens*. Desta forma, os resultados sugerem que poucas espécies de plantas se estabelecem nestas paisagens imersas em pastagem, e aquelas árvores mais rústicas que são capazes de se estabelecer em áreas com alta cobertura de gramínea e abertura de dossel, e que rebrotam após um incêndio, tornam-se dominantes. Para esses cursos d'água, com estreitas faixas de mata ciliar circundadas por pastagem de *U. decumbens*, a alta cobertura de gramíneas pode restringir a diversidade vegetal, alterando no curso e na velocidade da sucessão secundária destes ambientes.

Palavras-chave: cobertura de gramíneas, regeneração natural, largura de mata ciliar, gramíneas exóticas.

1 INTRODUCTION

Relationships among riparian vegetation along water courses and the health of the river's basin, regarding aquatic and terrestrial ecosystems associated with them, are widely discussed in literature (Ferreira and Dias 2004; Donadio, Galbiatti and Paula, 2005; Feld et al., 2018; Chua et al., 2019; Turunen et al., 2019; Burdon et al., 2020; Turunen et al., 2021). The Brazilian Forestry Code reformulation (federal law nº 12.651/2012) has increased this discussion in Brazil.

Debates about the environmental services that riparian's forests provide for protection of the hydrological resources and for conservation and restoration of biodiversity matters on these zones, have been growing along the present years. Currently in Brazil, with the Brazilian Forestry Code reformulation (federal law nº 12.651/2012), this discussion has gained a crescent space and has been an increasing discussion about the environmental services that the riparian forest plays (Carpanezzi, 2000; Barbosa, 2004; Barbosa, 2006; Toledo et al., 2010; Da Silva, et al., 2017a; Paolino et al., 2018).

Some functions exerted by the riparian forests on rivers basins includes the superficial run-off energy dissipation and the superficial soil and water filtering, reducing the risk of the silting up process and the risk of eutrophication. They can also act on the thermal water balance, due to the shadow produced by the riparian vegetation (Carpanezzi, 2000; Barbosa, 2004; Barbosa, 2006; Johnson and Almlöf, 2016, Thomas, Griffiths and Ormerod, 2016; Knouft et al., 2021).

From the conservation point of view, the riparian forests are important to the balance of the aquatic ecosystems productive chain and to nutrient cycling, acting as much in the organic matter decomposition as in the supply of food resources to the aquatic organisms (Thomas, Griffiths and Ormerod, 2016, Warren et al., 2016; Carpanezzi, 2000; Donadio, Galbiatti and Paula, 2005; Ferreira and Dias, 2004). Furthermore, the riparian forest is important to terrestrial flora and fauna traffic, acting as ecological corridors (Campos and Landgraf 2001; Brito et al., 2017; Paolino et al., 2018; Gutiérrez-Chacón, Valderrama-a and Klein, 2020).

However, the maintenance of these services and the conservation role that riparian forests provide may be affected by the regional landscape that surrounds the water course, and by the width and composition of the riparian vegetation associated with them (Campos and Landgraf, 2001; Donadio, Galbiatti and Paula, 2005). Studies in tropical regions points out that agricultural and pastures can play an intense restriction to native forest species maintenance and regeneration (Smit, Den Ouden and Müller-Schãrer, 2006; Sampaio, Holl and Scariot, 2007; Scervino and Torezan, 2015; Cury et al., 2020). Furthermore, to riparian forests, pastures landscapes and discontinuous narrow riparian vegetation along watercourses showed to be more susceptible to biological invasion by grasses and scrubs associated with anthropogenic areas than large continuous vegetation areas (Dislich, Kisser and Pivello, 2002; Feld et al., 2018).

On riparian forests surrounded by pastures, with regards to Brazilian pastures with African savanna grasses species, the grass invasion on the interior of the riparian forest zone is common, which is especially severe on narrow strips of riparian forests (Carvalho et al., 2010). Usually, the grasses that presents this behavior are represented by species with highly competitive capacity and efficient seed dispersal, and in many cases, associated with fire events (Puerta, 2002; Ribeiro et al., 2006; Scervino and Torezan, 2015; Cury et al., 2020).

In Brazil, the alien species *Urochloa decumbens* (Stapf) R.D. Webster, brachiaria-grass (former *Brachiaria decumbens*), is known as an aggressive species for the high competitive ability for water, light and nutrients in detriment to forest native species, as well for the great longevity of the seeds on the soil seed bank, an efficient energetic metabolism (C_4) and seed dispersal, with high production of biomass, being also associated with the increase of risk of fire in the dry season (Marod et al., 2002; Marod et al., 2004; Ribeiro et al., 2006; Scervino and Torezan, 2015; Ferreira et al., 2016; Cury et al., 2020; Xavier, et al., 2021).

In addition, some authors have identified the allelopathic effect exerted by *U. decumbens*, which is able to deplete the establishment of other species on their surroundings (Barbosa, Pivello and Meirelles, 2008; Da Silva, et al., 2017b). Also, *Urochloa* grasses can act in the soil nitrification process, inhibiting the conversion of ammonia (NH_4^+) into nitrite (NO_2^-) and nitrate (NO_3^-), which is often the form of nitrogen (NO_3^-) most absorbed by Atlantic Forest plant species (Boddey et al., 2004; Subbarao et al., 2009; Subbarao et al., 2012; Guareschi et al., 2014).

Currently, *Uroclhoa* genera is widespread on pasture fields in many regions in Brazil and has invaded natural areas in different biomes, altering vegetation structure, composition and acting on the ecosystem resilience (Boddey et al., 2004; Ferreira et al., 2016; de Oliveira et al., 2020). In this context, this study aimed to evaluate the relationships among grass cover and arboreal species diversity in watercourses surrounded by a pasture dominated with *Uroclhoa decumbens* (Stapf) R.D. Webster grass under the Atlantic Forest domain. Two hypotheses were tested, (i) watercourses with larger riparian forest width presents higher richness and abundance of native and zoochoric species, and with those associated to late succession stages of secondary succession in the Atlantic Forest, and (ii) watercourses with larger riparian forest width presents a lower *U. decumbens* grass cover on their interior.

2 MATHERIAL AND METHODS

Study site

The study was conducted under domain of the Semideciduous Seasonal Forest, belonging to the Atlantic Forest biome, Londrina district, northern are of Paraná State, south region of Brazil, at the former Refúgio farm, recently implanted as an Ecological reserve, the "Ecological Park João Milanês" (23°20'44''S 51°0'58''W; 371,95 ha).

The regional climate is Köppen's Cfa humid subtropical with hot and rainy summers and a dry winter with infrequent frosts (IAPAR, 2000). The annual average of the air temperature is 21º

C and the annual rainfall is 1.600 mm (IAPAR, 2000). The soil is classified as a mosaic of eutroferric red nitosols and lithosols (Tagima and Terabe, 2005). The terrain morphology is formed by soft slopes with features such as small mounds and shallow gullies (Tagima and Terabe, 2005), although some mounds present a terrain slope superior to 45° (Tagima and Terabe, 2005; Scervino, 2009; Scervino and Torezan, 2015).

The vegetation at the study site mostly comprises pasture areas with the introduced grass *Urochloa decumbens* (Stapf) R.D. Webster (former *Brachiaria decumbens*) with the occurrence of small patches of woody vegetation amidst an open pasture, which is dominated by species attributed to the first's stages of secondary succession (Scervino, 2009; Scervino and Torezan, 2015). These pastures were used by informal cattle farmers in low densities (≤ 1,0 head per ha) with occasional burnings in the late dry season until the implementation of the Ecological Park João Milanês (Scervino and Torezan, 2015). Also, the park includes riparian forests (Scervino, 2009) and woody vegetation patches on higher slope areas (Scervino and Torezan, 2015).

This Ecological Park is immersed in the Cambé's river watershed and contain three watercourses, Cristal river (site 1) tributary to São Lourenço river (site 2), that, in turn, is tributary to Cambé river (site 3). Cambé is the wider watercourse, however, all of these rivers are classified as small watercourses (Brazilian Forestry Code, federal law n. 12.651/2012) with width inferior to 10 m between both riversides. Also, they all share similar water physic-chemical properties and topography (Tagima and Terabe, 2005).

The riparian vegetation also shares similar characteristics and structure, encompassing woody vegetation with high abundance of pioneer species and high canopies openness. All riparian forests are inserted in pasture with *U. decumbens* alien grass (Scervino, 2009). It is estimated that 70% of the park is classified through the Brazilian Forest Code as permanent preservation areas (APPs) (Scervino, 2009), due to areas with high slope (>45°) and the presence these watercourses.

Sampling design

Transects of 200 meters long and one square plot of 5 x 5m (25 m^2) were allocated at each riparian forest of the three studied watercourses. In order to better evaluate the Cambé riparian forest, the longest, widest and most important watercourse of this watershed, four points were inventoried and three transects and plots were allocated. At one site of Cambé river it was not possible to allocate a plot due to the narrow riparian forest, and at another Cambé's forest site was not possible to sample one transect due to inaccessibility of the area (higher slope areas).

For vegetation sampling, both sides of the linear transect were evaluated (1,5 m at each site of the transect), and one plot was allocated randomly in one point of the transect area. It was adopted a minimal distance of 1 m of the river margin and pasture borders to the allocated transects and plots whenever possible. At each transect, the arboreal species richness and the width of the riparian forest were evaluated.

To estimate the width of the riparian forest at the transect, three measures per watercourse were taken and converted to a mean number. On the plot's area, the arboreal vegetation was inventoried as species richness, abundance and density, also *U. decumbens* cover was measured. The observed riparian forest width was arranged in two classes, such as riparian forest with equal or inferior to 5 m (≤ 5 m) or width equal or superior to 5 m (≥5 m).

Vegetation sampling

All the arboreal vegetation with diameter at the breast height (DBH) equal or superior to 3,0 cm (DBH ≥ 3,0 cm) were inventoried as species richness at the transect, and as species richness, abundance, and density at the plot area. In order to better evaluate the vegetation composition, the species were classified according to origin (native or alien), dispersal syndrome (biotic or abiotic) and as successional status (pioneer or late succession species). Due to the low number of late succession species and individuals, it wasn't possible to apply statistical analysis for this data.

Grass cover was estimated visually in 25% increments, with the aid of a measuring tape (Ruiz-Jaén and Aide, 2005).

To calculate density (individuals/hectare), the formula: DT= N x 10.000/A was applied, in which DT: means total density (ind/ha); N: number of individuals; A: total sampled area.

Data analysis

Normality was checked by Kolmogorov-Smirnov test, and data homogeneity by Levene's test. Data revealed to be non-parametric, thus the Mann-Whitney test was applied to compare species richness, abundance, and density, and to compare the grass cover among the riparian forests. The Spearman Correlation Rank (r) was applied to evaluate correlations among the riparian vegetation data with riparian forest width and grass cover. Due to the low number of late succession species and individuals, it wasn't possible to apply statistical analysis for this data.

Linear Regression (r, r^2) was used to evaluate those relationships that revealed to be significative by Spearman. Results were considered significative when $\alpha \leq 0.05$.

3 RESULTS

At the studied riparian forests, through both methods of vegetation sampling (transects and plots), 56 arboreal species belonging to 27 botanical families were inventoried. At the Cristal riparian forest, 30 species of trees were found, and at the São Lourenço's 27 arboreal species were inventoried. Among the four evaluated sites at the Cambé's riparian forest, 38 woody species were found. The richest family at all studied riparian forests was Fabaceae, followed by Euphorbiaceae, Sapindaceae, and Solanaceae botanical families **(Species Richness List).**

Arboreal species richness, abundance and density showed no significant differences between watercourses with different widths of riparian forests. Thus, watercourses with riparian forest width ≤ 5 m and ≥ 10 m share similar diversity (**Table 1**).

However, arboreal species abundance and density presented a positive correlation with the riparian forest width, indicating that the larger is the riparian strip the higher is the species density **(Table 2)**.

Table 1: Riparian Forest width (m), grass cover (%), species richness (number of arboreal species), abundance and density (inds/ha) at three riparians vegetation areas of watercourses surrounded by *Urochloa decumbens* pasture, under domain of Seasonal Atlantic Forest, at the "Ecological Park João Milanês", Londrina, Paraná, Brazil (23°20'44''S 51°0'58''W).

Tabela 1: Largura de nata ciliar (m), cobertura de gramíneas (%), riqueza de espécies (número de espécies arbóreas), abundância e densidade (inds/ha) em três mata ciliares de cursos d'água imersos em uma matriz de pastagem com *Urocloa decumbens*, no domínio da Floresta Estacional Semidecidual, Mata Atlântica, "Parque Ecológico João Milanês", Londrina, Paraná, Brasil (23°20'44''S 51°0'58''W).

Watercourse	Riparian forest widh (m)	Grass cover (%)	Species richness	Abundance	Density (inds/ha)
Cristal	22,3	45 (a)	30 (a) *	14 (a) **	5,600 (a) **
São Lourenço	5,0	83 (b)	27 (a) *	6 (a) **	2,400 (a) **
Cambé $_1$	12,6	72 (a)	30 (a) *	13 (a) **	5,200 (a) **
Cambé $_2$	5,3	90 (b)	20 (a) *	9 (a) **	3,600 (a) **
Cambé $_3$	15	72 (a)	9 (a) **	13 (a)**	5,200 (a) **
Cambé $_4$	1,8	97 (b)	7 (a) *	-	-

Note: * Data came from a linear transect (200 m); ** Data came from a plot (25 m^2); Different letters indicate difference of variables among riparian forest widths. Results were considered significative when α < 0,05.

Nota: * Dados amostrados em transecto linear (200 m); ** Dados obtidos em parcelas (25 m^2). Letras diferentes indicam diferença significativa entre as matas ciliares com diferentes larguras. Os resultados foram considerados significativos quando α < 0,05.

Table 2: Spearman correlation rank. Data came from three riparian forests present on watercourses surrounded by *Urochloa decumbens* pasture, under domain Seasonal of Atlantic Forest, at the "Ecological Park João Milanês", Londrina, Paraná, Brazil (23°20'44''S 51°0'58''W).

Tabela 2: Rank de Correlação de Spearman. Os dados foram obtidos em três matas ciliares de cursos d'água imersos em uma matriz de pastagem com *Urocloa decumbens* no domínio da Floresta Estacional Semidecidual, Mata Atlântica, no "Parque Ecológico João Milanês", Londrina, Paraná, Brasil (23°20'44''S 51°0'58''W).

	Species category	Riparian forest width	Grass cover
Abundance	Total	+ 0,947	n.s
	Native	+ 0,974	- 0,900
	Exotic	n.s	n.s
	Biotic dispersal syndrome	n.s	n.s
	Abiotic dispersal syndrome	+ 0,947	n.s
	Pioneer succession	+ 0,947	n.s
	Late succession	-	-

Density	Total	+ 0,950	- 0,836
	Native	+ 0,964	- 0,833
	Exotic	n.s	n.s
	Biotic dispersal syndrome	n.s	n.s
	Abiotic dispersal syndrome	+ 0,950	- 0,814
	Pioneer succession	+ 0,950	- 0,836
	Late succession	-	-

Note: n.s means non-significant data; sign -: means low number of individuals (non-possible to apply statistical analysis). Results were considered significative when $\alpha < 0{,}05$.

Nota: n.s: representa os dados não significativos e o sinal -: representa baixo número de indivíduos (não sendo possível aplicar análises estatísticas). Os resultados foram considerados significativos quando $\alpha < 0{,}05$.

The riparian forest width presents positive correlations (**Table 2**) with total abundance and density (Spear r= +0,947, r^2 = 0,79, r = 0,89, p = 0,04; Spear r= +0,950, r^2 = 0,79, r = 0,89, p = 0,04, respectively, **Figure 1**), with native species abundance and density (Spear r= +0,974, : r^2 = 0,88, r = 0,93, p = 0,02; Spear r= +0,964, r^2 = 0,88, r = 0,94, p = 0,02, respectively, **Figure 1**), with abundance and density of plants dispersed by abiotic syndromes (Spear r= +0,947, r^2 = 0,82, r = 0,90, p = 0,03; Spear r= +0,950, r^2 = 0,82, r = 0,90, p = 0,03, respectively, **Figure 1**) and with pioneer succession species abundance and density (Spear r= +0,947, r^2 = 0,81, r = 0,90, p = 0,04; Spear r= +0,950, r^2 = 0,81, r = 0,90, p = 0,04, respectively, **Figure 1**). Due to the low number of late succession species and individuals, it wasn't possible to apply statistical analysis for this data.

Moreover, grass cover presents a strong negative correlation with riparian strip width (Spear r= -0,956), indicating that narrow widths of riparian forests present higher grass cover (**Figure 2**).

Grass cover differed among different riparian forest widths, and the higher grass coverage was observed on riparian forests with width of five or less meters (≤ 5 m) (**Table 1, Figure 2** p= 0,008). Analyzing the influence of the grass cover over riparian tree diversity it was observed that the grass inside these forests has negatives correlations with species density and abundance (**Table 2, Figure 3)**. Presenting also negative correlation with total density (Spear r= -0,836, r^2 = 0,51, r = -0,71, p = 0,03), native species density (Spear r= - 0,833, r^2 = 0,64, r = -0,80, p = 0,01) and abundance (Spear r= - 0,900), with density of plants dispersed by abiotic syndromes (Spear r= - 0,814, r^2 = 0,58, r = -0,76, p = 0,02), and with pioneer succession trees species (Spear r= - 0,836, r^2 = 0,55, r = -0,74, p = 0,02).

Figure 1: Linear Regression between Riparian Forest width (m) **(A):** Total Abundance: r^2 = 0,79, r = 0,89, p = 0,04; **(B):** Total Density (ind/ha): r^2 = 0,79, r = 0,89, p = 0,04; **(C):** Abundance Native species: r^2 = 0,88, r = 0,93, p = 0,02; **(D):** Density Native species (ind/ha): r^2 = 0,88, r = 0,94, p = 0,02; **(E):** Abundance of Plants Dispersed by Abiotic Syndrome: r^2 = 0,82, r = 0,90, p = 0,03; **(F):** Density of Plants Dispersed by Abiotic Syndrome (ind/ha): r^2 = 0,82, r = 0,90, p = 0,03; **(G):** Abundance Pioneer Succession Species: r^2 = 0,81, r = 0,90, p = 0,04; **(H):** Density Pioneer Succession Species (ind/ha): r^2 = 0,81, r = 0,90, p = 0,04. Data came from three riparian forests present on watercourses surrounded by *Urochloa decumbens* pasture, under domain of Seasonal Atlantic Forest, at the "Ecological Park João Milanês", Londrina, Paraná, Brazil (23°20'44''S 51°0'58''W). Results were considered significative when $\alpha < 0{,}05$.

Figura 1: Regressão Linear entre Largura da Mata ciliar (m) com - **(A):** Abundância Total: : r^2 = 0,79, r = 0,89, p = 0,04; **(B):** Densidade Total (ind/ha): r^2 = 0,79, r = 0,89, p = 0,04**; (C):** Abundância de espécies Nativas: r^2 = 0,88, r = 0,93, p = 0,02; **(D):** Densidade de espécies Nativas (ind/ha): r^2 = 0,88, r = 0,94, p = 0,02; **(E):** Abundância de Plantas Abióticas: r^2 = 0,82, r = 0,90, p = 0,03; **(F):** Densidade de Plantas Abióticas (ind/ha): r^2 = 0,82, r = 0,92, p = 0,03; **(G):** Abundância de Espécies Pioneiras: r^2 = 0,81, r = 0,90, p = 0,04; **(H):** Densidade de Espécies Pioneiras: r^2 = 0,81, r = 0,90, p = 0,04. Os dados foram obtidos em três matas ciliares de cursos d'água imersos em uma matriz de pastagem com *Urocloa decumbens*, no domínio da Floresta Estacional Semidecidual, Mata Atlântica, no "Parque Ecológico João Milanês", Londrina, Paraná, Brasil (23°20'44''S 51°0'58''W). Os resultados foram considerados significativos quando $\alpha < 0{,}05$.

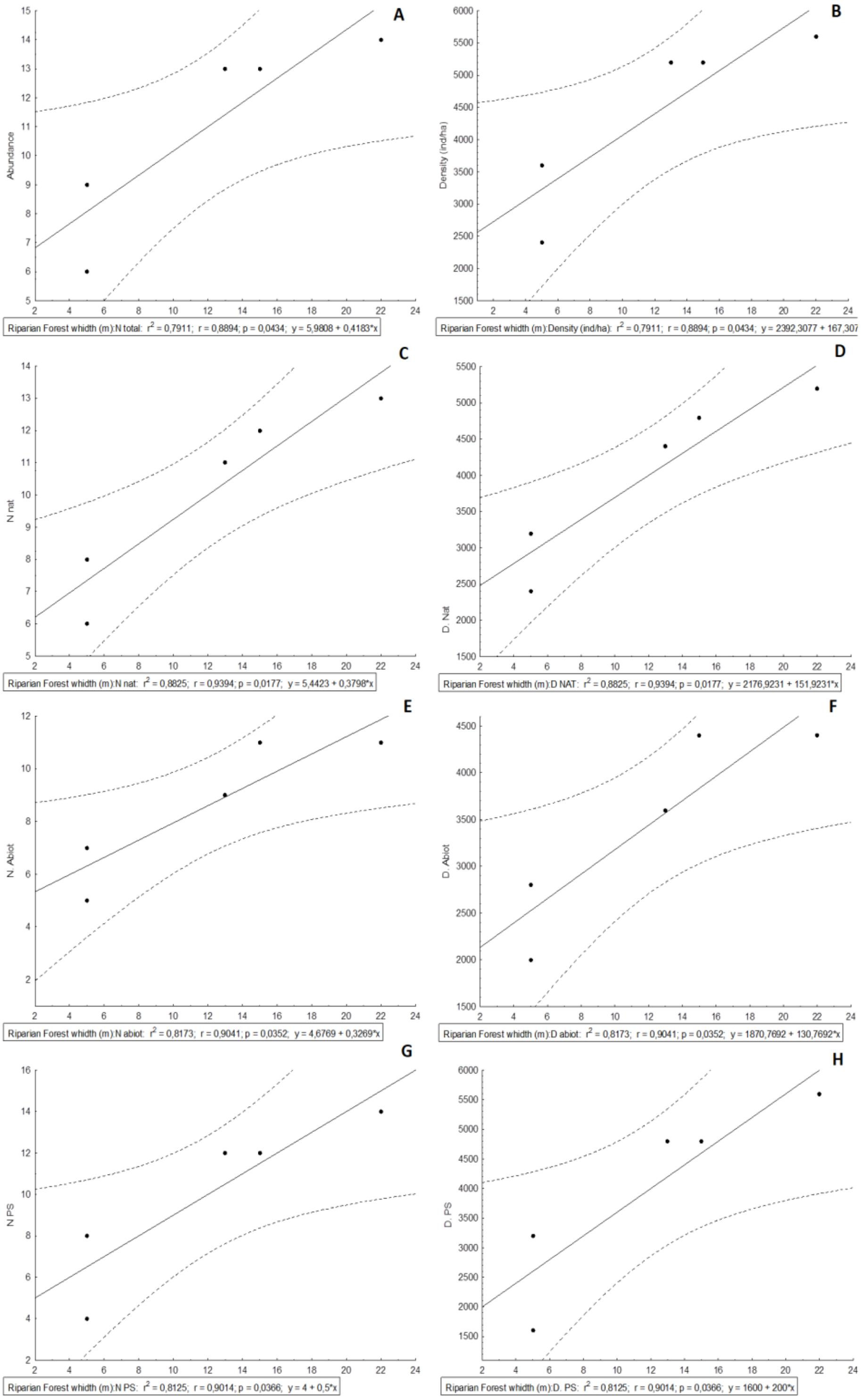


Figure 2 (A, B and C): Riparian forests width (m) and grass cover (%). Data came from three riparian forests present on watercourses surrounded by *Urochloa decumbens* pasture, under domain of Seasonal Atlantic Forest, at the "Ecological Park João Milanês", Londrina, Paraná, Brazil (23°20'44''S 51°0'58''W). Results were considered significative when α < 0,05.

Figura 2 (A, B e C): Largura de mata ciliar (m) e cobertura de gramíneas (%) em três matas ciliares de cursos d'água imersos em uma matriz de pastagem com *Urocloa decumbens* no domínio da Floresta Estacional Semidecidual, Mata Atlântica, no "Parque Ecológico João Milanês", Londrina, Paraná, Brasil (23°20'44''S 51°0'58''W). Os resultados foram considerados significativos quando α < 0,05.

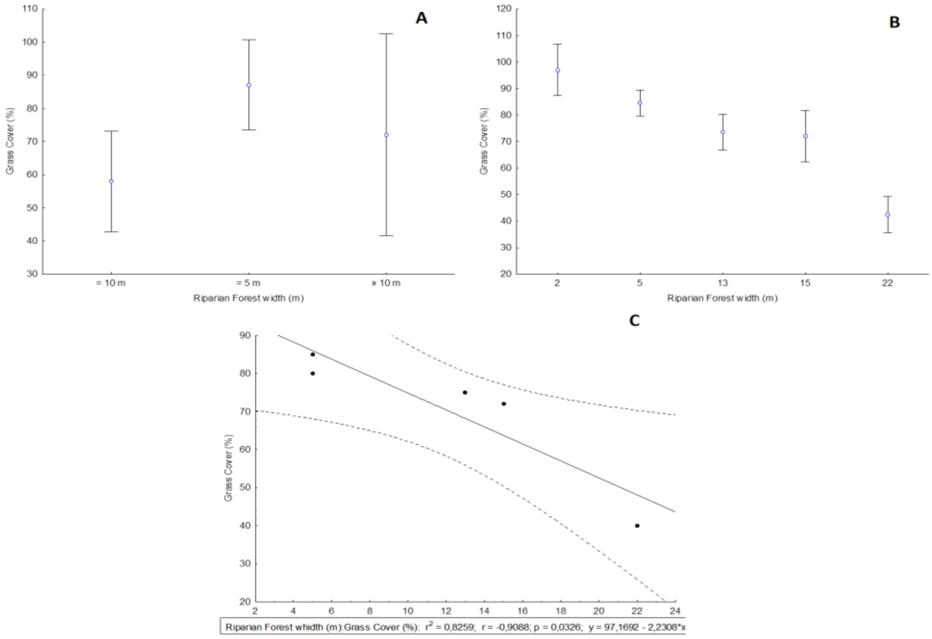
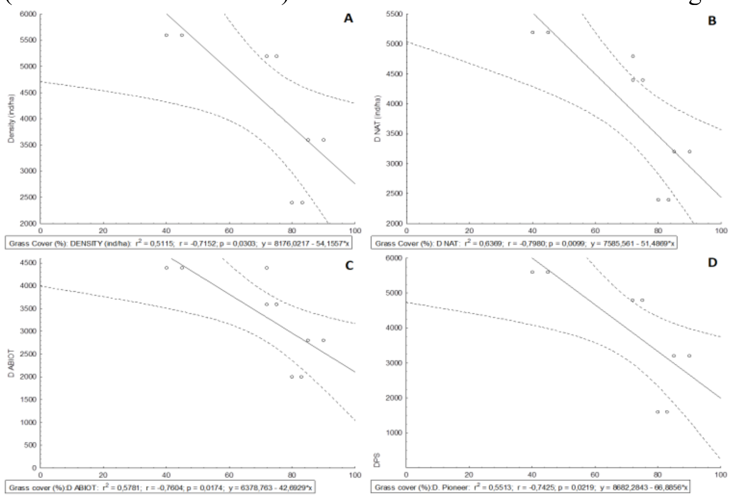


Figure 3: Linear Regression between Grass cover (%) with **(A):** Density (ind/ha): r^2 = 0,51, r = -0,71, p = 0,03; **(B):** Native species Density (ind/ha): r^2 = 0,64, r = -0,80, p = 0,01; **(C):** Density of Plants Dispersed by Abiotic Syndrome (ind/ha): r^2 = 0,58, r = -0,76, p = 0,02; **(D):** Density Pioneer Succession Species (ind/ha): r^2 = 0,55, r = -0,74, p = 0,02. Data came from three riparian forests present on watercourses surrounded by *Urochloa decumbens* pasture, under domain of Seasonal Atlantic Forest, at the "Ecological Park João Milanês", Londrina, Paraná, Brazil (23°20'44''S 51°0'58''W). Results were considered significative when α < 0,05.

Figura 3: Regressão Linear entre Cobertura de gramíneas (%) com **(A):** Densidade (ind/ha): r^2 = 0,51, r = -0,71, p = 0,03; **(B):** Densidade de espécies Nativas (ind/ha): r^2 = 0,64, r = -0,80, p = 0,01; **(C):** Densidade de Plantas Abióticas (ind/ha): r^2 = 0,58, r = -0,76, p = 0,02; **(D):** Densidade de Espécies Pioneiras: (ind/ha): r^2 = 0,55, r = -0,74, p = 0,02. Os dados foram obtidos em três matas ciliares de cursos d'água imersos em uma matriz de pastagem com *Urocloa decumbens*, no domínio da Floresta Estacional Semidecidual, Mata Atlântica, no "Parque Ecológico João Milanês", Londrina, Paraná, Brasil (23°20'44''S 51°0'58''W). Os resultados foram considerados significativos quando α < 0,05.



4 DISCUSSION

Among the different riparian forests, ranging to 1,8 m to 22,3 m of width vegetation, the woody species richness, abundance, and density did not differ significantly. In this way, the largest riparian forest is represented with similar diversity of the smallest riparian forest.

At these forests the richest botanical family was Fabaceae, followed by Euphorbiaceae, Sapindaceae and Solanaceae families, represented mostly by common species in the early stages of secondary succession in Atlantic Forests biome (Aide et al., 2000; Baylão-Junior et al., 2011; Guareschi et al., 2014; Scervino and Torezan, 2015; Scervino and Pereira, 2021) and also dispersed by anemochoric or zoochoric syndromes, in this case, mostly by birds and bats tolerant to open areas (Aide et al., 2000; Yang et al., 2010; Baylão-Junior et al., 2011; De Oliveira et al., 2020; Gutiérrez-Chacón, Valderrama-a and Klein, 2020; Turunen et al., 2021). This may be related to an intense edge effect that alters the micro-climate conditions and affect vegetation diversity on these riparian forests, favoring the establishment of species tolerant to high luminosity due an elevated canopy openness and climate stress (Puerta, 2002; Esquivel et al., 2008; Griscom, Griscom and Ashton, 2009; Yang et al., 2010; Massad et al., 2011; Paolino et al., 2018; Turunenet al., 2019; Turunen et al., 2021).

However, abundance and density present positive relationships with riparian forest width, and the larger the riparian forest is, the greater is the abundance and density of trees. This may be related to subtle changes on the larger riparian forests, such as small patches of better soil and micro-climate conditions, due to the higher accumulation of litter above soil that acts on the nutrient cycling increasing the soil fertility, and to more shadow micro-sites, providing more environmental heterogeneity and better conditions to the plant germination and establishment (Boddey et al., 2004; Cole, Holl and Zahawi, 2010; Guareschi et al., 2014; Burdon et al., 2020; Gutiérrez-Chacón, Valderrama-a and Klein, 2020; Xavier et al., 2021). Also, larger riparian forests can suffer less edge effects over vegetation on the riparian zone interior (Griscom, Griscom and Ashton, 2009; Feld et al., 2018; Burdon et al., 2020; Xavier et al., 2021).

On the other hand, species richness is not influenced by the width of the riparian forest, suggesting that only species more tolerant to stress, such as a great amplitude range of humidity and temperature of the air and soil, a compact soil and a high herbivory tax due to cattle grazing, are able to colonize these narrow riparian forest strips surrounded by *U. decumbens* pastures (Holl, 1999; Holl, 2002; Puerta, 2002; Griscom, Griscom and Ashton, 2009; Leitão, Marques and Ceccon, 2010; Massad et al., 2011; Guareschi et al., 2014; Brito et al., 2017; De Oliveira et al., 2020).

Nevertheless, a high positive correlation index was observed with riparian width and native species abundance and density, indicating that native woody species establishment is limited by the riparian strip width and that those rustic and alien trees species are more capable to colonize these environments (Holl, 1999; Cole, Holl and Zahawi 2010; Yang et al., 2010; Baylão-Junior et al., 2011; Warren et al., 2016; Burdon et al., 2020).

Also, the correlation found with species that present abiotic syndromes and a high tolerance to luminosity (pioneer species) indicates that trees that can colonize open areas are more suitable to establish on narrow strips of vegetation amidst an open pasture (Davis et al., 2005; Smit, Den Ouden and Müller-Schärer, 2006; Esquivel et al., 2008; Brooks, Setterfield and Douglas, 2010; Baylão-Junior et al., 2011; Guareschi et al., 2014; Scervino and Torezan, 2015). No relationships were found with species that present zoochoric dispersal syndrome, which can suggest that the fauna that visits these riparian forests does it independently of their vegetation strip width (Puerta,2002; Griscom, Griscom and Ashton, 2009; Baylão-Junior et al., 2011; Paolino et al., 2018; Gutiérrez-Chacón, Valderrama-a and Klein, 2020).

The *U. decumbens* cover inside the riparian forests is different on the studied watercourses, and the lagers forests present lower grass cover. This may be related to shadow micro-sites that reduce the luminosity on larger riparian forests, which can affect the *U. decumbens* growth under more shadowed conditions (Holl, 2002; Davis et al., 2005; Esquivel et al., 2008; Scervino and Torezan, 2015; Feld et al., 2018; Burdon et al., 2020; De Oliveira et al., 2020).

Relationship among grass cover and woody species was observed in the abundance and density of species, with high negative correlations with native species. *U. decumbens* is known by having an efficient seed dispersal mechanism, a high invasive potential and aggressive behavior compared to native Atlantic Forest species on the exploration of water, nutrients and light (Ziller, 2001; Boddey et al., 2004; Barbosa, Pivello and Meirelles, 2008; Griscom, Griscom and Ashton, 2009; Massad et al., 2011; Scervino and Torezan, 2015; Da Silva et al., 2017; De Oliveira et al., 2020). Also, the high production of aerial biomass and the formation of an intricate root web system on the superficial soil horizon can diminish forest seeds germination and the plant establishment, and it can increase the risk of fire on forests with higher grass cover (Marod et al., 2002; Marod et al., 2004; Ribeiro et al., 2006; Guareschi et al., 2014; Da Silva et al., 2017; Cury et al., 2020; De Oliveira et al., 2020; Xavier et al., 2021).

In addition, the *U. decumbens* dominance can reduce forest species establishment due to the inhibition of the nitrification process, reducing the N available to the forest plants' assimilation (Subbarao et al., 2009; Subbarao et al., 2012; Da Silva et al., 2017), and due to the production of allelopathic substances which can affect negatively other plants on their surroundings (Boddey et al., 2004; Barbosa, Pivello and Meirelles, 2008; Subbarao et al., 2009; Subbarao et al., 2012; Da Silva et al., 2017).

This suggests that few trees species can establish in these riparian forests immersed in *U. decumbens* pastures, and those more rustic species that are able to establish under high grass cover and to re-sprout after a fire, became more dominant and may present a higher density compared with other forest species (Holl et al., 1999; Holl et al., 2002; Ribeiro et al., 2006; Guareschi et al., 2014; Scervino and Torezan, 2015; Cury et al., 2020; De Oliveira et al., 2020; Xavier et al., 2021), altering the composition and structure of these *U. decumbens* invaded areas (Scervino and Torezan, 2015; De Oliveira et al., 2020; Xavier et al., 2021).

5 CONCLUSION

No difference was observed on arboreal species richness among the different widths of the riparian forests and no relationships of trees with zoochoric syndromes or late succession species were found. Although the riparian forest width presents strong positive correlations with trees abundance and density, suggesting that the width of the riparian forest can influence the native vegetation and act as a selective pressure for the establishment of forest species as much as can act on *U. decumbens* cover (%).

The larger riparian forests presented lower *U. decumbens* coverage. As expected, larger forests can create more shaded conditions and diminish grass cover. Also, the grass cover on the interior of the riparian forest had negative relationships with plant diversity. For these watercourses, with narrow riparian vegetation strips surrounded by a pasture, the high *U. decumbens* cover inside the riparian forest can restrict the seedling establishment, plant diversity and abundance and also can increase the risk of fire, which can retard the Atlantic Forest natural regeneration in the studied sites.

In this context, in order to gain scale to achieve environmental restoration agreements, in regard to restoration of Atlantic biomes and to climate changes matters, to improve the ecosystems services discharged by the riparian forest and to restore the woody vegetation diversity, it is recommended the abandonment of these forests to natural regeneration and/or also enrich these forests through reforestation with native late succession forest and zoochoric tree species, in addition to control the *U. decumbens* permanence and dominance. Although, the lack of replicates and reference areas prevents ultimate conclusions.

We also highlight the need of other complemental studies to test the best plants species that can endure the extremes conditions present in narrows strips of riparian forests surrounded by pastures, as an example to test the canopy density to ensure the choice of woody species that can produce bigger areas of shadow under them, in addition to studies to evaluate the vegetation structure and the resilience of these forests.

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Species Richness Lista: List of woody species inventoried at three riparian forests present on watercourses surrounded by *Urochloa decumbens* pasture, under domain of Seasonal Atlantic Forest, Atlantic Forest biome at "Ecological Park João Milanês", Londrina, Paraná, Brazil (23°20'44''S 51°0'58''W). NAT: means native species; EXO: exotic species; AN: anemochoric dispersal syndrome; AT: autochoric dispersal syndrome; ZOO: zoochoric dispersal syndrome; PS: pioneer succession; LT: late succession; and S: riparian forest site: Site 1: Cristal river; S2: Site 2: São Lourenço river; S3: Site 3: Cambé river.

Lista de Riqueza de Espécies: Lista de espécies arbóreas amostradas em matas ciliares de três cursos d'água imersos em uma matriz de pastagem com *Urochloa decumbens*, no domínio da Floresta Estacional Semidecidual, Mata Atlântica, "Parque Ecológico João Milanês", Londrina, Paraná, Brasil (23°20'44''S 51°0'58''W). NAT: representa as espécies nativas; EXO: espécies exóticas; AN: espécies de dispersão anemocórica; AT: espécies de dispersão autocórica; ZOO: espécies de dispersão zoocórica; LT: espécies tardias na sucessão ecológica; PS: espécies pioneiras na sucessão ecológica; S: área de mata ciliar, S1: ribeirão Cristal, S2: ribeirão São Lourenço; S3: ribeirão Cambé.

FAMILY	SCIENTIFIC NAME	ORIGIN	DS	S	SITE
ANACARDIACEAE	*Astronium graveolens* Jacq.	NAT	AN	LS	S3
	Schinus terebinthifolia Raddi	NAT	ZOO	PS	S1, S2
APOCYNACEAE	*Tabernaemontana catharinensis* A. DC.	NAT	ZOO	PS	S1, S2, S3
	Aspidosperma austral Mull. Arg.	NAT	NA	LS	S2
BIGNONIACEAE	*Tabebuia heptaphylla* (Vell.) Toledo	NAT	NA	PS	S1
	Tecoma stans (L.) Juss. ex Kunth	EXO	NA	PS	S2, S3
BORAGINACEAE	*Patagonula americana* L.	NAT	AN	PS	S2, S3
EUPHORBIACEAE	*Alchornea glandulosa* Poepp.&Endl.	NAT	ZOO	PS	S1, S2, S3
	Croton floribundus Spreng	NAT	ZOO	PS	S1, S2, S3
	Sebastiania brasiliensis (L.) Spreng	NAT	AT	PS	S1, S2, S3
	Sebastiana commersoniana (Bail L.B.S.M. & Downs)	NAT	AT	PS	S3
FABACEAE-CAESALPINOIDEAE	*Bauhinia forficata* Link	NAT	NA	PS	S3
	Peltophorum dubium (Spreng.) Taub.	NAT	ZOO	PS	S3
FABACEAE-FABOIDEAE	*Erythrina crista-galli* L.	NAT	AT	PS	S3
	Holocalyx balansae Micheli	NAT	NA	PS	S3
	Lonchocarpus campetris Mart. ex Benth.	NAT	AT	PS	S1, S2, S3
	Lonchocarpus muehlbergianus Hassl.	NAT	ZOO	PS	S3
	Machaerium aculeatum Raddi	NAT	NA	PS	S2
	Machaerium paraguariense Hassl.	NAT	NA	PS	S2, S3
	Machaerium stipitatum (DC.) Vogel	NAT	NA	PS	S1, S2, S3
	Machaerium scleroxylon Tul.	NAT	NA	PS	S1
FABACEAE-MIMOSOIDEAE	*Acacia polyphylla* D.C.	NAT	NA	LP	S2, S3
	Inga marginata Wild	NAT	ZOO	PS	S1
	Parapiptadenia rigida (Benth.) Brenan	NAT	AN	PS	S1, S2, S3
LOGANIACEAE	*Strychonos brasiliensis* (Spreng.) Mart.	NAT	ZOO	PS	S2, S3
LAURACEAE	*Octea elegans* Mez.	NAT	ZOO	PS	S1, S2, S3
MELASTOMATACEAE	*Tibouchina granulosa* Cogn.	NAT	NA	PS	S1
MELIACEAE	*Guarea kunthiana* A. Juss.	NAT	ZOO	PS	S1
	Melia azedarach L.	EXO	ZOO	PS	S1, S2, S3

Continuation: List of woody species inventoried at three riparian forests present on watercourses surrounded by *Urochloa decumbens* pasture, under domain of Seasonal Atlantic Forest, Atlantic Forest biome at "Ecological Park João Milanês", Londrina, Paraná, Brazil (23°20'44''S 51°0'58''W). NAT: means native species; EXO: exotic species; AN: anemochoric dispersal syndrome; AT: autochoric dispersal syndrome; ZOO: zoochoric dispersal syndrome; PS: pioneer succession; LT: late succession; and S: riparian forest site: Site 1: Cristal river; S2: Site 2: São Lourenço river; S3: Site 3: Cambé river.

Continuação: Lista de espécies arbóreas amostradas em matas ciliares de três cursos d' água imersos em uma matriz de pastagem com *Urochloa decumbens,* no domínio da Floresta Estacional Semidecidual, Mata Atlântica, "Parque Ecológico João Milanês", Londrina, Paraná, Brasil (23°20'44''S 51°0'58''W). NAT: representa as espécies nativas; EXO: espécies exóticas; AN: espécies de dispersão anemocórica; AT: espécies de dispersão autocórica; ZOO: espécies de dispersão zoocórica; LT: espécies tardias na sucessão ecológica; PS: espécies pioneiras na sucessão ecológica; S: área de mata ciliar, S1: ribeirão Cristal, S2: ribeirão São Lourenço; S3: ribeirão Cambé.

FAMILY	SCIENTIFIC NAME	ORIGIN	DS	S	SITE
LOGANIACEAE	*Strychonos brasiliensis* (Spreng.) Mart.	NAT	ZOO	PS	S2, S3
LAURACEAE	*Octea elegans* Mez.	NAT	ZOO	PS	S1, S2, S3
MELASTOMATACEAE	*Tibouchina granulosa* Cogn.	NAT	NA	PS	S1
MELIACEAE	*Guarea kunthiana* A. Juss.	NAT	ZOO	PS	S1
	Melia azedarach L.	EXO	ZOO	PS	S1, S2, S3
MORACEAE	*Ficus guaranitica* Chodat	NAT	ZOO	PS	S1
	Maclura tinctoria (L.) D. Don ex Steud.	NAT	ZOO	PS	S2, S3
	Morus nigra L.	EXO	ZOO	PS	S1, S3
MYRTACEAE	*Campomanesia xanthocarpa* Mart. ex O. Berg	NAT	ZOO	LS	S2, S3
	Eucalyptus grandis W. Mill ex Maiden	EXO	NA	PS	S1, S2, S3
	Myrciaria caulifolia (Mart.) O.Berg	NAT	ZOO	PS	S1
	Psidium guajava L.	EXO	ZOO	PS	S1, S2, S3
OLEACEAE	*Ligustrum lucidum* W. T. Aiton	EXO	ZOO	OS	S1, S2
PIPERACEAE	*Piper amalago* L.	NAT	ZOO	PS	S2, S3
POACEAE	*Bambusa sp.*	EXO	NA	PS	S1
POLYGONACEAE	*Ruprechtia laxiflora* Meisn.	NAT	NA	PS	S1, S3
ROSACEAE	*Prunus myrtifolia* (L.) Urb.	NAT	ZOO	PS	S1, S2
RUTACEAE	*Citrus limetta* Risso	EXO	ZOO	PS	S3
	Zanthoxylum rhoifolium Lam.	NAT	ZOO	PS	S3
SALICACEAE	*Casearia sylvestris* SW.	NAT	ZOO	PS	S2
SAPINDACEAE	*Allophylus guaraniticus* (A. St-Hill.)	NAT	ZOO	PS	S1, S2, S3
	Cupania vernalis Cambess.	NAT	ZOO	PS	S2
	Diatenopteryx sorbifolia Radlk.	NAT	AT	PS	S2
	Matayba elaeagnoides Radlk.	NAT	ZOO	LS	S3
SOLANACEAE	*Cestrum intermedium* Sendtn.	NAT	ZOO	PS	S1, S3
	Cestrum strigilatum Ruiz & Pav.	NAT	ZOO	PS	S1, S3
	Solanum granuloso-leprosum Dunal	NAT	ZOO	PS	S3
TILIACEAE	*Luehea divaricata* Mart.	NAT	AN	PS	S3
URTICACEAE	*Cecropia glaziovi* Snethl.	NAT	ZOO	PS	S1
ULMACEAE	*Trema micrantha* (L.) Blume	NAT	ZOO	PS	S1, S3
VERBENACEAE	*Aloysia virgata* (Ruiz & Pav.) Pers.	NAT	AN	PS	S3