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Original Article

Silviculture

Phytosociology of Native Species in the Understory of a *Corymbia citriodora* Stand in Espírito Santo State, Brazil

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ABSTRACT

This study is based on the hypothesis that unmanaged plantations of commercial species do not prevent understory colonization by native species. The research aimed to describe the floristic composition and structure of native arboreal species in the understory of a *Corymbia citriodora* stand. To this end, 112 plots (10 × 10 m; 1.12 ha) were installed. Six hundred native tree individuals distributed in 54 species, 44 genera, and 20 families were recorded. The regeneration diversity and evenness indices were 3.23 and 0.81, respectively. Native regeneration of *C. citriodora* understory shows features typical of semideciduous seasonal forests and seems to be at the early stage of regeneration. Results suggest that *C. citriodora* stands do not prevent understory colonization by native species.

Keywords: eucalyptus, natural regeneration, floristic diversity.

1. INTRODUCTION AND OBJECTIVES

Studies addressing the floristic composition and structure of native arboreal species are important for silvicultural knowledge and the conservation of rainforests (Felfili et al., 2011), because they identify the potential for sustainable use of available forest resources. These studies enable the development of conservation strategies because they assist with classifying the state of conservation of vegetation, evaluating the intensity of a degradation process and the regeneration capacity of degraded areas (Holl & Aide, 2011; Rodrigues et al., 2011).

Analysis of the structural parameters of the species in a given community enables characterization of their importance within the natural ecosystem, which contributes to expanding the understanding of species distribution patterns and inferring about their natural regeneration, assisting with the planning of reforestation (Rodrigues et al., 2011). However, scarcity of information on the floristic composition and structure of regeneration species is a factor that hinders forest recovery programs (Kageyama et al., 2008; Rodrigues et al., 2011). Therefore, analyzing native vegetation prior to selecting regeneration approaches result in more efficient use of resources and maximizes the success of regeneration (Holl & Aide, 2011; Kageyama et al. 2008).

Several initiatives associated with forest recovery in areas of eucalyptus stands have been assessed and discussed (Alencar et al., 2011; Aubert & Oliveira Filho, 1994; Calegário et al., 1993; Durigan et al., 1997; Neri et al., 2005; Onofre et al., 2010; Resende & Ferreira, 2009; Saporetti et al., 2003; Sartori et al., 2002; Silva et al., 1995; Souza et al., 2007). Sartori et al. (2002) and Turchetto et al. (2015) explained that the rapid covering of the area provided by species of the genera *Eucalyptus* and *Corymbia* would act as facilitator in the establishment of natural regeneration, favoring the development of a community with characteristics of advanced stages of succession. Other authors have reported that poorly executed management and silvicultural practices in commercial eucalyptus stands favor the colonization of spontaneous native species in the understory (Aubert & Oliveira Filho, 1994; Calegário et al., 1993). One of the main silvicultural treatments is the periodic cleaning of the understory, conducted to avoid the establishment, growth and development of native vegetation in these environments. This regenerating vegetation in the understory hinders the selective cutting and extraction of wood from the stands (Aubert & Oliveira Filho, 1994; Calegário et al., 1993). In addition, the advanced successional stage of native vegetation of the understory of commercial eucalyptus stands may result in impaired permission of environmental organs to harvest the wood, claiming that the vegetation will be damaged in the removal process (Brasil, 2006).

Considering all the previously mentioned assertions, since the 1990s, it has been indicated that studies on the floristic composition and structure of native species should be conducted in the understory of commercial stands, as well as in native forests near these plantations (Aubert & Oliveira-Filho, 1994; Calegário et al., 1993; Durigan et al., 1997; Silva et al., 1995). This was indicated in order to better understand the ecology of spontaneous species that could be used in forest regeneration or in stands consorted with eucalyptus. However, to better understand the potential of this practice, further studies addressing the regeneration of native vegetation in areas with commercial plantations should be conducted.

This study is based on the hypothesis that unmanaged plantations of commercial species do not prevent understory colonization by native species. Therefore, to verify this hypothesis, this study aimed to: (a) evaluate the floristic composition and regeneration structure of native tree species in the understory of a *Corymbia citriodora* stand; (b) classify this regeneration with respect to its phytophysiognomy and successional stage; and (c) determine the floristic similarity between the native regeneration of the stand understory and a fragment of Semideciduous Seasonal Forest (SSF) near this stand.

2. MATERIALS AND METHODS

The present study was conducted at the Federal Institute of Education, Science and Technology of Espírito Santo, Santa Teresa campus (IFES-ST). IFES-ST is located in the district of São João de Petrópolis, municipality of Santa Teresa, which is located in the central region of Espírito Santo state, Brazil (Figure 1).

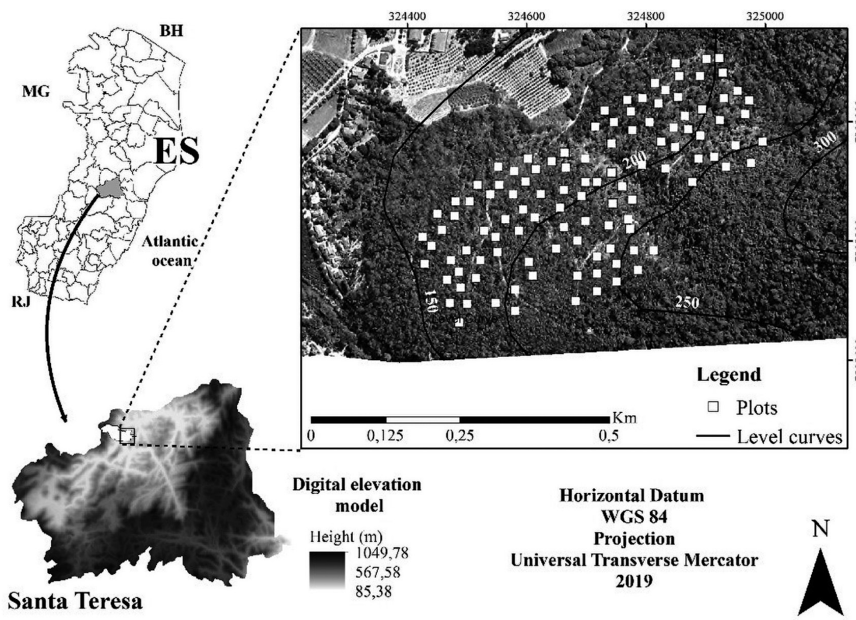

Figure 1. Study area location and distribution of the plots at the Federal Institute of Education, Science and Technology of Espírito Santo, Santa Teresa, Espírito Santo state.

Climate in the study region is humid subtropical (Cwa) according to the Köppen-Geiger classification (Alvares et al., 2013), presenting seasonal characteristics, with dry winters and hot and humid summers. According to data from the IFES-ST weather station, mean annual rainfall (1977-2011 series) is 948.66 mm, with December (167.9 mm) and August (30.29 mm) as the wettest and driest months, respectively; mean annual temperature is 25.6 °C, with maximum and minimum values of 28.6 °C and 14.5 °C in February and August, respectively.

An area of a *Corymbia citriodora* (Hook.) K.D. Hill & L.A.S. Johnson (Myrtaceae) stand, with regeneration of native arboreal species in its understory, was selected for this study (Figure 1). The plantation has an average slope of 20% with predominance of Red Argissoils (Ultisol) (Embrapa, 2013). This stand was implemented 50 m distant from the boarder of a SSF fragment. The arboreal species of higher occurrence in this fragment were *Astronium graveolens* Jacq., *Anadenanthera colubrina* var. *cebil* (Griseb.) Altschul, and *Pterogyne nitens* Tul, with absolute density of individuals of 1,330 ind.ha^{-1} and mean basal area of 23.16 m^2.ha^{-1}. Chronologically, the area where the eucalyptus stand was established was previously an SSF fragment, which was later converted into monoculture of forage pasture (*Brachiaria* sp.) for 12 years. The stand was implemented in 1980, in 3 × 3 m spacing, covering approximately 45 ha. The *C. citriodora* stand underwent silvicultural treatment of selective weeding for the control of invasive grasses during the first five years of its implantation. From 1985 to 1995, *C. citriodora* individuals underwent selective thinning and natural mortality. Since 1995, the eucalyptus stand has not received any type of intervention, such as wood extraction or silvicultural treatments. In January 2012, it showed mean density of 352 *C. citriodora* individuals with mean height of 15.4 m, mean diameter at breast height (1.30 m above soil surface) of 11.4 cm (diameter at breast height (DBH) = 11.4 cm), and basal area of 8.73 m^2 ha^{-1}.

For vegetation sampling, 10 × 10 m plots were distributed in the curve level direction in each of the four positions along a toposequence (lower third, middle third, upper third, and top). This procedure was adopted aiming at greater representativeness of the study area. Top and upper, middle and lower thirds included 12 (0.12 ha), 20 (0.20 ha), and 40 plots (0.40 ha), respectively, and 40 plots (0.40 ha) were used, corresponding to a total sampled area of 1.12 ha. In these plots, all native species trees and standing dead individuals, with stem girth at breast height (1.30 m above the ground) higher than 10 cm were measured and identified (GBH ≥ 10 cm). These individuals also had their height estimated with the use of high pruning shears with telescopic handle.

Botanical nomenclature followed the classification system of the Angiosperm Phylogeny Group (APG, 2009), and the authors of the species were verified at the website of "Flora do Brasil – Reflora" project (Reflora, c2019). The botanical samples were herborized and included in the collection of the herbarium of the Federal Rural University of Rio de Janeiro (RBR). The horizontal structure was characterized by estimating the following phytosociological parameters for each species: density, relative frequency, relative dominance, and importance value (IV), as indicated by Felfili et al. (2011). The Shannon-Weaver diversity (H') and the Pielou's evenness (J') indices were also calculated for the set of eucalyptus understory species (Magurran, 2011).

Aiming to verify the sample sufficiency, curves of the mean species accumulation and richness estimation were developed (Magurran, 2011). The method of mean species accumulation curve is more efficient than the collector's curve to evaluate sample adequacy because it is a mean curve, with a 95% confidence interval, generated from several different and random data (Magurran, 2011; Schilling & Batista, 2008; Schilling et al., 2012). In order to develop it, 1,000 simulations were conducted aiming to change the sampling unit entry order and assess the degree of stability of the sample, based on the central limit theorem (Schilling & Batista, 2008). From the mean species accumulation number as a function of the sampled area, species richness was estimated using the Chao 1 non-parametric method (Magurran, 2011). These curves were developed only for living individuals. These data were processed using the EstimateS® 9.1.0 software and the graphs were developed using the Sigmaplot 10.0® software.

Phytophysiognomic classification followed the precepts established in the Technical Manual of Brazilian Vegetation (IBGE, 2012), whereas the Successional Stage classification followed the model proposed by Conama in Resolution no. 29 (Conama, 1994). This resolution defines the qualitative and quantitative parameters to classify the successional stages of secondary vegetation of the Atlantic Rainforest in Espírito Santo state, Brazil. The native species were also classified according to their successional group and deciduousness from the observations of the research team. To this end, four succession groups (pioneer, early secondary, late secondary, and climax) and three degrees of deciduousness (deciduous, semideciduous, or perennial) were considered.

The same methodology used to sample the regeneration of native species in the *C. citriodora* stand understory was applied to sample the SSF fragment. The composition of tree species of the fragment was then compared with that of native regeneration species in the understory of the *C. citriodora* stand, and the similarity of floristic composition between the areas was calculated. For that, the Sørensen coefficient of similarity, which considers the presence/absence of species in the compared areas, was used (Magurran, 2011).

3. RESULTS AND DISCUSSION

Seven hundred and two trees and shrubs were sampled in the plots in the understory of the *C. citriodora* stand, of which 600 were living individuals of native natural regeneration and 102 were standing dead trees. Of the total of living individuals, 54 native arboreal species, belonging to 44 genera and 20 botanical families, were found in the *C. citriodora* stand understory (Table 1).

Table 1. Floristic composition and phytosociological parameters of species found in a *Corymbia citriodora* stand understory, Santa Teresa, Espírito Santo state, listed by descending order of importance value (IV).

Family	Scientific name	Dar	Fr	Dor	IV
Anacardiaceae	*Astronium graveolens* Jacq.	19.50	16.70	6.25	14.15
Fabaceae	*Anadenanthera colubrina* var. *cebil* (Griseb.) Altschul	5.33	2.90	15.82	8.02
Fabaceae	** *Pterogyne nitens* Tul.	6.33	7.35	6.22	6.63
Meliaceae	*Trichilia elegans* A. Juss.	6.83	6.01	3.11	5.32
Fabaceae	*Machaerium* sp.	5.00	5.12	5.15	5.09

Table 1. Continued...

Family	Scientific name	Dar	Fr	Dor	IV
Rubiaceae	*Alseis floribunda* Schott	4.17	4.45	6.35	4.99
Bignoniaceae	**Paratecoma peroba* (Record) Kuhlm.	3.17	3.56	6.54	4.42
Salicaceae	*Casearia decandra* Jacq.	4.50	4.68	2.03	3.74
Fabaceae	**Apuleia leiocarpa* (Vogel) J.F.Macbr.	3.50	3.56	4.04	3.70
Fabaceae	*Parapiptadenia pterosperma* (Benth.) Brenan	2.33	2.45	3.72	2.83
Fabaceae	*Acosmium lentiscifolium* Schott	3.00	3.12	2.07	2.73
Fabaceae	*Goniorrhachis marginata* Taub.	3.50	2.90	1.35	2.58
Fabaceae	***Platypodium elegans* Vogel	0.83	0.89	5.67	2.47
Fabaceae	*Pseudopiptadenia contorta* (DC.) G. P. Lewis & M. P. Lima	1.00	1.11	4.26	2.12
Anacardiaceae	*Astronium concinnum* Schott	1.67	2.00	2.19	1.95
Bignoniaceae	**,**Zeyheria tuberculosa* (Vell.) Bureau ex Verl.	2.00	2.67	1.03	1.90
Bignoniaceae	*Handroanthus chrysotrichus* (Mart. ex DC.) Mattos	1.67	2.23	1.67	1.85
Fabaceae	*Myrocarpus fastigiatus* Allemão	2.17	1.78	1.51	1.82
Boraginaceae	*Cordia trichotoma* (Vell.) Arráb. ex Steud.	1.67	2.00	0.88	1.52
Fabaceae	*Albizia polycephala* (Benth.) Killip ex Record	1.50	2.00	1.00	1.50
Fabaceae	*Piptadenia gonoacantha* (Mart.) J. F. Macbr.	1.00	1.34	2.13	1.49
Lecythidaceae	***Lecythis lurida* (Miers) S. A. Mori	1.33	1.56	1.55	1.48
Fabaceae	**,**Dalbergia nigra* (Vell.) Allemão ex Benth.	1.33	1.78	1.06	1.39
Meliaceae	*Trichilia hirta* L.	1.67	1.78	0.36	1.27
Fabaceae	*Swartzia langsdorffii* Raddi	0.83	0.89	1.98	1.24
Acharidaceae	*Carpotroche brasiliensis* (Raddi) A. Gray	1.83	1.11	0.78	1.24
Fabaceae	*Machaerium fulvovenosum* H. C. Lima	1.17	0.89	1.06	1.04
Fabaceae	*Abarema* sp.	0.50	0.45	1.82	0.92
Rubiaceae	*Alseis gardneri* Wernham	1.00	0.89	0.69	0.86
Symplocaceae	*Symplocos* sp.	1.00	1.11	0.44	0.85
Fabaceae	*Machaerium hirtum* (Vell.) Stellfeld	0.83	1.11	0.43	0.79
Moraceae	*Brosimum guianensis* (Aubl.) Huber	0.83	1.11	0.38	0.78
Fabaceae	***Amburana cearensis* (Allemão) A. C. Sm.	0.67	0.89	0.56	0.71
Rutaceae	***Balfourodendron riedelianum* (Engl.) Engl.	0.50	0.67	0.74	0.64
Erythroxylaceae	*Erythroxylum cuspidifolium* Mart.	1.00	0.67	0.22	0.63
Bignoniaceae	*Handroanthus umbellatus* (Sond.) Mattos	0.33	0.45	1.05	0.61
Fabaceae	*Swartzia flaeming* Raddi	0.50	0.67	0.39	0.52
Sapotaceae	*Chrysophyllum lucentifolium* subsp. *lucentifolium* Cronquist	0.67	0.67	0.19	0.51
Fabaceae	*Lonchocarpus* sp.	0.33	0.45	0.61	0.46
Rutaceae	*Dictyoloma vandellianum* A. Juss.	0.33	0.45	0.38	0.39
Anacardiaceae	*Myracrodruon urundeuva* Allemão	0.33	0.45	0.34	0.37
Sapotaceae	*Chrysophyllum* sp.	0.33	0.45	0.20	0.33
Fabaceae	*Pseudobombax grandiflorum* (Cav.) A. Robyns	0.17	0.22	0.51	0.30
Fabaceae	***Copaifera langsdorffii* Desf.	0.17	0.22	0.45	0.28
Bignoniaceae	*Tabebuia roseoalba* (Ridl.) Sandwith	0.17	0.22	0.19	0.19
Euphorbiaceae	*Brasiliocroton mamoninha* P. E. Berry & Cordeiro	0.17	0.22	0.18	0.19

Table 1. Continued...

Family	Scientific name	Dar	Fr	Dor	IV
Bignoniaceae	*Handroanthus riodocensis* (A. H. Gentry) S. Grose	0.17	0.22	0.11	0.17
Malvaceae	*Prockia crucis* P. Browne ex L.	0.17	0.22	0.10	0.16
Cactaceae	*Pereskia grandiflora* Haw.	0.17	0.22	0.07	0.15
Fabaceae	*Piptadenia paniculata* Benth.	0.17	0.22	0.07	0.15
Nyctaginaceae	*Guapira opposita* (Vell.) Reitz	0.17	0.22	0.06	0.15
Rutaceae	*Zanthoxylum rhoifolium* Lam.	0.17	0.22	0.02	0.14
Malvaceeae	*Cavanillesia umbellata* Ruiz & Pav.	0.17	0.22	0.03	0.14
Trigoniaceae	*Trigoniodendron spiritusanctense* E. F. Guim. & Miguel	0.17	0.22	0.01	0.13
Total		**100.00**	**100.00**	**100.00**	**100.00**

Dar: relative density; Fr: relative frequency; Dor: relative dominance; * endangered species; ** endangered species. Source: MMA (2014)*; IUCN (2014)**.

Fabaceae (22 species), Bignoniaceae (6 species), Anacardiaceae (3 species), and Rutaceae (3 species) were the botanical families that showed the greatest richness. These four families together corresponded to approximately 62% of the species sampled (Table 1). Among the families with the largest number of species found, only Fabaceae had already been reported among the most representative species in the understory of other eucalyptus stands (Neri et al., 2005; Onofre et al., 2010; Saporetti et al., 2003; Souza et al., 2007; Turchetto et al., 2015). Although also present in other surveys, the other families have not usually been described among those of greater abundance. The greater representativeness of the Fabaceae species in this study is considered normal, because this family has been commonly observed in studies conducted in semideciduous seasonal forests (Braga et al., 2011) and in the understory of eucalyptus stands (Neri et al., 2005; Onofre et al., 2010; Saporetti et al., 2003; Souza et al., 2007; Turchetto et al., 2015). Fabaceae richness in areas of eucalyptus stands could also be explained by the high biological nitrogen fixation and germination capacities of many species of this family (Freitas et al., 2010). These capacities would facilitate the regeneration of their species in degraded and low-fertility soils (Freitas et al., 2010), such as those found in the study region (Carvalho, Pereira, Guareschi et al., 2017; Carvalho, Pereira, Toledo et al., 2017;).

Machaerium and *Handroanthus* were the genera with greatest richness, with two species each, followed by *Alseis*, *Astronium, Chrysophyllum, Piptadenia, Swartzia*, and *Trichilia*, all with one species each (Table 1). Of these genera, only *Machaerium* has been reported as a representative genus in other surveys (Neri et al., 2005; Sartori et al., 2002; Souza et al., 2007); the other genera found in this study, when present, have not been usually cited as showing great richness in the understory of eucalyptus plantations.

The understory of this *C. citriodora* stand, which is approximately 35 years old and has undergone some thinning treatments, showed 54 native tree species. This richness value can be considered high compared with those observed in other studies conducted in eucalyptus understories. In stands located in the municipalities of Assis, SP; Bom Despacho, MG; Paraopeba, MG; Viçosa, MG; and Frederico Westphalen, RS, 25, 39, 47, 50, and 33 species were identified, respectively (Durigan et al., 1997; Neri et al., 2005; Saporetti et al., 2003; Souza et al., 2007; Turchetto et al., 2015). The high richness value found in this study can be attributed to the availability of different sources of native propagules of the Semideciduous Seasonal Forest (SSF) located near the study area, favoring the regeneration of the typical vegetation of the region (Onofre et al., 2010; Souza et al., 2007; Turchetto et al., 2015). Another relevant factor fostering the high natural regeneration richness in this study is the increased light influx to the forest floor (Calegário et al., 1993; Onofre et al., 2010; Turchetto et al., 2015). In the stand assessed, the increase of light influx to the forest floor was caused by the low mean height of the canopy and density of eucalyptus individuals – approximately 32% of the total measured, pendant braches of the *C. citriodora* species, and mainly by the opening in the canopy caused by selective thinning and mortality of eucalyptus individuals. Turchetto et al. (2015) reported that the thinning of trees and openings in the canopy favor the mentioned increase, with the latter being one of the main factors promoting natural regeneration of commercial stands. However, it is worth emphasizing that the comparisons made regarding richness and abundance should be considered with caution due to differences in the environments evaluated and methodologies used, such as sampling intensity. Nevertheless, it seems reasonable to assume that the larger number of species detected in the present study indicates that this stand, according to the conditions under which it was implemented and managed, does not represent a restriction for the establishment of native species in its regeneration.

Among the native species identified in the present study, 12 are included in the official lists of endangered species of the Brazilian Ministry of the Environment (Order no. 443, 2014) (MMA, 2014) and the International Union for Conservation of Nature (IUCN, 2014) (Table 1). These species are categorized into different threatening levels: four of them are listed as “Endangered” and four as “Vulnerable” (MMA, 2014; IUCN, 2014). The remaining four species are included in lower risk categories (IUCN, 2014). This result evidences the regeneration capacity of these environments, with colonization of native species in risk of extinction, which is important for the conservation of rainforests (Kageyama et al., 2008).

Considering only living individuals of native regeneration, the estimated total absolute density was 517 ind.ha^{-1} and the mean basal area was 7.63 m^2.ha^{-1}. This density value was lower than those found by Sartori et al. (2002), Souza et al. (2007), Onofre et al. (2010), and Turchetto et al. (2015), which were 1,083 ind. ha^{-1}, 884 ind.ha^{-1}, 2,021 ind.ha^{-1}, and 4,140 ind.ha^{-1}, respectively. The mean basal area per hectare observed in this study was lower than that found by Neri et al. (2005) and greater than those reported by Sartori et al. (2002), Souza et al. (2007) and Onofre et al. (2010), which were 8.34 m^2.ha^{-1}, 6.1 m^2.ha^{-1}, 3.46 m^2.ha^{-1} and 6.4 m^2.ha^{-1}, respectively. These differences between the absolute density and the mean basal area per hectare may be associated with the inclusion criterion of these studies. The aforementioned authors prioritized the sampling of individuals with smaller girth and height than those of the present study, favoring the detection of a larger number of individuals by also including small-sized species and smaller basal areas. The choice for inclusion of individuals with GBH ≥ 10 cm for the assessment of secondary vegetation in the present study is justified by the high rotation rate of natural regeneration in rainforests (Lopes et al., 2016).

The ten species with the highest IV in the study area accounted for approximately 59% of the community. Sartori et al. (2002) also reported that they accumulated nearly 80% of a native regeneration community in the understory of a *Eucalyptus saligna* stand in the municipality of Itatinga, SP. These authors attributed this fact to the low relative density of native individuals in the understory of this species. In general, the most abundant species were also those with the highest IV in the population sampled in this study (Table 1). *Astronium graveolens* was the species with the highest IV due to its greater representativeness among the sampled individuals (approximately 20%). *Anadenanthera colubrina* var. *cebil* showed the second highest IV because of its high relative dominance (Table 1), evidencing that larger individuals were the ones that probably initiated the colonization process in the plantation understory. The representativeness and IV ranking of the native regeneration species of this study can be explained by their adaptive advantages, such as tolerance to light influx, successional stage, as well as types and dispersion of seeds (Onofre et al., 2010; Turchetto et al., 2015). The three species with the highest IV, *A. graveolens*, *A. colubrina* var. *cebil* and *Pterogyne nitens*, produce large numbers of viable seeds, and are canopy heliophic trees characteristic of early secondary successional stage. *A. graveolens* and *P. nitens* have winged seeds that enable anemochorous dispersion to longer distances. It is worth mentioning that these species were most frequently observed in plots close to the SSF fragment, boarders of the stand, and access roads of the study area (Figure 1). *A. colubrina* var. *cebil* and *Apuleia leiocarpa* have also been reported as species of higher IV present in the understory of eucalyptus stands surrounded by a SSF (Souza et al., 2007; Resende & Ferreira, 2009).

Trichilia elegans and *Alseis floribunda* showed the third and fourth highest IV (Table 1), mainly because of their abundance in the regeneration community. These species correspond to small trees, tolerant to canopy shading, characteristic of late secondary successional stage. In addition, they produce large numbers of seeds dispersed mainly by the avifauna. All these characteristics enabled *T. elegans* and *A. floribunda* to effectively colonize the understory of the plantation studied.

The mean species accumulation curve for analysis of sample adequacy did not reach an asymptote, that is, it did not stabilize (Figure 2). Schilling et al. (2012) reported that mean species accumulation curves in tropical regions hardly present an asymptotic pattern because of the high environmental heterogeneity. The species richness observed in the plots (54) was close to that indicated by the Chao 1 estimator (59) (Figure 2), corresponding to 91.5% of the richness estimated for this community. Thus, it is judicious to conclude that the sampling was sufficient to represent the floristic composition of the native tree community under regeneration in the understory of the *C. citriodora* stand.

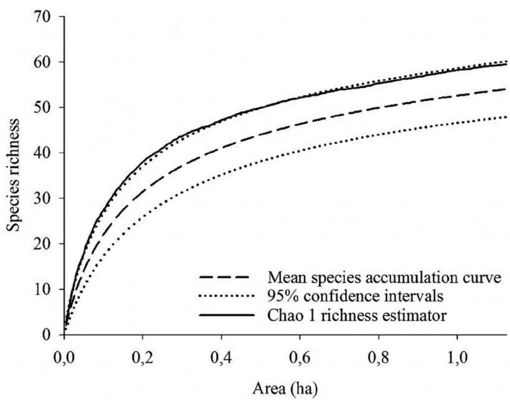

Figure 2. Mean species accumulation curve with respective confidence intervals and Chao 1 richness estimator for the native tree community in the *Corymbia citriodora* stand understory.

Diameter distribution of the native regeneration living individuals showed an inverted J-shaped curve, with mean DBH = 10.6 cm (Figure 3A). The height distribution (mean of 6.8 m) showed a similar result, with a larger number of individuals concentrated in the two lowest height classes (Figure 3B). Felfili et al. (2011) explained that the inverted J-shaped curve indicates that the community probably has no natural regeneration problems, if it is not heavily disturbed. The diameter and height distributions verified reinforce the interpretation that this community is undergoing a natural process of ecological succession (Turchetto et al., 2015). These distributions indicate that the community presents a normal natural regeneration dynamic, with predominance of establishment of young individuals (smaller diameters and heights) in the area.

The native arboreal community showed Shannon diversity and Pielou's evenness indices of 328 nats.ind^{-1} and 0.81 nats.ind^{-1}, respectively. When compared with indices described in other studies addressing natural regeneration in eucalyptus understories, Shannon and Pielou's indices found in the present study showed that the assessed vegetation has high diversity and little abundance of one or few species (Alencar et al., 2011; Durigan et al., 1997; Neri et al., 2005; Onofre et al., 2010; Resende & Ferreira, 2009; Saporetti et al., 2003;

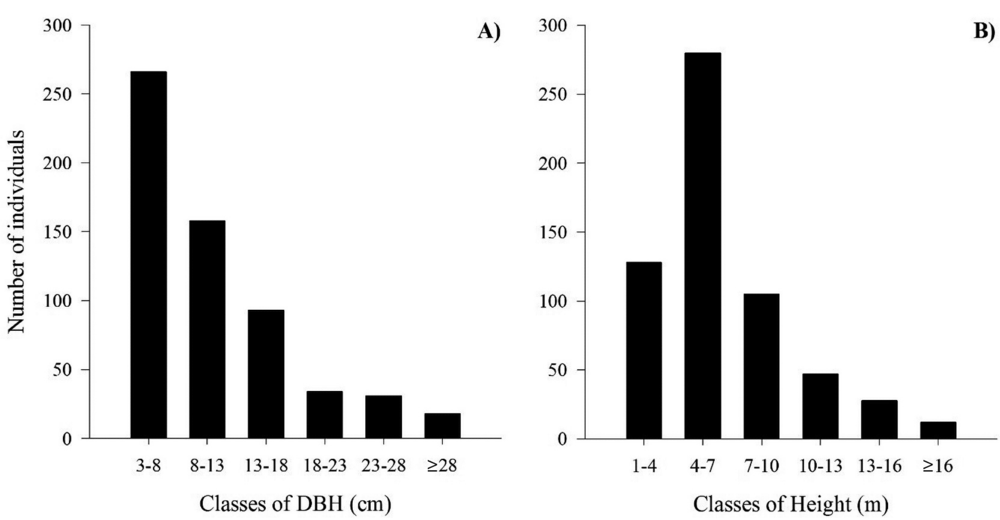

Figure 3. Diameter (A) and height (B) distributions of the native tree species in the understory of *Corymbia citriodora* stand. DBH: diameter at breast height.

Souza et al., 2007; Turchetto et al., 2015). As in the assessment of species richness of this study, comparisons of Shannon and Pielou's indices between studies with different sampling methods should be interpreted with caution (Magurran, 2011). Nevertheless, it seems sensible to infer that the observed values of diversity and evenness indicate that the eucalyptus stand did not prevent the diversity regeneration of native species in its understory.

Deciduous species were the most representative among the tree species sampled in the *C. citriodora* stand understory, followed by semideciduous and perennial species (Figure 4A). Deciduous and semideciduous species together accounted for 66.7% of the species surveyed. This finding evidences that the natural regeneration vegetation of the understory analyzed is, as expected, typical of semideciduous seasonal forest (IBGE, 2012).

It was expected that the pioneer and secondary groups, both early and late, showed the greatest species richness values (Figure 4B). These species are more adapted to the adverse and limiting conditions generally found in regeneration sites such as unmanaged eucalyptus stands (Alencar et al., 2011; Onofre et al., 2010; Souza et al. 2007; Turchetto et al., 2015). Nonetheless, the presence of 13 species from the late secondary group and four species from the climax group indicates that the area already presents environmental characteristics that enable the establishment of species of more advanced stages of natural regeneration (Onofre et al., 2010). As the establishment of different successional groups is essential to the regeneration of degraded areas (Kageyama et al., 2008; Rodrigues et al., 2011), this result strengthens the potential of eucalyptus stands to facilitate forest succession and regeneration of previously degraded areas (Alencar et al., 2011; Onofre et al., 2010; Turchetto et al., 2015).

Finally, the floristic composition similarity between the natural native regeneration of the *C. citriodora* stand understory and the neighboring SSF fragment was 0.41 (41%). This similarity level is regarded as low, especially when considering the proximity of the areas (Figure 1). This result is mainly due to the presence of colonizing species of more disturbed environments, which were not observed in the mature forest fragment. Onofre et al. (2010) also reported low floristic composition similarity (43.7%) between *E. saligna* stand understory and a neighboring Ombrophilous dense forest fragment in Parque das Neblinas, Bertioga, SP.

Aubert & Oliveira Filho (1994) reported that stands of *Eucalyptus* sp. and *Pinus* sp. located near forest fragments show significantly higher regeneration density of native species compared with that of plantations located farther from forest fragments. However, the authors also claimed that several species present in the understory of *Eucalyptus* sp. and *Pinus* sp. stands

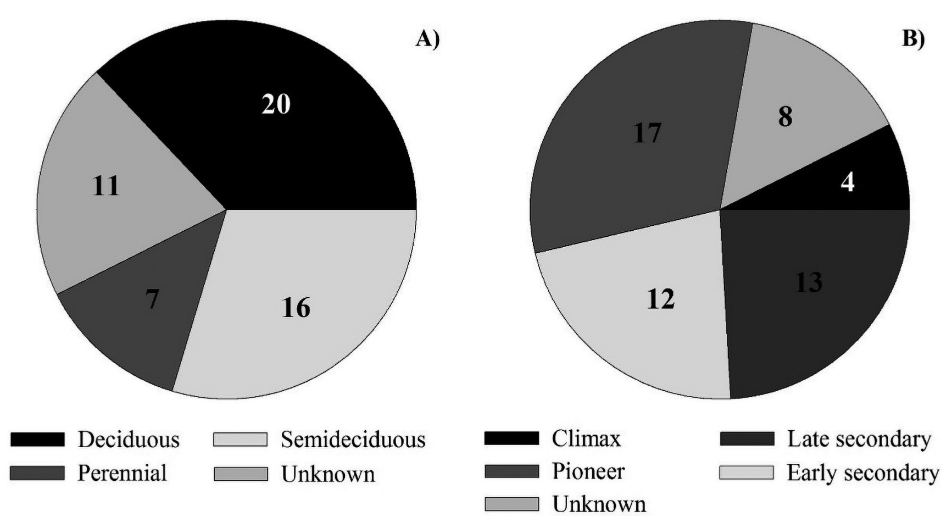

Figure 4. Classification according to deciduousness (A) and ecological groups (B) of the native tree species in the understory of *Corymbia citriodora* stand.

were not observed in the nearby forest fragments. This evidences that species from other environments rather than the neighboring forest fragment are being established in the understory analyzed, and that this fact can favor the recovery of regional vegetation diversity (Aubert & Oliveira Filho, 1994; Onofre et al., 2010).

Ratifying the aforementioned assertions, eucalyptus plantations have been in the midst of great controversy and continue to trigger discussion about their environmental impacts. Nevertheless, it is noted that, currently, eucalyptus stands are present in several regions worldwide, located at different altitudes, soils, and rainfall regimes. Therefore, abstract generalizations on the theme should be considered with caution or replaced with assertive contextual techniques. It is possible that this study's eucalyptus stand functions as a facilitator for the establishment of propagules from sources located at different distances, playing an important role in the regeneration of local and regional plant diversity. However, it should be highlighted that this research addressed a eucalyptus stand with specific environmental and climatic characteristics, and with original spacing between individuals of 3 × 3 m. It is also worth noting that the colonization of native species in understories of commercial stands will probably lead to difficulties in obtaining the exploitation license because of dense natural regeneration. Therefore, it is important that further studies seek to evaluate whether stands with different conditions lead to differences in the native species community that compose regeneration in their understories.

4. CONCLUSIONS

Assessment of the floristic composition and phytosociology of the *C. citriodora* stand understory showed greater diversity and evenness. Floristic composition similarity between the *C. citriodora* stand understory and the Semideciduous Seasonal Forest fragment located near the stand was considered low. However, results showed that this monoculture did not prevent the regeneration of native arboreal species of the region, which is in agreement with the hypothesis that abandoned, or inappropriately managed eucalyptus stands present significant development of their understory, indicating a successional process favorable to biodiversity regeneration.

The phytogeographic position of the study area, as well as the classification of the deciduous species, confirmed that the vegetation under regeneration is representative of semideciduous seasonal forests. The analyses of floristic composition, density, diameter and height distributions, and classification of the ecological groups of the species position the native regeneration observed in this study in the Early Stage of Regeneration. This result is the first evidence that the plantation provides conditions for the establishment of species typically found in the SSF fragments in the region. Although this vegetation is still in an early successional stage, it already presents richness and diversity values higher than those recorded in other understories of eucalyptus stands.

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