

Natural regeneration of tree species in the understory of *Corymbia citriodora* in Florestal city, Minas Gerais, Brazil

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Abstract

The natural regeneration of tree species in forested areas has been studied by several researches. This study aimed to evaluate the natural regeneration of tree species in *Corymbia citriodora* (Hook.) K. D. Hill & L. A. Johnson planted forest understory in Florestal, Minas Gerais, Brazil. Individuals with diameter at breast height (DBH) ≥ 5 cm were evaluated in seven 25 x 4 m plots randomly distributed. A phytosociological survey was carried out and the ecological groups and the dispersal syndromes of the regenerants were determined. We found 28 species belonging to 12 families, among which Fabaceae and Annonaceae stood out. Density was 1,557 regenerants ha⁻¹, and basal area was 23 m² ha⁻¹. The most important species were *Psidium* sp.; *Schefflera macrocarpa* (Cham. & Schltdl.) Frodin; *Pera glabrata* (Schott) Poepp. ex Baill.; *Astronium fraxinifolium* Schott & Spreng.; *Matayba guianensis* Aubl.; and *Plathymenia reticulata* Benth. We found 35% pioneer, 40% early secondary, 18% late secondary, and 7% climax species, of which 57% are zoochoric, 40% anemochoric, and 3% autochoric. It is concluded that the natural regeneration in the understory studied comprises typical species of the Seasonal Semideciduous Forest of the Atlantic Forest biome, presenting significant density and individuals from all ecological groups.

Keywords: Degraded area recovery, forest restoration, forest succession.

Regeneração natural de espécies arbóreas no sub-bosque de *Corymbia citriodora* no município de Florestal, Minas Gerais, Brasil

Resumo

A regeneração natural de espécies arbóreas em áreas com plantios florestais tem sido estudada por diversas pesquisas. Este estudo objetivou avaliar a regeneração natural de espécies arbóreas no sub-bosque de floresta plantada de *Corymbia citriodora* (Hook.) K. D. Hill & L. A. Johnson em Florestal, Minas Gerais, Brasil. Foram avaliados os indivíduos com diâmetro a altura do peito DAP ≥ 5 cm, em sete parcelas de 25 x 4 m, lançadas ao acaso. Elaborou-se estudo fitossociológico e determinou-se os grupos ecológicos e as síndromes de dispersão das regenerantes. Foram encontradas 28 espécies, pertencentes a 12 famílias, com destaque para Fabaceae e Annonaceae. A densidade foi de 1.557 indivíduos regenerantes ha⁻¹ e a área basal de 23 m² ha⁻¹. As espécies de maior importância foram *Psidium* sp.; *Schefflera macrocarpa* (Cham. & Schltdl.) Frodin; *Pera glabrata* (Schott) Poepp. ex Baill.; *Astronium fraxinifolium* Schott & Spreng.; *Matayba guianensis* Aubl. e *Plathymenia reticulata* Benth. Foram encontradas 35% de pioneiras, 40% secundárias iniciais, 18% secundárias tardias e 7% climáticas; sendo 57% zoocóricas, 40% anemocóricas e 3% autocóricas. Conclui-se que na regeneração natural no sub-bosque em estudo foram encontradas espécies típicas da tipologia Floresta Estacional Semidecidual do bioma Mata Atlântica, apresentando significante densidade e indivíduos de todos os grupos ecológicos.

Palavras-chave: Recuperação de áreas degradadas, restauração florestal, sucessão florestal.

Introduction

Despite its worldwide ecological and environmental relevance, the Atlantic Forest biome occupies only 11% to 16% of its original area, consisting now of small and isolated remnant fragments, of which 80% are smaller than 50 ha and distant, on average, 1,440 m apart (Ribeiro, Metzger, Martensen, Ponzoni, & Hirota, 2009).

This condition can greatly hinder the forest restoration process, given the limitations imposed on seed dispersal by

wind or fauna, the low permeability of the landscape matrix, and the poor conservation status of the remaining fragments (Viani, Durigan, & Melo, 2010). In this context, forest restoration practices require a combination of local- and landscape-scale approaches, as both are crucial in the natural regeneration process (Souza Leite, Tambosi, Romitelli, & Metzger, 2013).

In the case of tropical and subtropical forests, the restoration process involves the structuring, consolidation, and maturation stages (Brancalion, Gandolfi & Rodrigues,

2015). The initial and structuring phase consists of the formation of a canopy and a shaded forest habitat, enabling conditions for the contribution and gradual establishment of understory tree species, accompanied by the progressive elimination of invasive and competing species that may be present in the area (Gandolfi, 2017).

Possibilities for structuring the initial forest canopy include planting homogeneous forests, notably eucalyptus ones, provided that they allow the establishment of natural regeneration of native species at a satisfactory level in their understory (Carneiro & Rodrigues, 2007; Isernhagen, Rodrigues, Nave, & Gandolfi, 2009).

Studies show that homogeneous forest plantations can act as catalysts for secondary forest succession, facilitating the natural regeneration of native vegetation by favoring the entry, germination, and establishment of tree species in the understory as long as there is landscape resilience that can act as an allochthonous source of propagules (Viani et al., 2010).

This research evaluated the natural regeneration of tree species in the understory of a planted forest of *C. citriodora* in Florestal city, Minas Gerais, Brazil.

Materials and Methods

Study area

The study was conducted at the Federal University of Viçosa - Campus Florestal, in Florestal city, Minas Gerais, Brazil. The area has about 0.5 ha of *C. citriodora* forest, planted about 60 years ago at a spacing of 3 x 3 m. It is located at coordinates 19° 53' 05.39" S and 44° 25' 28.15" W, at an altitude of 781 m. The current density of planted *C. citriodora* trees remaining in the area is about 125 individuals.

The relief is characterized as 9% flat, 54% wavy, and 17% mountainous, with altitudes between 684 and 1,158 m. The Economic Ecological Zoning of Minas Gerais classifies the vegetation of the city as follows: 72% Seasonal Semideciduous Forest, 19% Grassland, 8% Eucalyptus, and 1% Cerrado.

According to the Köppen classification, the climate of the city is type Cwa - temperate humid with summer rains and dry winter. According to climatological normal data of the National Institute of Meteorology from 1981 to 2010, the average annual rainfall in Florestal city is 1,393 mm, with minimum and maximum average temperatures of 14.4 and 28.9 °C, respectively, and average annual relative humidity of 64%.

Floristic survey and phytosociological analysis

Trunk diameter at breast height (DBH at 1.30 m from the ground) was measured, and regenerating tree individuals with DBH \geq 5 cm found in the understory of eucalyptus plantation were botanically identified. Sampling was random and consisted of seven plots of 100 m² (5 x 20 m), as proposed by Rodrigues et al. (2013). Sampling sufficiency was verified by the species accumulation curve (Freitas & Magalhães, 2012).

Species were identified in the field, with their identification being confirmed by consulting the bibliography (Lorenzi, 2016; Carvalho, 2014). The classification system adopted was that proposed by the Angiosperm Phylogeny Group III, being verified in the Missouri Botanical Garden database via virtual access (www.tropicos.org).

The following phytosociological parameters were calculated: frequency, density, dominance, and importance value (Freitas & Magalhães, 2012). Species were classified according to dispersal syndrome (autochory, zoochory, and anemochory) and ecological group (pioneer, early secondary, late secondary, and climax) (Vieira, 2016; Barbosa, 2017).

Results and Discussion

A total of 109 tree individuals with DBH \geq 5 cm were found in natural regeneration under *C. citriodora* plantation, corresponding to 28 species belonging to 12 botanical families, of which Fabacea and Annonaceae stood out with 46% of the total (Table 1).

The most phytosociologically important species (43%) in the studied area were, respectively: *Psidium* sp. ('araça'); *Schefflera macrocarpa* (Cham. & Schlttdl.) Frodin ('mandioqueira'); *Pera glabrata* (Schott) Poepp. ex Baill. ('folha-miuda'); *Astronium fraxinifolium* Schott & Spreng. ('gonçalo-alves'); *Matayba guianensis* Aubl. ('camboata'); and *Plathymenia reticulata* Benth. ('vinhatico').

The species found are typical of the Seasonal Semideciduous Forest of the Atlantic Forest biome (Scolforo, Mello, & Silva, 2008; Barbosa, 2017), and occur in the region of Florestal city, Minas Gerais, Brazil (Vieira, 2016).

It is noteworthy that each specific ecological condition, in terms of climate, soil, relief, landscape, remnant fragments, etc., provides a unique trajectory of natural regeneration and stochastic forest succession and, consequently, of floristic composition and phytosociological importance of species (Gandolfi, 2017).

The richness of natural regeneration under eucalyptus plantation in Brazil can reach values of 30 to 140 native tree species (Onofre, Engel, & Cassola, 2010). Surveys include 79 families, 292 genera, and 721 native species already found in the understory of eucalyptus plantations in Brazil (Costa, 2018).

The density and diversity of natural regeneration under commonly planted homogeneous forests vary as a function of canopy density and light availability in the understory, age and species of the planted forest, distance and quality of surrounding native vegetation remnants, management of planted forest, and the history of use of the area (Viani et al., 2010).

The estimated total basal area and density of the regenerants found under *C. citriodora* planting were, respectively, 23.00 m² ha⁻¹ and 1,557 individuals ha⁻¹. According to Rodrigues, Isernhagen, and Brancalion (2009), for forest restoration purposes in the Atlantic Forest biome, the minimum required density of regenerants is 1,000 individuals ha⁻¹, regardless of the DBH class.

Costa (2018) found 2,140 individuals ha⁻¹ with DBH \geq 2.5 cm and basal area of 11.04 m² ha⁻¹ in natural regeneration under *Eucalyptus grandis* Hill ex Maiden planted 60 years ago. Compared to the density of 1,557 individuals ha⁻¹ observed in the present study, the higher density found by that author is certainly due to the sampling being performed on regenerating individuals with DBH \geq 2.5 cm. On the other hand, the basal area represents about 50% of that of the present study, indicating that regenerating individuals were smaller, particularly in trunk diameter.

The distribution of regenerating species in ecological groups in the present study was as follows: 35% pioneer, 40% early secondary, 18% late secondary, and 7% climax. Phytosociological parameters confirm the overwhelming dominance of pioneer and early secondary species in terms of spatial distribution (frequency), density of individuals, basal area (dominance), and importance value in the plant community from an approach in terms of horizontal structure (Table 2).

The dominance of pioneer and early secondary species indicates that natural regeneration is in the early stages of forest succession (Brancalion et al., 2015). On the other hand, the presence of species of all ecological groups in natural regeneration, from heliophilic pioneers to shade-tolerant late secondary, signals the possibility of progression of the successional process over time (Gandolfi, 2017), which will occur from senescence or intentional felling of eucalyptus trees still present in the area (Isernhagen et al., 2009).

Table 1. Species and families found in natural regeneration under a planted forest of *Corymbia citriodora* at the Federal University of Viçosa - Campus Florestal, Florestal city, Minas Gerais, Brazil, and their ecological aspects.

Family	Popular Name	Scientific Name	EG	DS	RF	RDe	RDo	IVI
Anacardiaceae	Gonçalo-alves	<i>Astronium fraxinifolium</i> Schott & Spreng.	ES	ANE	6.1	5.5	7.7	6.4
Annonaceae	Pindaíba	<i>Xylopia</i> sp.	P	ZOO	6.1	5.5	5.0	5.5
Annonaceae	Araticunzinho	<i>Annona</i> sp.	P	ZOO	3.0	5.5	5.7	4.7
Annonaceae	Araticum	<i>Annona</i> sp.	P	ZOO	3.0	1.8	3.5	2.8
Annonaceae	Pindaíba-vermelha	<i>Xylopia brasiliensis</i> Spreng.	LS	ZOO	3.0	1.8	0.3	1.7
Araliaceae	Mandioqueira	<i>Schefflera macrocarpa</i> (Cham. & Schlttdl.) Frodin	P	ZOO	6.1	7.3	8.0	7.1
Arecaceae	Jerivá	<i>Syagrus romanzoffiana</i> (Cham.) Glassman	P	ZOO	3.0	1.8	0.2	1.7
Bignoniaceae	Ipê-amarelo	<i>Handroanthus serratifolius</i> (Vahl) S.Grose	LS	ANE	4.5	4.6	4.7	4.6
Bignoniaceae	Ipê-caraíba	<i>Handroanthus caraiba</i> (Mart.) Mattos	LS	ANE	1.5	0.9	0.9	1.1
Fabaceae	Óleo-copaíba	<i>Copaifera langsdorffii</i> Desf.	C	ZOO	1.5	0.9	8.6	3.6
Fabaceae	Jacarandá-caviúna	<i>Dalbergia villosa</i> (Benth.) Benth.	P	ANE	3.0	1.8	1.3	2.07
Fabaceae	Sucupira-preta	<i>Bowdichia virgilioides</i> Kunth	P	ANE	1.5	0.9	2.4	1.6
Fabaceae	Bico-de-pato	<i>Machaerium nyctitans</i> (Vell.) Benth	P	ANE	1.5	0.9	0.2	0.9
Fabaceae	Vinhático	<i>Plathymenia reticulata</i> Benth.	ES	ANE	3.0	2.7	12.7	6.1
Fabaceae	Jacarandá	<i>Machaerium</i> sp.	ES	ANE	4.5	2.7	3.9	3.7
Fabaceae	Farinha-seca	<i>Peltophorum dubium</i> (Spreng.) Taub.	P	AUT	3.0	1.8	1.7	2.2
Fabaceae	Angico-branco	<i>Anadenanthera colubrina</i> (Vell.) Brenan	ES	ANE	1.5	0.9	2.4	1.6
Fabaceae	Angico-vermelho	<i>Anadenanthera macrocarpa</i> (Benth.) Brenan.	ES	ANE	1.5	1.8	0.7	1.4
Lauraceae	Canela	<i>Ocotea</i> sp.	LS	ZOO	3.0	5.5	1.3	3.3
Melastomataceae	Pau-prego	<i>Mouriri glazioviana</i> Cogn.	C	ZOO	4.5	2.7	1.8	3.0
Melastomataceae	Casca-de-arroz	<i>Miconia</i> sp.	LS	ZOO	1.5	0.9	0.6	1.0
Meliaceae	Calcanhar-de-cutia	<i>Guarea</i> sp.	ES	ZOO	1.5	3.7	0.8	2.0
Meliaceae	Cedro	<i>Cedrela fissilis</i> Vell.	ES	ANE	1.5	0.9	3.3	1.9
Myrtaceae	Araçá	<i>Psidium</i> sp.	ES	ZOO	4.5	14.7	11.8	10.3
Myrtaceae	Piúna	<i>Myrcia</i> sp.	ES	ZOO	7.6	6.4	1.1	5.0
Peraceae	Folha-miúda	<i>Pera glabrata</i> (Schott) Poepp. ex Baill.	P	ZOO	9.1	7.3	4.2	6.9
Sapindaceae	Camboatá	<i>Matayba guianensis</i> Aubl.	ES	ZOO	7.6	7.3	3.4	6.1
Sapindaceae	Camboatá-de-rego	<i>Matayba elaeagnoides</i> Radlk.	ES	ZOO	1.5	0.9	1.4	1.3
Total					100%	100%	100%	100%

Ecological groups (EG) - pioneer (P), early secondary (ES), late secondary (LS), and climax (C); dispersion syndromes (DS) - zoochory (ZOO), anemochory (ANE), and autochory (AUT); relative frequency (RF), relative density (RDe), relative dominance (RDo), and importance value index (IVI).

The seed dispersal syndromes of the regenerating species were as follows: 40% anemochoric, 57% zoochoric, and 3% autochoric. According to Carvalho (2010), most tropical tree species present zoochoric dispersion, indicating the importance of fauna, ecological corridors, and landscape permeability in both seed dispersal and area colonization (Arana & Almirante, 2007).

Costa (2018) found 68.8% nonpioneer (late secondary and climax) and 81.1% zoochoric species among native regenerants in the understory of *E. grandis* planted about 60

years ago.

The dominance of zoochoric species in natural regeneration attests that eucalyptus, despite being an exotic species in Brazil, acts to attract fauna (Costa, 2018) and mainly as a perch for avifauna.

Torresan, Vital, Araujo, and Cola (2011) recorded 53 bird species in a eucalyptus forestry area, being distributed in 23 families and 11 orders. One of the desirable characteristics of species planted during forest restoration is certainly their attractiveness to fauna, favoring the colonization of the area

by regional native species (Carneiro & Rodrigues, 2007).

Table 2. Values of phytosociological parameters by ecological group of regenerating species in the understory of a planted forest of *Corymbia citriodora* at the Federal University of Viçosa - Campus Florestal, Florestal city, Minas Gerais, Brazil.

Ecological Group	RF	RDe	RDo	IVI
Pioneer	3.4	33.0	30.6	33.3
Early Secondary	43.9	49.5	51.1	48.2
Late Secondary	13.6	13.8	7.9	11.8
Climax	6.1	3.7	10.4	6.7
Total	100%	100%	100%	100%

RF - Relative frequency, RDe - Relative density, RDo - Relative dominance, IVI - Importance value index.

On the other hand, the significant presence of wind-dispersed regenerants in the study area can be explained by the proximity (about 20 m) of a well-preserved Semideciduous Seasonal Forest fragment, enabling the contribution of anemochoric propagules (Viani et al., 2010).

Considering the dispersal syndromes by ecological group, there is a decrease in anemochory among late species, while zoochory is present among all ecological groups (Table 3). This fact reinforces the role of fauna in the reintroduction of biodiversity throughout forest restoration (Carnevale & Montagnini, 2002).

Table 3. Ecological groups and dispersal syndromes of regenerating species found in the understory of a planted forest of *Corymbia citriodora* at the Federal University of Viçosa - Campus Florestal, Florestal city, Minas Gerais, Brazil.

Ecological Group	Dispersal Syndrome		
	Autochory	Anemochory	Zoochory
Pioneer	0	30	38
Early Secondary	100	60	31
Late Secondary	0	10	19
Climax	0	0	12
Total	100%	100%	100%

The intensity of natural regeneration will likely depend on local conditions, defined by initial planting spacing, level of shading and invasive exclusion (Modna, Durigan, & Vital, 2010), and surrounding conditions associated with presence, distance, and conservation status of native vegetation remnants, besides the permeability of the surrounding landscape (Souza Leite et al., 2013; Almeida, 2016).

In addition to providing the shade and habitat required for the suppression of unwanted invasive species and the establishment of native tree species (Carnus et al., 2006; Carneiro & Rodrigues, 2007), planted forests should also be attractive to fauna (Torresan et al., 2011), enhancing the external contribution of propagules via zoochory (Brancalion et al., 2015; Gandolfi, 2017).

For homogeneous planted forests to play the role of pioneers and facilitators in restoring native forests (Modna et al., 2010), they must be managed in such a way as to preserve

the regeneration of native vegetation present in their understory (Viani et al., 2010).

Planted exotic trees should be gradually removed by selective felling of single trees or tree lines, maintaining the forest structure and mitigating damage to regeneration. Another possibility would be through ringing and poisoning, causing the death of standing trees, but maintaining perches and seed dispersal by birds (Isernhagen et al., 2009).

Conclusions

The *C. citriodora* forest provided natural regeneration with high density of individuals and species (mostly pioneer or early secondary) of the Atlantic Forest in its understory, with anemochoric or zoochoric dispersal syndromes.

Natural regeneration occurred due to the canopy structure and the creation of a forest habitat by *C. citriodora* trees, providing conditions for the attraction and establishment of native tree species in its understory, coming from preserved forest remnants existing around the studied area.

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