FIRE EFFECTS ON NATURAL REGENERATION IN SEASONAL SEMIDECIDUOUS FOREST

Fábia Maria dos Santos Souza[2*], Vinícius Barros Rodrigues[3] and Fillipe Tamiozzo Pereira Torres[3]

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[2] Universidade Federal de Viçosa, Programa de Pós-Graduação em Botânica, Viçosa, MG - Brasil. E-mail: <fabiasantossd@gmail.com>.
[3] Universidade Federal de Viçosa, Departamento de Engenharia Florestal, Viçosa, MG - Brasil. E-mail: <viniciusbrbio@gmail.com > and <tamiozzo@ufv.br>.
*Corresponding author.

ABSTRACT – Forest fire is considered a relevant environmental and ecological issue worldwide, as it causes population, ecosystem, and economic impacts, making monitoring and additional research necessary to understand post-fire forest recovery. Thus, the aim of this study was to evaluate the changes that occurred in the natural regeneration stratum in a fragment of Atlantic Forest in the municipality of Viçosa (MG), with and without the occurrence of fire. The phytosociological parameters and the functional diversity of the plant community were evaluated through 20 plots, 10 in the burnt area and 10 in the unburnt area, in 2018 and 2019, to follow the natural regeneration. There were collected, in the burnt and unburnt areas, respectively, 113 and 126 individuals, 23 and 16 species, and 13 and 9 botanical families. *Piper* sp.1, showed the highest values for the parameters: relative density, absolute frequency, and cover value, occurring in 100% of the plots. Areas with occurrence of fire present higher species richness. Species of the genus *Piper* occur frequently in areas of Semideciduous Seasonal Forest with signs of disturbance. The highest Shannon diversity and Pielou equitability indexes were found in the burnt area. The Jaccard index and the cluster analysis confirm the formation of groups with low similarity, showing floristic heterogeneity between the two areas, and the disturbance caused by fire is considered an important aspect for this floristic differentiation to occur. Therefore, the occurrence of forest fire in areas of Atlantic Forest increased the diversity values of species, with an increase in the equitability index, showing low floristic similarity between burnt and unburnt areas.

Keywords: Degradation; Forest Fires; Recovery.

EFEITOS DO FOGO NA REGENERAÇÃO NATURAL EM FLORESTA ESTACIONAL SEMIDECIDUAL

RESUMO – O incêndio florestal é considerado um relevante problema ambiental e ecológico em todo o mundo, pois causa impactos populacionais, ecossistêmicos e econômicos, tornando necessário o monitoramento e pesquisas adicionais para entender a recuperação florestal pós-fogo. Assim, o objetivo deste estudo foi avaliar as mudanças ocorridas no estrato de regeneração natural em um fragmento de Mata Atlântica no município de Viçosa (MG), com e sem a ocorrência de fogo. Os parâmetros fitossociológicos e a diversidade funcional da comunidade vegetal foram avaliados por meio de 20 parcelas, sendo 10 na área queimada e 10 na área não queimada, em 2018 e 2019, para acompanhar a regeneração natural. Foram coletados, na área queimada e não queimada, respectivamente, 113 e 126 indivíduos, 23 e 16 espécies e 13 e 9 famílias botânicas. ***Piper*** *sp.1 apresentou os maiores valores para os parâmetros: densidade relativa, frequência absoluta e valor de cobertura, ocorrendo em 100% das parcelas. As áreas com ocorrência de fogo apresentam maior riqueza de espécies. Espécies do gênero* ***Piper*** *ocorrem com frequência em áreas de Floresta Estacional Semidecidual com sinais de perturbação. Os maiores índices de diversidade de Shannon e equitabilidade de Pielou foram encontrados na área queimada. O índice de Jaccard e a análise de agrupamento confirmam a formação de grupos com baixa similaridade, mostrando heterogeneidade florística entre as duas áreas, e a perturbação causada pelo fogo é considerada um aspecto importante para que essa diferenciação florística ocorra. Portanto, a ocorrência de incêndios florestais em áreas de Mata Atlântica aumentou os valores de diversidade de espécies, com aumento do índice de equitabilidade, mostrando baixa similaridade florística entre áreas queimadas e não queimadas.*

Palavras-Chave: Degradação; Incêndios Florestais; Recuperação.

1. INTRODUCTION

Forest fire is considered a relevant environmental and ecological issue worldwide (Zhang et al., 2016), which appears in the geological record (charcoal fossils) since the emergence of land plants (Bowman et al., 2009). Evidence shows that the fire regime was affected by climate oscillations, both in their frequency and severity, influencing global ecosystem patterns and processes (Molina et al., 2017). These fires cause population, ecosystem and economic impacts, such as expenses to fight them (Zhang et al., 2016) and affect the distribution and structure of vegetation (Bhadouria et al., 2017).

Monitoring and researching are necessary to understand post-fire forest recovery (Roccaforte et al., 2018) and assist in decision-making processes, both to prioritize large-scale fire control actions and to identify changes in floristic composition of vegetation (Wang et al., 2017). Knowing the ecology and dynamic of plant communities, how they regenerate after being disturbed and which attributes are fundamental for this process to take place help to identify the problems of forest regeneration (Trauernicht et al., 2018).

There are many works on post-fire forest recovery in various biomes in Brazil, such as the Amazon (Cochrane and Laurance, 2002; Prestes et al., 2020; Silvério et al., 2019) and the Cerrado (Souchie et al., 2017; Zanzarini et al., 2019), as well as in other forest areas around the world (Keyser et al., 2017; Svátek et al., 2018; Richardson et al., 2018; González-De Vega et al., 2018). However, the after-effects of forest fires on vegetation, as well as their impacts on species diversity and seedling establishment in humid tropical forests are still highly questioned (Baker et al., 2008; Bhadouria et al., 2017).

In tropical forests, the main means of regeneration of species after the occurrence of natural or anthropic disturbances, such as fire, is through the soil seed bank, seed rain, or the regeneration by regrowth (Charles-Dominique et al., 2015). However, the results found on the effects of fire on natural regeneration show a complex response of vegetation to disturbances in composition, successional dynamics and species density (Camargos et al., 2010; Melo and Durigan, 2010; Santos et al., 2019). Some studies also point to significant ecological changes, ranging from changes in microclimate (Rocca et al., 2014) to seed germination (Lipoma et al., 2018). These studies indicate a variable regeneration potential, which changes according to the ecological characteristics of the vegetation and fire severity (duration, frequency and time of occurrence) (Morgan et al., 2014; Camargos et al., 2015; Bohlman et al., 2016).

A study carried out on the effect of fire in a tropical forest showed that the occurrence of forest fire caused changes in the structure of the upper stratum of the forest, with a significant increase in species of *Cecropia* sp. (Reis et al., 2018). In addition, it affected the mechanisms of tree mortality and regeneration (Svátek et al., 2018), with a decrease in the abundance and richness of vegetation species (Cochrane and Laurance, 2002; Costa et al., 2017). Although knowledge about the impacts of fire has advanced in recent years (Cochrane, 2003; Sansevero et al., 2017), few studies have analyzed these impacts in the Brazilian Atlantic Forest (Melo and Durigan, 2010) in order to identify the behavior of the fire of anthropic origin in the lower stratum and its possible effects on the dynamics of natural regeneration of the plant community.

Given the above information, this study aimed to evaluate the changes that occurred in the stratum of natural regeneration, in a fragment of Atlantic Forest in the municipality of Viçosa (MG), with two distinct environmental characteristics: with and without the occurrence of fire. The following hypotheses were tested: (I) species diversity is greater in the area affected by fire, since fire removes dominant individuals, facilitating the development of other species; (II) the expressiveness of the zoochoric syndrome is greater in the unburnt area, since the area was not disturbed and it is expected that it will have a greater presence of dispersing animals, which are attracted by the fruits; (III) the number of species with initial secondary succession will be higher in the burnt area, once, after passing through the disturbance caused by the fire, there will be an increase in species with later successions, since the site has been regenerating for four years.

2. MATERIAL AND METHODS

2.1. Study area

The work was carried out in a forest fragment known as "Recanto da Cigarra" located on the campus

of the Federal University of Viçosa, in the municipality of Viçosa, MG (20º45'26.7"S; 42°51'46.2"W) (Figure 1). The study site is located in the Atlantic Forest biome, which comprises different forest formations, and the studied area is occupied by Semideciduous Seasonal Forest (Costa et al., 2013).

The total area of the fragment is 75ha, with altitude ranging from 725 to 745 m, the climate of the region is Cwb (Köppen), mesothermic, with hot and rainy summers and cold and dry winters (Camargos et al., 2013; Miranda et al., 2012). It has an average annual rainfall of 1,229 mm and an average annual temperature of 20 °C (INMET, 2019).

On October 19th, 2014, a fire of human origin occurred in the area, burning about 30 ha of native vegetation. The fire descended approximately 30 m from the slope, reaching a trail (50 cm of average width) that delimited the burnt area, establishing a boundary between the burnt and unburnt area. Both areas were at the same stage of succession before this event. Although the fire was not measured, it showed a low intensity upon reaching the area as it naturally extinguished and could not overcome the trail barrier (50 cm).

(Source: the author).
(Fonte: a autora).

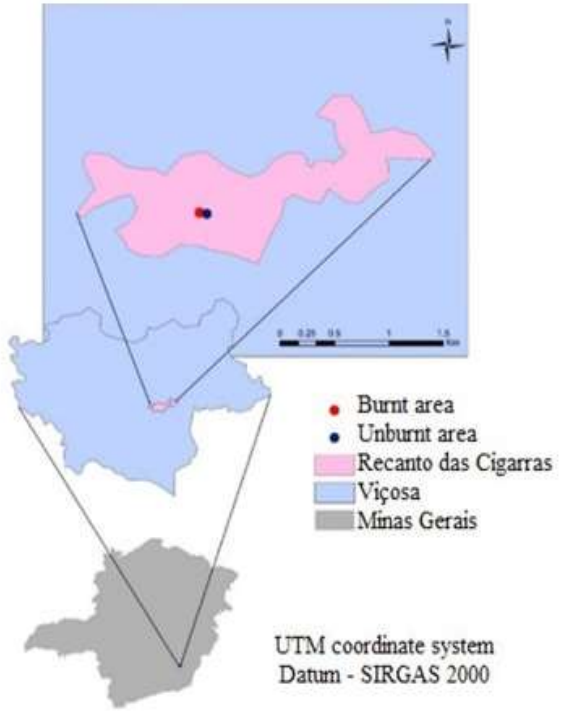

Figure 1 – Study site, located in Recanto das Cigarras, Viçosa, Minas Gerais Brazil.
***Figura 1** – Local de estudo, situado no Recanto das Cigarras, Viçosa, Minas Gerais Brasil.*

2.2. Sampling and data analysis

A vegetation survey was carried out in 20 plots, 1 x 1 m apart at 10 m, 10 plots in the burnt area (B) and 10 in the unburnt area (UB). These plots were assembled (with PVC pipe) and marked to have maximum precision in collecting information between the 2018 and 2019 surveys.

In 2018, the height, number of stems, circumference at ground and chest level of individuals with collar circumference < 5 cm were collected to calculate the phytosociological parameters of the area. In order to track regeneration, in 2019 the same information was collected from the previously identified individuals and from those that emerged after the first assessment.

Botanical identification was carried out in the field based on the vegetative characters of the species or by consulting the literature (Souza and Lorenzi, 2012). The phytosociological parameters of density, frequency, dominance and cover value index were calculated to evaluate the horizontal structure of natural regeneration. These parameters allow sorting the species hierarchically according to their importance in the community.

The Shannon-Weaver diversity index (H') and the complementary Simpson's specific diversity index (1-D) were calculated to test whether species diversity is greater in the area that was affected by fire or in the unburnt area. The higher the values found for these two indexes, the greater the indication that the area is diverse (Nóbrega et al., 2011). In addition, Pielou equitability index (J') was evaluated, which allows to represent the uniformity of distribution of individuals among all existing species (Uhl and Murphy, 1981).

Maximum richness was estimated with 1st order Jackknife. In order to compare the floristic composition between the areas, were calculated the grouping by the Unweighted Pair Group Method using Arithmetic Mean (UPGMA) based on the Jaccard similarity indexes (which expresses the similarity between environments, based on the number of common species), in the PAST program version 2.17c, from a

matrix of presence and absence of the species sampled in all plots of the two areas.

In order to assess if there was a statistical difference between the areas, the Generalized Linear Mixed Models (GLMM) was performed (Crawley, 2012). The plots were added as a random effect in the statistical model. To verify if the expression of the zoochoric syndrome is greater in the burnt area, the dispersion syndrome with the highest occurrence in the area was identified and, in order to identify if the number of species with initial secondary succession is greater in the burnt area, the successional groups of plants were evaluated (Calegari et al., 2013).

3. RESULTS

In the floristic survey of the burnt area (B), 113 individuals were found, distributed in 23 species and 13 botanical families, respectively. In the unburnt area (UB), there were 126 individuals, distributed in 16 species and 9 botanical families, respectively. Four species were not identified, as they did not present reproductive parts during the survey period.

In the burnt area, the families with the highest number of species were Melastomataceae and Rubiaceae, with four species each, followed by Arecaceae, Piperaceae, Rosaceae, Siparunaceae,

Table 1 – Number of individuals (N), relative density (RD), absolute frequency (AF) and coverage value (CV) of the species sampled in the burnt (B) and unburnt (UB) area in 2018, in a stretch of Seasonal Semideciduous Forest in Viçosa, MG.
Tabela 1 *– Número de indivíduos (N), densidade relativa (DR), frequência absoluta (FA) e valor de cobertura (VC) das espécies amostradas na área queimada (AQ) e não queimada (NQ) em 2018, em um trecho de Floresta Estacional Semidecidual em Viçosa, MG.*

SPECIES	BURNT (B)				UNBURNT (UB)			
	N	RD(%)	AF(%)	CV(%)	N	RD(%)	AF(%)	CV(%)
Piper sp.1	70	61,94	90	43,95	93	73,80	100	61,46
Miconia sp.	8	7,07	50	6,05	1	0,79	10	0,94
Archontophoenix alexandrae	5	4,42	20	2,99	1	0,79	10	0,40
Cestrum sp.	4	3,53	10	3,99	-	-	-	-
Piper sp.2	3	2,65	20	2,46	9	7,14	60	9,33
Guatteria sp.	2	1,76	20	1,34	-	-	-	-
Siparuna sp.	2	1,76	20	3,15	-	-	-	-
Psychotria sessilis	2	1,76	20	2,99	2	1,58	10	13,02
Psychotria sp.1	2	1,76	20	2,34	2	1,58	20	3,03
NI 1	2	1,76	20	2,94	-	-	-	-
Cecropia hololeuca	1	0,88	10	0,73	-	-	-	-
Cedrela fissilis	1	0,88	10	0,50	-	-	-	-
Miconia cinnamomifolia	1	0,88	10	1,01	1	0,79	10	0,41
Myrcia fallax	1	0,88	10	1,61	-	-	-	-
NI 3	1	0,88	10	0,75	-	-	-	-
Piptadenia gonoacantha	1	0,88	10	0,57	-	-	-	-
Piptocarpha macrophoda	1	0,88	10	7,19	-	-	-	-
Prunus sellowii	1	0,88	10	6,11	-	-	-	-
Prunus serrulata	1	0,88	10	6,11	-	-	-	-
Psychotria sp.2	1	0,88	10	1,01	-	-	-	-
Psychotria sp.3	1	0,88	10	0,86	-	-	-	-
Siparuna guianensis	1	0,88	10	0,59	2	1,58	20	2,09
Tibouchina granulosa	1	0,88	10	0,62	-	-	-	-
Anadenanthera peregrina	-	-	-	-	1	0,79	10	0,41
Ilex cerasifolia	-	-	-	-	1	0,79	10	0,64
Licuala grandis	-	-	-	-	8	6,34	80	3,19
NI 2	-	-	-	-	1	0,79	10	1,14
NI 4 (Euphorbiaceae)	-	-	-	-	1	0,79	10	0,45
Piper aduncum	-	-	-	-	1	0,79	10	2,59
Trichilia lepidota	-	-	-	-	1	0,79	10	0,41
Trichilia sp.1	-	-	-	-	1	0,79	10	3,61
Total	113	100	100	100	126	100	100	100

Legend: number of individuals (N), relative density (RD), absolute frequency (AF) and coverage value (CV), burnt (B) and unburnt (UB) area; (Source: the author).
Legenda: indivíduos (N), densidade relativa (DR), frequência absoluta (FA) e valor de cobertura (VC), área queimada (AQ) e não queimada (NQ); (Fonte: a autora).

with two species each. In the unburnt area, the most representative families were Piperaceae and Rubiaceae, with three species each, followed by Arecaceae, Melastomataceae and Meliaceae, with two species.

Analyzing the structure of the regeneration stratum, there was a dominance of some species in the plant community. The highest values found for the parameters evaluated for relative density (RD), absolute frequency (AF) and coverage value (CV) were presented by *Piper* sp.1, showing dominance in both areas, occurring in 100% of the plots (Table 1).

(Source: the author).
(Fonte: a autora).

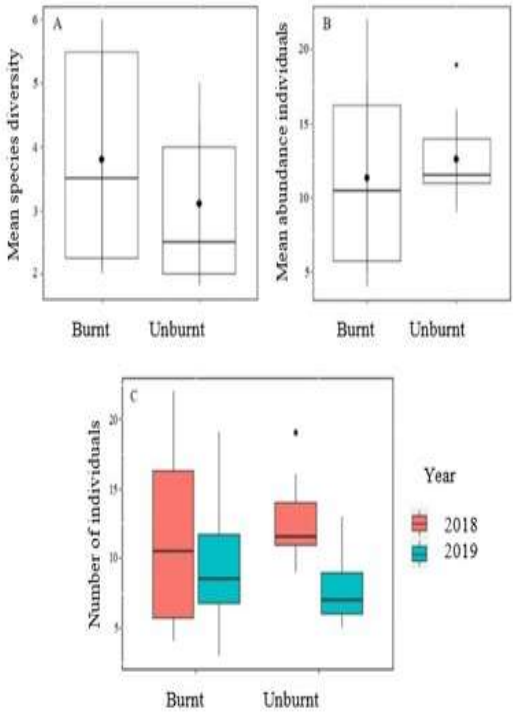

Figure 2 – Mean diversity of species (A) (p=0.4002) and mean abundance of individuals (B) (p=0.511) between the burnt and unburnt areas in 2018; number of individuals present in surveys carried out in 2018 and 2019 (C), in burnt and unburnt areas, in a stretch of Semideciduous Seasonal Forest in Viçosa, MG (p=0.006 between years); (p=0.614 between areas); (Source: the author).

***Figura 2** – Diversidade média de espécies (A) (p=0.4002) e abundância média de indivíduos (B) (p=0.511) entre as áreas queimada e não queimada em 2018; quantidade de indivíduos presentes nos levantamentos realizados nos anos de 2018 e 2019 (C), nas áreas queimada e não queimada, em um trecho de Floresta Estacional Semidecidual em Viçosa, MG (p=0.006 entre anos); (p=0.614 entre as áreas); (Fonte: a autora).*

Miconia sp. and *Archontophoenix alexandrae* H. Wendl. & Drude showed significant RD, AF and CV values in the burnt area, whereas in the unburnt area, they had lower values. *Licuala grandis* H. Wendl. was present only in the unburnt area, with RD (6.34%) and CV (3.19), occurring in 80% of the plots. *Piper* sp.2 occurred in both areas, with more representative values in the unburnt area (RD=7.14; AF=60% and CV=9.33) (Table 1).

The index results for the burnt area (B) were more representative when compared to the unburnt area (UB). Shannon and Simpson's values were 1.73 and 0.61 in B and 1.16 and 0.45 in UB, respectively. Pielou was 0.55 in B and 0.42 in UB; the Jackknife Estimator's value was 10 in each area and Jaccard's 0.25. From the statistical analysis, no significant difference was found in the diversity between the burnt and unburnt areas (p=0.4002) or in the number of individuals (p=0.511) (Figure 2A and Figure 2B). The dendrogram of similarity between plots (Figure 3) shows differences in species composition between the burnt and unburnt areas, showing floristic space heterogeneity between the two areas.

(Source: the author).
(Fonte: a autora).

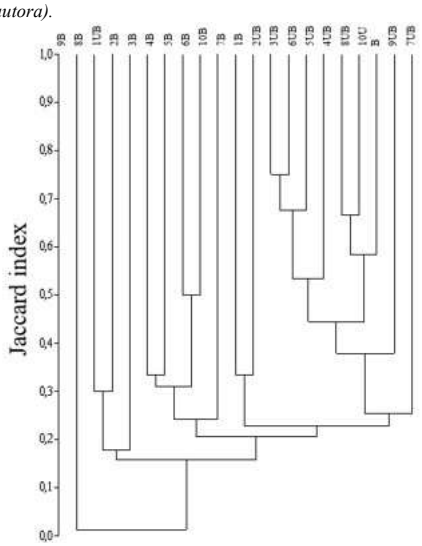

Figure 3 – Dendrogram obtained by the Unweighted Pair Group Method with Arithmetic Mean (UPGMA), based on the Jaccard index, for the sampled species, in the burnt and unburnt area, in a stretch of Semideciduous Seasonal Forest in Viçosa, MG.

***Figura 3** – Dendrograma obtido pelo Método de Grupo de Pares Não Ponderados com Média Aritmética (UPGMA), com base no índice de Jaccard, para as espécies amostradas, na área queimada e não queimada, em um trecho de Floresta Estacional Semidecidual em Viçosa, MG.*

The predominant dispersion syndrome was zoochoric, equivalent to 76% of the species present in the study. In the burnt area, 17 species with this syndrome were sampled and in the unburnt area, 13 species. The successional group in the burnt area had 30% of early secondary species and in the unburnt area, 31% of pioneers, the late secondary species were not very representative and nine species were not classified.

From the monitoring of regeneration, there was a reduction in the number of individuals between the years (p=0.006), but there was no difference between the areas (p=0.614) (Figure 2C), in addition, of the 23 species were found in the 2018 survey, eight of them did not occur in 2019, of these eight, the most representative was *Cestrum* sp., a zoochoric and pioneer species. When analyzing the functional groups of these eight species, they were mostly represented by zoochorous (5), pioneer (3) and early secondary (3) species. However, in 2019, there was the arrival of only *Tibouchina* sp., which is an initial secondary and anemochoric. The same behavior occurred between the burnt (B) and unburnt (UB) areas, with five more species disappearing in 2019, two in the B and three in the UB, these also presented insignificant values and belong to the same ecological groups.

4. DISCUSSION

The environment of the burnt area (B) showed similarity to the environment of the unburnt area (UB), in relation to the parameter of general richness. These results are similar to those found in understory areas of araucaria forests in Chile, where species richness was expressive in the unburnt forest, or in areas with low severity fires (Fuentes-Ramirez et al., 2020), since a reduction in species richness is common in relation to an increase in disturbance intensity (Blair et al., 2016).

Studies carried out in Seasonal Semideciduous Forests (Spósito and Stehmann, 2006; França and Stehmann, 2013; Franco et al., 2014; Freitas and Magalhães, 2014) have shown the importance of representative families in the floristic composition of this study, with greater relevance for the Rubiaceae family, due to its high number of shrub species naturally from understory areas (Franco et al., 2014; Torres-Leite et al., 2018). The families Melastomataceae, Myrtaceae and Rubiaceae are important in the development of the community, from the initial succession, mainly in the understory component of the forest, while Meliaceae is indicative of the modification from a pioneer forest to another with a more advanced successional stage (Tabarelli et al., 1994).

The species with the most representative phytosociological parameters *Piper* sp.1, *Miconia* sp., *Licuala grandis* and *Piper* sp.2 did not occur in a fragment close to the study site, in a floristic survey carried out in 2005, to characterize the regeneration stratum before the experiment with fire, using the same inclusion criteria (Camargos et al., 2010), however the same authors found species of the *Piper* and *Miconia* genera when evaluating the soil seed bank, before and after the fire treatment (Camargos et al., 2013). These two genera occur frequently in an area of Seasonal Semideciduous Forest with signs of disturbance due to the occurrence of fire (Yamamoto et al., 2005); in addition, *Piper* occurs with a representative number of species present in the secondary succession of the forest (Pinheiro and Monteiro, 2008), corroborating the results found in this work.

The high frequency of exotic species *Licuala grandis* and *Archontophoenix alexandrae* demonstrated their reproductive success in the area, justified by the high tolerance to severe ecological conditions (Heydari et al., 2016). These species were used to decorate the *campus* of the Federal University of Viçosa and, as they are species with zoochoric dispersion syndrome, the propagation may have been facilitated by the animals, which dispersed the seeds in the vicinity where the study area is located. The presence of non-dominant exotic species can also favor the arrival of native species (Durigan et al., 2013) due to their ease in germinating and developing seedlings, contributing to the deposition of the litter and humus layer and increasing the structural complexity of the area, but their monitoring is necessary, since as they are dominant, they can inhibit the development of native species (Durigan et al., 2013; Aranha et al., 2018).

The highest values found for the Shannon (H') and Simpson complementary (1-D) diversity indexes were in the burnt area, suggesting that this environment has relatively high species diversity when compared

to the unburnt area, confirming the first hypothesis of the study. The hypothesis test showed that there was no statistically significant difference in the diversity between the areas. However, it is expected that this difference will accentuate in a few years, since the results of the indexes pointed to a greater diversity in the burnt area. This greater diversity due to a local disturbance was also reported in another area of the Atlantic Forest (Rabelo et al., 2015), being justified by the attributes of the fire regime (severity, recurrence or duration) (Fernández-García et al., 2020). However, when it comes to fire of anthropic origin, it is not always possible to know the information regarding the fire regime.

Some studies point to the importance of fire severity and duration in changing the plant community, since places with low intensity fires have higher values of diversity (Morgan et al., 2015; Blair et al., 2016; Heydari et al., 2020) and the recurrence of fires also increase the Shannon diversity index (Fernández-García et al., 2020). In contrast, newly burnt sites with high-intensity or long-lasting fires show a significant decrease in forest cover and species diversity (Costa et al., 2017). Therefore, the patterns of structure and composition of vegetation affected by different levels of fire severity are important to be evaluated from the beginning of the fire, as they can help to better understand the possible paths for forest recovery (Fuentes-Ramirez et al., 2020).

The occurrence of fires in forest remnants induces tree mortality and randomizes its space pattern, keeping large individuals apart, which favors the opening of the canopy with the formation of gaps, and allows sunlight and germination of seeds present in the litter (Martins et al., 2008; Svátek et al., 2018; Heydari et al., 2020). In another study carried out in the same area, a similar pattern was found, in which the burnt area presented a greater opening of the canopy with formation of gaps, contributing to the greater diversity of species in the burnt area (Reis et al., 2018).

The values for the Pielou equitability indexes (B=0.55/UB=0.42) suggest low uniformity in the proportions of the amount of individuals/number of species (Rode et al., 2009), requiring an increment of 45 and 58% of species, to reach the maximum diversity of the plant community of the burnt and unburnt area, respectively (Ferreira Júnior et al., 2008). The effect of fire may slightly increase the evenness index, which justified the higher value found in the burnt area for this index (Heydari et al., 2020).

The values of the first order Jackknife estimator that were found indicate a potential richness that is lower or close to the values observed in the areas (B=10 estimated species; 23 observed; UB=10 estimated species; 16 observed). This nonparametric estimator makes a projection of the total number of species from the heterogeneity between samples (Heltshe and Forrester, 1983) and these results suggest that there was sample sufficiency in the collection.

Jaccard Similarity coefficient (JS) above 0.25% indicates high similarity (Mueller-Dombois and Ellenberg, 1976), so, according to this concept, the similarity analyzed between the areas (JS=0.25) can be considered low, suggesting a heterogeneous floristic composition. The study carried out in a fragment close to the area of this study found high similarity between the areas (JS=0.35), and the second survey was carried out two years after the fire experiment (Camargos et al., 2010). The survey of this study was carried out four years after the occurrence of the fire of anthropic origin. The cluster analysis confirmed the formation of groups with low levels of similarity, mainly in the burnt area, highlighting the floristic heterogeneity between the two evaluated areas. There was formation of a group by the plots of the burnt area and another in the unburnt area. However, the disturbance caused by the fire is considered an important aspect for this floristic differentiation to occur (Kunz et al., 2009).

The predominance of species with zoochoric dispersion syndrome in natural regeneration follows the well-known pattern found in Tropical Forests, in which 50 to 90% of trees and shrubs are dispersed by animals (Camargos et al., 2010; Sansevero et al., 2011; Coutinho et al., 2019). The high number of zoochorous species in the unburnt area confirms the second hypothesis established in this study, since the area was not disturbed and this contributes to a greater presence of animals that are attracted to the fruits, dispersing the seeds (Abelleira Martínez et al., 2015) and, later, enables the development and establishment of plant species, influencing the natural regeneration of the area (Rocha et al., 2016). This condition is indicative of plant communities in advanced stages of succession or the ones that are in a good state of conservation (Stefanello et al., 2010) and is due to

the presence of nearby forest remnants (Abelleira Martínez et al., 2015), which form a continuum with the studied area.

The expressiveness of pioneer species in the unburnt area was also reported in the Atlantic Forest area (Marcuzzo et al., 2014). These species improve soil quality, decreasing compaction and assisting in litter production, increasing soil fauna and the recruitment of species with secondary succession (Rocha et al., 2016). In the burnt area, confirming the third hypothesis of this study, the most representative species were the initial secondary ones, a result similar to that one found previously in a fragment with the same forest formation (Camargos et al., 2010). In addition, the presence of initial secondary species with greater representation in the burnt area was also reported in another area of Seasonal Semideciduous Forest in the Atlantic Forest, and it is explained by their ability to resprout after fire, what helps in the process of recovering richness floristics in disturbed areas after the occurrence of fire (Melo and Durigan, 2010).

With the monitoring of regeneration, there was a reduction in the number of individuals between the years. This can be explained by the specific characteristics of these individuals, the action of predators and pathogens, in addition to environmental factors such as a longer or shorter period of rainfall (Aguiar et al., 2019). The group of species that did not occur in 2019 had low phytosociological values in the 2018 survey, however they are species of important ecological groups, characterized as zoochoric, pioneer (as is the case of *Cestrum* sp.) and early secondary, which were responsible for the initial colonization of the disturbed area (Silva et al., 2017). The low values found for these species in 2018 and the absence of them in 2019 can be explained by the intermediate phase of the succession, which is the location studied, considering that, over the years, pioneer species change the conditions and/or availability of resources in a habitat, in a way that favors the entry and development of more demanding species, belonging to later successional groups (Martins, 2013).

5. CONCLUSIONS

The effect of fire altered the structure and floristic composition of the burnt area, since the floristic similarity patterns showed low similarity between the areas with the formation of a group by the plots of the burnt area and another in the unburnt area. The occurrence of fire in areas of Seasonal Semideciduous Forest increases the values of species diversity and slightly increases the evenness index. The largest amount of zoochoric species was in the unburnt area, since the area was not disturbed by the fire and this contributes to the attraction of animals that disperse seeds and allow the development of other plant species. The successional group of early secondary species was more representative in the burnt area, as these species increased over the four years after the disturbance caused by the fire, in addition, these species have the ability to resprout after the fire and facilitate the floristic recomposition of this area. These results confirm the hypotheses established in this study and indicate the need of monitoring the diversity for a longer time, in order to know the ecological characteristics that are changing in the disturbed areas over the years.

AUTHOR CONTRIBUTIONS

F. M. S. Souza: data collection and organization, bibliographical research, analysis and discussion of results, and article writing. V. B. Rodrigues: statistics analysis and discussion of results. F. T. P. Torres: designed the analysis and discussion of results.

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