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Biology-Ecology

Seed Rain in a Degraded Mining Area: The Role of Bird Perches and Pioneer Trees

Chuva de Sementes em Área Degradada pela Mineração: O Papel dos Poleiros de Aves e das Árvores Pioneiras

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ABSTRACT

Mining causes changes in natural areas, from the elimination of vegetation and the seed bank to physical changes in the soil and water dynamics. The recovery of such impacted areas depends on both the natural process of secondary succession and the use of techniques that assist the return of the flora. Aiming to evaluate the seed rain in an area of basaltic rock mining, 18 seed collectors of 0.5 m^2 were installed placed under artificial perches, pioneer trees (natural perches) and control collectors. After 12 months, 8976 seeds of 33 plant species were quantified with an average density of 997 seeds m^2 $year^{-1}$ that differed statistically between the different perches. Artificial perches were more efficient in facilitating the seed rain, the most abundant of which were Cecropia pachystachya Trécul (n=3218), Andropogon bicornis L. (n=1417), Urochloa plantaginea (Link) R.D.Webster (n=1179), and Leucaena leucocephala (Lam.) de Wit (n=1138) were more abundant and represented 77.4% of total collected seeds and 12.1% of species richness. The installation of artificial perches should be encouraged in degraded areas, because they facilitate the visitation of birds and seed dispersal, contributing both to the arrival of seeds and to an increase in seed richness in the area.

Keywords: Artificial perches, Dispersal syndromes, Secondary succession

RESUMO

A mineração provoca alterações nas áreas naturais dada pela retirada da vegetação e eliminação do banco de sementes e até alterações físicas e estruturais no solo e na dinâmica da água. A recuperação das áreas impactadas depende tanto do processo natural de sucessão secundária como do emprego de técnicas que auxiliam o retorno da flora ao local. Visando avaliar a ocorrência da chuva de sementes em uma área de exploração de rochas basálticas foram instalados 18 coletores de sementes de 0,5 m^2

posicionados sob poleiros artificiais, poleiros naturais e coletores controle. Após 12 meses foram quantificadas 8976 sementes de 33 espécies de plantas com densidade média de 997 sementes m^2 ano^{-1} que diferiu estatisticamente entre os diferentes poleiros. Os poleiros artificiais se mostraram mais eficientes no recebimento de sementes sendo que as mais abundantes foram de Cecropia pachystachya Trécul (n=3218), Andropogon bicornis L. (n=1417), Urochloa plantaginea (Link) R.D.Webster (n=1179) e Leucaena leucocephala (Lam.) de Wit (n=1138) que juntas responderam por 77,4% do total e 12,1% da riqueza de espécies. A instalação de poleiros artificiais deve ser estimulada em áreas degradadas, pois, facilitam a visitação das aves contribuindo para a chegada e aumento da diversidade de sementes na área.

Palavras-chave: Poleiros Artificiais, Síndromes de Dispersão, Sucessão Secundária

1 INTRODUÇÃO

The expansion of extensive agriculture and land use intensification in the late 20th century has led to deforestation, habitat fragmentation and many other impacts on ecosystems (MILLER and SPOOLMAN, 2021). These growing human activities, in addition to reducing the areas occupied by native vegetation, have led to the reduction of biodiversity, ecosystem services and the extinction of many species. Mining activities, despite important for society, are among the most important drivers of environmental degradation, which, in addition to promoting intense changes in the landscape, hinder the recovery process, either due to the elimination of biotic components of ecosystems or impacting soils, subsoils and surface and groundwater (AMARAL, 2013).

On the one hand, there is a need to use natural areas for the establishment of human activities, on the other, the current Brazilian legislation establishes that after the exploration has ceased, the mining areas that are degraded must be recovered (GASTAUER *et al*., 2018). Ecological restoration is attributed to the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed, which in most cases and due to the damage suffered, is generally different from its original condition (GANN *et al*., 2019).

According to Reis *et al*. (2010) in areas that have been impacted, secondary ecological succession can occur very slowly due to “in situ” conditions and in these cases nucleation techniques may be necessary to start or accelerate the natural process. Among the factors to be considered in the succession are the quantity and quality of seeds that arrive in a given area, whether they are already regenerating species, but preferably species that are allochthonous, in a phenomenon known as seed rain (DEL CASTILLO and RÍOS, 2008). Regarding the mechanisms of seed dispersal, it can occur via different vectors such as wind, rainwater and rivers, by animals and also by self-dispersion (ALMEIDA, 2016; SANTOS JÚNIOR and FERREIRA, 2018).

The artificial perch technique was developed in order to facilitate the seed dispersal process in open areas with a reduced number of trees (ZWIENER *et al*., 2014). The use of this technique assumes that the structure of the perches is interpreted by the birds as dry tree branches and in this way can be used as landing sites during the period of foraging and resting (REIS *et al*., 2003). The use of bird perches makes the environment more attractive to seed dispersing birds and over time enhance seed dispersal, seedling regeneration and the structural complexity of degraded habitats (BOCCHESE *et al*., 2008; BOANARES and AZEVEDO, 2014; SILVEIRA *et al*., 2015; VOGEL *et al*., 2018). Thus, bird perches promote the arrival of allochthonous plant species in the area, which increases the local diversity and contributes to the secondary succession process (DIAS *et al*., 2014).

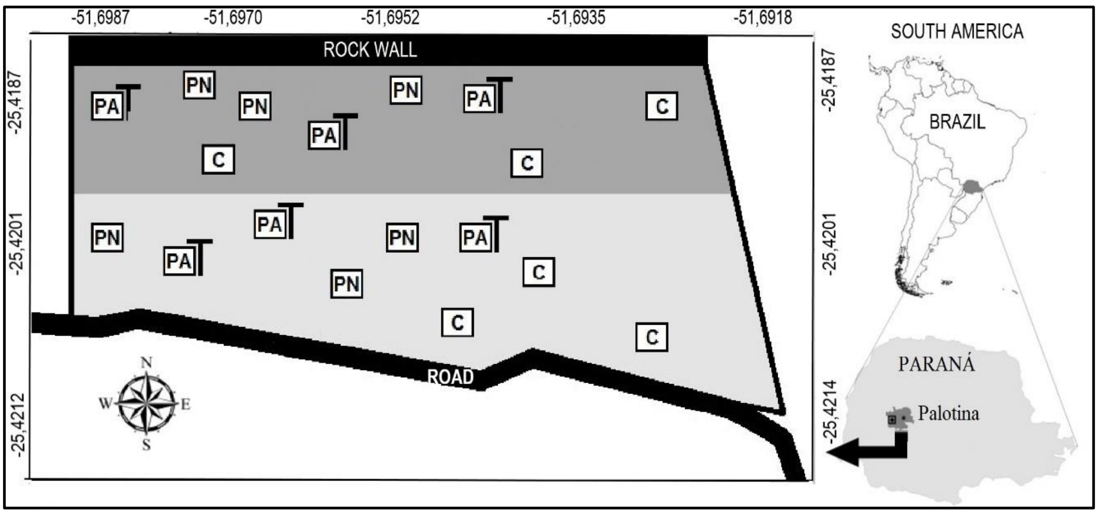
As for secondary succession in areas degraded by mining, the reestablishment of ecosystem structure and functions are influenced by environmental conditions, intensity and duration of impacts (ARAÚJO *et al*., 2006; SALOMÃO *et al*., 2007; JESUS *et al*., 2016). Studies that evaluate secondary succession in abandoned mining sites are fundamental because they provided the identification of species that develop in such degraded areas, environmental factors that positively or negatively influence the process of natural regeneration and, mainly, generate knowledge that can guide habitat recovery (KLEIN *et al*., 2009).

Given the current scenario of biodiversity crisis, considering the impacts caused by mining and the shortage of information, this study aimed to assess the seed rain and the influence of bird perches on the quantity and richness of seeds that arrive in an abandoned mining area in process of natural regeneration. More specifically, we aimed to answer the following questions: (i) can the seed rain be expected to occur in mined areas? (ii) Is the seed rain regular throughout the year? (iii) Does the use of bird perches lead to an increase in the abundance and richness of seed rain in areas degraded by mining?

2 MATERIAL AND METHODS

This study was conducted at the Minerpal Mining in Palotina/PR (Figure 1) in an area of 3.04 ha impacted by rock extraction. The region is part of the Paraná Sedimentary Basin, with lithology composed of basalts under a flat relief. Approximately thirteen years ago, after exploration ceased, the area received layers of soil from the blasting of rocks of other areas of the quarry. Since this material was deposited randomly and the soil horizons were mixed with saprolite fragments of different sizes, this soil can be classified as an Anthrosol.

Figure 1 — Location of the study area



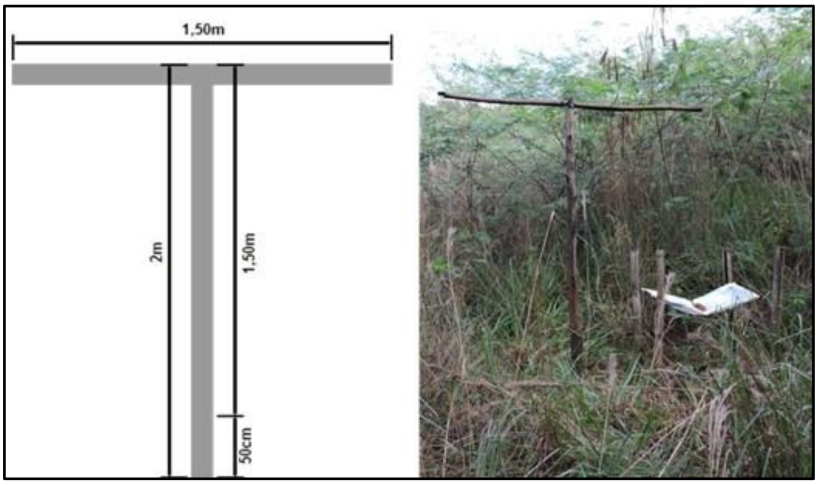
Source: Authors (2021)

The relief structure shows diverse features, from smooth to wavy with depressions and soil ridges with different heights. This irregular topographic pattern, associated with the unevenness of the rocky layer, induces the formation of flooding points even in periods of low precipitation, lagoons that persist in periods of drought, and elevated sites with greater soil thickness, which remain well drained for much of the year. The region's climate type, according to the Köppen classification, is Cfa with no dry season, average temperatures from 16 to 28.7 °C, and average annual precipitation of 1640 mm — with more frequent rains between October and February (IDR-PARANÁ, 2021).

5000 seedlings of native tree species were planted in the area in 2009. Since then, no other intervention has been made. Seedling establishment rate, however, did not reach 10%. In the same period, secondary succession began with the growth of an herbaceous stratum dominated by several species of grasses, in addition to the spontaneous arrival of Leucaena *leucocephala* from adjacent areas in the southern and eastern boundaries. Taking into account the current characteristics, the area's vegetation can be classified as the initial stage of succession (IAP, 2020).

The study area was subdivided into two lines, Paredão Line (LP) and Central Line (LC), according to vegetation development and environmental characteristics (Figure 1). Seed rain assessment was carried out using 18 0.5 m^2 collectors installed at 1 m above the ground. Nine collectors were placed in each line: three under artificial perches (PA), three under natural perches (PN, i.e. pioneer trees), and three control collectors (C). Artificial perches were made with two bamboo poles fixed together and arranged in a "T" shape 2.0 m high and 1.5 m wide (Fig.2).

Figure 2 — Dimensioning of the artificial perch



Source - Maristela Grunevald, 2018

Collections were carried out between Aug/17 and Jul/18, totaling 12 samplings per collector. Botanical identification of the seeds was based on the APG IV system. The nomenclature of the species was verified using the archives of the Brazilian Flora project (FLORA E FUNGA DO BRASIL, 2022). Seeds that could not be identified were listed as morphospecies. All material obtained was included in the collection of the Laboratory of Agricultural Ecology of the Federal University of Paraná, Palotina, PR. The identification of the dispersal syndrome of each morphospecies followed criteria proposed by PIJL (1972).

To compare the efficiency of artificial perches in relation to natural perches and control collectors, analysis of variance and Tukey's test ($p<0.05$) were conducted to identify differences between the means, regarding number of seeds, dispersal syndromes, abundance, and species richness. We tested the normality of ANOVA residuals using the Shapiro-Wilk test and for homoscedasticity, the Levene test. In cases where the data were not normally distributed, they were logarithmized. All tests were performed in PAST4.03® (HAMMER and RYAN, 2001) and SISVAR® (FERREIRA, 2014).

3 RESULTS

During the sampling period, 8976 seeds of 33 species/morphospecies (Table 1) were collected. 14 of these were identified up to the species level and another 19 as morphospecies (genus, family, or unidentified). Average seed density, considering all collectors, was 997 seeds m^2 $year^{-1}$. Separately, 4731 seeds (1577 seeds m^2 $year^{-1}$) were collected in collectors positioned under artificial perches, 2617 seeds (872 seeds m^2 $year^{-1}$) under natural perches, and 1628 seeds (542 seeds m^2 $year^{-1}$) in control collectors. In the Central Line, 5618 seeds (1248 seeds m^2 year-1) were quantified: 3133 seeds were collected in artificial perch collectors, 1516 seeds in natural perch collectors, and 969 seeds in control collectors. For the Paredão Line, 3358 seeds (746 seeds m^2 $year^{-1}$) were quantified, 1598 seeds in artificial perch collectors, 1101 seeds in natural perch collectors, and 659 seeds in control collectors. The most abundant species were *Cecropia pachystachya* (n=3218), *Andropogon bicornis* (n=1417), *Urochloa plantaginea* (n=1179), and *Leucaena leucocephala* (n=1138), which represented 77.4% of the total seeds collected and 12.1% of species richness.

Table 1 — Floristic list and total number of seeds collected

Continued...

Family	Genus / Species	Code	Number of seeds	DS
Anacardiaceae	*Lithraea molleoides* (Vell.) Engl.	M24	2	AU
Asteraceae	*Bidens alba* (L.) DC.	M10	573	AN
	Porophyllum ruderale (Jacq.) Cass.	M12	3	AN
Cecropiaceae	*Cecropia pachystachya* Trecul	M02	3218	ZO
Fabaceae	*Leucena leucocephala* (Lam.) de Wit	M03	1138	AU
	Mimosa bimucronata (DC.) Kuntze	M20	23	AU

Table 1 — Floristic list and total number of seeds collected

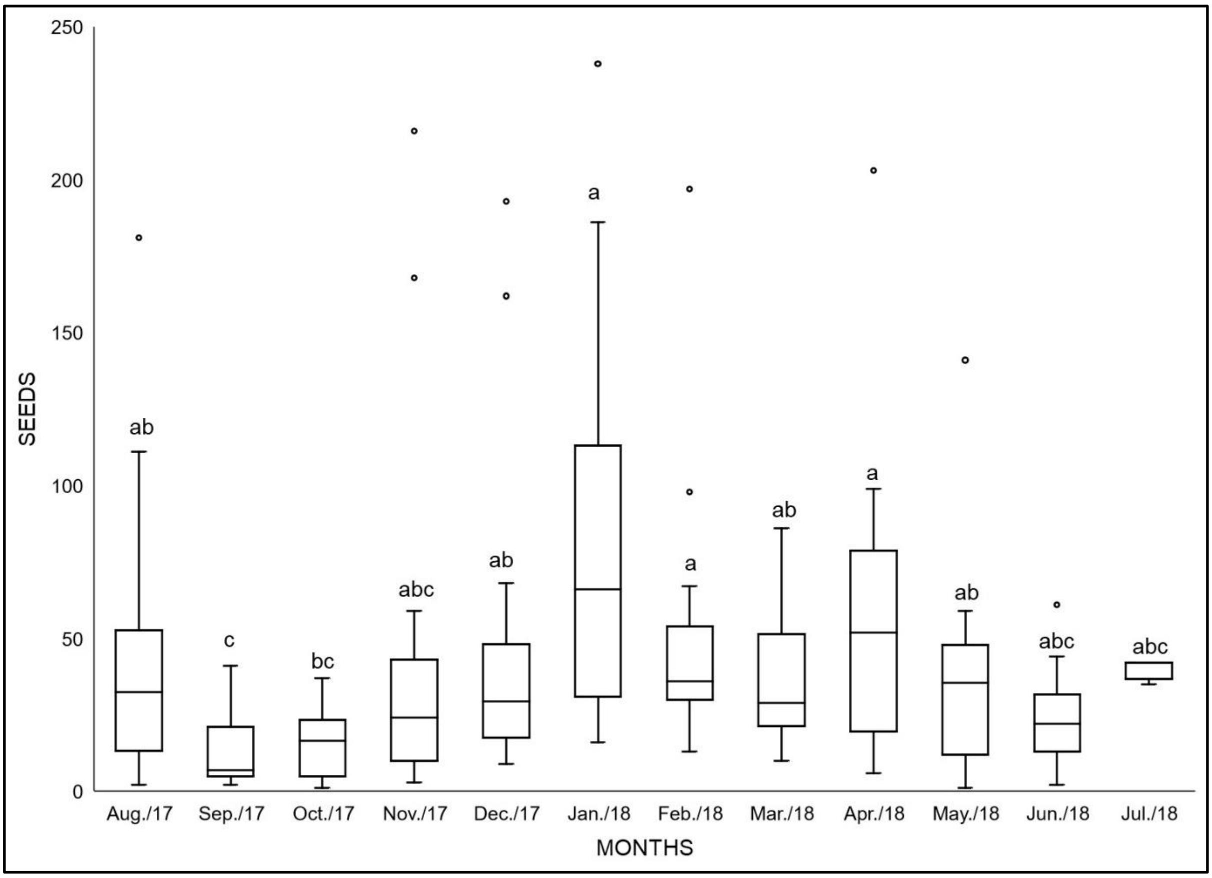
Conclusion

Family	**Genus / Species**	**Code**	**Number of seeds**	**DS**
Poaceae	*Andropogon bicornis* L.	M11	1417	AN
	Elionurus sp	M08	54	AN
	Melinis repens (Willd.) Zizka	M07	105	AN
	Panicum 1	M05	122	AN
	Panicum 2	M06	60	AN
	Sorghum halepense (L.) Pers.	M32	35	AN
	Urochloa plantaginea (Link) R. D. Webster	M14	1179	AN
	Grass 1	M09	40	AN
	Grass 2	M13	13	AN
	Grass 3	M17	28	ZO
Lauraceae	*Ocotea* sp	M15	3	ZO
Lecythidaceae	Lecythidaceae sp	M18	17	AU
Onagraceae	*Ludwigia sericea* (Cambess.) H. Hara	M30	326	AU
	Ludwigia sp	M33	6	AU
Ulmaceae	*Trema micrantha* (L.) Blume	M16	19	ZO
Primulaceae	*Myrsine umbellata* Mart.	M19	15	ZO
Rubiaceae	Rubiaceae sp	M22	1	ZO
Solanaceae	*Solanum* sp	M01	134	AU
Euphorbiaceae	*Alchornea triplinervia* (Spreng.) Müll.Arg.	M25	1	AU
	Euphorbia sp	M26	2	AU
Family 1	Morphospecies 1	M21	2	AU
Family 2	Morphospecies 2	M23	2	ZO
Family 3	Morphospecies 3	M27	39	AU
Family 4	Morphospecies 4	M28	3	ZO
Family 5	Morphospecies 5	M29	1	AU
Family 6	Morphospecies 6	M31	21	AU
Family 7	Morphospecies 7	M04	374	AN

DS = dispersion syndrome
Source: Authors (2021)

The number of seeds collected was quite irregular. The F test (0.05;11.60) = 2.403 revealed differences between the mean values for each month. The peaks of the number of seeds collected occurred in Aug/17, Jan, and Apr/18, corresponding to the period from late winter to early autumn (Figure 2).

Figure 3 — Variations in number of seeds collected. Different letters represent significant differences between months, tested with Tukey pair-wise comparisons



Source: Authors (2021)

As for the dispersal syndromes, the F test $_{(0.05;2.105)}$ = 9.682 showed significant differences between the number of seeds of different syndromes (Table 2). 53.7% of seeds (n=4820) were classified as anemochoric, 37.1% (n=3330) as zoochoric, and 9.2% (n=826) as autochoric.

Table 2 — Efficiency of the collectors

Continued...

Variation factor	DF	SS	MS	F	P
Overall efficiency of collectors					
Treatment	2	209385.083333	104692.541667	7.084	0.0016
Error	69	1019748.916667	14778.969807		
Corrected total	71				
CV (%)	97.52				
Overall average	124.66		Number of observations		72
Efficiency of collectors for zoochoric seeds					
Treatment	2	99753.694444	49876.847222	7.514	0.0011**
Error	69	458003.583333	6637.733092		
Corrected total	71				
CV (%)	169.05				
Overall average	48.19		Number of observations		72
Dispersal syndromes					
Treatment	2	245432.055556	122716.027778	9.682	0.0001**
Error	105	1330822.194444	12674.497090		
Corrected total	107				
CV (%)	130.03				
Overall average	86.58		Number of observations		108
Comparison between collector lines					
Treatment	1	70938.888889	70938.888889	4.287	0.0421*
Error	70	1158195.111111	16545.644444		
Corrected total	71				
CV (%)	103.18				
Overall average	124.66		Number of observations		72
Seed abundance among collectors					
Treatment	2	67555.027778	33777.513889	9.249	0.0001**
Error	213	777854.972222	3651.901278		
Corrected total	215				
CV (%)	144.46				
Overall average	41.83		Number of observations		216

Table 2 — Efficiency of the collectors

Conclusion

Variation factor	**DF**	**SS**	**MS**	**F**	**P**
		Seed richness among collectors			
Treatment	2	2.787037	1.393519	0.369	0.6917^{ns}
Error	213	803.861111	3.773996		
Corrected total	215				
CV (%)	53.12				
Overall average	3.65		Number of observations		216

Units = Units; GL = Degrees of freedom; SQ = Sum of squares; QM = Mean Square; CV (%) = Coefficient of variation; * = significant at 5% probability; ns = not significant.
Source: Authors (2021)

The results showed significant differences ($F_{(0.05;2.69)}$= 7.084) with respect to the number of seeds collected among different types of collectors, regarding the efficiency of the collectors for zoochoric syndrome seeds ($F_{(0.05;2.69)}$= 7.514), seed dispersal syndrome ($F_{(0.05;2.105)}$= 9.682), collector lines ($F_{(0.05;2.69)}$= 4.287), seed abundance ($F_{(0.05;2.213)}$= 9.249), and seed richness ($F_{(0.05;2.213)}$= 0.369). The results were submitted to Tukey's test to check for differences between the means of number of seeds by type of collector, zoochory, collector lines, seed abundance, and seed richness (Table 3).

Table 3 — Number of seeds collected

Continued...

	Collector efficiency	
Artificial perch	Natural perch	Control
197.12 a	109.04 b	67.83 b
	Dispersal syndromes	
Anemochory	Zoochory	Autochory
139.44 a	96.38 a	23.91 b

Table 3 — Number of seeds collected

Conclusion

Collector efficiency		
Artificial perch	Natural perch	Control
197.12 a	109.04 b	67.83 b
Dispersal syndromes		
Anemochory	Zoochory	Autochory
139.44 a	96.38 a	23.91 b
Efficiency of collectors for zoochoric seeds		
Artificial perch	Natural perch	Control
97.45 a	39.62 b	7.5 b
Comparison between collector lines		
Central Line		Paredão Line
156.05 a		93.27 b
Seed abundance among collectors		
Artificial perch	Natural perch	Control
65.70 a	36.34 b	23.44 b
Species richness among collectors		
Control	Natural perch	Artificial perch
3.79 a	3.66 a	3.51 a

Source: Authors (2021)

Lowercase letters compare line means. Means followed by equal letters in the lines do not differ statistically by Tukey's test at 5% probability.

Comparison of seed averages showed that artificial perches were more efficient in total seed collection and in receiving zoochoric seeds compared to natural perches and control collectors. The total number of seeds and of zoochoric syndrome did not statistically differ between natural perches and control collectors. Individual analysis by environment showed that the collectors in the Central Line received a greater number of seeds and were statistically different in relation to those placed in the Paredão Line.

Data regarding seed abundance showed that the collectors under artificial perches received the highest number of seeds per species. As for the species richness analysis, the numerical variation showed no statistical difference among collectors.

4 DISCUSSION

Considering the data regarding species richness (n=33), total number of seeds (n= 8976), and average seed density (n= 997 seeds m^{-2} $year^{-1}$), the results obtained differ from similar studies such as those of Barbosa and Pizo (2006), who found 32.792 seeds (618.7 seeds m^{-2} $year^{-1}$) from 31 species, Toscan *et al*. (2014), who reported the collection of 14091 seeds (1565 seeds m^{-2} $year^{-1}$) belonging to 75 morphospecies, and Tomazi *et al*. (2010), who collected a total of 21864 seeds (2590 seeds m^{-2} $year^{-1}$) from 51 morphospecies. These differences can be explained by the use of different sampling methods, such as the number of collectors installed, sampling period, and particularities of the studied areas, such as conservation conditions, predominant vegetation, and type, duration, and intensity of environmental impact. In the present study, species richness and seed abundance were affected by the history of basaltic rock exploration in the area. Mining activities promoted severe environmental damage with total removal of vegetation and elimination of the seed bank, propagules, and soil biota (ELAW, 2010), leading to a reduction in natural fertility, changes in soil structure and physics and soil water dynamics.

Seed rain throughout the year had peaks predominantly in the most favorable periods, such as late spring and summer. The isolated peak in August (period corresponding to late winter and early spring) may have been influenced by intrinsic phenological characteristics of species such as *Bidens alba*, *Leucena leucocephala* and *Andropogon bicornis* that fruit throughout the year (ORWA *et al*., 2009; ZANIN and LONGHI-WAGNER, 2011) and *Cecropia pachystachya* that release their seeds in winter (LORENZI, 2020). Seed production and arrival is influenced by certain climatic conditions such as thermal or water stress (MARQUES and OLIVEIRA, 2008; SCCOTI *et al*., 2015), and by the successional stage of surrounding forests (CARDOSO *et al*. 2019). For these authors, the irregular production of seeds during the year compromises the contribution of seeds that arrive in a certain area and, in this way, reduces the foraging periods of dispersing species such as birds. Despite not being able to say that the entry of seeds in the area follows a seasonal rhythm, it is likely that such factors have influenced the observed seed rain peaks.

When considering monthly collections individually, collectors under artificial perches ($\bar{X}$ = 197.12) received 80% more seeds compared to those under natural perches ($\bar{X}$ = 109.04), and almost three times more than control collectors ($\bar{X}$ = 67.83). Considering only zoochoric seed collection, the number of seeds in collectors under artificial perches ($\bar{X}$ = 97.45) also exceeded that of collectors under natural perches and control collectors ($\bar{X}$ = 39.62 and $\bar{X}$ = 7.5, respectively). The comparison between means (total number of seeds and zoochoric seeds) was statistically different between artificial perch collectors and the other collectors, regardless of their location. This higher number of seeds in artificial perches underscores their nucleating function, as they effectively contributed to the entry of animal-dispersed seeds (HEELEMANN *et al*., 2012; GUIDETTI *et al*., 2016; LA MANTIA *et al*., 2019).

On the other hand, the lower amount of seeds recorded in natural perches may be a result of the greater extension of the tree canopy, which exceeds several times the collector area and thus reduces the number of seeds received (ZWIENER *et al*., 2014). To overcome this limitation, an analysis of regeneration around natural perches can be performed, aiming to know and quantify the entry of new plant species in the environment (TOMAZI and CASTELLANI, 2016; TESSEMA *et al*., 2017).

When comparing the number of seeds in relation to the location of the collectors, the results showed that collectors in the Central Line received more seeds. This can be explained by the location of the Central Line since it is close to areas of tree vegetation at the outer limits of the mining company. The higher number of trees populating the site promotes favorable conditions for the transition of dispersers coming from other sites, thus resulting in the introduction of zoochoric seeds (PIOTTO *et al*., 2019) such as those found in the Central Line collectors.

Andropogon bicornis is among the anemochoric species that were most prolific in seed production. This species forms the dominant population of the herbaceous stratum and is found in reproductive stage throughout the year, while also adapting and colonizing diverse environments, and enduring unfavorable environmental conditions such as shallow soils, soils of low natural fertility, soils with good drainage, or even flooded soils (ZANIN and LONGHI-WAGNER, 2011). These characteristics make this grass one of the most important herbaceous species at the beginning of secondary vegetation development. *Urochloa plantaginea* was another anemochoric species that predominated, occurring in localized patches. However, its seeds were found in collectors of both lines and with greater occurrence in summer months when the species is fertile. Because it is grown as forage, this species has high invasive power in annual crops, making it an aggressive weed (LORENZI, 2008). Its dispersal is explained by the proximity of cultivated areas adjacent to the western boundary of the Paredão Line.

Among the autocoric species, *Leucaena leucocephala* was the most predominant and had many adult individuals already established in the area. For Drumond and Ribaski (2010), the presence of this species can help in the recovery of degraded environments due to its biological characteristics. However, it can easily become an invasive plant due to its high production of easily germinating seeds when its population is not controlled. In certain cases, the invasive effect of the leucena is neutralized by competition with tree species, leading the species to leave the succession system, while the surviving plants are displaced to the edges of the area (COSTA and DURIGAN, 2010).

Cecropia pachystachya was the most abundant of the plants with zoochoric dispersal seeds and was found in 90% of the collectors. Since it is a pioneer species, it presents rapid growth and is common in initial areas of natural succession, degraded areas, and areas of initial reforestation. This plant is visited by avifauna, bats, and various types of insects, such as ants and termites (VICENTINI *et al*., 2008). The ecological characteristics of this species are important for the succession process, because, besides providing forage, Cecropia plants provide high natural perches in relation to the predominantly herbaceous vegetation, while also withstanding soils with water saturation caused by floods that eventually occur in the area (SILVA *et al*., 2012).

The results show that seed rain is occurring in the studied area, but with limitations to the richness of species that mostly belong to the sucession's pioneer group. The absence of secondary and advanced stage trees is largely due to the quality of the vegetation resources surrounding the mining site. Factors such as quality of surroundings and distance from seed sources were raised by PEÑA-DOMENE *et al*. (2018) and CUBIÑA and AIDE (2001) as the main obstacles for seeds, in particular zoochoric, to reach areas undergoing succession processes. On the other hand, the predominance of herbaceous and anemochoric plants and the absence of larger individuals, like shrubs and trees, is a factor that limits avifauna visits to the area in search of forage, and thus intensifies the seed dispersal cycle (MARTÍNEZ-GARZA *et al*., 2009). At the same time, the seeds identified were from plants that are already established in the area, indicating the occurrence of a feedback process of seed rain by these autochthonous species.

As recovery initiatives began more than a decade ago and taking into account that the area still shows characteristics of an early stage, the succession process of this mining area appears to be stagnant or in arrested succession (THRIPPLETON *et al*., 2017). The interaction of factors such as low fertility, excessively drained, or poorly drained soils (BUSTAMANTE-SÁNCHEZ and ARMESTO, 2012), predominance of the herbaceous grassy layer, presence of exotic species, low vegetation quality of the surrounding area, distance from seed and propagule dispersal sources, and absence of zoochoric syndrome dispersers may be responsible for this interruption (GRONINGER *et al*., 2017).

However, the overall analysis shows that due to the degree of damage that the area was subjected to and subsequent isolation, the implementation of the seedling planting technique, the predominance of exotic grasses, its geographical location, and the quality of its surroundings, the occurrence of seed rain and the installation of perches will not be enough to reverse the apparent blocking of secondary natural succession. Overcoming limiting factors involves implementing other proven nucleation techniques such as introducing plant seedlings from other life forms, translocation of litter and soil, planting native trees in clusters and ecological steppingstones with functional groups (REIS *et al*., 2010), as well as the management of exotic species (TOBIN, 2018).

5 CONCLUSION

The total number and richness of seeds recorded confirmed the occurrence of seed rain in a degraded mining area undergoing secondary succession.

Natural perches and artificial perches enhance zoochoric seed dispersal, contributing to an increase in species abundance and richness, even though seed rain is not regular throughout the year.

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