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Phytosociology of weeds on Cerrado Mineiro coffee growing farms

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Abstract: Background: Phytosociological surveys of weeds in agricultural regions, such as the coffee growing Cerrado Mineiro Denomination, are essential for understanding the predominant species in a cultivation area.
Objective: This study aimed to determine the predominant weed species in coffee crops in Cerrado Mineiro through phytosociological surveys during two periods of the year.
Methods: 26 coffee farms in 12 municipalities within the Cerrado Mineiro Denomination of Origin of were visited. The inventory square method was used for the phytosociological surveys. In each area, 40 m^2 was evaluated and divided into two study periods (summer and winter). Calculations of the variables were performed using the following data: frequency, density, abundance, importance value index, similarity coefficient, rarefaction curve, Shannon index, and hierarchical grouping analysis using Jaccard's similarity.
Results: In the summer (rainy period), 54 species from 16 families were found, with Poaceae, Asteraceae, and Amaranthaceae predominating. In winter (dry season), 56 species from 16 families were found, predominantly Asteraceae, Poaceae, and Brassicaceae. There was a predominance of 17 and 16 species, with similarity levels (Jaccard) of 45.58% and 40.78% for summer and winter, respectively.
Conclusions: The weed community in the Cerrado Mineiro coffee plantation is dominated by two main families, Poacaeae and Asteraceae, with *Eleusine indica* (summer) and *Conyza* spp. (winter) being the species with the highest importance values.

Keywords: Coffee-growing; Diversity; Frequency; Density; *Eleusine indica*; *Conyza* spp.

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1. Introduction

Minas Gerais is the main coffee-producing state in Brazil, representing 59% of the national production (Companhia Nacional de Abastecimento, 2022). The state has four main production regions: Cerrado Mineiro, Mantiqueira de Minas, Matas de Minas, and Sul de Minas. The Cerrado Mineiro Denomination of Origin (D.O.) region is highly relevant in coffee farming because it is characterized as a region with high adoption of technological innovations and modern production systems (Ortega, Jesus, 2011). Currently, the average coffee production of Cerrado Mineiro is 5 million bags, representing 12.7% of Brazilian production and 25.4% of state production. The average productivity of the region is 35 bags/ha, higher than the averages of the state of Minas Gerais and Brazil at 24 and 23 bags/ha, respectively.

The presence of weeds in coffee is most critical during the flowering and fruiting seasons from October to March, during which the coffee plant has a greater demand for photoassimilates (Blanco et al., 1982). However, competition occurs throughout the year, especially during the rainy season (Fialho et al., 2010). Knowledge of the characteristics of the predominant weed population in a cultivation area through phytosociological survey identifies the predominant species in the area and assists in decision making for the choice of the most appropriate control method. This study of weed community composition in strategic regions for agricultural activity is relevant for assessing the impact of climatic variables and management systems, such as soil preparation, planting methods, fertilization and especially the use of new herbicide technologies (Rauber et al., 2018).

In its historical process of modernization, coffee growing in Cerrado Mineiro has resulted in the use of spacing to facilitate machine traffic, which creates ideal conditions for the growth and establishment of weed species. Despite the popularization of the planting of cover crops, mainly *Urochloa decumbens* or *Urochloa ruziziensis* and leguminous species, herbicides and mechanical control are the main control methods used. This has led to an increase in the infestation of difficult-to-control weeds, such as the climbing species of the *Ipomoea* genus, the Poaceae *Digitaria insularis* and *Eleusine indica*, and autumn-winter species, such as *Conyza* spp.

Consumers are increasingly demanding products from sustainable production systems. For this purpose, identifying the main weed species and their characteristics is the first step in obtaining efficient control with less environmental impact. Thus, this study aimed to identify the predominant weed species in coffee culture in the Cerrado Mineiro region through a phytosociological survey during summer and winter.

2. Material and Methods

The present study was conducted in two periods: summer and winter. The summer surveys were conducted in January to March 2018. The winter surveys were conducted exclusively in August 2018. In total, 26 coffee farms in 12 municipalities within the Cerrado Mineiro were visited (Figure 1). The criteria for selecting the areas was based on the choice of the main producing municipalities and representative area within the Cerrado Mineiro region. Among the evaluated areas, 42% had altitudes of 800 to 1,000 m, 50% of 1,000 to 1,200 m, and 8% of 1,200 to 1,400 m. The 26 areas and their respective geographic coordinates are listed in Table 1.

The climate of the region, according to the Köppen-Geiger classification, is tropical savanna with a dry season in winter (Aw) (Reboita et al., 2015). The climatological data in the period from 2010 to 2019, from the automatic stations of the National Institute of Meteorology (INMET) – Ministry of Agriculture, Livestock and Supply (MAPA), located in Araxá-MG (19º60'56. 96 "S and 46º94'96.17 "W – altitude of 1018 meters), Uberlândia (18º91'70.72 "S and 48º25'56.5717 "W – altitude of 875 meters) and Patrocínio-MG (18°59'48.04 "S and 46°59'09.57 "W – altitude of 978 meters are presented in Figure 1.

The inventory square method was used for the phytosociological survey. In each area, 40 m^2 was evaluated divided into two periods (summer and winter). Empty steel squares with a known area (1 m^2) were randomly placed, covering plots with coffee trees in the early and adult stages according to the methodology of Santos et al. (2004). The weeds in the 1 m^2 space were identified and quantified according to Angiosperm Phylogeny Group (2022). The plots were georeferenced so that they could be sampled in the summer and winter periods.

The following phytosociological variables were calculated using the survey data: frequency, density, abundance, and their relative derivations, that is, the variable in question for each species in relation to the total variable observed in the study area. For the calculation of these variables, the following formulas were used according to Mueller-Dombois and Ellenberg (1974): density (DE) = total number of individuals of the species/number of total frames; relative density (DR) = density of the species × 100/total density; frequency (FE) = number of frames containing the species/number of total frames; relative frequency (FR) = frequency of the species × 100/total frequency; abundance (AB) = total number of individuals of the species/number of frames of the species; relative abundance (RA) = abundance of the species × 100/total abundance, and the importance value index (IVI) = FR + DR + RA. Thus, the frequency (FRE) determines the distribution of species present in the area, density (DEN) represents the number of plants per species per unit area, abundance (ABU) determines the concentration of species in the area, and the importance value index (IVI) indicates the most important species observed during the survey.

Due to the variability in the number of species found and the need to create parameters to facilitate weed management in coffee growing in the Cerrado Mineiro, we sought to conduct biological diversity analyses. Therefore, the similarity coefficient was determined, which determines the similarity of botanical populations in two or more areas studied, in the two evaluation periods (summer and winter), The similarity of the two evaluation periods (summer and winter) and the analysis of species richness estimators were performed using rarefaction curves (Colwell, Coddington, 1994 and Gotelli, Colwell, 2001), Shannon index (H) (Pielou's equation) (Hill, 1973; Pielou, 1966) and hierarchical grouping analysis (cluster) (Borcard et al., 2011). The Vegan and BiodiversityR packages of the R software were used to calculate these variables, in which, the number of individuals of each species observed in the 26 properties was used.

Jaccard's similarity coefficient (SJ) was also calculated and indicated the proportion of shared species between the sampled properties in relation to the total number of species, that is, the level of similarity between two or more biological communities. To determine the similarity index and create the cluster, we used the abundance data of the main species of the survey; however, due to variation, the data were subjected to logarithmic transformation – log(X+1).

$$\textit{Shannon index-Weaver } (H) = \sum_{i=1}^{S} p_i \, log_b \, p_i$$

Where, "*pi*"is the proportion of species "", "*S*" is the number of species, and "*b*" is the base of the logarithm.

$$\textit{Jaccard similarity coefficient } (Sj) = \frac{c}{a+b-c} * 100$$

Where "*a*" is the number of common species found on the properties; "*b*" being the total number of species found on property B but not on property A and "*c*" as the total number of species found on the property A but not on B.

3. Results and Discussion

The areas assessed in the summer and winter periods were 1,040 m^2 and 520 m^2, respectively. In the summer, 15,009 plants were counted and categorized into 54

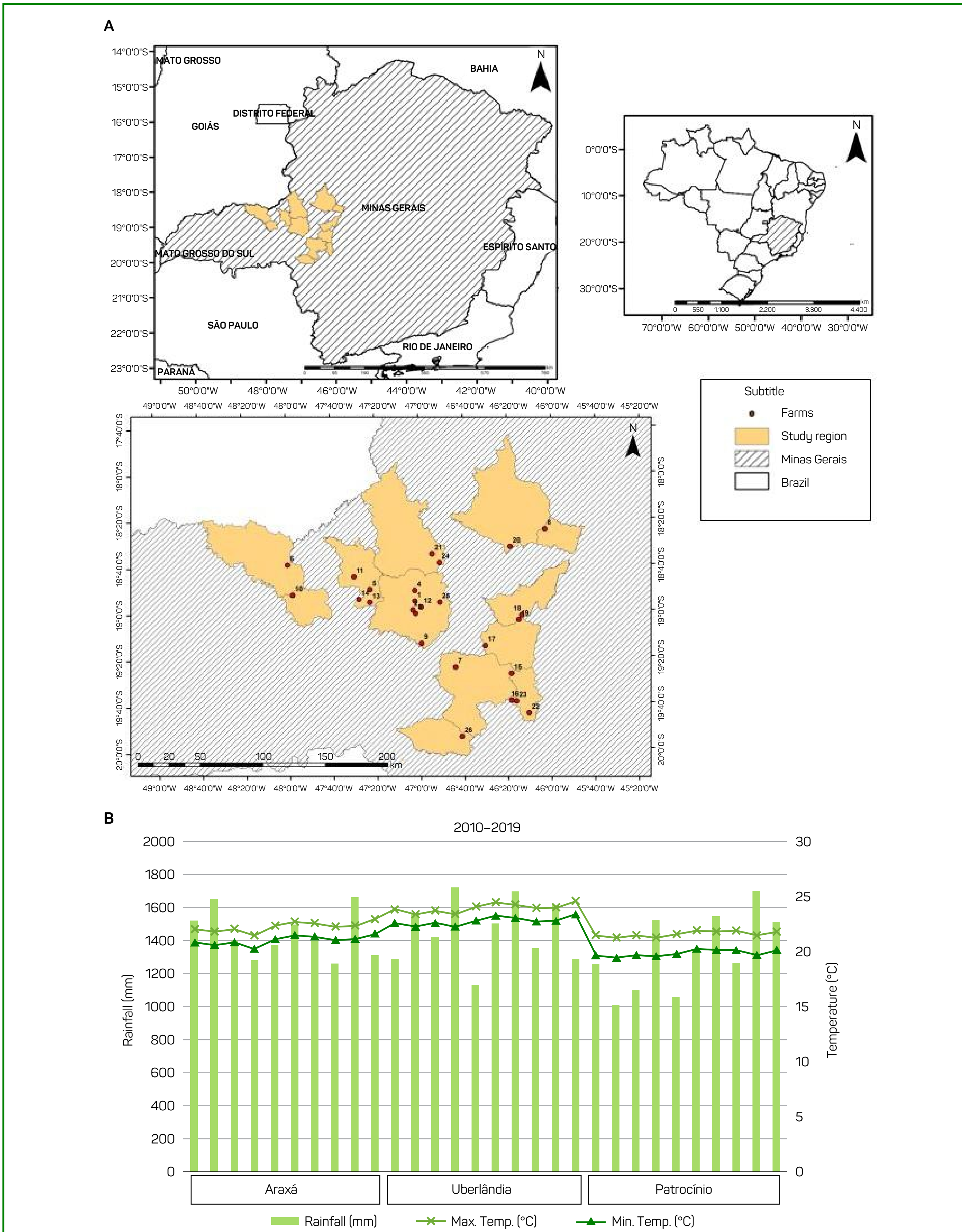

Figure 1 - (A) Location of the 26 areas where the phytosociological survey was conducted in two seasons (summer and winter), in the Cerrado Mineiro Region and (B) Climatic data of precipitation (mm) and average maximum and minimum temperature (°C) referring to the period 2010 to 2019, of the municipalities of Araxá-MG, Uberlândia- MG and Patrocínio-MG

Table 1 - Names of the 26 areas and their respective geographic coordinates

Areas name	Geographic coordinates
1. Congonhas	47°02′09″ W and 18°55′51.2″ S
2. Semente	47°03′08″ W and 18°59′41″ S
3. Rainha da Paz	47°01′53″ W and 19°01′11″ S
4. Freitas	47°02′09.34″ W and 18°51′12.04″ S
5. Rural Montes	47°22′34.8″ W and 18°50′37″ S
6. Bom Jardim	47°59′51.2″ W and 18°39′24.5″ S
7. Santa Maria	46°43′52.4″ W and 19°24′39.2″ S
8. São João	46°02′49.5″ W and 18°24′58.6″ S
9. Duas Pontes	46°59′13.8″ W and 19°14′06.4″ S
10. José Humberto	47°57′48.2″ W and 18°52′34.2″ S
11. Fucamp	47°29′48.1″ W and 18°45′03.7″ S
12. CEPC	46°59′12.30″ W and 18°58′25.33″ S
13. Londrina	47°22′37″ W and 18°56′09″ S
14. Castelhana	47°27′36.1″ W and 18°54′47″ S
15. Quilombo	46°18′21.8″ W and 19°27′29.6″ S
16. Amizade	46°18′18.6″ W and 19°39′09.2″ S
17. Eleven Thousand Virgins	46°30′12.1″ W and 19°15′21.6″ S
18. São Lourenço	46°13′29.7″ W and 19°02′07.9″ S
19. Cruzeiro	46°14′53.1″ W and 19°04′08.4″ S
20. Santiago	46°18′33.7″ W and 18°32′28.4″ S
21. Rio Brilhante	46°54′07.2″ W and 18°35′25.1″ S
22. Boa Sorte	46°10′18.8″ W and 19°44′41.6″ S
23. Espigão do Palmital	46°16′08″ W and 19°39′29.0″ S
24. Lajes	46°50′50.6″ W and 18°39′06.8″ S
25. Recanto	46°50′49.4″ W and 18°56′24.3″ S
26. São Francisco	46°41′12.2″ W and 19°54′43.6″ S

species and 16 families, with an average density of 28.86 plants/m^2. In descending order, the families with the highest number of counted individuals were: Poaceae, Asteraceae, Amaranthaceae, Brassicaceae, Euphorbiaceae, Portulacaceae, Malvaceae, Cyperaceae, Rubiaceae, Fabaceae, Oxalidaceae, Convolvulaceae, Commelinaceae, Lamiaceae, Phyllantaceae, and Solanaceae. *Eleusine indica*, belonging to the Poaceae family, was the species with the highest number of individuals (1,849), density (12.32), and relative frequency (10.37). The highest relative abundance (8.24) was observed in *Tridax procumbens*.

In winter, 9,577 individuals were counted, categorized into 56 species and 16 families, with an average density of 18.42 plants/m^2. The weed families observed in these periods differed from those observed in the summer with respect to the presence and number of individuals. In descending order, the families observed were: Asteraceae, Poaceae, Brassicaceae, Amaranthaceae, Malvaceae, Euphorbiaceae, Rubiaceae, Lamiaceae, Solanaceae, Commelinaceae, Convolvulaceae, Fabaceae, Boraginaceae, Oxalidaceae, Portulacaceae, and Aizoaceae. *Conyza* spp. was the species with the highest number (1,790), density (18.69), and relative frequency (10.48). The highest relative abundance (5.12) was observed in *Acanthospermum hispidum*.

In the summer evaluation, the species with the highest IVI, in descending order, were *Eleusine indica*, *Digitaria horizontalis*, *Amaranthus* spp., *Bidens pilosa*, *Urochloa decumbens*, *Galinsoga parviflora*, *Alternanthera tenella*, and *Sida* spp. In contrast, in the winter survey, the species with the highest IVI in descending order were: *Conyza* spp., *Urochloa decumbens*, *Lepidium virginicum*, *Bidens pilosa*, *Amaranthus* spp., *Eleusine indica*, *Sida* spp., *Galinsoga parviflora*, *Alternanthera tenella,* and *Digitaria horizontalis*.

For an exploratory analysis of the data (Figure 2), we used the results of the parameter densities (DR), frequencies (FR), and relative abundances (RA) of the 10 species with the highest IVI (Table 2) collected from the 26 properties (individual analysis). These species accounted for 52.47% and 54.71% of the IVI values during summer and winter, respectively. The data distribution in Figure 2 shows a summary of the species observed during the survey, in which high variability was observed, with discrepant values among the parameters analyzed. This can be explained by the interaction between the inherent biological characteristics of each species, management practices adopted, and edaphoclimatic conditions of each site at the time of evaluation.

In summer (Figure 2), *Eleusine indica* (highest IVI) showed the highest observed DR (Table 2), with a positive asymmetric data pattern and a mean value of 10.96%, with most observed values between 19.64% and 7.42% (interquartile range of 12.22%). However, in some areas, minimum and maximum values of 0% and 29.59% were obtained. *Digitaria horizontalis* obtained the second-highest IVI and FR (Table 2) with a negative asymmetric data pattern, with a mean value of 10.53% and most observed values between 12.6% and 5.59% (interquartile range 6.47%), and minimum and maximum values of 0% and 17.59% respectively. *Lipidium virginicum* species with the second-highest relative abundance (Table 2), after individual analysis, obtained a mean of 0% and discrepant values of 17.73% 21.33%, well above the upper limit observed, which can be explained by the large quantity of this species in only two areas.

In winter (Figure 3), an increase in disharmonious data was observed, indicating that in some areas, the species were found in large quantities, while in other areas, small numbers or a total absence were observed. For example, in the parameters evaluated, *Conyza* spp. presented values above the maximum limit in some locations, while in others, its presence was not detected. We can use the relative density as a detailed example. With a mean value of 8.06%, most values observed were between 1.82% and

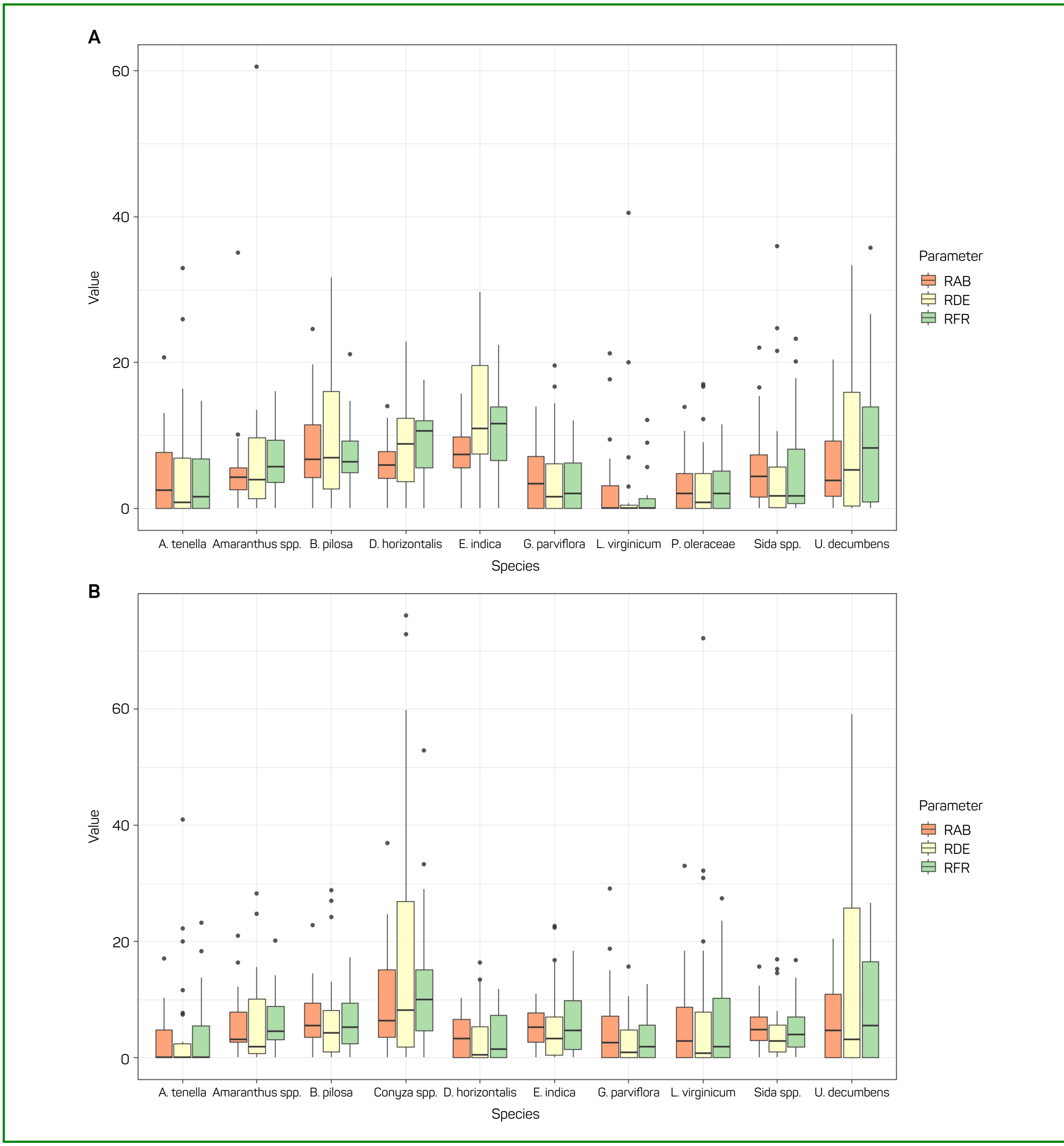

Figure 2 - Individual analysis of the 26 areas of the parameters: Relative Abundance (RAB), Relative Density (RDE) and Relative Frequency (RFR) for the ten main weed species during the (A) summer and (B) winter survey in the Cerrado Mineiro

26.92% (interquartile range of 25.09%), the minimum and maximum values were 0% and 59.82%, and the extreme values were 72.97% and 76.17%.

To detail the variability of the species surveyed in each area, we attempted to work with biological diversity estimators. The Cerrado Mineiro weed survey detected variations in the number of species and individuals. To mitigate this variation, we used the rarefaction technique (Figure 3), which calculates the expected number of species and individuals in the samples analyzed, seeking to correct the number of individuals to a standard size.

In summer, a minimum of 9 species and 220 individuals (an average density of 11.0 plants/m^2) were found in area 3, and the maximum values found were 26 species in area 16 and 1,257 individuals (an average density of 62.85 plants/m^2) in area 23 (Figure 1). When

Table 2 - Weeds, their respective families, and phytosociological parameters of the summer and winter periods: Number of Individuals (N°.); Present Plots (PP), Density (DE), Relative Density (RD), Frequency (FE); Relative Frequency (RF); Abundance (AB); Relative Abundance (RA) and Importance Value Index (IVI)

Family	Species	Summer/Winter Parameters								
		N°	PP	DE	RD	FE	RF	AB	RA	IVI
Aizoaceae	*Trianthema portulacastrum*	0/34	0/6	0.00/0.07	0.00/0.35	0.00/0.01	0.00/0.23	0.00/5.67	0.00/3.78	0.00/4.37
Amaranthaceae	*Alternanthera tenella*	856/339	262/96	1.65/0.65	5.70/3.64	0.50/0.18	7.53/3.63	3.27/3.53	1.49/2.36	14.72/9.58
	Amaranthus spp.	1447/625	220/160	2.78/1.20	9.64/6.53	0.42/0.31	6.32/6.14	6.58/3.91	3.01/2.61	18.97/15.27
	Chenopodium album	1/3	1/3	0.00/0.01	0.01/0.03	0.00/0.01	0.03/0.12	1.00/1.00	0.46/0.67	0.49/0.81
Asteraceae	*Acanthospermum australe*	111/34	14/23	0.21/0.07	0.74/0.36	0.03/0.04	0.40/0.88	7.93/1.48	3.63/0.99	4.77/2.22
	Acanthospermum hispidum	52/23	22/3	0.10/0.04	0.35/0.24	0.04/0.01	0.63/0.12	2.36/7.67	1.08/5.12	2.06/5.47
	Ageratum conyzoides	79/10	22/8	0.15/0.02	0.53/0.10	0.04/0.02	0.63/0.31	3.59/1.25	1.64/0.83	2.80/1.25
	Ambrosia artemisiifolia	0/33	0/14	0.00/0.06	0.00/0.34	0.00/0.03	0.00/0.54	0.00/2.36	0.00/1.57	0.00/2.46
	Bidens pilosa	1325/667	240/202	2.55/1.28	8.83/6.96	0.46/0.39	6.89/7.75	5.52/3.30	2.53/2.20	18.25/16.92
	Conyza spp.	541/1790	157/273	1.04/3.44	3.60/18.69	0.30/0.53	4.51/10.48	3.45/6.56	1.58/4.38	9.69/33.54
	Eclipta prostrata	0/1	0/1	0.00/0.00	0.00/0.01	0.00/0.00	0.00/0.04	0.00/1.00	0.00/0.67	0.00/0.72
	Emilia fosbergii	35/37	23/22	0.07/0.07	0.23/0.39	0.04/0.04	0.66/0.84	1.52/1.68	0.70/1.12	1.59/2.35
	Galinsoga parviflora	876/398	152/93	1.68/0.77	5.84/4.16	0.29/0.18	4.37/3.57	5.76/4.28	2.64/2.86	12.84/10.58
	Galinsoga quadriradiata	422/0	68/0	0.81/0.00	2.81/0.00	0.13/0.00	1.95/0.00	6.21/0.00	2.84/0.00	7.60/0.00
	Gamochaeta coarctata	0/8	0/2	0.00/0.02	0.00/0.08	0.00/0.00	0.00/0.08	0.00/4.00	0.00/2.67	0.00/2.83
	Hypochaeris chillensis	4/6	4/2	0.01/0.01	0.03/0.06	0.01/0.00	0.11/0.08	1.00/3.00	0.46/2.00	0.60/2.14
	Melampodium perfoliatum	12/0	8/0	0.02/0.00	0.08/0.00	0.02/0.00	0.23/0.00	1.50/0.00	0.69/0.00	1.00/0.00
	Parthenium hysterophorus	116/173	27/	0.22/0.33	0.77/1.81	0.05/0.10	0.78/1.96	4.30/3.39	1.97/2.26	3.51/6.03
	Sonchus oleraceus	27/63	11/48	0.05/0.12	0.18/0.66	0.02/0.09	0.32/1.84	2.45/1.31	1.12/0.88	1.62/3.38
	Tridax procumbens	18/27	1/15	0.03/0.05	0.12/0.28	0.00/0.03	0.03/0.58	18.00/1.80	8.24/1.20	8.38/2.06
	Vernonia polyanthes	0/2	0/2	0.00/0.00	0.00/0.02	0.00/0.00	0.00/0.08	0.00/1.00	0.00/0.67	0.00/0.77
Heliotropiaceae	*helioHeliotropium indicum*	0/52	0/10	0.00/0.010	0.00/0.54	0.00/0.02	0.00/0.38	0.00/5.20	0.00/3.47	0.00/4.40
Brassicaceae	*Coronopus didymus*	1/17	1/7	0.00/0.03	0.01/0.18	0.00/0.01	0.03/0.27	1.00/2.43	0.46/1.62	0.49/2.07
	Lepidium virginicum	600/991	62/130	1.15/1.91	4.00/10.35	0.12/0.25	1.78/4.99	9.68/7.62	4.43/5.09	10.21/20.42
	Raphanus raphanistrum	178/211	49/83	0.34/0.41	1.19/2.20	0.09/0.16	1.41/3.18	3.63/2.54	1.66/1.70	4.26/7.08
	Raphanus sativus	0/13	0/9	0.00/0.03	0.00/0.14	0.00/0.02	0.00/0.35	0.00/1.44	0.00/0.96	0.00/1.45
Commelinaceae	*Commelina benghalensis*	237/72	111/46	0.46/0.14	1.58/0.75	0.21/0.09	3.19/1.77	2.14/1.57	0.98/1.04	5.71/3.56
Convolvulaceae	*Ipomoea* spp.	282/59	134/42	0.54/0.11	1.88/0.62	0.26/0.08	3.85/1.61	2.10/1.40	0.96/0.94	6.69/3.17

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Continuation

Family	Species	Summer/Winter Parameters								
		Nº	PP	DE	RD	FE	RF	AB	RA	IVI
	Merremia cissoides	2/0	1/0	0.00/0.00	0.01/0.00	0.00/0.00	0.03/0.00	2.00/0.00	0.92/0.00	0.96/0.00
Cyperaceae	*Cyperus spp.*	99/0	13/0	0.19/0.00	0.66/0.00	0.03/0.00	0.37/0.00	7.62/0.00	3.48/0.00	4.52/0.00
Euphorbiaceae	*Chamaesyce hirta*	510/150	126/70	0.98/0.29	3.40/1.57	0.24/0.13	3.62/2.69	4.05/2.14	1.85/1.43	8.87/5.68
	Euphorbia heterophylla	175/172	2,13	0.34/0.33	1.17/1.80	0.13/0.06	1.90/1.19	2.65/5.55	1.21/3.70	4.28/6.69
	Ricinus communis	1/0	1/0	0.00/0.00	0.01/0.00	0.00/0.00	0.03/0.00	1.00/0.00	0.46/0.00	0.49/0.00
Fabaceae	*Aeschynomene denticulata*	72/34	8/20	0.14/0.07	0.48/0.36	0.02/0.04	0.23/0.77	9.00/1.70	4.12/1.13	4.83/2.26
	Desmodium tortuosum	45/5	3/5	0.09/0.01	0.31/0.05	0.01/0.01	0.09/0.19	15.33/1.00	7.02/0.67	7.41/0.91
	Neonotonia wightii	9/8	1/4	0.02/0.02	0.06/0.08	0.00/0.01	0.03/0.15	9.00/2.00	4.12/1.33	4.21/1.57
	Senna obtusifolia	5/8	5/6	0.01/0.02	0.03/0.08	0.01/0.01	0.14/0.23	1.00/1.33	0.46/0.89	0.63/1.20
Lamiaceae	*Leonotis nepetifolia*	0/4	0/3	0.00/0.01	0.00/0.04	0.00/0.01	0.00/0.12	0.00/1.33	0.00/0.89	0.00/1.05
	Leonurus sibiricus	101/104	17/27	0.19/0.20	0.67/1.09	0.03/0.05	0.49/1.04	5.94/3.85	2.72/2.57	3.88/4.69
	Marsypianthes chamaedrys	11/0	8/0	0.02/0.00	0.07/0.00	0.02/0.00	0.23/0.00	1.38/0.00	0.63/0.00	0.93/0.00
	Mesosphaerum suaveolens	0/14	0/3	0.00/0.03	0.00/0.15	0.00/0.01	0.00/0.12	0.00/4.67	0.00/3.11	0.00/3.38
Malvaceae	*Malvastrum coromandelianum*	11/1	6/1	0.02/0.00	0.07/0.01	0.01/0.00	0.17/0.04	1.83/1.00	0.84/0.67	1.08/0.72
	Sida spp.	593/363	171/141	1.14/0.70	3.95/3.79	0.33/0.27	4.91/5.41	3.47/2.57	1.59/1.72	10.45/10.92
Oxalidaceae	*Oxalis latifolia*	98/44	15/9	0.19/0.08	0.65/0.46	0.03/0.02	0.43/0.35	6.53/4.89	2.99/3.26	4.07/4.07
Phyllanthaceae	*Phyllanthus tenellus*	74/0	20/0	0.14/0.00	0.49/0.00	0.04/0.00	0.57/0.00	3.70/0.00	1.69/0.00	2.76/0.00
	poaAvena sativa	0/6	0/6	0.00/0.01	0.00/0.06	0.00/0.01	0.00/0.23	0.00/1.00	0.00/1.00	0.00/0.96
	Cenchrus echinatus	17/15	13/11	0.03/0.03	0.11/0.16	0.03/0.02	0.37/0.42	1.31/1.36	0.60/0.91	1.09/1.49
	Digitaria horizontalis	1334/329	310/103	2.57/0.63	8.89/3.44	0.60/0.20	8.91/3.95	4.30/3.19	1.97/2.13	19.76/9.52
	Digitaria insularis	68/273	32/100	0.13/0.53	0.45/2.85	0.06/0.19	0.92/3.84	2.13/2.73	0.97/1.82	2.34/8.51
	Echinochloa colona	5/1	2/1	0.01/0.00	0.03/0.01	0.00/0.00	0.06/0.04	2.50/1.00	1.14/0.67	1.23/0.72
	Eleusine indica	1849/503	361/169	3.56/0.97	12.32/5.25	0.69/0.33	10.37/6.49	5.12/2.98	2.34/1.99	25.03/13.72
Poaceae	*poaEragrotis pilosa*	332/197	109/69	0.64/0.38	2.21/2.06	0.21/0.13	3.13/2.65	3.05/2.86	1.39/1.91	6.74/6.61
	Panicum maximum	64/75	19/27	0.12/0.14	0.43/0.78	0.04/0.05	0.55/1.04	3.37/2.78	1.54/1.85	2.51/3.67
	Pennisetum glaucum	2/0	2/0	0.00/0.00	0.00/0.02	0.00/0.00	0.00/0.08	0.00/1.00	0.00/0.67	0.00/0.77
	Rhynchelytrum repens	9/58	3/25	0.02/0.11	0.06/0.61	0.01/0.05	0.09/0.96	3.00/2.32	1.37/1.55	1.52/3.11
	Setaria parviflora	4/7	1/5	0.01/0.01	0.03/0.07	0.00/0.01	0.03/0.19	4.00/1.40	1.83/0.93	1.89/1.20
	Sorghum halepense	1/3	1/2	0.00/0.01	0.01/0.03	0.00/0.00	0.03/0.08	1.00/1.50	0.46/1.00	0.49/1.11
	Urochloa decumbens/ ruziziensis	1095/1124	271/223	2.11/2.61	7.30/11.74	0.52/0.43	7.79/8.56	4.04/5.04	1.85/3.36	16.96/23.66

Continue

Continuation

Family	Species	Summer/Winter Parameters								
		Nº	PP	DE	RD	FE	RF	AB	RA	IVI
	Urochloa plantaginea	11/0	6/0	0.02/0.00	0.07/0.00	0.01/0.00	0.17/0.00	1.83/0.00	0.84/0.00	1.08/0.00
Portulacaceae	*Portulaca oleracea*	640/41	129/28	1.23/0.08	4.26/0.43	0.25/0.05	3.71/1.07	4.96/1.46	2.27/0.98	10.24/2.48
Rubiaceae	*Richardia brasiliensis*	434/231	120/99	0.83/0.44	2.89/2.41	0.23/0.19	3.45/3.80	3.62/2.33	1.65/1.56	7.99/7.77
Solanaceae	*Nicandra physaloides*	33/2	12/2	0.06/0.00	0.22/0.02	0.02/0.00	0.34/0.08	2.75/1.00	1.26/0.67	1.82/0.77
	Physalis angulata	1/20	1/13	0.00/0.04	0.01/0.21	0.00/0.03	0.03/0.50	1.00/1.54	0.46/1.03	0.49/1.73
	Solanum americanum	84/95	40/50	0.16/0.18	0.56/0.99	0.08/0.10	1.15/1.92	2.10/1.90	0.96/1.27	2.67/4.18
	Solanum grandiflorum	1/0	1/0	0.00/0.00	0.01/0.00	0.00/0.00	0.03/0.00	1.00/0.00	0.46/0.00	0.49/0.00

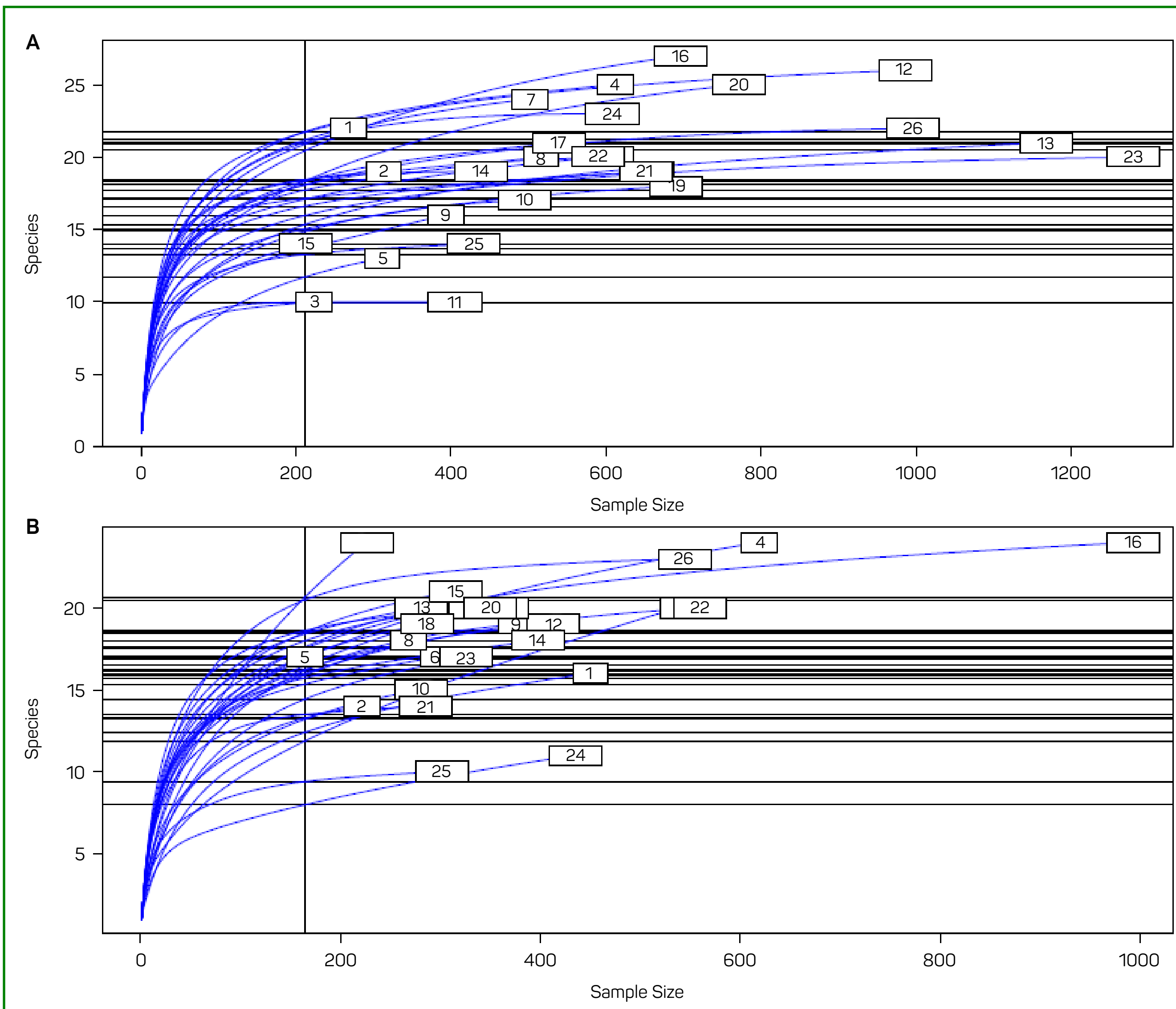

Figure 3 - Rarefaction curve showing the number of species and individuals observed in the 26 properties during the phytosociological survey in (A) summer and (B) winter

applying the correction of the rarefaction method, that is, equalizing the 26 properties into the same number of individuals, the average number of species that predominated during this period was 17. However, when applying the Shannon-Weaver index, it was observed that the average was 2.28, with maximum diversity of weed species obtained in area 12 (2.73) and minimum diversity in area 5 (1.51). When matching the abundance of species through Pielou's equability, the average diversity was 0.77, with the highest diversity found in area 14 (0.90) and the lowest in area 5 (0.59).

Precipitation and temperature indices are lower in winter. This limit the growth and development of weeds, and lower biological diversity parameters were observed compared to the summer period. Thus, it was observed that areas 25 and 5 presented minimum numbers of species (9) and individuals (186, with an average density of 9.3 plants/m^2), respectively, while areas 19 and 16 presented 23 species and 977 individuals (an average density of 48.85 plants/m^2), respectively. The average number of species obtained using the rarefaction method was 16. The average Shannon-Weaver index for the period was 2.02, with maximum diversity obtained in area 17 (2.56) and minimum in area 1 (1.10).

The areas visited had different and shared points concerning the number and abundance of weed species. Weed abundance data were used, and Jaccard's similarity index was applied. The similarity level reached 45.58% in summer, and 40.78% in the winter. According to Mueller-Dombois and Ellenberg (1974), two or more sites are considered similar when Jaccard's index is equal to or greater than 25.00%. A hierarchical cluster analysis was performed to facilitate understanding of the similarity level (Figure 4). In the summer cluster (Figure 4), the areas were separated into three main groups: the first group was formed by areas 1, 2, 3, 6, 8, 4, and 7; the second group by area 5; and the third group by areas 10, 9, 11, 22, 24, 20, 21, 18, 19, 25, 23, 25, 16, 15, 17, 13, 12, and 14.

In winter, four clusters were formed: the first group was formed by areas 11, 9, and 10; the second group was formed by areas 14, 15, 12, 13, 26, 23, 24, 18, 19, 21, 20, 22, 17, and 25; and the third group was formed by areas 3, 1, 2, 5, 4, 7, 6, and 8. The two clusters where the altitude range between 1,000–1,200 m showed a higher similarity index than the other ranges. In contrast, the dissimilarity observed in properties 1–11, some with certain proximity (Figure 1), is influenced by forms of weed management (mainly chemicals with a high selection factor for resistant species).

The intensity of damage caused by weeds is influenced by the competitive potential of the plants (Silva et al., 2018). The predominance of species in the Poaceae and Asteraceae families in the evaluations can be explained by the interactions between climatic conditions and the characteristics related to the biology of the plants. This includes the capacity for ecological dominance, high production of propagules, ease of dispersal, and tolerance to defoliation (Linder et al., 2018). Similar results were reported by Maciel et al. (2010), who conducted a phytosociological survey of weeds in organic coffee plants in the municipality of Garça-SP.

In the evaluations of both periods, except for the rankings, there was a difference between the two species with the highest IVIs, with *Portulaca oleraceae* in summer and *Conyza* spp. in winter. However, *Alternanthera tenella*, *Amaranthus* spp., *Bidens pilosa*, *Galinsoga parviflora*, *Lepidium virginicum*, *Sida* spp., *Eleusine indica*, *Digitaria hozizontalis,* and *Urochloa decumbens* were the most important weed species in both periods. According to Tredennick et al. (2018), this dominance may be related to the insensitivity of these species to soil moisture, such as developing competitive strategies over evolutionary cycles that protect them against rainfall variability.

Eleusine indica is one of the most common weeds found in coffee plantations in Minas Gerais, and this species showed the highest IVI in the summer evaluation. This result corroborates that of Cardoso et al. (2017), in which *Eleusine indica* and *Galinsoga parviflora* were the species with the highest IVI in perennial crops. Even though the first case of ACCase inhibitor herbicide resistance was reported for Eleusine indica in 2003, its control was not considered problematic. However, this situation changed after the emergence of the first resistant biotype to glyphosate, the most widely used herbicide in coffee farming, in 2016 (Heap, 2022).

Weeds of the genus *Digitaria* have a high capacity for tillering and forming new clumps. Furthermore, they are adept at competing for water, light, and nutrients, which guarantees aggressive dispersal and establishment of this genus. Santos and Cury (2011) identified *Bidens pilosa*, *Digitaria horizontalis,* and *Spermacoce latifolia* as species with the highest IVI in the second year of phytosociological survey in coffee trees intercropped with legumes. An example of the ability of competition was demonstrated by Fialho et al. (2010), where, in the presence of five weed species, including *Digitaria horizontalis*, young coffee trees showed reduced nutrients in the aerial parts. *Digitaria insularis* showed higher phytosociological parameters in winter, especially in areas above 1,200 m altitude. According to Reinert et al. (2013), although the emergence of this plant occurs year-round, the period from February to May is more favorable.

Urochloa decumbens or *U. ruziziensis* are among the most widely used forage in the Cerrado. It has become a popular cover crop plant in coffee cultivation in the last two decades. However, of the 26 areas visited, only one had this plant sown at the survey site to serve as a cover between the rows of coffee trees. The high abundances observed in other areas are explained by the fact that new plantings were made in areas previously occupied by *Urochloa* spp. As a perennial plant, its behavior in the survey was analogous to that of *D. insularis*, i.e., it obtained

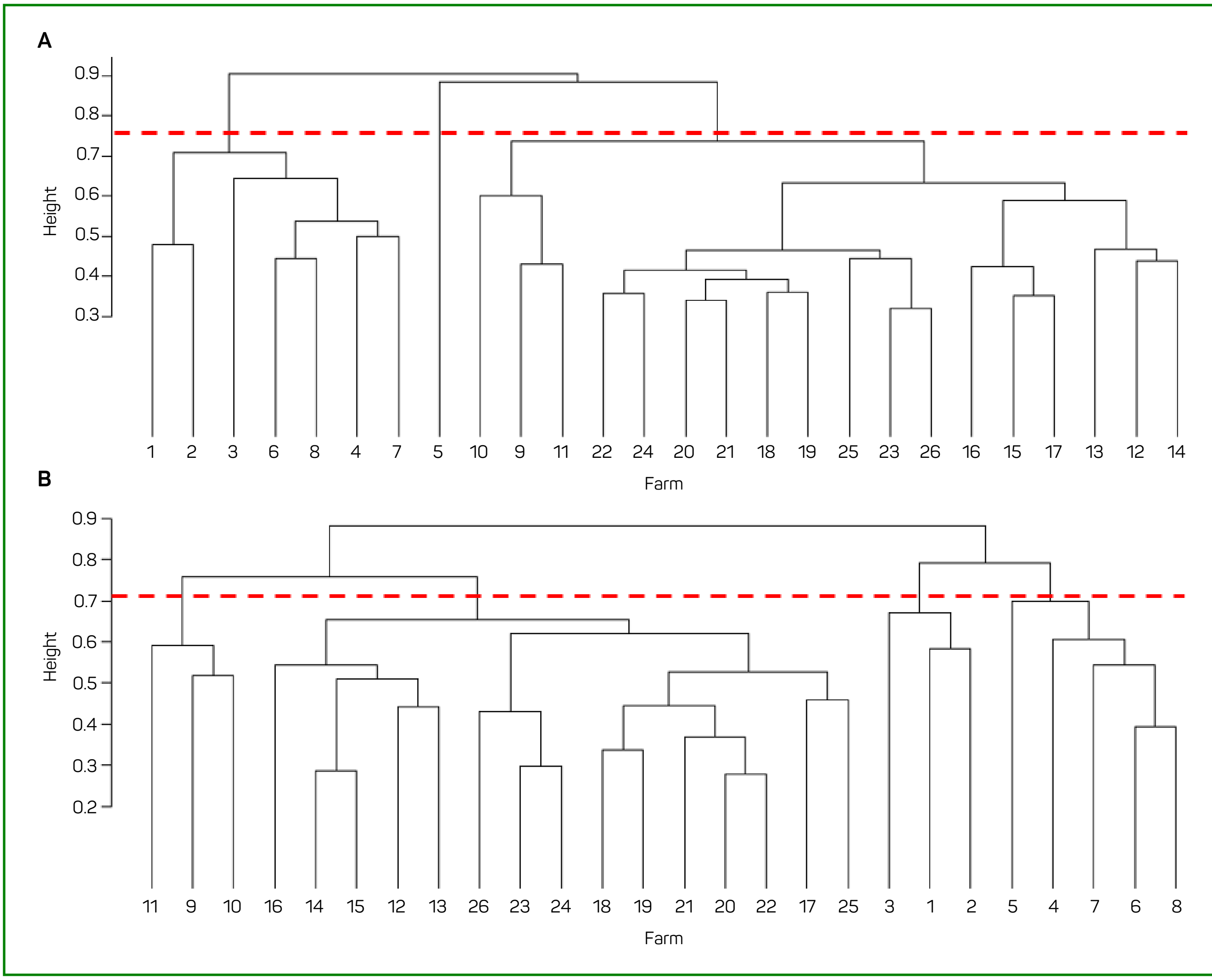

Figure 4 - Hierarchical clustering relating the incidence of weeds in the 26 visited areas period of (A) summer and (B) winter

the highest parameters in winter, configuring itself as the species with the second-highest IVI. To avoid competition between species, Souza et al. (2006) recommended a strip of 1 m on each side of the planting lines of coffee trees free from *Urochloa* spp.

Of the 16 species of the Asteraceae family found in both survey periods, *Bidens pilosa*, *Conyza* spp., and *Galinsoga parviflora* stand out because, in addition to having the highest IVIs, they are aggressive weeds that cause agricultural losses (Shen et al., 2019). Despite being easily found in coffee plantations, *G. parviflora* is not considered problematic and satisfactory control is achieved using broad-spectrum herbicides. In the phytosociological survey, it was one of the most abundant species in the areas above 1,000 m altitude in both periods.

Bidens pilosa is one of the most common weeds in annual and perennial crops. In the survey, it was found in 24 and 25 areas in summer and winter, respectively, with similar behavior in the three altitude ranges. At higher altitudes during this period, it was one of the species with higher densities and frequencies compared to altitudes up to 1,000 m. The interference of *Bidens pilosa* in coffee areas was demonstrated by Santos and Cury (2011), who identified the species with the highest IVI in the phytosociological survey.

Conyza spp. was the species with the highest IVI in winter, found on 23 farms, with a predominance on farms at altitudes up to 1,000 m. The average density on these farms was higher than the overall average for the period. Despite being an annual winter plant (Bajwa et al., 2016), the annual weed is found at different stages of development throughout the year in coffee plantations. In the summer evaluation, it was the eighth-most frequent species and the eleventh-most frequent IVI.

Weeds of the Amaranthaceae family have C4 photosynthetic metabolism, which guarantees a competitive advantage against coffee trees (C3) in summer. The genus *Amaranthus* is commonly found between rows of coffee trees. According to Alecrim et al. (2020), Amaranthaceae is one of the most frequent families in coffee plants during the rainy season.

Found infesting crops and pastures mainly in the Brazilian Cerrado, *Alternanthera tenella* is a weed that emerges in late summer. This explains the higher relative abundance of this species in winter (2.36) than in summer (1.49). Dias et al. (2008) demonstrated the predominance of fire blight in coffee trees, in which the species presented higher densities at the end of autumn in two years of evaluation.

Sida spp. are perennial plants that easily infest pastures. The phytosociological survey showed a higher relative frequency and IVI in winter. On the other hand, its representativeness was greater in the properties located between 800-1000 m altitude in the two periods evaluated, being higher in the summer in this altitude range. Although they can easily be found in coffee plantations, their interference tends to be small, even with young coffee trees, as demonstrated by Ronchi et al. (2007).

Lepidium virginicum was the main species in the Brassicaceae family in the survey. Although it is a winter plant, it was among the ten species with the highest IVIs in both periods. In winter, it was the third-most important and most abundant, especially for properties above 1,000 m altitude. Even as a highlight of this work, historically, there is no information on the interference of this species on coffee trees.

The Shannon-Wiener index was used to show the diversity and heterogeneity of weeds through the number and distribution of species present in the 26 areas visited. According to Cavalcanti and Larrazábal (2004), an index is considered high when it is above 3; average, between 2 and 3; low, between 1 and 2; and very low, less than 1. The average diversity found in summer (2.28) and winter (2.02) was similar to the work of Cardoso et al. (2017) in perennial jatropha crops and pastures at the end and beginning of the rainy season. However, the same authors found lower diversity values in pastures, with indexes of 1.51 and 1.40 at the end of each period, respectively.

The Pielou index refers to the uniformity of the number of individuals of different species in a community. Low values indicate the dominance of one or more species in the studied community, whereas high equitability (above 0.5) means uniform distribution among species in the sample and that, despite the complexity of the community, individuals tend to be well distributed (Cardoso et al., 2017; Pan et al., 2020). The summer and winter results indicate a uniform distribution; however, unlike in the summer, two areas (i.e., 1 and 24) had values below 0.5, which is explained by the predominance of the *Conyza* spp. species, which had IVI values of 142.14 and 148.40 for each area, respectively. This is much higher than the average IVI (33.54) of the species in the period.

The weed community in Cerrado Mineiro has a predominance of species that are highly competitive and difficult to control, alerting us to potential damage in case of negligence in management. Chemical control in coffee crops is mainly performed mechanically and with with herbicides. However, the period required without weeds is long (October to March) and re-infestation of weeds can easily occur. Because of the ease of application, coffee growers often opt to use non-selective herbicides, such as glyphosate. However, indiscriminate use of this herbicide can select resistant weeds. The Cerrado weed community is dominated mainly by weeds from the Poaceae and Asteraceae families, which have reported resistance to glyphosate in Brazil, such as *Conyza* spp., *Digitaria insularis* and *Eleusine indica* (Heap, 2022). Thus, identifying the species present in each coffee area is the first step in planning and deciding the control strategies, recommending the integration of one or more methods, and turning coffee growing, according to current precepts, into an increasingly fair and sustainable activity.

4. Conclusions

The weed community in the Cerrado Mineiro coffee plantation was dominated by two main families, Poaceae and Asteraceae. *Eleusine indica* and *Conyza* spp. had the highest IVIs in summer and winter.

The behavior of the species found in the survey revealed high variability in the parameters analyzed. However, similarities were observed among species found at the sites visited.

Author's contributions

All authors read and agreed to the published version of the manuscript. RJAR and GRC: conceptualization of the manuscript and development of the methodology. RJAR: data collection and curation. RJAR and AHG: data analysis. JPFC: data interpretation. ENA: project administration. AHG: supervision. RJAR and GRC: writing the original draft of the manuscript. RJAR and LSR: writing, review and editing.

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