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SPECIES ASSOCIATED WITH *Curitiba prismatica* (D. LEGRAND) SALYWON & LANDRUM IN A FAXINAL SYSTEM

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Resumo

Espécies associadas à Curitiba prismatica (D. Legrand) Salywon & Landrum no Sistema Faxinal. Curitiba prismatica (Myrtaceae) é uma espécie arbórea endêmica da Floresta Ombrófila Mista (FOM) que apresenta propriedades farmacêuticas presentes nos óleos essenciais extraídos de suas folhas. Diante disso, o objetivo do estudo foi descrever a florística, diversidade e a competição das espécies associadas à *C. prismatica* na Floresta Ombrófila Mista em Sistema Faxinal a fim de melhor compreensão das relações interespecífica da espécie e de com isto reflete em sua autoecologia. Para tanto, foi realizado o levantamento de 35 unidades amostrais, utilizando o método de Prodan, classificando-as os táxons arbóreos como iniciais (pioneiras e secundárias iniciais) e tardias (secundárias tardias e clímax). Foram observados 210 indivíduos lenhosos, pertencentes a 16 famílias, 23 gêneros e 29 espécies, sendo as espécies mais associadas: *C. prismatica*, *Casearia obliqua*, *Casearia sylvestris*, *Cinnamodendron dinisii*, *Ocotea odorifera* e *Casearia decandra*. Os índices de Shannon (H') e de Simpson (C) encontrados para a amostra de espécies associadas foi de 2,54 nats.ind^{-1} e 0,14 nats.ind^{-1}, respectivamente. De acordo com os índices de competição de BAL, Glover & Hool (IGH) e Hegyi, a competição sob a *C. prismatica* ocorre com maior intensidade nos indivíduos com DAP ≤ 25 cm. Pode-se concluir que o estudo contribuiu para uma melhor compreensão do comportamento ecológico das espécies associadas à *C. prismatica* na FOM em Sistema Faxinal.
Palavras-chave: Floresta Ombrófila Mista, Myrtaceae, murta, ecologia, interações

Abstract

Species associated with Curitiba prismatica (D. Legrand) Salywon & Landrum in a Faxinal System. Curitiba prismatica, belonging to the family Myrtaceae, is an endemic species of Araucaria Mixed Forest (AMF) areas whose leaf essential oils have pharmaceutical properties. The objective of this study was to describe the floristic aspects, diversity, competition and diametric transition of the species associated with *C. prismatica* in an Araucaria Mixed Forest area exploited in the Faxinal System. A survey of 35 sample units was carried out using the Prodan method, classifying them as initial (pioneer and early secondary) and late (old secondary and climax). Two hundred ten trees were observed, divided into 16 botanical families, 23 genera and 29 species, with the most associated species being: *C. prismatica*, *Casearia oblique*, *Casearia sylvestris*, *Cinnamodendron dinisii*, *Ocotea odorifera*, and *Casearia decandra*. The Shannon (H') and Simpson (C) indices of the associated species were 2.54 nats.ind^{-1} and 0.14 nats.ind^{-1}, respectively. According to the competition rates denoted by the indices of basal area (BAL), Glover and Hool (IGH) and Hegyi, competition of *C. prismatica* occurred with greater intensity in trees with DBH ≤ 25 cm. The results provide a better understanding of the ecological behavior of species associated with *C. prismatica* in AMF areas subject to Faxinal System.
Keywords: Araucaria Mixed Forest, Myrtaceae, murta, ecology, interactions

INTRODUCTION

The Faxinal System is a unique peasant system for exploitation of Araucaria Mixed Forest areas (AMF), predominantly in the center-south and southeast regions of the state of Paraná (WATZLAWICK *et al.*, 2011). The system is based on the collective use of land for animal production and forest extraction, mainly *Araucaria angustifolia* (Bertol.) Kuntze and *Ilex paraguariensis* A. St. Hil, constituting a way of maintaining the natural vegetation cover, especially in the upper stratum, thus having great ecological, sociocultural and historical importance in the state (ALBUQUERQUE *et al.*, 2011). In this context, *Curitiba prismatica* has been gaining prominence in recent studies due to its high tree density when occurring in Faxinal System, in particular noted for its economic potential due to the pharmaceutical properties of the essential oils extracted from its leaves, with the possibility of enhancing the maintenance of Faxinal System.

C. prismatica is a perennial arboreal species with small size, slow growth and late habit present in the understory of forests in intermediate to advanced stages of succession. Its leaves stand out for their bright green color on the adaxial face. The flowering of the species occurs in the summer, with white flowers that develop into oblong-prismatic fruits, in general in the month of April, with barochoric and ornithochoric seed dispersal, with high germination rates in colder environments. This is an endemic species of the Atlantic Forest biome, with records in the Montane Araucaria Mixed Forest in southern Paraná and northern Santa Catarina states, infrequent in general floristic surveys in AMF areas. However, it is frequently found with high density in Faxinal System, where its gregarious character stands out in the structure of these systems, probably an indirect result of the way these systems are used (SIMINSKI *et al*., 2011; SAUERESSIG, 2014). The species has a restricted geographic distribution (occupation area of about 120 km²) and is considered Vulnerable (VU) to extinction by the Red List of threatened species of the International Union for the Conservation of Nature and Natural Resources (RIBEIRO *et al*., 2020).

Due to the vulnerability and geographic restriction of the species, it is important to investigate how its occurrence allows the formation of vegetation nuclei with species that coexist in the environment, promoting the processes of ecological succession and expansion of vegetation, the autoecology and preservation of the species, and consequently the influence on synecology in the environments in which it occurs. Thus, the concept of associated species is applied, which are plants that facilitate the growth and development of other plant species (target species) below their canopy, by offering favorable microhabitats for seed germination and/or seedling recruitment than the surrounding environment (REN *et al*., 2008).

Among the ecological interactions, competition for resources stands out and can be studied using competition indices that express an estimate of the horizontal space occupied by a sample tree in relation to its neighbors (SILVA *et al*., 2012). In any forest community, the growth and development of a tree is affected by its neighbors, according to four factors: number, size, distance and position of neighbors.

Management strategies influence competitive interactions, and structural properties are affected by vertical and horizontal forest structures. Thus, the associated species can create adequate conditions for the growth and survival of other plants under their canopies (REN *et al*., 2008). In addition, information on associated species can contribute to the colonization of degraded areas (RUWANZA, 2019).

Given the ecological importance and economic potential of *C. prismatica*, the present work aimed to verify patterns in relation to the association of tree species in relation to *C. prismatica*, verifying floristic clusters, competition and growth, contributing to the autoecological study of the species as well as its influence on the arboreal community. The data obtained can serve as inputs for studies and practices for preservation and economic use of this vulnerable species.

MATERIAL AND METHODS

The research was carried out in Araucaria Mixed Forest fragments exploited via the Faxinal System, in the municipality of Rebouças, Paraná. Sampling was carried out in Faxinais Marmeleiro de Baixo (25°37'15"S and 50°49'34"W), Marmeleiro de Cima (25°35'13"S and 50°49'29"W) and Barro Branco (25°40'41.23"S and 50°29'07.96"W), at an average altitude of 850 m. The survey was carried out inside three permanent plots of 1 hectare (ha), subdivided into subunits of 10 x 10 m. For this, a minimum distance of 10 m between plots was considered, excluding marginal subunits, to avoid sampling trees outside the permanent plots.

Within the plots, 35 sampling units were established using the variable area method of Prodan (1968), which considers the measurement of the six closest trees and the distance or radius of the sixth tree as a reference for the sample plot. In addition, the radius of the plot is obtained by the distance from the central point to the sixth tree, plus the half diameter of this sixth tree. Considering this sampling method, trees of *C. prismatica* with DBH $\geq$ 10 cm were considered the center of each plot, and the six closest trees with DBH $\geq$ 10 cm were measured, which were considered associated.

Associated species were classified into early (as pioneer and early secondary) and (as secondary and climax), according to the classification by Carvalho (2003, 2006, 2008, 2010). Taxonomic classification of the species was performed based on APG IV (BYNG *et al*., 2016).

Density, relative frequency, along with Shannon-Wiener (H') and Simpson dominance (C) diversity indices of all early and late associated species were estimated. The central trees of *C. prismatica* and the associated early and late species were distributed in diameter classes at 10 cm intervals.

Table 1 describes the competition indices used to analyze the influence of early and late species, which are considered objective trees, due to the possibility of causing competition with *C. prismatica*, which in turn is considered an object tree, due to suffering the effect of competition.

Table 1. Independent and distance-dependent competition indices used between early and late species associated with *Curitiba prismatica*, in an Araucaria Mixed Forest area subject to a Faxinal System.
Tabela 1. Índices de competição independentes e dependentes da distância utilizados entre as espécies iniciais e tardias associadas à *Curitiba prismatica*, em Floresta com Araucária em Sistema Faxinal.

Index	Formula	Source
BAL (*Basal Area Larger*)	$BAL = \sum_{i=1}^{n} gi$	Kiernan *et al*. (2008)
IGH (Glover & Hool)	$IGH = \frac{di^2}{\bar{d}^2}$	Prodan *et al*. (1997)
Hegyi	$Hegyi = \left[\frac{d_j}{(d_i * dist_{ij}}\right]$	Hegyi (1974)

n = number of objective trees with DBH (cm) greater than the object tree; gi = cross-sectional area (m²) of the objective tree; di = DBH (cm) of the object tree; $\bar{d}$ = Average DBH (cm) of the objective trees; d_j = DBH (cm) of the objective tree; d_i = DBH (cm) of the object tree; $dist_{ij}$ = distance (m) between object and objective trees.

The BAL and IGH indices are independent of distance and the Hegyi index is dependent on the distance between the object and objective trees. Lower BAL index values mean less competition with the object tree. In turn, a decrease in the index represents an increase in competition with the object tree. Finally, the Hegyi index considers a unitary exponent for both the size quotient (dj/di) and the distance weight (1/distij).

The periodic increment (PI) and the annual periodic increment in diameter (API) of the early and late associated species were obtained considering the period from 2007 to 2018. Based on the diameter information, IPA and competition indices, descriptive statistics were calculated as well as Pearson's linear correlation (r_p). The analyses were performed using the software Assistat 7.7 (SILVA, 2014).

RESULTS

A total of 210 tree trees were sampled, divided into 16 botanical families, 23 genera and 29 species (Table 2). As for the absolute density and relative frequency, the species that presented the highest values were: *C. prismatica* (146.51 ind.ha^{-1} and 21.05%); *Casearia obliqua* Spreng (69.77 ind.ha^{-1} and 12, 78%); *Casearia sylvestris* Sw. (58.14 ind.ha^{-1} and 9.77%); *Cinnamodendron dinisii* Schwanke (30.23 ind.ha^{-1} and 7.52%); *Ocotea odorifera* (Vellozo) Rohwer (27.91 ind.ha^{-1} and 6.02%); and *Casearia decandra* Jacq. (20.93 ind.ha^{-1} and 6.02%). These species corresponded to 72% of the total number of trees sampled, with the species *C. prismatica* alone representing 30%.

In relation to the families, those with the largest number of associated species were Lauraceae (6), Myrtaceae (5) and Salicaceae (4). Of these, the Salicaceae family included three of the six most associated species. In the classification by ecological group, the early and late species corresponded to 59% and 41%, respectively. Among the six most associated species, four were early and two were late species.

Table 2. Estimates of phytosociological indices of species associated with *Curitiba prismatica*, in an Araucaria Mixed Forest area subject to a Faxinal System.
Tabela 2. Estimativas dos índices fitossociológicos das espécies associadas à *Curitiba prismatica*, em Floresta com Araucária em Sistema Faxinal.

Family/Species	DBH (cm) ± *S*	N	AD (ind.ha^{-1})	RF (%)	EG
Annonaceae					
Annona rugulosa (Schltdl.) H.Rainer	14.0±2.9	4	9.30	1.50	Ls
Aquifoliaceae					
Ilex paraguariensis A.St.-Hil.	18.0±2.6	5	11.63	3.01	Cl
Araucariaceae					
Araucaria angustifolia	78.3±0.0	1	2.33	0.75	Pi

Family/Species	DBH (cm) ± *S*	N	AD (ind.ha^{-1})	RF (%)	EG
(Bertol.) Kuntze					
Canellaceae					
Cinnamodendron dinisii Schwanke	22.0±7.6	13	30.23	7.52	Ls
Euphorbiaceae					
Sapium glandulosum (L.) Morong	42.0±0.0	1	2.33	0.75	Pi
Fabaceae					
Cassia leptophylla Vogel	48.0±10.0	3	6.98	0.75	Is
Lauraceae					
Ocotea puberula (Rich.) Nees	75.0±15.3	3	6.98	1.50	Is
Ocotea diospyrifolia (Meisn.) Mez	55.1±16.9	4	9.30	3.01	Ls
Ocotea odorifera (Vellozo) Rohwer	17.0±5.7	12	27.91	6.02	Ls
Nectandra megapotamica (Spreng.) Mez	50.4±9.3	2	4.65	1.50	Is
Cinnamomum glaziovii (Mez) Kosterm.	43.1±3.0	2	4.65	1.50	Ls
Ocotea porosa (Nees & Mart.) Barroso	14.1±3.3	4	9.30	1.50	Cl
Lythraceae					
Lafoensia vandelliana Cham. & Schltdl	29.6±0.0	1	2.33	0.75	Cl
Meliaceae					
Cedrela fissilis Vell.	45.6±17.9	5	11.63	3.76	Ls
Myrtaceae					
Myrciaria delicatula (DC.) O. Berg	47.4±0.0	1	2.33	0.75	Ls
Eugenia hiemalis Cambess.	20.5±6.5	5	11.63	3.76	Is
Myrceugenia miersiana (Gardner) D.Legrand & Kausel	24.2±0.0	1	2.33	0.75	Is
Campomanesia xanthocarpa (Mart.) O.Berg	36.8±11.6	4	9.30	2.26	Is
Curitiba prismatica (D.Legrand) Salywon & Landrum	16.2±6.9	63	146.51	21.05	Is
Picramniaceae					
Pricamnia parvifolia Engl.	15.3±3.9	2	4.65	1.50	Is

Family/Species	DBH (cm) ± *S*	N	AD (ind.ha^{-1})	RF (%)	EG
Rosaceae					
Prunus brasiliensis (Cham. & Schltdl.) Dietr.	37.8±10.1	2	4.65	1.50	Is
Rubiaceae					
Randia ferox (Shaw. & Schltdl.) DC.	23.4±0.0	1	2.33	0.75	Ls
Salicaceae					
Casearia sylvestris Sw.	15.3±4.2	25	58.14	9.77	Is
Casearia decandra Jacq.	16.6±5.0	9	20.93	6.02	Is
Casearia obliqua Spreng	26.8±13.0	30	69.77	12.78	Is
Casearia lasiophylla Eichler	18.6±5.0	3	6.98	2.26	Is
Sapindaceae					
Matayba elaeagnoides Radlk.	42.4±28.2	2	4.65	1.50	Is
Allophylus edulis (A.St.-Hil. et al.) Hieron. ex Niederl.	28.0±0.0	1	2.33	0.75	Is
Sapotaceae					
Chrysophyllum gonocarpum (Mart. & Eichler) Engl.	30.6±0.0	1	2.33	0.75	Ls

DBH = Diameter at breast height; *S* = standard deviation; N = number of trees sampled by species; AD = absolute density; RF = relative frequency; EG = ecological group; Pi = pioneer species; Is = initial secondary species; Ls = late secondary species e Cl = climax species.

The Shannon diversity index (H') considering all competing species was 2.54 nats.ind^{-1}. Simpson's dominance among all trees was 0.14 nats.ind^{-1}. In early and late species, the diversity and dominance indices were 1.92 nats.ind^{-1} and 0.23 nats.ind^{-1}; and 2.13 nats.ind^{-1} and 0.15 nats.ind^{-1}, respectively. Considering the diameter classes, no great oscillation was identified, except in the last classes.

Figure 1 shows the diameter distribution of the trees of *C. prismatica*, which were used as the center of the plot, as well as the trees of the associated early and late species. The frequencies of the sampling units correspond to the respective class centers. In both cases, the distribution pattern was negative exponential.

The largest number of object trees was concentrated in the first class (10-20 cm), with 27 trees. The same was observed among trees of early and late associated species, corresponding to 97 and 26 trees, respectively.

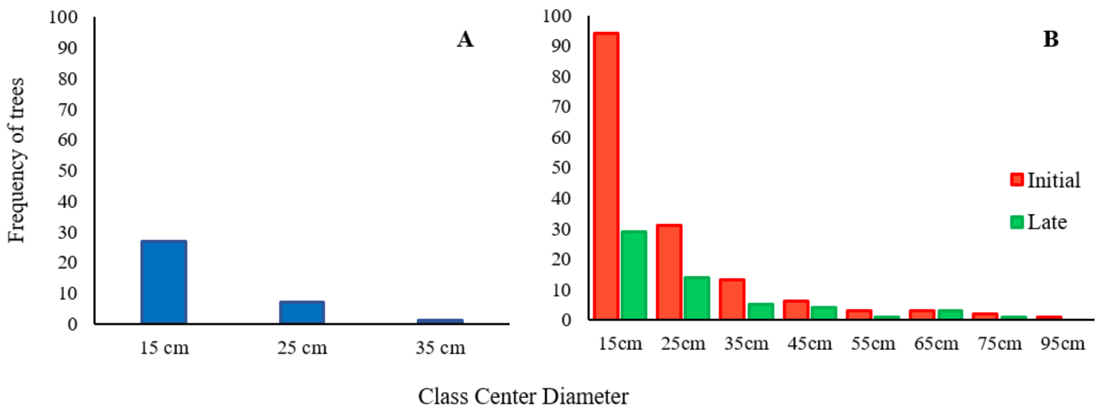

Figure 1. Diametric distribution of the species sampled, in an Araucaria Mixed Forest area subject to a Faxinal System. (A) *Curitiba prismatica* and (B) species associated.
Figura 1. Distribuição diamétrica das espécies amostradas, em Floresta com Araucária em Sistema Faxinal. (A) *Curitiba prismatica* e (B) espécies associadas.

Most associated species were concentrated in the first diameter classes, especially *C. prismatica*, *C. sylvestris*, *O. odorifera* and *C. obliqua*. The species *A. angustifolia*, *O. puberula*, *O. diospyrifolia*, *C. fissilis* and *Matayba elaeagnoides* were the only ones that presented trees in the upper classes (DBH ≥ 60 cm).

Trees of the early and late species associated with *C. prismatica* presented high diameter amplitude, varying between 10.03 and 91.99 cm for the early and from 10.22 to 70.03 cm for the late species, with high coefficients of variation (Table 3).

The competition indices had high coefficients of variation considering the initial species, mainly for Hegyi (*CV* = 80.66%). However, when only late species were evaluated, the coefficient was much lower, of 0.92% for the IGH and 1.05% for the BAL.

Table 3. Results of descriptive statistics of DAP and competition indices of early and late species associated with *Curitiba prismatica*, in an Araucaria Mixed Forest area subject to a Faxinal System.
Tabela 3. Resultados da estatística descritiva do DAP e dos índices de competição das espécies iniciais e tardias associadas à *Curitiba prismatica*, em Floresta com Araucária em Sistema Faxinal.

Variable	Minimum	Maximum	Mean	Median	*CV* (%)
Initial species					
DBH (cm)	10.03	91.99	21.68	15.66	65.55
BAL	0.01	1.09	0.23	0.18	0.91
IGH	0.10	1.70	0.72	0.58	61.98
Hegyi	0.40	8.40	2.50	1.84	80.66
Late species					
DBH (cm)	10.22	70.03	25.19	19.7	59.60
BAL	0.04	0.76	0.18	0.09	1.05
IGH	0.04	2.72	0.64	0.48	0.92
Hegyi	0.13	6.63	1.66	1.21	1.03

According to the BAL, Glover & Hool (IGH) and Hegyi competition indices, competition under *C. prismatica* occurred with greater intensity in trees with DBH up to 25 cm (Figure 2). In general, the indices revealed low competition intensity. In the case of the IGH index, the competition was lower among the initial species, with the competition decreasing with the increase of this index. Based on the results of Pearson's correlation analysis (r_p) between the competition indices and the annual periodic increments in diameter for the early and late species associated with *C. prismatica*, no significant correlations were found.

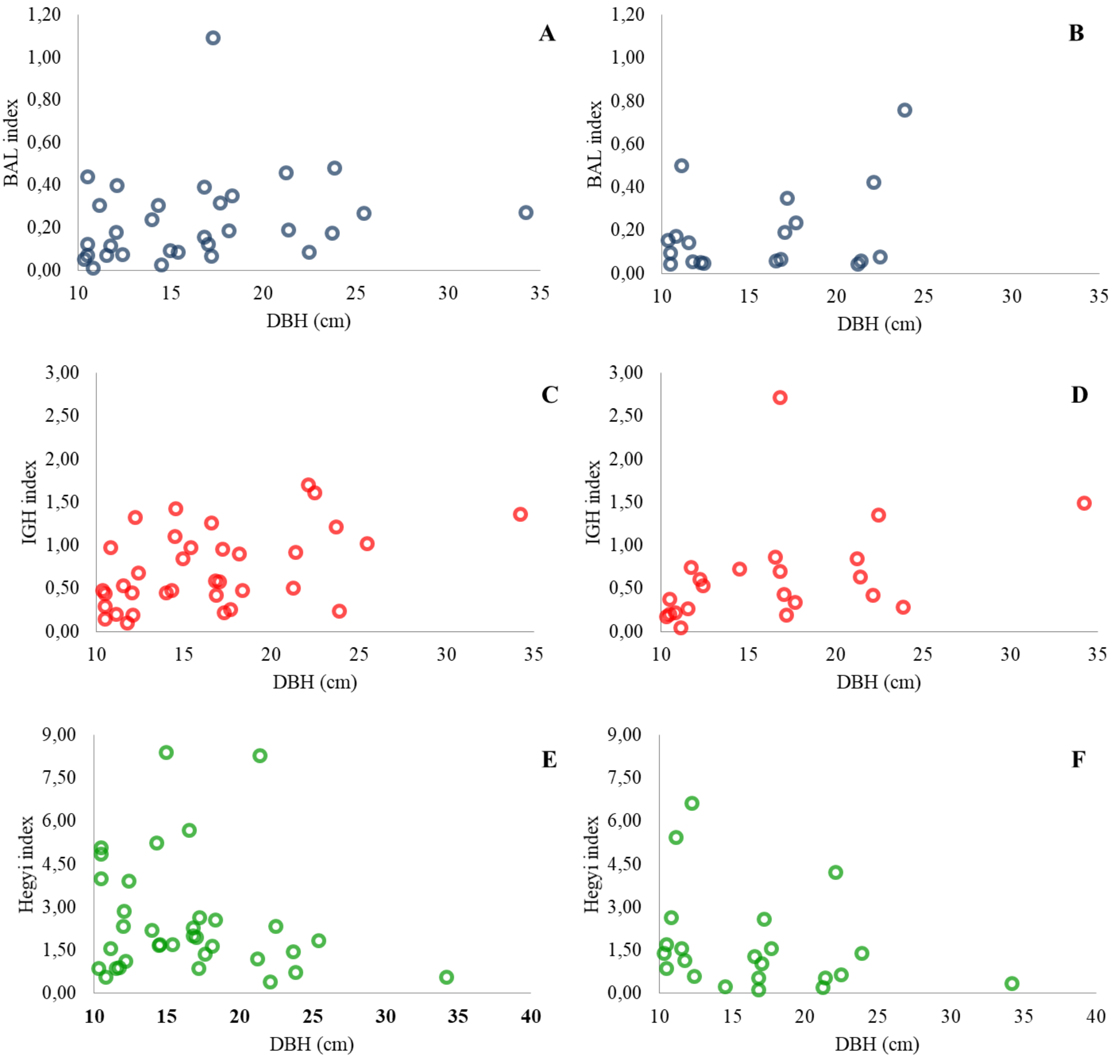

Figure 2. Competition indices between *Curitiba prismatica* and its associated species, in an Araucaria Mixed Forest area subject to a Faxinal System. (A) BAL for early species, (B) BAL for late species, (C) Glover & Hool (IGH) for early species, (D) Glover & Hool (IGH) for late species, (E) Hegyi for early species and (F) Hegyi for late species.

Figura 2. Índices de competição entre a *Curitiba prismatica* e suas espécies associadas, em Floresta com Araucária em Sistema Faxinal. (A) BAL para as espécies iniciais, (B) BAL para as espécies tardias, (C) Glover & Hool (IGH) para as espécies iniciais, (D) Glover & Hool (IGH) para as espécies tardias, (E) Hegyi para as espécies iniciais e (F) Hegyi para as espécies tardias.

DISCUSSION

Interactions among species in the plant community can be both positive and negative. However, interactions between species, such as species that coexist with *C. prismatica*, are not fixed. According to density and frequency, the object species itself presented higher values than the others. Thus, its character was gregarious (WATZLAWICK *et al*., 2011) and dominant in the study area, with 146.51 ind.ha^{-1}.

In this sense, *C. prismatica*, classified as an early secondary species, was preferentially associated with early secondary species, which despite being similar from a successional point of view, had some divergent morphological characteristics of diaspores and plants, in which the initial ones had greater variability (GOGOSZ *et al*., 2015). Added to this, we assumed that the animals that forage in the area do not show a preference for the leaves of the species. Additionally, the species *A. angustifolia* and *I. paraguariensis*, which were intensively exploited in the last century, were associated with low frequency of *C. prismatica*.

For the Shannon diversity index, the value (H' = 2.54 nats.ind^{-1}) was within the expected range for altered FOM areas, which normally ranges from 1.5 to 3.5 nats.ind^{-1}, being close to 3.5 nats.ind^{-1} in more conserved environments. Intransitive competition, which does not consider the best competitor and often occurs in nature, increases the diversity of species, but with homogenization of the environment, the percentage tends to decrease (SOLIVERES *et al*., 2015). This was reflected in the analyzed environment, which is subject to intense anthropic activity, with the use of some species for energy.

The dominance, considering all associated species, was relatively low (0.14 $nats.ind^{-1}$). The early species, despite including the highest species number, density and frequency, showed dominance values lower than the late ones. Thus, the probability of two trees being the same among the early species was 23% while among the late species it was 15%. In a sampling considering the entire forest, Albuquerque *et al*. (2011) detected that Simpson's dominance varied between 0.14 and 0.16 $nats.ind^{-1}$, values similar to those observed among species associated with *C. prismatica*.

Regarding the coexistence of different plant species, it is known that this is possible due to the distinction in their successional strategies, and a tendency exists for greater intraspecific than interspecific competition (KUNSTLER *et al*., 2015). As a result, we observed that the object species themselves presented intense intraspecific competition, due to the high density of trees. As for interspecific competition, it was more strongly associated with the secondary species *C. obliqua*, *C. sylvestris*, *C. dinisii*, *O. odorifera* and *C. decandra*.

Considering the diameter distribution between the early and late species, the community was undergoing intense regeneration, due to the number of trees in the first diameter classes. The "inverted-J form" characterizes the distribution as negative exponential, with no DBH variations between early and late species, ranging from 10.03 to 91.99 cm and from 10.22 to 70.33 cm, respectively.

Notably, *C. prismatica* rarely reached diameter greater than 30 cm, even with the sprouting of its stem, indicating that climax species, such as *O. porosa* and *I. paraguariensis*, interact very little, probably because of the intense uncontrolled exploitation of these species in the past. In this sense, both facilitation and competition can coexist in the community, the occurrence and magnitude of which depend on the spatial scale, where small trees are always facilitated by increasing density, while larger trees have no density effect (SIMINSKI *et al*., 2011; MOUSTAKAS *et al*., 2019).

In plant communities, interactions between trees of different species are expected to promote positive or negative interspecific spatial associations over small distances (RAJALA *et al*., 2018). In view of this, it was evident that with regard to competition for space, 60% of trees of early species and 72% of trees of late species effectively competed, since they had larger diameters than the object trees. Thus, the smaller the tree, the lower its ability to compete will tend to be.

Considering only density as a measure of competition to analyze the behavior of trees in mixed forests will not consider the effects of species variations (CUNHA and FINGER, 2013). The heterogeneity of natural forests, such as the one in this study, results in low correlations between the DBH, API and competition indices (CASTRO *et al*., 2014).

Knowledge of the main species associated with *C. prismatica* is useful for the recovery of degraded AMF areas. In addition, the species has a tendency to share its effective niche with early species. Thus, we recommend using nucleation or planting in agroforestry systems with the species *C. prismatica*, *C. obliqua*, *C. sylvestris*, *C. dinisii*, *O. odorifera*, and *C. decandra*.

CONCLUSIONS

- The main species associated with *C. prismatica* were: *C. prismatica* itself, *Casearia oblique*, *Casearia sylvestris*, *Cinnamodendron dinisii*, *Ocotea odorifera*, and *Casearia decandra*.
- The Lauraceae, Myrtaceae and Salicaceae families had the greater number of associated species.
- In the classification by ecological group, early and late associated species corresponded to 59% and 41%, respectively.
- Late species presented greater species diversity as well as less dominance.
- Competition occurred more intensely under *C. prismatica* trees with DBH ≤ 25 cm, with no correlation with the annual periodic increase in DBH.

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REFERENCES

ALBUQUERQUE, J. M.; WATZLAWICK, L. F.; MESQUITA, N. S. Efeitos do uso em Sistema Faxinal na florística e estrutura em duas áreas da Floresta Ombrófila Mista no munícipio de Rebouças, PR. **Ciência Florestal**, Santa Maria, v. 21, n. 2, p. 323-334, 2011.

BYNG, J. W.; CHASE, M. W.; CHRISTENHUSZ, M J.; FAY, M. F.; JUDD, W. S.; MABBERLEY, D. J.; SENNIKOV, A. N.; SOLTIS, D. E.; SOLTIS, P. S.; STEVENS, P. F. An update of the Angiosperm phylogeny Group classification for the orders and families of flowering plants: APG IV. **Botanical Journal of the Linnean Society**, London, v. 181, p. 1-20, 2016. DOI: 10.1111/boj.12385

CARVALHO, P. E. R. **Espécies arbóreas brasileiras**. Brasilia, DF: Embrapa Informação Tecnológica, v.1. 2003. 1039 p.

______. **Espécies arbóreas brasileiras**. Brasília, DF: Embrapa Informação Tecnológica, v2. 2006. 627 p.

______. **Espécies arbóreas brasileiras**. Brasília, DF: Embrapa Informação Tecnológica, v.3. 2008. 593 p.

______. **Espécies arbóreas brasileiras**. Brasília, DF: Embrapa Informação Tecnológica, v.4. 2010. 644 p.

CASTRO, R.; SOARES, C.; LEITE, H.; SOUZA, A.; MARTINS, F.; NOGUEIRA, G.; OLIVEIRA, M.; SILVA, F. Competição em nível de árvore individual em uma Floresta Estacional Semidecidual. **Silva Lusitana**, Oeiras, v. 22, n. 1, p. 43-66, 2014.

CUNHA, T. A.; FINGER, C. A. G. Competição assimétrica e o incremento diamétrico de árvores individuais de *Cedrela odorata* L. na Amazônia Ocidental. **Acta Amazonica**, Manaus, v. 43, n. 1, p. 9-18, 2013. DOI: 9.1590/S0044-59672013000100002

GOGOSZ, A. M.; BOEGER, M. R. T.; COSMO, N. L.; NOGUEIRA, A. C. Morfologia de diásporos e plântulas de espécies arbóreas da floresta com araucária, no Sul do Brasil. **Floresta**, Curitiba, v. 45, n. 4, p. 819 – 832, 2015. DOI: 10.5380/rf.v45i4.35017

HEGYI, F. **A simulation model for managing jackpine stands**. In: Fries, J. (Ed.), Proceedings of IUFRO meeting on Growth models for tree and stand simulation, Royal College of Forestry, 1974.

KIERNAN, D. H.; BEVILACQUA, E.; NYLAND, R. D. Individual-tree diameter growth model for sugar maple trees in uneven-aged northern hardwood stands under selection system. **Forest Ecology and Management**, Amsterdam, v. 256, p. 1579–1586, 2008. DOI: 10.1016/j.foreco.2008.06.015

KUNSTLER, G.; FALSTER, D.; COOMES, D. A. Plant functional traits have globally consistent effects on competition. **Nature**, London, v. 529, p. 204-207, 2015. DOI: 10.1038/nature16476

MOUSTAKAS, A.; DALIAKOPOULOS, I. O.; BENTON, T. G. Data-driven competitive facilitative tree interactions and their implications on nature-based solutions. **Science of the Total Environment**, Amsterdam, v. 651, p. 2269-2280, 2019. DOI: 10.1016/j.scitotenv.2018.09.349

PRODAN, M. **Forest biometrics**. New York: Pergamon, 1968. 447p.

PRODAN, M.; PETERS, R.; COX, F.; REAL, P. **Mensura Forestal**. San José: Instituto Interamericano de Cooperación para la Agricultura, 1997. 562p.

RAJALA, T.; OLHEDE, S. C.; MURRELL, D. J. When do we have the power to detect biological interactions in spatial point patterns? **Journal of Ecology**, Oxford, v. 107, n. 2, p. 711-721, 2018. DOI: 10.1111/1365-2745.13080

REN, H.; YANG, L.; LIU, N. Nurse plant theory and its application in ecological restoration in lower subtropics of China. **Progress in Natural Science**, v. 18, n. 2, p.137-142, 2008. DOI: 10.1016/j.pnsc.2007.07.008

RIBEIRO, C., HOFFMANN, P., LAROCCA, P., DA ROSA, P., MARTINELLI, G. & LIMA, D. 2020. ***Curitiba prismatica***. The IUCN Red List of Threatened Species 2020: e.T177059983A177804867. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T177059983A177804867.pt. Access: 19 Abril de 2022.

RUWANZA, S. Nurse plants have the potential to accelerate vegetation recovery in Lapalala Wilderness old fields, South Africa. **African Journal of Ecology**, Oxford, v. 57, n. 1, p. 82-91, 2019. DOI: 10.1111/aje.12536

SAUERESSIG, D. **Plantas do Brasil**: Árvores Nativas. 1. ed. Irati-PR: Editora Plantas do Brasil, 2014.

SILVA, F. A. S. **ASSISTAT: Versão 7.7 beta**. DEAG – CTRN – UFCG – Updated 01 de abril de 2014. Acesso em Jun. 2016.

SILVA, K. E.; MARTINS, S. V.; SANTOS, N. T.; RIBEIRO, C. A. A. S. Padrões Espaciais Arbóreas Tropicais. In: MARTINS, S. V. (Ed**.). Ecologia de florestas tropicais do Brasil**. Viçosa: Editora UFV, Universidade Federal de Viçosa, 2012. 371p.

SIMINSKI, A.; FANTINI, A. C.; GURIES, R. P.; RUSCHEL, A. R.; REIS, M. S. Secondary Forest Succession in the Mata Atlantica, Brazil: Floristic and Phytosociological Trends. **ISRN Ecology**, v. 2011, p. 1 – 19, 2011.

SOLIVERES, S.; MAESTRE, F. T.; ULRICH, W. et al. Intransitive competition is widespread in plant communities and maintains their species richness. **Ecology Letters**, Oxford, v. 18, p. 790–798, 2015. DOI: 10.1111/ele.12456

WATZLAWICK, L. F.; ALBUQUERQUE, J. M.; REDIN, C. G.; LONGHI, R. V.; LONGHI, S. J. Estrutura, diversidade e distribuição espacial da vegetação arbórea na Floresta Ombrófila Mista em Sistema Faxinal, Rebouças (PR). **Ambiência**, Guarapuava, v. 7, p. 415-427, 2011.