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Original Article

Arthropod fauna on the abaxial and adaxial surfaces of *Acacia mangium* (Fabaceae) leaves

Fauna de artrópodes nas superfícies abaxial e adaxial de folhas de *Acacia mangium* (Fabaceae)

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Abstract

Acacia mangium (Willd., 1806) (Fabales: Fabaceae) is a fast growing, rustic, pioneer species, with potential to fix nitrogen, and for programs to recover degraded areas. The objective was to evaluate the distribution and the functional diversity of interactions and the K-dominance of arthropod groups on *A. mangium* saplings. The number of individuals of eleven species of phytophagous insects, three bee species, and fourteen natural enemy species were highest on the adaxial leaf surface of this plant. Abundance, diversity and species richness of phytophagous insects and natural enemies, and abundance and species richness of pollinators were highest on the adaxial *A. mangium* leaf surface. The distribution of five species of sap-sucking hemipterans and six of protocooperating ants (Hymenoptera), with positive interaction between these groups, and three bee species (Hymenoptera) were aggregated on leaves of *A. mangium* saplings. *Aethalion reticulatum* (L.) (Hemiptera: Aethalionidae) and *Bemisia* sp. (Hemiptera: Aleyrodidae); *Brachymyrmex* sp. and *Camponotus* sp. (Hymenoptera: Formicidae); and *Trigona spinipes* Fabricius (Hymenoptera: Apidae) were the most dominant phytophagous insects, natural enemies, and pollinators, respectively, on *A. mangium* leaves. Knowledge of preferred leaf surfaces could help integrated pest management programs.

Keywords: aggregation, distribution, diversity, insect, K-dominance, spiders.

Resumo

Acacia mangium (Willd., 1806) (Fabales: Fabaceae) é uma planta pioneira com rápido crescimento, rusticidade, potencial nitrificador e importante em programas de recuperação de áreas degradadas. O objetivo foi avaliar a distribuição e a diversidade funcional das interações e a dominância-K de grupos de artrópodes em árvores jovens de *A. mangium*. Os números de indivíduos de onze espécies de insetos fitófagos, três de abelhas e quatorze de inimigos naturais foram maiores na superfície adaxial de folhas dessa planta. A abundância, diversidade e riqueza de espécies de insetos fitófagos e inimigos naturais, e a abundância e riqueza de espécies de polinizadores foram maiores na face adaxial de folhas de *A. mangium*. A distribuição de cinco espécies de hemípteros sugadores de seiva e seis de formigas protocooperantes (Hymenoptera), com interação positiva entre esses grupos, e três de abelhas (Hymenoptera) foi agregada em folhas de plantas jovens de *A. mangium*. *Aethalion reticulatum* (L.) (Hemiptera: Aethalionidae) e *Bemisia* sp. (Hemiptera: Aleyrodidae); *Brachymyrmex* sp. e *Camponotus* sp. (Hymenoptera: Formicidae); e *Trigona spinipes* Fabricius (Hymenoptera: Apidae) foram os insetos fitófagos, inimigos naturais e polinizadores mais dominantes, respectivamente, em folhas de *A. mangium*. A definição da superfície foliar preferida pode auxiliar programas de manejo integrado de pragas.

Palavras-chave: agregação, distribuição, diversidade, insetos, dominância-K, aranhas.

1. Introduction

Acacia mangium (Willd.,1806) (Fabales: Fabaceae) is a fast growing, rustic pioneer species with potential for nitrification and high litter production (Caldeira et al., 2018; Eloy et al., 2018). The high nitrogen fixation rate of this plant, in symbiosis with diazotrophic bacteria, increases the production of biomass and nutrients through litter, favoring plant succession (Paula et al., 2018). The high adaptability of *A. mangium* to acidic and infertile soils makes this plant important for recovering degraded areas (Balieiro et al., 2005; Wang et al., 2013). *Acacia mangium*

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wood is used in the construction of furniture, cabinets, frames, doors and window components, boxes and crates and in the production of coal, coal briquettes and activated carbon (Hegde et al., 2013). The sap-sucking insect *Aethalion reticulatum* (L., 1767) (Hemiptera: Aethalionidae); the defoliating insects *Periphoba hircia* (Cramer, 1775) (Lepidoptera: Saturniidae), and *Tropidacris collaris* (Stoll, 1813) (Orthoptera: Romaleidae); the stem apex chewing insect *Trigona spinipes* (Fabr., 1793) (Hymenoptera: Apidae); and the wood-borer insect *Oncideres ocularis* (Thomson, 1868) (Coleoptera: Cerambycidae) damage *A. mangium* trees (Lemes et al., 2013; Parreira et al., 2014; Silva et al., 2015, 2020).

Herbivorous insects can damage different plant parts, including their leaves (adaxial and abaxial surfaces) (Leite et al., 2008). Sap-sucking insects prefer the abaxial leaf surface due to its softer tissue, thin epidermis and more protuberant veins (Leite et al., 2008; Damascena et al., 2017). In addition, they are better protected against natural enemies and climatic factors (e.g., solar radiation) on this leaf surface (Leite et al., 2008). On the other hand, arthropods, such as defoliating Coleoptera and Orthoptera may prefer the adaxial leaf surface where less effort is required for movement (Salerno et al., 2018). The preference of insect pests for this leaf surface helps in their control (Leite et al., 2008), which becomes more difficult in the case of pests that live and feed on the abaxial leaf surface (Naranjo and Flint, 1995).

The distribution of herbivorous insects and of their natural enemies can be completely randomized (i); in groups, such as aggregated or contagious (ii); or evenly spread with uniform - regular (iii) distributions on the host plants or on the ground (Nickele et al., 2010). Knowledge of insect distribution is important for sampling plans and pest management (Nickele et al., 2010; Soti et al., 2018; Fernandes et al., 2019). The number of insect species per location is usually high with few dominant species (Monteiro et al., 2019). K-dominance indicates the distribution and uniformity of individuals between species and facilitates the identification of potential pests (Gee et al., 1985).

Functional diversity includes different physical, biochemical, behavioral and phenological characteristics, which are measurable (Cadotte et al., 2011). These characteristics are called functional because they are important for understanding how species richness and diversity are related to the ecosystem (Cadotte et al. 2009; Flynn et al. 2011), determining when and where they may exist and their interspecific interactions (e.g., predator and prey) (McGill et al., 2006). For this reason, measuring and understanding species characteristics helps in decision-making in restoration and environmental conservation programs (Cadotte et al., 2011).

The terms "hypotheses" and "predictions" are confused in studies of ecology. The hypothesis is an idea that can be verified by examining the predictions, which result from the assumption that the first is true (Farji-Brener, 2004). Therefore, the objective of this research was to test the following hypotheses: i) the number of phytophagous insects and pollinators and their natural enemies or protocooperating ants will be higher on the adaxial leaf surface due to the lower effort required for movement, therefore resulting in higher ecological indices (abundance, diversity, and species richness) of these groups; ii) the distribution of arthropods will be aggregated on the same host sapling, mainly of sap-sucking and protocooperating insects (e.g., ants, eusocial insects), protecting them against competitors and predators; and iii) the k-dominance of polyphagous insect pests or omnivorous insects (e.g., ants) will be greater on *A. mangium* saplings (younger trees).

2. Material and Methods

2.1. Experimental site

This study was carried out in a degraded area (≈ 1 ha) of the "Instituto de Ciências Agrárias da Universidade Federal de Minas Gerais (ICA/UFMG)" in the municipality of Montes Claros, Minas Gerais state, Brazil (latitude 16° 51' 38" S, longitude 44° 55' 00" W, altitude 943 m) for 24 months (April 2015 to March 2017). The climate of this area, according to the Köppen climate classification (Alvares et al., 2013), is tropical dry, with annual precipitation and temperature between 1,000 and 1,300 mm and ≥ 18 °C, respectively. The soil is Neosol Litolic with an Alic horizon (Silva et al., 2020).

2.2. Experimental design

The *A. mangium* seedlings were prepared, in March 2014, in a nursery in plastic bags (16 × 24 cm) with reactive natural phosphate mixed with the substrate at a dosage of 160g and planted, at the same time, in the final site in September of this year. Each *A. mangium* seedling was planted in a hole (40 × 40 × 40 cm) when they were 30 cm high with a 2-meter spacing between each one. The soil was corrected with dolomitic limestone with the base saturation increased to 50%, natural phosphate, gypsum, FTE (Fried Trace Elements), potassium chloride and micronutrients based on the soil analysis. A total of 20 L of dehydrated sewage sludge with its biochemical characteristics defined (Silva et al. 2020) was placed in a single dose, per hole. The young *A. mangium* trees (saplings in the vegetative period) were irrigated twice a week until the beginning of the rainy season (October). The design was completely randomized with 48 replications (one sapling each) with the adaxial and abaxial leaf surfaces as the treatments.

2.3. Counting the arthropods

The number of leaves/branch, branches/sapling and height (m) of *A. mangium* were ≈ 23, 34, and 34 and 59, 1,6, and 2,8 in the first and second years, respectively (unpublished data). All insects (e.g., Formicidae - eusocial insects) and spiders were counted, between 7:00 A.M. and 11:00 A.M., by visual observation, every two weeks on the adaxial and abaxial surfaces of the first 12 leaves expanded, per sapling. These leaves were assessed, randomly, on branches (one leaf per position) in the basal, middle and apical parts of the canopy – vertical axis - (0 to 33%, 33 to 66% and 66 to 100% of total sapling height, respectively) and in the north, south, east and west directions - horizontal axis. A total of 12 leaves/sapling/evaluation were observed on 48 *A. mangium* saplings starting six months after transplantion during 24 months (27,648 total leaves), covering the entire sapling (vertical and horizontal axis), capturing the highest possible number of arthropods (insects and spiders), especially the rarest ones. The evaluator approached, carefully, firstly assessing the adaxial leaf surface and, if it was not possible to visualize the abaxial one, with a delicate and slow movement, lifting the leaf to visualize it. The position of leaves of *A. mangium* saplings is, in general, tilted upwards, facilitating the visual assessment of arthropods on their leaf surfaces. Insects with greater mobility (e.g., Orthoptera), that flew, on approach, were counted as long as they were recognized (e.g., Order). The arthropods (insects and spiders) were not removed from the saplings during the evaluation.

A few arthropod specimens (up to 3 individuals) per species were collected using an aspirator (two hours per week), at the beginning of the study (between transplantation and first evaluation, six months after), stored in flasks with 70% alcohol, separated into morphospecies, and sent to specialists for identification (see acknowledgments). Any visible arthropod, not yet computed in previous evaluations, was collected, coded and sent to a taxonomist of its group.

2.4. Statistical ecological indices

Each replication is the total of individuals collected on 12 leaves (three heights and four sides of the sapling). The distribution of arthropods was defined by the Chi-square test using the BioDiversity© Professional software, Version 2 (Krebs, 1998). The ecological indices (abundance, diversity and species richness) were calculated per group (phytophagous insects, pollinators, and natural enemies) and treatments (adaxial and abaxial surfaces) using the aforementioned program. Abundance and species richness were the total number of individuals and species (Begon et al., 2007), respectively, per sapling. The diversity was calculated using Hill´s formula per sapling (Hill, 1973).

The data for abundance, diversity and species richness of phytophagous insects, pollinators and natural enemies were subjected to a non-parametric statistical hypothesis, the Wilcoxon signed rank test (p-value < 0.05) (Wilcoxon, 1945) using the Statistics and Genetics Analysis (SAEG) program, version 9.1 (UFV, 2007) (Supplier: “Universidade Federal de Viçosa”, Brazil). The data were subjected to second-degree regression or principal component regression (PCR), when linear (p-value < 0.05) to verify the possible interactions (e.g. protocooperation) between groups of arthropods (phytophagous insects, pollinators and natural enemies, including spiders). Simple equations were selected based on the criteria: i) distribution of the data in the figures (linear or quadratic response), ii) the parameters used in these regressions were the most significant ones (p-value < 0.05), iii) p-value < 0.05 and *F* of the Analysis of Variance of these regressions, and iv) the determination coefficient of these equations (R^2). The PCR model uses principal component analysis, based on a covariance matrix, to obtain the regression. These reduce the dimensions of the regression, excluding those that contribute to collinearity, that is, linear relations between the independent variables (Bair et al., 2006). The parameters used in these equations were all significant (p-value <0.05) according to the selection of the variables by the “Stepwise” method using the statistical program mentioned.

K-dominance was calculated by plotting the cumulative percentage of abundance according to the logarithmic classification of the species (Lambshead et al., 1983), using the aforementioned BioDiversity program. The K-dominance values indicate the distribution of dominance and the uniformity of the number of individuals between species (Gee et al., 1985).

The data presented in the text were the significant ones (p-value < 0.05) and the remaining are in the supplementary material I (used to calculate the ecological indexes).

3. Results

A total of 2,497 arthropods were collected on *A. mangium* leaves, 24.69% of which were phytophagous (> Hemiptera: 16.61%), 66.38% of natural enemies (> 49.74% of ants - Hymenoptera) and 8.93% of pollinating bees (> 5.73% of *T. spinipes* Hymenoptera). The numbers of individuals of eleven phytophagous insect species, three bee species, and fourteen natural enemy species, were highest (p-value < 0.05) on the adaxial leaf surface. The abundance, diversity and species richness of phytophagous insects and of natural enemies, and abundance and species richness of pollinators (p-value <0.05) were highest on the adaxial *A. mangium* leaf surface (Tables 1 and 2).

The distributions of five sap-sucking hemipterans, six protocooperating ant species (Hymenoptera) and three bee species (Hymenoptera) were the most abundant ones and aggregated on leaves of *A. mangium* saplings (Table 1). The number of Araneidae (Araneae) correlated, positively, with those of *Cerotoma* sp. (Coleoptera: Chrysomelidae), total Orthoptera, *Tropidacris collaris* (Stoll, 1813) (Orthoptera: Romaleidae) and *Trigona spinipes* (Fabr., 1793) (Hymenoptera: Apidae); Oxyopidae (Araneae) with *Tetragonisca angustula* (Latreille, 1811) (Hymenoptera: Apidae); *Aethalium reticulatum* (L., 1767) (Hemiptera: Aethalionidae) with *Pseudomyrmex termitarius* (Smith, 1855) (Hymenoptera: Formicidae); and *P. termitarius* with *Balclutha hebe* (Kirkaldy, 1906) (Hemiptera: Cicadellidae) and *A. reticulatum*. The number of Sternorrhyncha predators, Dolichopodidae, *T. collaris*, and *T. angustula* was lower on the *A. mangium* leaves with high numbers of protocooperating ants and those of *T. angustula* and spiders lower on the *A. mangium* leaves with high numbers of *T. spinipes* and phytophagous Hemiptera (Table 3).

The K-dominance (k) and total numbers (n) of *A. reticulatum* individuals were higher on the adaxial (k= 34.9 and n= 156, respectively) leaf surface while those of *Bemisia* sp. (Hemiptera: Aleyrodidae) were higher on the abaxial (k= 41.5 and n= 71, respectively) leaf surface. *Brachymyrmex* sp. and *Camponotus* sp. (Hymenoptera: Formicidae) were the most dominant natural enemies on the adaxial (k= 20.8 and n= 363, respectively), and abaxial

Table 1. Number of arthropods and their aggregated (Aggr.) or random (Ran.) distributions (Dist.) on the adaxial and abaxial leaf surfaces of *Acacia mangium* (Fabales: Fabaceae)/sapling (mean ± SE).

Arthropods	**Leaf surface***		**QT****
	Adaxial	**Abaxial**	**Dist.**
Araneae: Araneidae	1.63±0.28	0.38±0.11	Aggr.
Oxyopidae	1.00±0.19	0.25±0.09	Aggr.
Salticidae	1.08±0.24	0.54±0.22	Aggr.
Coleoptera: Chrysomelidae, *Stereoma anchoralis* Lacord.	0.58±0.22	0.08±0.05	---
Curculionidae	0.13±0.06	0.00±0.00	---
Lampyridae, *Photinus* sp.	0.17±0.09	0.00±0.00	Ran.
Diptera: Dolichopodidae	5.17±0.52	0.17±0.07	Aggr.
Syrphidae, *Syrphus* sp.	0.33±0.13	0.00±0.00	---
Otittidae, *Euxesta* sp.	0.75±0.16	0.00±0.00	---
Hemiptera: Aethalionidae, *Aethalium reticulatum* L.	6.50±4.4	0.04±0.04	Aggr.
Cicadellidae, *Balclutha hebe* Kirkaldy	0.92±0.10	0.17±0.09	---
Erythrogonia sexguttata Fabricius	0.33±0.13	0.00±0.00	---
Membracidae	1.13±0.38	0.08±0.05	Aggr.
Nogodinidae	0.17±0.09	0.00±0.00	Ran.
Bladina sp.	0.17±0.07	0.00±0.00	---
Pseudococcidae, *Phenacoccus* sp.	0.00±0.00	2.63±1.22	Aggr.
Hymenoptera: Apidae, *Apis mellifera* L.	0.71±0.20	0.17±0.13	Aggr.
Tetragonisca angustula Latreille	2.42±0.35	0.04±0.04	Aggr.
Trigona spinipes Fabricius	5.58±1.30	0.38±0.17	Aggr.
Formicidae, *Brachymyrmex* sp.	15.13±6.08	0.00±0.00	Aggr.
Camponotus sp.	13.08±1.91	1.21±0.32	Aggr.
Cephalotes sp.	4.00±1.99	0.08±0.05	Aggr.
Ectatoma sp.	1.83±0.37	0.04±0.04	Aggr.
Pheidole sp.	9.50±1.03	0.71±0.25	Aggr.
Pseudomyrmex termitarius Smith	5.63±0.81	0.54±0.21	Aggr.
Vespidae, *Polybia* sp.	4.33±2.70	0.08±0.05	Aggr.
Mantodea: Mantidae, *Mantis religiosa* L.	0.21±0.08	0.04±0.04	---
Orthoptera:Romaleidae, *Tropidacris collaris* Stoll.	2.13±0.28	0.08±0.05	Aggr.
Tettigoniidae	1.67±0.25	0.08±0.05	Aggr.

*WT = Wilcoxon test; **QT = Chi-square test; n= 48 per treatment; --- p-value > 0.05, and the remaining are significant.

(k= 21.0 and n= 29, respectively) leaf surfaces, respectively and *T. spinipes* was the dominant pollinator insect on the adaxial (k= 64.1 and n= 134) and abaxial (k= 64.3 and n= 9) leaf surfaces of *A. mangium* leaves.

4. Discussion

The greater number, in aggregate pattern, especially of sap-sucking hemipterans (i.e., *A. reticulatum*) and their protocooperating ants (i.e., *P. termitarius*), and the three bee species (i.e., *T. spinipes*) on the adaxial leaf surface of *A. mangium* saplings increased the ecological indices (abundance, diversity and species richness) of these groups (i.e. phytophagous insects) on this leaf surface of *A. mangium* saplings. This is, probably, due to the lower effort required by these arthropods to hold onto this surface compared to the abaxial one, confirming the first hypothesis (preference for the adaxial leaf surface). The wax content, hairiness, roughness, regular shape or not and the type and number of veins in the leaves of host plants affect arthropod walking and they prefer the leaf surface (adaxial or abaxial) requiring lower effort for movement (Peeters, 2002; Gorb et al., 2008; Gorb and Gorb, 2009; Prüm et al., 2012; Salerno et al., 2018). *Acacia mangium* leaves are large (11-27 cm long × 3-10 cm wide), hairless, smooth and present four main longitudinal ribs (Hegde et al., 2013)

Table 2. Abundance, diversity and species richness of phytophagous insects, pollinators, and natural enemies on the adaxial and abaxial leaf surfaces of *Acacia mangium* (Fabales: Fabaceae)/sapling (mean ± SE).

	Leaf surface		WT*	
	Adaxial	**Abaxial**	***TV£***	***P***
Abundance of Phytopagous	24.21 ± 5.18	7.58 ± 2.21	4.2	0.00
Diversity of Phytopagous	17.02 ± 2.14	4.18 ± 0.81	3.8	0.00
Species Richness of Phytopagous	8.25 ± 0.55	2.29 ± 0.33	5.4	0.00
Abundance of Polinators	8.71 ± 1.38	0.58 ± 0.21	5.2	0.00
Diversity of Polinators	1.44 ± 0.44	0.58 ± 0.19	0.7	0.25
Species Richness of Polinators	2.08 ± 0.16	0.38 ± 0.11	5.3	0.00
Abundance of Natural Enemies	63.88 ± 7.33	5.17 ± 0.70	5.7	0.00
Diversity of Natural Enemies	18.36 ± 1.43	6.85 ± 0.84	4.9	0.00
Species Richness of Natural Enemies	9.71 ± 0.49	3.13 ± 0.30	5.6	0.00

*WT = Wilcoxon test; n= 48 per treatment; £TV = Teste value.

Table 3. Relationships between the numbers of *Aethalium reticulatum*, Araneidae, *Balclutha hebe*, *Cerotoma* sp. (Cer.), Dolichopodidae, Orthoptera, Oxyopidae, phytophagous Hemiptera (Hemiptera), protocooperating ants (Ants), *Pseudomyrmex termitarius* (Pter.), spiders, Sternorrhyncha predators, *Tetragonisca angustula* (Tangu.), *Trigona spinipes* (T. spi.), and *Tropidacris collaris* (*T. collaris*) on *Acacia mangium* (Fabales: Fabaceae)/sapling.

Principal component regression equations	*ANOVA*		
	R^2	***F***	***P***
Spiders= 1.74 + 0.66 x Orthoptera -0.04 x Hemiptera	0.38	13.50	0.00
Araneidae= 0.33 + 0.95 x Cer. + 0.28 x *T. collaris* + 0.07 x T.spi.	0.44	11.63	0.00
Oxyopidae= 0.27 + 0.29 x *Tetragonisca angusta*	0.34	23.42	0.00
Aethalium reticulatum= -2.50 + 1.87 x *Pseudomyrmex termitarius*	0.22	13.02	0.00
Pter.= 1.76 + 1.80 x *Balclutha hebe* + 0.11 x *Aethalium reticulatum*	0.30	9.69	0.00
Second degree regression equations			
Sternorrhyncha predators = 0.49 + 0.19 x Ants -0.001 x Ants^2	0.60	33.74	0.00
Dolichopodidae = -0.03 + 0.17 x Ants -0.001 x Ants^2	0.73	62.09	0.00
Tropidacris collaris = -0.01 + 0.06 x Ants -0.0003 x Ants^2	0.60	33.37	0.00
Tetragonisca angustula = -0.09 + 0.07 x Ants -0.003 x Ants^2	0.63	37.97	0.00
Tetragonisca angustula = 0.56 + 0.37 x Tspi. -0.01 x Tspi.^{2}	0.28	8.78	0.00

n = 96.

and probably with a surface that provides restrict contact for arthropods to hold onto, which may have affected the number of these organisms on the adaxial leaf surface.

The aggregate distribution of five species of sap-sucking hemipterans, six protocooperating ant species (Hymenoptera) and three bee species (Hymenoptera) on *A. mangium* sapling leaves confirms the second hypothesis (distribution will be aggregated) as found for *A. reticulatum* and *Camponotus* sp. on *Bauhinia forficata* (Link, 1821) (Fabales: Fabaceae), Acrididae (Orthoptera) on several plants, *Bemisia tabaci* (Genn., 1889) (Hemiptera: Aleyrodidae) on *Capsicum annuum* (L., 1753) (Solanales: Solanaceae), *Dendroctonus ponderosae* (Hopkins, 1902) (Coleoptera: Curculionidae) on pine and *T. spinipes* on cucurbits (Bashir and Hassanali, 2010; Serra and Campos, 2010; Barônio et al., 2012; Goodsman et al., 2016; Kim et al., 2017). This behavior can increase the local population density of arthropods (Rivault et al., 1998; Le Goff et al., 2009), thus facilitating feeding and mating, attraction of mutualistic species, and protection against predators; however, it can also result in conflicts (e.g., competition) between them (Le Goff et al., 2009; Boulay et al., 2019). The positive correlation between spiders and phytophagous insects on *A. mangium* saplings is, probably, due to the predators following their prey, as observed on *Caryocar brasiliense* (Cambess., 1828) (Malpighiales: Caryocaraceae), *Leucaena leucocephala* (Lam.) de Wit (1961) (Fabales: Fabaceae) and *Pistacia lentiscus* (L., 1753) (Sapindales: Anacardiaceae) (Auslander et al., 2003; Damascena et al., 2017; Leite et al., 2017). The increase in the number of phytophagous insects (e.g., *Cerotoma* sp.) and pollinators (e.g., *T. spinipes*) allows higher numbers of spiders (e.g., Araneidae) on *A. mangium* saplings because the latter prey on insects in natural and agricultural systems (Venturino et al., 2008; Leite et al., 2012, 2016). On the other hand, the reduction in the number of spider individuals with the increase in that of sap-sucking insects is, possibly, due to interactions between protocooperating ants (e.g., *P. termitarius*) with these Hemiptera (e.g., *A. reticulatum*) on *A. mangium* saplings. Trophobiotic interactions between ants (protecting against natural enemies) and Sternorryncha (supplying sugary food substances) are one of the main mechanisms that maintain the overabundance of ants in ecosystems (Kaminski et al., 2010; Silva and Fernandes, 2016; Klimes et al., 2018), which may decrease that of natural enemies, including spiders (Venturino et al., 2008; Leite et al., 2012, 2016). The reduction in populations of Sternorrhyncha predators (e.g., Dolichopodidae) on *A. mangium* saplings by protocooperating ants shows the negative impact of the latter on the biological control of sap-sucking hemipterans (Karami-Jamour et al., 2018; Tong et al., 2019). The reduction in the number of *T. angustula* by *T. spinipes* indicate possible competition for food and space as observed for sap-sucking insects (e.g., aphids) with chewing insects (e.g., beetles), *Eurytoma* sp. (Hymenoptera: Eurytomidae) with three other galling hymenopterans on leaves of *C. brasiliense* (Leite et al., 2009, 2012, 2017) and *T. spinipes* with *Apis mellifera* (L., 1758) (Hymenoptera: Apidae) and *T. angustula* on cucurbits and *A. mangium* (Serra and Campos, 2010; Silva et al., 2020). Phylogenetic proximity tends to favor the formation and maintenance of groups of mixed species (eusocial or gregarious), possibly, due to similar size, life cycle and movement with easier communication between them (Boulay et al., 2019). However, it can increase competition between species that share similar ecological niches (Boulay et al., 2019). The balance between resource sharing and competition is important to understand species clusters, as well as for those occupying the same ecological niche presenting lower food availability or productive partners (Boulay et al., 2019). Interspecific competition can disproportionately benefit one species at the expense of another when arthropods use mixtures of chemical compounds, such as hydrocarbons, to communicate between them (Boulay et al., 2019).

The higher K-dominance and number of the phytophagous Hemiptera *A. reticulatum* and *Bemisia* sp., of the natural enemies *Brachymyrmex* sp. and *Camponotus* sp. and of the pollinator *T. spinipes* can be explained by the first two being pests in different cultures (polyphages) which may be feeding and reproducing on *A. mangium* saplings, confirming the third hypothesis (k-dominance of polyphagous pest insects or omnivorous insects will be greatest). The others are protocooperating sap-sucking insects, such as *A. reticulatum*, a pest that reduces the development of fruits and sprouts, leading to hypertrophy and cracks in the apex of seedlings and possibly killing plants of *Erythrina speciosa* (Andrews, 1806) (Fabales: Fabaceae) (Araújo et al., 2010; Zanuncio et al., 2015) in addition to damaging those of *A. mangium*, *Triplaris americana* (L., 1759) (Caryophyllales: Polygonaceae) and *Vernonia condensata* (Baker, 1875) (Asterales: Asteraceae) (Menezes et al., 2013; Pires et al., 2014; Silva et al., 2020). The whitefly *B. tabaci* transmits viruses to agricultural plants such as *Cucumis melo* (L., 1753) (Cucurbitales: Cucurbitaceae) (Felicio et al., 2019). Sap-sucking insects, especially at high densities, can be associated with ants of the genera *Camponotus* and *Brachymyrmex* with mutual benefit with direct correlation between these groups (Novgorodova, 2015; Sanchez et al., 2020) because they collectively and aggressively defend their resources (e.g., sap-sucking insects) (Novgorodova, 2015). The greater numbers of *Brachymyrmex* sp., *Camponotus* sp., and *T. spinipes* agrees with reports for these insects on *L. leucocephala* trees, which may be due to attraction by extrafloral nectaries in the leaf petioles of this plant (Damascena et al., 2017), and on *A. mangium*, with an extrafloral nectary on the leaf base (Hegde et al., 2013). The high numbers of *T. spinipes* is a common feature because this insect was reported in this condition on *A. mangium*, *Brassica oleracea* var. italica (Plank, 1794) (Brassicales: Brassicaceae), *L. leucocephala* and *Vaccinium* sp. (Ericales: Ericaceae) (Silveira et al., 2010; Dos Santos et al., 2012; Damascena et al., 2017; Silva et al., 2020). This insect removes fiber from buds and growth parts to build its nests and reduces pollination (e.g., Cucurbitaceae) because it does not carry pollen and frequently dislodges it from the plant (Serra and Campos, 2010). Bees associated with flowers obtain most of their food resources (e.g., nectar and pollen), but some of their interactions (e.g., *T. spinipes*) with sap-sucking insects (e.g., *A. reticulatum*) are an alternative to obtain honeydew as food (Dos Santos et al., 2019).

5. Conclusions

The higher values of ecological indices (e.g., abundance) of arthropods (e.g., phytophagous) on the adaxial *A. mangium* leaf surface is probably due to the reduced effort (e.g., easier walking) for insect on this surface compared to the abaxial one. Protocooperating ants, the most dominant natural enemies on *A. mangium* leaves, can reduce the growth of this plant because they are associated with sap-sucking insects and chase away natural enemies like spiders. The greater K-dominance of *A. reticulatum* and *T. spinipes* on *A. mangium* leaves may be a problem, because these insects can damage leaves and sprouts of this plant. The aggregation behavior of arthropods on the adaxial leaf surface of *A. mangium* favors the control of potential pests of this plant.

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Supplementary Material

Supplementary material accompanies this paper.

Supplementary material I. Number of arthropod species per leaf (mean ± SE) collected on *Acacia mangium* (Fabales: Fabaceae) sapling used to calculate the ecological indexes which were non-significant (p-value > 0.05)

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