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Original Article

# Positive relationships between insects and negative with spiders on *Acacia auriculiformis* (Fabaceae) plants in the savannah biome and their distribution pattern

## Relações positivas entre insetos e negativos com aranhas em plantas de *Acacia auriculiformis* (Fabaceae) no bioma savana e seus padrões de distribuição

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### Abstract

Forest restoration is mainly based on plant-soil relationships and plant species with economic potential, but those between insects and other arthropods are also important to this reestablishment. The objective was to evaluate, during 24 months, the relationships between tending ants, Hemiptera phytophagous, predators and their distribution pattern (aggregated, random or uniform). The arthropods were sampled, stored and identified and their relationships and distribution patterns calculated with the BioDiversity-Pro software. The number of tending ants and phytophagous Hemiptera, *Brachymyrmex* sp. and *Aethalion reticulatum*, *Cephalotes* and Aleyrodidae were positively correlated. Tending ants were negatively correlated with Sternorrhyncha predators on *A. auriculiformis* saplings. The distribution of arthropods was aggregated, except for *Teudis* sp. and *Cephalocoema* sp., with a random pattern. The herbivores *Stereoma anchoralis*, *Aethalion reticulatum* and *Tetragonisca angustula* and the predators *Brachymyrmex* sp. and Dolichopodidae were the most abundant arthropods. The relationships between the arthropods studied on *A. auriculiformis* indicate that this plant, even introduced, is suitable for programs to recover degraded areas in the savannah.

**Keywords:** aggregate, dispersal, random, savannah, tending ants, tropical.

### Resumo

A restauração florestal é baseada nas relações planta-solo e espécies vegetais com potencial econômico, mas aquelas entre insetos e outros artópodes são, também, importantes para esse processo. O objetivo foi avaliar as relações entre formigas, fitófagos Hemiptera e predadores e a distribuição (agregada, aleatória ou regular) de artrópodes, por 24 meses, em mudas de *Acacia auriculiformis* utilizadas na recuperação de áreas degradadas. Os artrópodes foram amostrados, armazenados e identificados e suas relações e padrões de distribuição calculados com o software BioDiversity-Pro. Os números de formigas cuidadoras se correlacionaram, positivamente, com os dos Hemiptera fitófagos *Aethalion reticulatum*, *Brachymyrmex* sp. e *Cephalotes* e Aleyrodidae. Insetos cuidadores de Hemiptera foram, negativamente, correlacionados com predadores Sternorrhyncha em plantas de *A. auriculiformis*. A distribuição dos artrópodes foi agregada, exceto *Teudis* sp. e *Cephalocoema* sp., com padrão aleatório. *Aethalion reticulatum*, *Stereoma anchoralis* e *Tetragonisca angustula* foram os herbívoros e *Brachymyrmex* sp. e Dolichopodidae os predadores mais abundantes. As relações entre os artrópodes estudados em *A. auriculiformis* indicam que esta planta, mesmo introduzida, é adequada para programas de recuperação de áreas degradadas no cerrado.

**Palavras-chave:** agregado, aleatória, dispersão, formigas cuidadoras, savana, tropical.

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## 1. Introduction

Forest restoration is mainly based in plant-soil relationships including the use of *Acacia auriculiformis* A. Cunn. ex Beth (Fabales: Fabaceae) with litter deposition with high N contents (Mota et al., 2023) and economic importance (Manhães et al., 2013). However, the relationships between organisms, one of the main indicators of ecosystem restoration, need further studies (Moir et al., 2018; Oliveira et al., 2021). Arthropods are important in nutrient cycling (Manhães et al., 2013), honeydew supply (Moir et al., 2018) and bird food (Valencia-Cuevas and Tovar-Sánchez, 2015), but defoliators reduce plant development (Almeida et al., 2021; Mota Filho et al., 2021). In addition, insects respond to environmental changes and, therefore, they are used as bioindicators (Mota et al., 2023; Oliveira et al., 2021) and to evaluate tritrophic interactions after savannah fires (Pires and Del-Claro, 2014). Increasing temperature changes the patterns and guild structure of herbivorous insects associated to host plants (Monteiro et al., 2020) and temperature, relative humidity, foliage chemistry, changes in plant development and exposure to predators impact arthropods (Schowalter et al., 2005). The sequential flowering of Malpighiaceae species affects the dynamics of interactions between herbivores, ants and plants within multitrophic networks, and the quantity and quality of food resources directly impact their population and community (Vilela et al., 2014). The ant species visiting *Peixotoa tomentosa* A. Juss (Malpighiaceae) floral nectaries may be more critical to the outcome of plant-ant interaction than the herbivore abundance (Vilela et al., 2014). This emphasizes the importance of using the adequate plants for reforestation programs and ecosystem restablishment.

The potential of arthropods as conservation indicators has been demonstrated in oak plantations (Valencia-Cuevas and Tovar-Sánchez, 2015). Mutualistic relationships affect community structure and species interactions and, therefore, those between ants need further studies (Guerra et al., 2011; Pires and Del-Claro, 2014). Fire altered the ant community on plants with extrafloral nectaries in tropical savanna in Brazil (Pires and Del-Claro, 2014). However, the knowledge on savanna recovering programs is limited.

Savannah cover about one third of the Earth's surface and anthropogenic activities increase vegetation and soil losses in this biome. Savannah soils are rich in potassium (K), but plant productive in this biome is low due to reduced nitrogen (N), phosphorus (P) and organic matter. In addition, these soils are shallow, rocky, and compacted, facilitating the carryover of nutrients after organic matter deterioration (Tang and Li, 2014). Vegetation affects temperature, humidity, and wind speed and, consequently, floristic composition and species diversity (Valencia-Cuevas and Tovar-Sánchez, 2015).

The *Acacia* spp. (Fabales: Fabaceae) growth in disturbed areas (Balieiro et al., 2018) is rapid with biological fixation of atmospheric nitrogen (BFAN) by associated rhizobacteria (Hung et al., 2017). *Acacia auriculiformis* stands out for its wood durability, low susceptibility to diseases and adaptability to soil variations such as erosion, low fertility, swamps, and saline (Wang et al., 2017). This plant increases moisture retention, deposition of potassium and organic carbon in the soil (through litter) and by phytoextracting heavy metals through mycorrhizal symbiosis (Rana and Maiti, 2018). *Acacia auriculiformis* is used in ecological restoration, but the distribution of the arthropod fauna in the treetops of this plant needs further studies (Nghiem et al., 2011), especially in commercial plantations (Hegde et al., 2013). This is necessary; as this plant is exotic, used in soil recovery and commercially important (Hegde et al., 2013) with extrafloral nectaries (Agrawal et al., 2006). These structures are important to fauna (Agrawal et al., 2006), as food for ants, bees, and wasps (Moir et al., 2018). Ants, in turn, protect the plant against herbivores by reducing leaf area losses and increasing fruit production (Pires and Del-Claro, 2014). The richness and diversity of phytophagous arthropods are usually lower on introduced plants with a great number of generalist herbivores (Valencia-Cuevas and Tovar-Sánchez, 2015).

Conservation studies based on the biogeographic theory use monitoring data over longer periods (Price et al., 2004). The role of each species in the community, such as *A. auriculiformis*, an introduced plant (Agrawal et al., 2006; Silva et al., 2023) and the relationships between insects, as indicators of ecosystem stability and recovery, should be studied. The objective was to evaluate, during 24 months, the relationships between tending ants, Hemiptera phytophagous, predators and the distribution pattern (aggregated, random or uniform) of arthropods on *A. auriculiformis* saplings used to recover degraded areas. The tested hypotheses are that tending ants benefit sucking insects by protecting them against predators and that the distribution of arthropods on the *A. auriculiformis* canopy can be aggregated (i), high population density, random (ii), probably determined by chance, oruniform (iii) with regular distribution (Rodrigues et al., 2010).

## 2. Methods

### *2.1. Study area*

The study was carried out in a severely degraded area of the Institute of Agricultural Sciences of the Federal University of Minas Gerais (ICA/UFMG) in the municipality of Montes Claros, Minas Gerais State, Brazil (latitude of 16º51'38 S, longitude of 44º55' 00" W, altitude 943 m) for 24 months (April 2015 to March 2017). The climate of the area, according to the Köppen climate classification (Alvares et al., 2013), is of dry tropical with annual precipitation between 1,000 and 1,300 mm, dry winter, and average annual temperature ≥18ºC. The soil is of the Litholic Neosol type, with an Alic horizon with described physicochemical characteristics (Silva et al., 2020).

### *2.2. Experimental design*

Seedlings of *A. auriculiformis* were prepared in March 2014 in a nursery in plastic bags (16 x 24 cm) with substrate mixed with 160 g of reactive rock phosphate. The seedlings, with 30 cm high, were planted in holes (40 x 40 x 40 cm) spaced two meters apart. The soil from these holes was corrected with dolomitic lime, increasing the base saturation to 50%, and adding gypsum, micronutrients, rock phosphate, potassium chloride and trace elements, according to soil analysis. Twenty liters of dehydrated sewage sludge with chemical and biological attributes described (Silva et al., 2020) were placed per hole in a single dose. The 48 seedlings of *A. auriculiformis* were irrigated twice a week until the beginning of the rainy season. This initial work aimed to identify the relationships of insects and spiders on *A. auriculiformis* because it is an exotic species widely used in the recovery of degraded areas. For this reason, no control group was needed and all arthropods were evaluted.

### *2.3. Arthropod collection*

Twelve leaves/plant/evaluation, from each of the 48 *A. auriculiformis* plants were sampled during 24 months from the age of six months, totaling 27,648 leaves during the experimental period. Insects were counted, between 7:00 and 11:00 A.M. on the abaxial and adaxial leaf sides from the apical, middle, and basal heights of the canopy in the north, south, east, and west orientations. Each sample consisted of 1,152 values of leaves from two leaf sides, three plant heights, four cardinal orientations, and 48 *A. auriculiformis* plants per replication where the arthropods were counted. The averages of arthropods per leaf and tree sides were used in the subsequent analysis to avoid pseudo-replication. The Arthropod specimens collected were stored in bottles with 70% alcohol, separated into morphospecies, and sent for identification.

### *2.4. Data analysis*

The experimental design was in a completely randomized block (rows of trees, planting lines) with six replications, and eight plants each, totaling 48 *A. auriculiformis* plants. Data were submitted to simple regression analysis at $P<0.05$ to verify the correlations between tending ants with phytophagous Hemiptera and predators. The average data were the numbers of arthropods on the leaf faces per tree. Data were submitted to second-degree regression analysis or principal components (PCR), when linear (p-value < 0.05) to verify the interactions between groups of arthropods. The criteria to selecting the simple equations were: data distribution in the figures (linear or quadratic response) (i), the parameters used in these regressions were the most significant p-value <0.05 (ii), and F of the analysis of variance of these regressions (iii), and the coefficient of determination of these equations ($R^2$) (iv). The PCR model based on a covariance matrix uses principal component analysis to obtain the regression. This reduces the dimensions of the regression, excluding those that contribute to collinearity, that is, linear relationships between independent variables (Bair et al., 2006). The parameters used in these equations were all significant according to the selection of variables by applying the "Stepwise" method (p-value <0.05). Arthropod interactions and distribution were defined by the Chi-square test using BioDiversity © Professional, Version 2 (Krebs, 1998) software. Abundance was calculated by group of sampled insects and treatments (lower, middle and upper thirds) using the aforementioned program. Abundance was the total number of individuals and species (Begon et al., 2007), respectively, per plant and the data obtained submitted to a non-parametric statistical hypothesis with the Wilcoxon signed rank test (p-value <0.05 (Wilcoxon, 1945) using Statistical and Genetic Analysis (SAEG Program, version 9.1 (UFV, 2007) (Provider: "Universidade Federal de Viçosa", Brazil).

## 3. RESULTS

### *3.1. Correlations between tending ants and phytophagous Hemiptera*

Correlations between numbers of tending ants and *Aethalion reticulatum* L. (Hemiptera: Aethalionidae), Aleyrodidae (Hemiptera), *Brachymyrmex* sp. (Hymenoptera: Formicidae), *Cephalotes* sp. (Hymenoptera: Formicidae), and phytophagous Hemiptera were positive and that of tending ants with Sternorrhyncha predators negative on *A. auriculiformis* saplings (Figure 1).

### *3.2. Insect distribution patterns on Acacia auriculiformis saplings*

The distribution patterns of the Coleoptera phytophagous [*Cerotoma* sp., *Parasyphraea* sp. and *Stereoma anchoralis* Lacord (Chrysomelidae)], Diptera [*Euxesta* sp. (Ulidiidae)], Hemiptera [Achilidae, *Aethalion reticulatum* L. (Aethalionidae), Aleyrodidae, *Balclutha hebe* Kirkaldy and *Erythrogonia sexguttata* Fabricius (Cicadellidae), Membracidae and Pachycoridae (Scutelleridae) Scopoli (Scutelleridae) Pachycoridae, pollinators [*Apis mellifera* L. and *Tetragonisca angustula* Latreille (Hymenoptera: Apidae)], and natural enemy spiders (Araneae and Oxyopidae), Diptera (Dolichopodidae), Hemiptera [*Podisus* sp. (Pentatomidae)] and Hymenoptera [*Brachymyrmex* sp., *Camponotus* sp., *Cephalotes* sp., *Ectatomma* sp., *Pheidole* sp., and *Pseudomyrmex termitarius* Smith (Formicidae), and *Polybia* sp. (Vespidae)] were aggregated ($P < 0.05$) on the *A. auriculiformis* leaves (Table 1).

The distribution of phytophagous Orthoptera [*Cephalocoema* sp. (Proscopiidae)] and natural enemies [Araneae and *Teudis* sp. (Anyphaenidae)] was random ($P < 0.05$) on the *A. auriculiformis* leaves (Table 1).

### *3.3. Most abundant arthropods on Acacia auriculiformis sapling*

The numbers of individuals of the phytophagous insects *S. anchoralis* and *A. reticulatum*; the native stingless bees *T. angustula*; and the natural enemies *Brachymyrmex* sp. and Dolichopodidae were the highest on *A. auriculiformis* leaves (Table 2).

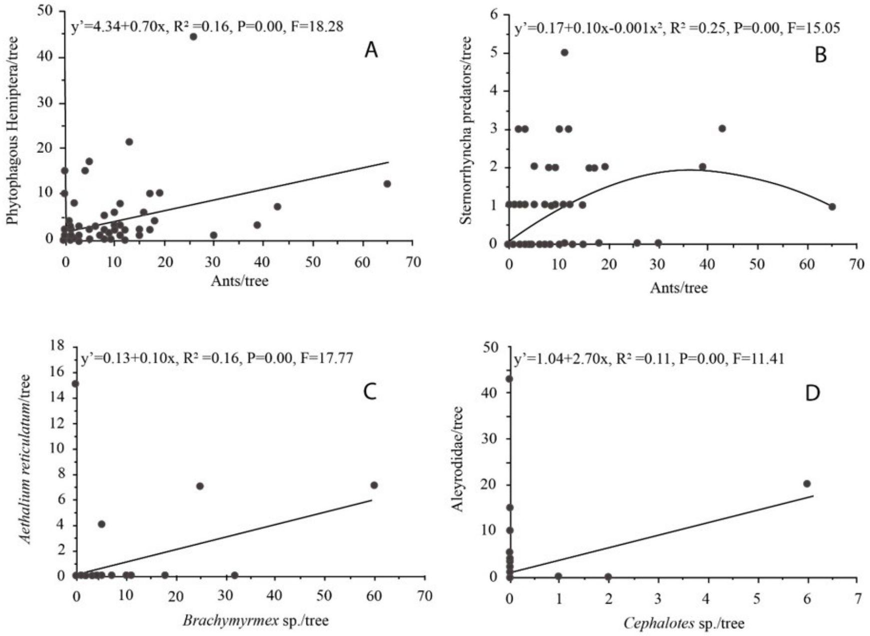

**Figure 1.** Relations between phytophagous Hemiptera with ants (A), Sternorrhyncha predators with ants (B), *Aethalium reticulatum* with *Brachymyrmex* sp. (C) and Aleyrodidae with *Cephalotes* sp. (D) on *Acacia auriculiformis* sapling.

**Table 1.** Random (Ra), regular (Re) and aggregated (Ag) distribution pattern (D) of arthropods on *Acacia auriculiformis* (Fabales: Fabaceae) leaves in a severely degraded area of the Instituto de Ciências Agrárias of the Universidade Federal de Minas Gerais in Montes Claros, Minas Gerais State, Brazil.

| Order: Family | Genus: Species | Chi-square | | | | |
|---|---|---|---|---|---|---|
| | | **Var** | **Med** | **Chi** | ***P*** | **D** |
| Araneae: Anyphaenidae | *Teudis* sp. | 0.09 | 0.07 | 106.0 | 0.04 | Ra |
| Oxyopidae | | 0.14 | 0.10 | 118.0 | 0.01 | Ag |
| Coleoptera: Chrysomelidae | *Cerotoma* sp. | 0.14 | 0.10 | 118.0 | 0.01 | Ag |
| | *Parasyphraea* sp. | 0.52 | 0.24 | 181.6 | 0.00 | Ag |
| | *Stereoma anchoralis* | 1.28 | 0.58 | 182.4 | 0.00 | Ag |
| Diptera: Dolichopodidae | | 0.71 | 0.51 | 115.2 | 0.01 | Ag |
| Ulidiidae | *Euxesta* sp. | 0.07 | 0.05 | 122.0 | 0.00 | Ag |
| Hemiptera: Achilidae | | 0.05 | 0.02 | 166.0 | 0.00 | Ag |
| Aethalionidae | *A. reticulatum* | 32.28 | 1.48 | 829.9 | 0.00 | Ag |
| Aleyrodidae | | 3.93 | 0.39 | 1814.8 | 0.00 | Ag |
| Cicadellidae | *Balclutha hebe* | 0.52 | 0.23 | 188.8 | 0.00 | Ag |
| | *E. sexguttata* | 0.07 | 0.05 | 122.0 | 0.00 | Ag |
| Membracidae | | 1.55 | 0.44 | 292.2 | 0.00 | Ag |
| Pentatomidae | *Podisus* sp. | 0.06 | 0.04 | 137.0 | 0.00 | Ag |
| Scutelleridae | *Pachycoris torridus* | 0.21 | 0.13 | 134.1 | 0.00 | Ag |
| Hymenoptera: Apidae | *Apis mellifera* | 0.27 | 0.14 | 156.0 | 0.00 | Ag |
| | *T. angustula* | 1.14 | 0.45 | 209.6 | 0.00 | Ag |
| Formicidae | *Brachymyrmex* sp. | 66.80 | 2.57 | 2156.2 | 0.00 | Ag |
| | *Camponotus* sp. | 7.57 | 1.82 | 345.0 | 0.00 | Ag |
| | *Cephalotes* sp. | 0.48 | 0.11 | 373.7 | 0.00 | Ag |
| | *Ectatomma* sp. | 0.96 | 0.37 | 215.6 | 0.00 | Ag |
| | *Pheidole* sp. | 5.30 | 1.63 | 269.5 | 0.00 | Ag |
| | *P. termitarius* | 1.59 | 0.63 | 208.5 | 0.00 | Ag |
| Vespidae | *Polybia* sp. | 0.40 | 0.29 | 116.0 | 0.01 | Ag |
| Orthoptera: Proscopiidae | *Cephalocoema* sp. | 0.09 | 0.07 | 106.0 | 0.04 | Ra |
| Romaleidae | *Tropidacris collaris* | 0.69 | 0.48 | 119.6 | 0.01 | Ag |

*A. reticulatum= Aethalion reticulatum, E. sexguttata= Erythrogonia sexguttata*, *T. angustula= Tetragonisca angustula, P. termitarius= Pseudomyrmex termitarius*, Med= Mediana, Var.= variance. *fd*= 83.

**Table 2.** Aggregated (Ag), random (Ra) or regular (Re) distribution of arthropods on *Acacia auriculiformis* (Fabales: Fabaceae) sapling.

| Order: Family | Genus: Species | Chi-square | | | | |
|---|---|---|---|---|---|---|
| | | Var. | Med | Chi | *P* | D |
| Araneae: Araneidae | | 0.26 | 0.25 | 87.0 | 0.36 | Ra |
| Oxyopidae | *Oxyopes salticus* | 0.02 | 0.02 | 82.0 | 0.51 | Ra |
| Salticidae | *Aphirape uncifera* | 0.15 | 0.14 | 86.0 | 0.39 | Ra |
| | *Uspachus* sp. | 0.02 | 0.02 | 82.0 | 0.51 | Ra |
| Sparassidae | *Quemedice* sp. | 0.04 | 0.04 | 81.0 | 0.54 | Ra |
| Tetragnathidae | *Leucauge* sp. | 0.04 | 0.04 | 81.0 | 0.54 | Ra |
| Thomisidae | *Tmarus* sp. | 0.01 | 0.01 | 83.0 | 0.48 | Ra |
| Coleoptera: Cantharidae | *Cantharis* sp. | 0.05 | 0.05 | 80.0 | 0.57 | Ra |
| Cerambycidae | | 0.01 | 0.01 | 83.0 | 0.48 | Ra |
| Chrysomelidae | *Alagoasa* sp. | 0.01 | 0.01 | 83.0 | 0.48 | Ra |
| | *Charidotis* sp. | 0.02 | 0.02 | 82.0 | 0.51 | Ra |
| | *Diabrotica speciosa* | 0.01 | 0.01 | 83.0 | 0.48 | Ra |
| | *Disonycha brasiliensis* | 0.12 | 0.11 | 93.7 | 0.20 | Ra |
| | *Eumolpus* sp. | 0.02 | 0.02 | 82.0 | 0.51 | Ra |
| | *Wanderbiltiana* sp. | 0.02 | 0.02 | 82.0 | 0.51 | Ra |
| Coccinellidae | *Cycloneda sanguinea* | 0.02 | 0.02 | 82.0 | 0.51 | Ra |
| Curculionidae | *Cratosomus* sp. | 0.05 | 0.05 | 80.0 | 0.57 | Ra |
| | *Lordops* sp. | 0.02 | 0.02 | 82.0 | 0.51 | Ra |
| | *Naupactus* sp. | 0.01 | 0.01 | 83.0 | 0.48 | Ra |
| Tenebrionidae | | 0.04 | 0.04 | 81.0 | 0.54 | Ra |
| Diptera: Syrphidae | *Syrphus* sp. | 0.04 | 0.04 | 81.0 | 0.54 | Ra |
| Hemiptera: Cicadellidae | *Acrogonia* sp. | 0.01 | 0.01 | 83.0 | 0.48 | Ra |
| Cicadidae | *Quesada gigas* | 0.10 | 0.08 | 101.0 | 0.09 | Ra |
| Coreidae | *Leptoglossus* sp. | 0.01 | 0.01 | 83.0 | 0.48 | Ra |
| Fulgoridae | | 0.01 | 0.01 | 83.0 | 0.48 | Ra |
| Membracidae | *Membracis* sp. | 0.01 | 0.01 | 83.0 | 0.48 | Ra |
| Nogodinidae | | 0.01 | 0.01 | 83.0 | 0.48 | Ra |
| Pentatomidae | | 0.05 | 0.05 | 80.0 | 0.57 | Ra |
| Hymenoptera: Apidae | *Trigona spinipes* | 0.01 | 0.01 | 83.0 | 0.48 | Ra |
| Lepidoptera: | | 0.327 | 0.29 | 95.0 | 0.17 | Ra |
| Mantodea: Mantidae | *Mantis religiosa* | 0.02 | 0.02 | 82.0 | 0.51 | Ra |
| Neuroptera: Chrysopidae | *Chrysoperla* sp. | 0.08 | 0.08 | 77.0 | 0.67 | Ra |
| Orthoptera: Tettigoniidae | *P. phyllinum* | 0.02 | 0.02 | 82.0 | 0.51 | Ra |
| Phasmatodea: Phasmatidae | | 0.02 | 0.02 | 82.0 | 0.51 | Ra |

Var.= variance. *fd* = 83. P.= *Phibalosoma.*

## 4. Discussion

### *4.1. Correlations between tending ants and phytophagous Hemiptera*

The positive correlation between tending ants and Hemiptera species was expected, as a trophobiotic interaction between these groups is one of the main mechanisms regulating the overabundance of ants in terrestrial ecosystems (Gomes et al., 2023). Sugary substances, excreted by Hemiptera species, are used as food by ants and they protect these insects against natural enemies (e.g., parasitoids) (Guerra et al., 2011; Moura and Carvalho, 2021). These substances are named honeydew (Blüthgen et al., 2000; Moura and Carvalho, 2021) as a food resource from Homoptera species throughout the year and rich in nutrients such as amino acids from symbiotic bacteria in their digestive tracts (Blüthgen et al., 2000). Ants of different genera feeding on nectaries are usually smaller than those associated with Homoptera species (Blüthgen et al., 2000). Furthermore, the distribution of nectaries throughout the plant difficulty their monopolization (Blüthgen et al., 2000) favoring ant abundance (Blüthgen et al., 2000). The finding of *Brachymyrmex* and *Pheidole* sp. and ants of other genera, such as *Paratrechina* (Hymenoptera: Formicidae) (Blüthgen et al., 2000) and *Cephalotes* visiting these structures is similar to that reported in Brazilian savannas (Byk and Del-Claro, 2010). Aggregate distribution pattern of most of the sampled groups is common among herbivorous insects, as a survival strategy and reflected in other groups, including ants and predators (Agrawal et al., 2006). The type of reproduction favors the aggregate pattern in Diptera (Brunel and Rull, 2010), but this is poorly known for species of the order Hymenoptera on individual trees (Guerra et al., 2011). The random distribution of *Teudis* sp. and *Cephalocoema* is related to the mutualism between these insects.

The positive correlation between *Brachymyrmex* sp. and *A. reticulatum* differs from that of species of the first genus generally associated with other insects such as the leafhopper *Dalbulus quinquenotatus* DeLong and Nault (Hemiptera: Cicadellidae) in shaded environments (Moya-Raygoza, 2005; Moya-Raygoza and Martinez, 2014), or disturbed by fire (Moya-Raygoza and Larsen, 2014). Associations of *A. reticulatum* with *Bauhinia forficata* (Fabales: Fabaceae) and, mainly, with ants of the genus *Camponotus* (Baronio et al., 2014), stingless bees such as *Trigona branneri* Cockerel (Hymenoptera: Apidae) (Baronio et al., 2014) and wasps such as *Synoeca septentrionalis* Richards (Hymenoptera: Vespidae) on *Piper aduncum* Linné (Piperales: Piperaceae) (Ramoni-Perazzi et al., 2006) and *Polistes erythrocephalus* on a Solanaceae plant in Peru (MacCarroll and Reeves, 2004) have been reported. The association of *Brachymyrmex* ants with extrafloral nectaries is similar to that reported for individuals of this genus among the most abundant ones in the warm season in mangroves in these structures of *Hibiscus pernambucensis* Arruda (Malvales: Malvaceae) (Cogni and Freitas, 2002). *Brachymyrmex obscurior* Forel (Hymenoptera: Formicidae) has been reported associated with extrafloral nectaries of *Acacia pennatula* (Schlencht and Cham) Benth (Fabales: Fabaceae) but this ant did not protect the plant against the non-myrmecophilous leafhopper *Sibovia* sp. (Hemiptera: Cicadellidae), the only herbivore observed on it (Moya-Raygoza, 2005). On the other hand, *Brachymyrmex minutus* Forel (Hymenoptera: Formicidae), associated with nectaries of *Pleopeltis crassinervata* (T. Moore) (Polypodiales: Polypodiaceae), protected this plant against larva herbivory (Koptur et al., 2013). Damage to plant leaves by herbivores with the presence of *Cephalotes pusillus* (Klug) (Hymenoptera: Formicidae) in extrafloral nectaries in Brazilian savannah were 6% lower (Byk and Del-Claro, 2010). The mutualism between *Cephalotes* sp. and Aleyrodidae explains their positive correlation with this ant being attracted by the honeydew produced by these phytophagous Hemiptera in aggregations and they protect them (Blüthgen et al., 2000). On the other hand, the protection of this plant, by these organisms, has been questioned (Byk and Del-Claro, 2010) because their jawn are small and its aggressiveness low, although some species can be more aggressive (Byk and Del-Claro, 2010). This increases the need of studying the behavior of each species per genus before generalizing the defensive behavior of the group (Byk and Del-Claro, 2010). Species of the genus *Cephalotes* cared *Eurystethus microlobatus* Ruckes (Hemiptera: Pentatomidae) (Guerra et al., 2011) and those of the subfamilies Pseudococcidae: Pseudococcinae and Coccinae: Myzolecanii share symbiotic bacteria (Pringle and Moreau, 2017). Aleyrodidae were associated with *Brachymyrmex* and other ants on *Croton floribundus* Spreng. (Malpighiales: Euphorbiaceae) in a semideciduous forest in southeastern Brazil (Queiroz and Oliveira, 2001) and with *Crematogaster* sp. (Hymenoptera: Formicidae) in French Guiana, protecting this insect against pathogenic fungi and natural enemies (Belin-Depoux and Bastien, 2002). The negative correlation between ants and Sternorrhyncha predators is due to tending ants protecting this plant (Lima et al., 2024), but this varies between species (Byk and Del-Claro, 2010). *Brachymyrmex* is generally more associated with plant defense against phytophagous (Moya-Raygoza, 2005), but trophobiotic interactions can decrease the number of Sternorrhyncha predators (Leite et al., 2016; Lima et al., 2024). This may reduce the biological control by Hemiptera (Karami-Jamour et al., 2018) as found in pine and coniferous and mixed forests- cereal steppes and aspen birch woods (Novgorodova, 2015) and *Cucumis sativus* L. cv. 'Superdominus' (Cucurbitales: Cucurbitaceae) (Karami-Jamour et al., 2018). However, damage by Hemiptera on *A. auriculiformis* was higher on young plants, due to sap suction by these insects (Hegde et al., 2013). The choice of host plants by Hemiptera varies with food availability due to the sessile habits of these insects during the first instar, obtaining shelter against sun exposure, which generally depend on the plant structure (Moura and Carvalho, 2021). Ant associations with Membracidae are more specialized (Blüthgen et al., 2000) and the former choose their trophobiotic partners according to nutritional need by behavioral patterns or with host tree characteristics (Blüthgen et al., 2000).

### *4.2. Insect distribution patterns on Acacia auriculiformis saplings*

The aggregated distribution pattern of Coleoptera and insects of the Chrysomelidae family, largely phytophagous mostly addresses larger spatial scales to establish more adequate sampling programs for their management (Reay-Jones, 2012; Silva et al., 2020). Aggregations of herbivorous insects are generally associated with food availability, directly affecting their abundance (Nogueira-de-Sá and Vasconcellos-Neto, 2003) and that of their predators (Agrawal et al., 2006). The host plant choice mechanisms are effective and phytophagous, generally, prefer those with evolutionary proximity (Valencia-Cuevas and Tovar-Sánchez, 2015). The distribution pattern of individuals from the Ulidiidae and Dolichopodidae (Diptera) families is aggregated with most of those from the first family being generalists and saprophagous (Brunel and Rull, 2010) and some defending the territory for mating and serving as an arena between males promoting aggregations (Brunel and Rull, 2010). Dolichopodidae are phytophagous and their larvae such as *Thrypticus sagittatus* Bickel and Hernandez (Diptera: Dolichopodidae) feed on scraped vascular bundles of *Eichhornia crassipes* Martius Solms-Laubach (Commelinales: Pontederiaceae) plants (Hernández, 2008). Most of its adult prey on a small number of soft-bodied arthropods such as Acari, Collembola, Homoptera and Thysanoptera (Hernández, 2008). Therefore, eating habits and reproductive behavior should be the main mechanisms, causing the aggregate pattern for groups of these insects and contributing to biological control (Hernández, 2008). The aggregate pattern in Hemiptera is common and the type of approach used in the study and the spatial scale vary, but most works carried out with Aleyrodidae, Aphidae, Cicadellidae and Pentatomidae aimed to improve sampling methods and, subsequently, the management of these insects (Riolo et al., 2014). Parental or ant care and reproductive behavior favor aggregations (Miranda, 2016) as the parasitism rate in *Alchisme thick* Fairmaire (Hemiptera: Membracidae) being, negatively correlated with the number of their aggregated females (Camacho et al., 2014). Furthermore, ant care affected the distribution of Membracidae in host plant patches or in individual ones (Cocroft, 2003). The factors that predispose the aggregated distribution of Hymenoptera on individual plants is poorly known. Most works emphasize the spatial distribution of their nests and the aggregate pattern mainly attributed to the availability of resources as in *Apis mellifera* L. (Hymenoptera: Apidae) (Baum et al., 2005), *Vespa velutina* Lepeletier (Hymenoptera: Vespidae) (Carvalho et al., 2020), *Ectatomma ruidum* Roger (Formicidae: Ectatomminae) and *Pheidole fallax* Mayr (Hymenoptera: Formicidae) (Dominguez-Haydar et al., 2018). Aggregation in stingless bees was attributed to mating in lek characteristic of *Trigona spinipes* F. (Hymenoptera: Apidae: Meliponinae), *Tetragona clavipes* (F.) (Hymenoptera: Apidae), and *Tetragonisca angustula* Latreille (Hymenoptera: Apidae) (Dos Santos et al., 2015). Resource recruitment explained the aggregation of *Vespula germanica* Fabricius (Hymenoptera: Vespidae) around the food source (Lozada et al., 2016). Distribution patterns varied between castes of *Pheidole pallidula* Nylander (Hymenoptera: Formicidae) ants with protection, resource availability and chemical signals left by nestmates being the main reasons for this aggregate pattern (Sempo et al., 2006). The tending behavior in *A. reticulatum* and Aleyrodidae explains the aggregated pattern of *Brachymyrmex* sp. and *Cephalotes* sp. On the other hand, this pattern of *T. collaris* and the random pattern of *Cephalocoema* sp. (Orthoptera) differ in this parameter, with some of its species aggregating due to adaptation to reduce or avoid predation and, eventually, improve the searching for resources (Dkhili et al., 2017). The population pattern of *Locusta migratoria* tibetensis Chen (Orthoptera: Acrididae) was aggregated due to food availability, reproductive traits, and anti-predator behavior (Jyoti et al., 2020). *Schistocerca gregaria* Forskål (Orthoptera: Acrididae) choose taller trees to rest at night, characterizing aggregation (Maeno and Ebbe, 2018). The aggregate pattern in spiders, such as *Oxyopes molarius* L. Koch (Aranae: Oxyopidae), on plant tops is due to search for food or competition between species, as with *Nabis kinbergii* Reuter bedbugs (Hemiptera: Nabidae) (Whitehouse et al., 2011). However, the random pattern of *Teudis* sp. and other species is due to the interspecific dispute for the same resource (Perkins et al., 2007). Aranophagy records in the Anyphaenidae family may be another behavioral factor influencing the distribution pattern of these Arthropods (Perkins et al., 2007).

### *4.3. Most abundant arthropods on Acacia auriculiformis sapling*

The greatest abundance of the herbivores *S. anchoralis*, *A. reticulatum*, the native bee *T. angustula* and the predators *Brachymyrmex* sp. and Dolichopodidae on *A. auriculiformis* sapling confirm the presence of these arthropods in the savanna as reported on *A. mangium* in this biome (Silva et al., 2020). Interactions between Hemiptera and ants are due to the relationship between the groups of the latter caring for and protecting Hemiptera and receiving honeydew, a sugary substance secreted by species of that order (Blüthgen et al., 2000). The native bee *T. angustula* has been reported as abundant in the savanna biome on different plant species used in the recovery of degraded areas such as *Leucaena leucocephala* Lam. de Wit (Fabales: Fabaceae) (Damascena et al., 2017). This should be favored by the small size and high dispersal capacity of this insect by the wind in searching for food such as nectar (Damascena et al., 2017). Dolichopodidae species are widely distributed in the world and their abundance may be mainly related to the different feeding habits of their larvae, phytophagous and their adults preying on small soft-bodied arthropods (Hernández, 2008).

*Acacia auriculiformis* is important in soil recovery and for populations of different groups such as Coleoptera phytophagous, Hemiptera, Hymenoptera, Orthoptera and Aranae. Ants of the genera *Brachymyrmex* and *Cephalotes* were positively correlated with *A. reticulatum* and Aleyrodidae, respectively, on the crown of this plant. The reduction in the number of Sternorrhyncha predators by ants supports the hypothesis that the latter protect the former against predators. The relationship between these groups is complex and shows the contribution of *A. auriculiformis*, even exotic, to local diversity. Structures such as extrafloral nectaries in this plant are important for the Arthropoda fauna. The distribution pattern of these organisms on *A. auriculiformis* plants was mainly aggregated, except for *Teudis* sp. and *Cephalocoema* with a random pattern.

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