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Original Article

Distribution pattern of arthropods and their ecological interactions on the leaf surfaces of *Terminalia argentea* saplings

Padrão de distribuição de artrópodes e suas interações ecológicas nas superfícies foliares de mudas de *Terminalia argentea*

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Abstract

Terminalia argentea tree, native to Brazil, is widely used in landscaping, recovering degraded areas, its wood, coal production, and the bark or leaf extracts has medicinal use. Despite of its importance, the arthropod fauna associated to this plant and its interspecific relationships still needs further studies. The objectives of this study were to evaluate the arthropods, their ecological indices and the distribution in the leaf faces on *T. argentea* saplings. The numbers of phytophagous insects (e.g., *Cephalocoema* sp.), pollinators (e.g., *Tetragonisca angustula*), and natural enemies (e.g., Oxyopidae), and their ecological indices (e.g., species richness), were higher on the adaxial leaf faces on *T. argentea* saplings. Aggregated distribution of phytophagous insects (e.g., *Aphis spiraecola*), pollinators (e.g., *Trigona spinipes*), and natural enemies (e.g., *Camponotus* sp.) on *T. argentea* saplings was observed. Abundance, diversity, and species richness of natural enemies correlated, positively, with those of phytophagous and pollinators insects. Predators and tending ants followed their prey and sucking insects, respectively. Tending ants protected sucking insects against predators, and reduced chewing insects. The high number of *Cephalocoema* sp. on *T. argentea* saplings is a problem, because this insect can feed on leaves of this plant, but its preference for the adaxial leaf face favors its control. The aggregation behavior of arthropods on *T. argentea* saplings favors the control of potential pests of this plant. There seems to be competition between tending ants for space and food resources on *T. argentea* saplings.

Keywords: Apidae, biodiversity, spiders, Sternorrhyncha.

Resumo

Terminalia argentea, árvore nativa do Brasil, é muito utilizada no paisagismo, na recuperação de áreas degradadas, sua madeira na produção de carvão e o extrato da casca ou das folhas tem uso medicinal. Apesar de sua importância, a fauna de artrópodes associada a esta planta e suas relações interespecíficas ainda carecem de estudos mais aprofundados. Os objetivos deste estudo foram avaliar os artrópodes, seus índices ecológicos e a distribuição nas faces foliares de mudas de *T. argentea*. O número de insetos fitófagos (ex.: *Cephalocoema* sp.), polinizadores (ex.: *Tetragonisca angustula*), e inimigos naturais (ex.: Oxyopidae), e seus índices ecológicos (ex.: riqueza de espécies), foram maiores nas faces adaxiais das folhas das mudas de *T. argentea*. Foi observada uma distribuição agregada de insetos fitófagos (ex.: *Aphis spiraecola*), polinizadores (ex.: *Trigona spinipes*) e inimigos naturais (ex.: *Camponotus* sp.) em mudas de *T. argentea*. A abundância, diversidade e riqueza de espécies de inimigos naturais correlacionaram-se, positivamente, com as de insetos fitófagos e polinizadores. Os predadores e as formigas cuidadoras seguiram as suas presas e os insetos sugadores, respectivamente. As formigas cuidadoras protegeram os insetos sugadores contra os predadores e reduziram os insetos mastigadores. O elevado número de *Cephalocoema* sp. em mudas de *T. argentea* é um problema, pois esse inseto pode se alimentar de folhas dessa planta, mas sua preferência pela face adaxial da folha favorece seu controle. O comportamento de agregação de artrópodes em mudas de *T. argentea* favorece o controle de potenciais pragas dessa planta. Parece haver competição entre as formigas cuidadoras por espaço e recursos alimentares nas mudas de *T. argentea*.

Palavras-chave: Apidae, biodiversidade, aranhas, Sternorrhyncha.

1. Introduction

Human action degrades natural ecosystems to maintain its population and economic growth (García-Orth and Martínez-Ramos, 2011; Magistrali et al., 2019). The recovery of these areas is a priority but requires time (Amaral et al., 2013; Reis et al., 2015; Silva et al., 2020). *Terminalia argentea* Mart. (Combretaceae), a secondary plant with up to 8 m high, native to the Southeastern and Central-West regions of Brazil, is widely used in landscaping and to recovering

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degraded areas (Carvalho et al., 2020). Also, *T. argentea* is used in wood and coal production and its bark or leaf extracts has medicinal use (Costa et al., 2021). Despite of its importance, the arthropod fauna associated to this plant and its interspecific relationships still needs further studies.

Arthropods can damage different parts of the plant or leaves (adaxial and abaxial faces). The sucking insects prefer the abaxial leaf face due to its softer tissue, thin epidermis and more protruding veins, besides greater protection against natural enemies and climatic factors (e.g., solar radiation) (Leite et al., 2008; Damascena et al., 2017). On the other hand, the arthropods may prefer the adaxial leaf face due to lower force applied to remain on this face (Salerno et al., 2018). The determination of the leaf face preferred by insect pests is important to improving their control (Leite et al., 2008), which is more difficult for those living and feeding on the abaxial leaf surface (Naranjo and Flint, 1995). The distribution of arthropods can be entirely randomly (i); in groups, such as aggregated or contagious distribution (ii); or spread evenly through regular or uniform distribution (iii), and this knowledge is important to sampling plans and pest management (Nickele et al., 2010). Relationships between insects can be intraspecific (within the same species) or interspecific (between species), and can be harmonic, without injuring the individuals involved, or disharmonious, when at least one is harmed (Begon et al., 2007). The harmonic interspecific relationship includes protocooperation, with individuals cooperating with each other, but not depending on each other to survive. The disharmonious relationships include predation (Begon et al., 2007), when one individual kills the other for food, and competition, with disputes over resources such as food, territory, etc (Leite et al., 2012).

The objectives of this study were to evaluate the arthropods, their ecological indices and the distribution (random, regular, or aggregated) in the leaf faces on *T. argentea* saplings. The three hypothesis were tested: (i) the arthropods may prefer the adaxial leaf face, (ii) the arthropods may prefer the aggregated distribution; and (iii) the arthropods have harmonic (e.g., protocooperation) or disharmonious (e.g., predation) relationships.

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 - Universidade Federal de Minas Gerais (ICA/UFMG) in the municipality of Montes Claros, Minas Gerais state, Brazil (latitude 16º 51' 38" S, longitude 44º 55' 00" W, altitude 620 m) for 24 months (April 2015 to March 2017). The climate of this area, according to the Köppen classification, is tropical dry, with annual precipitation and temperatures between 1,000 and 1,300 mm and ≥ 24ºC, respectively (Alvares et al., 2013). The soil is Neosol Litolic with an Alic horizon (Silva et al., 2020).

2.2. Experimental design

The *T. argentea* seedlings were prepared, in March 2014, in a nursery in plastic bags (16 x 24 cm) with reactive natural phosphate mixed with substrate at a dosage of 160g and planted at the same time in September 2014. Each *T. argentea* seedling was planted in a hole (40 x 40 x 40 cm) when they reached 30 cm high at 2-meter spacing between them. 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 defined biochemical characteristics (Silva et al., 2020) was placed in a single dose per hole. The 48 *T. argentea* saplings (young trees in the vegetative period) were irrigated twice a week until the beginning of the rainy season (October). The experimental design was completely randomized with two treatments (adaxial and abaxial leaf faces) with 24 replications, one sapling each.

2.3. Counting the arthropods

The number of arthropods were assessed, and all insects and spiders 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 [sampling unit (*n*) – one leaf]. Leaves were randomly assessed on the branch (one leaf per position) in the basal, middle, and apical parts of the canopy – vertical axis – (0 to 33%, 34 to 66%, and 67 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 *T. argentea* saplings (age = 12 months) starting six months after transplantation for 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 carefully approached, firstly assessing the adaxial leaf surface and, if in the possibility of nor visualizing the abaxial one, the leaf was lifted in a delicate and slow movement, and visualized. Insects with greater mobility (e.g., Orthoptera), that flew on approach were counted if 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 with an aspirator (two hours per week) between transplantation and first evaluation, six months after, stored in flasks with 70% alcohol, separated into morph species, 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 each group (e.g., family).

2.4. Statistical analysis

Each replication was a sapling with the insects collected on 12 leaves (three heights and four sides of the sapling) for 24 months. Ecological indices (abundance, Hill's diversity, and species richness) were calculated per treatment (leaf surface)/sapling. The ecological indices of arthropods and their numbers were subjected to Wilcoxon test. The type of aggregation (aggregated, random, or regular) of arthropods was defined by the Chi-square test. Interspecific arthropod relationships were subjected to second degree or principal component regressions (PCR) (*P*< 0.05). The regression model known as PCR, or regression on principal components, uses principal component analysis, based on the covariance matrix, to perform regression (Bair et al., 2006). Thus, it can reduce the regression dimension by excluding the dimensions that contribute to causing multicollinearity problem, that is, linear relationships between the independent variables. The parameters used in these regressions were those significant (P < 0.05) for the selection of the variables for the method "Stepwise". The data presented are statistically significant (*P* <0.05). The data showed are the significant ones (*P* <0.05) (Tables 1-3) and the others are in supplementary materials I-II.

3. Results

3.1. Distribution of arthropods on leaf surfaces

The numbers of the phytophagous Coleoptera *Disonycha brasiliensis*, *Gynandrobrotica* sp. (Chrysomelidae), *Parasyphraea* sp. (Chrysomelidae), *Cratosomus* sp. (Curculionidae), Hemiptera Aleyrodidae, *Mahanarva fimbriolata* (Cercopidae), Cicadellinae (Cicadellidae), *Quesada gigas* (Cicadidae), *Leptoglossus* sp. (Coreidae), and *Membracis* sp. (Membracidae), Lepidoptera and Orthoptera *Cephalocoema* sp. (Proscopiidae) and *Tropidacris collaris* (Romaleidae) were highest on the adaxial leaf faces, resulting in higher ecological indices on *T. argentea* saplings. The numbers of pollinators Hymenoptera *Tetragonisca angustula* (Apidae); and natural enemies Araneae *Teudis* sp. (Anyphaenidae), *Oxyopes salticus* (Oxyopidae), and *Leucauge* sp. (Tetragnathidae), Hemiptera *Podisus* sp. (Pentatomidae), Hymenoptera Braconidae, *Brachymyrmex* sp., *Camponotus* sp., and *Ectatomma* sp. (Formicidae), and Neuroptera *Chrysoperla* sp. (Chrysopidae) also were biggest on the adaxial leaf faces, resulting in higher ecological indices on these saplings. The numbers of phytophagous *Psiloptera* sp. (Coleoptera: Buprestidae) and natural enemies Araneae *Aphirape uncifera* (Salticidae) and *Aphantochilus rogersi* (Thomisidae) were highest on the abaxial leaf faces. The *Cephalocoema* sp. was the phytophagous with highest number on *T. argentea* saplings (Table 1).

3.2. Random, regular or aggregated distribution of arthropods

Phytophagous insects *Psiloptera* sp., Cerambycidae, *Alagoasa* sp., *Cerotoma* sp., *Lamprosoma* sp. (Coleoptera: Chrysomelidae), *Parasyphraea* sp., *Cratosomus* sp., *Diorymerus* sp. (Curculionidae), and *Epitragus* sp. (Tenebrionidae); Diptera *Liriomyza* sp. (Agromyzidae); Hemiptera Aleyrodidae, *Aphis spiraecola* (Aphididae), *M. fimbriolata*, Cicadellinae, Fulgoridae, Pentatomidae, and *Phenacoccus* sp. (Pseudococcidae); and *T. collaris* and Tettigoniidae showed aggregated distribution. Also pollinators Hymenoptera *Apis mellifera* and *Trigona spinipes* (Apidae); and natural enemies Araneae Araneidae, Oxyopidae, *A. uncifera*, and *Uspachus* sp. (Salticidae), Coleoptera *Cycloneda sanguinea* (Coccinellidae) and *Photinus* sp. (Lampyridae), Diptera Dolichopodidae, *Podisus* sp., *Brachymyrmex* sp., *Camponotus* sp., *Cephalotes* sp., *Ectatomma* sp., *Pheidole* sp., and *Pseudomyrmex termitarius* (Hymenoptera: Formicidae) showed aggregated distribution. On the other hand, *A. uncifera* and Hymenoptera *Polybia* sp. (Vespidae) showed random distribution on *T. argentea* saplings (Table 2).

3.3. Ecological interactions of arthropods

Abundance, diversity, and species richness of natural enemies correlated, positively, with those of phytophagous and pollinators insects. Number of Fulgoridae (Hemiptera) correlated, positively, with those of *Brachymyrmex* sp., *Pheidole* sp., and *P. termitarius*; that of *Camponotus* sp. that of Fulgoridae; that of Araneidae (Araneae) those of Fulgoridae and *T. spinipes*. Higher number of *Camponotus* sp. correlated, negatively, with those of *Brachymyrmex* sp., Dolichopodidae, *Lamprosoma* sp., and *P. termitarius*; that of *Brachymyrmex* sp. those of *Camponotus* sp., *Diorymerus* sp., *Parasyphraea* sp., and *Pheidole* sp.; that of *P. termitarius* those of *Camponotus* sp. and *Lamprosoma* sp. (Table 3).

4. Discussion

The greatest numbers of phytophagous (e.g., *Cephalocoema* sp.), pollinators (e.g., *T. angustula*), and natural enemies (e.g., Oxyopidae), increased the ecological indices values (e.g., species richness) of these species on the adaxial leaf face of *T. argentea* saplings, probably, due to the lower force applied by these arthropods to remain on this face compared to the abaxial one (Prüm et al., 2012; Salerno et al., 2018). These facts above confirmed the first hypothesis: the arthropods may prefer the adaxial leaf face. Factors such as wax content, hairiness, roughness, regular shape or not and the type and number of veins in the leaves of host plants can affect the ability of insects to walk, opting for the leaf surface (adaxial or abaxial) that requires lower force applied to the movement (Prüm et al., 2012; Salerno et al., 2018). The leaves of *T. argentea* have few and very short trichomes, concentrated on the abaxial leaf face (Linsingen et al., 2009), and thus are probably an example of a surface with low contact for insects to fix themselves on it, affecting their abundance on this leaf face.

Aggregate behavior of arthropods on *T. argentea* is similar to that of other insects, such as *Aethalion reticulatum* (Hemiptera: Aethalionidae) and *Camponotus* sp. on *Bauhinia forficata* (Fabaceae), Acrididae (Orthoptera) in several plants, *B. tabaci* on *Capsicum annuum* (Solanales: Solanaceae), *Dendroctonus ponderosae* (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). These results confirmed the second hypotheses: the arthropods may prefer the aggregated distribution. This behavior can increase the local population density of these arthropods (Goff et al., 2009), thus facilitating the acquisition of food and sexual partners and protection against predators; however, it can also result in conflicts (e.g., competition) between them (Goff et al., 2009; Boulay et al., 2019), maybe explaining the random distribution of *A. uncifera* and *Polybia* sp. on *T. argentea* saplings. *Aphis spiraecola*, with

Table 1. Number (average ± SE) of phytophagous, pollinators, and natural enemies and theirs ecological indices in the leaf faces on *Terminalia argentea*/sapling.

Phytophagous and pollinators	Leaf face		WT*	
	Abaxial	Adaxial	*VT*£	*P*
Coleoptera, *Psiloptera* sp.	0.06±0.03	0.02±0.02	1.75	0.04
Disonycha brasiliensis	0.02±0.02	0.75±0.28	2.97	0.00
Gynandrobrotica sp.	0.00±0.00	0.02±0.02	4.98	0.00
Parasyphraea sp.	0.02±0.02	0.27±0.10	7.16	0.00
Curculionidae (not identified)	0.08±0.05	0.21±0.08	2.03	0.02
Cratosomus sp.	0.00±0.00	0.04±0.02	2.40	0.01
Hemiptera, Aleyrodidae (not identified)	0.00±0.00	0.21±0.20	1.75	0.04
Mahanarva fimbriolata	0.00±0.00	0.40±0.28	2.26	0.01
Cicadellinae (not identified)	0.02±0.02	0.08±0.04	5.63	0.00
Quesada gigas	0.19±0.07	0.21±0.07	2.03	0.02
Leptoglossus sp.	0.00±0.00	0.02±0.02	2.85	0.00
Membracis sp.	0.00±0.00	0.02±0.02	2.68	0.00
Hymenoptera, *Tetragonisca angustula*	0.00±0.00	0.04±0.02	1.75	0.04
Lepidoptera (not identified)	0.10±0.05	0.73±0.14	4.14	0.00
Orthoptera, *Cephalocoema* sp.	0.21±0.13	4.83±0.85	2.68	0.00
Tropidacris collaris	0.17±0.08	1.06±0.23	1.75	0.04
Ecological indices				
Abundance of phytophagous	7.65±4.06	9.90±2.27	3.31	0.00
Diversity of phytophagous	1.75±0.36	5.33±1.06	1.90	0.02
Species richness of phytophagous	1.04±0.16	3.50±0.40	4.97	0.00
Abundance of pollinators	0.00±0.00	3.29±0.86	4.80	0.00
Diversity of pollinators	0.00±0.00	0.00±0.00	---	---
Species richness of pollinators	0.00±0.00	0.46±0.08	4.83	0.00
Natural enemies				
Araneae, *Teudis* sp.	0.00±0.00	0.02±0.02	1.75	0.04
Oxyopidae (not identified)	0.08±0.04	2.42±0.56	4.84	0.00
Oxyopes salticus	0.08±0.04	0.19±0.07	2.05	0.02
Salticidae (not identified)	0.04±0.02	0.00±0.00	2.21	0.01
Aphirape uncifera	0.06±0.03	0.02±0.02	1.75	0.04
Leucauge sp.	0.04±0.02	0.13±0.04	2.24	0.01
Aphantochilus rogersi	1.00±0.55	0.23±0.20	4.94	0.00
Hemiptera, *Podisus* sp.	0.08±0.04	0.40±0.10	4.65	0.00
Hymenoptera, Braconidae (not identified)	0.19±0.10	2.33±0.56	3.85	0.00
Brachymyrmex sp.	0.00±0.00	0.04±0.02	1.69	0.04
Camponotus sp.	0.00±0.00	0.04±0.02	2.03	0.02
Ectatomma sp.	0.02±0.02	1.29±0.26	1.75	0.04
Neuroptera, *Chrysoperla* sp.	0.04±0.04	0.23±0.08	4.49	0.00
Ecological indices				
Abundance of natural enemies	1.71±0.29	17.60±2.33	6.89	0.00
Diversity of natural enemies	2.83±0.55	8.04±1.14	2.68	0.00
Species richness of natural enemies	1.35±0.21	5.06±0.40	6.51	0.00

*WT= Wilcoxon test; £VT= value of test. n= 24 per treatment. --- = non generated.

Table 2. Random (Ra.) or aggregated (Ag.) distribution of arthropods on *Terminalia argentea*/saplings.

Phytophagous and pollinators	Var.[£]	Median	Chi-square test.		
			Chi-square	*P*	Di.
Coleoptera: *Psiloptera* sp.	0.13	0.06	184.20	0.00	Ag.
Cerambycidae (not identified)	0.08	0.06	115.40	0.02	Ag.
Chrysomelidae, *Alagoasa* sp.	1.16	0.12	850.00	0.00	Ag.
Cerotoma sp.	0.22	0.15	125.92	0.00	Ag.
Lamprosoma sp.	0.72	0.47	132.00	0.00	Ag.
Parasyphraea sp.	1.99	0.55	309.81	0.00	Ag.
Cratosomus sp.	0.30	0.16	158.00	0.00	Ag.
Diorymerus sp.	2.34	0.43	462.73	0.00	Ag.
Epitragus sp.	0.11	0.07	137.33	0.00	Ag.
Diptera: *Liriomyza* sp.	2.13	0.22	818.37	0.00	Ag.
Hemiptera: Aleyrodidae (not identified)	9.35	0.69	1158.11	0.00	Ag.
Aphis spiraecola	521.41	4.70	9434.50	0.00	Ag.
Mahanarva fimbriolata	0.13	0.06	184.20	0.00	Ag.
Cicadellinae (not identified)	0.05	0.02	170.00	0.00	Ag.
Fulgoridae (not identified)	0.39	0.19	177.50	0.00	Ag.
Pentatomidae (not identified)	0.30	0.16	158.00	0.00	Ag.
Phenacoccus sp.	1.16	0.12	845.00	0.00	Ag.
Hymenoptera: *Apis mellifera*	0.31	0.08	324.71	0.00	Ag.
Trigona spinipes	22.01	1.73	1079.82	0.00	Ag.
Orthoptera: *Tropidacris collaris*	1.87	0.69	231.07	0.00	Ag.
Tettigoniidae (not identified)	0.50	0.31	135.44	0.00	Ag.
Natural enemies					
Araneae: Araneidae (not identified)	14.39	0.94	1298.19	0.00	Ag.
Oxyopidae (not identified)	0.20	0.15	112.69	0.02	Ag.
Aphirape uncifera	0.09	0.07	108.67	0.04	Ra.
Uspachus sp.	0.07	0.05	125.00	0.00	Ag.
Coleoptera: *Cycloneda sanguinea*	0.13	0.06	184.20	0.00	Ag.
Photinus sp.	0.16	0.09	142.50	0.00	Ag.
Diptera: Dolichopodidae (not identified)	2.32	0.73	268.71	0.00	Ag.
Hemiptera: *Podisus* sp.	0.22	0.08	226.43	0.00	Ag.
Hymenoptera: *Brachymyrmex* sp.	9.92	1.41	598.98	0.00	Ag.
Camponotus sp.	25.17	2.81	760.15	0.00	Ag.
Cephalotes sp.	0.01	0.01	340.00	0.00	Ag.
Ectatomma sp.	5.08	0.63	688.15	0.00	Ag.
Pheidole sp.	7.45	1.48	428.95	0.00	Ag.
Pseudomyrmex termitarius	9.96	1.40	606.70	0.00	Ag.
Vespidae, *Polybia* sp.	0.34	0.27	107.87	0.04	Ra.

[£]Var.= variance; *Freedom degree* = 85.

high number on *T. argentea*, can be a problem because it is a pest of *Citrus* sp. (Rutaceae) (Kaneko, 2018).

Positive correlation between abundance, diversity, and species richness of natural enemies with phytophagous and pollinators insects on *T. argentea* saplings was, probably, due to these natural enemies followed these preys as related on *Caryocar brasiliense* (Caryocaraceae), *Leucaena leucocephala* (Fabaceae), and *Pistacia lentiscus* (Anacardiaceae) trees

Table 3. Relationships between abundance (Ab.), diversity (D.), and species richness (S.R.) of phytophagous insects (Phy.I.), pollinators (Pol.I.), natural enemies (N.E.), *Brachymyrmex* sp. (Bra.), Fulgoridae (Fu.), among others, on *Terminalia argentea* saplings.

Principal component regression equations	R^2	*F*	*P*
Ab. N.E.= 6,05 + 1,50 x Ab. Pol.I. + 0,13 x Ab. Phy.I.	0.31	20.38	0.00
D. N.E.= 3,93 + 0,43 x D. Phy.I.	0.13	14.33	0.00
S.R. N.E.= 1,18 + 1.94 x S.R. Pol.I. + 0.70 x S.R. Phy.I.	0.67	93.66	0.00
Fu.= -0,03 + 0,06 x *P. termitarius* + 0,05 x *Pheidole* sp. + 0,05 x Bra.	0.28	12.13	0.00
Araneidae= 0,18 + 2,18 x Fulg. + 0,20 x *T. spinipes*	0.23	13.91	0.00
Bra.= 0,93 + 2,01 x Fulg.	0.16	17.34	0.00
Camponotus sp.= 1,99 + 3,20 x Fulg.	0.16	17.17	0.00
Pheidole sp.= 1,03 + 1,74 x Fulg.	0.15	17.07	0.00
P. termitarius= 0,93 x 1,92 x Fulg.	0.14	15.59	0.00
Second-degree regression equations			
Lamprosoma sp.= 0,11+0,18x*Camponotus* sp.-0,01x*Camponotus* sp.^{2}	0.32	22.07	0.00
Lamprosoma sp.=0,19+0,36x*P. termitarius*-0,02x*P. termitarius*^{2}	0.27	17.50	0.00
Diorymerus sp.=0,05+0,41xBra.-0,02xBra.^{2}	0.18	10.00	0.00
Parasyphraea sp.=0,13+0,44xBra.-0,02xBra.^{2}	0.23	14.07	0.00
Dolichopodidae=0,22+0,31x*Camponotus* sp.-0,01x*Camponotus* sp.^{2}	0.20	11.42	0.00
Bra.=0,17+0,63x*Camponotus* sp.-0,02x*Camponotus* sp.^{2}	0.31	20.69	0.00
Camponotus sp.=0,83+2,11xBra.-0,09xBra.^{2}	0.39	30.17	0.00
Camponotus sp.= 1,22+2,40x*P. termitarius* -0,16x*P. termitarius*^{2}	0.25	15.50	0.00
Pheidole sp.=0,61+0,80xBra.-0,03xBra.^{2}	0.26	16.08	0.00
P. termitarius= 0,29+0,0,62x*Camponotus* sp.-0,02x*Camponotus* sp.^{2}	0.23	13.52	0.00

n=48.

(Auslander et al., 2003; Damascena et al., 2017; Leite et al., 2017). The increase of Araneidae number with those of Fulgoridae and *T. spinipes* on *T. argentea* saplings is due to spiders prey insects on insects in natural and agricultural systems (Venturino et al., 2008; Leite et al., 2012, 2016). Reduction in the number of individual Sternorryncha predators (e.g., Dolichopodidae) with increase in that of tending ants is, possibly, due to interactions between tending ants (e.g., *Camponotus* sp.) with phytophagous Hemiptera (e.g., Fulgoridae) on *T. argentea* saplings. Trophobiotic interactions between ants (offering protection 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 the abundance of natural enemies, including Sternorryncha predators (Karami-Jamour et al., 2018; Tong et al., 2019). Number of chewing insects (e.g., *Lamprosoma* sp.) reduction with increase in that of tending ants (e.g., *P. termitarius*) on *T. argentea* saplings. This fact, is, probably, due to for these ants protect sucking insects also of food resource competitors and, consequently, trees have less defoliating by insects, as observed in Fabaceae, Caryocaraceae, Malvacea, Musaceae, and Poaceae family plants, where the greater number of these ants reduced defoliation beetles, miners and caterpillars (Lepidoptera) (Ruberson et al., 1994; Eubanks 2001; Way et al., 2002; Leite et al., 2012). The reduction of *Brachymyrmex* sp. and *P. termitarius* numbers with increase that of *Camponotus* sp.; those of *Camponotus* sp. and *Pheidole* sp. that of *Brachymyrmex* sp.; and that of *Camponotus* sp. that of *P. termitarius* on *T. argentea* saplings indicates possible competition for food and space between these ants confirm our last hipothesis: it has competition among tending ants. This fact was observed between sympatric *Paratrechina longicornis* (Latreille) and *Tetramorium bicarinatum* (Nylander) (Hymenoptera: Formicidae) with *Tapinoma melanocephalum* (Fabricius), the latter with a close mutual relationship with *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae), by the honeydew of this sucking insect (Liu et al., 2020). The competition, by interference, between *T. melanocephalum* and *P. longicornis* interrupted the mutualism of the first species with *P. solenopsis* and reduced the escape activity of these ants, with aggressiveness, when their workers were in exploratory activity (Liu et al., 2020). The monopolization of resources by an ant species suggests mechanisms of coexistence between dominant and subordinate species as the monopolization suggests this (Houadria and Menzel, 2020). The niche variability of the ant *Carebara* sp.1 (Hymenoptera: Formicidae), more common, was greater than that of *Recurvidris* sp.2 (Hymenoptera: Formicidae), with lower monopolization rates. *Carebara* is more common because it is more competitive than those of *Lophomyrmex longicornis* Rigato (Hymenoptera: Formicidae) (Houadria and Menzel, 2020). These facts above confirming the third hypothesis:

the arthropods have harmonic (e.g., protocooperation) or disharmonious (e.g., predation) relationships on *T. argentea* saplings.

5. Conclusions

Higher number of *Cephalocoema* sp. may be a problem on *T. argentea* saplings because some Proscopiidae species are pests of plants, e.g. *Eucalyptus* sp. (Myrtaceae) (Flechtmann and Ottati, 1997), but its preference for the adaxial face, facilitates its control. The aggregation behavior of arthropods (e.g., *A. spiraecola*) on *T. argentea* saplings also favors the control of those, potentially, pests of this plant. Predators (e.g., Araneidae) and tending ants (e.g., *Camponotus* sp.) followed their prey (e.g., *T. spinipes*) and sucking insects (e.g., Fulgoridae), respectively. Tending ants (e.g., *P. termitarius*) protected sucking insects against predators (e.g., Dolichopodidae), and reduced chewing insects (e.g., *Diorymerus* sp.). There seems to be competition between tending ants (e.g., *Pheidole* sp. versus *Brachymyrmex* sp.) for space and food resources on *T. argentea* saplings.

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References

ALVARES, C.A., STAPE, J.L., SENTELHAS, P.C., GONÇALVES, J.L.M. and SPAROVEK, G., 2013. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift (Berlin)*, vol. 22, no. 6, pp. 711-728. http://doi.org/10.1127/0941-2948/2013/0507.

AMARAL, W.G., PEREIRA, I.M., AMARAL, C.S., MACHADO, E.L.M. and RABELO, L.D.O., 2013. Dynamics of the shrub and tree vegetation colonizing an area degraded by gold mined in Diamantina, Minas Gerais State. *Ciência Florestal*, vol. 23, no. 4, pp. 713-725. http://doi.org/10.5902/1980509812355.

AUSLANDER, M., NEVO, E. and INBAR, M., 2003. The effects of slope orientation on plant growth, developmental instability and susceptibility to herbivores. *Journal of Arid Environments*, vol. 55, no. 3, pp. 405-416. http://doi.org/10.1016/S0140-1963(02)00281-1.

BAIR, E., HASTIE, T., PAUL, D. and TIBSHIRANI, R., 2006. Prediction by supervised principal components. *Journal of the American Statistical Association*, vol. 101, no. 473, pp. 119-137. http://doi.org/10.1198/016214505000000628.

BARÔNIO, G., PIRES, A.C.V. and AOKI, C., 2012. *Trigona branneri* (Hymenoptera: Apidae) as a collector of honeydew from *Aethalion reticulatum* (Hemiptera: Aethalionidae) on *Bauhinia forficata* (Fabaceae: Caesalpinoideae) in a Brazilian Savanna. *Sociobiology*, vol. 59, no. 2, pp. 407-414. http://doi.org/10.13102/sociobiology.v59i2.603.

BASHIR, M.O. and HASSANALI, A., 2010. Novel cross-stage solitarising effect of gregarious-phase adult desert locust (*Schistocerca gregaria* (Forskål)) pheromone on hoppers. *Journal of Insect Physiology*, vol. 56, no. 6, pp. 640-645. http://doi.org/10.1016/j.jinsphys.2010.01.012. PMid:20138053.

BEGON, M., TOWNSEND, C.R. and HARPER, J.L., 2007. *Ecologia: de indivíduos a ecossistemas*. 4. ed. Porto Alegre: Artmed.

BOULAY, J., AUBERNON, C., RUXTON, G.D., EDOUIN, V.H., DENEUBOURG, J.L. and CHARABIDZE, D., 2019. Mixed-species aggregations in arthropods. *Insect Science*, vol. 26, no. 1, pp. 2-19. http://doi.org/10.1111/1744-7917.12502. PMid:28657138.

CARVALHO, J.C.N., SILVA, F.W.S., LEITE, G.L.D., AZEVEDO, A.M., TEIXEIRA, G.L., SOARES, M.A., ZANUNCIO, J.C. and LEGASPI, J.C., 2020. Does fertilization with dehydrated sewage sludge affect *Terminalia argentea* (Combretaceae) and associated arthropods community in a degraded area? *Scientific Reports*, vol. 10, no. 1, pp. 11811. http://doi.org/10.1038/s41598-020-68747-z. PMid:32678241.

COSTA, S.S.D., DEMOLIN-LEITE, G.L., SILVA, F.W.S., DOS SANTOS, J.B., AZEVEDO, A.M., SAMPAIO, R.A. and ZANUNCIO, J.C., 2021. Arthropods on *Terminalia argentea* (Combretaceae) fertilized with sewage sludge. *The Florida Entomologist*, vol. 104, no. 2, pp. 131-135.

DAMASCENA, J.G., LEITE, G.L.D., SILVA, F.W.S., SOARES, M.A., GUANABENS, R.E.M., SAMPAIO, R.A. and ZANUNCIO, J.C., 2017. Spatial distribution of phytophagous insects, natural enemies, and pollinators on *Leucaena leucocephala* (Fabaceae) trees in the Cerrado. *The Florida Entomologist*, vol. 100, no. 3, pp. 558-565. http://doi.org/10.1653/024.100.0311.

EUBANKS, M.D., 2001. Estimates of the direct and indirect effects of red imported fire ants on biological control in field crops. *Biological Control*, vol. 21, no. 1, pp. 35-43. http://doi.org/10.1006/bcon.2001.0923.

FLECHTMANN, C.A.H. and OTTATI, A.L.T., 1997. *Tetanorhynchus Leonardosi* (Mello-Leitão) (Orthoptera: Proscopiidae), nova praga em eucaliptos. *Neotropical Entomology*, vol. 26, no. 3, pp. 583-587.

GARCÍA-ORTH, X. and MARTÍNEZ-RAMOS, M., 2011. Isolated trees and grass removal improve performance of transplanted *Trema micrantha* (L.) Blume (Ulmaceae) saplings in tropical pastures. *Restoration Ecology*, vol. 19, no. 1, pp. 24-34. http://doi.org/10.1111/j.1526-100X.2009.00536.x.

GOFF, G.L., MAILLEUX, A.C., DETRAIN, C., DENEUBOURG, J.L., CLOTUCHE, G. and HANCE, T., 2009. Spatial distribution and inbreeding in *Tetranychus urticae. Comptes Rendus Biologies*, vol. 332, no. 10, pp. 927-933. http://doi.org/10.1016/j.crvi.2009.06.002. PMid:19819413.

GOODSMAN, D.W., KOCH, D., WHITEHOUSE, C., EVENDEN, M.L., COOKE, B.J. and LEWIS, M.A., 2016. Aggregation and a strong allee effect in a cooperative outbreak insect. *Ecological Applications*, vol. 26, no. 8, pp. 2621-2634. http://doi.org/10.1002/eap.1404. PMid:27862568.

HOUADRIA, M. and MENZEL, F., 2020. Temporal and dietary niche is context-dependent in tropical ants. *Ecological Entomology*, vol. 45, no. 4, pp. 761-770. http://doi.org/10.1111/een.12857.

KAMINSKI, L.A., FREITAS, A.V.L. and OLIVEIRA, P.S., 2010. Interaction between mutualisms: ant-tended butterflies exploit enemy-free space provided by ant-treehopper associations. *American Naturalist*, vol. 176, no. 3, pp. 321-334. http://doi.org/10.1086/655427. PMid:20645858.

KANEKO, S., 2018. Larvae of the exotic predatory ladybird *Platynaspidius maculosus* (Coleoptera: Coccinellidae) on citrus tree: prey aphid species and behavioral interactions with aphid-attenting ants in Japan. *Applied Entomology and Zoology*, vol. 53, no. 1, pp. 85-91. http://doi.org/10.1007/s13355-017-0531-y.

KARAMI-JAMOUR, T., MIRMOAYEDI, A., ZAMANI, A. and KHAJEHZADEH, Y., 2018. The impact of ant attendance on protecting *Aphis gossypii* against two aphidophagous predators and it's roleon the intraguild predation between them. *Journal of Insect Behavior*, vol. 31, no. 2, pp. 222-239. http://doi.org/10.1007/s10905-018-9670-4.

KIM, S., JUNG, M., SONG, Y.J., KANG, C., KIM, B.Y., CHOI, I.-J., KIM, H.G. and LEE, D.-H., 2017. Evaluating the potential of the extract of *Perilla* sp. as a natural insecticide for *Bemisia tabaci* (Hemiptera: Aleyrodidae) on sweet peppers. *Entomological Research*, vol. 47, no. 3, pp. 208-216. http://doi.org/10.1111/1748-5967.12211.

KLIMES, P., BOROVANSKA, M., PLOWMAN, N. and LEPONCE, M., 2018. How common is trophobiosis with hoppers (Hemiptera: Auchenorrhyncha) inside ant nests (Hymenoptera: Formicidae)? Novel interactions from New Guinea and a worldwide overview. *Myrmecological News*, vol. 26, pp. 31-45.

LEITE, G.L.D., PIMENTA, M., FERNANDES, P.L., VELOSO, R.V.S. and MARTINS, E.R., 2008. Fatores que afetam artrópodes associados a cinco acessos de ginseng-brasileiro (*Pfaffia glomerata*) em Montes Claros, Estado de Minas Gerais. *Acta Scientiarum. Agronomy*, vol. 30, no. 1, pp. 7-11. http://doi.org/10.4025/actasciagron.v30i1.1110.

LEITE, G.L.D., VELOSO, R.V.S., ZANUNCIO, J.C., ALMEIDA, C.I.M., FERREIRA, P.S.F., FERNANDES, G.W. and SOARES, M.A., 2012. Habitat complexity and *Caryocar brasiliense* herbivores (Insecta: Arachnida: Araneae). *The Florida Entomologist*, vol. 95, no. 4, pp. 819-830. http://doi.org/10.1653/024.095.0402.

LEITE, G.L.D., VELOSO, R.V.S., ZANUNCIO, J.C., ALONSO, J., FERREIRA, P.S.F., ALMEIDA, C.I.M., FERNANDES, G.W. and SERRÃO, J.E., 2016. Diversity of Hemiptera (Arthropoda: Insecta) and their natural enemies on *Caryocar brasiliense* (Malpighiales: Caryocaraceae) trees in the Brazilian Cerrado. *The Florida Entomologist*, vol. 99, no. 2, pp. 239-247. http://doi.org/10.1653/024.099.0213.

LEITE, G.L.D., VELOSO, R.V.S., ZANUNCIO, J.C., AZEVEDO, A.M., SILVA, J.L., WILCKEN, C.F. and SOARES, M.A., 2017. Architectural diversity and galling insects on *Caryocar brasiliense* trees. *Scientific Reports*, vol. 7, no. 1, pp. 16677. http://doi.org/10.1038/s41598-017-16954-6. PMid:29192234.

LINSINGEN, L.V., CERVI, A.C. and GUIMARÃES, O., 2009. Sinopse taxonômica da família Combretaceae R. Brown na Região Sul do Brasil. *Acta Botanica Brasílica*, vol. 23, no. 3, pp. 738-750. http://doi.org/10.1590/S0102-33062009000300013.

LIU, Y., XU, C., LI, Q. and ZHOU, A., 2020. Interference competition for mutualism between ant species mediates ant-mealybug associations. *Insects*, vol. 11, no. 2, pp. 91. http://doi.org/10.3390/insects11020091. PMid:32024041.

MAGISTRALI, P.R., BORGES, E.E.L., OLIVEIRA, J.A., FARIA, J.M.R., ATAIDE, G.M. and NASCIMENTO, J.F., 2019. Mercury affects aquaporins activity and germination of the embryonic axis of *Schizolobium parahyba* (Vell.) Blake (Fabaceae). *Revista Árvore*, vol. 43, no. 6, pp. 1-10. http://doi.org/10.1590/1806-90882019000600001.

NARANJO, S. and FLINT, H.M., 1995. Spatial distribution of adult of adult *Bemisia tabaci* (Homoptera; Aleyrodidae) in cotton and development of fixed precision sequential sampling plans for estimating population density. *Environmental Entomology*, vol. 24, no. 2, pp. 261-270. http://doi.org/10.1093/ee/24.2.261.

NICKELE, M.A., OLIVEIRA, E.B., FILHO, W.R., IEDE, E.T. and RIBEIRO, R.D., 2010. Spatial distribution of nests of *Acromyrmex crassispinus* (Forel) (Hymenoptera: Formicidae) in *Pinus taeda* plantations. *Neotropical Entomology*, vol. 39, no. 6, pp. 862-872. http://doi.org/10.1590/S1519-566X2010000600003. PMid:21271050.

PRÜM, B., SEIDEL, R., BOHN, H.F. and SPECK, T., 2012. Plant surfaces with cuticular folds are slippery for beetles. *Journal of the Royal Society, Interface*, vol. 9, no. 66, pp. 127-135. http://doi.org/10.1098/rsif.2011.0202. PMid:21642366.

REIS, S.M., MARIMON, B.S., MARIMON-JUNIOR, B.H., GOMES, L., MORANDI, P.S., FREIRE, E.G. and LENZA, E., 2015. Resilience of savanna forest after clear-cutting in the cerrado-amazon transition zone. *Bioscience Journal*, vol. 31, no. 5, pp. 1519-1529. http://doi.org/10.14393/BJ-v31n5a2015-26368.

RUBERSON, J.R., HERZOG, G.A., LAMBERT, W.R. and LEWIS, W.J., 1994. Management of the beet armyworm (Lepidoptera: Noctuidae) in cotton: role of natural enemies. *The Florida Entomologist*, vol. 77, no. 4, pp. 440-453. http://doi.org/10.2307/3495698.

SALERNO, G., REBORA, M., GORB, E. and GORB, S., 2018. Attachment ability of the polyphagous bug *Nezara viridula* (Heteroptera: Pentatomidae) to different host plant surfaces. *Scientific Reports*, vol. 8, no. 10975, pp. 1-14. http://doi.org/10.1038/s41598-018-29175-2. PMid:30030448.

SERRA, B.D.V. and CAMPOS, L.A.O., 2010. Polinização entomófila de abobrinha, *Cucurbita moschata* (Cucurbitaceae). *Neotropical Entomology*, vol. 39, no. 2, pp. 153-159. http://doi.org/10.1590/S1519-566X2010000200002. PMid:20498949.

SILVA, D.P. and FERNANDES, J.A.M., 2016. New evidences supporting trophobiosis between populations of *Edessa rufomarginata* (Heteroptera: Pentatomidae) and *Camponotus* (Hymenoptera: Formicidae) ants. *Revista Brasileira de Entomologia*, vol. 60, no. 2, pp. 166-170. http://doi.org/10.1016/j.rbe.2016.02.002.

SILVA, J.L., LEITE, G.L.D., TAVARES, W.S., SILVA, F.W.S., SAMPAIO, R.A., AZEVEDO, A.M., SERRÃO, J.E. and ZANUNCIO, J.C., 2020. Diversity of arthropods on *Acacia mangium* (Fabaceae) and production of this plant with dehydrated sewage sludge in degraded area. *Royal Society Open Science*, vol. 7, no. 2, pp. 191196. http://doi.org/10.1098/rsos.191196. PMid:32257306.

TONG, H., AO, Y., LI, Z., WANG, Y. and JIANG, M., 2019. Invasion biology of the cotton mealybug, *Phenacoccus solenopsis* Tinsley: current knowledge and future directions. *Journal of Integrative Agriculture*, vol. 18, no. 4, pp. 758-770. http://doi.org/10.1016/S2095-3119(18)61972-0.

VENTURINO, E., ISAIA, M., BONA, F., CHATTERJEE, S. and BADINO, G., 2008. Biological controls of intensive agroecosystems: wanderer spiders in the *Langa astigiana*. *Ecological Complexity*, vol. 5, no. 2, pp. 157-164. http://doi.org/10.1016/j.ecocom.2007.10.003.

WAY, M.J., JAVIER, G. and HEONG, K.L., 2002. The role of ants, especially the fire ant, *Solenopsis geminata* (Hymenoptera: Formicidae), in the biological control of tropical upland rice pests. *Bulletin of Entomological Research*, vol. 92, no. 5, pp. 431-437. http://doi.org/10.1079/BER2002185. PMid:12241568.

Supplementary Material

Supplementary material accompanies this paper.

Supplementary material I. Number (average ± SE) of arthropods in the leaf faces on Terminalia argentea/sapling.

Supplementary material II. Random (Ra.), regular (Re.), or aggregated (Ag.) distribution of arthropods on Terminalia argentea/sapling.

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