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Arthropods as possible losses and solutions on *Terminalia argentea* (Combretaceae) saplings

Artrópodes como possíveis fontes de perdas e de soluções em mudas de *Terminalia argentea* (Combretaceae)

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Abstract

Terminalia argentea native tree to Brazil and used in landscaping, wood and coal production, and civil construction, is adapted to poor and dry soils and cultivated in severely disturbed ecosystems. This plant has insecticidal activity, but arthropods can cause damage to its saplings. This study evaluates the herbivorous insects and of their natural enemies on 48 *T. argentea* saplings which were divided according to the damage they cause or reduce it on these saplings using the percentage of the Importance Index-Production Unknown (*% I.I.-P.U.*). The *Lamprosoma* sp., *Epitragus* sp., *Tropidacris collaris*, Cerambycidae, *Cratosomus* sp., *Psiloptera* sp., *Parasyphraea* sp., *Trigona spinipes*, and *Aphis spiraecola* showed the highest *% I.I.-P.U.* on leaves of *T. argentea*. The *Aphirape uncifera*, *Mantis religiosa*, *Uspachus* sp., *Podisus* sp., and Araneidae, with the highest *% I.I.-P.U.* on leaves of *T. argentea* saplings are possible solutions to reduce damage by these pests. These natural enemies can reduce herbivorous insects on *T. argentea* saplings. However, their populations should be increased, especially spiders. Nevertheless, the *Brachymyrmex* sp. associated to *A. spiraecola*, in future *T. argentea* commercial plantations, can increase populations of sap-sucking insect and, consequently, their damage.

Keywords: abundance, aggregation, chi-squared test, constancy, frequency.

Resumo

Terminalia argentea, árvore nativa do Brasil, é utilizada no paisagismo, produção de madeira e carvão, na construção civil, com adaptação adequada a solos pobres e secos, pode ser utilizada na recuperação de ecossistemas, severamente perturbados. Essa planta tem atividade inseticida, mas artrópodes podem causar danos em suas mudas. Insetos herbívoros e seus inimigos naturais foram avaliados em 48 mudas de *T. argentea* e classificados, usando a porcentagem do Índice de Importância-Produção Desconhecida (*% I.I.-P.U.*), de acordo com seus danos ou potencial para reduzir organismos pragas nessas mudas. *Lamprosoma* sp., *Epitragus* sp., *Tropidacris collaris*, Cerambycidae, *Cratosomus* sp., *Psiloptera* sp., *Parasyphraea* sp., *Trigona spinipes* e *Aphis spiraecola* apresentaram os maiores *% I.I.-P.U.* nas folhas de *T. argenteae*. *Aphirape uncifera*, *Mantis religiosa*, *Uspachus* sp., *Podisus* sp. e Araneidae, com os maiores *% I.I.-P.U.* em folhas de mudas de *T. argentea*, são possíveis soluções por reduzir os danos causados por essas pragas. Esses inimigos naturais podem ser importantes para *T. argentea* por reduzir as populações de insetos herbívoros em mudas dessa planta. Contudo, suas populações, principalmente as de aranhas, precisam ser aumentadas. No entanto, a associação de *Brachymyrmex* sp. com *A. spiraecola*, em futuros cultivos comerciais de *T. argentea*, pode aumentar os danos por insetos sugadores de seiva.

Palavras-chave: abundância, agregação, teste qui-quadrado, constância, frequência.

1. Introduction

Terminalia argentea Mart. & Zucc. (Myrtales: Combretaceae), a secondary growth deciduous tree, can reach over 8 m. This plant is native to Southeastern and Central-western Brazil is adapted to poor and dry soils and widely used in landscaping, wood and coal production, civil construction, and in programs to recover severely disturbed ecosystems (Lorenzi, 1992). *Terminalia argentea* is rich in phytochemicals which exudate from its trunk/leaves as gums benefiting visiting insects as *Trigona branneri* (Crockere, 1912) and *Mesembrinella bicolor* (Fabricius, 1805) (Hymenoptera: Apidae) (Boff et al., 2008) or with insecticidal activity against pests such as *Spodoptera frugiperda* (J.E. Smith, 1797) (Lepidoptera: Noctuidae) (Rodrigues et al., 2008). Plants of the genus *Terminalia* are hosts of insects including species of the genus *Lamprosoma* (Coleoptera: Chrysomelidae) such as *L. seraphinum* Lacordaire (after Fiebrig, 1910 and Erber, 1988), *L. bicolor* W. Kirby, 1818, and *L. amethystinum* Perty, 1832 (Casari and Teixeira, 2008).

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Arthropods can cause losses but are also solution sources against pests on *T. argentea* saplings.

The Importance Index (*I.I.*) determines the causes of loss and solution sources in a system in specific areas (e.g., agronomy) when the production (e.g., fruits) is known (Demolin-Leite, 2021). The magnitude (numerical measurements), frequencies, and distributions (aggregate, random, or regular) of events and the *I.I.* bases on this triplet differs (Demolin-Leite, 2021). Usually, the higher the magnitude and frequency of aggregated distribution, greater is the problem or the solution (e.g., natural enemies versus pests) (Demolin-Leite, 2021). The final production of a system is difficult to determine (e.g., degraded area recovery), but a derivation of the *I.I.* as the percentage of Importance Index-Production Unknown (*% I.I.-P.U.*) can detect losses and solution sources in systems where the production is unknown (Demolin-Leite, 2024a).

The objective of this study was to determine the sources of losses (e.g., herbivores insects) and solutions (e.g., natural enemies) classifying them according to their importance based on their to damage or as solution source for these damages on 48 *T. argentea* saplings - system with unknown production.

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).

2.3. Counting the arthropods

The percentage of defoliation (leaf area loss) on a 0–100% scale with 5% increments for leaf area removed (Kogan and Turnipseed, 1980), and the damage score from sap-sucking insects: I = non-damage; II = appearance of yellow chlorotic spots (leaf with 1% to 25% of attack symptoms); III = some yellow chlorotic spots and/or start of black sooty mold (leaf with 26% to 50% of attack symptoms); IV = several yellow chlorotic spots and/or severe blackening of leaves (leaf with 51% to 75% of attack symptoms); and V = yellowing or complete leaf drying (leaf with 76% to 100% of attack symptoms) (Demolin-Leite, 2024a), were assessed visually, 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 number of arthropods on the trunks of these saplings was also assessed in each evaluation. 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).

The definition of what is a loss (*L.S.*) or solution (*S.S.*) sources was made by field observation (e.g., leaf damage), feed habits, and literature. This also applied, for prey-predator and sap-sucking insects- tending ant relationships.

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. The distribution type (aggregated, random, or regular) for the *L.S.* or *S.S.* was defined by the Chi-square test using the R-package 'IIProductionUnknown' (Demolin-Leite and Azevedo, 2022) (Supplementary materials I and II). The data were subjected to simple regression analysis and their parameters were all significant (P< 0.05) using the R-package 'IIProductionUnknown' (Demolin-Leite and Azevedo, 2022) (Supplementary material III). The selection of simple equations was based on the criteria: i) data distribution in the figures (linear or quadratic response), ii) the parameters used in these regressions were the most significant ones (P< 0.05), iii) P< 0.05 and F of the Analysis of Variance of these regressions, and iv) the coefficient of determination of these equations (R^2). The *L.S.* and *S.S.* with $P< 0.05$ are in the supplementary material III. All the data were used in the Percentage of Importance Index-Production Unknown (*% I.I.-P.U.*).

Percentage of Importance Index-Production Unknown (*% I.I.-P.U.*) (Demolin-Leite, 2024a) is: *% I.I.-P.U.*= $[(ks_1 \times c_1 \times ds_1)/\Sigma(ks_1 \times c_1 \times ds_1)+(ks_2 \times c_2 \times ds_2)+(ks_n \times c_n \times ds_n)] \times 100$ (Demolin-Leite, 2021), where:

i) the *key source* (*ks*) is: *ks* = damage (non-percentage) (*Da.*)/total *n* of the *L.S.* on the samples or *ks* = reduction of the total *n.* of *L.S.* (*R.L.S*)/total n. of the *S.S* on the samples (Demolin-Leite, 2024a), where *Da.* or *R.L.S.* = $R^2 \times (1 - P)$, when it is of the first degree, or $((R^2 \times (1 - P)) \times (\beta_2/\beta_1)$, when it is of the second degree, where $\mathbf{R^2}$ = determination coefficient and $\boldsymbol{P}$ = significance of ANOVA, β_1 = regression coefficient, and β_2 = regression coefficient (variable²), of the simple regression equation of the loss source (*L.S.*) or solution source (*S.S.*) (Demolin-Leite, 2024a).

The separation of *Da* was separated in two or more *L.S.* by dividing it among the *L.S.* as a proportion of their respective "total *n*". *Da.* = 0 when *Da.* was non-significant for damage or non-detected by *L.S.* on the system (Demolin-Leite, 2024a). When an *S.S.* operates in more than one *L.S.*, that caused damage, its *ks* are summed. *R.L.S.* = 0 when *Da.* by *L.S.* or *R.L.S.* was non-significant for damage by *L.S.* or reduced *L.S.* by *S.S.* on the system (Demolin-Leite, 2024a).

ii) *c* (*constancy*) = Σ of occurrence of *L.S.* or *S.S.* on samples, where absence = 0 or presence = 1 (Demolin-Leite, 2021).

iii) *ds* (*distribution source*) = 1 - ***P*** of the chi-square test of *L.S.* or *S.S.* on the samples (Demolin-Leite, 2021). Counts (non-frequency) of *L.S.* or *S.S.* are used to perform the chi-square test.

These data, above, are obtained, by R-package 'IIProductionUnknown' (Demolin-Leite and Azevedo, 2022).

Percentage of *R.L.S.* per *S.S.* (*%R.L.S.S.S.*) = (*R.L.S.S.S.*/total *n* of the *L.S.* – abundance or damage) x 100, where *R.L.S.S.S.* = *R.L.S.* x total *n* of the *S.S.*, with the *R.L.S.* not being summed in this case (Demolin-Leite, 2024a). These data, above, are obtained, by R-package 'IIProductionUnknown' (Demolin-Leite and Azevedo, 2022).

3. Results

The loss sources with the highest *% I.I.-P.U.* on leaves of *T. argentea* saplings were: *Lamprosoma* sp. (23.78%), *Epitragus* sp. (Coleoptera: Tenebrionidae) (19.01%), *Tropidacris collaris* Stoll. 1813 (Orthoptera: Romaleidae) (14.97%), non-identified Cerambycidae (Coleoptera) (11.42%), *Cratosomus* sp. (Coleoptera: Curculionidae) (9.94%), *Psiloptera* sp. (Coleoptera: Buprestidae) (9.51%), *Parasyphraea* sp. (Coleoptera: Chrysomelidae) (4.46%), *Trigona spinipes* (Fabr. 1793) (Hymenoptera: Apidae) (3.95%), and *Aphis spiraecola* Patch 1914 (Hemiptera: Aphididae) (2.23%) (maximum damage score = III), among 40 herbivorous arthropods (≈ 0.02%) (Table 1).

The solution sources with the highest *% I.I.-P.U.* on leaves of *T. argentea* saplings were: *Aphirape uncifera* Tullgren 1905 (Araneae: Salticidae) (50.96%), *Mantis religiosa* L. 1758 (Mantodea: Mantidae) (26.86%), *Uspachus* sp. (Araneae: Salticidae) (12.79%), *Podisus* sp. (Hemiptera: Pentatomidae) (5.45%), non-identified Araneidae (Araneae) (2.17%), and the tending ants *Ectatoma* sp. (0.88%), *Brachymyrmex* sp. (0.53%), and *Pheidole* sp. (0.37%) among 26 natural enemies (= 0.00%). The numbers of *M. religiosa* reduced those of *Wanderbiltiana* sp. (Coleoptera: Chrysomelidae) (50.26%); those of Araneidae those of *Cephalocoema* sp. (Orthoptera: Proscopiidae) (27.04%), *Psiloptera* sp. (17.19%), and *Cratosomus* sp. (2.10%) (a total reduction of 46.33%), and *A. uncifera* decreased those of *Alagoasa* sp. (Coleoptera: Chrysomelidae) (7.00%), *Disonycha brasiliensis* Costa Lima 1954 (Coleoptera: Chrysomelidae) (9.38%), and *Diorymerus* sp. (Coleoptera: Curculionidae) (1.21%) (a total reduction of 17.59%). Similar effects were observed between the numbers of *Uspachus* sp. and *Camponotus* sp. in relation to that of *Lamprosoma* sp. (0.63 and 3.86% of reduction, respectively). The numbers of *Podisus* sp. and *Ectatoma* sp. reduced those of *T. spinipes* and Cerambycidae in 0.10 and 11.65%, respectively. The numbers of *Pheidole* sp. decreased those of *T. collaris*, non-identified Tettigoniidae (Orthoptera) in 1.03% and 2.95% and those of *Brachymyrmex* sp. that of *Parasyphraea* sp. in 2.70%, respectively. However, the numbers of *Brachymyrmex* sp. increased the damage by *A. spiraecola* (69.65%) on *T. argentea* saplings (Tables 2 and 3).

4. Discussion

The loss sources *Lamprosoma* sp., *Epitragus* sp., *T. collaris*, Cerambycidae, *Cratosomus* sp., *Psiloptera* sp., *Parasyphraea* sp., *T. spinipes*, and *A. spiraecola* on leaves of *T. argentea* saplings presented the highest *% I.I.-P.U.* The genus *Lamprosoma* includes *L. seraphinum* on *Teminalia hassleriana* Chod. (Myrtales: Combretaceae), *L. bicolor* and *L. amethystinum* on *Terminalia catappa* L. (Myrtales: Combretaceae), *L. chorisiae* Monrós 1948 on *Chorisia speciosa* A. St.-Hil. and *C. insignis* Kunth. (Malvales: Malvaceae) plants, and *L. azureum* Germar 1824 on *Psidium cattleianum* Sabine (Myrtales: Myrtaceae) plants (Casari and Teixeira, 2008), and *Lamprosoma* sp. on *Acacia mangium* Willd. (Fabales: Fabaceae) saplings (Silva et al., 2020; Demolin-Leite, 2024a). *Epitragus* sp. was observed on *A. mangium* saplings (Silva et al., 2020; Demolin-Leite, 2024a) and *E. sallaei* (Champion 1884) on *Mangifera indica* L. (Sapindales: Anacardiaceae) (Cruz-Lopez et al., 2001). *Tropidacris collaris* damages on *T. argentea* saplings confirms its polyphagy because it was reported damaging *Acacia auriculiformis* (Fabales: Fabaceae), *A. mangium* Willd., *Azadirachta indica* A. Juss. (Sapindales: Meliaceae), *Casuarina glauca* Sieber (Casuarinales: Casuarinaceae), *Leucaena leucocephala* (Lam.) de Wit (Fabales: Fabaceae), and *Platycyamus regnellii* (Benth) (Fabales: Fabaceae) plants (Poderoso et al., 2013; Damascena et al., 2017; Silva et al., 2020; Demolin-Leite, 2022a,b, 2023, 2024a; Mota et al., 2023). Many Cerambycidae species are pests [e.g., *Anoplophora chinensis* (Forster 1771)], on some plants [e.g., *Citrus* spp.(Sapindales: Rutaceae)] girdling and detaching branches and tree trunks for oviposition (Lemes et al., 2015; Herard and Maspero, 2019.). These insects were observed on *A. mangium* and

Table 1. Total number (*n*), damage (*Da.*), key-source (*ks*), constancy (*c*), distribution source (*ds*), number of importance indices (*n. I.I.*), sum of *n. I.I.-P.U.* (Σ *n. I.I.*), and percentage of *I.I.* by loss source (*L.S.*) on 48 *Terminalia argentea* (Combretaceae) saplings.

Loss source								
L.S.	***n***	***Da.***	***ks***	***c***	***ds***	***n. I.I.***	**Σ n. I.I.**	***% I.I.***
Lamprosoma sp.	42	0.3110	0.0074	23	0.99	0.1694	0.712	23.78
Epitragus sp.	8	0.1906	0.0238	6	0.95	0.1354	0.712	19.01
T. collaris	63	0.2489	0.0040	27	1.00	0.1067	0.712	14.97
Cerambycidae	6	0.1128	0.0188	5	0.87	0.0813	0.712	11.42
Cratosomus sp.	27	0.2389	0.0088	8	1.00	0.0708	0.712	9.94
Psiloptera sp.	5	0.1129	0.0226	3	1.00	0.0677	0.712	9.51
Parasyphraea sp.	47	0.1066	0.0023	14	1.00	0.0318	0.712	4.46
T. spinipes	248	0.4110	0.0017	17	1.00	0.0282	0.712	3.95
A. spiraecola	404	0.8010	0.0020	8	1.00	0.0159	0.712	2.23
Tettigoniidae	28	0.0028	0.0001	18	1.00	0.0018	0.712	0.25
Clytrini	19	0.0019	0.0001	16	0.39	0.0006	0.712	0.09
Cerotoma sp.	13	0.0013	0.0001	8	1.00	0.0008	0.712	0.11
Diorymerus sp.	37	0.0037	0.0001	8	1.00	0.0008	0.712	0.11
Lepidoptera	8	0.0008	0.0001	8	0.24	0.0002	0.712	0.03
D. speciose	4	0.0004	0.0001	4	0.40	0.0002	0.712	0.02
D. brasiliensis	5	0.0005	0.0001	5	0.36	0.0002	0.712	0.02
Walterianela sp.	3	0.0003	0.0001	3	0.44	0.0001	0.712	0.02
Wanderbiltiana sp.	3	0.0003	0.0001	3	0.44	0.0001	0.712	0.02
Alagoasa sp.	10	0.0010	0.0001	1	1.00	0.0001	0.712	0.01
Cephalocoema sp.	4	0.0004	0.0001	1	1.00	0.0001	0.712	0.01
Curculionidae	1	0.0001	0.0001	1	0.53	0.0001	0.712	0.01
Eumolpus sp.	1	0.0001	0.0001	1	0.53	0.0001	0.712	0.01
Gryllidae	1	0.0001	0.0001	1	0.53	0.0001	0.712	0.01
Gynandrobrotica sp.	1	0.0001	0.0001	1	0.53	0.0001	0.712	0.01
Lordops sp.	1	0.0001	0.0001	1	0.53	0.0001	0.712	0.01
Aleyrodidae	59	0.0000	0.0000	6	1.00	0.0000	0.712	0.00
B. hebe	2	0.0000	0.0000	2	0.49	0.0000	0.712	0.00
Cicadellinae	2	0.0000	0.0000	1	1.00	0.0000	0.712	0.00
E. sexguttata	2	0.0000	0.0000	2	0.49	0.0000	0.712	0.00
Euxesta sp.	10	0.0000	0.0000	7	1.00	0.0000	0.712	0.00
Fulgoridae	64	0.0000	0.0000	18	1.00	0.0000	0.712	0.00
Leptoglossus sp.	1	0.0000	0.0000	1	0.53	0.0000	0.712	0.00
Liriomyza sp.	19	0.0000	0.0000	2	1.00	0.0000	0.712	0.00
M. fimbriolata	5	0.0000	0.0000	3	1.00	0.0000	0.712	0.00
Membracidae	3	0.0000	0.0000	3	0.44	0.0000	0.712	0.00
Membracis sp.	1	0.0000	0.0000	1	0.53	0.0000	0.712	0.00
Nasutitermes sp.	100	0.0000	0.0000	2	1.00	0.0000	0.712	0.00
Pentatomidae	15	0.0000	0.0000	8	1.00	0.0000	0.712	0.00
Phenacoccus sp.	10	0.0000	0.0000	1	1.00	0.0000	0.712	0.00
Q. gigas	4	0.0000	0.0000	4	0.40	0.0000	0.712	0.00

I.I.-P.U. = *ks* x *c* x *ds*. *ks* = *Da.*/total *n* of the *L.S.*. *Da.* = R^2 x (1 - *P*) when it is of the first degree, or ((R^2 x (1 - *P*))x(β_2/β_1) when it is of the second degree, where $\mathbf{R^2}$ = determination coefficient and ***P*** = significance of ANOVA, β_1 = regression coefficient, and β_2 = regression coefficient (variable²), of the simple regression equation, or non-percentage of damage per *L.S.*. *c* = Σ of occurrence of *L.S.* on each sample, 0 = absence or 1 = presence. ***ds*** = 1 - ***P*** of chi-square test of the *L.S.*. *Da.* = 0 when *Da.* non-significant for damage or non-detected by *L.S.*.

Table 2. Total number (*n*), reduction of *L.S.* (*R.L.S.*), key-source (*ks*), constancy (*c*), distribution source (*ds*), number of importance indices (*n. I.I.*), sum of *n. I.I.-P.U.* (Σ *n. I.I.*), and percentage of *I.I.* by solution source (*S.S.*) on 48 *Terminalia argentea* (Combretaceae) saplings.

Solution source								
S.S.	***n***	***R.L.S.***	***ks***	***c***	***ds***	***n. I.I.***	**Σ n. I.I.**	***% I.I.***
A. uncifera	6	0.2692	0.04487	5	0.86	0.193	0.379	50.96
M. religiosa	10	0.1508	0.01508	7	0.96	0.102	0.379	26.86
Uspachus sp.	4	0.0664	0.01661	3	0.97	0.048	0.379	12.79
Podisus sp.	7	0.0362	0.00517	4	1.00	0.021	0.379	5.45
Araneidae	82	0.0306	0.00037	22	1.00	0.008	0.379	2.17
Ectatoma sp.	58	0.0120	0.00021	16	1.00	0.003	0.379	0.88
Brachymyrmex sp.	136	0.0093	0.00007	29	1.00	0.002	0.379	0.53
Pheidole sp.	183	0.0080	0.00004	32	1.00	0.001	0.379	0.37
A. rogersi	4	0.0000	0.00000	4	0.40	0.000	0.379	0.00
Braconidae	2	0.0000	0.00000	2	0.49	0.000	0.379	0.00
C. sanguinea	5	0.0000	0.00000	3	1.00	0.000	0.379	0.00
Camponotus sp.	307	0.0000	0.00000	42	1.00	0.000	0.379	0.00
Cephalotes sp.	1	0.0000	0.00000	1	0.53	0.000	0.379	0.00
Chrysoperla sp.	5	0.0000	0.00000	5	0.36	0.000	0.379	0.00
Dolichopodidae	64	0.0000	0.00000	26	1.00	0.000	0.379	0.00
Leucauge sp.	3	0.0000	0.00000	3	0.44	0.000	0.379	0.00
O. salticus	2	0.0000	0.00000	2	0.49	0.000	0.379	0.00
Oxyopidae	14	0.0000	0.00000	12	0.77	0.000	0.379	0.00
P. termitarius	125	0.0000	0.00000	26	1.00	0.000	0.379	0.00
Photinus sp.	8	0.0000	0.00000	5	1.00	0.000	0.379	0.00
Polybia sp.	23	0.0000	0.00000	17	0.75	0.000	0.379	0.00
Quemedice sp.	4	0.0000	0.00000	4	0.40	0.000	0.379	0.00
Salticidae	19	0.0000	0.00000	14	0.76	0.000	0.379	0.00
Syrphus sp.	5	0.0000	0.00000	5	0.36	0.000	0.379	0.00
Teudis sp.	1	0.0000	0.00000	1	0.53	0.000	0.379	0.00
Tmarus sp.	2	0.0000	0.00000	2	0.49	0.000	0.379	0.00

I.I.-P.U. = *ks* x *c* x *ds*. *ks* = *R.L.S.*/total *n.* of the *S.S.*. *R.L.S.*= R^2 x (1 - *P*) when it is of the first degree, or ((R^2 x (1 - *P*))x(β_2/β_1) when it is of the second degree, where $\mathbf{R^2}$ = determination coefficient and ***P*** = significance of ANOVA, β_1 = regression coefficient, and β_2 = regression coefficient (variable²), of the simple regression equation. *c* = Σ of occurrence of *S.S.* on each sample, 0 = absence or 1 = presence. *ds* = 1 - ***P*** of chi-square test of the *S.S.*. When a *S.S.* operates in more than one *L.S.*, that caused damage, its *ks* are summed. *E.S.*. = 0 when *Da.* by *L.S.* or *E.S.* non-significant for damage by *L.S.* or reduced *L.S.* by *S.S.*.

A. auriculiformis leaves (Silva et al., 2020; Mota et al., 2023; Demolin-Leite, 2023, 2024a). *Oncideres saga* (Dalman 1823) and *Acanthophorus confinis* (Castelnau 1840) are important pests of *Stryphnodendron adstringens* (Mart.) Coville (Fabales: Fabaceae) (Soares et al., 2022) and of *Acacia senegal* (Hasbab), and *Acacia seyal* (Talh) (Fabales: Fabaceae) plants, respectively (Jamal, 1994). *Cratosomus* sp. damages *Annona muricata* L. (Magnoliales: Annonaceae) (Sobrinho et al., 1999) and it was found, at low densities, on *A. auriculiformis* saplings (Mota et al., 2023; Demolin-Leite, 2024a). *Psiloptera* sp., a pest on *Acacia senegal* (Hasbab) and *Acacia seyal* (Talh) (Fabales: Fabaceae) (Jamal, 1994), was found in low numbers on *A. mangium* saplings (Silva et al., 2020; Demolin-Leite, 2023). *Parasyphraea* sp. was reported in high numbers on *A. mangium* (≈0.30/tree) and *A. auriculiformis* (≈0.80/tree) saplings (Silva et al., 2020; Mota et al., 2023). *Trigona spinipes* damages shoots and plant growth by removing fibers to build nests, as reported on *A. mangium*, *A. indica*, and *L. leucocephala* (Damascena et al., 2017; Silva et al., 2020; Demolin-Leite, 2022a, 2023). This bee also damaged the flowers of *Zantedeschia aethiopica* (L.) Spreng. (Commelinales: Araceae) plants and *Caryocar brasiliense* Camb. (Malpighiales: Caryocaraceae) trees (Carvalho et al., 2018; Demolin-Leite, 2024b). In addition, it can reduce pollination on *Cucurbita moschata* Dusch (Cucurbitales: Cucurbitaceae) plants due to insufficient pollen transportation (small body size) and/or chasing other pollinators by flying in flocks and with aggressive behavior (Serra and Campos, 2010) which has been led to the destruction of its nest (Demolin-Leite, 2024b). *A. spiraecola*

Table 3. Percentage of reduction in abundance and/or damage (*%R.*) of loss source (*L.S.*) per solution source (*S.S.*), sum (Σ), and total of Σ of *R.L.S.* (T.Σ) on 48 *Terminalia argentea* (Combretaceae) saplings.

Loss sources	*%R.L.S.S.S.- abundance*									*T.Σ
	Solution sources									
	Araneidae	***A. uncifera***	***Uspachus* sp.**	***Podisus* sp.**	***Brachymyrmex* sp.**	***Camponotus* sp.**	***Ectatoma* sp.**	***Pheidole* sp.**	**M. religiosa**	
Alagoasa sp.	---	7.00	---	---	---	---	---	---	---	**7.00**
Lamprosoma sp.	---	---	0.63	---	---	3.86	---	---	---	**4.49**
Parasyphraea sp.	---	---	---	---	2.70	---	---	---	---	**2.70**
Wanderbiltiana sp.	---	---	---	---	---	---	---	---	50.26	**50.26**
D. brasiliensis	---	9.38	---	---	---	---	---	---	---	**9.38**
Diorymerus sp.	---	1.21	---	---	---	---	---	---	---	**1.21**
Psiloptera sp.	17.19	---	---	---	---	---	---	---	---	**17.19**
Cratosomus sp.	2.10	---	---	---	---	---	---	---	---	**2.10**
Cerambycidae	---	---	---	---	---	---	11.65	---	---	**11.65**
T. spinipes	---	---	---	0.10	---	---	---	---	---	**0.10**
Cephalocoema sp.	27.04	---	---	---	---	---	---	---	---	**27.04**
T. collaris	---	---	---	---	---	---	---	1.03	---	**1.03**
Tettigoniidae	---	---	---	---	---	---	---	2.95	---	**2.95**
***T.Σ**	**46.33**	**17.59**	**0.63**	**0.10**	**2.70**	**3.86**	**11.65**	**3.98**	**50.26**	**137.1**
	%R.L.S.S.S.- damage									
Loss sources	**Solution sources**									
	Brachymyrmex sp.									
A. spiraecola	-69.65									

--- = *L.S.* was not reduced per *S.S.* *%R.L.S.S.S.* = (*R.L.S.S.S.*/total *n* of the *L.S.* – abundance or damage) x 100, where *R.L.S.S.S.* = *R.L.S.* x total n of the *S.S.*. *R.L.S.* = R^2 x (1 - *P*) when it is of the first degree, or ((R^2 x (1 - *P*))x(β_2/β_1) when it is of the second degree, where $\mathbf{R^2}$ = determination coefficient and ***P*** = significance of ANOVA, β_1 = regression coefficient, and β_2 = regression coefficient (variable²), of the simple regression equation. ***T.Σ** = total of Σ of *R.L.S.*

damages *Baccharis trimera* (Less.) DC. and *Calendula officinalis* L. (Asterales: Asteraceae), and *Citrus* sp. grunting of new leaves and sooty mold production from honeydew deposition resulting in lower photosynthetic activity (Leite et al., 2011; Wäckers et al., 2017; Kaneko, 2018), as reported for *T. argentea* saplings in this study.

The 65% of reduction in loss sources (e.g., *Psiloptera* sp.) on leaves of *T. argentea* saplings by spiders (e.g., *A. uncifera*) as the main solution sources, confirms the importance of these predators on *A. auriculiformis*, *A. mangium*, and *P. regnellii* saplings in Brazilian degraded areas (Silva et al., 2020; Demolin-Leite, 2022b, 2023, 2024a; Mota et al., 2023; Lima et al., 2024); against coleopteran defoliators on *C. brasiliense* trees in the Brazilian Cerrado (Leite et al., 2012a, b) and Orthoptera (Greek pastures and forests); and other agroecosystem in Europe and USA (Landis et al., 2000; Öberg et al., 2008; Venturino et al., 2008; Zografou et al., 2017). *Mantis religiosa*, a generalist predator negatively impacted the beetle *Wanderbiltiana* sp. and, in general, it decreased biomass and numbers of other arthropods, except herbivorous Miridae (Hemiptera). It probably happens due to an indirect effect (Fagan and Hurd, 1994), maybe a greater free space. The impact of *Tenodera sinensis* (Saussure, 1871) (Mantodea: Mantidae) is usually displayed weaker on arthropod density compared to of *M. religiosa*, but it is more frequent (Fagan et al., 2002). The negative impact of Mantids is, in general, weaker on the density for most taxa, but stronger on some taxa, like *T. sinensis* against Diptera and Hemiptera (herbivores as a group), and *Stagmomantis carolina* (Johansson, 1763) (Mantodea: Mantidae) negative or non-significant (Fagan et al., 2002). The abundance of defoliators and pollinators increased that of predators, including *M. religiosa* on *A. mangium* saplings (Silva et al., 2020), with a density of around 0.15 per tree, higher than on *A. auriculiformis* saplings (≈0.04/tree) (Mota et al., 2023). *Podisus* sp. decreased the number of *T. spinipes* by around 0.10% on *T. argentea* saplings. *Podisus placidus* Uhl. and *Podisus maculiventris* Say fed on honeybees (Bromley, 1948). Species of this genus are important predators as *Podisus distinctus* (Stål, 1860) and *P. nigrispinus* (Dallas, 1851) preying on larvae and pupae of Coleoptera and Lepidoptera defoliators on *Eucalyptus* spp. (Myrtales: Myrtaceae) (Zanuncio et al., 2014). However, the density of *Podisus* spp. is, generally, low on plants, as found in *A. mangium* (0.08/tree) and *A. auriculiformis* (0.06/tree) saplings (Silva et al., 2020; Mota et al., 2023). This makes it necessary to release *P. nigrispinus* when population levels of caterpillars are below the economic injury level (e.g., nine caterpillars/100 leaves) on *Eucalyptus* spp. (Zanuncio et al., 2014). This predator preys on 4-5 first and second instars larvae or 2-3 fourth and fifth instar caterpillars per day (Zanuncio et al., 2014). Finally, the tending ants (e.g., *Ectatoma* sp.), reduced 22.2% defoliator insect numbers (e.g., *Lamprosoma* sp.), representing 16.19% of the total reduction in *T. argentea* saplings. However, *Brachymyrmex* sp. increased the damage by *A. spiraecola* by around 70% on *T. argentea* saplings. This may not be a problem but, depending on the conditions (e.g., monoculture, climate, soil, and/or favorable fertilization), it can increase this sap-sucking insect population and, probably, the tending becoming a problem on *T. argentea* trees, especially in monoculture. The role of tending ants in productive systems is controversial, but its higher populations on leaves and extrafloral nectaries reduce the percentage of defoliation by herbivorous Lepidoptera and Coleoptera, and the numbers of *Eunica bechina* Talbot 1928 (Lepidoptera: Nymphalidae), *Edessa rufomarginata* De Geer 1773 (Hemiptera: Pentatomidae), *Prodiplosis floricola* (Felt, 1907) (Diptera: Cecidomyiidae), petiole gall insects (Hymenoptera: Chalcidoidea) on *C. brasiliense* trees (Freitas and Oliveira, 1996; Oliveira, 1997; Leite et al., 2012a, b, c), and *Cephalocoema* sp. (Orthoptera: Proscopiidae) on *A. auriculiformis* saplings (Demolin-Leite, 2024a). Besides, these ants are bioindicators of recovering degraded areas (Sanchez, 2015). However, *Crematogaster* sp. increased the abundance of *Pseudococcus* sp. (Hemiptera: Pseudococcidae) and *Dikrella caryocar* (Coelho, Leite, and Da-Silva, 2014) (Hemiptera: Cicadellidae) on *C. brasiliense* trees (Leite et al., 2015). *Brachymyrmex* sp. increased (≈93%) populations of *Aethalion reticulatum* L. 1767 (Hemiptera: Aethalionidae) and *Cephalotes* sp. that of Aleyrodidae (Hemiptera) (≈2%), and damage by Aleyrodidae (≈30%) on *A. auriculiformis* saplings (Demolin-Leite, 2024a). Sap-sucking insects, especially at high densities, are associated with ants (mutual benefit) with a direct correlation between these groups (Leite et al., 2012c, 2015, 2016; Novgorodova, 2015; Sanchez et al. 2019). These ants collectively and aggressively defend these phytophagous insects (their food resources) (Novgorodova, 2015) reducing the biological control of sap-sucking hemipterans (Karami-Jamour et al., 2018; Tong et al., 2019), and, in the agricultural systems, this fact can increase pest problems (Sagata and Gibb, 2016). High population levels of these predator populations per herbivorous insect may control herbivore's abundance (e.g., *Psiloptera* sp.) through top-down effects, increasing the survival of *T. argentea*.

5. Conclusions

The loss sources *Lamprosoma* sp., *Epitragus* sp., *T. collaris*, Cerambycidae, *Cratosomus* sp., *Psiloptera* sp., *Parasyphraea* sp., *T. spinipes*, and *A. spiraecola* showed the highest *% I.I.-P.U.* on leaves of *T. argentea* saplings and may be problems in commercial crops. The solution sources spiders, the main predator group, Araneidae, *A. uncifera*, and *Uspachus* sp. (Araneae: Salticidae), *M. religiosa*, *Podisus* sp., and tending ants *Ectatoma* sp. and *Pheidole* sp. had the highest *% I.I.-P.U.* on leaves of *T. argentea* saplings. These natural enemies can reduce herbivorous insect numbers on *T. argentea* saplings, but it is necessary to increase their populations, especially spiders. *Brachymyrmex* sp. associated with *A. spiraecola* increased the numbers and damage by this sap-sucking insect.

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Supplementary material

Supplementary material accompanies this paper

Supplementary Material I. Aggregated (Agg.), regular (Reg.), or random (Ran.) distribution (Dist.) of the loss sources on 48 Terminalia argentea (Combretaceae) saplings..

Supplementary Material II. Aggregated (Agg.), regular (Reg.), or random (Ran.) distribution (Dist.) of the solution sources on 48 Terminalia argentea (Combretaceae) saplings.

Supplementary Material III. Simple regression equations of damage per loss source (L.S.) and reduction or increase of abundance or damage (Da.) of L.S. per solution source (S.S.) on Terminalia argentea (Combretaceae) saplings.