Percentage of importance indice-production unknown: loss and solution sources identification on system

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Abstract

Indices are used to help on decision-making. This study aims to develop and test an index, which can determine the loss (e.g., herbivorous insects) and solution (e.g., natural enemies) sources. They will be classified according to their importance regarding the ability to damage or to reduce the source of damage to the system when the finanicial costs are high. Acacia auriculiformis (Fabales: Fabaceae), a non-native pioneer species in Brazil, with fast growth and rusticity, is used in restoration programs, and it is adequate to evaluate a new index. The formula was: Percentage of the Importance Indice-Production Unknown (% I.I.-PU) = \((ks \times c \times d_1) \Sigma (ks \times c \times d_2)\) x 100. The loss sources Aethalion reticulatum L., 1767 (Hymenoptera: Aethalionidae), Aleyrodidae (Hemiptera), Stereoma anchoralis Lacordaire, 1848 (Coleoptera: Chrysomelidae), and Tettigoniidae, and solution sources Usphacus sp. (Araneae: Salticidae), Salticidae (Araneae), and Pseudomyrmex termittarius (Smith, 1877) (Hymenoptera: Formicidae) showed the highest % I.I.-PU on leaves of A. auriculiformis saplings. The number of Diabrotica speciosa Germar, 1824 (Coleoptera: Chrysomelidae) was reduced per number of Salticidae; that of A. reticulatum that of Usphacus sp.; and that of Cephalocoema sp. (Orthoptera: Proscopiidae) that of P. termitarius on A. auriculiformis. However, the number of Aleyrodidae was increased per number of Cephalotes sp. (Hymenoptera: Formicidae) and that of A. reticulatum that of Brachymyrmex sp. (Hymenoptera: Formicidae) on A. auriculiformis saplings. The A. reticulatum damage was reduced per number of Usphacus sp., but the Aleyrodidae damage was increased per number of Cephalotes sp., totaling 23.81% of increase by insect damages on A. auriculiformis saplings. Here I show and test the % I.I.-PU. It is an new index that can detect the loss or solution sources on a system when production is unknown. It can be applied in some knowledge areas.

Keywords: abundance, aggregation, agriculture, chi-squared test, constancy, forestry production, frequency, natural system.

Resumo

Índices são usados para ajudar na tomada de decisões. Este trabalho teve como objetivo desenvolver e testar um índice capaz de determinar fontes de perda (ex.: insetos herbívoros) e de solução (ex.: inimigos naturais). Eles serão classificados de acordo com sua importância quanto a habilidade de danificar ou reduzir danos no sistema, quando a produção final é desconhecida. Acacia auriculiformis (Fabales: Fabaceae), uma espécie pioneira não nativa do Brasil com rápido crescimento e rusticidade, usada em programas de restauração, é adequada para avaliar um novo índice. A fórmula foi: Porcentagem de Índice de Importância-Produção Desconhecida (% I.I.-PD) = \((ks \times c \times d_1) \Sigma (ks \times c \times d_2)\) x 100. As fontes de perda Aethalion reticulatum L., 1767 (Hymenoptera: Aethalionidae), Aleyrodidae (Hemiptera), Stereoma anchoralis Lacordaire, 1848 (Coleoptera: Chrysomelidae) e Tettigoniidae, e as fontes de solução Usphacus sp. (Araneae: Salticidae), Salticidae (Araneae) e Pseudomyrmex termittarius (Smith, 1877) (Hymenoptera: Formicidae) apresentaram maiores % I.I.-PD nas folhas das mudas de A. auriculiformis. O número de Diabrotica speciosa Germar, 1824 (Coleoptera: Chrysomelidae) foi reduzido pelo número de Salticidae; o de A. reticulatum pelo de Usphacus sp.; e o de Cephalocoema sp. (Orthoptera: Proscopiidae) pelo de P. termitarius em mudas de A. auriculiformis. Entretanto, o número de Aleyrodidae foi aumentado pelo número de Cephalotes sp. (Hymenoptera: Formicidae) e o de A. reticulatum pelo de Brachymyrmex sp. (Hymenoptera: Formicidae) em mudas de A. auriculiformis. O dado de A. reticulatum foi reduzido pelo número de Usphacus sp., mas o dado de Aleyrodidae foi aumentado pelo número de Cephalotes sp., totalizando 23.81% de aumento de danos em mudas de A. auriculiformis. Aqui eu apresento e testo o % I.I.-PD. Ele é um novo índice capaz de detectar fontes de perda e de solução no sistema quando não se conhece a produção final. Ele pode ser aplicado em algumas áreas do conhecimento.

Palavras-chave: abundância, agregação, agricultura, constância, frequência, produção florestal, sistema natural, teste do chi-quadrado.

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Received: June 12, 2021 – Accepted: October 8, 2021

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1. Introduction

Indices are used to help on decision-making, and, whenever possible, determining key factor. They might be crucial in various areas, such as agrarian (Peterson, et al. 2009; Da Silva et al., 2017: Demolin-Leite, 2021), educational (Davis and Wigelsworth, 2018), industrial (Lin et al., 2007), medical (Liu et al., 2017; Goldenberg and Grantcharov, 2019), among others. These indices, in general, are used to laborious to be obtained. The Importance Indice (I.I.) can determine the loss and solution sources on a system in some knowledge areas (e.g., agronomy), since production is known (Demolin-Leite, 2021). Events (e.g., agricultural pest) can have different magnitudes (numerical measurements), frequencies, and distributions (aggregate, random, or regular) of event occurrence, and I.I. bases in this triplet (Demolin-Leite, 2021). In general, the higher magnitude and frequency, with aggregated distribution, is the greater will be the problem or the solution (e.g., natural enemies versus pests) on the system (Demolin-Leite, 2021). However, the final production of the system is not always known or is challenging to measure (e.g., degraded area recovery).

The earleaf acacia, *Acacia auriculiformis* A. Cunn. ex Benth. (Fabales: Fabaceae), is native from Australia, Papua New Guinea, and Indonesia (Doran and Turnbull, 1997). Its leaves are dense, bipinnate with petioles and size from 8 to 22.5 cm and 10 to 52 mm with three longitudinal and many secondary ribs (Doran and Turnbull, 1997). This plant is a priority species for the International Union of Forest Research Organisations (IUFRO) for research and development in tropical areas (Wickneswari and Norwati, 1993). Its wood is of high quality for particleboard, pulpwood, tannin, and timber (Firmansyah et al., 2020). *Acacia* spp. (Fabales: Fabaceae) are used to recover degraded areas (Balieiro et al., 2017), although the introduction of non-native plants may impact natural ecosystems. The abiotic characteristics of the area and the life history facilitate the establishment and dispersal of mangium tree, *Acacia mangium* Wild. (Fabales: Fabaceae), in the Amazonian savannas (Aguilar Junior et al., 2014). On the other hand, local biotic resistance may reduce the dispersal of introduced *Acacia* spp. as an invasive species (Londe et al., 2020). The durability of the *A. auriculiformis* wood is long-term, and the susceptibility to diseases and adaptability to poor soils by this plant is high (Wong et al., 2011; Rahman et al., 2017). *Acacia auriculiformis* can increase moisture retention, deposition of potassium and organic carbon in the soil (litter). It can also make the phytoextraction of heavy metals from the soil (through mycorrhizal associations) (Rana and Maity, 2018) and biological fixation of atmospheric nitrogen via bacteria in its roots. Arthropods on this and other *Acacia* spp. (Rodriguez et al., 2020) have been studied, but their importance is unknown.

The objective of this study was to develop and test an index, which can determine the loss (e.g., herbivores insects) and solution sources (e.g., natural enemies), classifying them according to their importance regarding the ability to damage or reduce the source of damage on 48 *A. auriculiformis* saplings - system with production unknown.

2. Material and methods

2.1. Experimental site

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

2.2. Experimental design

The *A. auriculiformis* seedlings were prepared, in March 2014, in a nursery in plastic bags (16 x 24 cm) with reactive natural phosphate mixed with the substrate at a dosage of 160g and planted, at the same time, in the final site in September of this year. Each *A. auriculiformis* seedling was planted in a hole (40 x 40 x 40 cm) when they were 30 cm high with a 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 its biochemical characteristics defined (Silva et al., 2020) was placed in a single dose, per hole. The young 48 *A. auriculiformis* 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

Defoliation - leaf area loss on a 0–100% scale with 5% increments for removed leaf area (Silva et al., 2020) - and boring of branches by insects, and score damage by 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 starting 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 drying leaves (leaf with 76% to 100% of attack symptoms) - were assessed visually, and all insects (e.g., Formicidae - eusocial insects) and spiders were counted, between 7:00 A.M. and 11:00 A.M., by visual observation, every two weeks on the adaxial and abaxial surfaces of the first 12 leaves expanded, per sapling. These leaves were
assessed, randomly, on branches (one leaf per position) in the basal, middle, and apical parts of the canopy – vertical axis - (0 to 33%, 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 A. auriculiformis saplings 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 approached, carefully, firstly assessing the adaxial leaf surface and, if it was not possible to visualize the abaxial one, with a delicate and slow movement, the leaf was lifted and visualized. The position of leaves of A. auriculiformis saplings is generally tilted upwards, facilitating the visual assessment of arthropods on their leaf surfaces. Insects with greater mobility (e.g., Orthoptera), that flew, on approach, were counted as they were recognized (e.g., Order). The arthropods (insects and spiders) were not removed from the saplings during the evaluation.

A few arthropod specimens (up to 3 individuals) per species were collected with an aspirator (two hours per week), at the beginning of the study (between transplantation and first evaluation, six months after), stored in flasks with 70% alcohol, separated into morph species, and sent to a taxonomist of its group. The arthropods (insects and spiders) were not removed from the saplings during the evaluation.

2.4. Statistical analysis

Each replication is the total of individuals collected on 12 leaves (three heights and four sides of the sapling) for 24 months. The type of distribution (aggregated, random, or regular) of lost source (L.S.) or solution source (S.S.) was defined by the Chi-square test using the BioDiversity Professional program, version 2 (Krebs, 1989) (Tables 1 and 2). The data were subjected to simple regression analysis and their parameters were all significant (P < 0.05) using the statistical program System for Analysis Statistics and Genetics (Saeg, 2007), version 9.1 (Table 3). Simple equations were selected by observing the criteria: i) distribution of data 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 (R²). Only L.S. and S.S. with P < 0.05 were shown in tables 1-3. It is necessary knowledge of the system to select the possible loss sources and solution sources.

Percentage of Importance Indice-Production Unknown (% I.I.-PU) was named because three other indexes, two with lower and one with higher knowledge of the system (Demolin-Leite, 2021), were created, but are not presented on this paper.

The developed formula is Equation 1:

\[
\% \text{ I.I.-PU} = \left[ \frac{(k_1 + k_2 + k_3)}{(k_1 + k_2 + k_3 + k_4 + k_5 + k_6)} \right] \times 100.
\]  

where,

i) key source (ks) is Equation 2:

\[
ks = \frac{\text{damage (non percentage) (Da.)}}{\text{total n of the L.S. on the samples}} - \frac{\text{reduction of the total n. of L.S. (R.L.S.)}}{\text{total n of the S.S. on the samples}}
\]  

Where,

\[Da. \text{ or R.L.S.} = R^2 \times (1 - P)\]

\[= \left(\frac{(R^2 \times (1 - P))x(\beta_1/\beta_0)}{\text{Si}}\right)\text{, when it is of the first degree,}\]

\[= \left(\frac{(R^2 \times (1 - P))x(\beta_2/\beta_1)}{\text{Si}}\right)\text{, when it is of the second degree,}\]

\[\text{where,}\]

\[R^2 = \text{determination coefficient and } P = \text{significance of ANOVA, } \beta_1 = \text{regression coefficient, and } \beta_2 = \text{regression coefficient (variable)}, \text{of the simple regression equation of the loss source (L.S.) or solution source (S.S.).}\]

When it is not possible to separate the Da. between two or more L.S., divide the Da. among the L.S. in proportion to their respective “total n.” Da. = 0 when Da. non-significant for damage or non-detected by L.S. on the system. When a 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. non-significant for damage by L.S. or reduced L.S. by S.S. on the system.

ii) c (constancy) = \Sigma of occurrence of L.S. or S.S. on samples, where, absence = 0 or presence = 1.

iii) ds (distribution source) = 1 - Po the chi-square test of L.S. or S.S. on the samples.

The Percentage of R.L.S. per S.S. is Equation 3:

\[
\% \text{Percentage of R.L.S. per S.S.} = \left(\frac{R.L.S.}{S.S.}\right) \times \text{total n of the L.S. – abundance or damage} \times 100
\]  

where,

\[R.L.S. = R.L.S. \times \text{total n of the S.S.},\]

In this case, the R.L.S. are not summed.

3. Results

The loss sources, per individual, Aethalion reticulatum L., 1767 (Hemiptera: Aethalionidae) (38.86%), Aleyrodidae (Hemiptera) (37.69%), Stereoma anchoralis Lacordaire, 1848 (Coleoptera: Chrysomelidae) (13.90%), and Tettigonidae (5.54%), among 35 herbivorous insects (= 0.10%), revealed the highest enemies (= 0.00%), among 24 natural enemies (= 0.00%), revealed the highest % I.I.-PU on leaves of A. auriculiformis saplings (Table 4).

The solution sources, per individual, Uspachus sp. (Araneae: Salticidae) (96.72%), Salticidae (Araneae) (2.83%), and Pseudomyrmex termittarius (Smith, 1877) (Hymenoptera: Formicidae) (0.45%), among 24 natural enemies (= 0.00%), revealed the highest % I.I.-PU on leaves of A. auriculiformis saplings. The number of Diabrotica speciosa German, 1824 (Coleoptera: Chrysomelidae) was reduced per number of Salticidae (13.85%); that of A. reticulatum that of Uspachus sp. (1.01%); and that of Cephaloeca sp. (Orthoptera: Proscopiidae) that of P. termittarius (23.54%), totaling 38.40% of reduction of these herbivorous insects (numbers) on A. auriculiformis saplings. However, the number of Aleyrodidae was increased per number of Cephalotes sp. (Hymenoptera: Formicidae) (2.10%) and that of A. reticulatum that of Brachymyrmex sp. (Hymenoptera: Formicidae) (93.01%), totaling 95.11% of increase of these sap-sucking insects on A. auriculiformis saplings. The final balance was negative, with an increase of herbivorous
insects of 56.71% in these saplings. The *A. reticulatum* damage, per individual, was reduced per number of *Uspachus* sp. (6.17%); but the Aleyrodidae damage, per individual, was increased per number of *Cephalotes* sp. (30.00%), totaling 23.81% of increase by insect damages on *A. auriculiformis* saplings (Tables 5 and 6).

### 4. Discussion

The Percentage of Importance Indice-Production Unknown (% I.I.-PU) was effective in identifying loss (e.g., Tettigoniidae) and solution (e.g., Salticidae) sources and of the S.S. important on damage reduction by L.S. (e.g.,

| Loss Sources | Var.* | Mean | C.sq. | P  | Dist. |
|--------------|-------|------|-------|----|-------|
| Coleoptera: Cerambycidae | 0.02 | 0.02 | 44.00 | 0.47 | Ran. |
| Chrysomelidae, *Alagoasa* sp. | 0.04 | 0.04 | 43.00 | 0.52 | Ran. |
| Cerotoma sp. | 0.24 | 0.18 | 59.50 | 0.06 | Ran. |
| Charidotis sp. | 0.02 | 0.02 | 44.00 | 0.47 | Ran. |
| *Diabrotica* speciosa Germar, 1824 | 0.21 | 0.20 | 46.00 | 0.39 | Ran. |
| *Disonycha* brasiliensis Costa Lima, 1954 | 0.04 | 0.04 | 43.00 | 0.51 | Ran. |
| *Eumolpus* sp. | 0.04 | 0.04 | 43.00 | 0.52 | Ran. |
| *Parasyphraea* sp. | 1.03 | 0.44 | 101.50 | 0.00 | Agg. |
| *Stereoma anchoralis* Lacordaire, 1848 | 2.04 | 1.09 | 82.33 | 0.00 | Agg. |
| *Walterianela* sp. | 0.04 | 0.04 | 43.00 | 0.52 | Ran. |
| Curculionidae | 0.04 | 0.04 | 43.00 | 0.52 | Ran. |
| *Cerotoma* sp. | 0.04 | 0.04 | 43.00 | 0.52 | Ran. |
| *Lordops* sp. | 0.06 | 0.07 | 42.00 | 0.56 | Ran. |
| *Naupactus* sp. | 0.06 | 0.07 | 42.00 | 0.56 | Ran. |
| Tenebrionidae, Alleculinae | 0.02 | 0.02 | 44.00 | 0.47 | Ran. |
| *Hemiptera: Aethalionidae, Aethalion reticulatum* L., 1767 | 71.05 | 2.76 | 1134.55 | 0.00 | Agg. |
| *Aleyrodidae* | 8.65 | 0.82 | 462.87 | 0.00 | Agg. |
| Cicadellidae, *Achillidae* | 0.09 | 0.04 | 88.00 | 0.00 | Agg. |
| *Cicadellidae* | 0.09 | 0.04 | 88.00 | 0.00 | Agg. |
| *Acrogonia* sp. | 0.02 | 0.02 | 44.00 | 0.47 | Ran. |
| *Balclutha hebe* Kirkaldy, 1906 | 0.93 | 0.42 | 97.05 | 0.00 | Agg. |
| *Erythrogonia sexguttata* Fabr., 1803 | 0.13 | 0.09 | 63.50 | 0.03 | Ran. |
| Cicadidae, *Quesada gigas* Oliver, 1854 | 0.04 | 0.04 | 43.00 | 0.51 | Ran. |
| Coreidae, *Leptoglossus* sp. | 0.02 | 0.02 | 44.00 | 0.47 | Ran. |
| *Fulgoridae* | 0.02 | 0.02 | 44.00 | 0.47 | Ran. |
| Membracidae | 0.10 | 0.11 | 40.00 | 0.64 | Ran. |
| *Membracis* sp. | 2.60 | 0.82 | 139.35 | 0.00 | Agg. |
| *Nogodinidae* | 0.02 | 0.02 | 44.00 | 0.47 | Ran. |
| Pentatomidae | 0.62 | 0.53 | 51.00 | 0.22 | Ran. |
| Scutelleridae, *Pachycoris torridus* Scopoli, 1772 | 0.70 | 0.38 | 80.94 | 0.00 | Agg. |
| Hymenoptera: *Apidae, Trigona spinipes* Fabr., 1793 | 0.04 | 0.04 | 43.00 | 0.51 | Ran. |
| Lepidoptera | 0.13 | 0.16 | 38.00 | 0.73 | Ran. |
| Orthoptera: *Proscopiidae, Cephaloecaema* sp. | 0.16 | 0.13 | 54.00 | 0.14 | Ran. |
| Romaleidae, *Tropidacris collaris* Stoll., 1813 | 0.97 | 0.93 | 45.86 | 0.39 | Ran. |
| Tettigoniidae | 0.61 | 0.73 | 36.55 | 0.78 | Ran. |
| Phasmatodea: *Phasmatidae, Phibalosoma phyllinum* Gray, 1835 | 0.02 | 0.02 | 44.00 | 0.47 | Ran. |

* = variance and £ = chi-square.
Table 2. Aggregated (Agg.), regular (Reg.), or random (Ran.) distribution (Dist.) of the solution sources on 48 *Acacia auriculiformis* (Fabaceae) saplings.

| Solution Sources | Qui-square test |
|------------------|-----------------|
|                  | Var.* | Mean | C.sq. | P   | Dist. |
| Araneae: Araneidae | 0.48  | 0.48 | 44.91 | 0.52 | Ran.  |
| Anyphaenidae, *Teudis* sp. | 0.16  | 0.13 | 55.33 | 0.14 | Ran.  |
| Oxyopidae        | 0.24  | 0.17 | 61.00 | 0.06 | Ran.  |
| *Oxyopes salticus* Hentz, 1845 | 0.04  | 0.04 | 44.00 | 0.51 | Ran.  |
| Salticidae       | 0.29  | 0.26 | 49.33 | 0.30 | Ran.  |
| *Aphirape uncifera* Tullgren, 1905 | 0.06  | 0.07 | 43.00 | 0.56 | Ran.  |
| *Uspachus* sp.   | 0.14  | 0.11 | 59.40 | 0.07 | Ran.  |
| Sparassidae, *Quemodice* sp. | 0.06  | 0.07 | 43.00 | 0.56 | Ran.  |
| Tetragnathidae, *Leucoagia* sp. | 0.02  | 0.02 | 45.00 | 0.47 | Ran.  |
| Thomisidae, *Tmarus* sp. | 0.08  | 0.09 | 42.00 | 0.60 | Ran.  |
| Coleoptera: Cantharidae, *Cantharis* sp. | 0.02  | 0.02 | 45.00 | 0.47 | Ran.  |
| Coccinellidae, *Cycloneda sanguinea* L., 1763 | 0.08  | 0.09 | 42.00 | 0.60 | Ran.  |
| Syrphidae, *Syrphus* sp. | 0.17  | 0.93 | 56.49 | 0.12 | Ran.  |
| Hymenoptera: Formicidae, *Brachymyrmex* sp. | 117.31 | 5.39 | 979.16 | 0.00 | Agg.  |
| Camponotus sp.   | 13.00 | 4.07 | 143.86 | 0.00 | Agg.  |
| *Cephalotes* sp. | 0.87  | 0.20 | 200.56 | 0.00 | Agg.  |
| *Diptera* sp.    | 1.88  | 0.83 | 102.42 | 0.00 | Agg.  |
| *Pseudomyrmex termitarius* (Smith, 1877) | 21.00 | 3.63 | 261.32 | 0.00 | Agg.  |
| Vespidae, *Polybia* sp. | 0.61  | 0.52 | 52.67 | 0.20 | Ran.  |
| Hemiptera: Pentatomidae, *Podisus* sp. | 0.11  | 0.07 | 73.67 | 0.00 | Agg.  |
| Mantodea: Mantidae, *Mantis religiosa* L., 1758 | 0.04  | 0.04 | 44.00 | 0.51 | Ran.  |
| Neuroptera: *Chrysoperla* sp. | 0.04  | 0.04 | 44.00 | 0.51 | Ran.  |

*= variance and ^= chi-square.

Table 3. Simple regression equations of damage per loss source (L.S.) and reduction or increase of L.S. (abundance or damage) per solution source (S.S.) on 48 *Acacia auriculiformis* (Fabaceae) saplings.

| Simple regression analysis | R² | ANOVA |
|---------------------------|----|-------|
|                           |    |       | F     | P     |
| Defoliation=4.02-0.33x*Stereoma anchoralis*+0.13x*Stereoma anchoralis*² | 0.20 | 5.46 | 0.0075 |
| Defoliation=4.22-1.03x*Tettigoniidae*+0.51x*Tettigoniidae*² | 0.18 | 4.98 | 0.0111 |
| Damage=-0.03+0.08xAleyrodidae | 0.98 | 1881.6 | 0.0000 |
| Damage=-0.0005+0.19xAethalion reticulatum | 0.99 | 3217.0 | 0.0000 |
| Aleyrodidae damage=0.11+0.42x*Cephalotes* sp. | 0.30 | 19.41 | 0.0001 |
| A. reticulatum damage=0.09+1.86x*Uspachus* sp.-0.96x*Uspachus* sp.² | 0.17 | 4.53 | 0.0161 |
| Aethalion reticulatum=0.50+9.25x*Uspachus* sp.--4.75x*Uspachus* sp.² | 0.15 | 3.98 | 0.0256 |
| Aethalion reticulatum=0.25+0.10x*Brachymyrmex* sp. | 0.14 | 7.50 | 0.0088 |
| Aleyrodidae=1.69+4.78x*Cephalotes* sp. | 0.29 | 18.32 | 0.0001 |
| *Diabrotica speciosa*=0.11+1.09x*Salticidae*+0.57x*Salticidae*² | 0.20 | 5.61 | 0.0067 |
| *Cephalocoena* sp.=-0.01+0.22x*P. termitarius*--0.03x*P. termitarius*² | 0.17 | 4.45 | 0.0173 |
Table 4. Total number (n), damage (Da.), key-source (ks), constancy (c), distribution source (ds), number of importance indice (n. I.I.), sum of n. I.I.-PU (Σ n. I.I.), and percentage of I.I. by loss source (L.S.) on 48 Acacia auriculiformis (Fabaceae) saplings.

| Loss source | L.S. | n   | Da.  | ks   | c   | ds   | n. I.I. | Σ n. I.I. | % I.I. |
|-------------|------|-----|------|------|-----|------|---------|-----------|--------|
| Aethalion reticulatum | 37   | 0.9800 | 0.0268 | 4    | 1.00 | 0.1070 | 0.28    | 38.86    |
| Aleyrodidae | 124  | 0.9800 | 0.008  | 13   | 1.00 | 0.1038 | 0.28    | 37.69    |
| Stereocampa anchoralis | 49   | 0.0782 | 0.0016 | 24   | 1.00 | 0.0383 | 0.28    | 13.90    |
| Tettigoniidae | 33   | 0.0881 | 0.0027 | 26   | 0.22 | 0.0153 | 0.28    | 5.54     |
| Tropidacris collaris | 42   | 0.0087 | 0.0002 | 26   | 0.61 | 0.0032 | 0.28    | 1.18     |
| Paretosa phrygae sp. | 20   | 0.0041 | 0.0002 | 11   | 1.00 | 0.0023 | 0.28    | 0.82     |
| Bot Fromosa sp. | 8    | 0.0017 | 0.0002 | 6    | 0.94 | 0.0012 | 0.28    | 0.42     |
| Diabrotica speciosa | 9    | 0.0019 | 0.0002 | 8    | 0.61 | 0.0010 | 0.28    | 0.37     |
| Cephaloeca sp. | 6    | 0.0012 | 0.0002 | 5    | 0.86 | 0.0009 | 0.28    | 0.32     |
| Leptoglossus sp. | 7    | 0.0014 | 0.0002 | 7    | 0.27 | 0.0004 | 0.28    | 0.14     |
| Lordops sp. | 3    | 0.0006 | 0.0002 | 3    | 0.44 | 0.0003 | 0.28    | 0.10     |
| Naupactus sp. | 3    | 0.0006 | 0.0002 | 3    | 0.44 | 0.0003 | 0.28    | 0.10     |
| Alagoa sp. | 2    | 0.0004 | 0.0002 | 2    | 0.49 | 0.0002 | 0.28    | 0.07     |
| Disonycha brasiliensis | 2    | 0.0004 | 0.0002 | 2    | 0.49 | 0.0002 | 0.28    | 0.07     |
| Eumolpus sp. | 2    | 0.0004 | 0.0002 | 2    | 0.49 | 0.0002 | 0.28    | 0.07     |
| Walterianela sp. | 2    | 0.0004 | 0.0002 | 2    | 0.49 | 0.0002 | 0.28    | 0.07     |
| Cretosomus sp. | 2    | 0.0004 | 0.0002 | 2    | 0.49 | 0.0002 | 0.28    | 0.07     |
| Curculionidae | 2    | 0.0004 | 0.0002 | 2    | 0.49 | 0.0002 | 0.28    | 0.07     |
| Charidotis sp. | 1    | 0.0002 | 0.0002 | 1    | 0.53 | 0.0001 | 0.28    | 0.04     |
| Allocultinae | 1    | 0.0002 | 0.0002 | 1    | 0.53 | 0.0001 | 0.28    | 0.04     |
| Phibalosoma phyllinum | 1    | 0.0002 | 0.0002 | 1    | 0.53 | 0.0001 | 0.28    | 0.04     |
| Cerambycidae | 1    | 0.0000 | 0.0000 | 1    | 0.53 | 0.0000 | 0.28    | 0.00     |
| Achilliidae | 2    | 0.0000 | 0.0000 | 1    | 0.53 | 0.0000 | 0.28    | 0.00     |
| Acrogonia sp. | 1    | 0.0000 | 0.0000 | 1    | 0.53 | 0.0000 | 0.28    | 0.00     |
| Balclutha hebe | 19   | 0.0000 | 0.0000 | 10   | 0.10 | 0.0000 | 0.28    | 0.00     |
| Erythrogonia sexguttata | 4    | 0.0000 | 0.0000 | 3    | 0.97 | 0.0000 | 0.28    | 0.00     |
| Quiescidae sp. | 2    | 0.0000 | 0.0000 | 2    | 0.49 | 0.0000 | 0.28    | 0.00     |
| Leptoglossus sp. | 1    | 0.0000 | 0.0000 | 1    | 0.53 | 0.0000 | 0.28    | 0.00     |
| Fulgoridae | 1    | 0.0000 | 0.0000 | 1    | 0.53 | 0.0000 | 0.28    | 0.00     |
| Membracidae | 5    | 0.0000 | 0.0000 | 5    | 0.36 | 0.0000 | 0.28    | 0.00     |
| Membracid sp. | 37   | 0.0000 | 0.0000 | 19   | 1.00 | 0.0000 | 0.28    | 0.00     |
| Nogodinidae | 1    | 0.0000 | 0.0000 | 1    | 0.53 | 0.0000 | 0.28    | 0.00     |
| Pentatominidae | 24   | 0.0000 | 0.0000 | 19   | 0.78 | 0.0000 | 0.28    | 0.00     |
| Pachycoris torridus | 17   | 0.0000 | 0.0000 | 9    | 1.00 | 0.0000 | 0.28    | 0.00     |
| Trigona spines | 2    | 0.0000 | 0.0000 | 2    | 0.49 | 0.0000 | 0.28    | 0.00     |

LI.-PU = ks x c x ds. ks = Da. (total n of the L.S.), Da. = R² x (1 - P) when it is of the first degree, or (R² x (1 - P) x β1/β2) when it is of the second degree, where R² = determination coefficient and P = significance of ANOVA, β1 = regression coefficient, and β2 = regression coefficient (variable²), of the simple regression equation, or non-percentage of damage per L.S., c = % 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.

Uspachus sp. versus A. reticulatum) on a system with production unknown (e.g., A. auriculiformis saplings). The loss sources A. reticulatum, Aleyrodidae, S. anchoralis, and Tettigoniidae presented the highest % LI.-PU on leaves of A. auriculiformis saplings. These herbivorous insects are related as a pest in some crops. The A. reticulatum is a pest that reduces the development of fruits and sprouts, leading to hypertrophy and cracks in the apex of...
Table 5. Total number (n), reduction of L.S. (R.L.S.), key-source (ks), constancy (c), distribution source (ds), number of importance indice (n. I.I.), sum of n. I.I.-PU (Σ n. I.I.), and percentage of I.I. by solution source (S.S.) on 48 Acacia auriculiformis (Fabaceae) saplings.

| Solution source | S.S. | n   | R.L.S. | ks   | c   | ds   | n. I.I. | Σ n. I.I. | % I.I. |
|-----------------|------|-----|--------|------|-----|------|--------|----------|-------|
| Uspachus sp.    | 5    | 2.7800 | 0.5560 | 4    | 0.93 | 2.06 | 2.13   | 96.72    |
| Salticidae      | 12   | 0.1039 | 0.0087 | 10   | 0.70 | 0.06 | 2.13   | 2.83     |
| Pseudomymex termitarius | 62   | 0.0228 | 0.0004 | 26   | 1.00 | 0.01 | 2.13   | 0.45     |
| Araneidae       | 22   | 0.0000 | 0.0000 | 17   | 0.48 | 0.00 | 2.13   | 0.00     |
| Teudis sp.      | 6    | 0.0000 | 0.0000 | 5    | 0.86 | 0.00 | 2.13   | 0.00     |
| Oxyopidae       | 8    | 0.0000 | 0.0000 | 6    | 0.94 | 0.00 | 2.13   | 0.00     |
| Oxyopes salticus | 2    | 0.0000 | 0.0000 | 2    | 0.49 | 0.00 | 2.13   | 0.00     |
| Aphirape uncifera | 3    | 0.0000 | 0.0000 | 3    | 0.44 | 0.00 | 2.13   | 0.00     |
| Quenedecidae sp. | 3    | 0.0000 | 0.0000 | 3    | 0.44 | 0.00 | 2.13   | 0.00     |
| Leucaugia sp.   | 1    | 0.0000 | 0.0000 | 1    | 0.53 | 0.00 | 2.13   | 0.00     |
| Tmarus sp.      | 4    | 0.0000 | 0.0000 | 4    | 0.40 | 0.00 | 2.13   | 0.00     |
| Cantharis sp.   | 7    | 0.0000 | 0.0000 | 6    | 0.78 | 0.00 | 2.13   | 0.00     |
| Brachymyrmex sp. | 248  | 0.0000 | 0.0000 | 28   | 1.00 | 0.00 | 2.13   | 0.00     |
| Camponotus sp.  | 187  | 0.0000 | 0.0000 | 41   | 1.00 | 0.00 | 2.13   | 0.00     |
| Cephaleotes sp. | 9    | 0.0000 | 0.0000 | 3    | 1.00 | 0.00 | 2.13   | 0.00     |
| Ectatoma sp.    | 38   | 0.0000 | 0.0000 | 18   | 1.00 | 0.00 | 2.13   | 0.00     |
| Pheidole sp.    | 167  | 0.0000 | 0.0000 | 41   | 1.00 | 0.00 | 2.13   | 0.00     |
| Polybia sp.     | 24   | 0.0000 | 0.0000 | 18   | 0.80 | 0.00 | 2.13   | 0.00     |
| Podisius sp.    | 3    | 0.0000 | 0.0000 | 2    | 1.00 | 0.00 | 2.13   | 0.00     |
| Mantis religiosa | 2    | 0.0000 | 0.0000 | 2    | 0.49 | 0.00 | 2.13   | 0.00     |
| Chrysoperla sp. | 2    | 0.0000 | 0.0000 | 2    | 0.49 | 0.00 | 2.13   | 0.00     |

I.I.-PU = ks x c x ds, ks = R.L.S. (total n. of the S.S.; R.L.S. = R² x (1 - P) when it is of the first degree, or (R² x (1 - P))x(β₁/β₂) when it is of the second degree, where R² = determination coefficient and P = significance of ANOVA, β₁ = regression coefficient, and β₂ = 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 Dn. by L.S. or E.S. non-significant for damage by L.S. or reduced L.S. by S.S.

seedlings and possibly killing plants of “mulungu” Erythrina speciosa Andrews (Fabales: Fabaceae) (Araújo et al., 2010; Zanuncio et al., 2015). In addition, this sap-sucking insect damages A. mangium, ant tree Triplaris americana L. (Caryophyllales: Polygonaceae), and bitterleaf Vernonia condensata Baker (Asterales: Asteraceae) (De Menezes et al., 2013; Pires et al., 2015; Silva et al., 2020; Gomes et al., 2023; Lima et al., 2024). Aleyrodidae family has Bemisia tabaci (Genn., 1889), as a pest of several plants, including sweet pepper Capsicum annuum L. (Solanales: Solanaceae), melon Cucumis melo L. (Cucurbitales: Cucurbitaceae), soybean Glycine max (L.) Merrill (Fabales: Fabaceae) and common bean Phaseolus vulgaris L. (Fabales: Fabaceae), and tomato Solanum lycopersicon Mill. (Solanales: Solanaceae) by sucking sap, injecting toxins, transmitting viruses, and favors the development of fumagine (Zhang et al., 2004; Mansaray and Sundufu, 2009; Kim et al., 2017; Felicio et al., 2019). The species S. anchoralis damages A. mangium and leucaena Leucaena leucocephala (Lam.) de Wit (Fabales: Fabaceae) trees (Damascena et al., 2017; Silva et al., 2020), and Meroncidius intermedius (Brunner von Wattenwyl, 1895) (Orthoptera: Tettigoniidae) damaged grasses and banana Musa spp. fruits (Zingiberales: Musaceae) (Zanuncio-Junior et al., 2017). The solution sources Uspachus sp., Salticidae, and P. termitarius showed the highest % I.I.-PU on leaves of A. auriculiformis saplings. The numbers of D. speciosa, A. reticulatum, and Cephalochaeta sp. were reduced per numbers of Salticidae, Uspachus sp. (also reduced damage by this pest, ≈ 6%), and P. termitarius, respectively, on A. auriculiformis saplings. Spiders are important predators, as an example, on A. mangium and pequi tree Caryocar brasiliense Camb. (Malpighiales: Caryocaraceae) trees, in the Brazilian Cerrado (Leite et al., 2012a; Silva et al., 2013).
Table 6. 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. (Σ) on 48 Acacia auriculiformis (Fabaceae) saplings.

| S.S.          | D. speciosa | A. reticulatum | Aleyrodidae | Cephalocoema sp. |
|---------------|-------------|----------------|-------------|------------------|
| Salticidae    | 13.85       | ---            | ---         | ---              |
| Uspachus sp.  | ---         | 1.01           | ---         | ---              |
| Brachymyrmex sp. | ---        | -93.01         | ---         | ---              |
| Cephalotes sp. | ---         | ---            | -2.10       | ---              |
| P. termitarius | ---         | ---            | ---         | 23.54            |
| Σ             | 13.85       | -92.00         | -2.10       | 23.54            |
| Σ            | -56.71      | ---            | ---         | ---              |

--- = 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. = R² x (1 - P) when it is of the first degree, or ((R² x (1 - P))x(σ₁/σ₂)) when it is of the second degree, where R² = determination coefficient and P= significance of ANOVA, f₁ = regression coefficient, and f₂ = regression coefficient (variable²), of the simple regression equation.

2020); on pastures and forests in Greece, and in A. auriculiformis saplings in a degraded area in Brazil, being directly correlated with Orthoptera (Zografou et al., 2017; Mota et al., 2023); in many agroecosystems in the USA (Landis et al., 2000) and Italy (Venturino et al., 2008); and in 12 agricultural landscapes in the low mountain ranges of Central Hesse (Germany) (Öberg et al., 2008). Moreover, ants can reduce defoliation and fruit-boring insect populations (e.g., Coleoptera and Lepidoptera) (Leite et al., 2012a; Gonthier et al., 2013; Fagundes et al., 2017; Dassou et al. 2019) besides, they are bioindicators of the recovery of degraded areas (Sanchez, 2015). However, the numbers of Aleyrodidae and A. reticulatum were increased per numbers of Cephalotes sp. (increasing Aleyrodidae damage = 30%) and Brachymyrmex sp., respectively, totaling, ≈95% of increase of these sap-sucking insects on A. auriculiformis saplings. These facts can be a problem in A. auriculiformis commercial crops. Sap-sucking insects, especially at high densities, can be associated with ants (mutual benefit), showing a direct correlation between these groups (Leite et al., 2012b, 2015, 2016; Novgorodova, 2015; Sanchez et al., 2020) because they collectively and aggressively defend their resources (e.g., sap-sucking insects) (Novgorodova, 2015). Dominant ants form mutualistic relationships with sap-sucking insects, with the negative impact of the latter on the biological control of sap-sucking hemipterans (Karami-Jamour et al., 2018; Tong et al., 2019). This relationship increases pest problems in agricultural systems (Sagata and Gibb, 2016).

5. Conclusions

The loss sources A. reticulatum, Aleyrodidae, S. anchoralis, and Tettigonioidea showed the highest %I.I.-PU on leaves of A. auriculiformis saplings. These insects turn into problems on A. auriculiformis plantations since they are related to pests in some crops. The solution sources Uspachus sp., Salticidae, and P. termitarius showed the highest %I.I.-PU on leaves of A. auriculiformis saplings. These natural enemies can be important to A. auriculiformis because they can reduce herbivorous damages (e.g., A. reticulatum damage versus Uspachus sp.). However, ants Cephalotes sp. and Brachymyrmex sp. increased around 95% of Aleyrodidae and A. reticulatum populations and can be a problem in A. auriculiformis commercial crops. Here I showed and tested the %I.I.-PU, a new index that can detect the loss or solution sources, when production is unknown, on a system, and it can be applied in various knowledge areas.

Acknowledgments

I wish to thank the taxonomists Dr. Antônio Domingos Brescovit (Butantan Institute, São Paulo State, Brazil - Arachnida), Dr. Ayr de Moura Bello (Osvaldo Cruz Foundation, Rio de Janeiro State, Brazil - Coleoptera), Dr. Carlos Matrangolo (University of Montes Claros, Minas Gerais State, Brazil - Formicidae), Dr. Ivan Cardoso Nascimento (EMBRAPA-ILHÉUS Cocoa Research Center, CEPLAC, Itabuna, Bahia State, Brazil - Formicidae), Dr. Luci

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Boa Nova Coelho (Federal University of Rio de Janeiro, Rio de Janeiro State, Brazil – Cicadellidae), and Dr. Paulo Sérgio Fiuza Ferreira (Federal University of Viçosa, Minas Gerais State, Brazil - Hemiptera) for the identification of specimens. The voucher numbers are 1595/02 and 1597/02 (CDZOO, Federal University of Paraná, Paraná State, Brazil).

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