

Full Length Research Paper

Effectiveness of adhesive and pitfall traps in arthropod sampling in crop areas and surroundings

**Aldair Zandwaide Abdou Sanhá Baió¹, Carlos Zacarias Joaquim Júnior^{2*},
Bernardino Domingos Mango², Nelito Nhanca Nbalí², Jorge Luis Tejada³, Luan Tiago dos
Santos Carbonari², Paulo Henrique Cerutti², Indianara Ignacio Milkievicz²,
Mauro Bitencourt de Souza², Henrique de Sá Albino², Micrela Daniel Fernandes¹ and
João Gutemberg Leite Moraes¹**

¹Institute of Rural Development, College of Agronomy, University of International Integration of the African-Brazilian Lusophone (IDR/UNILAB), Ceará, Brazil.

²Center for Agro-Veterinary Sciences, College of Agronomy, Santa Catarina State University (CAV/UDESC), Lages-SC, Brazil.

³Department of Plant Sciences, College of Agronomy, National Agrarian University (UNALM), La Molina, Lima, Peru.

Received 13 January; 2025, Accepted 2 July, 2025

This study aimed to investigate the arthropod fauna in cultivated areas of maize (*Zea mays*), cowpea (*Vigna unguiculata*), sesame (*Sesamum indicum*), and cotton (*Gossypium hirsutum*), as well as their surroundings, using pitfall traps and yellow sticky traps, associated with the occurrence of harmful phytophagous species. Fifteen days after sowing, two traps were installed at the center of each cultivated area. Additionally, eight more traps of each type were installed in the surrounding area, positioned at the midpoint of each side, spaced 10 m apart, extending perpendicularly from the edges of the crops into the forest. Based on the results obtained, A total of 15,540 specimens distributed across six Insecta orders were recorded from both traps. Diptera and Coleoptera orders were the most frequent and dominant in cultivated areas and their surroundings (forest) when captured using yellow sticky traps. The Coleoptera and Hymenoptera orders were the most frequent and dominant in cultivated areas when pitfall traps were used. Greater diversity and uniformity in the species captured by the sticky trap were observed in the forest environment. In contrast, lower diversity and higher dominance were observed in sticky trap captures, but high diversity in pitfall trap captures was noted in environments with *V. unguiculata*. The pitfall trap proved to be more effective in capturing a greater diversity and uniform distribution of species, especially in crops such as *V. unguiculata* and *G. hirsutum*.

Key words: Arthropods, biodiversity, agricultural entomology, agroecosystem, cultural control.

INTRODUCTION

Biodiversity refers to the variety of life on Earth, ranging from genetic diversity within species to the diversity of entire ecosystems. It is essential for the health and

sustainability of the planet, directly influencing human well-being and the stability of ecosystems. Biodiversity conservation is crucial for mitigating the impacts of

human activities and ensuring a sustainable future (Kaplan, 2019; Fontana and Massa, 2023).

In the agricultural context, agrobiodiversity is crucial for the sustainability of agroecosystems, promoting environmental services such as nutrient cycling and biological pest control. However, the diversification of crops and habitats not only enhances natural pest regulation but also contributes to soil conservation and nutrient use efficiency (Liu et al., 2023; Jernigan et al., 2024).

Habitat simplification has a significant negative impact on insect diversity, which in turn affects the ecosystem services they provide, such as pollination, pest control, and nutrient cycling. The reduction in habitat structural complexity is associated with a decrease in species richness and functional diversity, which can compromise the sustainability of ecosystems (Flores et al., 2018).

The use of capture traps is an essential tool for monitoring pest insects, offering significant benefits in terms of ease of collection and accessibility. Traps allow for an effective survey of insects, serving as an important procedure for pest monitoring and observation (Preti et al., 2020).

The use of yellow sticky traps is a passive collection method, where the colors attract insects, phytophagous species, and agricultural pests in different ways. It is also useful in faunal surveys and population monitoring, being especially effective in capturing insects such as dipterans and hymenopterans, as well as some groups of lepidopterans and coleopterans (Carrillo-Arámbula et al., 2022).

In contrast, pitfall traps are widely used to capture arthropods that inhabit the soil, such as beetles, ants, and spiders. These traps are effective for studying the diversity and abundance of these terrestrial invertebrates, which typically do not fly and spend part of their lives on the ground. They are valuable tools for studying terrestrial arthropods, but their effectiveness depends on several factors, including design, color, spatial arrangement, and the use of attractants. Adjustments to these parameters can optimize capture and provide more accurate data for biodiversity and ecology studies (Yamanaka et al., 2023).

Given the aforementioned, the present study aimed to investigate the arthropod fauna in the cultivated areas of *Zea mays*, *Vigna unguiculata*, *Sesamum indicum*, and *Gossypium hirsutum*, as well as their surroundings, through the use of yellow sticky traps and pitfall traps.

MATERIALS AND METHODS

The research was conducted at the Experimental Farm of the

University of International Integration of the African-Brazilian Lusophone (UNILAB), located in the Piroás community, in the rural area of the Barra Nova District, municipality of Redenção, Ceará, Brazil. The geographic coordinates are 4°12'39" S latitude, 38°27'56" W longitude, and an altitude of 327 m. The climate of the region is classified as AW (tropical), meaning it is hot with a predominance of rainfall during the summer and autumn seasons. The average temperature and precipitation during the evaluation period were 26.39°C and 100.4 mm, respectively.

The experiment was conducted under field conditions during the rainy season, with natural infestation conditions. The arthropod survey area was in the surroundings and within the cultivated areas of *Z. mays*, *V. unguiculata*, *S. indicum*, and *G. hirsutum*, where four plots were established. Each cultivated area measured 6 m in width and 10 m in length, with each crop spaced 2 m apart, totaling 308 m² of cultivated area.

For the arthropod captures, two trap models were used. Each model was chosen based on the diversity of species collected and the cost/efficiency relationship of the traps. The following trap models were used which were the yellow Biotrap® sticky trap and the pitfall trap. Five traps were installed within each cultivated area, and eight traps were distributed at each midpoint around the area, approximately 10 m apart, extending perpendicularly from the edges of the crops toward the forest.

For the installation of the yellow sticky traps, supports were used, fixed 1.0 m above the ground, on which the traps were attached with the help of polyvinyl chloride (PVC) pipes, and secured with a wire hook to hold the adhesive in place. The pitfall trap consisted of a wide-mouth plastic container with a diameter of 10 cm and a height of 10 cm, buried level with the ground. It was filled with a preservative solution (300 mL) made from a mixture of 5 L of water, 15 mL of bleach, 5 mL of neutral detergent, and 50 g of NaCl, and buried up to ground level.

The collections and replacements of both trap types were conducted weekly from March 22 to May 3, 2018, totaling seven collections over 49 days. The material collected with the sticky traps was wrapped in PVC film and then taken to the Zoology Laboratory at the Auroras Campus, identified, and placed in the refrigerator for later sorting.

Concerning the collections and replacements using the pitfall traps were also carried out weekly during the same period and methods as the sticky traps, totaling seven collections. During each collection, the solution inside the traps was replaced. The captured insects were collected and placed in plastic containers, properly labeled (with the date, collection site, and trap type), containing 70% ethanol for preservation. After collection, the insects were transported to the laboratory, where identification and sorting were carried out.

The sorting and identification of the insects were carried out at the Zoology Laboratory of UNILAB, where all samples were identified at the order level using a magnifying glass, with the help of taxonomic keys as a reference. After sorting, the material collected from the pitfall traps was labeled and stored in vials containing a preservative solution (70% ethanol). The frequency of each collected order was determined by:

$$F = \frac{\text{Number of individuals of the captured order}}{\text{Total number of individuals captured}} \times 100$$

where F = frequency of each collected order. Calculations were

*Corresponding author. E-mail: cjoaquim188@gmail.com.

performed for the Shannon Diversity Index, Simpson's dominance index, and Shannon's evenness index, using the DivEs® program.

The Simpson's dominance index was calculated using the following formula:

$$D = \sum_{i=1}^S P_i^2 \quad (1)$$

where D = Simpson's dominance index, S = Total number of species in the community, and P_i = Proportion of individuals of species "i" relative to the total number of individuals in the community.

The Shannon evenness index (J) was calculated using the following formula:

$$J = \frac{H'}{\ln(S)} \quad (2)$$

The Shannon diversity index (H') was calculated using the following formula:

$$H' = - \sum_{i=1}^S P_i \ln(P_i) \quad (3)$$

where P_i = The proportion of individuals of species "i" in relation to the total number of individuals in the community, S = Total number of species in the community, and $\ln(S)$ = The natural logarithm of the total number of species (maximum possible diversity).

RESULTS AND DISCUSSION

During the study period, a total of 15,540 species were captured, distributed across six orders of Insecta, in addition to Araneae. Among the collected insects, 14,106 were captured using the yellow sticky traps, both inside and outside the cultivated area. However, 5,990 insects were captured only in the cultivated areas (Table 1), and 8,116 were captured in the surrounding areas of the cultivation.

In all the evaluated cultivated areas, it was observed that insects from the order of Diptera were the most frequent, followed by the order of Coleoptera, with 62.80 and 21.50% of the individuals collected in the cultivated area of *G. hirsutum*; 71.13 and 16.75% in the cultivated area of *V. unguiculata*; 59.47 and 24.55% in the cultivated area of *S. indicum*; respectively 62.60 and 20.76% in the cultivated area of *Z. mays*, respectively. Lower frequencies were observed in the order Lepidoptera. These results directly influenced the dominance of Diptera and Coleoptera in relation to the other groups. On the other hand, 8,116 insects were captured in the surrounding areas of cultivation. Similarly, insects from the orders Diptera and Coleoptera were the most frequent in these areas, as was observed in the cultivated areas.

Of the insects collected, 1,434 were captured using pitfall traps, both inside and outside the cultivated area. However, 479 insects were captured only in the cultivated areas (Table 2) and 955 in the surrounding areas of cultivation.

In the cultivated areas, it was observed that insects from the order Hymenoptera were the most frequent, followed by insects from the order Coleoptera, with 30.56 and 29.63% of the individuals collected in the cultivated area of *G. hirsutum*, respectively and 33.65 and 26.92%, in the cultivated area of *S. indicum* (Table 2).

In the cultivated areas of *V. unguiculata* (30.19 and 26.42%) and *Z. mays* (30.56 and 27.78%), an inverse predominance was observed, meaning a higher frequency of Coleoptera followed by Hymenoptera. Lower frequencies were observed in the orders Lepidoptera and Neuroptera. These results directly influenced the dominance of Diptera and Coleoptera in relation to the other groups.

The reason why the yellow sticky trap captured a larger number of insects is that it is suitable for both soil-dwelling and flying insects, making it the most recommended for insect control in agricultural areas. This represents one of the best cultural management strategies in crop fields.

The Shannon diversity index (H') is a widely used measure to assess species diversity, considering both species richness and evenness. However, it is sensitive to the relative abundance of species and may be biased in small samples. Higher values indicate greater diversity. The Simpson's dominance index is a measure that expresses the concentration of species dominance in a community, weighted by the abundance of species. It is used to assess the structure of biological communities and their diversity. Lower values indicate less dominance by a few species, which generally reflects higher diversity.

The evenness index (E) or Shannon's equitability is a measure that evaluates the uniformity of the proportional abundances of species in an ecosystem, or the ability of a statistic to assign similar scores to equally noisy relationships of different types. However, the current study suggests that this index is influenced by the predominance of certain insect species, such as Diptera and Coleoptera, and is related to plant diversity, microclimatic conditions, and the structure of insect communities. Higher values indicate that the species are more evenly distributed.

When applying the sticky traps, it was noticed that the forest area showed a higher Shannon diversity index (H'), while the pitfall trap provided a higher index in the areas of *V. unguiculata*. The Simpson's dominance was higher in *V. unguiculata* areas with sticky traps and higher in the forest areas with sticky traps. On the other hand, the J (Shannon) evenness was higher in the forest areas with sticky traps, while with the use of pitfall traps, this index

Table 1. Number of insects captured per collection (Col.), frequency % (Freq.), and dominance (Dom.) in yellow sticky traps within the cultivated area.

Order	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Total	Freq.	Dom.
<i>Gossypium hirsutum</i>										
Dip	125	92	115	183	49	92	124	780	62.80	D
Hem	12	15	9	4	7	12	9	68	5.48	Nd
Col	48	43	41	21	27	41	46	267	21.50	D
Hym	6	20	20	10	15	18	15	104	8.37	Nd
Lep	3	1	0	0	0	0	0	4	0.32	Nd
Ara	3	0	1	2	2	2	3	13	1.05	Nd
Neu	2	0	2	1	1	0	0	6	0.48	Nd
Total	199	171	188	221	101	165	197	1242	100	-
<i>Vigna unguiculata</i>										
Dip	172	92	116	341	229	308	326	1584	71.13	D
Hem	9	11	12	11	8	15	15	81	3.64	Nd
Col	47	51	52	46	50	80	47	373	16.75	D
Hym	9	9	15	20	20	55	24	152	6.83	Nd
Lep	2	3	1	1	1	3	0	11	0.49	Nd
Ara	2	3	4	0	1	4	0	14	0.63	Nd
Neu	2	1	2	5	0	0	2	12	0.54	Nd
Total	243	170	202	424	309	465	414	2227	100	-
<i>Sesamum indicum</i>										
Dip	140	89	98	106	108	85	137	763	59.47	D
Hem	22	10	6	5	7	7	17	74	5.77	Nd
Col	85	48	35	29	35	49	34	315	24.55	D
Hym	18	16	9	15	13	29	12	112	8.73	Nd
Lep	0	1	0	0	0	0	0	1	0.08	Nd
Ara	1	4	3	2	1	0	1	12	0.94	Nd
Neu	0	2	1	3	0	0	0	6	0.47	Nd
Total	266	170	152	160	164	170	201	1283	100	-
<i>Zea mays</i>										
Dip	161	87	106	185	69	61	106	775	62.60	D
Hem	13	12	9	10	7	6	14	71	5.74	nd
Col	31	44	45	36	39	33	29	257	20.76	D
Hym	6	12	18	21	15	16	18	106	8.56	nd
Lep	1	0	1	0	0	1	1	4	0.32	nd
Ara	0	3	1	3	2	1	1	11	0.89	nd
Neu	1	1	4	6	1	0	1	14	1.13	nd
Total	213	159	184	261	133	118	170	1238	100	-

Dip: Diptera; Hem: Hemiptera; Col: Coleoptera; Hym: Hymenoptera; Lep: Lepidoptera; Ara: Araneae; Neu: Neuroptera; D: dominant; nd: non-dominant.

Source: UNILAB in Redenção-CE (2018).

was higher in the areas of *G. hirsutum* (Table 3).

The results obtained in the present study suggest that with the use of sticky traps, the Shannon diversity index (H') values range from 0.9440 (*V. unguiculata*) to 1.1452 (forest). The forest environment shows the highest

diversity, while *V. unguiculata* exhibits the lowest diversity. Regarding Simpson's dominance, the values range from 0.3885 (forest) to 0.5268 (*V. unguiculata*). This indicates that the forest has lower dominance (indicating greater diversity), while *V. unguiculata* exhibits

Table 2. Number of insects captured per collection (Col.), Frequency % (Freq.), and Dominance (Dom.) in pitfall traps within the cultivated area.

Order	Col. 1	Col.2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Total	Freq.	Dom.
<i>Gossypium hirsutum</i>										
Dip	4	3	5	2	2	0	4	20	18.52	D
Hem	1	2	3	2	0	1	1	10	9.26	nd
Col	6	5	6	4	4	3	4	32	29.63	D
Hym	7	4	7	5	3	4	3	33	30.56	D
Lep	0	0	1	0	0	0	0	1	0.93	nd
Ara	2	2	2	2	2	0	1	11	10.17	nd
Neu	0	1	0	0	0	0	0	1	0.93	nd
Total	20	17	24	15	11	8	13	108	100	-
<i>Vigna unguiculata</i>										
Dip	5	2	4	4	3	4	6	28	17.61	D
Hem	4	2	2	2	2	2	2	16	10.06	nd
Col	7	12	7	6	3	5	8	48	30.19	D
Hym	6	5	8	9	2	6	6	42	26.42	D
Lep	1	1	0	1	1	1	1	6	3.77	nd
Ara	2	2	2	3	2	2	2	15	9.43	nd
Neu	1	0	0	0	1	1	1	4	2.52	nd
Total	26	24	23	25	14	21	26	159	100	-
<i>Sesamum indicum</i>										
Dip	2	3	2	3	1	2	2	15	14.42	D
Hem	1	5	2	1	1	1	0	11	10.58	nd
Col	4	6	5	6	2	2	3	28	26.92	D
Hym	3	9	7	6	3	3	4	35	33.65	D
Lep	0	2	1	0	0	0	0	3	2.88	nd
Ara	0	4	1	1	1	1	1	9	8.67	nd
Neu	0	1	0	1	0	1	0	3	2.88	nd
Total	10	30	18	18	8	10	10	104	100	-
<i>Zea mays</i>										
Dip	3	4	3	3	3	1	4	21	19.44	D
Hem	0	1	2	1	1	2	1	8	7.41	Nd
Col	8	2	4	5	5	4	5	33	30.56	D
Hym	4	2	5	6	6	3	4	30	27.78	D
Lep	1	1	0	0	1	1	0	4	3.70	Nd
Ara	1	1	1	2	1	1	2	9	8.33	Nd
Neu	0	0	1	1	1	0	0	3	2.78	Nd
Total	20	17	24	15	11	8	13	108	100	-

Dip: Diptera; Hem: Hemiptera; Col: Coleoptera; Hym: Hymenoptera; Lep: Lepidoptera; Ara: Araneae; Neu: Neuroptera; D: dominant; nd: non-dominant.

Source: UNILAB in Redenção-CE (2018).

higher dominance of a few species. When analyzing the Shannon evenness index, it was observed that the values range from 0.5127 (*V. unguiculata*) to 0.7083 (forest). This allows us to infer that the forest shows greater uniformity in species distribution, while the *V. unguiculata* area has the lowest evenness.

When using pitfall traps, the Shannon diversity index (H') values range from 1.4341 (*G. hirsutum*) to 1.6468 (*V. unguiculata*), with the first environment exhibiting the lowest diversity, while the second shows the highest diversity. In terms of Simpson's dominance, the values range from 0.1847 (*S. indicum*) to 0.2083 (forest). The

Table 3. Average values of the Diversity Indices for sticky traps obtained from the seven weekly collections.

Faunistic Indices	Sticky trap				
	Cotton	Cowpea	Sesame	Corn	Forest
Shannon diversity index (H')	1.0707	0.9440	1.0730	1.0983	1.1452
Simpson's dominance index (D)	0.4462	0.5268	0.4352	0.4383	0.3885
Shannon's evenness index (J)	0.6211	0.5127	0.6450	0.5984	0.7083

Faunistic Indices	Pitfall trap				
	Cotton	Cowpea	Sesame	Corn	Forest
Shannon diversity index (H')	1.4341	1.6468	1.5099	1.5683	1.4747
Simpson's dominance index (D)	0.2081	0.1884	0.1847	0.1857	0.2083
Shannon's evenness index (J)	0.9206	0.8877	0.9047	0.8903	0.9187

Cotton (*Gossypium hirsutum*), Cowpea (*Vigna unguiculata*), Sesame (*Sesamum indicum*), Corn (*Zea mays*), and Forest.
Source: Redenção-CE (2018).

first environment shows lower dominance (indicating greater diversity), while the second exhibits higher dominance. As for the Shannon evenness, the values range from 0.8877 (*V. unguiculata*) to 0.9206 (*G. hirsutum*), with the *G. hirsutum* environment showing the highest evenness, while *V. unguiculata* exhibits the lowest.

By comparing the indices, it is possible to infer that in the Shannon diversity (H'), the pitfall trap records higher values, suggesting that it captures a greater diversity of species compared to the adhesive trap. In terms of Simpson's dominance, the dominance values are consistently lower in the pitfall trap, indicating higher diversity in comparison to the adhesive trap. The evenness is higher in the pitfall traps, suggesting that the species distribution is more uniform.

Just as the forest environment provided higher diversity and evenness in species captured by the adhesive trap, the environment with *V. unguiculata* showed lower diversity and higher dominance in captures by the adhesive trap. However, high diversity was observed in the pitfall trap. The pitfall trap appears to be more effective in capturing a greater diversity and more even distribution of species, especially in crops such as *V. unguiculata* and *G. hirsutum*.

Therefore, the maintenance of surrounding vegetation can positively support the natural biological control of pests in crops. It also provides resources such as pollen, nectar, and shelter for beneficial fauna, thereby offering valuable contributions to integrated pest management strategies, especially when considering non-action levels, as observed by previous studies on the *G. hirsutum* crop (Moraes et al., 2014).

The results obtained in the present study revealed a significant presence of insects in the study areas, with a higher frequency in the cultivated areas compared to the surrounding areas. The main insects belong to the orders Diptera, Coleoptera, and Hymenoptera. However, the

presence of these insects in these areas highlights their survival nature and the diversity of cultivated species, with some being specialists in nectar collection, which enhances the pollination of these species.

Insects from the order Diptera, which include flies, are one of the most diverse groups of pollinators, making a significant contribution to plant biodiversity and agricultural production. They are essential for the pollination of many medicinal, edible, and ornamental plants, ensuring or increasing seed and fruit production (Orford et al., 2015). Therefore, it is believed that the presence of these insects is due to their search for food sources, such as the nectar produced by cultivated plant species like *G. hirsutum*, *V. unguiculata*, *S. indicum*, and *Z. mays*.

Insects of the order Coleoptera, which include beetles and weevils, play a crucial role in agroecosystems due to their functional diversity and ecological impact. They are essential for agricultural sustainability, contributing to biological pest control, nutrient cycling, and pollination. They help maintain soil structure and fertility, in addition to being a food source for other animals. Some species, such as ladybugs, are important biological control agents by preying on aphids and other harmful insects (Kumar et al., 2019).

Insects from the order Hymenoptera, which include wasps, bees, and ants, play crucial roles in agroecosystems, primarily as biological control agents and pollinators. This order includes families such as Eulophidae, known for being ectoparasitoids or endoparasitoids of a wide range of hosts, including insect eggs and other arthropods, playing an important role in the biological control of agricultural pests (Marchiori, 2022), besides other families.

The higher frequency of Coleoptera in the pitfall trap is due to the fact that several species spend at least part of their life cycle in the soil. The non-disturbance of the soil promotes the development of entomofauna due to the

increased availability of decomposing plant material on the surface, which serves as food, as well as maintaining greater stability in temperature and soil moisture in no-till farming systems.

The higher presence of Hymenoptera in pitfall traps compared to adhesive traps may be related to the fact that ants move extensively across the soil surface, making them more prone to capture. It should also be considered that the large amount of plant residues on the soil favors the development of these insects, especially the mentioned species.

An evaluation of the entomofauna present in genetically modified maize cultivation revealed that Coleoptera and Hemiptera were the most commonly found orders, with Coleoptera predominating, as was observed in the present study. The authors also highlight that predators from this group found in soil traps contribute to the biological control of pests in maize cultivation. The family Carabidae (Coleoptera) preys on Lepidoptera larvae, which belong to one of the orders that includes many of the pests of maize, such as *Heliothis zea*, *Agrotis ipsilon*, *Helicoverpa zea*, and *Helicoverpa armigera* (Vidotto et al., 2018).

Conclusions

The Diptera and Coleoptera orders were the most frequent and dominant in cultivated areas and their surroundings (forest) when captured using yellow sticky traps, while the Coleoptera and Hymenoptera orders were the most frequent and dominant in cultivated areas when pitfall traps were used. Greater diversity and uniformity in the species captured by the sticky trap were observed in the forest environment. In contrast, lower diversity and higher dominance were observed in sticky trap captures, but high diversity in pitfall trap captures was noted in environments with *V. unguiculata*. The Pitfall trap proved to be more effective in capturing a greater diversity and uniform distribution of insect species, especially in crops such as *V. unguiculata* and *G. hirsutum*.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

The authors thank the Institute of Rural Development (IDR) of the University of International Integration of the Afro-Brazilian Lusophone Countries (UNILAB).

REFERENCES

- Carrillo-Arámbula L, Infante F, Cavalleri A, Gómez J, Ortiz JA, Fans BG, González FJ (2022). Colored sticky traps for monitoring phytophagous thrips (Thysanoptera) in mango agroecosystems and their impact on beneficial insects. *PLoS ONE* 17(11):e0276865. <https://doi.org/10.1371/journal.pone.0276865>
- Flores LMA, Zanette LRS, Araujo FS (2018). Effects of habitat simplification on assemblages of cavity nesting bees and wasps in a semiarid neotropical conservation area. *Biodiversity and Conservation* 27:311-328. <https://doi.org/10.1007/s10531-017-1436-3>
- Fontana P, Massa B (2023). Remarks on the misunderstood use of the term biodiversity. *International Journal of Zoology and Animal Biology* 6(6):000537. <https://doi.org/10.23880/izab-16000537>
- Jernigan AB, Kao-Kniffin J, Pethybridge S, Wickings K (2024). Microarthropods improve oat nutritional quality and mediate fertilizer effects on soil biological activity. *Agronomy Journal* 116(4):2007-2033. <https://doi.org/10.1002/agj2.21597>
- Kaplan DM (2019). Biological diversity. In: Kaplan DM (eds) *Encyclopedia of Food and Agricultural Ethics*. Springer. Dordrecht https://doi.org/10.1007/978-94-024-1179-9_300198
- Kumar K, Joshi PC, Arya MK (2019). Assessment of seasonal and altitudinal variation in population density and biomass of beetles (Coleoptera) in Nanda Devi Biosphere Reserve. *Western Himalaya. India. Environment and Bio-Science* 33(2):275-286.
- Liu X, Floate K, Gorzelak M, Holman D, Hrycauk S, Kubota H, Lupwayi N, Neilson J, Ortega Polo R, Petri R, Tran L, Wang H, Wilches D, Yang X, Zorz J, Guarna M (2023). Prairie agroecosystems: Interconnected microbiomes of livestock, soil and insects. *Agriculture* 13(2):326. <https://doi.org/10.3390/agriculture13020326>
- Marchiori CH (2022). Family Eulophidae of economic importance for agriculture (Insecta: Hymenoptera). *Open Access Research Journal of Multidisciplinary Studies* 3(1):060-084. <https://doi.org/10.53022/oarjms.2022.3.1.0034>
- Moraes JGL, Farias FC, Bleicher E (2014). Population fluctuation of aphids and their natural enemies in cotton crops. *Revista de Ciências Agroambientais* 12(1):1-5.
- Orford KA, Vaughan IP, Memmott J (2015). The forgotten flies: The importance of non-syrphid Diptera as pollinators. *Proceedings of the Royal Society B* 282:20142934. <https://doi.org/10.1098/rspb.2014.2934>
- Preti M, Verheggen F, Angeli S (2020). Insect pest monitoring with camera-equipped traps: Strengths and limitations. *Journal of Pest Science* 94:203-217. <https://doi.org/10.1007/s10340-020-01309-4>
- UNILAB in Redenção-CE (2018). Redenção-CE. University of International Integration of the African-Brazilian Lusophone Countries. Institute of Rural Development. Available at: <https://unilab.edu.br/>
- Vidotto FL, Vilela VLD, Silva CV, Schneider LCL (2018). Entomofauna present in genetically modified corn plantation. *Revista Terra and Cultura* 30(59):27-38. <http://publicacoes.unifil.br/index.php/Revistateste/article/view/143/157>
- Yamanaka S, Yamaura Y, Ozaki K (2023). Examining the bias of pitfall traps with enclosure experiments and removal sampling. *Insect Conservation and Biodiversity* 16(5):555-565. <https://doi.org/10.1111/icad.12661>