Scientific Paper

Functional entomofauna diversity in an association of forage tree-basis pasture in the Cuban animal husbandry context

Osmel Alonso-Amaro[1] https://orcid.org/0000-0003-1078-0605, Ileana Fernández-García[2], Juan Carlos Lezcano-Fleires[1] https://orcid.org/0000-0002-8718-1523 and Moraima Suris-Campos[3] https://orcid.org/0000-0002-7032-8250

[1]*Estación Experimental de Pastos y Forrajes Indio Hatuey, Universidad de Matanzas, Ministerio de Educación Superior. Central España Republicana, CP 44280, Matanzas, Cuba.* [2]*Instituto de Ecología y Sistemática. Carretera de Varona, km 3,5. Capdevila, Rancho Boyeros, La Habana, Cuba.* [3]*Centro Nacional de Sanidad Agropecuaria. Autopista Nacional y Carretera de Tapaste, San José de las Lajas, CP 11300, Mayabeque, Cuba. E-mail:* osmel.alonso@ihatuey.cu, ileanafg@ecologia.cu, lezcano@ihatuey.cu, msuriscampos84@gmail.com

Abstract

Objective: To evaluate the diversity of the entomofauna community, according to its biological function in the most representative forage tree-basis pasture association in Cuban animal husbandry.

Materials and Methods: Two animal husbandry agroecosystems were evaluated, with different productive aims, composed by the association of *Leucaena leucocephala* (Lam.) de Wit cv. Peru with *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs cv. Likoni. In both, from the inventory of the insect community, the following ecological indexes were calculated: species richness, Margalef richness, Simpson's dominance, Shannon-Wiener diversity and equitability, as alpha diversity, and at the same time, Morisita-Horn index, as beta diversity, through the programs Species Diversity & Richness 3.02 and SIMIL, respectively.

Results: The values of the Margalef and Shannon's indexes, regarding phytophagans and beneficial insects, in both areas, were higher in the herbaceous stratum (6,138-6,365; 4,471-4,697 and 1,902-2,238; 2,327-2,394) with regards to the tree stratum (4,156-4,706; 4,132-4,158 and 0,722-0,851; 1,721-2,521), which indicated an abundant richness of species and moderate diversity. The equitability of the insect species was also higher in the herbaceous stratum, because there was trend to all of them being equally abundant. Meanwhile, the similarities among the insect communities, according to the Morisita Horn index, showed evident similarity among species, with more than 70 % of coincidence among phytophagans and beneficial insects in each stratum.

Conclusions: The ecological indexes showed that there is numerous and similar diversity of insects in the sampled areas, with higher values, although not representative, for the herbaceous stratum compared with the tree one. In addition, due to the compatibility between leucaena and Guinea grass, the composition, structure and functioning of this insect community can be better understood.

Keywords: biodiversity, insects, *Leucaena leucocephala-Megathyrsus maximus*

Introduction

Biological diversity (biodiversity) can be described in terms of number, abundance, composition and spatial-temporary distribution of its entities or organisms (genotype, species, communities in the ecosystems) and functional characters and interactions among its components (Hooper *et al*., 2005). The functional diversity stands out, as the one that explains, to a larger extent, the effects of biodiversity on the provision of ecosystemic services in the agroecosystems, mainly the regulation ones (Salgado-Negret, 2016).

The ecological resilience capacity is related to the presence of different functional groups and their interactions. Thus, if one of them disappears, changes will occur in the biological activity of ecosystems. This allows to understand that functional redundancy (presence of several species in each functional group) can increase the capacity of response or adaptation to environmental changes (Hooper *et al*., 2005). For such reason, in the transition towards the development of sustainable agriculture on agroecological bases, the quality of agroecosystems is essential to increase the positive interactions of biodiversity, so that they contribute to pest regulation (Matienzo-Brito *et al*., 2019).

Insects, as components of biodiversity in the ecosystems, develop numerous and complex interactions, due to the different functions they perform (phytophagans or herbivores, detritivores, coprophagans, organic matter decomposers, pollinators), especially the ones that act as natural enemies (Angelo, 2017). Hence it is essential to know the species that coexist in an agroecosystem before establishing habitat management practices, in order to modify the relations among the insect communities (Baños-Díaz *et al*., 2020).

The application of the ecological indexes to define the existing diversity of insects in animal

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husbandry agroecosystems, composed by associations of woody and herbaceous plants (from different families, grasses and legumes, fundamentally), which provide the associated entomofauna with habitats and participate in the better performance of these agroecosystems (Murgueitio-Restrepo *et al.*, 2016), constitutes important knowledge in the field of ecology, and their measurement is essential to determine ecosystem health (Daly *et al.*, 2018).

Considering the limited available scientific information, regarding studies of insect diversity in the agroforestry systems in Cuba, the objective of this research was to evaluate the diversity of the entomofauna community, according to its biological function, in the forage tree-basis pasture (leucaena-Guinea grass) association, in the Cuban animal husbandry context.

Materials and Methods

Experimental areas, location, general characterization and duration of the research. During three years, at the Pastures and Forages Research Station Indio Hatuey (EEPFIH, for its initials in Spanish), located in the Matanzas province, Cuba, two animal husbandry agroecosystems were evaluated, established on a lixiviated Ferralitic Red soil, according to the classification by Hernández-Jiménez *et al.* (2015). Both were composed by the most representative association in the animal husbandry of Cuba, with commercial varieties approved by MINAG (2017): *Leucaena leucocephala* (Lam.) de Wit cv. Peru (*Fabaceae*) as forage tree, and *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs cv. Likoni (*Poaceae*) as basis pasture.

The productive destination of an association was the fattening of growing cattle, corresponding to the Siboney de Cuba (⅝ Holstein x ⅜ Zebu) genotype, in a silvopastoral system (SPS) of 1,3 ha, with a density of 396 trees ha^{-1} and six years of exploitation. The purpose of the other association was the production of seed in a basic seed field of leucaena (BSF) of 0,2 ha; 3 000 trees ha^{-1} and 16 years of exploitation.

Management of the productive systems with regards to plant health. During the experimental period no organic or inorganic fertilization, irrigation or chemical or biological pesticides, was applied. Only defoliation (strategic pruning) was performed on the tree, in alternate rows, in both areas, in the first and third year, to guarantee the feed for the animals in the paddock during the scarcity period (dry season), and to stimulate seed production of the legume in the basic seed field, where the Guinea grass was also cut at the moment of the leucaena harvest. The browsing and trampling action of the animals was also considered, when they were introduced in the silvopastoral system in each rotation (with stocking rate that varied between 1,1 and 3 animals ha^{-1}) after the adequate resting time, according to the season (from 28 to 45 days in the rainy season and from 49 to 66 in the dry season).

Entomofauna evaluation and sampling methods. To quantify the insects present in the studied areas, in five spots, according to the envelope method, every 15 days the leaves, inflorescences and pods of *L. leucocephala* cv. Peru (according to the phenological status of the legume at that moment), and the foliage of *M. maximus* cv. Likoni, were sampled.

In order to achieve the highest possible capture of the individuals, two collection methods were used: the entomological net (100 passes in the sampling spots, which is equivalent to 25 m^2) in the tree stratum as well as in the herbaceous one, and the transparent nylon bag, in 5 % of the leucaena trees, distributed in the five spots in which the samples were taken. For such purpose a pole was used, at a height of 2 m, approximately (browsing zone) in the paddock, and up to 3 m in the seed field.

Identification of the insects and determination of the functional groups. The insects that were collected were transferred to the plant protection laboratory of the EEPFIH and the entomology laboratory of the National Center of Agricultural Health (CENSA, for its initials in Spanish), for their identification through taxonomic keys, revision and comparison with the insect collections of the Institute of Ecology and Systematics (IES) and of the Marta Abreu Central University of Las Villas. The authors also had the contribution of other specialists from different institutions (scientific and educational) of the country.

After the identification of each insect species, its function per groups was determined, according to the criterion expressed by Ruíz and Castro (2005), through the information about the main feeding habit, described in scientific literature, and the observations that were made in the field. Specifically two groups were delimited: phytophagous and beneficial insects (among which predators, parasitoids, pollinators, organic matter decomposers, coprophagans and mycophagans are included).

Determination of the diversity of the insect community in the agroecosystems. The biological diversity of the entomofauna was determined through different ecological indexes, according to the classification of the measurement methods at species level, described by Moreno (2001). As indicators, in the alpha diversity, in both areas, among the specific richness measures, the indexes of species richness (S), given by the total number of species obtained by the community census, as well as Margalef diversity or richness index (DMg), were evaluated. In the case of the structure measurements, among the proportional abundance indexes, Simpson's dominance index (DSp), and the equity ones: Shannon-Wiener diversity index (H'), and the equitability or uniformity index (E), respectively, were used. Meanwhile, for the measurement of the beta diversity, between both communities, the similarity/dissimilarity index or Morisita Horn distance was applied, with quantitative data.

The alpha diversity was considered because it represents how diverse an ecosystem is at local scale, that is, the diversity of the species at individual scale, in each area that was sampled. The beta diversity was also studied, because it responds to the relation that can exist between both ecosystems, which constitutes the percentage of different or not different communities, similar criterion to the one reported by Baselga and Gómez (2019).

As evaluation criterion of the index H´, it was assumed that it is expressed with a positive number, which varies according to the ecosystems, between 0,5 and 5. Values lower than 2 are considered negligible; from 2 to 3, moderate, and higher than 3, significant (Pla, 2006). Meanwhile for DMg, it was estimated that the values lower than 2 are of scarce richness, and those close to 5 express optimum or abundant richness (Mora *et al*., 2017). In the Simpson index, the scale proposed by Acebey and Ramírez (2014) was taken into consideration, with numbers that vary between 0 and 1; between 0 and 0,33 they indicate reduced diversity, between 0,34 and 0,66 moderate, and more than 0,67, remarkable or numerous. Regarding the equitability index, the indication made by Martella *et al*. (2012) was adopted, with values between 0 and 1, where number 1 indicates that all the species are equally abundant, and 0, the absence of uniformity.

To affirm the existence of similarity among the species of the two areas, it was taken as premise that the index value should be higher than 0,7 (70 %) because when it is equal to 1, there is full similarity, and when it is 0, the communities do not have species in common, according to the results obtained by Pérez and Sola (1993).

The calculation of the alpha diversity indexes was done through the program Species Diversity & Richness 3.02 (Henderson and Seaby, 2002), and the beta diversity, with the online computer program SIMIL (Pérez and Sola, 1993).

Results and Discussion

In general, as result of the calculation of the ecological indexes referred to the community of insects according to their biological function, in both agroecosystems (SPS and BSF) similar values were observed in the tree as well as in the herbaceous stratum (table 1).

Nevertheless, in the herbaceous stratum of the SPS, in the case of the species number or richness (S), phytophagans reached a slightly higher value than the one found in the BSF. Meanwhile, the contrary occurred in the beneficial ones (table 1).

In that same tree stratum, when calculating Margalef index, coincidence was found with the above-described species richness (S), due to the influence of the number of individuals, distributed on the higher vertical space of the leucaena plant with regards to the quantity of present species. The related DMg values, which show optimum or abundant richness (Mora-Donjuán *et al*., 2017), for phytophagans as well as for beneficial, in both areas, indicated that in the insect communities there is adequate balance between consumers and regulators (table 1).

Also in the herbaceous stratum, when analyzing the data of the calculation of the Shannon-Wiener index, the highest values were found in the insect population of the SPS, in favor of the beneficial ones, which showed to be moderately diverse compared with phytophagans, which reached negligible diversity, according to the criteria expressed by Pla (2006). Meanwhile the lowest values were found in the BSF, but in the same proportion (table 1).

This performance occurred in both areas, due to the higher dominance of phytophagans, with numbers that showed remarkable or numerous diversity with regards to the beneficial ones, which indicated a reduced diversity, according to the report by Acebey and Ramírez (2014). *Heteropsylla cubana* Crawford was the most frequent (up to 80 %) and abundant insect (up to 84,8 %) in the community, which coincides with the report by Alonso *et al*. (2018). In addition, there was relation with the absence of equitability or uniformity shown by the species (table 1), with the exception of beneficial insects in the SPS area, which experienced a trend

Table 1. Performance of the ecological indexes of the entomofauna in the evaluated areas.

In the tree stratum	SPS		BSF	
Index	Phytophagous	Beneficial	Phytophagous	Beneficial
Number of species (S)	46	31	41	33
Richness index (DMg)	4,706	4,132	4,156	4,158
Diversity index (H´)	0,851	2,521	0,722	1,721
Dominance index (DSp)	0,707	0,115	0,753	0,308
Equitability index (E)	0,222	0,734	0,194	0,492
Number of individuals (N)	14 215	1 423	15 138	2 198
Herbaceous stratum	SPS		BSF	
Index	Phytophagous	Beneficial	Phytophagous	Beneficial
Number of species (S)	47	36	52	34
Richness index (DMg)	6,138	4,697	6,365	4,471
Diversity index (H´)	2,238	2,394	1,902	2,327
Dominance index (DSp)	0,218	0,140	0,325	0,137
Equitability index (E)	0,581	0,668	0,481	0,660
Number of individuals (N)	1 797	1 722	3 020	1 604

SSP silvopastoril system
BSF-basic seed field

to all the species being equally abundant, in correspondence with the report by Martella *et al*. (2012).

In the herbaceous stratum, in both areas, the number of species (S) showed a similar trend to that of the tree one, regarding the minimum difference among the values, although with a higher number of phytophagous and beneficial species. However, there was a lower quantity of individuals in both functional groups in the two areas, except in the beneficial insects in the SPS, which was slightly higher (table 1).

The values of the Margalef index, in both functional groups of each area, exceeded the ones that were obtained in the tree stratum, just like those of the H´ index, which were remarkably higher, and only slightly lower in the beneficial ones in the SPS. Hence the DMg index indicated optimum or abundant species richness, and the H´ pointed at moderate species diversity (Pla, 2006; Mora-Donjuán *et al.,* 2017). The values of the dominance index were qualified as of moderate diversity, according to Acebey and Ramírez (2014), for phytophagans and beneficial insects in the SPS and in the BSF (table 1).

The results for the equitability index were higher than those reached in the tree stratum, with the exception of those of the group of beneficial insects in the SPS, which indicated a trend to all the species being equally abundant, according to the report by Martella *et al.* (2012). This performance was due to the lower distribution of habitats with regards to the ones offered by leucaena as shrub, because its foliage occupies higher area in the vertical space. Hence there was higher diversity (H´) in the herbaceous stratum, which was specifically qualified as moderate, with trend to be significant according to Pla (2006).

The highest diversity of insect species in the prevailing pastureland grass, Guinea grass likoni, proved the absence of any organism, by acting as pest in the herbaceous stratum, due to the architecture and texture of the plant. Although the presence of the psyllid (*H. cubana*) contributed remarkably to the population of phytophagans, mainly in the legume (83,86 % in the SPS and 86,62 % in the BSF); besides being present in the herbaceous stratum (42,57 % in the SPS and 55,13 % in the BSF) which provides refuge for it (Altieri and Nicholls, 2010).

The above-described results indicate that a higher balance occurred between the community of insect species in the herbaceous stratum with regards to the tree stratum, because in the former higher balance is achieved among the populations of the different insect species (existing a lower number of individuals), which in turn do not have the same functions, higher preponderance being shown in the BSF. In this last one, the Guinea grass plants, as they were not grazed, show a more voluminous tiller structure, which offers more refuge options to beneficial insects. Meanwhile, in the tree stratum, composed by the leucaena plants, there was higher dominance of the phytophagan *H. cubana*.

Nevertheless, Alonso and Lezcano (2014) and Vázquez *et al.* (2014) stated that the use of tree legumes in animal husbandry agroecosystems (which are qualified as complex) can be one of the ways that allows to increase the conservation of natural enemies, by providing appropriate refuge and feeding conditions, especially for the predators of phytophagan insects, although to a lesser extent than Guinea grass in the herbaceous stratum.

With these results the importance of biodiversity is reaffirmed, according to the criterion expressed by Iermanó and Sarandón (2016). These authors state that the diversity of plant species is an important component in the reduction of the probabilities of pest development, as a numerous population of susceptible hosts to a specific pest does not exist; at the same time it offers habitats to many insect species that constitute natural enemies of others that are deleterious.

Ramírez-Barajas *et al.* (2019) indicated that the inclusion of trees and shrubs in a paddock increased not only the quantity of plant species, but (and maybe most importantly) the number of adequate refuges, microclimates and habitats so that a higher number of organisms can coexist, such as insects. Nevertheless, in the functional biodiversity birds, reptiles, mammals, amphibians and mollusks, among many other groups of living beings, can also coexist, which along with the presence of cattle, which constitute the main animal component in the SPS compared with the BSF, actively participate in the agroforestry dynamics. This grants the systems higher connectivity to natural ecosystems, with regards to the conventional ones with pastures in monoculture, which in turn suggests ideas for the integration between animal production and biodiversity conservation (Harvey *et al*., 2004). The latter can be favored by the action of beneficial insects, such as coprophagous coleopterans, or ants, as pest bioregulators, among others, which are considered bioindicators in these agroecosystems (Sinisterra *et al*., 2016; Chamorro *et al*., 2018)

Another important contribution of the studied productive systems was the reaffirmation of the criterion stated by Vázquez *et al*. (2014) and Vázquez and Jacques (2019), who indicated that the agroecosystems that have an ecological service close to the one of natural systems, have higher stability of their beneficial fauna. In addition, due to their condition of polycrops, according to Altieri and Nicholls (2010), increase occurs in the abundance of predators and parasitoids, due to higher availability of alternative preys, nectar sources and appropriate microhabitats. Thus, these diversified agroecosystems, which are managed through practices of ecological agriculture, have higher advantages than the highly simplified ones, such as conventional agricultural systems, according to Lichtenberg *et al*. (2017), where the ecological unbalances that occur are more frequent and dangerous (Nicholls *et al*., 2016).

In addition, the authors coincided with the criterion expressed by Cucchi *et al*. (2020), because the biological control in pest management was favored, as part of the structure of biodiversity management. In turn, the positive repercussion of this type of control to achieve a more biological and sustainable agriculture was reaffirmed, due to the benefits it contributes to the agroecosystem. In the specific case of biological control by conservation, in these agroecosystems a contribution was also made to the reduction of the toxic load, by not using imported pesticides, which is one of their positive impacts, although that contribution is still to be quantified, according to Vázquez and Pérez (2017) and Márquez *et al*. (2020).

Regarding the similarity among the communities of existing insect species in the SPS and the BSF, according to the strata, the functional groups and total of insect species that were detected in each case are shown in table 1. As result of the calculation of the Morisita-Horn index (table 2), it could be observed that, in both areas, there was evident (although not complete) similarity between phytophagans and beneficial insects, in the tree as well as the herbaceous stratum, because the value was higher than 0,7 in all cases, with slight superiority for phytophagans. This indicates that there was more than 70 % coincidence among the insect species that were captured (from 77 to 99 %), according to the criterion indicated by Pérez and Sola (1993).

This means that although each area had different productive destination and plantation management, this condition did not influence the fact that remarkable differences were found among the collected species. However, there was a decreasing trend of the number of insect species, observed from one year to another, in the two strata of each

Table 2. Similarity among the communities of insect species in the evaluated areas.

Areas	Stratum	Functional group	Common insect species	Morisita-Horn index
SPS/BSF	Tree	Phytophagous	39	0,998
		Beneficial	26	0,777
	Herbaceous	Phytophagous	40	0,929
		Beneficial	26	0,823

SSP silvopastoril system, BSF-basic seed field

area (table 3), except phytophagans in the third year in the SPS and beneficial ones in the second year in the BSF, which slightly increased in the tree stratum, and beneficial insects in year 2 in the BSF, which remained in equal quantity in the herbaceous stratum. For such reason, it is necessary to make adequate management of such associations, according to their productive aim.

This performance could have been related to the fact that as the exploitation time increases, there is trend to the decrease of species diversity in these animal husbandry systems. Thus was noted by Alonso-Lazo *et al.* (2007) in a SPS with the same legume and grass as the ones evaluated in this research, due to the significant effect of the tree pruning, and to the action of the animal when browsing in both strata. Hence the premise to be fulfilled, regarding management, so that these plantations last in time with the necessary biodiversity and the required biological balance between the populations of phytophagous and beneficial insects.

The possibility of competition, replacement or dominance of certain insect species in the communities was also evident; besides the effect of parasitoidism or predation, resource availability, and variation of the abiotic factors of the environment and of other disturbance regimes, which due to the complexity of the systems could not be measured in an autoecological way. From the above-stated facts, it is deduced that the insect species can generate a synergic effect with all those factors, which in turn can be modified by the action of man on the management of these agroecosystems, criteria that coincide with the report by Hooper *et al.* (2005).

It was understood that the complexity of the interactions among natural enemies, associated crops and other possible host plants, as well as the inherent characteristics of the studied agroecosystems, are determinant factors, regarding the need and success of the dispersal of beneficial insects, which has positive repercussion on the sustainability of pest management, as reported by Vázquez and Jacques (2019).

Conclusions

The ecological indexes proved the existence, in general, of a numerous and similar insect diversity in the sampled areas, with higher, although not representative, values, for the herbaceous stratum, although the species in this stratum had access to a lower number of habitats with regards to the tree stratum. The study of diversity in the community of insects present in the associations of leucaena and Guinea grass, representative of the most utilized type of agroforestry system in the country, allowed to understand better the composition, structure and functioning of this insect community.

With the results from this study, the bases are initially available for the establishment of an agroecological plant health management of such plantations. However, it should be still determined to what extent the management practices of the productive systems object of research (plantations and animals) have repercussions on the magnitude and

Table 3. Number of insect species collected per year in each experimental area.

Year	Tree stratum				Herbaceous stratum			
	SPS		BSF		SPS		BSF	
	P	B	P	B	P	B	P	B
1	39	27	33	23	33	25	38	23
2	29	17	26	25	30	21	30	23
3	30	14	22	11	25	19	27	16

P: Phytophagans, B: Beneficial insects, SSP silvopastoril system, BSF-basic seed field stability of the populations of bioregulator insects, as well as the most effective way to achieve their better conservation during a period as long as possible.

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Authors' contribution

- *Osmel Alonso-Amaro*. Planned and executed the experimental protocol of the study, searched for bibliographic information, processed the data about the ecological indexes through the utilized programs, and carried out the analysis and interpretation of the results, wrote the manuscript and did its revision during the edition process until its publication.
- *Ileana Fernández-García*. Facilitated one of the programs for the calculation of the ecological indexes and instructed about its execution, provided bibliographic information and participated in the analysis and interpretation of the results.
- *Juan Carlos Lezcano-Fleires*. Contributed bibliographic information, participated in the analysis and interpretation of the results, and collaborated with the writing of the manuscript and its revision during the edition process until its publication.
- *Moraima Suris-Campos*. Revised, from the methodological point of view, the experimental protocol of the research, provided one of the programs for the calculation of the ecological indexes, and emitted the pertinent orientations for its execution, participated in the data processing and analysis and in the interpretation of results, and collaborated with the revision of the manuscript during the edition process until its publication.

Conflict of interests

The authors declare that there is no conflict of interests.

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