Scientific Paper

Weeds-beneficial entomofauna ecological relation in silvopastoral systems of western Cuba

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Abstract

The objective of the study was to determine the species of weeds and beneficial entomofauna present in the silvopastoral systems (SPSs) evaluated in western Cuba, as well as their ecological interrelation in those animal husbandry agroecosystems. For such purpose, during one year eight SPSs composed by associations of *L. leucocephala* plus pasture grasses were sampled. The weeds were sampled at the beginning and end of the experiment; while the beneficial insects were collected every 15 days, for their identification in each case. A total of 34 weeds and 79 beneficial insect species were found. From the former, five are considered possible hosts of 27 beneficial insects that were captured (11 predators, 12 parasitoids and 4 pollinators). Among them, in the first group five ladybird beetles stood out as bioregulators of *Heteropsylla cubana* (main pest of *L. leucocephala* worldwide) and a thrip-controlling flower bug; while in the second group an ichneumonid and several chalcid wasps that regulate *Spodoptera frugiperda* stood out; and in the third group the bee *Apis melifera* stood out as pollinator. It was proven that it is necessary to determine which are the weed species whose presence is convenient in SPSs in order to enhance the ecological processes that occur in them, based on agrodiversity, the area covered by the prevailing pastures and the management of these productive systems; this would contribute to propitiate the regulation of the main associated pests and to maintain the biological balance, as occurred in the evaluated paddocks, in order to reach the economic and environmental sustainability of such agroecosystems in time.

Keywords: ecology, sustainability, useful insects, *Leucaena leucocephala*

Introduction

Silvopastoral systems (SPSs), with emphasis on the intensive ones, constitute an important innovative solution to increase animal production, mainly cattle and sheep-goat production (of milk as well as meat, and of other associated goods), and face the climate change in countries from Latin America and the Caribbean, and from other tropical and subtropical areas of the world (Murgueitio *et al*., 2015).

The above-stated facts are based on the advantages of these systems (higher efficiency of the biological processes that occur in them, because the transformation of solar energy into biomass is maximized, soil fertility is favored with the biological fixation of atmospheric nitrogen, there is higher solubilization of phosphorus and accumulation of organic matter because of the animal dejections – urine and excreta), and on the agroecological principles that are applied to manage them, such as: use of rational-rotational grazing, with high instantaneous stocking rate of resistant animals adapted to certain climate conditions, in an environment where there is adequate conservation of biodiversity, pastures and forages have the necessary resting time for them to reach the required nutritional quality, and the water resource is correctly managed, in order to guarantee animal welfare. This, as a whole, causes higher CO_2 sequestration in the soil and lower CH_4 emissions; and climate change resilience to increase, with minimum use of agrochemicals, hormones and antibiotics with regards to conventional systems.

Another aspect to be emphasized in SPSs with agroforestry arrangements, according to the criteria expressed by Murgueitio-Restrepo *et al*. (2016) and Sisa-Benavides (2017), is the inclusion of weeds within the herbaceous component (in addition to the pasture species of grasses and twining legumes, mainly), which interact with the tree stratum (forage trees and shrubs, fruit trees, timber trees, among others) and with the animals.. Thus, in the animal husbandry sector the criterion that they are considered as indicators of inadequate management of the pastureland should be re-analyzed, according to Milera *et al*. (2014).

In addition, weeds play an important role in the trophic network of complex agroecosystems, because they interact directly and indirectly with others of their components and offer a broad spectrum of ecological and agronomic functions, such as pollination and pest regulation, by serving as refuge for natural and biological control agents (Caballero-López *et al*., 2012). This enhances the management of agrobiodiversity, and their function is explained by the biotic regulation through the bottom-up and top-down mechanisms (Altieri and Nicholls, 2010; Ratnadass *et al*., 2012), specifically the latter, because by having a reservoir of predators and parasitoids the pest control by its natural enemies would be achieved.

In that sense, the objective of the study was to determine the species of weeds and beneficial entomofauna present in the silvopastoral systems (SPSs) evaluated in western Cuba, as well as their ecological interrelation in those animal husbandry agroecosystems.

Materials and Methods

The experimental areas corresponded to SPSs (paddocks) composed by associations of the four commercial varieties of the tree legume *Leucaena leucocephala* (Lam.) de Wit –approved in Cuba, according to MINAG (2017)– and different pasture grasses, which had the particularities that are related in table 1.

The experimental period was one year, taking into consideration the months of higher presence of insects in these systems (March, May, October and November), previously determined by Alonso (2009).

Weed sampling was carried out at the beginning and the end of the evaluation period, in five spots of each paddock (envelope method), using a framework of 1 m^2. The collection of beneficial insects was performed every 15 days, before the animals entered to graze in all the areas, using two methods –based on the proposal made by Nielsen (2003)– to guarantee the highest possible capture of individuals present: the entomological net (in the tree as well as the herbaceous stratum), which was passed 100 times in five spots of the evaluated fields, which is equivalent to 25 m^2 according to Faz (1990); and the transparent nylon in the case of trees, with which a sample was taken of the organs present in the browsing zone (2 m of height, approximately) on the four cardinal points, according to the phenology of the *L. leucocephala* crop at the moment of sampling.

The functional subgroups of the captured insects were formed, according to the criterion expressed by Ruiz and Castro (2005) and the observations of their main feeding habit, conducted on site.

Among the main management indicators of productive systems that were taken into consideration in the performance of the weeds and beneficial

Table 1. Characterization of the animal husbandry systems.

Productive systems	Area (ha)	Location	YE♦	Soil type (Hernández *et al*., 2015)	Tree variety	Prevailing pasture (herbaceous stratum)
SPS-1	1,3	EEPFIH	6	Lixiviated Ferralitic Red	Peru	*Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs
SPS-2	1,3				Cunningham	*M. maximus*
SPS-3	1,3				CNIA-250	Natural pastures
SPS-4	1,1	EPGM	8	Brown with Carbonates	Cunningham	*M. maximus*
SPS-5	2,0	EPJM		Sandy	Peru	*Digitaria eriantha* Steud.
SPS-6	1,0	EPN		Grayish Brown	Ipil Ipil	*Cynodon nlemfuensis* Vanderyst.
SPS-7	2,0	EPVP		Brown with Carbonates	Ipil Ipil	Natural pastures
DPSPS	0,2	EEPFIH	16	Lixiviated Ferralitic Red	Peru	*M. maximus*

SPS: silvopastoral system, DPSSP: double-purpose SPS (cattle fattening-seed production), EEPFIH: Pastures and Forages Research Station Indio Hatuey, EPGM: Genetic Animal Husbandry Enterprise of Matanzas, EPJM: Animal Husbandry Enterprise José Martí (Matanzas province), EPN: Animal Husbandry Enterprise Nazareno (Mayabeque province), EPVP: Animal Husbandry Enterprise Valle del Peru (Mayabeque province), YE: years of exploitation; ♦: indicates from the second year of establishment to the moment of evaluation.

insects are: defoliation (pruning or cutting) in the feed (forage) shortage period; resting time of the paddocks after grazing (28-45 days in the rainy season and 49-66 in the dry season); and non-application of inorganic or organic fertilization, irrigation, chemical or biological pesticides. In addition, the percentage of area covered by the prevailing herbaceous pastures as part of the floristic composition was determined, through the step method EEPFIH (1980).

The identification of weeds and insects was made in the plant protection laboratories of the EEPFIH and in the insect taxonomy laboratory of the Agricultural Research Center (CIAP) of the Central University Marta Abreu of Las Villas (UCLV) –Villa Clara, Cuba–, using taxonomic keys (Borror and White, 1970; Sánchez and Uranga, 1993; Peck, 2005, among others), the revision and comparison with the insect collections of the UCLV, and the contribution of other specialists from different institutions of the country.

Results and Discussion

Weeds, after sampling in the eight animal husbandry systems under study, did not appear in two (SSP-1 and SSP-2); while in the other six 34 species, which are listed in table 2, were found and identified.

From these weeds *M. pudica* and *S. rhombifolia* stood out, present in five of the areas; *D. cinerea*, in four; and *S. geniculata*, *A. aspera* and *P. guajava*, in three, which are considered typical pastureland species in Cuba according to the reports of the animal husbandry.

Regarding the beneficial insects captured in the sampled areas, 79 species were identified (44 predators, 30 parasitoids and 5 pollinators), belonging to the orders Coleoptera, Hymenoptera, Diptera, Hemiptera, Orthoptera, Mantodea, Neuroptera, Dermaptera, Odonata and Thysanoptera. From them, 27 can find refuge or feed from five of the found weeds and regulate nine of the phytophagous pests also found in these silvopastoral systems, according to the criterion expressed by several authors about their interaction in the Cuban agricultural sector (table 3).

Nevertheless, in other crops in different countries the relation between the beneficial insects and weeds that were found in this study is reported, which is described below:

In the case of *I. trifida*, in zones close to rice, corn and cotton crops in Colombia, insects were hosted from the families Chalcididae (Hymenoptera), for example: *Conura* sp. and *Brachymeria* sp.; Anthocoridae (Hemiptera) (*Orius* sp.), Dolichopodidae (Diptera) (*Condylostylus* sp.), Syrphidae (Diptera), Coccinellidae (Coleoptera) (*C. maculata* and *Scymnus* sp.) and Reduviidae (Hemiptera) (*Zelus* sp.); in addition, along with *S. acuta*, they provided pollen and nectar for insects from the family Vespidae (Hymenoptera); while *C. diffusa* was host of insects from the family Syrphidae (Bedoya *et al.*, 2018). On the other hand, *B. pilosa,* considered in Peru as weed of the lucuma crop [*Pouteria lucuma* (Ruiz & Pav.) Kuntze], served as host for insects of the family Coccinellidae (Castillo *et al.*, 2015).

The weed-beneficial insect ratio in this study could have been influenced by the management of the productive systems, which is a response essentially to the covering of the area by pasture and forage species (table 4).

In paddocks 6 and 7, two of the ones that had lower AC PHP percentage, the highest number of weeds was found; which was also related to the fact that in the first paddock the pruning was not correctly performed according to the established rules, and in the second paddock no pruning was done and the animals did not rotate adequately due to problems with the perimeter fence. In turn, an increase of the presence of beneficial insects stands out, because the weeds serve as refuge or food (pollen or nectar) for the adults, as stated by Altieri and Nicholls (2007).

In paddock 3 the AC PHP percentage was even lower, because of the prolonged flooding before and during the experimental period, which caused the emergence of other plants, but in this case pastures (*Indigofera oxycarpa* Desv. (= *I. mucronata* Spreng. ex DC.), from the family *Fabaceae* and non-weed plants.

The presence of the higher number of beneficial species in SPS-1, DPSPS and SPS-4, where there was an adequate AC PHP percentage, was related to the tillering condition of Guinea grass, which generates a higher number of habitats where predator, parasitoid and pollinator insects take refuge, among other beneficial ones (Alonso, 2009); and, on the other hand, it coincides with the criterion expressed by Nicholls-Estrada (2008) concerning the fact that the higher surface covered by the pastureland favors the population dynamics of natural enemies, and that there is higher index of the biotic regulation potential.

The above-described results indicate that it is necessary to elucidate, in practice, the repercussion

Table 2. Weed species in the silvopastoral systems.

Family	Species	Common name
Amaranthaceae	*Achyranthes aspera* L.	Chaff-flower
Asteraceae	*Bidens pilosa* L.	Beggar's ticks
	Emilia sonchifolia (L.) D. C.	Cupid's shaving brush
	Parthenium hysterophorus L.	Santa Maria
Bixaceae	*Bixa orellana* L.	Achiote
Caesalpinaceae	*Cassia occidentalis* L.	Coffee senna
Commelinaceae	*Commelina diffusa* Burm. F.	Climbing dayflower
Convolvulaceae	Unidentified species	-
	Ipomoea trifida (H. B. K.) D.	Wild sweet potato
Cucurbitaceae	*Cucumis anguria* Lin.	Maroon cucumber
	Momordica charantia Lin.	Bitter melon
Cyperaceae	*Cyperus esculentus* L.	Yellow nutsedge
Esterculiaceae	*Waltheria indica* L.	Sleepy morning
Euphorbiaceae	*Chamaesyce hyssopifolia* (L.) Small.	Hyssoleaf sandmat
	Croton lobatus L.	Rushfoil
	Euphorbia heterophylla L.	Mexican fireplant
Fabaceae	*Centrosema lobatum* (Britt. et Wils.) urb. H. C.	Centrosema
	Crotalaria sp.	Rattlepods
Labiadae	*Mentha piperita* Lin.	Peppermint
Malvaceae	Unidentified species	-
	Sida acuta Buró. F.	Common wireweed
	Sida rhombifolia L.	Arrow leaf sida
Meliaceae	*Trichilia hirta* L.	Broomstick
Mimosaceae	*Dichrostachys cinerea* (L.)Wight & Arn.	Sicklebush
	Mimosa pudica L.	Sensitive plant
Myrtaceae	*Psidium guajava* Lin.	Common guava
Poaceae	*Bothriochloa pertusa* (L.) A. Camus	Pitted beard grass
	Setaria geniculata (Lam.) Beauv.	Knotroot foxtail
	Sporobolus indicus (L.) R. Br.	Smutgrass
Poligonaceae	*Persicaria portoricensis* (Bert.) Small.	Denseflower knotweed
Solanaceae	*Cestrum nocturnum* Lin.	Night-blooming jasmine
	Solanum nodiflorum Jacq.	Black nightshade
Typhacea	*Typha angustifolia* Lin.	Lesser bulrush
Verbenaceae	*Priva lappulacea* (L.) Pers.	Catstongue

of the weeds-crops-insects (phytophagous and beneficial) complex in the different agroecosystems, with emphasis on animal husbandry ones; because, as reported by Blanco and Leyva (2009) when they studied weeds and their associated entomofauna in the corn crop after the competition period, they are highly important for agroecology. This allows to deduce that, with such response, the reasons why a noxious agent considered harmful does not reach that condition from the economic point of view could be better known.

Thus, it is possible to consider the groups of weeds within agroecosystems as biological corri-

Table 3. Ecological relation among weeds, beneficial insects and phytophagous pests associated to the evaluated SPSs.

Host weed	Associated beneficial insect (Order: Family)	Captured pest it regulates (Order: Family)
P. hysterophorus	*Bachyacantha decora* Casey■ *Chilocorus cacti* Linnaeus■ *Coccinella maculata* (De Geer)■ *Cycloneda sanguinea limbifer* Casey■	*Heteropsylla cubana* Crawford△ (Hemiptera: Psyllidae) *Ascia monuste eubotea* (Godart)△ (Lepidoptera: Pieridae) *Spodoptera* sp.△ *Diaphania hyalinata* (Linnaeus)△ (Lepidoptera: Pyralidae) Leafhoppers△
	Diomus ochroderus (Mulsant)■	*H. cubana*
	Diomus roseicollis (Mulsant)■	*H. cubana*
	Psyllobora sp.■	
	Scymnus distinctus Casey■ (Coleoptera: Coccinelidae)	
	Apanteles sp.✦ (Hymenoptera: Braconidae)	
	Lasioglossum sp. (1)°	
	Lasioglossum sp. (2)° (Hymenoptera: Halictidae)	
	Campsomeris trifasciata (Fab.)✦ (Hymenoptera: Scoliidae)	
	Zanysson armatus (Cresson)■ (Hymenoptera: Sphecidae)	
	Pachodynerus nasidens (Latreille)■ (Hymenoptera: Vespidae)	
B. pilosa	*Orius pumilio* (Champion)■ (Hemiptera: Anthocoridae)	*Frankliniella tritici* Fitch (Thysanoptera: Thripidae) *Podothrips* sp. (Thysanoptera: Phlaeothripidae)
P. hysterophorus *C. hyssopifolia* *C. diffusa* Asteráceas	*Apis melifera* L.° (Hymenoptera: Apidae)	-
C. hysopifolisa	*C. maculata*	*H. cubana*
C. hyssopifolia *C. diffusa* Asteráceas	*Exomalopsis pulchella* Cresson° (Hymenoptera: Apidae)	-
C. diffusa	*Rogas* sp.✦ (Hymenoptera: Braconidae)	

■ predators, ✦ parasitoids; ° pollinators, △ pests regulated by *C. cacti*, *C. maculata* and *C. sanguinea limbifer*.
Source: Bruner *et al.* (1975), Fernández T. *et al.* (2001), Valenciaga (2003), Veitía (2004), Martínez *et al.* (2007), Milán *et al.* (2008), Vázquez *et al.* (2008), Alonso (2009).

dors, that is, they constitute natural biodiversity where beneficial insects find refuge and alternative food, and exert their dominance by attacking pest insects (Tapia-Mayer, 2013), which indicates direct trophic interaction (Norris and Kogan, 2000).

Table 3. Continuation.

Host weed	Associated beneficial insect (Order: Family)	Captured pest it regulates (Order: Family)
P. hysterophorus *C. hyssopifolia*	*Brachymeria flavipes* (Fab.)✦	
	Brachymeria hammari (Cresson)✦	Pupae from: *Apotomorpha rotundipennis* (Walsingham) (Lepidoptera: Tortricidae)
	Brachymeria ovata (Say)✦	
	Brachymeria incerta (Cresson)✦ (Hymenoptera: Chalcididae)	
	Enicospilus purgatus (Say)✦ (Hymenoptera: Ichneumonidae)	Larvae from: *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae)
P. hysterophorus *C. hyssopifolia* Asteráceas	*Conura feromata* (Fabricius)✦	
	Conura sp. (1)✦	*S. frugiperda*
	Conura sp. (2)✦	*S. frugiperda*
	Conura sp. (3)✦	*S. frugiperda*

■ predators, ✦ parasitoids; ○ pollinators.
Source: Bruner *et al.* (1975), Fernández T. *et al.* (2001), Valenciaga (2003), Veitía (2004), Martínez *et al.* (2007), Milán *et al.* (2008), Vázquez *et al.* (2008), Alonso (2009).

Table 4. Quantity of taxa of weeds and beneficial insects and percentage of area covered by the herbaceous pastures prevailing in the SPSs.

Productive system	Weeds		% AC PHP♦	Insects		
	No. of families	No. of species		No. of species P + B	Beneficial	Pr + Pa
SPS-1	0	0	72	80	33	28
SPS-2	1	1	80	33	16	14
SPS-3	2	4	47	40	16	14
SPS-4	4	10	77	61	29	27
SPS-5	6	9	81	45	19	19
SPS-6	11	21	55	50	21	18
SPS-7	10	17	61	40	14	11
DPSPS	0	0	78	75	33	26

% AC PHP: percentage of area covered by the prevailing herbaceous pasture, P + B: phytophagous + beneficial, Pr + Pa: predators + parasitoids, ♦ Indicates at the end of the experiment.
SPS: silvopastoral system, DPSSP: double-purpose SPS (cattle fattening-seed production).

In addition, it is necessary to take into consideration the report by Vázquez *et al.* (2004), who state that weeds constitute host or «alluring» plants, which influence the performance of beneficial organisms and, particularly, the type, abundance and colonization time of parasitoids (Waage and Greathead, 1986). At the same time, they offer many resources to natural enemies, such as: preys or alternative hosts, pollen or nectar, and microhabitats that are not available in the monocrop (Altieri and Nicholls, 2007) and are available in complex (silvopastoral) systems, in which several plant and animals species converge.

Conclusions

Five weeds and an Asteraceae plant, which represented 15 % of the total, are considered as possible hosts of 27 of the captured biological controls (11 predators, 12 parasitoids and 4 beneficial ones, also pollinators). Among the predators the ladybird beetles *C. cacti*, *C. maculata*, *C. sanguinea limbifer*, *D. ochroderus* and *D. roseicollis* as bioregulators of *H. cubana* and the flower bug *O. pumilio,* controller of *F. tritici* and *Podothrips* sp, stood out. From the parasitoids, the ichneumonid *E. purgatus* and the chalcid wasps *Conura* spp., which regulate *S. frugiperda*, stood out; likewise, the bee *A. melifera* stood out as pollinator.

It was proven that it is necessary to determine which are the weed species that it is convenient to include in SPSs (perhaps as natural biological corridors) in order to enhance the biological processes that occur in them, based on agrodiversity, the area covered by the prevailing pastures and the management of these productive systems; this would contribute to propitiate the regulation of the main associated pests and to maintain biological balance, with the objective of reaching economic and environmental sustainability of such agroecosystems in time.

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