Husbandry and Nutrition

Original

Foliage, Leaf Litter, and Edaphic Fauna Associated to Three Forest Species in Livestock Ecosystem Hedgerows

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Received: October 2020; Accepted: November 2020; Published: December 2020.

ABSTRACT

Background: Cattle ecosystems require serious transformations in management systems that rely on agroecological principles, where agroforestry can play an important role. **Aim:** to characterize foliage, leaf litter, and the edaphic fauna associated to three forest species in livestock ecosystem hedgerows, on serpentine soil, in Camagüey, Cuba.

Methods: A two-year study of *Gliricidia sepium* (Jacq) Kunth ex Walp, *Bursera simaruba* (L) Sargent, and *Moringa oleifera* Lam was done at Habana Cooperative Farm, Minas livestock company, Camagüey. These species were established in adjacent hedgerows, planted at a distance of 1.0 m. Foliage yield, leaf litter deposition, and the edaphic macrofauna associated to each tree species, were evaluated. The descriptive statigraphs (Mean and SE) were determined, and simple ANOVA was performed in each variant. The means were compared through the Tukey's HSD multiple range test, with a significance of $p< 0.05$.

Results: The results indicate the beneficial use of these species as hedgerows, considering high production of foliage (between 1.02 and 2.54 kg DM/t/cut), as well as their positive environmental effects by contributing with considerable amounts of leaf litters to the soil, and hosting large amounts of edaphic fauna.

Conclusions: The species evaluated produce high forage and leaf litter levels in the soil, as well as abundant associated edaphic fauna.

Citation (APA)
Loyola Hernández, O., Triana González, D., Batista Cruz, C., Díaz Hernández, E., & Pérez Lezcano, E. (2021). Foliage, Dry Leaves, and Edaphic Fauna Associated to Three Forest Species in Hedges of Cattle Ecosystems Journal of Animal Production, *33*(1). https://revistas.reduc.edu.cu/index.php/rpa/article/view/e3686

Key words: livestock, soil fauna, agroforestry systems *(Source: Agrovoc)*

INTRODUCTION

In many tropical areas, livestock production is severely limited by the lack and poor quality of forage. The low contents of crude protein is the most commonly observed limitation in the native grass cultivation; some systems have been developed to complement or improve the ingestion of crude protein by animals grazing on natural grass, with seasonal or permanent access to areas covered with tropical tree species with forage values (Lok, 2016).

The province of Camagüey is characterized by a high production of cattle, most of it on fersiallitic soils (over 7% of the provincial lands), which poses serious limitations to cattle raising, particularly due to the low levels of N, P, and K, and high Mg levels, producing low quality pasture (Loyola, 2012).

The introduction of forest-grazing technologies in tropical cattle raising systems improves the nutritional quality of the diet, and contributes to lower emissions of methane from bovines. It also helps recover degraded areas, enhancing soil fertility through atmospheric nitrogen, and nutrient recycling; it improves carbon capture, the protection of biodiversity, and water sources (Loyola *et al*., 2015; Montagnini, 2015; Murgueitio *et al*., 2015; Schindler *et al*., 2016, and Martínez-Pastur *et al.*, 2017).

In Cuba, as in other areas of the Americas, the reinstatement of trees and shrubs in grasslands (forest-grazing systems) is a choice of interest to recover soil fertility (Bacab *et al.*, 2013; Jacobo *et al.*, 2016; Kieck *et al.*, 2016; Jiménez *et al.*, 2019).

Special significance is given to hedgerows, since they provide a large variety of products, among them, the production of fencing stakes, forage for animals, firewood, fruits, and honey through apiculture, thus becoming sustainable indicators for systems (De La Ossa-Lacayo, 2013; Muchanea *et al.*, 2020).

The production and decomposition of dry leaves are essential to transfer energy and nutrients into the soil, a flow that supplies an important fraction of rapidly mineralized nutrients in deciduous forests (Doll *et al.*, 2018).

Velasquez and Lavelle (2019), and Hernández-Chávez *et al.* (2020) stressed the advantages in the utilization of macro-invertebrate communities as indicators of soil quality, due to their simplicity and low cost, as well as their high sensitivity to soil conditions.

In Cuba, *Gliricidia sepium* (Jacq) Kunth ex Walp, *Bursera simaruba* (L) Sargent and *Moringa oleifera* Lam are widely cultivated species. Their use in hedgerows is outstanding, with low establishment costs, and high income, compared to other types of fencing (Loyola *et al*., 2014). Additionally, it ensures the production of firewood, live stakes, and forage (Loyola, 2012), including the environmental benefits that they offer.

Aim:

To characterize yields in foliage, leaf litter, and the edaphic fauna associated to three forest species used in hedgerows in cattle systems on serpentine soil, in the province of Camagüey.

MATERIALS AND METHODS

The study was conducted for two years (from September 2018 to September 2020), on Habana Finca Cooperative (UBPC), that belongs to the Minas Livestock Company, in Camagüey, Cuba. It is located on 21º28’50” - 21º29’15” north latitude, and 77º39’50” - 77º40’20” west longitude, 85 meters above sea level. It used gliricidia trees (*Gliricidia sepium* (Jacq) Kunth ex Walp), **gumbo-limbo** (*Bursera simaruba* (L) Sargent*)*, and Moringa (*Moringa oleifera* Lam), which were already established in neighboring fences planted at a distance of 1.0 m each, at six years of age.

The experimental work was conducted on brown-red ferromagnesium fersiallitic soil, according to the site map, and corroborated with Hernández *et al.* (2015). The predominating pasture was *Dichanthium annulatum* (Forsk.) Stapf. (bluestem) and *Dichanthium caricosum* (L.) A. Camus) (Nadi bluegrass).

The local climate is tropical, with high evaporation and high air temperature (mean values of 25.2 °C. The relative humidity value is 79%, and the average yearly precipitation values are 1 400 mm (CITMA, 2018).

Foliage yields

Following a completely randomized experimental design, foliage samples were collected from 20 trees of every species, at 90 days following re-shooting, after an establishment cut that removed all the foliage from the tree.

Dry matter yield was determined from the DM percents obtained by Loyola *et al*. (2013) in similar conditions to the soil and climate. They found that B. *simaruba, G. sepium*, and *M. oleifera* have 32, 36.2, and 41% DM contents, respectively.

Leaf litter deposition

In all the hedgerows studied, 20 plots (0.50 x 0.50 m) by species were set. They were placed at random under the trees, cleared from weeds, and all kinds of organic material. All the material deposited as a result of natural defoliation of trees, was collected every 15 days, between September 2018 and September 2020 (Fuentes *et al.*, 2018).

Edaphic macrofauna

Considering the assessment of the possible positive impact of different tree species associated to the fauna in the soil, 20 sampling plots (0.5 x 0.5 m) were made for each variant under trees from hedgerows, and grassland with no trees, respectively. All the vegetation from the plots was cleared, and the areas were dug up to 10 cm deep, then all the individuals from different fauna species were counted (Barreto-García *et al*., 2018). Samplings of macrofauna were made between 7:00 and 9:00 am.

The plots under the trees were made 0.5-1.5 m away from them.

Statistical analysis

The descriptive statigraphs (Mean and SE) were determined, and simple ANOVA was performed in each variant. The means were compared through the Tukey's HSD multiple range test, with a significance of $p<0.05$. Normal distribution of data and variance homogeneity were checked before the previous analyses. The former was based on standardized bias and standardized kurtosis, and the latter through the F-test, to compare standard deviations of the variances from the two samples. StatGraphics Centurion XV, Version 15.2.06 (2007) was used for the analyses.

RESULTS AND DISCUSSION

Foliage yields

Table 1 shows the productive results of *G. sepium, B. simaruba, and M. oleifera,* in relation to the amount of green material and dry matter produced.

Table 1. Foliage production by tree in each cut

Species	kg GM/t/cut	kg DM/t/cut
B. simaruba	3.21 [a]	1.02 [a]
G. sepium	3.75 [b]	1.35 [b]
M. oleifera	6.19 [c]	2.54 [c]
±SE	0.1423	0.0699

a, b, c: Unequal superscripts on the same column indicate significant differences among the means, according to Tukey's HSD (p <0.05).

As shown, when cuts are made 90 days after, green foliage production varies between 3.21 and 6.19 kg/t/cut, and the DM collected by tree was 1.02, 1.35, and 2.54 kg DM/t/cut, for *B. simaruba*, *G. sepium y M. oleifera,* respectively, with significant differences ($p <0.05$) among the species studied.

The highest production levels demonstrated it in *M. oleifera*, followed by *G. sepium,* and finally *B. simaruba.* This was related to the high capacity of re-shooting of the first plant, regardless of the size of its folioles, producing a large amount of foliage in 90 days.

These results on the farm may mean protein bank values of 10.2, 13.5, and 25.4 t/DM/ha/cut for *B. simaruba*, *G. sepium* and *M. oleifera*, respectively, considering 1 x 1 m plantation ranges. These values are quadrupled annually, so an approximately 40 t/DM/ha/year can be obtained from *B. simaruba,* 54 t/DM/ha/year from *G. sepium*, and up to 100 t/DM/ha/year from *M. oleifera,* considering the variant of protein banks. On the other hand, hedgerows may produce 4-10 t/DM/km/year if four cuts are made. These results show the promising use of *M. oleifera* in hedgerows in these agroecosystems.

In *M. oleifera*, the results were higher than the ones found by Loyola *et al.* (2013), and Loyola *et al.* (2014) in the edaphoclimatic conditions of the municipality of Santa Cruz del Sur, province of

Camagüey, with +15 year-old trees grown from stakes. In the previously mentioned study, the authors obtained 4.88 kg/t/cut of GM; 1.97 kg DM/t/cut; and 1.31t DM/km/cut. All these values were 25% higher in all the variables in this study, which may be given by the age of plants studied in this case (one year old), with probably more vigor. Moreover, these plants grew from seedlings, so their root system is deeper and more vigorous, allowing the plant to extract the necessary nutrients from greater depths.

These results are similar to the findings of Gómez (1994), in *G. sepium* who reported annual productions of green forage between 55.5 and 80.6 t/ha^{-1}, with cuttings producing 12.5-20 t/DM/ha $^{-1}$. The results achieved in this scenario were higher than the results reported by Pedraza and Gálvez (2000), in *G. sepium*, in Camagüey, where these authors indicated the possibility that a *G. sepium* tree produces approximately 2.5 kg GM/tree/cut, and 10 kg/year/GM, in four cuts every 90 days.

In this species, edible biomass that can contribute with 4.4 kg of GM/tree, have been reported at 120 days of re-shooting, following the strategic pruning, with a dry matter digestibility of 58-69% (Pedraza *et al.*, 2003). This availability would be enough to feed three animal/tree/day in the form of forage cuts supplied in houses or the fields. The utilization of foliage from these hedgerows may bring collateral beneficial effects to the ecosystem and the economy of the farm.

Pedraza (2005) noted that 1 km of hedgerows of G. *sepium* planted at a distance of 1.5 m between trees, can provide cost-effective nutrients throughout the year, so that 20 cows, after 240 lactation days consuming average quality pasture, produced about 1 kg/day milk more, provided that pasture and water availability were stable.

Studies conducted by Cordoví *et al.* (2013), in Mozambique concluded that *G. sepium* and *M. oleifera* yielded 9.56 and 8.68 t of DM/ha^{-1}, respectively. According to Vennila *et al.* (2016) *G. sepium* cut at two, four, and six months, produced 17.5 t ha^{-1}year $^{-1}$; 16.26 t ha^{-1} year; and 15.02 t ha^{-1}year^{-1}, respectively. Argüello-Rangel *et al.* (2019) found that *G. sepium* can provide 8.57 t ha^{-1}year $^{-1}$ of DM, in the dry season.

Leaf litter deposition

Table 2 shows the amount of leaf litters deposited by the trees evaluated, with statistically significant differences by species, in the hedgerows.

Table 2. Leaf litter deposition

Species	g/m^2	$kgha^{-1}$
G. sepium	35.31^c	353.16^c
B. simaruba	33.03^b	330.40^b
M. oleifera	27.66^a	276.66^a
± *SE*	0.3838	3.8387

a, b, c: Unequal superscripts on the same column indicate significant differences among the means, according to Tukey's HSD (p <0.05).

The greatest deposition is made by *G. sepium,* followed by *B. simaruba*, in keeping with the types of leaves from these species, which, apart from being compound, the folioles have much greater limbs than those of *M. oleifera.* Moreover, *G. sepium* has 7-17 foliole leaves; and *B. simaruba* has 5-7 foliole leaves (Loyola *et al*., 2019).

In this study, leaf litter deposition varies between 276.5 and 353 kg ha^{-1}, which equals 3.31, 3.96, and 4.23 t ha^{-1} a year, by *M. oleifera, B. simaruba,* and *G. sepium*, respectively.

These results are higher than the ones reported by Triana *et al*. (2013) and Triana *et al.* (2014), who found monthly leaf litter depositions of 332.0 ± 0.05 kg ha^{-1} in hedgerows on fersiallitic soils. Likewise, they are superior to the reports by Fuentes *et al.* (2018), who found annual levels of 0.47 t ha^{-1} during the dry season, and 0.10 t ha^{-1} in the rainy season, in natural forests.

These results are inferior to the findings of Hernández and Simón (1995), when determining the deposition of *Albizia lebbeck* (L.) Benth leaf litters on the soil. They observed a production of 10 and 13.6 t ha^{-1} in the rainy season (RS) and dry season (DS), respectively. In this particular case, it is a species with a greater diameter and height, with a top; hence, foliage and leaf litter production are greater. Hernández and Hernández (2005) found that with *G. sepium* it is possible to achieve 2.6 t $Dmha^{-1}$/year of leaf litter, and 51 kg Nha^{-1}/year.

With a sponge-like action, leaf litters keep the moisture conditions that favor regulating activity of microorganisms. Hence, there is a balance between the covering, leaf litters, breaking down elements and nutrients, perhaps the basic balance so that rain forest ecosystems endure time (Hernández and Hernández, 2005).

During defoliation, the leaf litters fall gradually on the soil, functioning as covering, and later nutrients are added through leaf litter breakdown, which increases pasture quality (Moreno *et al*., 2018).

Leaf litter production and breakdown are critical process for preservation and/or recovery of vegetable formations, because they promote circulating processes of nutrients and community maintenance. Therefore, it is important to know the organic matter contributions made by plant species to ensure nutrient return (Gaspar *et al*., 2015).

Leaf litter coverage not only supplies OM, but also regulates the temperature of the soil, so OM decomposition, and nutrient supply takes place continuously and gradually, which also holds back processes like soil erosion, land degradation and desertification, producing a decreased capacity of the ecosystem to generate goods or supply services to beneficiaries (FAO, 2017).

According to Hernández and Hernández (2005), the contribution of trees to nutrient recycling is associated to the fact that, depending on the species and edaphic conditions, they are capable of absorbing nutrients, and returning them to the surface, with natural fallen foliage, branches, and fruits, or by pruning; thus recycling nutrients like Ca, K, Mg, and S.

Edaphic macrofauna

Table 3 shows the behavior of the edaphic fauna in the system studied. Tree systems (forest-grazing) showed greater abundance of macrofauna, which coincided with the findings of Cabrera-Dávila *et al.* (2017), and must be the result of greater soil coverage that offered optimum temperature and humidity conditions to develop the edaphic fauna.

Table 3. Behavior of edaphic fauna in the system studied (individuals/m^3)

Species fauna	Gumbo-limbo	Gliricidia tree	Moringa	No trees	± SE
Millipede (diplopods)	16.95^b	21.95^c	21.95^c	16.0^a	0.3293
Annelids	178.0^b	197.8^c	198.8^c	86.95^a	5.1881
Coleopteran (larvae)	207.0^c	226.65^d	98.0^b	46.0^a	8.4429
Centipede (chilopodes)	38.0^c	41.85^d	22.0^b	9.0^a	1.4810
Total (individuals /m^2	440.0c	488.7d	340.75b	157.95a	14.2508

a, b, c, d: Unequal scripts on the same column indicate significant differences among the means, according to HSD Tukey (p <0.05).

Coleopterans and annelids were the main groups of animals found in the ecosystem studied, similar to the findings of Rodríguez *et al*. (2003) and Rodríguez *et al.* (2008) in different grassland systems, whether in mono-cropping or in association.

Importantly, the amount of coleopterans in the tree systems, with significant differences in all the cases studied, had a greater presence in association with *G. sepium,* followed by *B. simaruba.* A similar behavior in relation to tree species was shown by chilopodes, (centipedes), though they were inferior in number.

Annelids and diplopods (millipedes) had slightly different behaviors, since their large numbers were associated to *M. oleifera*; in these two species of the marcofauna, significant differences were observed among the different tree species, but not between *G. sepium* and *M. oleifera.* In all the cases, the number of edaphic fauna individuals was higher in the tree systems.

As shown in the previous table, the average of individuals/m^2 observed in the study period also underwent statistically significant differences between all the variants studied. The system without trees showed the lowest number of individuals/m^2, whereas the highest number (440.0 and 488.7) were reported in the systems with *B. simaruba and G. sepium,* respectively, coinciding with the fact that these are broad-leaf species, providing greater soil coverage, and therefore, broader areas of shade and moisture.

The above evidences the beneficial effect of including these species in hedgerows, since they provide important volumes of leaf litters, and regulate soil temperature as a result of shading, which favors proper development of the edaphic fauna, with ensued soil improvements. These organisms help break down organic matter from the leaf litters, and contribute in terms of manure and coprolites (Crespo, 2008).

This is in compliance with recent studies conducted by Wu and Wang (2019), who checked the hypothesis based on the dependence of macrofauna on the specific conditions of soil micro-habitats created by the vegetation.

Results reported by Escobar *et al*. (2020) showed the abundance of soil macrofauna in forestgrazing conditions, which indicates the health of the soil in the areas under the trees. The same authors found that beetles (*Scarabaeidae*) had the largest presence in the soil under the trees, whereas the soil worm (*Lumbricidae*) was the species with the greatest number of individuals in all the ecosystems.

Camero and Rodríguez (2015) found greater abundance of soil worms in forest-grazing systems than in graminaceae mono-cropping; on the contrary, Murillo *et al.* (2019) found differences between forest-grazing systems and the native vegetation. Leyva *et al*. (2018) also indicated greater values of orders and abundance in forest-grazing systems.

According to Rodríguez *et al.* (2008), some of these organisms, especially coprophagous, such as coleopterans, are critical agents of prairie cleaning, and can integrate the feces from cattle and other animals in the system to the soil within 24 hours. The digging action performed by coleopterans considerably reduces the pollution caused by the accumulation of stools in the grassland, and therefore, leads to better use of available pasture, preventing grass refusal by cattle. It also favors water retention in the soil, and the removal of soil horizons (Cárdenas-Castro and Páez-Martínez, 2017).

The increase of edaphic fauna, and the number of coprolites in the soil must improve, considering the increase in vegetation, and the contributions with leaf litters, which favors the welfare of these cattle agroecosystems. Rodríguez *et al.* (2003) reported remarkable increases of the biotic components of the soil when the number of trees is higher in grazing areas, due to the beneficial effects of trees in soil micro-climate, and leaf litter deposition.

Generally, among the agroforestry techniques, the utilization of these species in hedgerows is outstanding, since it involves low establishment costs and high income, in relation to other types of fences.

A greater abundance of soil fauna was observed in the areas with hedgerows, since the trees contribute with high amounts of leaf litters, and improve the physical properties of the soil, by increasing the number of micropores in charge of draining and aerating the soil (Hernández *et al*., 2020). In these systems, OM in the soil is kept at satisfactory levels for fertility. Base recycling in trees residues can contribute to reduce or halt acidification processes, besides controlling erosion and OM losses (Benavides *et al*., 2005).

CONCLUSIONS

The species evaluated produced high levels of forage and leaf litters in the soil, with the greatest contribution made by *M. oleifera* and *G. sepium,* respectively.

Species variability, and the number of edaphofauna individuals are abundant in the ecosystem studied, higher in the hedgerow systems, compared to areas without trees.

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AUTHOR CONTRIBUTION

Conception and design of research: OLH, DTG, CBC, EDH, EPL; data analysis and interpretation: OLH, DTG; redaction of the manuscript: OLH, DTG, CBC, EDH, EPL.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.