Journal of Animal Prod. 31 (2), https://revistas.reduc.edu.cu/index.php/rpa/article/view/e3009

Effect of *Samanea saman* (Jacq.) Merr. on Grass Agroproductivity in a Forest-grazing System

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ABSTRACT

Background: The utilization of forest-grazing systems is an alternative for implementation of sustainable agricultural productions. The aim of this research was to evaluate the effect of *Samanea saman* (Jacq.) consumption, based on the need to increase the use of these systems in the province of Camagüey. Effect of Samanea saman (Jacq.) Merr. on Grass Agroproductivity in a Forest-grazing System

Methods: The main graminaceae and leguminosae were identified, and their botanical composition, availability, and bromatological composition were determined. One-way analysis of variance was performed to compare the bromatological variables, and the t-test for availability was made. The Duncan's multiple range test was used for comparison of means (P<0.05 significance). StatGraphics Centurion XV, Version 15.2.06 was used in the analyses.

Results: Exploration across the experimental areas showed the presence of 15 leguminous species, with high predominance of subfamily Faboideae. The forest-grazing system was better than the traditional system. The main contribution to availability was made by graminaceae. The leguminosae showed higher protein levels than the rest of the species, along with improved quality of tree-associated graminaceae (FGS) in relation to standalone graminaceae.

Conclusions: The positive effect of forest-grazing systems was corroborated when compared to the traditional system, including higher availability of leguminosae due to their high protein levels and improved quality of tree-associated graminaceae (SSP) compared to the standalone graminaceae.

Key words: *leguminosae, grass productivity, forest-grazing*

INTRODUCTION

Internationally, availability of natural resources has been reduced due to the pressure caused by the increase of population, larger grasslands, and the reduction of forest areas. The world population reached 7 200 millions in 2014, and by 2050 it is expected to add other 2 000 million, causing a substantial expansion of land for farming and grazing (UN, 2014).

The increase in food production to meet the growing demands of the population must be linked to the reduction of environmental problems, more efficient use of natural resources, preservation of biodiversity, fight against greenhouse gases, soil degradation, and the spreading of deserts. It would contribute to slowing down climate change (Montagnini *et al.*, 2015).

Individually, the different existing agroproductive systems are competing (forest, fruit producing areas, grasslands, crops, livestock raising); hence, some, or all, of these systems should take place alternatively, which would be a viable opportunity that might help cut down costs. Agroforestry is in charge of that (Zuluaga *et al.*, 2011).

Today, the implementation of sustainable farming systems is critical; therefore, the utilization of forest-grazing systems is an alternative to achieve that goal. Trees are important in that they enhance the physical, chemical, and biological characteristics of soils, and they increase the contents of organic matter, improve the capacity for cationic and anionic exchange, as well as the structure of soils. Additionally, trees provide goods and services, which are beneficial to humans (Braun, Van Dijk, and Grulke, 2016). Accordingly, more in-depth studies are required in the area of leguminous-tree use in grazing lands.

Objective

To evaluate the effect of *Samanea saman* (Jacq.) Merr inclusion on the botanical composition, availability, and grass quality in a forest-grazing system, under the edaphoclimatic conditions of Roberto Rodríguez Cooperative (CCS), in the municipality of Sierra de Cubitas, province of Camagüey.

MATERIALS AND METHODS

Location of the experimental area, soil, and climate

Location

The study was conducted for two years (July 2014-September 2016) on two cattle farms at Roberto Rodríguez Cooperative (CCS), municipality of Sierra de Cubitas, Camagüey, Cuba, located on 21º 40´ north latitude, and 77º 39´west longitude, 40 m above sea level.

Soils

The soil of the location studied is brown with typical carbonates, according to the cartographic charts, and corroborated by Hernández, Pérez, Bosch, and Castro (2015). The pH is slightly acidic (6.4), and the effective depth is 25 cm.

Climate

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).

The farms included in the study are engaged in bull fattening since 2008; twenty-four enclosures were set up on each farm, averaging 1.1 and 0.4 ha of beams between enclosures, for a total 26.84 ha used for fattening on each farm.

Farm No. 1 (traditional system) was established on location previously used for sugar cane plantations, then after a period of idleness, cattle was brought in. Farm no. 2 (forest-grazing) was covered with *Samanea saman* (Jacq.) Merr (local algarroba), as a replacement of sugar cane, using a plantation frame of 10.0 x 10.0 m, which is known as a forest-grazing system today. A total of 30 animals make up farm No. 1: 15 young bulls and 15 crossbred Zebu bulls, whereas farm No. 2 houses 36 crossbred Zebu animals: 18 young bulls and 18 bulls.

Evaluations

Exploration of grass species (graminaceae and leguminosae) in the study area

Exploration was made in all the study area early in 2014 without contrasting the two systems. Then it was done consecutively until September 2016, following the methodology stated by Hernández and Hernández (1991). The plants collected were classified by the authors and, in some cases, by comparing with samples existing at the Herbarium of the University of Camagüey (HIPC), province of Camagüey. Emphasis was made on family *fabaceae* due to its significance in terms of nitrogen fixation capacity and source of protein.

Botanical composition and grass availability and quality in each system

Botanical composition of the grassland

The botanical composition was determined in 50% of the grazing areas belonging to each farm studied (13.2 ha) for two years (2014-2016), using the step method described by Corbea and García Trujillo (1982) cited by Peña and del Pozo (2004), twice a year, in the middle of the rainy season (RS) and dry season (DS). On average, 100 observations/ha were made in each evaluation, indicating the population percentage of each population.

$E (\%) = (n/N)* 100$

Where:

E= Frequency of species emergence in the ecosystem.

N= Total observations.

n= Total observations of the species.

Particularly, the number of tree individuals was determined by counting the plants that emerged in the area.

Availability of the main species

Availability was determined in the grazing areas of each farm for two years, during the RS and DS, using the practical variant of Haydock and Shaw's visual method for production areas (Senra and Venereo, 1986). Samplings were made at the end of every rotation (five in the RS and three in the DS), at a rate of 80 observations/ha.

The main leguminosae and graminaceae were separated from all the material cut, and were weighed; the percentage of dry matter was determined. The samples were dried at 70 °C in a stove with forced air circulation, until constant weight was achieved. Each species' availability was determined according to the number of times it emerged in the frame, and each species' weight in the frames, divided by the total number of observations. The total availability per frame would be the sum of the availabilities of each species.

Bromatological composition

Along with availability samplings, compound samples of the predominant grass types were collected (300 g) in order to estimate their bromatological composition. The samples were sent to the laboratory of the Provincial Soil Headquarters, Ministry of Agriculture (MINAG), to determine the bromatological composition. Dry matter, calcium, phosphorus, and crude protein were determined by AOAC (2012).

Statistical analysis

The descriptive statistics mean, SE, P value were determined. A proportion analysis was performed for exploration and botanical composition, which were expressed in percent. A square-chi test was made to determine the differences of proportions.

One-way analysis of variance (ANOVA) was performed to compare the bromatological variables of either system (forest-grazing and traditional) in each season (RS and DS). A T-test was made to compare availabilities in the two systems (forest-grazing and traditional) during the RS and the DS.

Normal distribution of data and variance homogeneity were checked before the previous analyses. The former was based on standardized cut and curtosis, and the latter through the F-test to compare standard deviations of the variances from the two samples.

The means were compared through the Duncan's multiple range test, with a $P<0.05$ significance. StatGraphics Centurion XV, Version 15.2.06 (2007) was used for the analyses.

RESULTS AND DISCUSSION

Exploration of grass species (graminaceae and leguminosae) in the study area

Exploration across the experimental areas showed the presence of 15 leguminous species. During the RS, 13 species from 10 genera were explored, whereas 14 species from 12 genera were spotted during the DS (Table 1). Upon exploration, the main graminaceous species found were bahiagrass (*Paspalum notatum* Flüggé), Guinea grass (*Panicum maximum* Jacq.), African Bermudagrass (*Cynodon nlemfuensis* Vanderyst) and hurricane grass (*Bothriochloa pertusa* (L.) A. Camus).

Table 1. Number of leguminous species per subfamily found on the location of the study

Subfamily	DS		RS		Proportions
	Number of species	%	Number of species	%	
Caesalpinioideae	2	15.44	2	14.30	0.4808
Mimosoideae	4	30.76	5	35.70	0.5371
Faboideae	7	53.80	7	50.00	0.4816
Total	13	100	14	100	

DS: Dry season RS Rainy season

Subfamily *faboideae* stands out within the *fabaceae* family due to its high representativeness in terms of number of species (7), accounting for 50 and 53.8% of all the species observed on the location.

Other outstanding species were *Desmodium angustifolium* (Kunth) DC. and *Senna robiniaefolia* (Benth.) Irwin *et* Barneby, which are endemic taxons in Cuban flora. The above points to the importance of leguminosae in local plant formations, and the value these areas have as reservoirs of endemic species (Loyola, 2012).

The mean proportion analysis showed no differences regarding the number of leguminosae species per subfamily in the seasons studied.

The predominance of *Faboideae* subfamily species, as in other studies conducted in the province, is linked to the high ecological plasticity of most genera (Loyola, 2012), which somehow justifies the statistical similarity of these botanical groups in the two systems studied.

Previously planted, important nitrogen-fixing species *Vachellia farnesiana* (L.) Wight & Arn., *Samanea saman* (Jacq.) Merr., and genera *Alysicarpus*, *Mimosa*, and *Desmodium*, were also spotted in the area. *Desmodium* is locally represented by two species: *Desmodium triflorum* (L.) DC. and *Desmodium canum* (J. F. Gmel.) Schinz & Thell., which are important local forage resources (Loyola, Triana, Valido, Curbelo, and Guevara, 2015a).

Moreover, the local graminaceae are well adapted, and can withstand intensive grazing and droughts, which is advantageous for cattle raising. Studies conducted in other areas in Cuba have shown that these plants make up a high percent of grasslands, covering over 70% of the animal diet. Their crude protein levels may vary critically in mono-cropping, and up to 10.8% when they are associated to leguminosae. The average milk production/year/cow/day may vary depending on that condition (3.3 kg/cow/day in mono-cropping, and up to 6 kg/cow/day in association with leguminosae) (Curbelo, 2004).

The exploration of vegetation in cattle raising areas not only allows for better understanding of the local species and their forage value for cattle, but also they provide essential information for uncommon species' management and preservation in the grassland plant community (Loyola, 2012). This includes niches of unusual, relict, or endemic species, along with the conditions of landscape, which can be important to areas with unique features, conditioned by the specifics of soil and climate.

Botanical composition, availability, and quality of grass in both systems

Botanical composition of the grassland

Table 2 shows the percent composition (botanical composition) of the species found in the grassland experimental areas during the RS and DS. The analysis of mean proportions showed no statistically significant differences between forest-grazing and the traditional systems; however, the group comprising other species did show differences from the mean proportions in the DS.

Table 2. Botanical composition of grassland experimental area during the RS and DS.

Species	RS			DS		
	FGS	TS	Proportions	FGS	TS	Proportions
Alysicarpus vaginalis (L.) DC.	13.2	7.5	0.6376	6.2	4.2	0.5961
Desmodium triflorum (L.) DC.	2.7	2.4	0.5294	1.9	1.7	0.5277
Desmodium angustifolium (Kunth) DC.	10.1	9.0	0.5287	9.1	7.3	0.5548
Centrosema virginianum (L.) Benth.	15.3	13.4	0.5331	14.2	11.0	0.5634
Other leguminosae	17.3	18.0	0.4900	19.7	17.4	0.5309
Graminaceae	39.6	40.2	0.4962	45.4	42.3	0.5176
Others	1.8	9.8	0.1551	3.5	16.1	0.1785*

DS: Dry season RS: Rainy season FGS: System Forest-grazing TS: Traditional system
*Indicates significantly different from the overall mean at 95% confidence level.

The most populated leguminous species were *entrosema virginianum* (L.) Benth., *Desmodium angustifolium* (Kunth) DC., and *Alysicarpus vaginalis* (L.) DC., followed by other leguminosae. Graminaceae were also very commonly found, between 45.4 and 39.6% in the dry and rainy seasons, whereas it was 42.3 and 40.2% under the forest-grazing and traditional systems, respectively.

These are encouraging values if the intention is to perform ecological management, since they indicate the possibilities for the species of family *Fabaceae*, which must be enhanced due to their important role in grassland ecosystems (Curbelo, 2004; Loyola, Curbelo, Guevara, and Triana, 2011; Triana, Loyola, Curbelo, and Guevara, 2013).

These results corroborate the advantages of grass management in forest-grazing areas, so that the soil remains protected (Triana, Loyola, Castaños, and Valido, 2014a; Loyola *et al.*, 2015c).

Availability of the main species

Table 3 shows the total availability of each management system used, particularly in relation to graminaceae and leguminosae. For each variable analyzed, availability under the forest-grazing system was higher than under the traditional system, though there were significant differences for total DM availability and graminaceae availability. Meanwhile availability of leguminosae showed no significant differences.

Table 3. Behavior of graminaceae and leguminosae availability (t/DM/ha) under both working systems

	RS				DS			
	FGS	TS	SE	P value	FGS	TS	SE	P value
Total DM	3.58[a]	2.54[b]	0.1803	0.0002	2.60[a]	1.83[b]	0.1300	0.0001
Graminaceae	2.20[a]	1.61[b]	0.1017	0.0001	1.58[a]	0.99[b]	0.0984	0.0000
Leguminosae	1.19	0.77	0.1134	0.0616	0.91	0.85	0.0350	0.4180

a, b: unequal letters on the same row for each season indicate significant differences ($P<0.05$).
DM: Dry matter FGS: Forest-grazing system TS: Traditional system

The main contributions were made by graminaceae (1.58 and 0.99 t DM/ha) in FGS and TS, respectively, and 2.20 and 1.61 t DM/ha in the DS and TS, respectively, in the RS. Overall, leguminosae accounted for 0.91 and 0.85 t DM/ha in the two systems during the DS, but these values were higher during the RS. The superiority of FGS over the TS was observed in all the variables analyzed during the two periods.

This superiority is linked to the effect of shades on the grass, since they minimize the stress caused by high temperatures largely. Another important reason is the association with leguminous trees in the system, which contributes to proper development and quality of grass through nitrogen fixation. The results achieved on the forest-grazing farm provide higher value to proper use of native grass in association with leguminous trees; they also supply nutrients to the soil, and at certain times, they can produce high protein foliage for animal consumption (Ruiz *et al.*, 2014; cited by Roca *et al.*, 2018).

According to the contributions made by López *et al*. (2015), the forest-grazing systems can produce high quality forage throughout the year, which improves nutrient balances in animals, with ensuing improvements in body condition and quality of the immune response. In concert with a favorable surrounding, these conditions can increase animal welfare and create greater resilience.

The productive results are largely influenced by the current botanical composition, which coincides with Curbelo (2004) and Triana *et al.* (2014b), who claimed the need to rescue grassland productivity and conduct in-depth analysis of animal management situations and the supply of excess food into the system.

Bromatological composition of the grass

Table 4 shows the results achieved through bromatological analysis of different species, leguminosae have higher protein levels than the rest of the species, which proves the relevance of their presence in these ecosystems. Graminaceae associated to trees (FGS) also showed higher quality, which may have a favorable effect on productive increases, particularly meat (Loyola, Pérez, Triana, Valido and Yero, 2014; Triana, Loyola, Tejas and Pompa, 2018).

Table 4. Bromatological composition of grassland components

Variable	Component			SE	P value
	Leguminosae	Graminaceae (TS)	Graminaceae associated to leguminosae (FGS)		
D.M.	25.6 [a]	32.32 [c]	30.78 [b]	0.3880	0.0000
CP	9.20 [c]	4.43 [a]	5.28 [b]	0.2704	0.0000
P	0.08	0.08	0.08	0.0008	0.5689
K	0.42 [c]	0.24 [a]	0.27 [b]	0.0086	0.0000
Ca	0.69 [c]	0.29 [a]	0.33 [b]	0.0204	0.0000
Mg	0.21 [a]	0.30 [c]	0.28 [b]	0.0049	0.0000

a, b, c: unequal letters on the same row mean significant differences ($P<0.05$).

FGS- Forest-grazing system TS-Traditional system

Remarkably, the associated graminaceae had higher CP, K, and Ca contents than the standalone graminaceae, which might shed light on the advantages of graminaceae-leguminosae association under these edaphoclimatic conditions (Curbelo, 2004; Loyola *et al.*, 2015a). These results had a marked effect on the local animal production, as well as on cost-effectiveness, which are key elements to improve agriculture and increase competitiveness (García, Albarrán, and Avilés, 2015; Loyola, Valido, Triana, Curbelo, and Guevara, 2015b; Triana, Curbelo, Loyola, Estrada, and Pacheco, 2016; Triana *et al.*, 2018). Molina, Angarita, Mayorga, Chará, and Barahona-Rosales (2016) claimed that the animals grazing in FGS consume more dry matter, protein, calcium, and fat than the ones involved in graminaceae mono-cropping.

CONCLUSIONS

The positive effects observed were higher in the forest-grazing system than in the traditional one. This included the presence of 15 leguminous species, especially *Centrosema virginianum* (L.) Benth., *Desmodium angustifolium* (Kunth) DC., and *Alysicarpus vaginalis* (L.) DC., with the largest populations.

In the forest-grazing system, the highest protein levels were observed in leguminosae, along with higher quality of graminaceae associated to trees (FGS), than the standalone graminaceae, which proves the relevance of *fabaceae* in these ecosystems.

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Received: 2-8-2019
Accepted: 3-26-2019