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SHORT NOTE [NOTA CORTA]

PRODUCTIVITY OF A SILVOPASTORAL SYSTEM UNDER INTENSIVE MIXED SPECIES GRAZING BY CATTLE AND SHEEP

[PRODUCTIVIDAD DE UN SISTEMA SILVOPASTORIL INTENSIVO BAJO PASTOREO SIMULTÁNEO DE BOVINOS Y OVINOS]

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SUMMARY

The presence of forage trees in pastures enhances yield and nutritional quality of forage available for animal feeding. We assessed forage yield and nutritional quality, and weight gain of cattle and sheep foraging in a silvopastoral system containing *Guazuma ulmifolia* Lam. and the grasses *Digitaria eriantha* Stent (cv. Pangola), *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf (cv. Insurgentes) and *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs (cv. Tanzania), during three seasons (windy, dry and rainy) in two grazing treatments: 1) mixed species grazing by four to five Criollo Lechero Tropical heifers and six female Pelibuey lambs, and 2) simple species grazing by 12 female Pelibuey lambs. Weight gain was greater ($P<0.05$) in mixed (444.4 kg ha^{-1} $year^{-1}$) than in simple grazing (321.7 kg ha^{-1} $year^{-1}$). Forage availability was higher in the *G. ulmifolia-D. eriantha* association (21.6 ton MS ha^{-1} $año^{-1}$) than in the other tree-grass associations. *G. ulmifolia*, *D. eriantha* and the association between them yielded more crude protein than other species and associations, and the highest crude protein content was observed during the windy season. It was concluded that the *G. ulmifolia-D. eriantha* association was the best of the evaluated associations and that mixed species grazing produced more meat per unit area per year.

Key words: Silvopastoral system; *Guazuma ulmifolia*; cattle; sheep; mixed species grazing

RESUMEN

La introducción de árboles forrajeros en los potreros incrementa la cantidad y calidad nutricional del forraje disponible para el ganado. Se cuantificó la producción y calidad nutricional del forraje, la ganancia de peso de becerras y ovejas bajo pastoreo-ramoneo en un sistema silvopastoril integrado por *Guazuma ulmifolia* Lam. y las gramíneas *Digitaria eriantha* Stent cv. Pangola, *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf cv. Insurgentes o *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs cv. Tanzania, durante las tres épocas del año (nortes, seca y lluvias), en dos tratamientos: 1) pastoreo mixto integrado por cuatro a cinco becerras Criollo Lechero Tropical y seis ovejas Pelibuey; y 2) pastoreo simple formado por 12 ovejas Pelibuey. El incremento de peso del ganado fue superior ($P < 0.05$) en el pastoreo mixto (444.4 kg ha^{-1} $año^{-1}$) que en el simple (321.7 kg ha^{-1} $año^{-1}$). La disponibilidad de forraje fue mayor en la asociación *G. ulmifolia-D. eriantha* (21.6 ton MS ha^{-1} $año^{-1}$) que en las otras asociaciones. *G. ulmifolia*, *D. eriantha* y su asociación presentaron mayor contenido de proteína cruda en época de nortes. La asociación *G. ulmifolia-D. eriantha* es la mejor asociación árbol-gramínea de las evaluadas, y el pastoreo mixto produce mayor cantidad de carne por unidad de superficie por año.

Palabras clave: Sistema silvopastoril; *Guazuma ulmifolia*; bovinos; ovinos; pastoreo simultáneo de especies.

INTRODUCTION

Cattle ranching in the tropical zones of Mexico have limitations that significantly reduce their productivity. Some of the major limitations are the strong dependency on grasses as forage, drought during long periods of the year, low level of technology and reduced application of sanitary measures (Murgueitio *et al.*, 2006; Pérez and Díaz, 2008). However, one of the greatest limitations is the low production of forage and low nutritional quality of forage during the dry season. In these systems where cattle forage depends on the pasture, cattle cannot satisfy their nutritional requirements during periods of drought and their production decreases.

One alternative to improve forage availability in spite of local precipitation are agro- and silvopastoral systems that contain forage trees (Torres, 1983; Bautista *et al.*, 2011). Silvopastoral systems are integrated production systems of species of trees associated with grasses for livestock to graze, in the same soil space, in a sequential or simultaneous manner (Torres, 1982; Avendaño and Acosta, 2000). In these systems, natural resources are managed with a holistic vision to improve animal production by promoting a rational use of the resources (Torres, 1982; Huxley, 1983). At the same time, conservation of biodiversity is promoted in three strata: a) the superior strata integrates trees that produce forage fruits and foliage with good nutritional quality (Murgueitio *et al.*, 2006); b) the middle strata integrates shrubs for browsing with other forage vines; and c) the lower or herbaceous strata represents the grasses and remaining vegetation adapted to this microclimate (Avendaño and Acosta, 2000).

Silvopastoral systems having forage trees are focused on improving animal food and in these the nutritional quality of the available forage is substantially improved because tree foliage has higher nutritional quality than grasses (Mueller *et al.*, 2001; Carranza-Montaño *et al.*, 2003; Sosa *et al.*, 2004). *Guazuma ulmifolia* Lam. is a tree species with the potential to integrate silvopastoral systems to browsing, and is adapted to distinct moisture and soil conditions (Villa *et al.*, 2009; Manríquez *et al.*, 2011), has adequate nutritional-chemical characteristics and a low content of secondary metabolites (Lizárraga *et al.*, 2001; Carranza-Montaño *et al.*, 2003), is adapted to defoliation and produces forage in the dry season to complement cattle feeding (Ortega *et al.*, 2009). In the state of Veracruz, it has been found in crop fields, in pastures and along roadsides, and is resilient to cutting, burning and cattle browsing (Villa *et al.*, 2009; Manríquez, 2010).

Simultaneous grazing and browsing by cattle and sheep in silvopastoral systems might permit a better utilization of forage in the middle and lower strata because of the relatively distinct habits these species have for their relative method of foraging. While cattle prefer grasses and other forage of the superior strata, sheep graze more selectively and better explore the inferior strata due to their small mouths (Pueyo *et al.*, 2005). Silvopastoral systems thus permit diversify production in ranches, thus improving income and sustainable use of forage resources (Nahed, 2002).

Increased production indices of a pasture were traditionally based only on grasses. Given the previous information, the objective of this work was to determine the productivity and nutritional quality of forage in a silvopastoral system which combined *G. ulmifolia* and the grasses *Digitaria eriantha* Stent., *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf and *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs, and their effect on meat production of cattle and sheep in mixed species (cattle and sheep) and single species (sheep) pastures.

MATERIALS AND METHODS

Study location

The study was conducted at Colegio de Postgraduados, Campus Veracruz, located in the physiographic province of the Coastal Plain of the Southern Gulf (Lat. 19° 10' N, Long. 96° 10' W, altitude 18 masl) and between the limits of the terrestrial systems of dunes and ridges (Chiappy-Johnes *et al.*, 2002). The climate is hot sub-humid Aw_1 with rains during summer, 1286 mm of annual precipitation and an annual average temperature of 27 °C (García, 1978). The soils where the experiment was performed were sandy-clay with a pH of 5.8 to 6.2, 2.7 to 2.8 % organic matter, 0.11 % N, 16.8 to 35.8 mg kg^{-1} P, 0.8 to 0.12 cmol kg^{-1} K, 1.78 to 1.87 cmol kg^{-1} Mg and 3.6 to 8.19 cmol kg^{-1} Ca.

Silvopastoral system

The silvopastoral system (3.1 ha) used was established between July 2006 and April 2007, and combined the tree species *G. ulmifolia* (GUUL) with the grasses *D. eriantha* (DIER), *B. brizantha* (BRBR) and *M. maximus* (MEMA). The trees were obtained from seeds germinated in a nursery (Manríquez, 2010) and established in the field at 2 months of age during the rainy season. Their arrangement was as double hedges with 1 m between the hedges in a pair, 1 m of space between plants, and alleys of 4 m in width between hedge pairs. Grasses were established on cleared ground during the first months of 2007. Trees and grass were maintained free of weeds during their growth using manual and chemical methods. Chemical control was accomplished using 2 L ha^{-1} of Faena® (356 g of I.A. glyphosate L^{-1} of water; Monsanto).

The system was divided into 10 pastures of 0.31 ha each. When the trees had reached 1.4 years of age, an initial maintenance pruning was performed by cutting the main stem to 70 cm in height, and the primary branches to 40 cm from the main stem. This pruning was performed on previously paddocks in sequence, at five-day intervals (for rotational grazing). At the same time, the grasses were uniformly cut to a height of 10 cm above the soil to standardize the regrowth of both species in the system. The system was maintained without irrigation during the windy season, with the natural precipitation during the rainy season, and only during the dry season was it irrigated using a low pressure sprinkler system.

Treatments and animals examined

We evaluated the grazing-browsing of cows and sheep from October 2007 to October 2008 in two treatments: 1) mixed grazing with cattle and sheep, and 2) single species grazing using only sheep. The animals were weighed, vaccinated, dewormed and given vitamins as preventative measures. We used Criollo Lechero Tropical heifers and female Pelibuey sheep. During the windy season (October to January), the mixed species treatment contained six heifers of 165±8 kg live weight (LW) and six sheep of 13.8±2 kg LW, while the single species treatment contained 12 sheep of 13.8±4 kg LW. During the dry season (February to May), the mixed group contained five heifers of 135±8 kg LW and six sheep of 13.5±3 kg LW, while in the single species treatment there were 12 sheep of 14.0±3 kg LW. During the rainy season (June to September), the mixed species treatment had five heifers of 127±14 kg LW and six sheep of 14.2±2 kg LW, while in the single species treatment there were 12 sheep of 13.0±2 kg LW. The animals in each group entered into the silvopastoral system at the same time, in contiguous pastures divided by electric fencing, and remained there 24 h per day. The pastures were rotated using five days of occupation and 30 days of rest. The animals were dewormed at the beginning of each experimental stage, and were given free access to mineral salts and water, and were exposed to the same management and environmental conditions.

Forage allocation during each period of pasture utilization was performed according to the number of animal units in each treatment. This was accomplished by weighing the cows and sheep in the mixed species treatment and the sheep in the single species treatment and converting them to animal units (1 AU=450 kg of LW), and the assigning an appropriate number of AUs to each treatment assuming each group would utilize between 60 and 70 % of the available forage; therefore, the sizes of the pastures for each experimental group differed.

Sampling and variable measurement

Animal performance was evaluated, as was the availability of chemical-nutritional quality of the forage in the three tree-grass associations (GUUL-DIER, GUUL-BRBR and GUUL-MEMA) and the gain in weight of the animals during three time periods annually: 25 weeks during the windy season, 17 weeks during the dry season, and 17 weeks during the rainy season. Samples of forage from the three associations were collected during each of the seasons evaluated (windy, dry and rainy) in selected pastures. The samplings were carried out before the animals entered and after they exited to determine the amount of available and remaining forage (kg DM ha^{-1}) as well as dry matter utilization (kg DM ha^{-1}). The amount of grass biomass in the pastures was estimated from samples (n=20) cut at 10 cm above the soil (Juárez *et al.*, 2009) from inside rectangular 0.25 m^2 quadrats placed in the pastures systematically along perpendicular transects to the tree hedges. The edible foliage (leaves, and herbaceous and semi-woody stems) from 20 trees selected randomly in each pasture also was sampled by using garden scissors to cut all new growth since the last pasture utilization. When the new growth had semi-woody stems, they were included in the sample because personal observation of cattle grazing *G. ulmifolia* has shown them to remove short tender and semi-woody stems up to a point where they can no longer break the branch without difficulty. Four samples of forage by treatment (mixed and single species) were collected from each component of the system (grasses and trees) in each one of the three tree-grass associations in each evaluated season; in the samples from trees, leaves were included, as were tender and semi-woody stems. Also, combined forage samples were prepared from each silvopastoral association based on the combination of proportions of apparent consumption by the animals (bovine and ovine) that was calculated using the difference in dry weight among the material offered and that rejected; this was performed during each season of the experiment. All samples were dried at 60 °C for 48 h (AOAC, 1990), then ground in a Culatti hammer mill (Net Inter Lab S.A.L. DFH45, 75 W, 6,000 rpm) utilizing a 1 mm sieve and then stored for later laboratory analysis.

Forage yield in the silvopastoral system (kg ha^{-1} $year^{-1}$) was determined by summing the quantity of dry matter in the system before each period of utilization, with each contribution calculated for each tree-grass association separately and later adding them together. Productivity of the animal component was determined by converting the kilograms of meat gained in each experimental group to kg of live weight (LW) ha^{-1} $year^{-1}$. The animals were weighed on an electronic scale (ACEMEX CW11-3F of 9 Volts) every 14 days at 07:00 h with prior fasting for 12 h.

Bromatological analysis were carried out separately on the plant samples from each tree-grass association (GUUL-DIER, GUUL-BRBR and GUUL-MEMA) and also on combined samples from each association. Crude protein (CP) content was determined according to AOAC (1990), the content of acid detergent fiber (ADF) using the method of Van Soest *et al.* (1991), and the content of neutral detergent fiber (NDF), and lignin and cell content following Van Soest (2002).

Statistical analysis

Forage productivity data from the silvopastoral system were analyzed using a completely randomized design in the program GLM, and in the model the treatment effects were included, as were season and treatment by season interaction; animal weight gain was analyzed using the Student t-test (SAS/STAT, 2004). Data on utilization in the different tree-grass associations, as well as those on chemical-nutritional quality, were calculated using only descriptive statistics.

RESULTS AND DISCUSSION

Productivity, availability and utilization of forage by season and year

Forage availability in the pastures assigned to each grazing treatment by season was 2.6±2.5, 2.7 ± 2.2 and 3.8±1.0 t DM ha^{-1} (by grazing period) in the mixed species treatment, and 2.2±1.4, 1.9 ± 1.9 and 3.4±1.1 t DM ha^{-1} in the single species treatment, during the windy, dry and rainy seasons, respectively.

Forage yield was similar between treatments ($P > 0.05$), yet there was an effect of season on the availability of dry matter ($P = 0.003$), as evidenced by the smaller quantity of biomass during the windy and dry seasons, and the largest during the rainy season ($P < 0.05$; Figure 1).

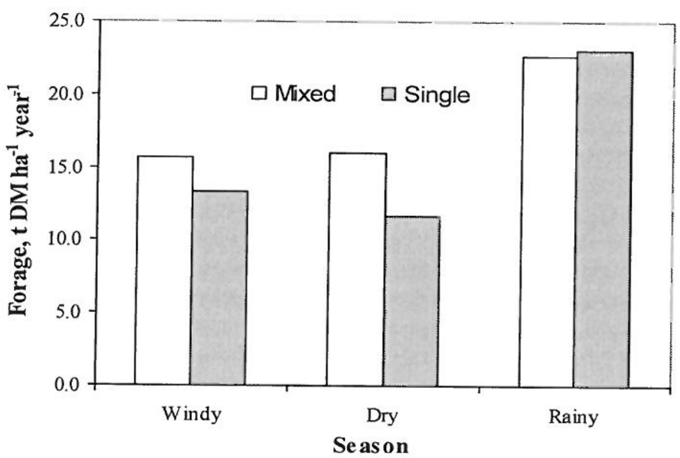

Figure 1. Forage yield in a silvopastoral system being grazed by sheep (single species treatment) and simultaneously by cows and sheep (mixed species treatment) during three annual seasons. The silvopastoral system was composed of associations of *Guazuma ulmifolia* Lam. with *Digitaria eriantha* Stent, *Brachiaria brizantha* A. Richard Staf, or *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs.

Forage production by season for the GUUL-DIER association ranged from 17.0 to 20.6 t DM ha^{-1} over the seasons (Figure 2), and the quantity of tree foliage was a small percentage of that biomass (7.7 to 17.0 %). In the GUUL-BRBR association, the total biomass varied between 6.5 and 9.7 t DM ha^{-1} over the seasons, and of this the quantity of tree foliage was lower (1.0 to 5.2 %). In the GUUL-MEMA association, the biomass varied between 2.2 and 12.6 t DM ha^{-1} and the quantity of GUUL foliage was lowest (1 to 4.5 %).

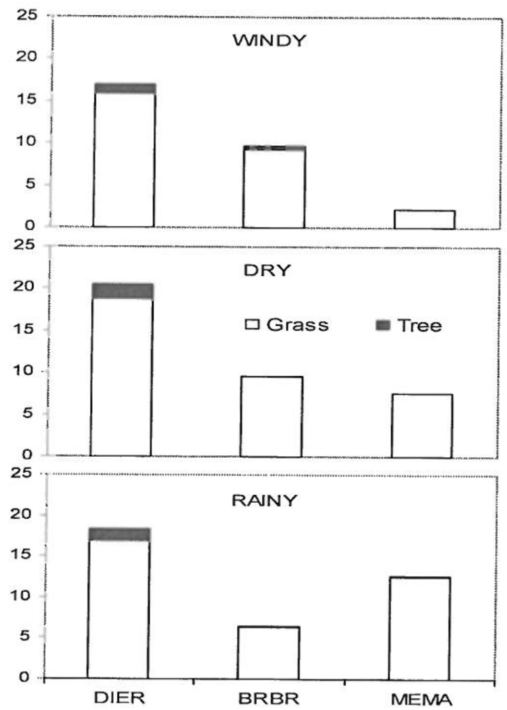

Figure 2. Forage production in a silvopastoral system being grazed by sheep (single species) or simultaneously by cows and sheep (mixed species), by tree-grass association, and over three seasons of the year. The silvopastoral system was composed of associations of *Guazuma ulmifolia* Lam. with *Digitaria eriantha Stent* (DIER), *Brachiaria brizantha* A. Richard Staf (BRBR), or *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs (MEMA).

Forage utilization varied over the seasons of the year, yet maintained similar values between the two treatments independently of the tree-grass association (Figure 3). In general, lower utilization was observed during the windy season, although there was a noticeable difference among associations during this season, with MEMA being less utilized and DIER most utilized.

The productivity in the GUUL-DIER system in this investigation was similar to that reported in other studies using *D. eriantha* in monoculture. Esqueda and Tosquy (2007) obtained 2.9 t DM ha^{-1} at regrowth of 45 days and Juárez *et al.* (2009) indicated 2 t DM ha^{-1} at regrowth of 50 days. Michel *et al.* (2006), however, reported greater values (9.8 t DM ha^{-1}) at regrowth of 28 days probably under different management conditions. In *M. maximus*, Juárez *et al.* (2009) reported 5.0 t DM ha^{-1} at regrowth of 50 days (wet and dry seasons) and Ramírez *et al.* (2009) observed similar values (3.4 t DM ha^{-1}) during the dry season, but a greater quantity during the rainy season (16.4 t DM ha^{-1}), with similar greater productivity also found in our investigation. Being this one a highly productive grass, the lower yields obtained in this study might be explained by the low fertility of soils used.

The smaller quantity of foliage produced by GUUL in all the associations was primarily a result of low tree production since the trees in this experiment were very young (17 to 47 weeks of age). It is known that with age, the basal area of trees increases and with it their production also increases (Westwood *et al.*, 1970); Giraldo (1998) and Lizarraga *et al.* (2001) showed evidence of this relationship in naturally occurring *G. ulmifolia* trees. On the other hand, the trees occupied proportionately less space in the silvopastoral system in comparison with the grasses (20 % trees and 80 % grasses), which also limits the quantity of dry matter that the trees can contribute. In plantations of this same species, but at greater densities, Wagner and Colón (2007) found 2.0 and 2.2 t DM ha^{-1} at regrowth of 60 and 75 days, respectively, at a cutting height of 0.75 m.

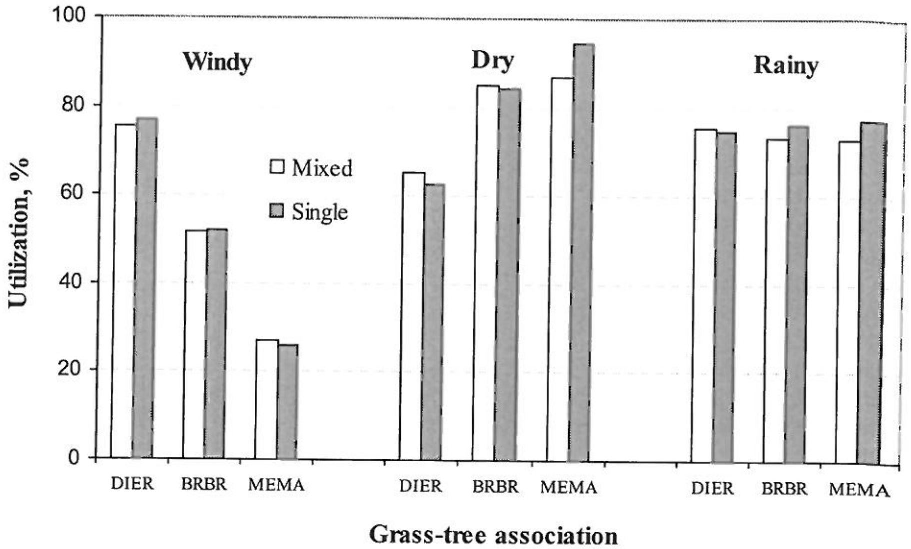

Figure 3. Forage utilization (%) in a silvopastoral system being grazed by sheep (single species) and simultaneously by cows and sheep (mixed species), during three seasons of the year. The silvopastoral system was composed of associations of *Guazuma ulmifolia* Lam. with *Digitaria eriantha* Stent, *Brachiaria brizantha* A. Richard Staf, or *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs.

Tree chemical composition

Crude protein content in *G. ulmifolia* varied between 12 and 19 %, but was greater in all associations during the windy season and lowest during the dry and rainy seasons (Table 1). The NDF ranged between 37.2 and 52.7 % and was greatest during the windy season (39.4, 43.1 and 52.7 %) and lowest in the other seasons without showing a definable tendency. Tree ADF varied between 21.0 and 28.5 % and was greatest during the rainy season (21.5, 27.1 and 28.5 %). The concentration of lignin in the foliage varied within and among seasons with the highest values occurring during the rainy season (5.0, 5.1 and 7.2 %) and the lowest values during the windy season (2.8, 4.7 and 5.4 %). Cellular content ranged between 47.3 and 62.8 %, and was greatest during the dry season (49.0, 54.4 and 62.8 % for BRBR, DIER and MEMA, respectively) and lowest during the windy season (47.3, 56.9 and 60.6 % for DIER, BRBR and MEMA, respectively).

Crude protein values lie within the observed range in other studies with this tree species. López *et al.* (2008) revealed a 13.8 % CP level in regrowth after 120 days during the dry season. Lizárraga *et al.* (2001) 16 %; Vargas and Elvira (1994) showed 14.7 % in regrowth after 84 days; Wagner and Colón (2007) observed 15 % between 60 and 75 days after regrowth. Smaller ranges to those found in this study were reported by Cárdenas *et al.* (2003) and Cuadrado *et al.* (2004) (8.5 and 10.5 %, respectively). Nevertheless, a higher content (23.1 %) was reported by Araya *et al.* (1994), probably in more fertile soil conditions or with younger foliage. The values for NDF are within the range observed in other studies with this tree species. López *et al.* (2008) observed 45.1 % during the dry season, while Lizárraga *et al.* (2001) reported 43 % during the rainy season and Flores *et al.* (1998) observed 52 % in regrowth after 5 months. Yet, Cuadrado *et al.* (2004) found greater values (64.1 and 67.7 % during the rainy and dry seasons, respectively). The ranges for ADF are smaller to those found in other studies with this tree species, and smaller values (28.1, 36 and 29.1 %) were found by Flores (1994) during the dry season.

Table 1. Chemical-nutritional characteristics of foliage from *Guazuma ulmifolia* Lam. (GUUL) in a silvopastoral system with *Digitaria eriantha* Stent (DIER), *Brachiaria brizantha* A. Richard Staf (BRBR), or *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs (MEMA), at 30 days of age after regrowth.

Biomass	Season*	CP (%)	NDF (%)	ADF (%)	Lignin (%)	CC (%)
GUUL-DIER	Windy	19.0	52.7	21.4	2.8	47.3
GUUL-BRBR	Windy	16.1	43.1	25.3	5.4	56.9
GUUL-MEMA	Windy	17.0	39.4	21.0	4.7	60.6
GUUL-DIER	Dry	16.1	45.6	24.7	5.1	54.4
GUUL-BRBR	Dry	15.4	51.0	26.9	4.5	49.0
GUUL-MEMA	Dry	12.0	37.2	21.9	5.8	62.8
GUUL-DIER	Rainy	15.4	49.0	27.1	5.0	51.0
GUUL-BRBR	Rainy	13.5	39.7	21.5	5.1	60.3
GUUL-MEMA	Rainy	15.9	51.9	28.5	7.2	48.1

*Windy=October to January, Dry=February to May, Rainy=June to September, CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber, CC=cellular content

NDF and ADF are indicators of the quality of forage dry matter and can vary between studies due to the age of plant regrowth and that comparisons with other studies could differ in their objectives. What is important is that the results obtained in this work are comparable to those observed in other studies and comparable to the quality of other tropical forages.

Chemical composition of grasses

The crude protein content in grasses varied between 6.2 and 10.8 %, was greatest during the windy season (8.1, 8.2 and 10.8 % in BRBR, MEMA and DIER, respectively), and lowest (6.2, 6.2 and 7.1 % for DIER, MEMA and BRBR, respectively) during the dry season (Table 2). The content of NDF in grasses varied between 69.1 and 76.0 %, was greatest during the rainy season (74.4, 75.3 and 76.0 % in DIER, MEMA and BRBR, respectively) and lowest during the dry season (69.1, 72.3 and 73.6 % for the same associations). The content of ADF in grasses varied between 40.6 and 46.7 %, was greatest during the windy season (43.3, 43.5 and 46.7 % in DIER, MEMA and BRBR, respectively) and lowest during the dry season (40.6, 41.3 and 45.9 % in BRBR, DIER and MEMA, respectively). Lignin content in grasses varied between 4.5 and 7.6 % during the year, was greatest during the rainy season (5.2, 6.7 and 7.6 % in MEMA, DIER and BRBR, respectively) and lowest during the windy season (4.5, 6.8 and 7.3 % in MEMA, BRBR and DIER, respectively). Cell contents varied between 24.0 and 30.9 %, was greatest during the dry season (26.4, 27.7 and 30.9 % in BRBR, MEMA and DIER, respectively) and lowest during the rainy season (24.0, 24.7 and 25.6 %, in BRBR, MEMA and DIER, respectively).

The CP results were similar to those found in other studies. Michel *et al.* (2006) indicated 9.0, 9.4 and 8.8 % at regrowth of 28, 35 and 42 days, respectively. Juárez *et al.* (2009) found 9.2%, Cuadrado *et al.* (2004) observed 9.3 and 10.5 % at regrowth of 24 days in BRBR during the dry and rainy seasons, respectively. These values confirm those of Enríquez *et al.* (1999) who indicated that DIER associated with trees increased the CP content at regrowth of 21 and 42 days (8.3 and 8.8 %, respectively). However, smaller values of 4.6 % were obtained by Juárez *et al.* (2009) in MEMA monocultures.

The values found for MEMA are similar to ranges observed by Juárez *et al.* (2009) who obtained 74.6 %. However, Michel *et al.* (2006) showed lower values (48.2, 54.8 and 56.6 %) at regrowth of 28, 35 and 42 days, respectively. Juárez *et al.* (2009) obtained 65.6 % and Cuadrado *et al.* (2004) observed 67.7 and 64 % during the dry and rainy seasons, respectively, at regrowth of 24 days.

Table 2. Chemical-nutritional characteristics of foliage from *Digitaria eriantha* Stent (DIER), *Brachiaria brizantha* A. Richard Staf (BRBR), or *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs (MEMA), from a silvopastoral system containing *Guazuma ulmifolia* Lam. (GUUL) at a regrowth age of 30 days.

Biomass	Season*	CP (%)	NDF (%)	ADF (%)	Lignin (%)	CC (%)
GUUL-DIER	Windy	10.8	72.5	43.3	7.3	27.5
GUUL-BRBR	Windy	8.1	75.6	46.7	6.8	24.4
GUUL-MEMA	Windy	8.2	73.7	43.5	4.5	26.3
GUUL-DIER	Dry	6.2	69.1	41.3	5.0	30.9
GUUL-BRBR	Dry	7.1	73.6	40.6	6.6	26.4
GUUL-MEMA	Dry	6.2	72.3	45.9	5.6	27.7
GUUL-DIER	Rainy	9.1	74.4	42.1	6.7	25.6
GUUL-BRBR	Rainy	7.5	76.0	45.4	7.6	24.0
GUUL-MEMA	Rainy	7.7	75.3	45.3	5.2	24.7

*Windy=October to January, Dry=February to May, Rainy=June to September, CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber, CC=cellular content

These values are within the range observed in other studies with this species. Cuadrado *et al.* (2004) observed 40.6 % at regrowth of 24 days during the dry season in BRBR. Yet, smaller values have been found (31.2, 32.6 and 33.9 %) at regrowth of 28, 35 and 42 days, respectively (Michel *et al.*, 2006). Cuadrado *et al.* (2004) reported 30.8 % during the rainy season in BRBR.

Chemical composition of tree-grass associations

CP in the combined samples, independently of the association, varied between 8.0 and 13.8 %, was highest during the windy season (11.4, 13.5 and 13.8 % in BRBR, DIER and MEMA, respectively), and appeared to be lowest during the rainy season for BRBR and MEMA (8.0 and 10.2 %, respectively) and during dry periods in MEMA (8.9 %; Table 3).

The NDF in GUUL-grasses varied between 51.6 and 73.2 % and was highest during the rainy season (70.3, 71.7 and 73.2 % in DIER, BRBR and MEMA, respectively), and was observed to be lowest during the windy season (51.6, 62.0 and 66.4 % in MEMA, BRBR and DIER, respectively). ADF content in GUUL-grasses varied between 26.4 and 44.6 % and was highest during the rainy season (40.0, 40.7 and 44.6 % in DIER, BRBR and MEMA, respectively) and lowest during the windy season (26.4, 39.8 and 40.1 % in MEMA, BRBR and DIER, respectively).

Lignin content varied between 3.9 and 7.8 %, was highest during the windy season (4.3, 5.8 and 7.8 % in MEMA, DIER and BRBR, respectively) and was lowest during the dry season (3.9, 4.0 and 5.1 % in MEMA, BRBR and DIER, respectively). Cellular content ranged from 26.8 to 48.4 %, was highest during the windy season (33.6, 38.0 and 48.4 % in DIER, BRBR and MEMA, respectively) and lowest during the rainy season 26.8, 28.3 and 29.7 % in MEMA, BRBR and DIER, respectively).

Animal weight gain

Animal weight gain was higher ($P < 0.05$) in the mixed species grazing treatment (444.4 kg ha^{-1} $year^{-1}$) than in the single species treatment (321.7 kg ha^{-1} $year^{-1}$). Although daily weight gains are not comparable among treatments, cows gained 0.512, 0.346 and 0.333 kg day^{-1} during the dry, rainy and windy seasons, respectively, while sheep in the same treatment gained 0.071, 0.108 and 0.077 kg day^{-1} during the same seasons. Sheep in the single species grazing treatment gained 0.054, 0.164 and 0.065 kg day^{-1} during the same seasons. The gains in weight by the cows are considered adequate for females of a race having small to medium body size such as the Criollo Lechero Tropical. Cuadrado *et al.* (2004), for example, observed greater weight gain (0.600 kg) in bovines grazing BRBR, providing greater body size, especially in males. As for weight gains in sheep, they were not high in any of the treatments, although there was some increase in weight in all seasons evaluated.

Table 3. Chemical-nutritional characteristics of foliage from *Guazuma ulmifolia* Lam. (GUUL) associated with *Digitaria eriantha* Stent (DIER), *Brachiaria brizantha* A. Richard Staf (BRBR), or *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs (MEMA), in a silvopastoral system at 30 days of regrowth

Biomass	Season*	CP (%)	NDF (%)	ADF (%)	Lignin (%)	CC (%)
GUUL-DIER	Windy	13.5	66.4	40.1	5.8	33.6
GUUL-BRBR	Windy	11.4	62.0	39.8	7.8	38.0
GUUL-MEMA	Windy	13.8	51.6	26.4	4.3	48.4
GUUL-DIER	Dry	11.5	64.3	37.0	5.1	35.7
GUUL-BRBR	Dry	9.2	72.1	37.4	4.0	27.9
GUUL-MEMA	Dry	8.9	71.4	43.7	3.9	28.6
GUUL-DIER	Rainy	10.2	70.3	40.0	4.6	29.7
GUUL-BRBR	Rainy	8.0	71.7	40.7	5.1	28.3
GUUL-MEMA	Rainy	10.7	73.2	44.6	5.6	26.8

*Windy=October to January, Dry=February to May, Rainy=June to September, CP=crude protein, NDF=neutral detergent fiber, ADF=acid detergent fiber, CC=cellular content

CONCLUSION

Under the conditions in which this experiment was carried out, the production of forage in the silvopastoral system having the tree *G. ulmifolia* associated with grasses is within the ranges of production for tropical pastures. The association GUUL-DIER was the most productive and of better chemical-nutritional quality for most of the year, and above all during the dry season when a greater need for forage exists. The production of dry matter of *G. ulmifolia* under the density and management implemented in this investigation contributes a low quantity to the total forage produced in this silvopastoral system. Yet, its higher chemical-nutritional quality relative to grasses improves the quality of the total forage, making it a good species for inclusion in silvopastoral systems in tropical zones where this species is adapted. As well, the simultaneous grazing of cows and sheep in a silvopastoral system is a viable option for increasing the production of meat per hectare per year.

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