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Effects of different regrowth ages and cutting heights on biomass production, bromatological composition and in vitro digestibility of *Guazuma ulmifolia* foliage

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Abstract *Guazuma ulmifolia* (*G. ulmifolia*) is a tropical tree species with potential in ruminant feeding. The objective of this study was to evaluate the biomass production, chemical composition and in vitro digestibility of *G. ulmifolia* foliage at different regrowth ages and cutting heights in two seasons. Sixty *G. ulmifolia* trees were selected and distributed in two heights (25 and 50 cm) and three regrowth ages (30, 60 and 90 days). A randomised design with a $2 \times 3 \times 2$ factorial arrangement was used. In both seasons, the biomass production and the nutritional content increased ($P < 0.05$) with increasing regrowth age, except for crude protein (CP), which was decreased in the dry season ($P < 0.05$) at a cutting height of 25 cm. In the rainy season, the parameters, dry matter and CP were higher at a cutting height of 25 cm and at 60 and 90 days after regrowth ($P < 0.05$), while NDF, ADF and hemicellulose were lower ($P < 0.05$). There was a similar behaviour in the dry season, although at a cutting height of 50 cm. In-vitro digestibility was higher in the rainy period ($P < 0.05$), although in the dry season, digestibility at a cutting height of 25 cm was greater. In the rainy period, forage should be collected at a height of 25 cm and after a regrowth period of 60 days, while in the dry period, the ideal cutting height is 50 cm, at a regrowth age of 60 days.

Keywords Ruminants · Silvopastoral systems · Tropical dry forest · Tropical tree fodder

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Introduction

Livestock production in the tropics is limited by the shortage of resources, both natural and economic, as well as the restricted access to new technologies (Arandas et al. 2012). In addition, low precipitation and high temperatures cause considerable reductions in the nutritional properties of forage species (Ulukan 2011). On the other hand, livestock rearing in the tropics presents several problems, among which the variability of forage quantity and quality throughout the year stands out, which negatively affects productive and reproductive ruminant parameters (Sosa et al. 2004). Tropical areas, with their high biodiversity, contain several tree and shrub species which can potentially be used as an alternative food source for ruminants during the dry season; such species are adapted to the local soil and climatic conditions, which guarantees their survival, persistence and growth (Fernández and Fandiño 2013). In previous studies,

they have successfully been used to improve animal performance (Castrejón-Pineda et al. 2016) and to meet the nutritional requirements of ruminants to maintain or improve their productivity during dry periods (Turcios 2008).

The use of arboreal and shrub species in pastures contributes to the sustainability of agricultural, agroforestry and silvopastoral systems, since these species provide both products and environmental services. Therefore, trees and shrubs can produce fodder, fruits, seeds, wood and poles; they also provide environmental services such as nutrient cycling, erosion control, the improvement of physical and biological soil conditions infiltration and water flow regulation and regeneration (Sosa et al. 2004; Guerrero 2014).

The tree species *Guazuma ulmifolia*, described by several authors (Giraldo 1998; Manríquez-Mendoza et al. 2011 ; Insuasty-Santacruz et al. 2013), belongs to the family Steculiaceae. It reaches a height of 10–20 m and a diameter of up to 60 m, with a round and extended canopy. It stands out for its robustness, resistance and capacity to adapt to different climatic conditions, conserving its phenological and nutritional properties. It grows well in warm areas with average temperatures of 24–28 °C and an annual precipitation of 700–1500 mm, at an elevation of up to 1200 m above sea level. It occurs in light and heavy soils with good drainage (Escobar and Sutherland 1986). In addition, it provides multiple products and services in different areas and is used in agriculture, agroforestry, animal husbandry (livestock) and alternative medicine (Manríquez-Mendoza et al. 2011).

According to Villa-Herrera et al. (2009) and Manríquez-Mendoza et al. (2011), *Guazuma ulmifolia* is a species with a high nutritional potential. Its forage contains 12–17% of crude protein, is palatable and edible by ruminants. However, the nutritional value and the digestibility of its leaves at different seasons, ages and cutting heights have rarely been studied which hinders the correct application of this species in ruminant feeding. Therefore, the objective of this study was to evaluate the biomass production, the chemical composition and the in vitro digestibility of the foliage of *G. ulmifolia* at different ages and cutting heights in two seasons.

Materials and methods

Location

The study was carried out on the "El Recreo" farm located in Guamo, department of Tolima (Colombia), 4°01′41″N, 74°58′12″W, at 321 m above sea level. Average annual temperature is 28 °C, with an average annual precipitation of 1488.82 mm and a relative humidity of 73%. The area is characterised by a bimodal behaviour and, according to Holdridge and Grenke (1971), represents a tropical dry forest. Climatic data during the experimental period (Fig. 1) were recorded daily via a climatic station established in the study area. Average temperature and total rainfall in the dry and rainy period were 29.1 and 27.1 °C as well as 52 and 252 mm, respectively.

Treatments

The farm contained a crop area of 2500 m^2, with approximately 170 *Guazuma ulmifolia* (*G. ulmifolia*) trees obtained through natural regeneration. For this study, 60 trees were selected and distributed in two treatments according to the cutting height of green forage: T1, cutting height of 25 cm; T2, cutting height of 50 cm. Each of the treatments was evaluated in three different regrowth ages (30, 60 and 90 days) and seasons (dry; June, July and August; rainy; October, November and December).

After the initial pruning, the trees were marked and immunised. Data were collected individually for each specimen of *G. ulmifolia*; green forage was cut for the determination of forage biomass (DM) as well as the nutritional and photochemical quality of the trees.

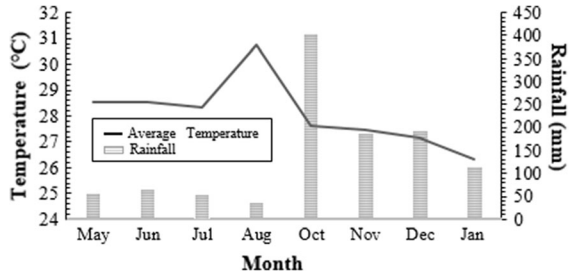

Fig. 1 Average temperature and rainfall values at the study site (data were obtained from the microclimatic station at the farm "El Recreo", University of Tolima, Colombia, from 2016 to January 2017)

Fresh forage weight was obtained using a field balance; subsequently, the samples were labelled, packed in paper bags and transported to the Animal Nutrition Laboratory of the University of Tolima. In the laboratory, they were oven-dried at 55 °C for 3 days and subsequently weighted to estimate biomass production in grams of foliage dry matter.

Bromatological composition

In the laboratory, we determined the following parameters: dry matter (DM), crude protein (CP), ethereal extract (EE), ashes or mineral matter (MM) according to (AOAC 2012), neutral detergent fibre (NDF) and acid detergent fibre (ADF) according to Van Soest et al. (1991).

In-vitro digestibility

The in vitro DM *digestibility* (IVDMD) of the *G. ulmifolia* foliage was determined based on the technique of Tilley and Terry (1963), adapted to the DAISY II®-ANKOM® artificial rumen. To obtain ruminal fluid, a rumen-cannulated Gyrolando steer was used, which was maintained with grass and *G. ulmifolia* foliage. Of each foliage sample (pre-ground to 1 mm), 0.5 g were placed into F57 ANKOM® filter bags, which were then distributed in four glass containers with buffered solutions A and B and ruminal inoculum. Subsequently, they were introduced into the DAISY II® incubator for 48 h at a constant temperature of 39 °C. At the end of this period, 40 ml of 6 N HCl and 8 g of pepsin were added (EC 3.4.23.1 Sigma®) and the samples were left in the incubator for an additional 24 h. Subsequently, the bags were dried at 105 °C for 8 h; DIVMS was calculated as the difference between the incubated feed and the residue after incubation.

Photosynthetic pigments

The leaves were labelled, packed in aluminium foil and refrigerated. Subsequently, they were transported to the Microbiology Laboratory of the Colombian Agricultural Research Corporation (CORPOICA), where the photosynthetic pigments of the collected samples were determined according to the protocol developed by Wellburn (1994) and modified by Johan et al. (2014), with the following steps: (1) removal of the larger veins from the leaves and cutting into small pieces (0.5 × 0.5 cm); (2) placing of the leaf pieces into a mortar with liquid nitrogen and macerating to a fine powder (in the dark); (3) placing about 0.03 of the powder into 50-mL falcon tubes covered with aluminium foil and adding 10 mL of cold 80% acetone (4 °C); (4) shaking for 45 min and centrifuging at 10,000 rpm for 5 min at 4 °C; (5) absorbance reading at the wavelengths 663, 647 and 470 nm and calculating the concentrations of chlorophyll (a) and (b). Chlorophyll a and b calculations were based on the equations developed by Lichtenthaler (1987) and described in Melgarejo (2010):

Chlorophyll a (mg/L) = (12.25 × A663 nm) − (2.79 × A647 nm) and Chlorophyll b (mg/L) = (21.5 × A647 nm) − (5.1 × A663 nm), where A663 nm = absorbance at 663 nm and A647 nm = absorbance at 647 nm.

To obtain the chlorophyll concentration of the plant material, multiply the concentrations obtained in the equation by the volumetric volume and divide by the initial mass of the sample, (Chl a and Chl b (mg/g fresh material) = (ng/L × 0.010 L)/ω), where w = initial weight of the sample and ng/L = concentrations of chlorophyll a and chlorophyll b in ng/L.

Statistical analysis

The experimental design was completely randomised and distributed in a 2 × 3 × 2 factorial arrangement with five repetitions; analysis of variance was performed using the software package SAS (2004). Means were compared using the least significant difference in Tukey's test at the 5% level for each age and height in both seasons to compare between ages (30, 60 and 90 days) as well as between heights (25, 50 cm).

Results

Biomass production

Differences in dry matter production ($P < 0.05$) were observed between the three cutting ages in both seasons (Table 1). In the dry season, biomass production was higher at 90 days, with 32.58 g/DM/plant/cut for the height of 25 cm and 72.86 g/DM/plant/cut for the height of 50 cm. In the dry season, the same pattern

Table 1 Production of edible dry matter g/MS of *G. ulmifolia* at different heights and cutting ages in two seasons

Season	Cutting height (cm)	Regrowth age (days)			SEM*
		30	60	90	
Dry	25	15.88^{Aa}	31.84^{Ab}	32.58^{Ab}	2.51
	50	18.20^{Aa}	45.56^{Aab}	72.86^{Bb}	8.24
	SEM**	1.24	7.52	7.29	
Rainy	25	19.32^{Aa}	96.16^{Bb}	107.78^{Ab}	19.55
	50	20.60^{Aa}	57.36^{Aa}	146.96^{Ab}	14.22
	SEM**	1.85	7.49	28.58	

*Standard error mean between cutting heights, **standard error mean between regrowth ages; different uppercase letters within one column indicate significant differences in between cutting heights; different lowercase letters within rows indicate significant differences between regrowth ages by Tukey's test

was found, with 107.78 g/DM/plant/cut for the height of 25 cm and 146.96 g/MS/plant/cut for the height of 50 cm. In addition, in the dry period, we observed differences in terms of biomass production between the treatments at the age of 90 days ($P = 0.0045$) and in the rainy season at the age of 60 days ($P = 0.0064$). We also observed differences between the periods at the age of 90 days ($P = 0.0480$) for the height of 25 cm and for the height of 50 cm ($P = 0.0233$); the other two ages showed a similar behaviour in terms of biomass production in both periods.

Bromatological composition

In the dry season, DM levels were highest in the 90-day-old cut as well as at a cutting height of 50 cm ($P < 0.05$). With increasing cutting age, the values of MM, NDF, FDA, HEMI, CEL and EE significantly increased ($P < 0.05$), with the highest increase at 90 days, while PC was reduced ($P < 0.0001$). On the other hand, a cutting height of 50 cm resulted in increased DM values compared to a cutting height of 25 cm ($P < 0.05$), irrespective of the age. Cutting at 50 cm resulted in higher NDF and ADF values at both 30 and 90 days of age, while the PC in the 25-cm cut was higher at 30 days (Table 2).

In the rainy season. DM am 25 cm was lower ($P = 0.0130$) at 30 days compared to the DM values of the other regrowth ages, while at 50 cm increasing regrowth age did not generate an increase in DM ($P = 0.1433$). With increasing regrowth age, the nutritional values of MM, ADF, HEMI, CEL and EE were increased, while the CP at 50 cm and 30 days was higher than that at 60 days ($P < 0.05$) (Table 3).

Comparing the nutrient contents of the different heights, cutting at 25 cm showed the highest DM values at 90 days, a reduction in NDF, ADF and CEL at 60 and 90 days as well as a higher concentration of CP at 60 days compared to a cutting height of 50 cm.

In-vitro digestibility

Differences in in vitro digestibility were observed in the dry season ($P < 0.05$) between the three cutting ages for both cutting heights (Table 4). Highest values were observed for a regrowth age of 60 days with 57.90% for a cutting height of 25 cm and 52.65% for a cutting height of 50 cm. In rainy season, there were no differences ($P > 0.05$) between the treatments.

Photosynthetic pigments

In the dry season, chlorophyll a concentrations were highest (1.72 mg/g) at a cutting height of 50 cm and a regrowth age of 60 days; lowest values were found at a cutting height of 25 cm and a regrowth age of 90 days. Regarding chlorophyll b a similar behaviour was found, with the highest value (14.33 mg/g) for a cutting height of 50 cm and a regrowth age of 60 days, while the lowest value was observed for 50 cm and 90 days (Table 5).

The concentration of photosynthetic pigments in the rainy season differed between cutting heights and regrowth ages. Chlorophyll a was reduced to 25 cm between 30 and 90 days and showed the highest values

Table 2 Bromatological analysis of foliage of *G. ulmifolia* in the dry period (June to August) at different cutting heights and regrowth ages

Nutrients	Cutting height (cm)	Regrowth age (days)			SEM*
		30	60	90	
DM (%)	25	27.80^{Aa}	27.96^{Aa}	29.49^{Ab}	0.25
	50	29.09^{Ba}	30.55^{Bb}	34.83^{Bc}	0.34
	SEM**	0.34	0.28	0.28	
MM (%)	25	8.46^{Aa}	8.91^{Aab}	9.87^{Ab}	0.34
	50	8.82^{Aa}	9.30^{Aab}	9.53^{Ab}	0.18
	SEM**	0.21	0.13	0.41	
NDF (%)	25	35.97^{Aa}	38.11^{Ab}	48.06^{Ac}	0.39
	50	37.87^{Ba}	39.29^{Aa}	65.59^{Bb}	0.88
	SEM**	0.46	0.40	1.00	
ADF (%)	25	23.07^{Aa}	25.93^{Ab}	31.39^{Ac}	0.55
	50	24.74^{Ba}	26.93^{Ab}	33.23^{Bc}	0.48
	SEM**	0.44	0.60	0.49	
HEMI (%)	25	13.18^{Aa}	13.33^{Aa}	18.08^{Ab}	0.53
	50	13.69^{Aa}	13.64^{Aa}	24.20^{Bb}	0.92
	SEM**	0.57	0.59	1.01	
CEL (%)	25	10.91^{Aa}	12.95^{Ab}	16.29^{Ac}	0.53
	50	11.81^{Aa}	13.18^{Aa}	16.97^{Ab}	0.60
	SEM**	0.49	0.57	0.62	
CP (%)	25	16.47^{Bc}	15.62^{Ab}	14.07^{Aa}	0.12
	50	14.94^{Aa}	15.11^{Aa}	14.59^{Aa}	0.17
	SEM**	0.13	0.17	0.15	
EE (%)	25	1.38^{Aa}	1.58^{Ab}	2.47^{Ac}	0.02
	50	1.50^{Aa}	1.65^{Aa}	2.75^{Bb}	0.09
	SEM**	0.08	0.07	0.02	

*Standard error mean between cutting heights. **Standard error mean between regrowth ages; different uppercase letters within one column indicate significant differences in between cutting heights; different lowercase letters within rows indicate significant differences between regrowth ages by Tukey's test

at 50 cm and 90 days. In contrast, chlorophyll b was reduced at 25 cm with increasing regrowth age, while at 50 cm the levels increased with age, reaching maximum values at a cutting height of 50 cm and between 60 and 90 days of regrowth age.

Discussion

Biomass production

Biomass production in both seasons was affected by the frequency of cutting, but not by the cutting height. The increase in the production of edible dry matter (EDM) at a regrowth age of 90 days in both seasons was expected since the plant has more time to replenish the biomass; this has also been found by Lugo-Soto et al. (2012) and Stür et al. (1994). It should be pointed out that slow initial regrowth is a result of the small leaf area; over time, growth is more rapid, resulting in maximum biomass production with increased leaf production, followed by height increases and, finally increases of the woody biomass, with a relatively stable number of leaves.

At a regrowth period of 30 days. EDM increased by 200%, while for 60 and 90 days, the increase was 400% in summer and 280 and 580% in the rainy season, respectively. This increase can be attributed to the intrinsic characteristics of the plant and to the climatic conditions. In this sense, Reyes et al. (2008) point out that forage plants in the tropics grow rapidly during periods of high precipitation and high temperature and that cuttings made in forage trees in different seasons (dry season *vs* humid season) and in different phases of development (reproductive *vs* vegetative) can influence the following sprout.

Table 3 Bromatological analysis of *G. ulmifolia* foliage during the rainy season at different cutting heights and regrowth ages

Nutrients	Cutting height (cm)	Regrowth age (days)			SEM*
		30	60	90	
DM (%)	25	24.63^{Aa}	27.24^{Ab}	27.46^{Bb}	0.62
	50	25.23^{Aa}	25.95^{Aa}	26.52^{Aa}	0.43
	**	0.58	0.70	0.19	
MM (%)	25	8.56^{Aa}	8.66^{Aa}	9.68^{Ab}	0.18
	50	8.78^{Aa}	8.92^{Aab}	9.82^{Ab}	0.24
	**	0.27	0.14	0.20	
NDF (%)	25	26.26^{Aa}	39.50^{Ab}	42.15^{Ac}	0.47
	50	26.68^{Aa}	51.02^{Bb}	59.55^{Bc}	0.48
	**	0.26	0.59	0.52	
ADF (%)	25	18.39^{Aa}	25.00^{Ab}	25.26^{Ab}	0.39
	50	18.55^{Aa}	32.76^{Bb}	37.37^{Bc}	0.50
	**	0.33	0.48	0.50	
HEMI (%)	25	8.53^{Aa}	15.52^{Ab}	21.52^{Ac}	0.56
	50	8.83^{Aa}	18.64^{Bb}	21.85^{Ac}	0.41
	**	0.36	0.59	0.49	
CEL (%)	25	12.67^{Aa}	17.74^{Ab}	13.79^{Aa}	0.30
	50	12.32^{Aa}	23.46^{Bb}	20.69^{Bb}	0.78
	**	0.26	0.39	0.91	
CP (%)	25	20.97^{Aa}	20.92^{Ba}	20.63^{Aa}	0.19
	50	21.88^{Ab}	19.43^{Aa}	20.78^{Aab}	0.58
	**	0.43	0.22	0.57	
EE (%)	25	1.33^{Aa}	1.37^{Aa}	2.07^{Ab}	0.07
	50	1.51^{Ba}	1.50^{Aa}	2.21^{Ab}	0.08
	**	0.001	0.12	0.05	

*Standard error mean between cutting heights. **Standard error mean between regrowth ages; different uppercase letters within one column indicate significant differences in between cutting heights; different lowercase letters within rows indicate significant differences between regrowth ages by Tukey's test

Table 4 DM in vitro digestibility (%) of *G. ulmifolia* at different cutting heights and regrowth ages

Season	Cutting height (cm)	Regrowth age (days)			SEM*
		30	60	90	
Dry	25	58.76^{Ab}	57.90^{Bab}	55.05^{Ba}	0.85
	50	57.75^{Ab}	52.65^{Aa}	51.58^{Aa}	0.62
	**	0.35	0.62	1.07	
Rainy	25	60.25^{Aa}	59.68^{Aa}	60.27^{Aa}	0.64
	50	60.28^{Aa}	61.07^{Aa}	59.13^{Aa}	0.79
	**	0.87	0.76	0.48	

*Mean standard error between cutting heights. **Mean standard error between regrowth ages; different uppercase letters within one column indicate significant differences in between cutting heights; different lowercase letters within rows indicate significant differences between regrowth ages by Tukey's test

In Mexico, in a tropical dry forest with an average annual temperature of 26.5 °C and an average annual rainfall of 953 mm Casanova-Lugo et al. (2014a) have evaluated the potential of biomass production in plots with 30 individuals of *G. ulmifolia* and *Leucaena leucocephala* with a height of 1 m subjected to a cutting frequency of 90 days. Drip irrigation was used twice a week in the morning for 3 h. The authors

Table 5 Photosynthetic pigments in *G. ulmifolia* in the dry and the rainy season at different cutting heights and regrowth ages

Period	Chlorophyll (mg/g)	Cutting height (cm)	Regrowth age (days)			SEM*
			30	60	90	
Dry	A	25	1.37^{Bb}	1.44^{Ab}	0.76^{Aa}	0.04
		50	1.05^{Ab}	1.72^{Bc}	0.79^{Aa}	0.05
		**	0.05	0.06	0.02	
	B	25	10.31^{Bb}	10.43^{Ab}	6.04^{Aa}	0.29
		50	7.34^{Ab}	14.33^{Bc}	5.78^{Aa}	0.27
		**	0.40	0.26	0.11	
Rainy	A	25	1.62^{Bb}	1.61^{Ab}	1.31^{Aa}	0.04
		50	1.20^{Aa}	1.60^{Ab}	1.96^{Bc}	0.07
		**	0.05	0.08	0.05	
	B	25	12.37^{Bb}	12.07^{Aab}	11.00^{Aa}	0.24
		50	10.11^{Aa}	14.56^{Bb}	14.72^{Bb}	0.32
		**	0.19	0.33	0.31	

*Standard error mean between cutting heights. **Standard error mean between regrowth ages; different uppercase letters within one column indicate significant differences in between cutting heights; different lowercase letters within rows indicate significant differences between regrowth ages by Tukey's test

report that the seasons did not affect the biomass production of the specie, obtaining an average forage yield per season of 71.6 g/DM/plant/cut. These results agree with those obtained in this experiment in the dry period at a height of 50 cm and a regrowth age of 90 days without irrigation, which proves the hardiness and resistance of the species to adverse climatic conditions. However, in this study, a higher biomass production was obtained in the rainy period under the same management conditions. In addition, *G. ulmifolia* has a higher yield than other species. such as *Leucaena leucocephala*, *Trichantera gigantea and Morus alba* Linn, which in similar studies, obtained edible biomass values in dry period of 12.81 g/DM/plant/90 days, 92.2 g/GF/plant/90 days and 57.6 g/DM/plant/90 days, while in the rainy period, the yields were 12.5 g/DM/plant/90 days. 102 g/GF/plant/90 days and 71.9 g/DM/plant/90 days, respectively (Gómez and Murgueitio 1991; Francisco 1998; Noda et al. 2007).

Bromatological composition

Increasing plant age results in higher leaf DM values (Ezenwa et al. 1995) which explains the higher DM values at the 90-day regrowth age. However, previous studies have also reported high CP values within relatively short regrowth periods (Rincon et al. 2008; Lugo-Soto et al. 2009, 2012; Ortega-Vargas et al. 2013). In this context, Lugo-Soto et al. (2012) observed the highest percentage of protein in *Tithonia diversifolia* at a cutting height of 20 cm and a cutting frequency of 30 days when compared with 60 and 85 days. Relating more tender leaves with a greater protein synthesis and a higher metabolism (Chacón-Hernández and Vargas-Rodríguez 2009) observed similar results when studying the digestibility and quality of *Pennisetum purpureum* cv. King Grass at three regrowth ages, with increasing DM values at higher regrowth ages and obtaining values of 13.03, 13.79 and 14.43% at 60, 75 and 90 days respectively, which was also reflected in an increase in cell wall components (FDN and FDA) and a reduction in PC concentration; these findings agree with those obtained in the present study and become important when using foliage in the diet of ruminants, since ruminal degradation is highly related to the concentration and quality of the fibre (García-castillo et al. 2008; Slanac et al. 2011).

In the rainy season, we found higher nutrient values at a height of 25 cm compared with 50 cm; in this case the yield would be more related to the root properties than to the surface area of the trunk, since cutting at different heights results in varying values, depending

on the species. Medina et al. (2006) and Noda et al. (2007), studying the species *Morus alba*, observed the highest production values at low cutting heights, since soluble carbohydrates in the form of starch are conserved in the roots of this species and can be used faster in regrowth. However, for other species such as *Leucaena leucocephala*, cutting at a lower height resulted in the delay in the growth phase because of the smaller nutrient reserves in the active parenchyma and the meristematic stem tissue (Bacab et al. 2012); this tissue allows a greater mobilisation of soluble carbohydrates through the phloem, allowing a higher biomass production (Stür et al. 1994).

It should be noted that climatic conditions have a direct impact on the concentration of nutrients (Ulukan 2011), regardless of regrowth age or cutting height, with higher values in the rainy season. Similarly, Casanova-Lugo et al. (2014a, b) observed a higher nutritional quality in terms of CP, NDF and ADF when comparing the rainy season with the dry period in both *G. ulmifolia* and *Leucaena leucocephala*.

In-vitro digestibility

In the dry season, the lowest regrowth ages presented greater digestibility due to the lower concentration of nutritional components such as ADF and lignin, which increase with age and sometimes due to heat and hydric stress (Lugo-Soto et al. 2009, 2012; Ulukan 2011). In contrast, *G. ulmifolia* presents a higher IVDMD than legume species such as *M. lathyroides*, *M. atropurpureum* and *P. acutifolius*, which were collected every 15 days obtaining values of 59.5, 56.6 and 49.3%, respectively (Alatorre-Hernández et al. 2018). IVDMD was similar to those of *Medicago sativa* the arboreal species *Albizia lebbeck*, *Ceiba pentandra*, *Senna siamea*, and *Azadirachta indica,* which in studies carried by López et al. (2018) and by Ansah et al. (2018), presented values of 58, 66, 55,5, 66 and 61.7%, respectively. On the other hand, some species, such as *Khaya senegalensis* and the arboreal genus *Gmelina*, which have been used as a supplement for ruminants, showed a lower digestibility than *G. ulmifolia*, with 38 and 48%, respectively (Ansah et al. 2018). Generally, the IVDMD was in the acceptable range for feeding grazing ruminants or cutting food systems, taking into account that the digestibility of various tropical grasses is below 50% (Lugo-Soto et al. 2012; Rodríguez-Zamora and Elizondo-Salazar 2012; Quintero et al. 2015). When measuring the in situ degradability of *G. ulmifolia* foliage, a completely degradable soluble fraction of 22.38% and a potentially degradable insoluble fraction of 55.17% in adult trees have been reported.

Photosynthetic pigments

The photosynthetic process is fundamental for the performance and productivity of a plant, and the amount of chlorophyll indicates a plant´s photosynthetic capacity. According to the results of this study, samples collected at a cutting height of 50 cm and a regrowth age of 60 days had a higher photosynthesis activity; after 90 days, the assimilation rate decreased and chlorophyll was reduced with leaf senescence, resulting in lower photosynthesis rates (Table 5); this was correlated with the decrease in CP contents, so that the highest biomass accumulation was between 60 and 90 days. It is expected that in the dry period, the highest DM content would be found for a cutting height of 50 cm and a regrowth age of 60 days (Table 2) (Lohman et al. 1994; Lei et al. 1996).

Climatic factors influenced the dynamics of the photosynthetic pigments, with higher chlorophyll a (1.96 mg/g) and b (14.72 mg/g) contents after a regrowth age of 90 days. This means that in the rainy season, leaf senescence in *G. ulmifolia* occurs more slowly. Similarly, the contents of chlorophyll a and be were higher in the rainy than in the dry period. Chlorophyll is related with temperature, pH, soil nutrients and humidity (Ashton 2012). In the rainy season, an average stable temperature below 28 °C was observed, while in the dry season, there was a notable increase in temperature at 90 days regrowth age (Fig. 1). Temperature influences enzymatic reactions, and at an optimal temperature, plants increase their photosynthesis rates, while high temperatures can inhibit or damage the components of the photosystem II (Havaux 1992). Humidity influences numerous metabolic processes, and enzymatic activities are also disturbed by water stress, which has an effect on plant growth and yield (Anjum et al. 2003). Therefore, in the rainy period, the greater photosynthetic activity can be related to the chlorophyll content and the availability of biomass.

Conclusion

Guazuma ulmifolia is a plant with a high potential as a forage plant in the diet of ruminants during dry seasons, mainly because of its biomass production. The optimum time for the collection of forage from *G. ulmifolia* in the rainy season is after a regrowth period of 60 days at a height of 25 cm. In the dry season, forage should be cut at a height of 50 cm and after 60 days of regrowth.

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