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Article

Production and nutritional quality of *Tithonia diversifolia* (Hemsl.) A. Grey in three seasons of the year and its effect on the preference by Pelibuey sheep

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Abstract:

Production, nutritional quality and preference of *T. diversifolia* by Pelibuey sheep was determined, at different ages, in three seasons of the year. Dry matter (DM) production and nutritional quality of forage were measured every 14 d, from the cut to 84 d of age. Leaf and stem samples were taken to determine crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF). Eight adult Pelibuey sheep were used to determine their preference for *T. diversifolia* foliage at 42, 56 and 70 d of regrowth. Total DM production was similar in autumn and winter and both greater than spring. In autumn at 56 d and in winter at 70 d after the cut, the production of DM was 9 t ha^{-1}, while in S at 84 d, it was close to 3 t ha^{-1}. The increase or decrease of the morphological components of the biomass over time was different between the seasons evaluated and showed a curvilinear behavior over time, within each season. CP increased linearly with the cutting age. In autumn and winter, there was a higher percentage of NDF and ADF. The 42-d plants had a lower percentage of ADF. The yield of DM and the nutritional quality of *T. diversifolia* differs depending on the season of year and the age of regrowth. The cutting age of the plant affected its preference by Pelibuey sheep (*P*=0.0091), it was higher for the foliage of 42 d, followed by 56 and 70 d.

Key words: Grazing sheep, *Cynodon nlemfuensis*, Tropics, Forage resources.

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Introduction

The feeding of sheep in the Mexican tropics is based on the grazing of grasses with low crude protein (CP) value, high in neutral detergent fiber (NDF), and acid detergent fiber (ADF), and low digestibility of dry matter (DM)[1,2,3]; this causes low productivity, particularly in growing sheep that produce weight gains of less than 70 g d^{-1}[4,5]. The diet quality of sheep could be improved with the use of forage shrubs and trees known to have high CP contents (14-30 %), lower NDF (28.4 - 51.9 %) and ADF (19.5 - 37.5 %), and higher digestibility (48-80 %); the supplementation of the diet with foliage of this type of plants improves the consumption of grasses[2,6], the digestibility of DM[7,8], and generates benefits to the environment[9].

A shrub species with forage potential is *Tithonia diversifolia* (Hemsl.) A. Gray, of the Asteraceae family, which produces up to 19.5 t of DM ha^{-1} yr^{-1}[10], and, increased with fertilization, may contain 11.7 to 30 % CP[11,12,13], rumen degradability of 50 to 90 %[14], low contents of ADF (24.1 to 48.9 %) and NDF (14.8 to 55.9 %), acceptable levels of secondary compounds such as phenols (30.5 %) and tannins (5.7 %)[15,16], so its use can improve the productivity and profitability of production units, without affecting the quality of products[17,18]. In addition, the use of *T. diversifolia* improves nutrient recycling[19], prevents soil erosion[20] and is used in cutting and carrying systems, as a forage bank or grazing in silvopastoral systems[13,20].

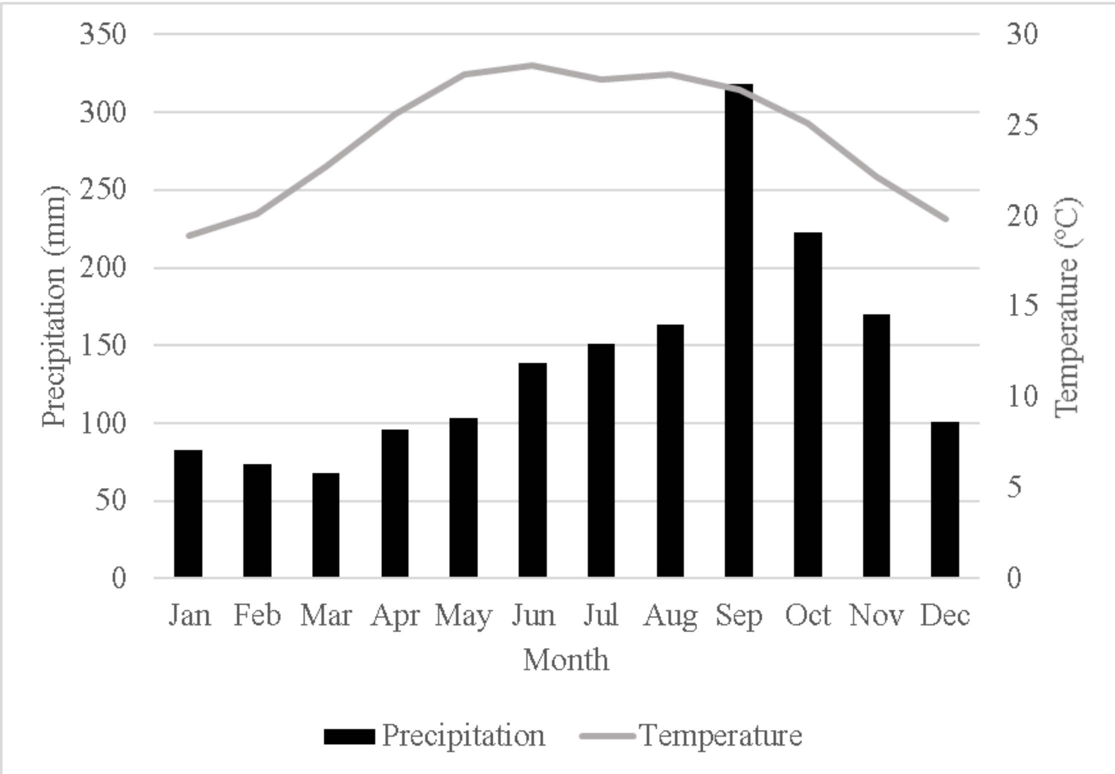
The objective was to evaluate the amount produced of *T. diversifolia* DM, the nutritional quality at four cutting ages, in the autumn, winter and spring seasons; and the preference of sheep for foliage for this species at different ages of regrowth.

Material and methods

Location of the research and description of the experimental site

The study was conducted at the Center for Teaching, Research and Extension in Tropical Livestock of the FMVZ-UNAM; located in the municipality of Tlapacoyan, at 20°02' N and 97°06' W, at 151 m asl. The climate in the region is Af(m)w"(e), warm humid[21] with an average annual temperature of 23.5 °C and annual rainfall of 1,991 mm. Three seasons of the year are distinguished: rains from July to October, northerly winds from November to February (autumn and winter), and dry from March to June (spring; Figure 1). The soil at the site is of the ultisol type; acidic of low fertility and reddish brown, *tepetate* immediately underlies, which originates a subterranean layer semipermeable to water that causes temporary flooding.

Figure 1: Monthly temperature and rainfall of the experimental site



Phases of the research

The research was conducted in three phases. The first phase was carried out in July, to establish a plot of 158 x 55 m (8,715 m^2) of *T. diversifolia*. The second was carried out from October 2018 to June 2019, to evaluate the dry matter yield and nutritional value of

DM in three seasons of the year (autumn, winter and spring). In the third stage, from March 13 to April 1, 2019, a test of the preference of sheep for *T. diversifolia* forage at three ages was carried out.

Phase 1. Establishment of *Tithonia diversifolia*

A plot was established with *T. diversifolia* using cuttings of 20 to 30 cm in length, planted 60 x 60 cm apart for a density of 27,778 ha^{-1} plants. The plants remained without irrigation or fertilization, only manual control of weeds was carried out.

Phase 2. Evaluation of yield and nutritional value of dry matter of *Tithonia diversifolia*

Forage samplings were carried out in each season: autumn (October 9 to December 21, 2018); winter (January 6 to April 2, 2019) and spring (March 28 to June 20, 2019). In each season, a plant uniformization cut was made at 50 cm in height, 14 d prior to samplings.

Fifty-two plants were selected and of these, four were randomly assigned to each of the six cutting ages (14, 28, 42, 56, 70 and 84 d). Forage samplings were planned to be carried out every 14 d until the plants reached their point of best forage condition; the plants reached that point before the beginning of flowering(13), therefore, observations of the phenology were made so that the last cut coincided with the first signs of flowering.

In each sampling, the plants were cut 5 cm above the soil surface. The material of each plant was weighed and separated into leaves, stems, flowers and dead material, and dried in a forced air oven at 60 ºC for 72 h. The concentration of CP in leaves(22), NDF, ADF were determined by the filter bag method (ANKOM2000; Ankom Technology, NY, USA).

Phase 3. Preference test

For the preference test, the whole plant of *T. diversifolia* at 42, 56 and 70 d of regrowth age was used, the plants were pruned from January 12 to 16 for the age of 70 d, from January 16 to 30 for 56 d, and from January 30 to February 13 for 42 d. Eight adult sheep of the Pelibuey breed were used, with an average weight of 52 kg and approximate age of 14 mo; these animals were used to consume *T. diversifolia* from weaning, and under grazing of *C. nlemfuensis*. The experiment was carried out over a period of 20 d; the first 10 d were for adaptation(23); during this period, the animals remained in paddocks of *C. nlemfuensis* (6 x 5 m) 24 h a day and moved to the pen daily from 1200 to 1230 h to accustom them to handling. From day 11 to 20, the preference test was performed; 600 g of chopped green forage (whole plant) of *T. diversifolia*, equivalent to 77.1, 84.6 and 91.7 g DM of 42, 56 and 70 d, respectively, were offered daily. The foliage was offered for 15 min (from 1200 to 1215 h) simultaneously in a feeder with its respective separations. The preference for the age of *T. diversifolia* forage was estimated by the consumption of foliage of each regrowth age that was obtained based on the amount of DM offered minus the residual DM during the 15 min in which it was offered. A sample by age offered was collected daily to determine DM, CP, NDF, ADF and lignin.

Statistical analysis

As age is a continuous variable, with the data of the biomass produced at the different ages of regrowth, a trend analysis was carried out using orthogonal polynomials, in order to determine if the effects of first to fifth degree of the age of the plant were significant or not. Likewise, the seasons were compared with each other, and the linear, quadratic and logarithmic responses were compared between seasons.

The means of least squares and their standard errors (y) were plotted against the age of regrowth (x) for each season, and to determine the type of growth that the plant presented in the different seasons, resulting in a sigmoid curve for autumn and winter and one of the exponential type for spring. In the first two, they adjusted to the data with the following logistic model:

$$\frac{a}{1+\left(\frac{b}{x}\right)^{c}}$$

Where: a is the asymptotic value or maximum yield of DM (kg ha^{-1}); b are the days at the value a/2; and c is a constant that determines the slope. For the spring season, the classic exponential growth equation was used, which is:

$$y = ae^{c*x}$$

Where: a is the value of the DM yield when x = 0, and c is the relative growth rate (kg kg^{-1} day^{-1}). GraphPad Prism© v 7.05 was used to adjust these models.

To determine the preference of sheep for any of the three ages of regrowth of *T. diversifolia*, a generalized mixed model (GLM procedure) was used for a completely randomized design and the model included the effect of treatment (age), day and the interaction treatment*day; the GLM procedure and the LSMEANS mean test of the Statistical Analysis System Version 9.3 were used.

Results

Dry matter yield (DMY)

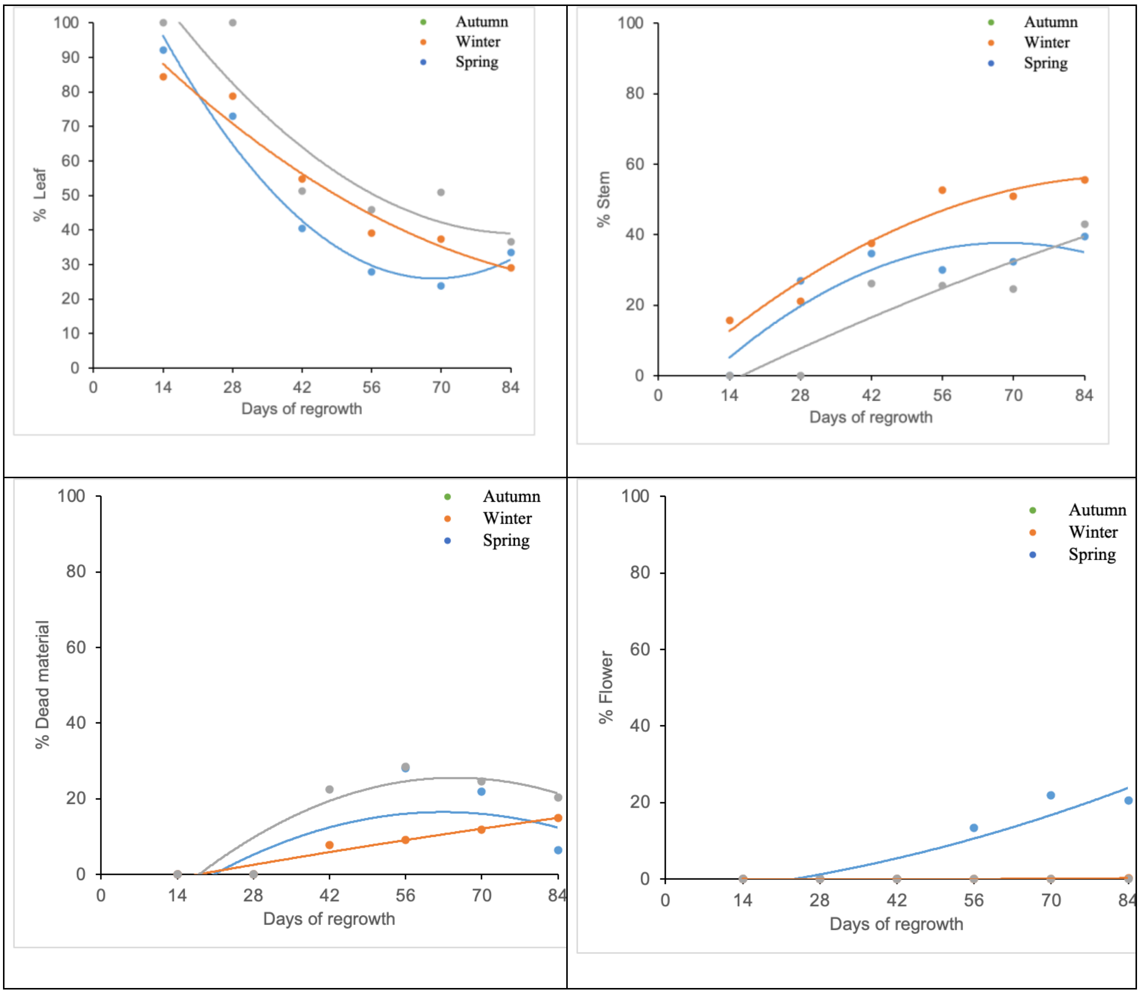
In total DMY (kg d^{-1}), the main effects of age, season and their interaction were significant, however, the main effects of regrowth age and season lose relevance by themselves, when interacting with each other (P<0.001), the age response depends on the season. Only the first-order effect of age (P<0.001) was found, while the second- to fifth-order effects were not significant (Table 1). With respect to the season, autumn and winter were similar to each other (P=0.4036) and both exceeded spring (P<0.0005 and P<0.0001, respectively). The linear effect of age was different between winter and spring (P<0.0214) and between autumn and spring (P<0.0001). For its part, the quadratic effect only differed between autumn and spring (P<0.0001), the same happened with the cubic effect (P<0.0001). All of this suggests a curvilinear response of the DMY that differs partially between seasons.

Table 1: Comparisons of first- to fifth-order effects of regrowth age according to the season of the year

Contrast	**Estimator**	**Standard error**	**t-value**	**Pr > |t|**
.... *Age*				
Linear	55635.00	6039.16	9.21	<.0001
Quadratic	-10024.00	6604.19	-1.52	0.1421
Cubic	-17372.00	9677.15	-1.80	0.0852
Quartic	1416.64	3814.71	0.37	0.7136
Quintic	-4228.24	11416.00	-0.37	0.7143
……… Season ………				
Winter *vs* Autumn	-765.59	900.39	-0.85	0.4036
Winter *vs* Spring	3529.51	880.92	4.01	0.0005
Autumn *vs* Spring	4295.11	148.15	28.99	<.0001
……… Linear x Season ………				
Winter *vs* Autumn	-4649.11	18453.00	-0.25	0.8032
Winter *vs* Spring	44443.00	18061.00	2.46	0.0214
Autumn *vs* Spring	49092.00	3104.37	15.81	<.0001
……… Quadratic x Season ………				
Winter *vs* Autumn	11108.00	20214.00	0.55	0.5877
Winter *vs* Spring	-20541.00	19775.00	-1.04	0.3093
Autumn *vs* Spring	-31649.00	3314.05	-9.55	<.0001
……… Cubic x Season ………				
Winter *vs* Autumn	-13391.00	29590.00	-0.45	0.6549
Winter *vs* Spring	-43049.00	28956.00	-1.49	0.1501
Autumn *vs* Spring	-29658.00	4924.77	-6.02	<.0001
……… Quartic x Season ………				
Winter *vs* Autumn	-4077.04	11670.00	-0.35	0.7299
Winter *vs* Spring	-3243.43	11419.00	-0.28	0.7788
Autumn *vs* Spring	833.61	1927.01	0.43	0.6692
……… Quintic x Season ………				
Winter *vs* Autumn	23420.00	35010.00	0.67	0.5099
Winter *vs* Spring	18496.00	34233.00	0.54	0.5940
Autumn *vs* Spring	-4923.63	5559.25	-0.89	0.3846

The DMY at the age of regrowth in each season, as shown in Figure 2, autumn and winter showed a very similar behavior and the logistic model was adequately adjusted (R^2>0.9) to the data. For its part, the exponential model in spring also had an R^2>0.9.

Figure 2: Relationship between days of regrowth and percentage contribution to the botanical composition of the flower, dead material, stem and leaf components of *Thitonia diversifolia* in the humid tropics of the state of Veracruz



Morphological components of the plant

The type III test of fixed effects revealed that the age of regrowth, the season and the interaction of both were significant in the models of the percentages of leaf, stem, dead material and flower that make up the DM of the plants. As in the DMY, the response to the effect of age depended on the season (*P*<0.0001). For this reason, comparisons of the linear, quadratic, cubic, up to fifth-order effects of the seasons were also made (Table 2). Most of the contrasts were highly significant (*P*<0.0001), which indicated that the morphological composition of the plant changed at each season, and that this change was curvilinear. The increase (or decrease) in the number of leaves (Figure 2, Table 3), for example, only coincided in cubic increments between winter and spring (P=0.3662), and quartic and quintic increments between autumn and spring (P=0.9221 and P=0.4229, respectively).

Table 2: Probabilities of the comparisons between seasons of first- to fifth-order effects of regrowth age on the percentage of leaf, stem, and dead material (EM) of *Tithonia diversifolia*

Contrast	Morphological component			
	Leaf	**Stem**	**EM**	**Flower**
	.... Linear......................................			
Winter *vs* autumn	<.0001	<.0001	0.3362	<.0001
Winter *vs* spring	0.0085	0.3349	<.0001	0.7830
Autumn *vs* spring	<.0001	<.0001	0.0007	<.0001
	.... Quadratic....................................			
Winter *vs* Autumn	<.0001	0.0318	<.0001	<.0001
Winter *vs* Spring	0.0017	0.0019	<.0001	0.7939
Autumn *vs* Spring	<.0001	<.0001	0.0979	<.0001
	.... Cubic...			
Winter *vs* Autumn	<.0001	<.0001	<.0001	<.0001
Winter *vs* Spring	0.3662	0.0002	0.0011	0.8614
Autumn *vs* Spring	<.0001	<.0001	<.0001	<.0001
	………………... Quartic ……….……………..			
Winter *vs* Autumn	<.0001	0.0006	0.0930	<.0001
Winter *vs* Spring	<.0001	0.0010	0.0004	0.9286
Autumn *vs* Spring	0.9221	<.0001	<.0001	<.0001
	…………………... Quintic …………….………..			
Winter *vs* Autumn	<.0001	0.0283	<.0001	<.0001
Winter *vs* Spring	0.0002	0.0002	0.6374	0.9747
Autumn *vs* Spring	0.4229	0.1098	<.0001	<.0001

Table 3: Parameters and adjustment statistics of the second- and third-degree polynomials, used to see the effect of the regrowth age (14, 28, 42, 56 and 84 d) on the percentage of the morphological components of the *Tithonia diversifolia* plant

Season	Parameters				Adjustment statistics		DF
	B_0	B_1	B_2	B_3	$S_{y.x}$	R^2	
Autumn	171.0	-4.476	0.033850	-----	1.997	0.9948	2
Winter	108.1	-1.519	0.006833	-----	6.097	0.9579	3
Spring	135.0	-2.237	0.013040	-----	14.210	0.8489	3
Autumn	-55.330	5.238	-0.099310	0.000601	1.946	0.9923	2
Winter	-4.246	1.303	-0.006961	-----	5.142	0.9640	2
Spring	-11.670	0.735	-0.001491	-----	10.450	0.8463	2
Autumn	-20.180	1.166	-0.009266	-----	9.300	0.4480	3
Winter	-4.641	0.2684	-0.000417	-----	1.481	0.9419	3
Spring	-23.300	1.502	-0.011550	-----	5.314	0.8244	3
Autumn	-4.369	0.1303	0.002447	-----	5.18	0.8560	3
Winter	0.1462	-0.01007	0.0001332	-----	0.07136	0.7857	3
Spring	3.418E-15	-2.82E-16	3.222E-18	-----	1.982E-15	0.6153	3

B_0= intercept; B_1, B_2, B_3= regression coefficients of first, second and third order, respectively; Sy.x= standard deviation of the residual; R^2= is the one adjusted by the number of parameters in the equation.

Consistent with the decrease in leaves and the increase in stems with age, the amount of dead material (Figure 2, Table 3) also increased, showing a curvilinear behavior that differs in some contrasts (Table 2) but with a tendency to increase in the three seasons. The presence of flowers was only observed in the autumn and from d 42.

Chemical composition of DM of leaves

The CP content increased linearly as the cutting age increased (Table 4), with values ranging from 18.3 ± 2.9 to 21.3 ± 1.8 % for the ages of 42 and 84 d, respectively. The concentration of NDF, ADF and lignin increased from 42 to 56 d and remained from 70 to 84 d. The highest percentage of ADF and lignin was recorded in the autumn and winter seasons and the lowest during the spring; with respect to age, there was a higher percentage in plants 56 d old and lower in 84 d.

Table 4: Content (%) of crude protein, neutral detergent fiber, acid detergent fiber and lignin of *T. diversifolia* at different seasons of the year

Age (days)	CP	NDF	ADF	Lignin
Autumn				
42	17.0	47.5	35.0	22.3
56	21.7	52.0	37.7	23.7
70	-	-	-	-
84	19.7	46.3	33.3	20.2
Winter				
42	21.3	48.9	34.5	21.4
56	19.6	51.7	38.5	25.1
70	18.1	48.0	34.5	22.9
84	20.9	41.4	24.2	12.6
Spring				
42	16.1	31.8	18.9	8.0
56	17.3	32.1	18.8	11.6
70	22.0	39.3	22.9	13.4
84	23.5	44.6	28.5	18.7
Average ± standard deviation				
	19.8±2.4	42.6±6.6	28.3±6.8	17.4±5.2

CP= crude protein, NDF= neutral detergent fiber, ADF= acid detergent fiber.

Preference of sheep for *Tithonia diversifolia*

In the preference test, the consumption (mean ± SE) of DM of *T. diversifolia* at 42, 56 and 70 d of regrowth was 62.6 ± 2.1; 42.7 ± 3.1; 34.7 ± 3.7 g DM d^{-1}, respectively (P<0.0001) and the consumption of foliage of 42 d (P<0.05) was higher. When analyzing the daily consumptions of dry matter, a marginal interaction of the regrowth age x the test day (P=0.06) was observed, which caused the consumptions to vary throughout the days. In the first 2 d, foliage consumption increased at all three cutting ages. While from day 2 to 4 at the age of 42 d intake decreased 49.1 %, from 56 and 70 d of regrowth it decreased 25.7 and 45.3 %, respectively. However, from the fourth day at the age of 42 d, the intake increased and at the age of 56 the intake was maintained. After d 5, consumption remained without major fluctuations in the three ages of foliage.

Discussion

Dry matter yield

It has been reported that, with rainfall values less than 50 mm/month, the DM yield of *T. diversifolia* can decrease by up to 90 %[24], because it is a plant that responds widely to humidity[23,25]. The results obtained in the present study are similar to those obtained in other studies[26]. In all three seasons, yield slowly increased in the first few weeks after the cut (Figure 2); in autumn at 56 d and in winter at 70 d after the cut, the plants reached a yield close to 9.0 t DM ha^{-1}, while in spring, at 84 d, the production was close to 3 t DM ha^{-1}. The stabilization of growth between 56 and 70 d of regrowth in autumn and winter is due to pre-flowering, as other authors have mentioned[11,13,27], who recommend harvesting the forage between 50 and 60 d of regrowth, when its protein and NDF contents are higher. This shows that, in the agroecological conditions where the research was carried out, autumn and winter are the seasons with the optimal conditions for the growth of *T. Diversifolia*. This lower production of DM in spring was the result of lower rainfall and high temperatures (Figure 1), which even comes from winter[28]; the same authors recommend a cutting frequency of 60 d in the rainy season and 80 d in the dry season. Others[29] also recommend making the use of forage of 45 to 60 d of rest in the rainy season and 70 to 90 d in the rainy season. It is considered, in cuts of 70 to 90 d, a good production and nutritional quality of DM[26].

The adjustment to the logistics of autumn and winter and the exponential of spring are due to the availability of humidity from the rainfall registered in each season, while in autumn and winter, a rainfall of 164.7 mm and 74.6 mm is observed, in spring it was 112.7 mm with a temperature of 22.4 in autumn, 20.6 in winter and 27.3 in spring; however, rainfall in spring was minimal during the assessment year, coupled with the lower rainfall observed in the winter, which could explain the lower production of DM.

The amount of dry matter in the present study (9 t ha^{-1} of DM for autumn and winter) is similar to the 9.1 t ha^{-1} with 20,000 plants/ha and cut at 40 cm[30], but lower than that reported by others[31], which, in addition to the lower rainfall received in the present trial, could also be related to the use of young plants in spring because their planting was carried out in July 2018, and at this age they have fewer branches and consequently lower yield of total dry matter, in addition to the availability of rainfall received.

In Colombia, production was approximately 30 to 70 t ha^{-1} per cut of green forage, depending on planting density, soils and vegetative stage[32]. On the other hand, they cite an annual production of 13.52 t DM ha^{-1} per year, with significant differences between the rainy period (9.1 t DM ha^{-1} per year) and the less rainy period (4.42 t DM ha^{-1} per year)[25]. Other authors[7] mention that, if the cuts are made at a younger age, for example, between 30 and 60 d of regrowth, the production of DM is greater than that obtained with cuts at 90 and 110 d of age of the plant[25]. The yield of 3 t DM ha^{-1} in spring is lower than the 3.5 t DM ha^{-1} at 60 d of age reported[28] in dry season and lower than the 4.42 t DM ha^{-1} per year[25].

Morphological components of biomass

Although the change in the DMY of leaves was curvilinear, the tendency was to a decrease in leaves over time (Figure 2; Table 3), with a slight increase towards the end of spring; this is because the plants experience a second period of growth with the presence of rains in the last harvests, in June the presence of the first rains of the season is usually registered.

The effect of age on the number of stems that varies between seasons is reasonable and is primarily explained by the age of the plants, since, as the plants grow the leaf-to-stem ratio decreases, the plants accumulate more stem as a supporting structure; this fact can vary between the seasons due to the effect of climatic variables, mainly rainfall, which induces a rapid and proportional growth between leaves and stems, while in dry season spring and winter (season with lower temperatures), the plants can limit the growth of leaves or present senescence of leaves, decreasing the leaf:stem ratio(33).

The tendency in the appearance of dead matter is expected at older ages of the plants, which is natural, but there may also be a decrease in this material in the course of the growth period because the senescent leaves become detached or because there are growth upswings that change the relationships between the components of the plants(29,34). As observed with the decrease of leaf in autumn until 56 days and with the increase of stem at the same age.

The presence of flowers was observed from 42 to 70 d of regrowth in autumn, this increase observed at the beginning of autumn and decrease at the end of the same season are associated with the decrease in temperature at the beginning and end of autumn, respectively, and that continues in winter, similar results are reported by other authors(11,13,34). A slight decrease is also reported at a higher age of regrowth in spring and autumn associated with an increase in temperature(25). The forage capacity of *Tithonia diversifolia* and its nutritional quality are determined, among other factors, by the phenological stage(34), however, when evaluating the cut of *T. diversifolia* in different phenological stages (pre-flowering, flowering and after flowering), it has been reported that yields are higher after flowering(35).

Therefore, 42 d is recommended as the most appropriate time to harvest the forage during the autumn, without causing damage to the crop in the pre-flowering stage and with greater preference of Pelibuey sheep. Likewise, the presence of flowers observed in autumn from d 42 coincides with what is indicated in other studies(29,36).

Some authors suggest the cut of 50 d with a green biomass production of 3.5 t DM ha^{-1}(13,25,29). However, other authors recommend at 60 days with 7.2 t DM ha^{-1} yr(7,28) or 70 d(36), on the other hand, in browsing, the recovery of the plant requires longer periods, 60 to 90 d depending on the climate(29,30). Although, contrary to the number of leaves over time, the number of stems tends to increase with increasing age of regrowth[11,24]; all increases in yield are different between seasons, except for the similarity of the linear effect between winter and spring.

It can be observed that there are differences in the cutting age for better yield, this is related to the climatic conditions of each region, so it could be suggested that the cut is made in pre-flowering or at the beginning of flowering[34,35].

Chemical composition

The CP content increased linearly as the cutting age increased, these data are similar to those reported in Cuba when studying 29 *T. diversifolia* materials[26]. It has been found 14.1 % CP at 56 d of regrowth in the whole plant[10], and also 29.79 and 17.27 % CP[7] at 30 and 60 d of age, respectively.

The values of NDF and ADF recorded in the present study are similar to those reported by other authors (32.62 to 41.83 %), in different cultivars of *T. diversifolia*[26] and those of ADF (14.8 to 18.92 %) are slightly lower than those of the present trial. Elevated values of NDF (53.81 %) and ADF (48.18 %)[10], among others[36], have been reported, but they were performed with the whole plant, at ages greater than 56 d and with a cutting height (30 cm) lower than that of the present trial. However, the NDF value of *T. diversifolia* in the present trial is lower when compared to that reported in *Digitaria eriantha*[37], and similar to that reported in *Leucaena leucocephala*[38] under grazing. The content of NDF and ADF recorded may explain why *T. diversifolia* is a plant with a high percentage of degradability, which makes it very palatable for sheep[36]. The percentage of ADF and lignin shows a tendency to increase at 56 d in autumn and winter and to decrease during spring, this could be related to the presence of flowering in the autumn, while in winter, the decrease in humidity and low temperature also have an effect.

Preference of sheep for *Tithonia diversifolia*

Sheep preferred the forage of 42 d of age, followed by that of 56 and 70 d, which indicates that, at an older age, the lower the consumption; this may be due to a better nutritional quality at 42 d, due to its higher CP content and lower fiber content, as has already been reported[23], in addition to the fact that, the younger the plant, the higher the leaf proportion and the more tender the stems, which generates a greater leaf-stem ratio[38]. After d 5, consumption was higher and remained without large fluctuations in the three ages of foliage. This confirms the observation that sheep require 6 to 8 d to stabilize their consumption of *T. diversifolia* [23].

The trend in the interaction (age x day) of 42 d of regrowth on d 4 of the test could be due to different factors such as the age of the plant, but also the season[39] and the soil where the harvested plant is, as reported in *T. diversifolia* and *Gliricidia sepium*[40].

Conclusions and implications

The dry matter yield and nutritional quality of *T. diversifolia* differ according to the season of the year, it is higher in autumn and winter than in spring, so, under the agroecological conditions that prevail in the area, it is recommended to use the foliage at 42 d of regrowth in autumn, at 70 d in winter and after 84 d in spring. Sheep consume the foliage of this species at any age offered between 42 and 84 d of age, however, they prefer the younger foliage that has higher nutritional quality. Harvesting plants at 42 d to meet sheep preference involves sacrificing biomass yield at such an early age. This dilemma requires more precise research to know the voluntary consumption and weight gain of sheep when the age of the foliage offered increases. The potential yield, the high nutritional value and the preference shown by sheep, make this plant have a high forage potential for feeding this species and other ruminants in tropical conditions. It is necessary to deepen the research on T. *diversifolia* to evaluate different planting densities in the climatic seasons that occur and their relationship with yield, nutritional quality, animal response and the environment.

Acknowledgments and conflict of interest

The authors declare that they have no conflict of interest of any kind.

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