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Development of Tropical Forages in Veracruz, Mexico: Agronomic Approach for the New Forage Legume *Cratylia argentea*

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Additional information is available at the end of the chapter

Abstract

Pastures in the coast of the Gulf of Mexico are characterized by native species (*Paspalum* spp., *Axonopus* spp., etc.). These, are limited by productivity due to their low nutritional quality and poor persistence on grazing. The adaptation of new grass and legume species is essential to improve the productivity of animal production. An initial assessment should include the climatic and edaphic adaptation to the region. Species, such as *Andropogon gayanus*, *Pueraria phaseoloides*, *Centrosema* spp., *Arachis pintoi*, and Cratylia argentea, were evaluated, showing encouraging results compared to native species; our efforts were focused on *C. argentea*. Several research methods were applied to meet the objectives outlined for each experiment, including methodologies for the establishment of new species. All these trials were subject to rigorous experimental designs, and data were analyzed statistically, using the most adequate programs. These experiences allow us to visualize the most promising materials for the specific conditions of climate and soil. The potential results of this new forage species stand out. Also, these experiments allowed the development of new management practices to improve the productivity of the animal production systems of the region. *C. argentea* demonstrated its high forage value as a species suitable for silvopastoral systems.

Keywords: tropical pastures, edaphic and climatic adaptation, Cratylia argentea, Veracruz, México

1. Introduction

Livestock in the tropical region of Mexico has pastures composed of *Paspalum* spp., *Axonopus* spp., and legumes of the genus *Desmodium, Indigofera, Centrosema*, and *Mimosa*, called "native grams" [1, 2]. These species appear in natural form after cut-down and burning of the original forest [3]. However, the animal production achieved with these species is 50% lower than that obtained with introduced grasses. Daily growth rates for these species do not regularly exceed 25 kg DM/ha/day, in addition to showing a marked seasonal growth, which limits sustainable levels of dairy and meat production. This seasonality is the result of variations in climate during the year, especially in the winter or "Nortes" (November to February). This season is critical for forage production due to the low temperatures for tropical species (around 16°C), high cloudiness, and monthly precipitation of 100 mm [2]. Also, overgrazing contributes to nutrient and soil organic matter losses, partly because farmers do not fertilize their pastures due to the high costs of fertilizers and due to the low response to this practice, in terms of forage yield.

Due to this problem, it is necessary to find forages that adapt to these critical times. There are some legume species adapted to the conditions of the dry season, which have already been tested in other tropical regions of Latin America [4], so it is possible that some of them could be established in the central region in the state of Veracruz (Mexico).

Tropical forage legumes could be alternative solutions to these problems, since they present high nutritional quality and can also fix N to the soil, which, over time, becomes available to the associated grasses, increasing the production of pastures. Moreover, legumes in association with grasses can increase the amount of charcoal sequestered by pastures [5, 6]. Therefore, these plants can contribute to diminish the negative impact that the pastoral industries have on the environment.

Species, such as *Cratylia argentea* could be evaluated under grazing, associated to native or introduced grasses, or as a protein bank, however, their capacity to improve pasture production and productivity in this region could be verified [7]. *C. argentea* is a shrub legume native to Brazil, Peru, and Bolivia, which adapts well from sea level up to 900 m asl, in places with humid or subhumid climates, and dry periods of five to six months. It is also adapted to acidic soils of medium fertility with good drainage [8]. The accession CIAT 18516 is the most evaluated and can be harvested every 12–14 weeks yielding from 8 g of MS/plant in the municipality of Isla, Veracruz. It grows well in the dry season, producing about 30–50% of annual forage yield.

2. First evaluations of *C. argentea* under cutting regime

2.1. Total dry matter and nutritive quality of four *C. argentea* accessions after a year of the establishment period

2.1.1. Reasoning

C. argentea shows an abundant growth during its establishment period that usually lasts one year during which high-quality forage can be harvested to be used (fresh or dry) as a grazing

herd supplement, or included in dry rations. In addition, numerous nonedible stems accumulate which can be dried and used as fuelwood in rural homes.[1]

For this reason, it is speculated that it is necessary to evaluate—in a first stage—the production of edible fodder as well as the secondary aspects, such as inedible biomass production, which could be an energy source.

2.1.2. Materials and methods

The objective of this experiment was to evaluate—under conditions of warm and humid climate and acid soils—the forage yield and the nutritive quality of the accessions of *C. argentea* CIAT 18516, 18666, 18668, and 18676 to the cut of establishment, after almost a year of uninterrupted growth.

The study was carried out at the F1 Heifer Production Unit of the Center for Teaching, Research and Extension in Tropical Livestock (CEIEGT, its acronym in Spanish), Faculty of Veterinary Medicine and Animal Husbandry, National Autonomous University of Mexico. The unit is located in the municipality of Atzalan, state of Veracruz (Mexico), at 20°02' N latitude, 97°34' W length and 111 m above sea level.

The minimum and maximum temperature averages, in addition to rain, during the experimental period were 20.0, 30.4°C, and 1.926 mm, respectively. The soil texture in the first 20 cm is 52, 28, and 20% clay, silt, and sand, respectively, with an acidity of pH 4.7 and with low total N (0.983 g·kg^{-1}), extractable P (0.04 cmol·kg^{-1}), extractable K (1.45 cmol·kg^{-1}), and cation exchange capacity (11.95 cmol·kg^{-1}).

The experimental area was cultivated in a conventional manner, and sowing, using seed, was performed on September 1, 2006. The spacing between furrows and sowing sites was 1 m each. The first harvest of forage was made from August 23–27, 2007 at a cutting height of 70 cm. The experimental design was a randomized complete blocks, using the slope as criteria to block, with three blocks as repetitions.

The plant parts analyzed were leaves (L), edible stems (ES, <3 mm diameter), and nonedible stems (NES, >3 mm diameter). Plants were dried at 60°C, and milled at 2 mm. Samples used for gas in vitro methodology were milled at 1 mm.

Chemical analyses were performed for crude protein (CP, %); Kjeldahl [9]. The methodology of Van Soest et al. [10] was used for determining neutral detergent fiber (NDF, %), acid detergent fiber (ADF, %), and lignin (LIG, %).

The in situ disappearance (ISD, %) of leaves at 3, 6, 9, 12, 24, 48, and 72 h of ruminal incubation was done in triplicate in three rumen-fistulated cows using the nylon bag technique [11], without pretreatment with pepsin in acid medium. The time-out disappearance was estimated in duplicate, washing with water at 38°C for 30 min.

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[1]Data from this experiment were already published by: Castillo-Gallegos E., Estrada -Flores J.G., Valles-de la Mora B., Castellan-Ortega O.A., Ocaña-Zavaleta E., y Jarillo-Rodríguez J. 2013. Rendimiento total de materia seca y calidad nutritiva de hojas y tallos jóvenes de cuatro accesiones de *Cratylia argentea* en el trópico húmedo de Veracruz, México. Avances en Investigación Agropecuaria (México), 17(1):79-93. ISSN:0188789-0.

The data were adjusted to the model proposed by these same authors: $y = a + b (1 − e (−c * t))$, where "y" is the dry matter (%) degraded at time t, "a" is the highly soluble dry matter when t = 0, "b" is the slowly degradable (%) dry matter, "a + b" is the extent of digestion (%), "c" is the fractional rate of degradation of "b" (fraction/h), and "t" is the incubation time in the rumen (h).

The kinetics of in vitro gas production of edible leaves and stems was evaluated [12]. The generated data were adjusted to the exponential equation of Krishnamoorthy et al. [14]: $y = b (1−e−c * (x−L))$, where "y" (ml) is the accumulated gas production at time "x" (h), "B" is the asymptote or potential gas production accumulated as "x" → J (ml), "C" is the fractional rate at which gas production accumulates at time "x", and "L" is the lag time (the time h, that takes the ruminal microbes to colonize and initiate gas production from the NDF of slow degradability).

In order to meet the assumptions of the analysis of variance, the percentage units were transformed to "arcsin $\sqrt{\%}/100$" and the consumable material ratio (L + ES) 84 to nonconsumable stems (NES), which is dimensionless, was transformed to values of "natural log of y + 1". The model of analysis of variance had the effects of block as a repetition (the cow confused with the block in the case of ISD), accession, component of the plant, and the interaction accession × plant component. Proc GLM of SAS was used to perform analyses. LS means option was used to generate minimum squares means and comparisons between them [13].

2.1.3. Results

The accession had no significant effect on the dry matter yield at the first cut of the L, ES, and NES components, which showed mean ± standard errors of 2580 ± 212, 33 ± 5, and 2444 ± 233 kg/ha, respectively. In contrast, the proportions of nonedible leaves and stems were significantly affected by the accession (**Table 1**). CIAT 18668 showed the highest HO ratio, which was not statistically different from CIAT 18516 and 18676, but statistically superior to CIAT 18666, which was the lowest of all accessions.

From the effects of the model, only the component of the plant was significant ($P < 0.05$) on all chemical components, whereas the other effects (block, accession, and the interaction ×

CIAT accession	Leaf	Edible stem	Nonedible stem	Edible/onedible
		%		
18516	48.96 ab	0.78 a	50.25 ab	0.99 ab
18666	45.92 b	0.66 a	53.40 a	0.88 b
18668	56.35 a	0.59 a	43.03 b	1.32 a
18676	54.65 ab	0.45 a	44.89 ab	1.23 ab

Means followed by the same letter are statistically similar ($P > 0.05$).

Table 1. Percentage of total yield of dry matter at first cut, occupied by leaf, edible stem, nonedible stem, and edible/nonedible ratio, of four accessions of *Cratylia argentea* grown in the humid tropics of the state of Veracruz, Mexico.

component of the plant) were not significant. The general means ± standard errors were: 19.10% ± 0.70% for CP, 61.10% ± 1.00% for NDF, 42.20% ± 1.20% for ADF, and 14.20% ± 0.30% for LIG. The leaves had significantly more CP than the edible stems (20% vs. 16.20%), and were significantly lower than stems in NDF (57.10% vs. 65.20%) and ADF (36.8% vs. 47.50%), but not in LIG, as the leaves showed a significantly higher content than the edible stems (15.10% vs. 13.30%).

With respect to the ISD of the leaf component, the effect of the block was not significant on "a" and "b", but it was on the "c" fractional rate. The effect of the accession was significant only on "a", but not on the other parameters. Likewise, neither the effect of the cow or the accession × cow interaction affected the parameters.

The average coefficient of determination of the individual curves was 0.8970 with a standard error of ± 0.0222. Therefore, the accessions only differed in the proportion of the highly soluble component of the dry matter: 29.97, 30.06, 33.15, and 31.32% for CIAT 18516, 18666, 18668, and 18676, respectively; 18668 being significantly higher than the others, which did not differ from each other; while all had a common fractional degradation rate (0.0488 ± 0.0192 per hour) of the slowly degradable dry matter component (30.60% ± 4.52%), as shown in **Figure 1**.

The parameters of this model [14] were not affected by the block, accession, or the interaction accession × component of the plant. The fit of the individual curves was quite good, given that the average of the determination coefficients was 0.9907 with a standard error of ± 0.0070. Therefore, a single curve could be used to describe the dynamics of in vitro gas production of the four accessions, which is presented in **Figure 2**, where it is also shown that the effect of the plant component was significant on all the parameters.
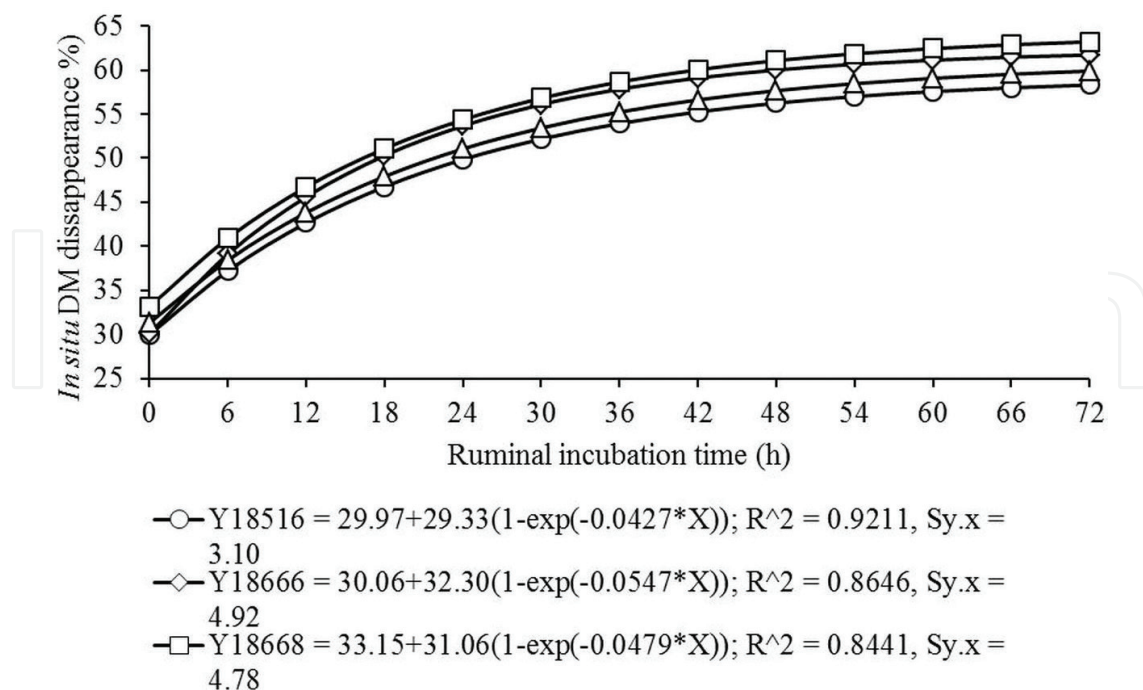

$$Y18516 = 29.97 + 29.33(1-\exp(-0.0427*X)); R^2 = 0.9211, Sy.x = 3.10$$

$$Y18666 = 30.06 + 32.30(1-\exp(-0.0547*X)); R^2 = 0.8646, Sy.x = 4.92$$

$$Y18668 = 33.15 + 31.06(1-\exp(-0.0479*X)); R^2 = 0.8441, Sy.x = 4.78$$

Figure 1. In situ dry matter disappearance as a function of the incubation time in the rumen, according to Ref. [11], of leaves of the first harvest of four accessions of *Cratylia argentea* cultivated in the humid tropics of Veracruz, Mexico.
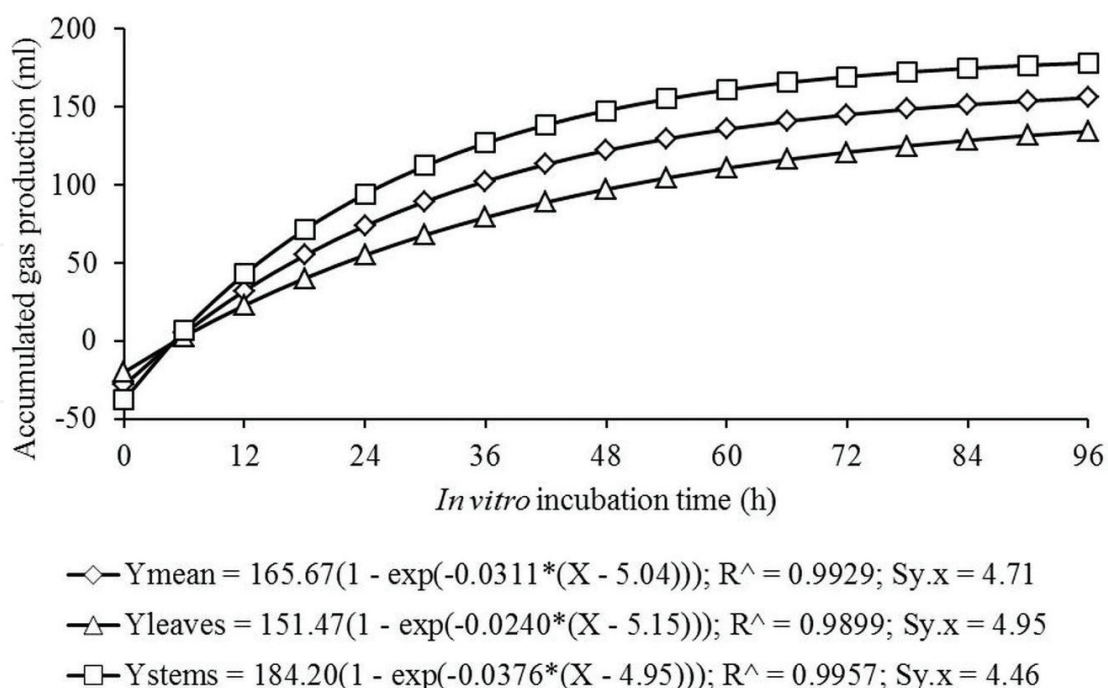
Figure 2. In vitro gas production as a function of incubation time [14] of leaves, edible stems, and both components, averaged through the four accessions of *Cratylia argentea* grown in the humid tropics of Veracruz, Mexico.

2.1.4. Discussion

The average dry matter yield of leaves, edible stems, and nonedible stems were statistically the same. The proportion of leaves was higher in CIAT 18668 than in CIAT 18666, which showed the lowest leaves ratio. The average dry matter yield of leaves, edible stems, and nonedible stems were statistically the same. On the other hand, CIAT 18516 and CIAT 18676 were similar to CIAT 18668, implying that the first two would be as good candidates to be selected as the latter (**Table 1**). In summary, the dry matter yield variables and the derived variables were only useful in selecting the least productive accession.

After nearly 12 months of uninterrupted growth, 51.50% of the aerial biomass were leaves, which resulted in a ratio of 1.1:1 with respect to edible material:nonedible stems. In Costa Rica, *C. argentea* was harvested every 12 weeks for a year, and the leaf:stem ratio was found to be 1.76:1 for "meson" soils and 1.43:1 for "terrace" soils [15]. The Costa Rican values are higher than those of the present experiment, because there was a difference of 40 weeks (52 vs. 12) in cutting age. In any case, ratios > 1:1 reflect the *C. argentea*'s ability to retain both young and mature leaves.

In the present study, the chemical composition of *C. argentea* foliage (**Table 2**) was fairly uniform despite changes in the environment and the management. This is a desirable feature to improve livestock production in low-quality pastures. The chemical composition of the 4 accessions did not change drastically with plant age and remained at acceptable levels after nearly 12 months of uninterrupted growth.

The accessions were statistically similar with respect to their contents of crude protein, neutral detergent fiber, acid detergent fiber, and lignin. The leaves in this aspect exceeded the

Botanical component	Chemical variables, %			
	CP	NDF	ADF	LIG
Leaves	20.0	57.1	36.8	15.1
Edible stems	16.2	65.2	47.5	13.3

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

Table 2. Chemical components of *C. argentea* leaves and edible stems after 364 days of uninterrupted growth, in the humid tropic of Veracruz, Mexico.

edible stems. In fact, since the contribution of the edible stems to the total dry matter yield was so small, only leaf yield should be considered to select the best accession.

Regarding the in situ dry matter degradability, of leaves and young stems, no statistical effect of the age of harvest on this variable was found. An experiment [16] reported that the parameter values model [11] for 2, 3, and 4 months of age were, respectively: for "a", 31.30, 28.20, and 24%; for "b", 30.30, 24.40, and 26.50%; for "c", 0.08, 0.08, and 0.07 per hour. The values of "a" and "b" are very similar to those of the present study (**Figure 1**), whereas those of "c" are higher by about 0.03 units; the difference may have been due to the higher proportion of mature leaves in the present experiment, in which the plants were harvested at an advanced stage of maturity.

The gas production dynamics were different between leaves and edible stems, the former having a lower gas production potential and fractional rate than the latter. Leaf tannins are known to interfere with the amount and rate of gas production [17]. Therefore, the leaves are digested at a slower rate and to a lesser extent than the young stems.

C. argentea has been classified as nontaniniferous [18]. These authors found that the nontannic legumes *Vigna unguiculata* and *C. argentea*, with 0% condensed tannins, had asymptotic gas production values (214 and 157 ml, respectively) and dry matter degradation (68.50 and 51.20%, respectively) higher, compared to hays of the taniniferous species *Calliandra calothyrsus* (23% of condensed tannins) and *Flemingia macrophylla* (3.66% of condensed tannins) which produced less gas (93 and 80 ml, respectively), and whose dry matter was less degraded (25.60 and 25%, respectively). Given these results, tannin determinations are unnecessary in *C. argentea*.

On the other hand, the two bioassays made in the edible material did not show any practical or statistical differences between accessions in terms of the in situ degradation of the dry matter or the in vitro gas production dynamics (**Figures 1**, **2**).

2.1.5. Conclusions

None of the accessions was superior to the others. The four accessions of *C. argentea* were similar in yield of DM leaf, edible stem, and nonedible stems, as well as in the nutritive value of its edible constituents, which in leaf were close to 20% crude protein, which can be a good protein supplement, given fresh or dry, for animals grazing tropical grasses of low nutritional quality. New studies are needed, with cuts at different ages of regrowth and at different climatic seasons of the year, to identify the most productive accession.

2.2. Performance of *C. argentea* during three climatic seasons and several ages of cutting[2]

2.2.1. Reasoning

The use of shrub legumes with high nutritional quality that can thrive at the time of year when most grasses do not becomes an alternative to address the shortage of food in the dry period. However, not all the forage trees or shrubs yield enough amounts of biomass to feed cattle. The age of regrowth and climatic seasons are documented to affect the yield and forage quality of woody forage species [19].

Cutting forage trees at different seasons of the year (dry season vs. wet season) and at different stages of development (flowering vs. vegetative) may also influence subsequent regrowth. Many studies have reported that the highest total biomass yield is obtained in the longer harvest intervals. Accessions CIAT 18674 and CIAT 22406 were identified as promising for DM production, particularly in the dry season. In Quintana Roo, Mexico, an experiment [20] was carried out, evaluating several legumes. Among them *C. argentea* showed an effect of the season and cutting age on the dry matter yield of this legume. These authors observed that performance among species varied within each season. In the tropics of Mexico, native pastures are the basis of grazing for cattle. This type of vegetation is of low quality, and due to the climatic variations, it presents a high seasonality of its growth. This occurs regularly in the dry and wintry seasons. This situation has received very little attention in the Mexican humid tropics, so it needs to be evaluated. The objective of this study was to evaluate the effect of different regrowth ages on the yield and forage quality of four accessions of *C. argentea* in three climatic seasons.

2.2.2. Materials and methods

This experiment was carried out at the same site as that described previously, and the climatic conditions are shown in **Figure 3**.

On September 1, 2006, four forage accessions of *C. argentea* were established in 10 × 3 m plots, with an arrangement within them of 1 m distance between rows and within rows. The plots were subdivided into 4 areas, each corresponding to each cut age (6, 9, 12, and 15 weeks). Eleven months after this planting, a first cut was made to standardize the treatments. Later, the cuts corresponding to each age were made. The cut-off dates for each of the seasons were as follows: rainy season (October 10 and 29, November 24, and December 10, 2007); winter season (January 31, February 20, March 12, and April 2, 2008); and dry season (May 19, June 4 and 25, and July 15, 2008). The height of cutting (above ground level) was 70 cm for all cases. The following variables were evaluated: dry matter yield (DMY, kg·ha^{-1}), crude protein (CP, g·kg^{-1} DM), neutral detergent fiber (NDF, %), acid detergent fiber (ADF, %), lignin (LIG, %), and 72 h in situ dry matter degradation (ISDMD, %).
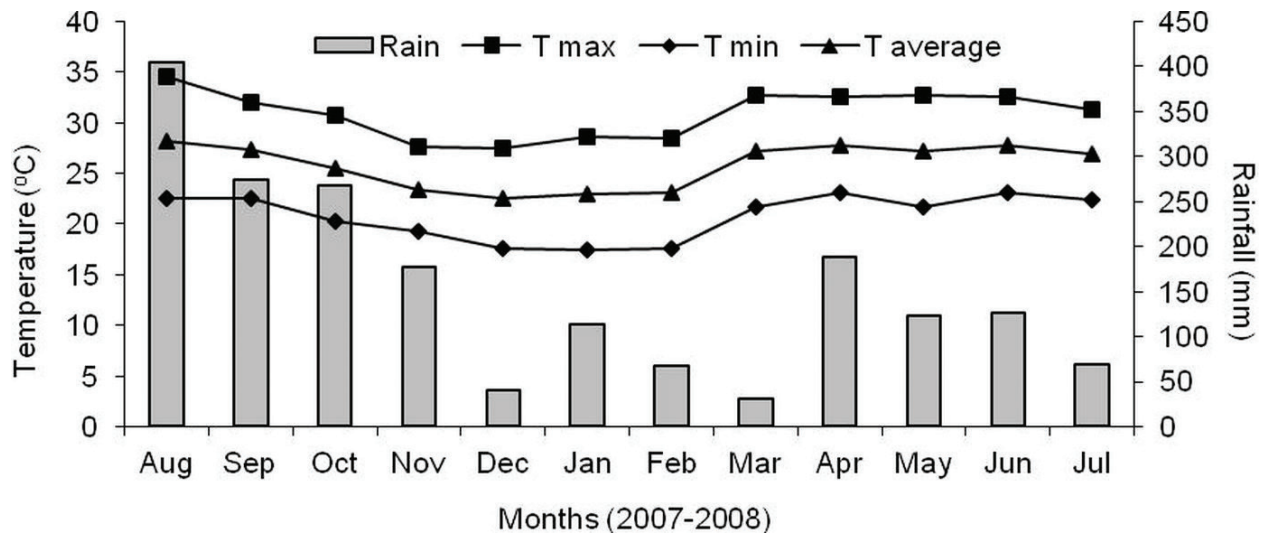

Figure 3. Maximum (T max), minimum (T min), and average temperature (T average), and rainfall (rain) during the experimental period in Veracruz, Mexico.

To analyze the harvested material in the laboratory, leaves (leaflets and petiole) and stems up to 3 mm were separated. These parts of the plant are considered the consumable material by cattle. Samples of these materials were analyzed to determine the percent dry matter (DM), crude protein [9], neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin (LIG) [10]. Also, DM yield was calculated [21]. In situ dry matter digestion was estimated, with incubation times of 3, 6, 9, 12, 24, 48, and 72 h [11]; degradation parameters were obtained by fitting the data to a model where, $y = a + b (1 - e - ct)$, where $y = DM$ degraded at time "t" (%), a = rapidly degradable fraction (intercept) (%), b = slowly degradable fraction (%), $a + b$ = potentially degradable DM (extent of degradation) (%), c = rate of degradation (degradable fraction per hour), t = time of incubation in the rumen (h), and e = base of the natural logarithms [22].

A randomized complete block design and three replications (blocks) were applied as the experimental design for this experiment. We used the slope of the terrain as a criterion for blocking. Also, we assigned four plots (one per accession) to each one of the blocks. PROC MIXED of Statistical Analysis System [23] was performed for the ANOVA. The exponential growth model: $y = ae^{bx}$, where $y = DMY$ (kg·ha^{-1}), $a = DMY$ when $x = 0$, b = rate constant expressed in inverse x units ($1 \cdot x^{-1}$), x = age of regrowth in weeks, was used to adjust data. Also, for each season, a fitting process was done. Dry matter yield and quality variables were analyzed with PROC MIXED; and ANOVA with least squares means "t" test comparisons was performed. For ISDMD, a particular curve for each combination of accession and regrowth age was fit, so each parameter could be analyzed individually as the response variable in the analysis of variance.

2.2.3. Results and discussion

2.2.3.1. Estimations of dry matter yield for average age of regrowth corresponding to each season

For DMY, the analysis of variance resulted with statistical differences ($P < 0.0001$) corresponding to the effect of age of regrowth and season. Each one of the seasons was different among

them: the means and standard error (±) for rainy, winter, and dry seasons were 2615 ± 188, 1783 ± 61, and 3632 ± 306 kg·ha⁻¹, respectively. These values represented an annual forage distribution of 33, 22, and 45%, respectively. Over the three seasons, the mean values per 18516, 18666, 18668, and 18676 accessions were 2311 ± 261, 3048 ± 321, 2567 ± 280, and 2781 ± 301 kg·ha⁻¹, respectively. The averages considering the three seasons at 6, 9, 12, and 15 weeks were: 1225, 29138, 3366, and 4062 kg·ha⁻¹, respectively. Regardless of season, forage production showed no statistical differences within regrowth ages. Also, the accessions behaved similarly (data not shown) (**Table 3**).

In the dry season, *C. argentea* and other legumes were evaluated [2] and were found to produce low yields averaging 0.6 t·ha⁻¹. This value is considerably lower than the 3.6 ± 0.32 t·ha⁻¹ averaged over the four regrowth ages. Also, in the dry season in Venezuela, the same 4 accessions showed a range of forage production (leaves) from 651 to 862 kg·ha⁻¹ per cut [24]. Other authors [7] in Isla, Veracruz, Mexico (summer rainfall, 1000 mm·year⁻¹) mentioned that in the dry season the total annual yield was only 25%, compared to 55% and 20% during the rainy and winter seasons, respectively. Also, in Anzoategui, Venezuela (rainfall, 1044 mm·year⁻¹), an experiment reported that these same accessions produced more forage in the rainy season, while the dry season's yield was only 37% of that achieved in the rainy season [25].

2.2.3.2. Crude protein content by season and age of regrowth

Levels of crude protein in *C. argentea* by season are shown in **Table 4**. Values of crude protein by season were: 224 ± 2.5 g·kg⁻¹ DM, 263 ± 2.4 g·kg⁻¹ DM, and 259 ± 5.8 g·kg⁻¹ DM for the rainy, winter, and dry seasons, respectively. Linear regression equations (Y = a + bx) were developed for each accession in order to look for variations in this parameter, yielding the following results for the accessions 18516, 18666, 18668, and 18676: $Y = 24.17 - 0.007x$, $R^2 = 4.3668 \times 10^{-6}$; $Y = 22.69 + 0.198$, $R^2 = 0.54$; $Y = 22.31 + 0.27$, $R^2 = 0.75$; $Y = 22.82 + 0.25x$, $R^2 = 0.64$, respectively.

The content of crude protein shown here are different or similar to those found by other researchers. In Colombia (Antioquia) researchers reported that during dry season, the height

Season	18516	18666	18668	18676
	Average 6–15 weeks			
Rainy	2289 ± 374	3011 ± 358	2608 ± 278	2552 ± 486
	Exponential growth model: $Y = 842e^{0.1026}$, $R^{2*} = 0.50$, RSE = 937, n = 48			
Winter	1396 ± 245	2106 ± 411	1495 ± 298	1930 ± 314
	Exponential growth model: $Y = 440e^{0.1256}$, $R^2 = 0.45$, RSE = 840, n = 46			
Dry	3248 ± 544	4026 ± 721	3544 ± 620	3711 ± 610
	Exponential growth model: $Y = 873e^{0.1278}$, $R^2 = 0.56$, RSE = 1415, n = 48			

*R^2: coefficient of determination; RSE: residual standard error. ± Average standard error.

Table 3. Dry matter yield (DMY, kg ha⁻¹) of four *Cratylia argentea* accessions as average of four regrowth ages, in three climatic seasons.

Season	Cutting age (weeks)	*Cratylia argentea* CIAT accessions			
		18516	18666	18668	18676
		CP, %			
Rainy	6	25.1±0.5 [a]	24.5±0.5 [a]	23.5±0.3 [a]	25.0±0.8 [a]
	9	22.6±0.9 [ab]	22.9±0.5 [a]	23.2±0.6 [a]	22.9±0.8 [a]
	12	20.7±0.3 [b]	21.9±0.4 [a]	21.5±0.2 [a]	20.7±1.1 [b]
	15	20.6±0.4 [b]	21.0±0.2 [a]	20.7±0.2 [a]	21.9±1.1 [a]
Winter	6	24.5±1.3 [a]	24.2±0.9 [a]	24.6±0.5 [a]	25.1±0.3 [a]
	9	27.7±0.5 [a]	27.5±0.5 [a]	28.3±0.4 [a]	27.8±0.3 [a]
	12	26.3±0.4 [a]	25.6±0.5 [a]	27.9±0.3 [a]	26.3±0.7 [a]
	15	25.7±1.0 [a]	26.7±1.2 [a]	26.1±1.7 [a]	26.6±0.6 [a]
Dry	6	23.5±0.1 [ab]	24.1±0.3 [b]	23.6±0.1 [b]	24.1±0.5 [b]
	9	23.4±0.4 [ab]	22.4±0.5 [b]	21.7±0.3 [b]	21.8±0.5 [b]
	12	20.0±0.7 [b]	31.5±1.5 [a]	26.0±2.3 [ab]	30.8±0.2 [a]
	15	29.1±0.8 [a]	30.9±0.7 [a]	31.0±0.5 [a]	30.2±0.2 [a]

For each accession within season, different letters in the same column mean significative differences ($P \leq 0.0001$).

Table 4. Crude protein content in four accessions of *C. argentea*, at four regrowth ages (averaged over accessions) in the rainy, winter, and dry seasons.

of cutting and age of regrowth did not affect the content of CP, resulting in a small range of values: 191–207 g·kg⁻¹ [26].

In the department of Cauca, Colombia (1800 mm annual rainfall), 38 accessions of *C. argentea* were evaluated, including accessions 18516, 18668, and 18676, reporting a range of CP of 184–237 g·kg⁻¹ in leaves [27]. These concentrations coincide with the range of values obtained in this experiment.

2.2.3.3. NDF, ADF, and lignin according to season and regrowth age

Mean contents of NDF, ADF, and LIG related to season and age of regrowth are shown in **Table 5**. The responses of these variables to regrowth age were determined by the season. The NDF content at regrowth age from 6 to 12 weeks was similar; and an increase close to 6% units was registered at 15 weeks of regrowth. This variable showed ups and downs during the winter season: at the age of 3 weeks of regrowth, the NDF content was lower, followed by an increase of 7% units in 6 and 9 weeks of regrowth; after that, a decrease around 3% units at 15 weeks of regrowth was recorded. Neither ADF nor LIG increased, as expected, due to the effect of regrowth age pattern. This response is similar to the results found by other authors [27] during the rainy season, where NDF and ADF were lower (42 and 26%) with respect to the dry period (43 and 29%). These results indicated that the climatic season affected the quality of the plants.

Season	Variable (%)	Harvesting age (weeks)			
		6	9	12	15
Rainy	NDF	56.7 ± 1.1[b]	55.5 ± 0.2[b]	55.9 ± 0.2[b]	61.8 ± 1.2[a]
	ADF	35.7 ± 0.8[b]	35.5 ± 0.3[b]	36.9 ± 0.4[b]	41.8 ± 1.0[a]
	LIG	14.8 ± 0.8[b]	18.5 ± 0.2[a]	18.0 ± 1.0[ab]	20.6 ± 0.5[a]
Winter	NDF	58.7 ± 0.7[c]	65.4 ± 0.9[a]	65.6 ± 0.5[a]	62.3 ± 1.1[b]
	ADF	49.5 ± 0.6[a]	42.6 ± 0.6[b]	47.2 ± 1.0[a]	40.4 ± 0.8[b]
	LIG	26.0 ± 1.0[a]	22.6 ± 0.4[ab]	26.9 ± 1.2[a]	19.2 ± 0.7[b]
Dry	NDF	65.5 ± 0.8[bc]	64.2 ± 0.6[c]	67.4 ± 1.0[ab]	69.3 ± 1.0[a]
	ADF	46.5 ± 0.8[a]	48.8 ± 0.4[a]	48.6 ± 0.9[a]	47.4 ± 1.4[a]
	LIG	24.3 ± 0.6[a]	24.7 ± 0.3[a]	23.3 ± 1.5[a]	23.8 ± 0.7[a]

For each regrowth age within season, means in rows followed by different letters differ statistically ($P \leq 0.0001$).

Table 5. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin (LIG) in *Cratylia argentea*, at four harvesting ages, in three climatic seasons (average of the four accessions).

2.2.3.4. Degradation kinetics of dry matter of leaves and stems

In general, the model parameters of degradation [22], namely the rapidly degradable fraction (a), slowly degradable fraction (b), potentially degradable DM (a + b fractions), and the rate of degradation (c), were not affected by accession, week, or their interaction ($P > 0.05$). The parameter 'a' was affected by week, accession × week, and accession in the rainy, winter, and dry seasons, respectively ($P < 0.05$). Parameters "b" and "c" were only affected by accession in the dry season. The parameters (a + b) were similar during the rainy and dry seasons, considering the age of harvest as well as accession. During the winter season a high variation was observed (**Table 6**).

Accession/age	a	b	c	RSD	R²
18516	15.4–32.6	32.6–39.0	0.04–0.06	2.42–4.82	0.89–0.96
18666	15.8–29.6	33.5–39.9	0.03–0.06	2.14–3.79	0.93–0.96
18668	28.9–31.1	34.7–42.1	0.01–0.06	21.8–4.52	0.89–0.97
18676	25.4–32.6	31.0–37.4	0.04–0.05	2.21–3.84	0.93–0.95
6	28.8–32.6	32.1–42.3	0.04–0.05	2.11–4.33	0.92–0.97
9	23.4–35.4	34.3–35.6	0.03–0.05	2.20–4.63	0.89–0.97
12	20.4–31.0	31.7–36.5	0.04–0.06	2.15–4.40	0.91–0.96
15	21.8–30.5	33.1–45.2	0.02–0.07	2.77–3.59	0.94–0.96

RSD: residual standard deviation.

Table 6. Ranges for three seasons (rainy, winter, and dry) in parameters for the Ørskov equation, of the four *Cratylia argentea* accessions and four regrowth ages, during the rainy season of 2007, obtained as least square means.
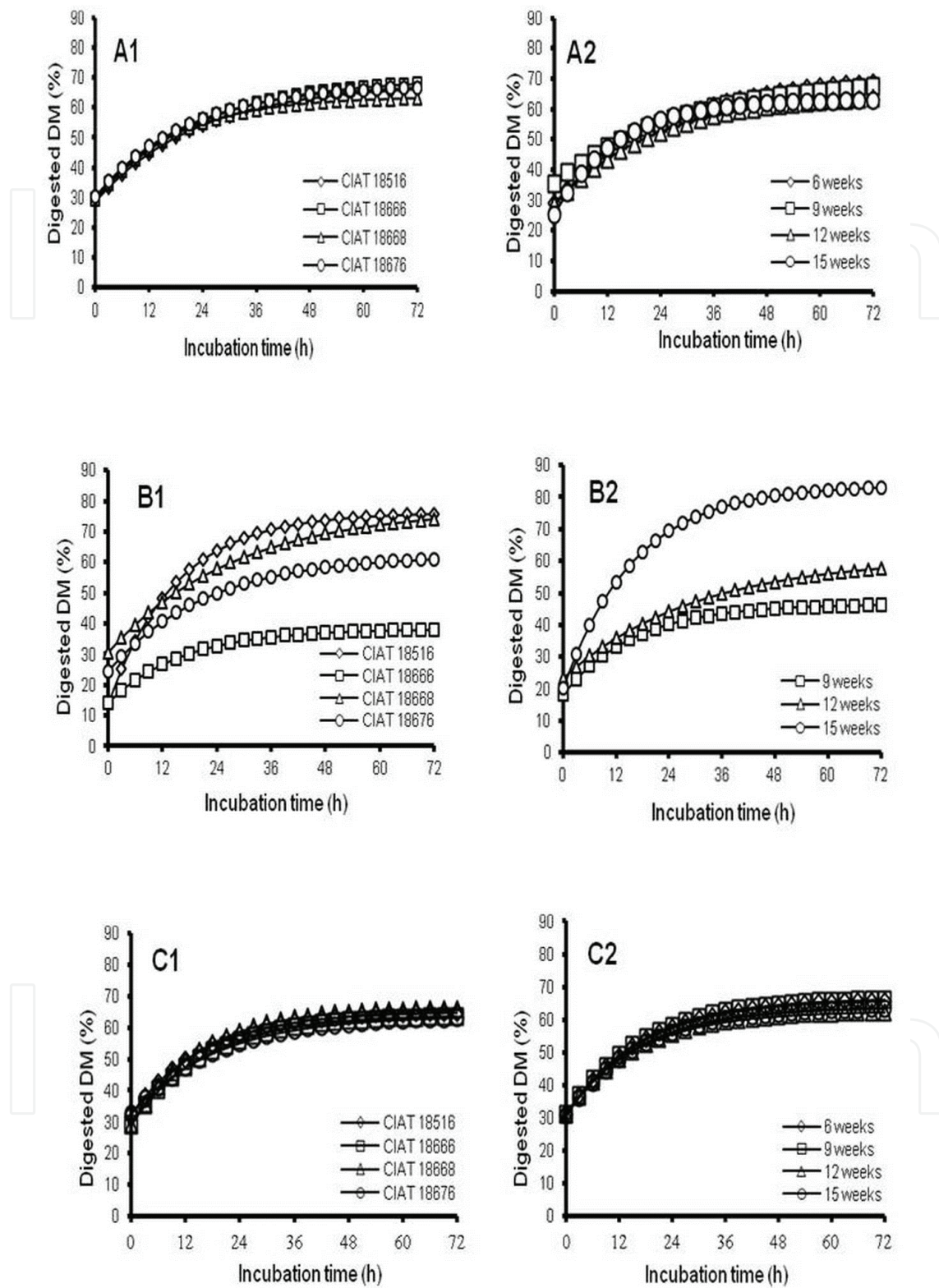
Figure 4. In situ dry matter (DM) degradation (%) of *Cratylia argentea* in three climatic (A = rainy, B = winter, C = dry) seasons, by accessions (A1, B1, C1) and by cutting ages (A2, B2, C2).

A value of 36% was reported by other authors for "a", however, other legume species showed values from 29 to 60% [28]. Other researchers have reported similar values in tropical native woody legumes [15]. Also, degradation rate values (c) coincide with the range of 7–8%, reported by other authors [14].

Figure 4 shows the degradation kinetics of dry matter (leaves + stems < 3 mm) in the rumen, according to the described model [11], for accessions, harvest ages, and ages. During the rainy season, degradation per accession and per week has a very similar pattern, reaching for both cases a value of 66 and 65%, respectively, at 72 h. Considering the age of 9 weeks, a more accelerated degradation was observed during the first 6 h of incubation. A slight variation for accessions and age of regrowth was observed during the winter period. The accessions CIAT 18668 and 18676 highlighted over the rest, but the trend for regrowth age was as expected, and higher digestibility values were presented at 9 (R^2 = 0.96) weeks. During the rainy and dry seasons, 48 h in situ DM degradability values for both accessions and regrowth ages were above 60%. Values lower than 35% in leaves of *C. argentea* harvested every 3 months had been reported by other researchers [15].

2.2.4. Conclusions

C. argentea is a reliable forage resource for the dry season in silvopastoral systems, mainly for its high performance in this season. Forage production increased as the ages of regrowth also increased. Considering the obtained results, mainly the quality of evaluated materials, their use at 9–12 weeks of regrowth could be suggested. Also, it is important to emphasize that *C. argentea* has a great potential as a forage resource, observing the high content of CP and digestibility during the rainy and dry seasons.

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