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Yield and protein content in forage and silage of Insurgente grass and *Urochloa* hybrids

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Abstract

Livestock in the state of Tamaulipas is affected due to a marked seasonality in forage production, which causes shortages during the dry season, therefore, forage conservation is necessary to face this problem. Therefore, the objective of this study was to evaluate, in stormy conditions and during the season of greatest rainfall, the yield (t ha^{-1}) of total dry matter (TDM) and leaf (DML); as well as, the crude protein content (CP,%) in forage and silage of Insurgente, Mulato II, Cobra and Cayman grass. The data were analyzed in a completely randomized design, with four repetitions and comparison of means using Tukey (p= 0.05). The Cayman hybrid presented higher accumulation (p≤0.05) of TDM and DML (8.34 and 8.27 t ha^{-1}, respectively) compared to Insurgente (6.38 and 6.25 t ha^{-1}, respectively). The highest (p≤ 0.05) content of CP in forage was presented by Cayman and Cobra, with 16.1% on average, while Mulato II and Insurgente were those with the lowest value for this variable (14.6%, on average). The CP in the silage was similar (p> 0.05) for the cultivars evaluated, with an average of 14.4%. The Cayman and Cobra hybrids showed higher forage yield and crude protein content, compared to Insurgente. The crude protein content present in the silage was greater than 14%, which indicates that these cultivars can be preserved using this technique.

Keywords: Mulato II, *Urochloa* hybrid CIAT BR02/1752, *Urochloa* hybrid CIAT BR02/1794.

Reception date: January 2020
Acceptance date: March 2020

Introduction

Livestock in the state of Tamaulipas focuses on the production of bovine meat and, to a lesser extent, on goats and sheep; where the main food comes from grasslands or grassland, which are used, either by cutting or grazing (Ramírez *et al*., 2008; Zárate *et al*., 2012). For the year 2017, within the livestock agrifood chain cattle meat ranked first with 36% of the value of its production, which meant for the state more than 247 billion pesos (SIAP, 2017) hence the importance to increase productivity in these livestock systems, through technologies that allow the production and conservation of a greater quantity of forage, as well as its nutritional value.

Forage production in the state of Tamaulipas presents various difficulties, mainly due to its geographical location, which gives rise to dry tropic conditions and to the north, a transition zone in which they have semi-arid climates. These environmental conditions favor that the rainy period occurs during the summer (around 80% of the annual precipitation) and scarcity the rest of the year; which causes seasonality in forage production (Gómez *et al*., 2007; Garay-Martínez *et al*., 2018). The different forage species vary considerably in terms of their ability to adapt to climate and soil conditions, which causes some to have adaptation mechanisms to limiting factors such as temperature, humidity and nutrient availability (Atencio *et al*., 2014).

Due to this situation, the International Center for Tropical Agriculture (CIAT) started a genetic improvement program for the *Urochloa* genus (formerly *Brachiaria*), with the aim of increasing the production and nutritional value of forage, tolerance to drought, etc. (Miles *et al*., 2006). From this program, two *Urochloa* hybrids were released: Mulato (year 2000) and Mulato II (year 2004) through Papalotla Group, a Mexican seed company (Hare *et al*., 2007) and with the advancement of The Cobra and Cayman hybrids were subsequently released, which, like Mulato II grass, have desirable productive characteristics such as higher dry matter yield, adaptability and excellent nutritional value; in such a way that they can be an alternative for forage production in the face of various climatic problems (droughts and floods) and edaphic problems (poor fertility), which affect animal production systems (González, 2013).

In Asia, Africa and America, there are studies carried out on hybrids of the *Urochloa* genus (Mulato II, Cobra and Cayman) that have shown higher production of dry matter, leaf and seed, higher digestibility values and crude protein content, in addition to tolerance to drought compared to other brachiarias (Pizarro *et al*., 2013). *Urochloa* hybrids (Cayman and Cobra) have been reported to exceed up to 14% (10.8 vs. 9.4 t ha^{-1} yr^{-1}) in dry matter yield to the most widely used grass (Buffel grass) in the Center of Tamaulipas and that 90% of the annual forage production occurs during the period of greatest precipitation (Garay-Martínez *et al*., 2018).

To cope with food shortages during the dry season, forage conservation can be used, in this sense, silage can be an option, which allows forage produced during the rainy season to be preserved and used for food of cattle during the dry season (Zambrano *et al*., 2006). The yield and nutritional value of the silage will depend mainly on the forage used and the age of the plant at the time of harvest (Titterton and Bareeba, 2001). In this regard, differences have been observed in the characteristics of the silage (dry matter, protein, crude fiber and digestibility) at different harvest intervals (Coromoto, 2013). Therefore, the objective of this research was to evaluate the yield and content of crude protein in the forage and silage of Insurgente grass and hybrids of *Urochloa*: Mulato II, Cobra and Cayman during the period of maximum precipitation and in temporary conditions in the center of the state of Tamaulipas, Mexico.

Materials and methods

The study was carried out under storm conditions, during the months of May to October 2016 (period of maximum precipitation) in Common San Juan and El Ranchito, Victoria, Tamaulipas, Mexico, located at coordinates 23° 42' 57.33'' north latitude and 98° 59' 47.72'' west longitude, at 249 masl. The climate is classified as semi-arid [BS_1(h')hw; Vargas *et al*., 2007]. The climatic conditions accumulated monthly precipitation and average monthly temperature (maximum and minimum) that were recorded during the study period are observed in Figure 1.

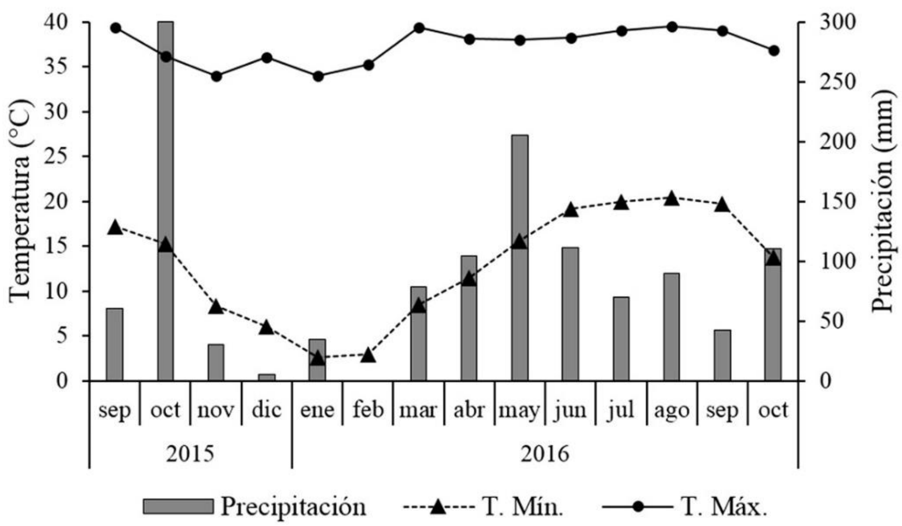

Figure 1. Accumulated monthly precipitation and minimum (T. Min.) and maximum (T. Max.) temperature of the site during the study period. Common San Juan and El Ranchito, Cd. Victoria, Tamaulipas, Mexico.

Four grasses of the *Urochloa* genus were evaluated: three hybrids (Mulato II, Cobra and Cayman) and *U. brizantha* cv. Insurgente. The total area used for the development of the experiment was 1 563 m^2 (34 × 46 m). The size of the experimental plots was 25 m^2 (5 × 5 m), with a useful plot of 1 m^2 in the center. Before sowing, a germination test was carried out to determine the percentage of pure germinable seed (PGS) and with this the required sowing dose was determined (6 kg ha^{-1} PGS).

For the establishment of the grassland, the land was prepared by conventional cultivation work using a tractor and agricultural implements such as harrow and disc plow for the breaking. The plots were sown broadcast with botanical seed on September 10, 2015. Two fertilizations were applied, one at planting time and the other immediately after the first uniform cut (January 10, 2016) taking advantage of an atypical rain (34 mm; Figure 1), at a dose of 60, 30 and 30 kg ha^{-1}

of N, P and K, respectively. MAP, KCl and ammonium sulfate were used as fertilizer sources. The presence of weeds was controlled by applying the herbicide 2-4 D-amine + Picloram (3 L ha^{-1}) and subsequently, manually. When the evaluation began, the grassland were 8 months old and another uniform cut was made (May 15, 2016) at 15 cm above ground level.

The forage present in 1 m^2 at 15 cm above ground level was harvested every 28 days, weighed and a sub-sample of 200 g was taken, which was separated into its morphological components: leaf (pod + leaf blade) and stem. Subsequently, the samples were placed in a forced air stove at 65 °C for 48 h. After the drying period, the dry weight of the forage subsamples was recorded and the yield and accumulation of total dry matter (TDM; t ha^{-1}) and leaf (DML; t ha^{-1}) were estimated. Plant height (PH; cm) was determined before each cut, as the average of three measurements per repetition, from ground level to the upper end of the plant and without stretching the leaves.

From the subsample, the leaf blades of 10 stems were taken to determine the specific leaf area (SLA; cm^2 g^{-1}) and the leaf area index (LAI), with a model area integrator Cl-202 (CID Bio-Science, lnc®). The percentage of crude protein in both forage and silage was determined with the total nitrogen content of a subsample of each repetition, using the micro Kjeldahl method (Horwitz, 2000) and the nitrogen value, multiplied by the factor 6.25, to get the crude protein content.

For the elaboration of the experimental silages (experimental units), the forage was harvested from the evaluated cultivars, every 28 days of regrowth, by means of a forage harvester and they were deposited in 25 × 60 cm, 6-gauge polyethylene bags. The compression and sealing of the bag was done manually. 45 days after silage, a 300 g sample was removed and placed in a forced air oven at 65 ºC until constant weight was obtained. Subsequently, the dry silage was crushed in a mill with a 2 mm screen and the determination of the crude protein content was carried out.

The data was analyzed with the GLM procedure (SAS, 2002), in a completely randomized design, with four replications. When a significant statistical difference was found, the comparison of means was performed using the Tukey test (p= 0.05).

Results and discussion

Leaf and total dry matter yield

It was observed that in each of the samplings there were significant differences ($p\leq 0.05$) between the evaluated cultivars (Table 1). From the first to the third sampling, Cayman presented the highest TDM yields, 5.46, 0.27 and 1.03 t ha^{-1}, while, in the fourth and fifth samples, Cobra presented the highest values (1.25 and 1.67 t ha^{-1}, respectively). Regardless of the sampling, the cultivar Insurgente presented the lowest values ($p\leq 0.05$) of TDM: 3.99, 0.13, 0.64, 0.63 and 0.98 t ha^{-1}, from the first to the fifth sampling, respectively.

Despite the fact that the yield of Cayman decreased significantly towards the end of the samplings, it was the cultivar that accumulated the greatest amount of forage (8.34 t ha^{-1}), compared to the other cultivars that on average accumulated 6.63 t ha^{-1}. In general terms, it was observed that the hybrids were superior in total dry matter yield to Insurgente grass (Table 1). It was observed that the DML values were similar to those of the TDM in all the samplings, except for the first one, where it was observed that the values were lower, as a consequence of the appearance of stems (Table 1).

Table 1. Yield and accumulation of total dry matter and Insurgente grass leaf and three *Urochloa* hybrids during the period of maximum precipitation (2016).

Cultivate	Sampling date					Accumulated
	June 25	July 23	August 20	September 17	October 15	
	Total dry matter yield (t ha^{-1})					
Insurgente	3.99 b	0.13 b	0.64 ab	0.63 c	0.98 bc	6.38 b
Mulato II	4.15 ab	0.12 b	0.64 ab	0.57 c	1.14 b	6.63 b
Cobra	3.23 b	0.12 b	0.61 b	1.25 a	1.67 a	6.87 b
Cayman	5.46 a	0.27 a	1.03 a	0.86 b	0.71 c	8.34 a
	Leaf dry matter yield (t ha^{-1})					
Insurgente	3.93 b	0.13 b	0.64 ab	0.57 c	0.98 bc	6.25 b
Mulato II	4.13 ab	0.12 b	0.64 ab	0.54 c	1.14 b	6.57 b
Cobra	3.11 b	0.12 b	0.61 b	1.25 a	1.67 a	6.76 b
Cayman	5.40 a	0.27 a	1.03 a	0.86 b	0.71 c	8.27 a

Different literals among cultivars (a, b and c) indicate significant statistical difference (Tukey; $p= 0.05$).

The forage yield obtained during the evaluation period (maximum precipitation) was attributed to the availability of humidity and temperature (Figure 1), which favored the growth of cultivars (Cruz *et al.* 2011; Cruz-Hernández *et al*., 2017), since there is a positive relationship between the amount of rain and the dry matter yield (Ramírez *et al*., 2009; Cruz *et al*., 2011). In another study carried out in Güemes, Tamaulipas, the same *Urochloa* cultivars were evaluated at three regrowth ages, for one year, and it was found that the total dry matter accumulation was 6.49, 8.77, 6.31 and 8.89 t ha^{-1} for Insurgente, Mulato II, Cobra and Cayman, respectively, in six samplings carried out during maximum rainfall and 4 weeks of regrowth (Garay-Martínez *et al*., 2018).

In this investigation, Cayman showed the highest yield compared to the other cultivars as in this study. Cobra presented the highest yields at the end of the samplings (Table 1), when there was a considerable decrease in precipitation (Figure 1), because this cultivar presents greater tolerance to drought (Rojas-García *et al*., 2018).

In this sense, according to Pizarro *et al*. (2010), the Cobra and Cayman hybrids, are second generation cultivars, with high potential for forage production. However, the lower forage yield at the evaluated regrowth age (4 weeks) is a consequence of the short interval of the plant for the accumulation of reserves (Donaghy *et al*., 2008), which translates into a lower growth rate (Cruz-Hernández *et al*., 2017).

In the present study, it was observed that during the evaluation period (maximum precipitation), there was only differentiation of the plant organs (leaves and stems) in the first sampling, which is due to the change of tissues as a result of the active growth of pastures (Castro *et al*., 2013); consequence of greater precipitation for that sampling (Figure 1). In this sense, Bernal *et al*. (2016) mention that the Cayman and Mulato II hybrids are cultivars that produce more leaves and, according to Cruz *et al*. (2011), the leaf is the component that contributes the most to yield.

Plant height

Of the five samplings carried out, there were significant differences ($p \leq 0.05$) between cultivars in three samplings (1, 4 and 5) regardless of the sampling, the cultivar Insurgente and Cobra showed the lowest and highest ($p \leq 0.05$) plant height, 24 and 30.9 cm, respectively (Table 2).

Table 2. Plant height, leaf area index (LAI) and specific leaf area (SLA) in Insurgente grass and three *Urochloa* hybrids, during the period of maximum precipitation.

Cultivate	Sampling dates					Average
	June 25	July 23	August 20	September 17	October 15	
			Plant height (cm)			
Insurgente	35.4 a	18.1 b	19.1 a	19.9 b	27.6 bc	24 c
Mulato II	43.1 a	18.3 b	22.4 a	24.4 ab	31.7 b	28 b
Cobra	42.3 a	17.6 b	20.8 a	32.2 a	41.7 a	30.9 a
Cayman	39.4 a	23.3 a	17.2 a	26.6 ab	23 c	25.9 b
			LAI			
Insurgente	4.3 b	0.3 b	0.8 a	0.5 b	0.8 b	1.3 b
Mulato II	5.6 ab	0.3 b	0.9 a	0.6 b	0.8 b	1.6 ab
Cobra	4.8 b	0.2 b	0.7 a	1.3 a	1.3 a	1.7 ab
Cayman	6.8 a	0.5 a	0.8 a	0.9 ab	0.5 b	1.9 a
			SLA (cm^2 g^{-1})			
Insurgente	167 c	195 b	145 b	113 a	126 a	149 c
Mulato II	174 c	248 a	175 a	113 a	125 a	167 b
Cobra	207 b	195 b	178 a	118 a	114 ab	162 b
Cayman	237 a	250 a	182 a	122 a	102 b	179 a

Different literals among cultivars (a,b,c) indicate significant statistical difference (Tukey; $p = 0.05$).

The differences observed between cultivars are due to the characteristic growth habit of each one. The Cobra cultivar is described as an erect growth habit (Hare *et al*., 2015) unlike Cayman, which is semi-decumbent (Enríquez *et al*., 2015). In this sense, Caetano and Bernardino (2008) describe Insurgente grass as erect growth; however, in this study, Insurgente showed decumbent habit, which was probably due mainly to environmental and management conditions (consecutive cuts). In a study by Machado *et al*. (2007), found that the height of the Insurgente grass grassland had a linear relationship with the supply of forage. For this same cultivar, it was reported that as the forage allocation increased, the height of the grassland was increased to a point where it remains stable (Mesquita *et al*., 2010; Casagrande *et al*., 2011).

Leaf area index (LAI)

During the evaluated season, it was found that the leaf area index varied between cultivars ($p\leq$ 0.05). Of the five samples carried out, there were significant differences ($p\leq$ 0.05) between cultivars in four samples, with the exception of sample three. During the evaluated season (maximum precipitation) it was observed that the Cayman, Cobra and Mulato II hybrids presented higher LAI with values of 1.9, 1.7 and 1.6, respectively, compared to Insurgente grass that was 1.5 (Table 2).

The differences between the evaluated cultivars, in relation to the LAI, was due to the height of the plant. In this regard, it has been indicated that there is a positive correlation between plant height and LAI (Guenni *et al*., 2005; Gomide *et al*., 2009). Also, it has been pointed out that in *Urochloa* spp. grassland, when the LAI is higher than 3, forage losses occur due to death of leaf blades in the lower stratum (Zanchi *et al*., 2009).

In the present study, it was observed that all the evaluated cultivars presented an LAI lower than 3, with the exception of sampling one, where all the cultivars presented values higher than 3 and it was the cultivar Cayman who presented the maximum value (6.8). In this sense, the LAI increases as the plant grows (Gómez-Carabali *et al*., 1999) and this increase is closely related to the tillering of the prairie and the ground cover (Rincón *et al*., 2007; Ramírez-García *et al*., 2012).

Therefore, as the LAI of the prairie increases, the amount of light reaching the ground is reduced, which can prevent or slow the growth of weeds (Garay *et al*., 2017). In a study carried out in Ecuador in five cultivars of *Urochloa*, Garay *et al*. (2017) found significant differences between cultivars at 4 weeks of regrowth, where Insurgente grass and Mulato II had LAI of 1.8 and 2.6, respectively, similar values to those obtained in the present study, for the same cultivars (1.5 and 2, respectively) .

Specific leaf area (SLA)

During the evaluated season, there were significant differences ($p\leq$ 0.05) in the SLA between cultivars. Regardless of the sampling, Cayman presented the highest values in the SLA ($p\leq$ 0.05), with 179 cm^2 g^{-1}; followed by Mulato II and Cobra, who on average were 167 and 162 cm^2 g^{-1}, respectively, and Insurgente had the lowest value, 149 cm^2 g^{-1} (Table 2). The differences observed in the SLA of the evaluated cultivars could be due to the fact that they presented variations in the morphology and structure of the leaf. In this regard, Baruch and Guenni (2007) reported for *U. decumbens* and *U. brizantha*, averages of 300 and 270 cm^2 g^{-1}, respectively, at four weeks of age. It has been indicated that the grasses with the highest SLA have thinner leaves and high nitrogen concentrations (Pérez *et al*., 2004; Garay *et al*., 2017) and are consumed by animals in greater quantity (Zheng *et al*., 2014).

Therefore, the *Urochloa* hybrids could have a higher protein content and better acceptance by animals, since the trend in SLA values was higher compared to the cultivar Insurgente. In a study carried out in five cultivars of *Urochloa* in Ecuador, significant differences were found between cultivars at 4 weeks of regrowth, where Insurgente grass and Mulato II had SLA values of 216 and 190 cm^2 g^{-1}, respectively (Garay *et al*., 2017), values higher than those obtained in the present study, for the same cultivars, 149 and 167 cm^2 g^{-1}, respectively.

Crude protein (CP) content in forage and silage

The content of CP in forage was different ($p \leq 0.05$) among the cultivars evaluated; where the Cayman and Cobra hybrids presented 1.5% more CP compared to Mulato II and Insurgente (Table 3). In this regard, it has been observed that tropical grasses have low protein content compared to other forage sources, which means that their forage production is more efficient for each unit of dry matter produced than per unit protein in the plant (Juárez -Hernández and Bolaños-Aguilar, 2007).

Table 3. Raw protein content (%) in forage and in silage of Insurgente grass and three *Urochloa* hybrids, harvested four weeks after regrowth, at the beginning of the period of maximum precipitation.

Cultivate	Forage	Ensilage
Insurgente	14.7 b	14.3 a
Mulato II	14.5 b	14.3 a
Cobra	16.2 a	14.4 a
Cayman	16.1 a	14.5 a
Average	15.4	14.4

Different literals among cultivars (a, b) indicate significant statistical difference (Tukey; $p= 0.05$).

The crude protein content decreases with the age of the plants (Avellaneda *et al*., 2008; Garay *et al*., 2017) following a curvilinear pattern with a greater rate of decrease until a certain age of the plants and a lower decreasing rate (Gómez *et al*., 2000). The protein content obtained in Mulato II grass (14.5% CP) was very similar to that obtained by Garay *et al*. (2017) in the same cultivar (14.6% CP) and at the same regrowth age (4 weeks). In this sense, these values are similar to those found by Castillo *et al*. (2006), at three weeks of regrowth (15%).

In the present study, the values obtained from crude protein in the cultivars evaluated were higher than those reported by Costa *et al*. (2011) who, when evaluating the nutritional value of the forage of *Urochloa* cultivars harvested at 40 days of regrowth and prior to silage, found values of 12.8, 13.4 and 13.9% CP in Insurgente, Xaraes and Piata, respectively. Regardless of the cultivar, the values obtained for CP in forage were higher than those found in other studies, probably due to the proportion of leaves, which was 98%, since, according to Pérez-Silva *et al*. (1999) the highest content of N is found in leaves.

To choose a cultivar, various productive parameters must be considered such as the yield of DM of the leaf, the concentration of CP, the rate of regrowth, the response to fertilizers, etc. (Garay *et al*., 2017). In another study, when evaluating the growth curve and quality of Cobra grass at two cutting intensities, Rojas-García *et al*. (2018) obtained 14.3% CP in leaf, at 5 weeks of regrowth, a similar result to that obtained in the present study, at 4 weeks.

The crude protein content in silage had a similar behavior among the cultivars evaluated (p> 0.05); on average, they obtained 14.4% (Table 3). When evaluating the quality of the silage of *Urochloa* cultivars harvested at 40 days of regrowth and open at 60 days, Costa *et al*. (2011) found values of 9.12, 9.24 and 9.78% CP in Insurgente, Xaraes and Piata, respectively; however, they found no significant difference.

In this regard, it has been observed that the genotype and the age of regrowth cause variations in the protein content and it is suggested to select forages with less dilution of CP, so that the nutritional value is preserved for a longer time (Juárez *et al*., 2011) and take advantage of the forage for a longer period (Juárez-Hernández and Bolaños-Aguilar, 2007). In this sense, when evaluating the content of crude protein in forage and silage in cultivars of *Urochloa*, Costa *et al*. (2011) found a decrease between forage and silage from 12.8 to 9.1, from 13.4 to 9.2 and from 13.9 to 9.8% CP for Insurgente, Xaraes and Piata, respectively. In the present study, the values obtained for crude protein in forage and in silage were very similar, indicating that the forage conservation method using silage could be a viable alternative during times of scarcity, since it practically maintains the same protein content.

Conclusions

The Cayman and Cobra hybrids showed higher forage yield and crude protein content, compared to Insurgente. The crude protein content present in the silage was over 14%, which indicates that these cultivars can be preserved using this technique and be a feeding alternative for the lean season.

Acknowledgments

Its thank the National Council for Science and Technology (CONACYT) for the scholarship awarded to the first author. To the Papalotla Group for the facilities to carry out this investigation.

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