Article

Yield and nutritional value of forage and silage of native corns in subtropical conditions

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Abstract

The yield and nutritional value of forage and silage of native corns with forage potential in subtropical conditions were evaluated. The variables evaluated were yield (t ha^{-1}) of total dry matter (TDM) and by component: leaf blade (LB), stem, bracts, green corn cob, panicle and sheath, SPAD units, leaf area index (LAI) and specific leaf area (SLA, cm^2 g^{-1}). In forage and silage, the contents (%) of crude protein (CP), ashes (AS), neutral detergent fiber (NDF) and acid detergent fiber (ADF) were evaluated. The variables were analyzed with a randomized complete block design with three repetitions and the Tukey mean comparison test was applied (α= 0.05). The Tuxpeño Norteño × Ratón genotype had the highest values (p< 0.05) of TDM, LB and stem (10.66, 1.89 and 3.97 t ha^{-1}, respectively), NDF (57.4%) and ADF (26.6%). While the V-402 genotype had the highest yield of green corn cobs (4.2 t ha^{-1}). The CP content in silage was higher (p< 0.05) than in forage (8.2 and 7.8%, respectively). The Ratón × Tuxpeño genotype had the highest CP content in forage (8.6%), in contrast, Tuxpeño Norteño × Elotes Occidentales showed the highest CP content (8.7%) in silage. The Tuxpeño Norteño × Ratón genotype could be an alternative as forage due to the higher yield of total dry matter and nutritional value, desirable characteristics in forage corns.

Keywords: *Zea mays*, forage behavior, native corn.

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Introduction

In Mexico, around 60% of the national territory (≈110 million hectares) is allocated to livestock activity (FIRA, 2010). Beef cattle farming is the most productive and distributed activity, since it generates raw materials, foreign exchange and jobs for the country; however, in recent years, in the Mexican livestock sector, productivity has decreased due to the increase in production costs, derived from increases in raw materials, loss of profitability, reduction of production units, among others (Carrera and Bustamante, 2013; Hernández *et al*., 2016).

Feed represents most of the production costs, which sometimes reach up to 70%; therefore, it is important that farmers reduce these costs, through the production of forage, since it is a cheaper feed compared to whole diets (Hernández *et al*., 2016). However, it should be borne in mind that forage production is variable during the year, about 90% of the annual forage production is produced in the season of greatest rainfall; while in the dry season, the availability of this resource to feed ruminants is limited (Garay-Martínez *et al*., 2018).

An alternative to counteract the lack of feed during the dry season is the conservation of forage, which can be through the silage process (Daniel *et al*., 2019). Corn forage is the most ensiled, in particular, due to its high biomass yield and high content of available carbohydrates (Fuentes *et al*., 2001).

Mexico is the center of origin and domestication of corn and one of the most recognized centers of diversification (González *et al*., 2013). Many native populations of Mexico have been the basis for the development of improved cultivars around the world. The native germplasm of Tamaulipas, as in all of Mexico, has high variability, high potential for grain yield and adaptation to restrictive environments, which demonstrates its high phytogenetic value and high potential for uses (Castro *et al*., 2013); however, a high percentage is produced exclusively for grain production. Therefore, the objective of this study was to evaluate the yield and nutritional value of fresh forage and silage produced from native corn under subtropical conditions.

Materials and methods

This study was carried out during the autumn-winter (A-W) cycle 2017 at the facilities of the Zootechnical Post 'Ing. Herminio García González' of the Faculty of Engineering and Sciences of the Autonomous University of Tamaulipas. The geographical coordinates are 23° 56' 26.5" north latitude and 99° 05' 59.9" west longitude, at 193 masl, the maximum temperature is around 37.2 °C and the minimum is 8.4 °C, the accumulated annual precipitation is 730 mm (SMN. 2020). The climate of the place is classified as BS_1 (h')hw (Vargas *et al*., 2007).

The soil of the place has a clay texture, pH of 8.3 and contents of organic matter and nitrogen of 4.2 and 0.25%, respectively (Garay-Martínez *et al*., 2018). From a collection of 100 populations of native corn (González-Martínez *et al*., 2018), populations with outstanding characteristics for forage production were visually selected: thin stem, height of 2.5 to 3 m, more than 8 leaves and leaf blades of greater area. This selection resulted in 10 populations of native corns with forage characteristics and the synthetic variety V-402 (Breve Padilla Variety) was used as a control (Table 1).

Table 1. Genetic material evaluated (native corns and one improved corn) and origin.

Treatment	Genotype	Origin
1	Ratón × Olotillo I	Jaumave
2	Ratón × Olotillo II	Jaumave
3	Ratón I	Tula
4	Tuxpeño	Jaumave
5	Ratón × Tuxpeño	Jaumave
6	Tuxpeño Norteño × Ratón	Jaumave
7	Ratón II	Jaumave
8	Ratón × Olotillo III	Tula
9	Vandeño	Jaumave
10	Tuxpeño Norteño × Elotes Occidentales	Jaumave
11	V-402	INIFAP

The experiment was established with a pre-sowing irrigation and supplemental irrigations at field capacity. The preparation of the land was carried out through the agricultural work recommended in the technological package for the production of corn in the central and northern area of the state of Tamaulipas (Reyes, 2017). Sowing was carried out manually (two furrows per each experimental unit) and three seeds were placed per hole. The separation between plants and furrows was 0.5 and 0.8 m, respectively; to obtain a density ≈50 000 plants ha^{-1}.

The genotypes evaluated showed no statistical differences for the days to female flowering, so the harvest was made 15 days after the end of this flowering. In each experimental unit, two plants were harvested, separated into morphological components: sheath, leaf blade, stem, panicle, green corn cob and bracts; the dead or senescent material was not considered due to absence. Each component was then deposited in paper bags and dried on a forced air oven (OMS60, Thermo Scientific®, USA) at 65 °C for 72 h. All components were weighed before and after drying to determine the dry matter (DM) content and estimate the yield of each one in t ha^{-1}.

SPAD units were determined by three readings on the ear leaf and subsequently they were averaged. The leaf area was determined for the aforementioned leaf by means of a portable laser meter (CI-202, Kosmos Scientific®, USA), then it was dried and weighed to determine the leaf area index (LAI) and specific leaf area (SLA; cm^2 g^{-1}). To make the silos (PVC pipe, 6” × 40 cm), five complete plants were harvested from each experimental unit, chopped into pieces of 1 to 3 cm, deposited in the silos, they were compacted and sealed, after 90 days they were opened, and samples were obtained for analysis. Chemical analyses of forage and silage were determined in the five genotypes that had the highest dry matter yield.

The contents of crude protein and ashes were analyzed with the methodologies described by the AOAC (Horwitz, 2000). NDF and ADF were determined using the Ankom method (Ankom Technology, 2010). For each variable, an analysis of variance (SAS, 2002) was performed under a randomized complete block design with three repetitions. When statistical differences were found, the Tukey mean comparison test (α= 0.05) was applied.

Results and discussion

The genotypes with the highest yield of TDM were Tuxpeño Norteño × Ratón and Ratón × Tuxpeño, 10.45 t ha^{-1} on average (p< 0.05). The Ratón I genotype was the one with the lowest yield, with 6.53 t ha^{-1} (Table 2). The maximum values (p< 0.05) of dry matter of leaf blade occurred in V-402, Tuxpeño and Tuxpeño Norteño × Ratón, with 1.8, 1.83 and 1.89 t ha^{-1}, respectively; the lowest value was obtained by Ratón II with 1.23 t ha^{-1}. The Tuxpeño Norteño × Ratón genotype produced the highest stem yield (3.97 t ha^{-1}), while Ratón × Olotillo I, Ratón × Olotillo II, Ratón I, V-402 and Ratón II had the lowest values (1.96, 1.89, 1.59, 1.63 and 1.72 t ha^{-1}, respectively).

The Ratón × Tuxpeño genotype had the highest bract yield, 1.92 t ha^{-1} (p< 0.05), in contrast, Ratón I, Ratón II, Ratón × Olotillo III and Vandeño had the lowest yields, with 1.20, 1.25, 1.26 and 1.06 t ha^{-1}, respectively. The control (V-402) obtained the highest production of green corn cobs, 4.2 t ha^{-1} (p< 0.05), while Ratón × Olotillo I and Vandeño had the lowest yield (0.82 and 0.85 t ha^{-1}, respectively). For the variable panicle, most of the genotypes evaluated behaved similarly, except V-402, which obtained the lowest value, with 0.14 t ha^{-1} (p< 0.05). In the component sheath, the Vandeño genotype was the one that had the highest production (p< 0.05) with 1.07 t ha^{-1} compared to Ratón II, which had the lowest yield 0.67 t ha^{-1} (Table 2).

Table 2. Yield of total dry matter (TDM) and by morphological component in native corns and one synthetic variety.

Genotype	Dry matter yield (t ha^{-1})						
	LB	Stem	Bract	Green corn cob	Panicle	Sheath	TDM
Rat × Olo I	1.53 ab	1.96 d	1.4 abc	0.82 e	0.23 ab	0.93 ab	6.87 ef
Rat × Olo II	1.45 ab	1.89 d	1.36 bc	1.4 cde	0.24 a	0.8 ab	7.14 def
Rat I	1.43 ab	1.59 d	1.2 c	1.26 de	0.24 a	0.82 ab	6.53 f
Tux	1.83 a	2.08 cd	1.47 abc	1.34 cde	0.26 a	0.94 ab	7.91 cdef
Rat × Tux	1.75 ab	3.03 b	1.92 a	2.47 bc	0.27 a	0.81 ab	10.24 ab
Tux Nor × Rat	1.89 a	3.97 a	1.82 ab	1.79 cde	0.23 ab	0.96 ab	10.66 a
Rat II	1.23 b	1.72 d	1.25 c	3.26 ab	0.22 ab	0.67 b	8.34 cd
Rat × Olo III	1.62 ab	2.7 bc	1.26 c	2.27 bcd	0.28 a	0.88 ab	9.01 bc
Van	1.70 ab	3.09 b	1.06 c	0.85 e	0.28 a	1.07 a	8.04 cde
Tux Nor × E O	1.55 ab	2.71 b	1.55 abc	2.99 b	0.2 ab	0.82 ab	9.81 ab
V-402	1.8 a	1.63 d	1.37 abc	4.2 a	0.14 b	0.86 ab	10 ab

Means with different letters in a column are statistically different (Tukey, α= 0.05). Rat × Olo I= Ratón × Olotillo I; Rat × Olo II= Ratón × Olotillo II; Rat I= Ratón I; Tux= Tuxpeño; Rat × Tux= Ratón × Tuxpeño; Tux Nor × Rat= Tuxpeño Norteño × Ratón; Rat II= Ratón II; Rat × Olo III= Ratón × Olotillo III; Van= Vandeño; Tux Nor × EO= Tuxpeño Norteño × Elotes Occidentales; V-402= synthetic variety Breve Padilla; LB= leaf blade.

In a study with native and hybrid corns, Lucio *et al*. (2018) found that the DM yields of the native corns were higher than hybrids by up to 79%. However, Godina *et al*. (2020) mention that the TDM yield of the Tuxpeño Norteño genotype exceeded V-402 by 99%; whereas, in the present study, the native corns and the control (V-402) were statistically similar. The maximum TDM yields obtained in the present work are lower than those reached by Lucio *et al*. (2018) and higher than those obtained by Godina *et al*. (2020), who report 16.85 and 8.88 t ha^{-1}, respectively. In another study, Balseca-Guzmán *et al*. (2018) show that, during the spring summer cycle, the native germplasm had higher total DM yield than a commercial hybrid, so they mention that this germplasm has the potential to be used for biomass production.

The above results are due to the high adaptation to environments of the Center of Tamaulipas of the native populations evaluated, and to their high variability. To obtain corn forage with high energy value, it is necessary to use materials that have at least 54% of ear of corn (Núñez *et al*., 2003); it is worth mentioning that none of the materials evaluated in this study showed this value; however, V-402 and Ratón II had values of 42 and 39%, respectively.

There were no statistical differences ($p > 0.05$) in the variable SPAD (Table 3), whose overall average was 52.1. As for the SLA, the Ratón I genotype showed the maximum value (180 cm^2 g^{-1}), while Vandeño had the lowest SLA (142 cm^2 g^{-1}). The genotypes V-402, Tuxpeño, Ratón × Tuxpeño and Tuxpeño Norteño × Ratón showed the highest LAI with a value around 2.9; however, Ratón II had the lowest value 1.8 (Table 3).

Table 3. SPAD units, leaf area index (LAI) and specific leaf area (SLA; cm^2 g^{-1}) in native corns and one synthetic variety.

Genotype	Parameters		
	SPAD	SLA	LAI
Rat × Olo I	51.7 a	167 ab	2.6 ab
Rat × Olo II	51.7 a	169 ab	2.5 ab
Rat I	47.6 a	180 a	2.6 ab
Tux	51.9 a	158 ab	2.9 a
Rat × Tux	53.2 a	158 ab	2.8 a
Tux Nor × Rat	52.6 a	161 ab	3 a
Rat II	54.3 a	150 ab	1.8 b
Rat × Olo III	48.6 a	156 ab	2.5 ab
Van	48.2 a	142 b	2.4 ab
Tux Nor × EO	56.6 a	148 ab	2.3 ab
V-402	56.7 a	168 ab	3 a

Means with different letters in a column are statistically different (Tukey, $\alpha = 0.05$). Rat × Olo I= Ratón × Olotillo I; V-402= synthetic variety Breve Padilla; SLA= specific leaf area; LAI= leaf area index; Rat × Olo II= Ratón × Olotillo II; Rat I= Ratón I; Tux= Tuxpeño; Rat × Tux= Ratón × Tuxpeño; Tux Nor × Rat= Tuxpeño Norteño × Ratón; Rat II= Ratón II; Rat × Olo III= Ratón × Olotillo III; Van= Vandeño; Tux Nor × E O= Tuxpeño Norteño × Elotes Occidentales.

When evaluating different corn genotypes in the state of Tamaulipas, Castro-Nava *et al*. (2014) reported that the native corns of Tamaulipas had a higher leaf area index in the localities of Güémez (1.73 *vs* 1.49) and Río Bravo (2.45 *vs* 2), Tamaulipas, during the autumn-winter cycle of 2008 and with high temperatures; while, in this study, some materials reached values between 2.9 and 3 (Tuxpeño, Ratón × Tuxpeño and Tuxpeño Norteño × Ratón; Table 3). In this sense, Camacho *et al*. (1995) mentioned that the grain yield in corn increases as the leaf area and the leaf area index increase, because it is a direct consequence of the total leaf area per plant.

Table 4 shows the chemical analysis of forage and silage of the five genotypes with the highest DM yield. The crude protein (CP) content in silage was higher ($p< 0.05$) than in forage (8.2 *vs*. 7.8%). Significant differences were found in CP content in both forage and silage. The genotype that had the highest CP content in forage was Ratón × Tuxpeño (8.6%); whereas the one that showed the lowest content within this same group was Ratón × Olotillo III (7.1%). In silage, the genotype that showed the highest CP content was Tuxpeño Norteño × Elotes Occidentales (8.7%), while the lowest value was shown by Tuxpeño Norteño × Ratón (7.5%).

Table 4. Mean test of the chemical analysis of forage and silage of five selected corn genotypes with high yields in total dry matter (TDM).

Genotype	Chemical analysis (%)			
	CP	AS	NDF	ADF
		Forage		
V-402	7.8 ab	5.2 a	51.9 b	22.6 b
Rat × Tux	8.6 a	5.7 a	54.5 b	23.3 b
Tux Nor × Rat	7.8 ab	5.5 a	57.4 a	26.6 a
Rat × Olo III	7.1 b	5.5 a	53.2 b	22.3 b
Tux Nor × EO	7.8 ab	5.5 a	53.9 b	23.8 b
Average	7.8 B	5.5 B	54.2 A	23.7 B
		Silage		
V-402	8.3 ab	6.9 a	48.5 b	23.3 b
Rat × Tux	8.4 ab	6.8 a	53.2 a	26.6 a
Tux Nor × Rat	7.5 b	6.2 a	54.4 a	26.8 a
Rat × Olo III	8.3 ab	6.2 a	54.8 a	26.2 a
Tux Nor × EO	8.7 a	6.6 a	52 ab	25.6 ab
Average	8.2 A	6.5 A	52.6 B	25.7 A

Means with different letters (a, b, c, d) in a column and between groups (A, B) are statistically different (Tukey, α= 0.05). Rat × Tux= Ratón × Tuxpeño; Tux Nor × Rat= Tuxpeño Norteño × Ratón; Rat × Olo III= Ratón × Olotillo III; Tux Nor × EO= Tuxpeño Norteño × Elotes Occidentales; CP= crude protein; AS= Ashes; NDF= neutral detergent fiber; ADF= acid detergent fiber.

In one study, when evaluating different hybrid corns, Zaragoza-Esparza *et al*. (2019) found significant differences in crude protein content, in a range of 7.8 to 9%, which coincide with those obtained in the present study. However, Velázquez-Martínez *et al*. (2018) mention that, in some places, corn for forage is harvested until the plants are in senescence, which decreases their nutritional value. In addition, it results in greater loss of feed, since the cattle only consume the leaves, in case of providing the whole plant.

On the other hand, in a study carried out with hybrid corns of the intermediate and early groups, Núñez *et al*. (2001) found crude protein values between 8 and 9.2% in the intermediate genotypes and from 8.4 to 9.4% CP in early genotypes, results similar to those obtained in the present study with native corns. This suggests that ruminants fed with this forage of native corn will use the energy from cellulose and hemicellulose, since the minimum concentration of crude protein in the diet of ruminants should be 7%, to support the optimal activity of the population of microorganisms and ensure adequate digestion of fiber in the rumen (Belachew *et al*., 2013).

Ash (AS) content was higher ($p< 0.05$) in silage compared to forage (6.5 *vs* 5.5%), whereas there was no difference ($p> 0.05$) between the genotypes within these two groups. Significant differences ($p< 0.05$) were observed in both the content of neutral detergent fiber (NDF) and the content of acid detergent fiber (ADF). Within the forage evaluation, Tuxpeño Norteño × Ratón had the highest content of NDF and ADF (57.4 and 26.6%, respectively).

When comparing between groups, the forage had higher NDF content and lower ADF content (54.2 and 23.7%, respectively). In silage, the genotypes Ratón × Tuxpeño, Tuxpeño Norteño × Ratón and Ratón × Olotillo III had the highest content of NDF and ADF (54.1 and 26.5%, respectively). In this sense, in silage, V-402 showed the lowest NDF and ADF contents with values of 48.5 and 23.3%, respectively. In the present study, higher NDF values were obtained in forage than in silage (54.2 *vs* 52.6). It should be considered that the concentration of neutral detergent fiber (NDF) and acid detergent fiber (ADF) determine the nutritional quality of forages (Van Soest, 1994), since high fiber contents in forages generate a decrease in its digestibility and it is considered of low nutritional value (Segura *et al*., 2007).

The ashes represent the fraction corresponding to the minerals of the feed, incinerating all the organic matter, leaving only the inorganic compounds (Caravaca *et al*., 2005). Within the analyses corresponding to forage and silage, there were significant differences between the genotypes, from 5.2 to 5.7% of ashes for forage and 6.2 to 6.9% for silage.

In this regard, when analyzing the percentage of ash at different days of age, Amador and Boschini (2000) found that in each cut there are different percentages, without an increase relationship, observing that, at 121 days, it was 8.1% and it was at this age, where the highest yield of total dry matter was produced.

Conclusions

The Tuxpeño Norteño × Ratón genotype had the highest yield of total dry matter and nutritional value, desirable characteristics in forage corns. The nutritional value of the forage was preserved through silage, so this process could be an alternative for preserving native corn forage for critical times in subtropical conditions.

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