Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 7(4) pp. 130-136, April, 2018 Issue.
Available online http://garj.org/garjas/home

Full Length Research Paper

Forage Yield and Quality of Yellow Grain Maize (*Zea mays* L) Cultivars at Two Population Densities in the Tropical Region of Tamaulipas Mexico

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Accepted 24 April, 2018

White grain Maize (*Zea mays* L.) in México is intended primarily to produce grain for human consumption and the yellow one could be used as fodder. This experiment was conducted to evaluate the production and quality of forage at 1/3 milk line of commercial and experimental yellow grain cultivars formed and developed for tropical climatic conditions at two population densities (D50= 50000 y D85= 85000). Ten cultivars (six experimental cultivars: from the Campo Experimental Rio Bravo of INIFAP; three commercial hybrids and a native one) were settled with a completely randomized block design with a split plot arrangement. Quality analysis were performed in the Universidad Autónoma de Tamaulipas in the northeastern region of Mexico. The total number of leaves (NTH), days to male and female flowering (DFM and DFF), plant height (AP), whole plant green and dry matter production (MV and MS), crude protein of forage (PCF) and cob (PCMZ), and digestible dry matter (MSD) were evaluated. For the DFM y DFF differences were observed between cultivars ($P < 0.05$). For the MS production cv. native produced 11.4 t $ha^{-1}$and the highest MSD (8.4 t ha^{-1}; $P < 0.05$). There was a significant effect ($P < 0.05$) for the interaction cultivar by density for the AP. It is concluded that some of the yellow grain maize cultivars are an option to produce grain and quality forage under the tropical conditions of Mexico.

Keywords: yellow grain maize, México maize production, maize forage production, maize cultivars

INTRODUCTION

In Mexico, about 73% of the imported yellow grain maize is used in the livestock sector mainly for the manufacture of balanced feed and as seed for forage production (SAGARPA, 2016). In the country, maize forage production increased by 33% between 2009 and 2016 (SIAP, 2016), because there is demand for this fodder in the milk production systems (Peña *et al*., 2012). Maize cultivars could be an alternative for forage production because of, its great potential to produce high quality biomass (Peña *et al*., 2006) and because of its genetic diversity and its adaptability to different environments (Peña *et al*., 2012). The use of native genotypes may be an option with an aggregated value to grain production by using the crop as an alternative to feed animals, because its high potential for production of fodder or in maize breeding programs for forage yield mostly due to its wide adaptability and rusticity (Pecina *et al*., 2011).

There are some maize agronomic management strategies that could contribute to the improvement of quality maize forage production, such as the use of different genotypes developed for grain yield and adapted to the environmental conditions of the region where they are to be developed (Peña *et al*., 2012), the identification of native cultivars that occupy from 70 to 80% of the cultivated area in Mexico (Pascual *et al*., 2015) and the management of population density that allows to increase grain yield per unit area and total dry matter production without significantly affecting forage digestibility (Peña *et al*., 2010).

In this regard, Peña *et al*. (2006) mentioned that for every 20000 plants ha^{-1}increment in population density, the production of dry matter per hectare could be improved by 2.25 t and bovine milk production increased by up to 0.95 t ha^{-1}, because of the content of protein and fiber remain unchanged. The present paper objective was to evaluate the production and quality of maize forage at two population densities to 1/3 of milkline of maize cultivars formed to produce yellow grain and developed for the tropical climatic conditions of Tamaulipas, Mexico.

MATERIALS AND METHODS

Experimental site

The experiment was conducted during the 2014 spring-summer harvest in the animal production ranch “Ingeniero Herminio García González”, in the municipality of Güémez, Tamaulipas, located at 23° 56'LN and 99° 05'LW, with an altitude of 193 meters over sea level (INEGI, 2015) and in the animal nutrition laboratory (CILO) belonging to the Universidad Autónoma de Tamaulipas.

Experimental design and treatments

Ten cultivars (cv) of yellow grain maize (six experimental cv.: 121×119, 122×119, 6×8, 6×9, 6×10 and 11×12 from Experimental Rio Bravo INIFAP Center; three (control) commercial hybrids cv.: H-443A, 30R50, G-8801 and a native CAm cv. from the municipality of Hidalgo Tamaulipas) were planted. Sowing was done manually with two seeds per hole and the cultural practices as recommended by INIFAP (2012). Two sowing densities (D50 = 50000 and D85 = 85000 plants ha^{-1}) were used and fertilized twice after sowing with a 140-40-00 dose. The experimental plots (8 m^2) consisted of two 5 m long rows with 0.80 m spacing. For the density D50 and D85 the distance between plants in the furrow was 0.20 m and 0.15 m respectively. When the seedling was 25 cm height sowing density was adjusted through thinning. The samples were harvested at 1/3 milk line which occurred from 95 to 106 days after sowing. A completely randomized block design with a split-plot arrangement with four replicates was used. The whole plot (plant density) was split into subplots (cultivars) and the Tukey pair wise comparison test was performed with α = 0.05 if significance was found.

$$Y_{ijkl} = \mu + \beta_i + D_j + \delta_{k(j)} + G_l + (DG)_{jl} + \varepsilon_{ijkl}$$

Where:β_i = block effect; D_j = density fixed effect (whole plot); $\delta_{k(j)}$ = random whole plot error ~N(0, σ_δ^2); G_l = cultivars fixed effect; $(DG)_{jl}$ = density by cultivar interaction fixed effect and ε_{ijkl} = random split plot error ~ N(0, σ^2).

Measurements

The agronomic variables evaluated were: plant height (AP; cm), measured from the base of the stem to the apex of the panicle; total number of leaves (NTH), was quantified in three plants; male flowering (DFM) was quantified in each cultivar as the number of days from sowing until 50% of the plants had emitted pollen; female flowering (DFF) was measured as the point at which 50% of the plants exhibited completely exposed stigma; floral asynchrony (AF), was estimated as the difference between DFF and DFM; production of green matter (MV; t ha^{-1}), eight plants were weighed for D50 and 14 plants for D85; dry matter yield (MS; t ha^{-1}), three whole plants were cut and placed in bags for three days in the oven at 60 °C until constant weight was obtained.

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Table 1. Means for days to male (DFM) and female (DFF) flowering, and plant height (AP) in yellow grain maize cultivars between sowing densities.

Cultivars		DFM	DFF	Earliness	AP
		(days)			(cm)
Experimental	121×119	68^{bc}	72^{bc}	Intermediate	183.3^{ab}
	122×119	67^{bcd}	74^{ab}	Intermediate	196.7^{a}
	6×8	63^{d}	69^{c}	Early	191.7^{ab}
	6×9	65^{cd}	70^{bc}	Early	181.7^{ab}
	6×10	64^{d}	68^{c}	Early	183.3^{ab}
	11×12	68^{bc}	74^{ab}	Intermediate	186.7^{ab}
Commercial hybridscontrol)	H-443A	71^{ab}	74^{ab}	Intermediate	176.7^{bc}
	30R50	73^{a}	77^{a}	Late	180.0^{abc}
	G-8801	68^{bc}	73^{b}	Intermediate	161.7^{c}
Native	CAm	67^{bcd}	72^{bc}	Intermediate	195.0^{ab}

Note: Means with different letter within columns are statistically significant (Tukey, $P<0.05$).

For the quality variables, a sample of three complete plants was taken, each plant was weighed, chopped and mixed separately, then dried in the forced air oven at 60 °C for 48 h. The dried samples were milled using a sieve of one millimeter in diameter and stored in plastic bags. The crude protein content of the forage (PCF;%) and of the cob (PCMZ;%) (AOAC, 1997) were estimated. The *in vitro* dry matter digestibility (DIVMS;%) was determined by the methodology proposed by Theodorou *et al*. (1994). The digestible dry matter (MSD t ha^{-1}) was estimated (MSD = MS * DIVMS).

For the definition of precocity, the cultivars were grouped by fractionating in intervals of equal amplitude the DFF (Gil-Muñoz *et al*., 2004), considering the methodology suggested by Martínez (2005) and number of intervals = $\frac{\text{Range for DFF}}{\text{m}}$, where m = interval amplitude = 1 + 3.3 log(n) and n = observations number. Classifying in this way the cultivars, as early, the range from 65 to 70 d, intermediate, from 71 to 76 d and late, from 77 to 82 d.

RESULTS

For the cultivar factor, significant differences ($P< 0.05$) were observed for all agronomic and quality variables except for DIVMS ($P= 0.349$). It was found a significant effect ($P< 0.05$) for the population density by cultivar interaction for the AP, PCF and PCMZ variables. There were no significant differences ($P> 0.05$) for the agronomic and quality variables between the two densities under study.

Earliness

In this study and under the environmental conditions of the site commercial hybrid cv. 30R50 is considered late, but not different ($P> 0.05$) to cvs. H-443A, 11×12 and 122×119 (intermediate) due to the wide range in DFF that showed this cultivar (77 to 82 d). Likewise, native cv. CAm and cv. 121×119 on average can be considered as intermediate, but not different ($P> 0.05$) to cvs. 6×8 and 6×10 (early) because the range of these two cultivars in DFF was 69 to 74 d (Table 1). In the present study, it was found a negative correlation (r = -0.216) between DFF and AP ($P= 0.09$; Ho r = 0) likewise between DFM and AP (r = -0.302; $P=0.01$, Ho r=0).

Agronomic variables

For the AP the cvs. 122×119 and native cv. CAm presented the taller plants, with a difference ($P<0.05$) of 33 to 35 cm between these cultivars and commercial hybrid cv. G-8801 which was the smaller one (Table 1). The native cv. Cam was the taller cultivar (195 cm) with an average NTH of 18 leaves for the two densities, similar ($P> 0.05$) to commercial hybrids cvs. 30R50, H-443A and cv. 11×12 (Table 2). For MS cvs. 11×12 and native CAm were superior (11.2 and 11.4 t ha^{-1}) than the commercial hybrid cv.G-8801, with a difference of about 4 t of MS ha^{-1}, which is an indicator of the potential of biomass production of the native maize cultivar (Table 2).

Table 2. Means for total number of leaves (NTH), green matter production (MV) and dry matter yield (MS) in yellow grain maize cultivars between sowing densities.

Cultivars		NTH	MV	MS
			t ha^{-1}	
Experimental	121×119	16.7 ^{cde}	41.5 ^{abc}	9.7 ^{ab}
	122×119	16.8 ^{bcd}	42.7 ^{abc}	10.9 ^{ab}
	6×8	16.5 ^{de}	30.2 ^{de}	9.5 ^{ab}
	6×9	16.5 ^{de}	32.0 ^{cde}	9.7 ^{ab}
	6×10	16.7 ^{cde}	33.6 ^{bcde}	9.9 ^{ab}
	11×12	17.0 ^{abcd}	46.4 ^{a}	11.2 ^{a}
Commercial hybrids (control)	H-443A	18.0 ^{a}	40.8 ^{abcd}	8.9 ^{ab}
	30R50	17.7 ^{abc}	43.8 ^{ab}	10.5 ^{ab}
	G-8801	15.7 ^{e}	27.2 ^{e}	6.8 ^{b}
Native	CAm	17.8 ^{ab}	37.6 ^{abcde}	11.4 ^{a}

Note: Means with different letter within columns are statistically significant (Tukey, ***P***<0.05).

Quality variables

The quality of the forage that is produced is important when considering the objective of biomass production. The commercial hybrid cv. G-8801 produced the lowest MS, but the PC of its forage was superior to the other cultivars with a DIVMS only below (***P***> 0.05) of the commercial hybrid cv. 30R50 (Table 3).

It is important to mention that for PCF and PCMZ (Table 4) there was a significant effect of the interaction cultivar by density (***P***<0.05), observing that the commercial hybrid cv. H-443A, obtained the highest percentage (7.3%) and not different (***P***> 0.05) to the commercial hybrids cvs. 30R50 and G-8801 in density D85 (Table 4), which may be an indicator that the contribution of cob protein of the cultivars under study could be significant to produce high quality forage to 1/3milkline. In the agricultural production systems, it is important to estimate the digestible dry matter (DMD) because it is an indicator of the production of the plant to be transformed into products of animal origin. In the present study, it was observed that even though for DIVMS there were not significant differences (***P***> 0.05) among cultivars, for the MSD the native cv. CAm stands out with 8.4 t ha^{-1} (Table 3).

DISCUSSION

Earliness

One way to know the earliness of a crop is to estimate the days from sowing to the appearance of 50% of stigmas (Gil-Muñoz *et al.*, 2004). the earliness diversity is common among native maize populations as it is an important indicator of the cultivars adaptation to the thermometric and fluviometric conditions that could occur in each region (Ángeles-Gaspar *et al.*, 2010). This was confirmed by Tadeo *et al.* (2012) in a research carried out in three environments in Valles Altos, Mexico in the spring - summer harvest, whom reported that for DFF no differences were found between the early yellow-grain varieties evaluated, associating these results with the limited moisture present in the cycle. The negative correlation between DFF and AP in the present study is different from that reported by Dzib-Aguilar *et al.* (2011) who concluded that the earliest populations were of smaller plants and the later ones of higher plants.

In this regard, Pecina-Martínez *et al.* (2009) in a study carried out with native maize populations and improved varieties of white grains evaluated at the same site as the present research with planting date in march, found an average AP of 140 cm with DFF between 69 and 72 d in a population density of 50000 plants ha^{-1}, different from what it was found in the present investigation because in march the vegetative stage of maize develops in cooler temperatures than in the sowings of september the month in which it was realized this research and this makes the internodes shorter so that the corn plant reaches less height.

Agronomic variables

The highest height found in the native cv. CAm with respect to the other cultivars in higher population density (D85) could be an indication that increasing the number of plants per hectare would generate more forage production (Table 4), these results agree with Sánchez-Hernández *et al.* (2011) in a research conducted in Oaxaca, in a tropical

Table 3. Means for quality variables in yellow grain maize cultivars between sowing densities.

		PC (%)		DIVMS (%)		MSD t ha^{-1}
	Cultivars	§Stover	†Ear	WP	Stover	Stover
Experimental	121×119	8.2 abc	6.1 ab	58.9 a	69.1 a	6.7 ab
	122×119	9.0 ab	6.1 ab	60.3 a	71.9 a	7.8 ab
	6×8	8.3 abc	5.7 b	57.9 a	71.9 a	6.9 ab
	6×9	7.9 bc	5.9 b	60.5 a	72.2 a	6.9 ab
	6×10	7.6 c	6.0 ab	60.3 a	74.2 a	7.4 ab
	11×12	9.2 a	5.9 b	60.2 a	71.6 a	8.0 ab
Commercial hybrids (control)	H-443A	8.7 abc	7.3 a	60.4 a	72.1 a	6.4 ab
	30R50	8.6 abc	6.9 ab	63.8 a	72.8 a	7.6 ab
	G-8801	9.3 a	6.4 ab	61.0 a	72.5 a	4.9 b
Native	CAm	8.2 abc	6.1 ab	61.0 a	73.6 a	8.4 a

Note: Means with different letter within columns are statistically significant (Tukey, ***P***<0.05). PC= Crude Protein; DIVMS= *In vitro* digestibility of dry matter; MSD= Digestible dry matter; §Forage= Stem, leaves and inflorescence; †Ear= bracts, cob and grain; WP = Whole plant.

Table 4. Whole plant means for the interaction cultivar by sowing density in yellow grain maize cultivars.

	AP (cm)		PCF (%)		PCMZ (%)	
Cultivars	D50	D85	D50	D85	D50	D85
121×119	**ABC 186.7 *abcd	ABC 180.0 abcd	C 7.5 bc	A 8.9 abc	A 5.9 ab	AB 6.3 ab
122×119	A 200.0 a	AB 193.3 abc	A 9.7 a	AB 8.2 abc	A 6.3 ab	AB 5.9 ab
6×8	AB 196.7 ab	AB 186.7 abcd	ABC 8.8 abc	AB 7.9 abc	A 6.1 ab	B 5.3 b
6×9	BC 166.7 bcd	A 196.7 ab	ABC 8.7 abc	B 7.1 c	A 5.5 b	AB 6.3 ab
6×10	ABC 180.0 abcd	AB 186.7 abcd	BC 7.8 abc	AB 7.5 bc	A 6.1 ab	AB 5.9 ab
11×12	ABC 186.7 abcd	AB 186.7 abcd	A 9.7 a	AB 8.8 abc	A 5.9 ab	AB 5.9 ab
H-443A	ABC 183.3 abcd	BC 170.0 abcd	ABC 8.4 abc	A 8.9 abc	A 6.7 ab	A 7.8 a
30R50	ABC 183.3 abcd	ABC 176.7 abcd	ABC 8.7 abc	AB 8.5 abc	A 6.9 ab	AB 6.9 ab
G-8801	C 163.3 dc	C 160.0 d	AB 9.4 ab	A 9.2 ab	A 5.7 b	AB 7.2 ab
CAm	ABC 190.0 abcd	A 200.0 a	ABC 7.9 abc	AB 8.5 abc	A 6.7 ab	B 5.5 b

* Means with different lower-case letter within row are statistically significant (Tukey, ***P***<0.05).

** Means with different capital letter within column are statistically significant (Tukey, ***P***<0.05). AP= plant height; PCF= forage protein crude (Stem, leaves and inflorescence); PCMZ= Cob protein crude (bracts, cob and grain.). D50 = 50000 plants ha^{-1}; D85 = 85000 plants ha^{-1}.

climate, who found that native maize was superior to the hybrids in three densities evaluated obtaining their highest AP (270 cm) to 83000 ha^{-1} plants, which may be an indicator of the potential of using native cv. CAm in plant breeding programs to produce fodder.

For NTH, the late cultivar (30R50)had more leaves than the earliest cultivars as it was suggested by Tollenaar (1991). In this regard Castro-Nava *et al*. (2014) in a Güémez, Tamaulipas study in the fall-winter harvest with commercial and native genotypes the NTH averaged 18.6 and 18.7 leaves respectively, when the populations were evaluated in Güémez (center region of Tamaulipas), but of 20.3 and 19.8 when the cultivars were evaluated in Rio Bravo (northern region of Tamaulipas), which could be attributed to a better adaptation and performance of native cultivars in different environmental conditions (Ángeles-Gaspar *et al*., 2010).

Quality variables

The balance between production of biomass and protein is important in agricultural systems, in this regard, García-Castillo *et al*. (2013) in a research carried out in Nayarit, Mexico observed average values of PCF for a variety of experimental forage maize of 12.0% with an DIVMS of 52.1%.It is important to mention that, in an investigation carried out by Núñez *et al*. (2003) the grain content has a significant effect on DIVMS, mainly due to the high percentage of digestibility of the grain (Peña *et al*., 2010), which agrees with the findings of the present study where in average all the cultivars showed an increment of more than ten percentage units in DIVMS by including the ear (grain + cob + rachis) to the forage analyzed (Table 3).

CONCLUSION

Sixty percent of the cultivars were intermediate and with high variability in the days to the female flowering. For the cultivar by density interaction for plant height native cv. CAm stood out in the two densities. The experimental cvs. 11×12, 122×119 and native CAm obtained higher production of dry matter and dry digestible matter. The production of forage with yellow grain maize was not affected by population density, but the protein yield. The experimental cvs. 11×12 and 122×119 showed the highest percentage of forage protein. It is concluded that native cv. Cam and the experimental 11×12 and 122×119 according to the agronomic and quality characteristics could be used in the production of quality forage in the region.

ACKNOWLEDGEMENTS

To the National Council of Science and Technology (CONACYT) for the support given to the first author, to carry out master’s studies. To the Universidad Autónoma de Tamaulipas through the Faculty of Engineering and Sciences and to INIFAP for the contribution of its maize genetic materials.

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