Article

Yield of grain, forage and forage quality of new corn hybrids from High Valleys

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Abstract

In the Faculty of Higher Studies Cuautitlán (FESC-UNAM) and in the National Institute of Forestry, Agricultural and Livestock Research (INIFAP), there are hybrids in experimental phase or recent release for the High Valleys of Mexico, which are competitive with existing commercial hybrids. In this research, 10 corn hybrids were evaluated in two localities and in one of them with two sowing dates; that is; three different evaluation environments in the State of Mexico, in each environment two experiments were established with the 10 genotypes, in the first the objective was to determine the grain productivity and in the second they were to determine the productivity and quality of forage. A randomized complete block experimental design with 10 genotypes and three repeats was used, the statistical analysis was performed with a factorial arrangement, which considered the 10 hybrids and three environments, as well as the genotype x environment interaction. In the conclusions it was determined that the hybrid Atziri Puma presented the highest grain yield (8 044 kg ha^{-1}), followed by the hybrid Tsíri Puma (7 783 kg ha^{-1}), both recently released commercially by FES Cuautitlán, UNAM. The hybrid Tlaoli Puma had the highest yield of green forage (70 202 kg ha^{-1}). In forage quality analyses, no significant differences between hybrids were observed. Atziri puma, Tlaoli puma and Tsiri puma already have their registration with the National Catalog of Plant Varieties (CNVV) and Breeder's Title.

Keywords: *Zea mays*, corn, forage quality, genotypes, grain yield, productivity.

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Introduction

Corn is the crop from which the world's largest grain production (1 060 million tons) is obtained each year. There are different varieties of corn for each infinity of agrosystems, crop management, environments, altitude, with specific and specialized use by farmers. More than 600 different uses are known. Seventy-six percent of corn is sown under irregular and scarce rainfall humidity and the remaining 24% under irrigation. In Mexico, center of origin, 22.1 million tons are produced, with an average yield of 2.8 t ha^{-1}, 16 to 18 million tons of yellow corn are imported each year, so a total of 32.1 million tons are required, total apparent consumption (Espinosa and Tadeo, 2018 a; Espinosa *et al*., 2019). According to SADER (2020), 7.4 to 7.7 million hectares have been sown in Mexico from 2010 to 2018 in 2.3 million production units.

Since the 80s in the Faculty of Higher Studies Cuautitlán, UNAM (FES Cuautitlán, UNAM) and in the Valle de México Experimental Field of the National Institute of Forestry, Agricultural and Livestock Research (CEVAMEX-INIFAP), various androsterile white hybrids of intermediate cycle are generated, developed and evaluated for early sowings, some of which have expressed good forage yield (Tadeo-Robledo *et al*., 2016; Espinosa-Calderón and Tadeo-Robledo, 2018b; Espinosa-Calderón *et al*., 2019; Zaragoza-Esparza *et al*., 2019). From an outstanding group of trilinear hybrids, which have androsterility to facilitate seed production (Tadeo-Robledo *et al*., 2018 b), some have been selected, which have consistently presented yield advantages compared to controls and which are registered in the National Catalogue of Plant Varieties (CNVV, for its acronym in Spanish) for their extensive commercial use.

In the early ideotypes (called archetypes) of corn, they were not discriminated according to their use. It was accepted that silage yield and quality were determined by grain yield and (%) of grain above the rest of the plant components (Zaragoza-Esparza *et al*., 2019). Therefore, plant breeders and producers argued that the best corns for grain production were the most suitable for silage, so the best hybrid for grain was the best for forage. Consequently, the improvement was directed to the development of germplasm and hybrids for grain production only.

In general, forage hybrids are arbitrarily selected for their dry matter-producing capacity, and little interest has been placed in improving their nutritional quality (Peña *et al*., 2002). It was considered appropriate to define the most appropriate materials, which present a high grain yield and also express good productivity and forage quality; therefore, in the present work, the objective was to determine the yield of grain, green matter, dry matter, protein content and digestibility of 10 white grain hybrids for High Valleys of Mexico, as well as to define which hybrid can be used for dual purpose, both in grain and forage production.

Materials and methods

The present work was carried out in two localities, in the spring-summer 2016 cycle. The first in the Valle de México Experimental Field (CEVAMEX), belonging to INIFAP, located in Santa Lucía de Prías, Municipality of Texcoco, State of Mexico at an altitude of 2 240 m, the second locality was in the Faculty of Higher Studies Cuautitlán (FES-Cuautitlán), Field 4, of the National

Autonomous University of Mexico (UNAM) located in Cuautitlán Izcalli, State of Mexico at an altitude of 2 274 m. In the first locality, two experiments were sown on two sowing dates, the first sowing date was May 27, 2016, and the second on June 24, 2016, in the case of the second locality, only one sowing date was managed, on June 06, 2016.

Ten genotypes were evaluated, four obtained in the genetic improvement program of FES Cuautitlán, UNAM and six of INIFAP. Two experiments were established with the 10 materials, the first at a population density of 65 000 plants ha^{-1}, for its evaluation of grain productivity, this experiment was harvested at 170 days after sowing (Table 1).

The same 10 genotypes were established in the second experiment at a population density of 80 000 plants per hectare, to be evaluated for production and quality of forage, in this case the harvest was carried out 115 days after sowing (Table 1). In both experiments, a randomized complete block experimental design was used, with 10 genotypes (hybrids), three repetitions, each trial was established in three environments: two of them in CEVAMEX (Santa Lucía 1 and Santa Lucía 2) as well as another in FES Cuautitlán, UNAM. The statistical analysis was carried out with a factorial arrangement, which considered the factors: genotypes (G: 10), environments (E: three), as well as the genotype by environment interaction (G x E). All statistical analyses were performed using the SAS program version 9.0 (SAS Institute, 2002).

Table 1. UNAM and INIFAP's corn hybrids used in two types of experiments to determine grain yield, productivity and forage quality in three evaluation environments of high valleys in the spring-summer 2016 cycle.

No. Treat	Commercial name	Type of hybrid	Origin	Plant density (thousands) grain	Days to harvest (grain)	Plant density (thousands) forage	Days to harvest (forage)
1	H 61	TH	INIFAP	65	170	80	115
2	TLAOLI PUMA	TH	UNAM	65	170	80	115
3	(IA449RMIA44 X MIA47)	SCH	UNAM	65	170	80	115
4	TSIRI PUMA	TH	UNAM	65	170	80	115
5	ATZIRI PUMA	TH	UNAM	65	170	80	115
6	H 47 AE	TH	INIFAP	65	170	80	115
7	H 49 AE	TH	INIFAP	65	170	80	115
8	H 53 AE	TH	INIFAP	65	170	80	115
9	H 50	DCH	INIFAP	65	170	80	115
10	H 51 AE	TH	INIFAP	65	170	80	115

TH= trilinear hybrid; SCH= single-cross hybrid; DCH= double-cross hybrid.

The experimental plot consisted of a furrow 5 m long by 0.8 m wide, giving a total of 4 m^2 as a useful plot, with 28 plants for grain production and 32 plants for forage production. In all environments, on the three different sowing dates, the land was prepared in a conventional way, consisting of ploughing, two passes of harrowing and tracing furrows. At the time of the furrowing, it was fertilized with a dose of 80-40-00 (N, P, K), using urea and ammonium phosphate.

For the CEVAMEX experiment, the irrigation was applied at sowing and later two supplemental irrigations were applied, on the other hand, in FES Cuautitlán, UNAM, only one irrigation was given at sowing and in the rest of the cycle the water requirement was covered with the humidity of rainfall. For weed control, herbicide was applied 15 days after irrigation, based on a mixture of 3 kg of Gesaprim caliber 90, 1 L of Hierbamina and 1 L of Sansón 4 SC per hectare (Tadeo-Robledo *et al*., 2018). At 35 days after sowing, in each experiment the population density was adjusted to 32 and 28 plants per furrow to obtain a density of 80 000 and 65 000 plants ha^{-1}, for the forage and grain experiments, respectively.

To evaluate grain yield, the following variables were evaluated: grain yield, days to male flowering, days to female flowering, plant height, ear height, ear length, ear diameter, cob diameter, rows per ear, grains per row, grain moisture, grain volumetric weight, weight of 200 grains and percentage of grain/cob.

To evaluate forage yield, the following variables were evaluated: green matter yield, dry matter yield, dry matter percentage, ear percentage and dry ear weight. Forage quality was evaluated with the help of the following variables: protein percentage and digestibility percentage. Protein percentage was obtained using the Microkjeldahl method (AOAC, 2012). In the case of the percentage of digestibility, it was determined by the method of *in vitro* digestibility of dry matter with the technique of Tilley and Terry (1963).

Results and discussion

In the experiments to determine grain productivity, the results of the variables analyzed in the evaluation of the 10 hybrids, across three environments, showed for the variation factor, environments, highly significant (p< 0. 01) differences, except in ear height. For the variable grain yield, the coefficient of variation was 9.2% and the overall mean was 6 742 kg ha^{-1} (Table 2). For the variation factor, genotypes (hybrids), highly significant differences in the variables yield and plant height were found. In the interaction (G x E), significant differences were identified only for the variable, plant height (Table 2).

Table 2. Mean squares and statistical significances obtained from the analysis of variance for various variables to determine the grain productivity of ten corn hybrids evaluated in three environments of High Valleys. P-V 2016.

Variation factor	DF	Grain yield (kg ha^{-1})	MF	FF	PH	EH	VW	% DM	W200G
ENV	2	6668068.45*	532.07**	481.23**	3390.87**	23.41	39.87**	71.11**	1841.41**
GEN	9	4988016.13**	4.19	4.19	2419.3**	250.35	10	0.88	88.07
ENV∗GEN	9	4598991.49	8.22	8.22	1051.91*	103.02	8.91	0.96	65.34
BLO(ENV)	9	7371237.89	1.65	1.65	1029.02	245.45	8.5	2.15	113.34
ERROR	54	1675383	3.27	3.27	515.94	160.27	6.52	0.76	46.99
CV		19.19	2.29	2.29	9.33	10.57	3.37	1	10.26
MEAN		6741.84	78.7	78.7	243.31	119.71	75.77	3.08	66.81

*= significant at 0.05 probability of error; = highly significant at 0.01 probability of error; FV= factor of variation; DF= degrees of freedom; MF= male flowering; FF= female flowering; PH= plant height; EH= ear height; VW= volumetric weight; W200G= weight of 200 grains; CV= coefficient of variation.

In the second experiment, to determine forage productivity and quality, the analysis of variance of the evaluation of the 10 hybrids, across three environments, detected for the variation factor, environments, significant ($p< 0.05$) differences for the variable green matter yield, as well as highly significant ($p< 0.01$) differences for the variables, dry matter yield, dry matter percentage, ear percentage, ear weight, protein percentage and digestibility percentage (Table 3). For the genotype variation factor, highly significant ($p< 0.01$) differences were detected in the variables green matter yield and dry matter yield. For the variables ear percentage and ear weight, significant ($p< 0.05$) differences between the genotypes evaluated were defined, while for the variables % dry matter, % protein and % digestibility, there were no significant differences (Table 3).

For the variation factor of the interaction (environment x genotype), highly significant ($p< 0.01$) differences were found for the variables: ear percentage and ear weight. In the rest of the variables, no statistical significance was detected (Table 3).

Table 3. Mean squares and statistical significances obtained from the analysis of variance for various variables to determine the forage productivity and quality of ten corn hybrids evaluated in three environments of High Valleys. P-V 2016.

Variation factor	DF	GM yield	DM yield	%DM	%Ear	EW	%Prot	%Digest
ENV	2	634092361*	125885209.5**	315.96**	6968.35**	1.073**	12.68**	278.71**
GEN	9	1436999691**	106031022.7**	11.57	54.51*	0.023*	1.16	19.71
ENV∗GEN	9	12545733	13398110.2	16.72	55.29**	0.023**	1.01	17.38
BLO(ENV)	9	88360417	14353318.1	37.09	24.71	0.009	2.56	45.8
ERROR	54	136618904	14805911	24.31	23.1	0.009	0.63	34.48
CV		19.69	25	18.73	16.58	21.33	8.77	8.56
MEAN		59355.56	15382.19	26.31	28.97		9.08	68.54

*= significant at 0.05 probability of error; **= highly significant at 0.01 probability of error; FV= factor of variation; DF= degrees of freedom; GM yield= green matter yield; DM yield= dry matter yield; %Ear= ear percentage; EW= ear weight; %Prot= protein percentage; % Digest= digestibility percentage; CV= coefficient of variation.

For the first experiment, that is, to determine grain productivity, in the test of comparison of means in the three environments evaluated (Table 4), in the variable of grain yield, two groups of significance were defined, placing Santa Lucía 1, first sowing date, with the highest grain yield (7 282 kg ha^{-1}), 11.2% higher than the yields obtained in FES Cuautitlán, UNAM and Santa Lucía, second date (6 467 kg ha^{-1}). These results are like those reported by Espinosa-Calderón *et al*. (2018), for the locality of Santa Lucía (CEVAMEX).

These results were probably a consequence of the 10 days of difference in flowering that occurred, compared to FES Cuautitlán, UNAM, which possibly caused a greater use of the wet period in the locality of Santa Lucía, possibly the 18 days of difference in sowing between the first date and second date of the locality of Santa Lucía is also the consequence of the difference in yield between the two environments; likewise, in Santa Lucía, supplemental irrigations were applied compared to FES Cuautitlán, UNAM, where the water requirements of the crop were covered with rainfall.

In the variable plant height, the Santa Lucía 1 environment was superior and significantly different from the other two environments, which probably influenced grain and forage yield (Zaragoza-Esparza *et al*., 2019). For the variable percentage of grain, three groups of significance were defined; that is, significant differences were obtained in the three localities, on the other hand, in the variables volumetric weight and weight of 200 grains, two groups of significance were defined, where the highest values were obtained in FES Cuautitlán, UNAM, compared to the environments of Santa Lucía. This could be a consequence of an environment that favored the growth and development of the crop and therefore, the formation of the ear (Table 4).

Table 4. Comparison of means between environments for various variables to determine grain productivity considering the mean of ten corn hybrids. P-V 2016.

Environment	Grain yield (kg ha^{-1})	MF (days)	FF (days)	PH (cm)	EH (cm)	%DM	%G	VW (kg hL^{-1})	W200G (g)
Santa Lucía 1	7 282 a	75 B	78 b	255 a	119 a	88 a	85 b	75 ab	61.4 b
FESC-UNAM	6 467 b	82 A	83 a	238 b	121 a	85 b	87 a	77 a	75.8 a
Santa Lucía 2	6 467 b	74 B	75 c	236 b	120 a	88 a	83 c	75 b	63.2 b
HSD (0.05)	805	1	1	14	8	0.54	0.97	2	4.26

HSD= honest significant difference ($p < 0.05$); MF= male flowering; FF= female flowering; PH= plant height; EH= ear height; %DM= percentage of dry matter; %G= grain percentage; VW= volumetric weight; W200G: weight of 200 grains.

For the second experiment; that is, to determine forage productivity and quality, in the test of comparison of means in the three environments evaluated (Table 5), in the variable for green matter yield, two groups of significance were defined, placing Santa Lucía 1 (first sowing date), with the highest yield of green forage (64 392 kg ha^{-1}), which was 9.5% higher compared to the yield of Santa Lucía 2 (second date) and this in turn 14% more compared to FES Cuautitlán, UNAM (55 383 kg ha^{-1}). These results are higher than those reported by Elizondo and Boschino (2001); Hernández-Sánchez *et al*. (2011).

It can be considered that the percentage of ears was the variable that directly affected the yield of green matter, this is because when the population density increases (from 65 000 to 80 000 plants ha^{-1}), the interception of photosynthetically active radiation by the canopy increases, thus promoting the accumulation of dry matter at the population level, especially for early varieties (Li *et al*., 2020), in this sense, the first sowing date of the genotypes, with a difference of 28 days with respect to the second date in the first locality and 10 days with respect to the second, had a direct impact on the forage yield.

For the comparison of means in the variable dry matter yield, two groups of significance were defined, the highest yield occurred (17 458.3 kg ha^{-1}) in Santa Lucía 2 (second date), this may be due to the lower amount of humidity, due to the low rainfall compared to FES Cuautitlán, UNAM and the late sowing compared to the first date. The dry matter yield is related to the percentage of dry matter, so the results in these variables are similar (Table 5).

Table 5. Comparison of means between environments for various variables to determine the productivity and quality of forage considering the mean of 10 corn hybrids. P-V 2016.

Environment	GM yield	DM yield	%DM	%Ear	EW	%Prot	%Digest
FESC UNAM	55 383 b	13 362 b	24.3 b	15.8 c	0.6 a	8.58 b	69.56 a
Santa Lucía 1	64 392 a	15 326 ab	24.5 b	45.7a	0.3 c	8.84 b	65.13 b
Santa Lucía 2	58 290 ab	17 458 a	30 a	25.4 b	0.5 b	9.82 a	70.94 a
HSD (0.05)	7 273	2 394	3.1	2.99	0.061	0.49	3.65

HSD= honest significant difference ($p< 0.05$); GM yield= green matter yield; DM yield= dry matter yield; % Ear= ear percentage; EW= ear weight; % Prot= protein percentage; %Digest= digestibility percentage.

For the variable percentage of protein, two groups of significance were defined, placing in the highest value the environment of Santa Lucía 2 (second date), which had 9.82% protein. The other two environments showed no significant differences (Table 5). Another important variable for forage quality is the digestibility percentage, where no significant differences were found between FES Cuautitlán, UNAM (69.56%) and Santa Lucía second date (70.94%).

In the comparison of means for the 10 genotypes evaluated, in the first type of experiments, (determination of grain productivity), considering the mean of the three evaluation environments, in the variable grain yield, two groups of significance were defined, placing the hybrid Atziri Puma with the highest grain yield, at 12% moisture (8 044 kg ha^{-1}), statistically superior to hybrid H 51 AE and H 47 AE. These results are like those reported in other research papers (Tadeo *et al*., 2016; Tadeo *et al*., 2018a; Tadeo *et al*., 2018 b; Tadeo-Robledo *et al*., 2020).

The results obtained are within the range of grain yield (3.89 to 11.71 kg ha^{-1}) reported by Velasco-García et *al*. (2019), for High Valleys of the Mexican Tropics. At CEVAMEX, the hybrid Atziri Puma exhibits yields above what was obtained in the studies of (Tadeo *et al*., 2018a; Tadeo *et al*., 2018b; Tadeo-Robledo *et al*., 2020), which showed yield ranging from 6 876 to 7 528 kg ha^{-1}.

The second hybrid with the highest grain yield was Tsíri Puma with 7 783 kg ha^{-1}, which is important, since this hybrid was recently released for commercial use, is registered in the National Catalogue of Plant Varieties (CNVV), has breeder's title (Tadeo-Robledo *et al*., 2016). The other genotypes exhibited statistically similar yields. The hybrids Tsíri Puma, H49AE and H51AE presented plants with greater height. In the variables male flowering, female flowering and ear height, there were no significant differences (Table 6).

In the comparison of means for the variables, dry matter percentage, grain percentage and volumetric weight, there are no significant differences between the genotypes evaluated. For the weight of 200 grains, differences between the hybrid H 51 AE were observed, which was higher than H 62 (Table 6).

Table 6. Comparison of means between environments for various variables to determine forage productivity and quality considering the mean of ten corn hybrids. P-V 2016.

Genotype	Yield grain (kg ha^{-1})	MF (days)	FF (days)	PH (cm)	EH (cm)	%DM	%G	VW (kg hl^{-1})	W200G (g)
Atziri Puma	8 044 a	77 a	80 a	241 abc	120 a	86 a	86 a	75 a	66 ab
Tsíri Puma	7 783 ab	77 a	78 a	268 a	111 a	87 a	87 a	77 a	65 ab
H 49AE	7 002 ab	77 a	79 a	256 ab	114 a	87 a	87 a	77 a	69 ab
(ENS4@QRL-#) X MIA47	6 969 ab	77 a	80 a	242 ab	122 a	87 a	87 a	76 a	66 ab
H 53AE	6 752 ab	77 a	79 a	256 ab	120 a	86 a	86 a	74 a	67 ab
Tlaoli Puma	6 689 ab	77 a	78 a	230 bc	118 a	87 a	87 a	76 a	70 ab
H-61	6 334 ab	76 a	77 a	233 abc	119 a	87 a	87 a	74 a	62 b
H-50	6 049 ab	77 a	79 a	237 abc	124 a	87 a	87 a	76 a	66 ab
H 51AE	5 986 b	76 a	78 a	256 ab	131 a	87 a	87 a	77 a	72 a
H 47AE	5 811 b	77 a	78 a	212	118 a	87 a	87 a	77 a	63 ab
HSD 0.05	2 013	3	3	35	20	1	1	4	10.66

HSD= honest significant difference ($p < 0.05$); MF= male flowering; FF= female flowering; PH= plant height; EH= ear height; %DM= percentage of dry matter; %G= percentage of grain; VW= volumetric weight; W200G: weight of 200 grains.

For the second type of experiment, forage productivity and quality, in the test of comparison of means between the 10 hybrids for the three environments evaluated, in the variable green matter yield. Four groups of significance were detected, with the hybrid Tlaoli Puma being placed with the highest yield of green forage (70 202 kg ha^{-1}), statistically higher than H 51 AE and H 47 AE.

For its part, the hybrid H 47AE presented the lowest yield compared to the other hybrids, being lower by 46.4% than the hybrid Tlaoli Puma, the above is important since Tlaoli Puma was registered in the National Catalog of Plant Varieties (CNVV) and has a breeder's title in the name of UNAM (Tadeo-Robledo *et al*., 2018; Tadeo-Robledo *et al*., 2020). In second place was the hybrid Tsíri Puma with 68 750 kg ha^{-1}. The hybrid Tlaoli Puma had an average yield of dry matter of 19.6 tonne ha^{-1}, being higher ($p < 0.05$) than the hybrids H 61, H 51AE and H 47AE by 34.1%, 37% and 59%, respectively. In ear weight, the hybrid H 53AE was superior ($p < 0.05$) to the hybrids H 61 and H 47AE (Table 7).

The three best materials in dry matter yield were Tlaoli Puma, Tsíri Puma and H 49 AE, with 19 615 kg ha^{-1}, 17 567 kg ha^{-1} and 17 474 kg ha^{-1} respectively, all three are in the same group of significance and surpass the hybrid H 50 (Table 7). This hybrid exhibited a dry matter yield of 15 278 kg ha^{-1}, indicating that the materials indicated with better yields could be disseminated for extensive use, which could well replace H 50, which has been the most sown corn in the High Valleys of Mexico for 22 years (Espinosa-Calderón *et al*., 2019).

In the comparison of means of the 10 genotypes for the variables of protein percentage and digestibility percentage, which represent forage quality, they did not show significant differences, which is a good indicator of the forage quality that each of them has, since all were within acceptable values for these variables (Table 7). Under arid conditions such as those of the Lagunera Region, Coahuila, using the same population density that was used in this research (80 000 plants ha^{-1}) and increasing irrigation as evapotranspiration increased (from 60 to 100%), yields from 47 665 kg ha^{-1} to 57 665 kg ha^{-1} were obtained (Yescas *et al*., 2015), which shows that the amount of water supplied to the crop causes a sufficiency or lack of moisture to the soil, which is directly reflected in the yield of the crop and in its different variables such as green forage and dry matter yield.

Table 7. Comparison of means between hybrids to determine forage productivity and quality considering the mean of three evaluation environments in high valleys. P-V 2016.

Genotype	GM Yield	DM Yield	%DM	%Ear	EW	%Prot	%Digest
Tlaoli Puma	70 202 a	19615 a	27 a	27 a	0.5 ab	9.7 a	67 a
Tsíri Puma	68 750 ab	17567 abc	26 a	31 a	0.5 ab	9.6 a	67 a
H 49AE	68 472 ab	17474 abc	25 a	28 a	0.5 ab	9.3 a	68.5 a
H 53AE	66 694 ab	15876 abc	24 a	27 a	0.6 a	9.3 a	70.3 a
Atziri Puma	66 333 ab	18543 ab	28 a	29 a	0.4 ab	9.2 a	68.3 a
(ENS4@QRL#) x MIA47	63 417 ab	16055 abc	25 a	26 a	0.5 ab	9 a	70 a
H 50	58 944 abc	15278 abc	26 a	27 a	0.4 ab	9 a	69 a
H 61	51 167 bc	12922 bcd	26 a	30 a	0.4 b	8.7 a	68.1 a
H 51AE	45 194 cd	12419 cd	26 a	32 a	0.4 ab	8.7 a	71 a
H 47AE	32 556 d	8072 d	27 a	33 a	0.3 b	8.7 a	67 a
HSD (0.05)	18 179	5984.4	7.66	7.47	0.15	1.23	9.13

HSD= honest significant difference ($p < 0.05$); DM yield= dry matter yield; %Ear= ear percentage; EW= ear weight; % Prot= protein percentage; % Digest= digestibility percentage.

The mean obtained for protein percentage was 9.12%, a figure higher than that reported by Núñez-Hernández *et al*. (2015), who also obtained an average percentage of digestibility of 8.6%. Yescas *et al*. (2015) reported that in case of an increase in the irrigation sheet and population density (from 80 000 to 16 0000 plants ha^{-1}), the percentage of protein does not increase significantly, finding values of 8.51 to 8.6% under a density of 80 000 plants ha^{-1}, a similar case with % expressed by the hybrids evaluated in this research (from 8.7 to 9.7%); however, it should be noted that in that research only one hybrid was evaluated. The differences found here can be attributed to the genetic constitution of each hybrid evaluated (Arellano-Vázquez *et al*., 2017), remembering that these are single crosses, trilinear crosses and double crosses.

In the comparison of means between genotypes, no significant ($p < 0.05$) differences are found. An average of 68.2% *in vitro* digestibility was obtained for the hybrids evaluated. For the comparison of means between the hybrids, there are no significant ($p < 0.05$) differences, but the single-cross hybrid (ENS4@QRL-#) xMIA47 had the highest value of this characteristic.

These results are like those obtained by Núñez-Hernández *et al*. (2015), who report that *in vitro* digestibility values range from 62.6 to 67.8% in intermediate cycle hybrids and from 67.2 to 73.2% in early hybrids.

Conclusions

The hybrid Atziri Puma had the highest grain yield, which was statistically superior to the hybrids H 51 AE and H 47 AE. The hybrid Tlaoli Puma exhibited the highest yield of green forage, statistically superior to H 51 AE and H 47 AE. Based on yields of grain, forage and their quality, the hybrids Atziri Puma and Tlaoli Puma showed favorable characteristics to be considered dual-purpose materials.

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