Article

Forage yield of maize adapted to the humid tropic of Mexico

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Abstract

A study was carried out in Loma Bonita, Oaxaca with the objective of evaluating the forage yield of maize genotypes adapted to the humid tropics of Mexico. The preparation of the land consisted of a fallow, tracing, crossed and furrowed, the establishment of the genotypes was on October 6, 2012, having as treatments six maize genotypes: NH-5, HE-1A17, VS-536, H -564C, DK-357 and H-520 that were distributed in a randomized block experimental design with divided plots and three replications, where the effect of three planting densities for each genotype was evaluated at 50 000, 62 500 and 83 333 plants ha^{-1}. To estimate the differences between genotypes and sowing densities, the information was subjected to an analysis of variance and Tukey's mean comparison test ($p \leq 0.05$). At the time of harvesting the forage in January 2013, the characters plant height (Alp), male and female flowering (Dfm, Dff), leaf area (Aft), stem diameter (Dta), total leaves and leaves above of corn (Nho, Hae), cobs per plant (Epp), knots per plant (Npp), weight of leaves and stems (Pho, Pet), weight of corn with and without bracts (Peho, Pesh), length and diameter of corn (Lel, Delo), rows per corn, grains per row and grains per corn (Nhel, Ngh, Nge), weight of cobs (Pes) and yield in fodder (ren) were studied.. The results indicated that on average of three planting densities the genotypes VS-536 (38.8 t ha^{-1}) and H-564C (36.6 t ha^{-1}) excelled in forage production. The sowing density of 83 333 plants ha^{-1}, in average of genotypes, produced the highest forage yield of 41.8 t ha^{-1}. Considering the interaction of genotype by density, there was a high production of green biomass with the variety VS-536 (49.5 t ha^{-1}) established at 83 333 plants ha^{-1}.

Keywords: Gramineae, forage production, hybrids, synthetic variety.

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Introduction

Corn (*Zea mays* L.) is considered the most important cereal in the world in terms of total production, with a value of 1 007 473 t, produced during 2014 (Kurtz *et al*., 2016; Mahama *et al*., 2016) , it is cultivated in a great variety of environments with differences in precipitation, solar radiation, temperature and production systems (Sanchez *et al*., 2016), generating a wide genetic diversity after thousands of years of domestication, selection and improvement that allowed it a wide adaptation to diverse types of climates and soils, thriving in tropical zones with more than 1 500 mm of rain per year (Bedoya *et al*., 2013).

Globally, corn is planted on more than 140 million hectares with grain yields of 6.7 t ha^{-1} in developed countries and 2.4 t ha^{-1} in developing countries, tropical maize is produced in 66 countries and is of economic importance in 61 of them (Paliwal, 2001; Khalily *et al*., 2010). Mexico is considered the center of origin, domestication and dispersion of maize, where 59 races have been described, representing 27% of the diversity existing in the American continent for which three hundred different races are reported (Salinas, 2013; Flores-Rosales, 2015). In Mexico, maize evolved in parallel with beans (*Phaseolus* spp.), potatoes (*Solanum tuberosum* L), chili (*Capsicum* spp.), squash (*Cucurbita* spp.), tomatoes (*Solanum lycopersicon* L.), cotton (*Gossypium hirsutum* L.), henequen (*Agave* spp.), vanilla (*Vanilla planifolia* Andrews), cacao (*Theobroma cacao* L.) and tequila (*Agave tequilana*) (Mera and Caballero, 2013).

Thus, in 2016, 7.8 million hectares for grain and 578 thousand for forage corn were established in Mexico, with an average yield of 29.1 t ha^{-1} of green matter (SIAP, 2017). At the present time of this grass the bracts of the ear (green or dry), stems, spikes, cobs, cobs and the grains are used, being the corn the cultivated plant with greater diversity of uses, applications, forms and conditions of production (Mera and Caballero, 2013).

Livestock producers consider that the corn plant is an excellent fodder to feed dairy cows, sheep and farm animals, in pasty state (1/3 of the milk line) it is ideal to be used as fodder or silage, since it contains more dry matter and digestible elements than any other crop, although it is known that in tropical countries silage is not as common as in cold climates. Corn remains that remain in the field as stubble after harvesting the grain are also used as fodder (Paliwal, 2001). The density of plants to produce forage is greater in forage maize than in those destined for grain production (Paliwal, 2001; Mera and Caballero, 2013).

In this way, planting densities of 30 000 to 90 000 plants ha^{-1} have been recommended, depending on irrigation, genotype and level of fertilization, although in other trials a greater amount of biomass has been obtained using 73 000 to 80 000 plants ha^{-1} (Vázquez *et al*., 2013).

In corn hybrids, different performance characters must be considered when evaluating and selecting genotypes for forage purposes from the amount of leaf, stem, corn and its relation, as well as considering the whole plant, characteristics that will affect the protein content, energy metabolizable, neutral and acid detergent fiber (Chávez, 1995). For genetic improvement purposes, it is recommended that forage maize germplasm present a rapid growth, resistance to pests and diseases, tolerance to high planting densities and a high biomass production capacity. In addition, it should be palatable and of great nutritional value with a high content of sugars in milky doughy state (Elizondo and Boschini, 2002), in some areas yellow corn is preferred to feed cattle because of its high content of protein and carotenoids (Malvar *et al*., 2008).

Elizondo and Boschini (2002) indicated that any type of corn can be grown for fodder, but the regional varieties are the best because they are mostly tall, the hybrids being small they produce less forage per unit area. However, corn hybrids used for forage in Mexico were selected mainly because they are grain yields and not because of their biomass yield potential (Peña *et al*., 2004). Due to the above, the objective of this study was to determine the forage yield of different corn genotypes grown for their adaptation to the conditions of Loma Bonita, Oaxaca, Mexico, under the assumption that corn hybrids present a similar forage yield in relation to synthetic varieties established by local producers.

Materials and methods

The study was carried out in the Experimental Field of the University of Papaloapan, Campus Loma Bonita, located at 18° 06’ 25’’ North latitude and 95° 52’ 50’’ West longitude, at a height of 25 masl. The climate of the place is Am that corresponds to a warm humid, with abundant rains in summer. The precipitation and average annual temperature are 1 845 mm and 25 °C, respectively. The soils of the area are classified as arenosols and acrisols (Anónimo, 2005). The sowing ground was prepared with machinery making a fallow, tracking, crossing and furrowing after this process was proceeded to sow the seeds manually depositing two seeds per bush at 25, 20 and 15 cm.

A plant was thinned by bush to adjust the densities to 50, 62.5 and 83.3 thousand plants ha^{-1}. To control the weeds, manual weeding was carried out during the vegetative development of the crop and even before flowering in order not to allow the weeds to compete with the crop. Soil pests such as blind hen (*Phyllophaga* sp.) and wireworm (*Agrotis* sp.) Were the pests to be controlled by the application of phoxim at 5%. Foliage pests such as armyworm (*Spodoptera frugiperda*), false meter (*Trichoplusia*) and armyworm (*Spodoptera exigua*), were controlled with ethyl chlorpyrifos (0.75 L ha^{-1}).

At the beginning of the study, a soil analysis was performed taking a subsample every 10 m, in the form of X. The results obtained were pH (4.8), organic matter (2.7%), nitrogen (18.4 mg kg^{-1}), phosphorus (22.4 mg kg^{-1}), potassium (32 mg kg^{-1}), calcium (148 mg kg^{-1}), magnesium (30 mg kg^{-1}), iron (263 mg kg^{-1}) and minor elements Cu^{2+}, Zn, Mn and Boro, the texture is sandy loam (sand 53%, silt 40%, clay 7%), apparent density 1.39 t m^{-3}, field capacity (11.4%) and permanent wilting point of 6.1%.

It was fertilized with the formula 161-46-00 by urea (46% N) and diammonium phosphate (18% N, 46% P). The first application was at the time of planting, applying all the phosphorus and half of the nitrogen, while the second fertilization was done 30 days after the first. Foliar fertilization was applied to complement the crop with minor elements such as Cu, B, Zn, Mn, Mo, for this, Bayfolan Forte was used in a dose of 1 L ha^{-1}.

The fodder maize hybrids evaluated were: H-520, H564C, HE1A, A7573, NH5 and the synthetic variety VS536, the genotypes under study were established at three planting densities (50 000, 62 500, 83 333 plants ha^{-1}), considering three repetitions. The variables under study were: plant height (Alp, cm) that considered the distance from the base, above the neck of the root, to the upper part of the same, for its determination a flexible tape was used. Flowering male (Dfm) and feminine (Dff) by experimental plot were counted the days in which 50% of male inflorescences (spikes) or feminine (jilotes) were had. Foliar area per plant (Aft, cm^2) was estimated from measuring the length and width of each leaf of the plant and the value obtained was multiplied by 0.75 (Tanaka and Yamaguchi, 1984).

Stem diameter (Dta, cm) was measured in the middle part of the corn plant. Number of leaves per plant (Nho) was determined by counting the total number of leaves each plant had. In the case of the number of leaves above the corn (Hae) were considered those leaves that were above the female inflorescence. Number of cobs per plant (Epp). The number of cobs of corn that each plant presented was counted. The knots per plant (Npp) were expressed as the number of total knots of the plant where the leaves are inserted. The weight of leaves of the plant (Pho, g), weight of stems (Pet, g), weight of corn with its bracts or leaves (Peho, g), weight of corn without bracts (Pesh, g) were estimated using a EURA-50 digital scale.

Corn length (Lel, cm) was measured from the base to the narrowest part where the corn ends in a point. Diameter of corn (Delo, cm) was made using a flexible tape. Number of rows per corn (Nhel) and number of grains per row (Ngh) were used to estimate the number of grains per corn (Nge). The variable weight of cobs (Pes, g) was obtained by separating the spike of each plant and the weight of each of them was estimated. Yield in forage (Ren, t ha^{-1}) was recorded in tons per hectare for each of the genotypes under study.

The treatments under study were distributed in an experimental design of random blocks, according to divided plots and three repetitions, to estimate the differences between genotypes shown in the different variables under study. The field information was subjected to an analysis of variance using the statistical program Sas (SAS, 2010). The statistical model used was: $Y_{ijkl} = \mu + R_i + D_j + G_k + IGxD_{kj} + E_{ijkl} + W$. Where: μ is the general average; R_i random effect of the i-th repetition; D_j effect of the j-th density; G_k effect attributable to the k-th genotype; $IGxD_{kj}$ genotype interaction by density; E_{ijkl} random effect attributable to experimental error and W is the effect attributable to intraparcelar error. A multiple comparison of treatment means was performed using the Tukey test ($p \leq 0.05$).

Results and discussion

The analysis of variance indicated that the genotypes under study showed significant statistical differences for all the characters studied (Table 1). Indicating that there was a different yield among the different maize and that their ability to adapt to the tropical conditions of Loma Bonita, Oaxaca influenced this behavior. The planting densities were significant at 1% for the characters days to male and female flowering, leaf area per plant, number of cobs per plant, weight of leaves, weight of stems, number of rows per corn and yield in forage, being these 5% differences for knots per plant, length of corn and number of grains per row, the rest of the variables did not show statistical difference for the source of variation densities.

Table 1. Medium squares of 20 characters for six forage-producing corn genotypes.

	Means	CV	Rep	Den	Gen	IntGxD	E	W
Apl	181.3	7.7	550.4 ns	585.5 ns	15 229.1**	3 628.2**	3 001.6	196.4
Dfm	66	5	61.9**	299.8**	425.3**	65.8**	72.5	0.15
Dff	70.9	4.7	95.7**	314.5**	330.5**	76.4**	72.9	0.11
Aft	2939.6	22.4	10688866.6**	4112100.3**	2437669.1**	19532199**	13041584.7	433349.6
Dta	5.2	12.8	0.5 ns	1.2 ns	11.3**	5.6**	4.6	0.5
Nho	10.3	9.8	1.3 ns	2 ns	13.9**	4.5**	6.1	1
Hae	6.7	6.7	0.3 ns	1 ns	7**	0.9 ns	2.4	0.5
Epp	1.1	30.6	0.2 ns	1.2**	0.5**	0.1 ns	0.3	0.1
Npp	10.7	10.7	0.6 ns	5.5*	40.3**	19.3**	11.3	1.3
Pho	145.6	32.8	26 851.2**	19 685.4**	28 089.4**	23 045.2**	20 993.1	2 289.4
Pet	95.5	33.3	1 788.5 ns	5 198.2**	35 149.9**	9 961.6**	9 687.1	1 014.4
Peho	277.8	23.3	9 148.3 ns	4 872.8 ns	31 608.8**	3 0871.3**	24 481.4	4 179.2
Pesh	180.5	21	2 063.8 ns	1 524.5 ns	14 951.6**	10 964.2**	7 932	1 436.6
Lel	17	12	12.9*	18.7*	41.3**	14.5**	19	4.2
Delo	4.5	7.6	0.2 ns	0.2 ns	2.9**	1.9**	0.9	0.1
Nhel	13.2	12.3	9.9*	12.8**	64.8**	8.9**	10.9	2.6
Ngh	31.1	16.7	167.8**	15.1ns	364.5**	36.9 ns	114.4	26.8
Nge	410.3	20.5	15 498.8 ns	22 977.6*	124 876.6**	24 359.4**	25 937.6	7 082.5
Pes	6.5	29.7	14.7*	8.2 ns	55.6**	33.7**	35.2	3.7
Ren	34.1	23	563.5**	9 892.3**	857.1**	750.5**	614.8	61.6
Gl			2	2	5	10	34	486

Alp= plant height; Dfm= days to male flowering; Dff= days to feminine flowering; Aft= leaf area per plant; Dta= stem diameter; Nho= number of leaves per plant; Hae= number of leaves above the corn; Epp= number of cob per plant; Npp= knots per plant; Pho= weight of leaves; Pet= weight of stems; Peho= weight of corn with leaves; Pesh= corn fat without leaves; Lel= length of corn; Delo= diameter of corn; Nhel= number of rows per corn; Nhg= number of grains per row; Nge= number of grains per corn; Pes= weight of corb; Ren= forage yield; Gl= degrees of freedom.

The repetitions were not significant for 11 out of 20 characters analyzed, which reflects that the conduct of the experiment allowed the genotypes and densities to be expressed as main factors of study. Note that the interaction of genotypes by densities showed that 17 of the 20 characters analyzed were highly significant. The synthetic variety VS536 according to the mean comparison test by Tukey ($p\leq 0.05$) presented the highest (ALP) plant height with a value of 203.1 cm, compared with the five hybrids that were studied (Table 2).

Table 2. Average behavior of 20 characters, on average of three planting densities, in corn genotypes with forage aptitude.

FV	Dms	Means	Genotype					
			VS536	DK357	H520	NH5	HE1A17	H564C
Alp	5.49	181.7	203.1 a[¥]	191.5 b	178.7 c	172.4 de	167.2 e	177.3 cd
Dfm	0.16	66	66.4 c	64.7 e	65.8 d	62.6 f	68.1 b	68.4 a
Dff	0.14	70.9	71.2 c	70 e	70.4 c	68 f	72.7 b	73.2 a
Aft	280.77	2939.6	2900.4 ab	2958.6 ab	2799.4 b	2727.9 b	3128.1 a	3122.7 a
Dta	0.28	5.2	5.1 cd	4.8 e	5 de	5.7 a	5.3 bc	5.5 ab
Nho	0.42	10.3	10.7 a	10.3 ab	10.6 ab	10.2 b	9.6 c	10.4 ab
Hae	0.3	6.7	6.8 a	6.5 bc	6.7 ab	7 a	6.3 c	7 a
EPP	0.14	1.1	1 b	1 b	1.15 ab	1 b	1.1 ab	1.26 a
Npp	0.49	10.7	12 a	10.7 bc	11.1 b	10.5 c	9.9 d	10.3 cd
Pho	20.40	145.6	160.7 a	128.4 c	139.7 bc	122.9 c	160 ab	162.3 a
Pet	13.58	95.5	130.8 a	82.6 c	88.9 c	81.4 c	82.4 c	106.9 b
Peho	27.57	277.8	297.4 ab	258.1 c	275.9 abc	272.9 c	259.6 c	302.9 a
Pesh	16.17	180.5	185.1 a	186.2 a	178.6 a	185.4 a	155.6 b	191.9 a
Lel	0.87	17	16.5 b	16.9 b	16.4 b	16.4 b	16.9 b	18.2 a
Delo	0.46	4.5	4.6 a	4.4 ab	4.5 a	4.6 a	4.2 c	4.3 b
Nhel	0.69	13.2	12.7 cd	14.7 a	12.2 d	13.3 bc	12.9 bc	13.6 b
Ngh	2.26	31.1	30 bc	31.7 ab	33.2 a	28.2 c	30 bc	33.3 a
Nge	35.89	410.28	380 b	462.7 a	403.8 b	374.5 b	390.8 b	450 a
Pes	0.82	6.5	7.7 a	5.6 d	6.5 bc	5.8 cd	6.3 bcd	7 ab
Ren	3.3	34.1	38.8 a	30.7 c	33.3 c	31.7 c	33.3 bc	36.6 ab

Alp= plant height; Dfm= days to male flowering; Dff= days to feminine flowering; Aft= leaf area per plant; Dta= stem diameter; Nho= number of leaves per plant; Hae= number of leaves above the corn; Epp= number of cobs per plant; Npp= knots per plant; Pho= weight of leaves; Pe = weight of stems; Peho= weight of corn with leaves; Pesh= corn fat without leaves; Lel= length of corn; Delo= diameter of corn; Nhel= number of rows per corn; Nhg= number of grains per row; Nge= number of grains per corn; Pes= weight of cobs; Ren= forage yield (t ha^{-1}); FV= source of variation; Dms= minimum significant difference, abc= averages with different letters in rows are statistically different (Tukey, $p \leq 0.05$).

Sierra *et al.* (2010) they obtained plant heights of 233 cm for the synthetic VS536 and a height of 228 cm for the hybrid H-520, which are different from those found in this study, as a consequence of the time in which this experiment was carried out, specifically in the spring-summer cycle that is consistent with the rainiest months in the humid tropics where Loma Bonita Oaxaca is located. Acosta (2009) assured that both the creole and synthetic maize have a plant height ranging from 2.2 to 3.2 m, which is in accordance with what was shown with the synthetic variety that exceeded plant hybrids in height.

García (2008) proposed that corn plantings in the Lower Papaloapan Basin region should be carried out from October 15 to November 20 in order to reduce risks of moisture deficit in the most critical stages of corn cultivation that are flowering and filling the grain. The height of the plant as a function of the planting density, in average of genotypes, had a similar behavior in all the genotypes (Table 3), which suggests that the number of plants per hectare did not influence the components of the study yield.

Table 3. Yield in forage of maize genotypes in three planting densities for 20 characters, on average of six genotypes adapted to the humid tropics.

Fv	Dms	Means	Planting density		
			50 000	62 500	83 333
Alp	3.2	181.7	180.2 a	182.1 a	182.8 a
Dfm	0.1	66	66.6 b	66.9 a	64.6 c
Dff	0.1	70.9	71.4 b	71.9 a	69.4 c
Aft	163.1	2939.6	2962.3 a	2778.3 b	3078 a
Dta	0.1	5.2	5.3 a	5.2 a	5.2 a
Nho	0.2	10.3	10.2 a	10.3 a	10.4 a
Hae	0.2	6.7	6.7 a	6.7 a	6.8 a
Epp	0.1	1.1	1.1 a	1.2 a	1 b
Npp	0.3	10.7	10.5 b	10.8 ab	10.9 a
Pho	11.8	145.6	155.2 a	147.2 a	134.5 b
Pet	7.9	95.5	98 a	99.2 a	89.3 b
Peho	16.0	277.8	281.2 a	280.5 a	271.8 a
Pesh	9.4	180.5	183 a	181.2 a	177.3 a
Lel	0.5	17	17.3 a	16.7 b	16.7 b
Delo	0.1	4.5	4.5 a	4.4 a	4.4 a
Nhel	0.4	13.2	12.9 b	13.4 a	13.4 a
Ngh	1.3	31.1	31 a	31.4 a	30.9 a
Nge	20.9	410.28	398.9 b	421.5 a	410.5 a
Pes	0.5	6.5	6.7 a	6.5 a	6.3 a
Ren	1.9	34.1	27 c	33.4 b	41.8 a

Alp= plant height; Dfm= days to male flowering; Dff= days to feminine flowering; Aft= leaf area per plant; Dta= stem diameter; Nho= number of leaves per plant; Hae= number of leaves above the corn; Epp= number of cobs per plant; Npp= knots per plant; Pho= weight of leaves; Pet= weight of stems; Peho= weight of corn with leaves; Pesh= corn fat without leaves; Lel= length of corn; Delo= diameter of corn; Nhel= number of rows per corn; Nhg= number of grains per row; Nge= number of grains per corn; Pes= weight of cobs (g); Ren= forage yield; (t ha^{-1}). Fv= source of variation; Dms= minimum significant difference; abc= averages with different letters in rows are statistically different (Tukey, $p \leq 0.05$).

To obtain reference information on the precocity of the genotypes under study, the days to male and female flowering of the corn crop were estimated, with an average between genotypes of 66 days at male flowering and 70 at female flowering. The hybrid H520 averaged 65.8 days at male flowering and 70.4 days at female flowering (Table 2) confirming that it is a later hybrid. The NH5 hybrid was precocious, presenting 62.6 and 68 days at male and female flowering, respectively (Table 2).

According to Tosquy *et al*. (1995) have registered 52 days at the start of male flowering in the synthetic VS536. In the case of H520 in southeastern Mexico it takes from 54 to 56 days to male flowering with plant heights of 228 cm and an ear height of 139 cm (Sierra *et al*., 2008, Sierra *et al*., 2010). The largest leaf area was obtained with the hybrids H564C (3 122.7 cm^2) and HE1A17 (3 128.1 cm^2) (Table 2). Sierra *et al* (2011) indicated that in the humid tropics the hybrid H-564C presents a good development of the plant, it is associated with outstanding plant characters, suggesting establishing it in spring-summer or autumn-winter. Castro-Nava *et al*. (2014). Estimated in native maize of Tamaulipas during the fall-winter cycle of 2008 and high temperatures a total foliar area of 2 988.3 cm^2 in the town of Güémez and 4 730.7 cm^2 in commercial maize in the town of Rio Bravo.

Considering planting density, the major leaf areas were obtained at densities of 50 000 and 83 333 plants ha^{-1} (Table 3) with values of 2 962.3 and 3 078 cm^2, respectively. This is explained because plants that grow at low densities have less competition for light, water and nutrients forming more vigorous canopies while at higher densities, having a greater number of plants increases their height which increases the leaf area. This information differs from that found by Dwyer and Stewar (1986), who quantified in the cultivation of corn leaf areas of 4 570 cm^2.

The density of 83 333 plants per hectare exceeded forage yield (41.8 t ha^{-1}) at the densities of 50 000 and 62 500 plants ha^{-1} (Table 3). When analyzing the leaf area considering the interaction between genotypes and planting densities. The genotype HE1A17 in the density of 83 333 plants ha^{-1} accumulated the largest leaf area 4 490.2 cm^2 (Table 4).

Table 4. Genotype interaction*density of 20 characters in maize with forage aptitude.

Fv	VS536			DK357		
	50 000	62 500	83 333	50 000	62 500	83 333
Alp	209.9 a	194.5 b	204.7 a	180 b	198.7 a	195.8 a
Dfm	68 a	66.7 b	64.7 c	68 a	64.7 b	61.7 c
Dff	72.7 a	71.7 a	69.3 b	73.3 a	70 b	66.7 c
Aft	3 475.3 a	2 390 c	2 836 b	2 212.5 b	3 455.5 a	3 207.9 a
Dta	5.6 a	4.4 b	5.4 a	4.7 b	5.2 a	4.6 b
Nho	10.8 ab	10.4 b	11 a	10.1 b	10.4 ab	10.5 a
Hae	6.7 b	6.7 b	7.1 a	6.2 b	6.7 a	6.5 a
Epp	1 b	1.1 a	1 a	1.1 a	1.1 a	1 b
Npp	12 a	11.3 b	12 a	10.5 b	10.6 ab	11.1 a
Pho	167.3 a	160.3 a	154.6 a	121 b	152 a	112.1 b
Pet	132.1 a	133.1 a	127.2 a	76.3 b	97.7 a	73.7 b
Peho	308.4 a	279.9 b	303.7 a	253.9 b	294.6 a	226 c
Pesh	192.4 a	174.6 b	188.5 a	178.3 b	212.3 a	167.9 c
Lel	16.8 a	16.3 b	16.4 ab	17.2 a	17.7 a	16.1 b
Delo	4.6 a	4.5 a	4.5 a	4.4 b	4.7 a	4.2 b
Nhel	12.8 a	12.4 b	12.8 a	13.8 b	15.2 a	15 a
Ngh	30.7 a	29 b	30.3 ab	30.8 b	34 a	30.3 b
Nge	391.8 a	360.6 b	387.6 a	422.4 c	516.2 a	449.5 b
Pes	8.3 a	6.7 b	8.3 a	5.3 b	6.5 a	5.1 b
Ren	30.8 c	36.3 b	49.5 a	22.8 b	34.4 a	34.7 a

Alp= plant height; Dfm= days to male flowering; Dff= days to feminine flowering; Aft= leaf area per plant; Dta= stem diameter; Nho= number of leaves per plant; Hae= number of leaves above the corn; Epp= number of cobs per plant; Npp= knots per plant; Pho= weight of leaves; Pet= weight of stems; Peho= weight of corn with leaves; Pesh= corn fat without leaves; Lel= length of corn; Delo= diameter of corn; Nhel= number of rows per corn; Nhg= number of grains per row; Nge= number of grains per corn; Pes= weight of cobs (g); Ren= forage yield; (t ha^{-1}). Fv= source of variation; abc= averages with different letters in rows are statistically different (Tukey, $p \leq 0.05$).

Table 4. Genotype interaction*density of 20 characters in maize with forage aptitude (continuation).

Fv	H520			H564 C		
	50 000	62 500	83 333	50 000	62 500	83 333
Alp	167.9 b	182.8 a	185.5 a	188.7 a	185.2 a	158 b
Dfm	66.5 a	66.6 a	64.3 b	67 c	69.7 a	68.7 b
Dff	70.8 a	71.3 a	69 b	72 b	74 a	73.7 a
Aft	2645.9 a	2840.7 a	2911.5 a	4149 a	3153.6 b	2064.9 c
Dta	4.9 b	5.4 a	4.7 c	6 a	5.8 b	5 c
Nho	10.2 b	10.7 a	10.8 a	10.7 a	10.7 a	9.7 b
Hae	6.8 a	6.7 a	6.8 a	7.1 a	7 a	6.9 b
Epp	1.1 b	1.3 a	1 c	1.4 a	1.3 a	1.1 b
Npp	10.3 b	11.5 a	11.7 a	10.8 b	11.4 a	8.7 c
Pho	131.7 b	157.2 a	130.2 b	184.9 a	191 a	111.2 b
Pet	85.3 b	99 a	82.5 b	125.2 a	127.7 a	67.8 b
Peho	263.9 b	302.6 a	261.3 b	318.7 a	329.7 a	260.5 b
Pesh	174.7 b	189.2 a	172.1 b	197.6 a	205.8 a	172.3 b
Lel	16.6 a	16.5 a	16.1 a	18.3 a	18.3 a	18 a
Delo	4.4 a	4.5 a	4.5 a	4.4 a	4.5 a	4 b
Nhel	12 a	12.3 a	12.2 a	13.7 a	14 a	12.9 b
Ngh	32.6 b	34.1 a	33 b	33.8 a	33.5 a	32.7 a
Nge	387.3 b	421.2 a	402.9 b	460.4 a	466.7 a	422.7 b
Pes	5.7 b	7.6 a	6.2 b	8.1 a	7.8 a	5.3 b
Ren	24.3 c	35.4 b	40 a	31.8 c	41 a	37 b

Alp= plant height; Dfm= days to male flowering; Dff= days to feminine flowering; Aft= leaf area per plant; Dta= stem diameter; Nho= number of leaves per plant; Hae= number of leaves above the corn; Epp= number of cobs per plant; Npp= knots per plant; Pho= weight of leaves; Pet= weight of stems; Peho= weight of corn with leaves; Pesh= corn fat without leaves; Lel= length of corn; Delo= diameter of corn; Nhel= number of rows per corn; Nhg= number of grains per row; Nge= number of grains per corn; Pes= weight of cobs (g); Ren= forage yield; (t ha^{-1}). Fv= source of variation; abc= averages with different letters in rows are statistically different (Tukey, $p \leq 0.05$).

Table 4. Genotype interaction*density of 20 characters in maize with forage aptitude (continuation).

Fv	NH5			HE1A17		
	50 000	62 500	83 333	50 000	62 500	83 333
Alp	171.5 b	167.2 b	178.6 a	163.3 b	164 b	174.2 a
Dfm	62.3 b	63.8 a	61.7 b	68 b	70 a	66.3 c
Dff	67 b	70.4 a	66.7 b	72.7 b	74.3 a	71.3 c
Aft	2950.2 a	2276.1 b	2957.5 a	2340.3 b	2553.8 b	4490.2 a
Dta	5.7 ab	5.6 b	6 a	5.3 a	5.5 a	5.4 a
Nho	10.3 a	10.1 a	10.3 a	9.1 c	9.6 b	10.1 a
Hae	6.8 a	6.9 a	7.1 a	6.4 a	6.1 b	6.4 a
Epp	1.1 a	1.1 a	1 b	1.2 a	1.2 a	1 b

Fv	NH5			HE1A17		
	50 000	62 500	83 333	50 000	62 500	83 333
Npp	10.3 b	10.4 b	10.9 a	9.4 b	9.6 b	10.6 a
Pho	129.9 b	96.2 c	142.6 a	196.7 a	126.5 c	156.4 b
Pet	92.1 a	59.8 b	92.3 a	77.2 a	77.7 a	92.4 a
Peho	295.1 a	227.6 b	295.9 a	246.8 a	248.5 a	283.6 a
Pesh	206.2 a	154.1 c	195.9 b	148.5 a	151.3 a	167 a
Lel	17.8 a	14.8 c	16.4 b	16.9 a	16.6 a	17.1 a
Delo	4.8 a	4.1 b	4.8 a	4.1 b	4.1 b	4.3 a
Nhel	13.2 ab	13.1 b	13.5 a	11.9 b	13.2 a	13.7 a
Ngh	29 b	37.6 a	28.3 b	29.1 a	30.4 a	30.6 a
Nge	380.1 a	361.1 b	382.3 a	351.4 b	403.1 a	417.8 a
Pes	6.4 a	4.6 a	6.4 b	6.3 a	6.0 a	6.4 a
Ren	26.2 b	24.3 b	44.8 a	26.3 b	28.7 b	44.9 a

Alp= plant height; Dfm= days to male flowering; Dff= days to feminine flowering; Aft= leaf area per plant; Dta= stem diameter; Nho= number of leaves per plant; Hae= number of leaves above the corn; Epp= number of cobs per plant; Npp= knots per plant; Pho= weight of leaves; Pet= weight of stems; Peho= weight of corn with leaves; Pesh= corn fat without leaves; Lel= length of corn; Delo= diameter of corn; Nhel= number of rows per corn; Nhg= number of grains per row; Nge= number of grains per corn; Pes= weight of cobs (g); Ren= forage yield; (t ha^{-1}). Fv= source of variation; abc= averages with different letters in rows are statistically different (Tukey, $p \leq 0.05$).

So this genotype is suitable for forage production, which focuses on contributing to animal feed in the region of the Lower Papaloapan Basin, where the production of cattle for meat, milk or dual purpose system is of utmost importance. The hybrid NH5 had the lowest accumulation of leaf area with a value of 2 727.9 cm^2, presenting a plant height of 172.4 cm (Table 2). Camacho *et al*. (1995) assured that the grain yield in maize increases as the leaf area does and the leaf area index is a direct consequence of the total leaf area per plant.

It is noteworthy that in the main components of forage yield such as: plant height, number of leaves per plant, leaf area, number of cobs per plant, weight of bracts of the plant, weight of stem, weight of corn with and without leaves, length and diameter of corn, as well as forage yield showed significant statistical differences ($p \leq 0.05$) between the different genotypes under study (Table 1). This variability is attributed to the different origin of the genotypes studied and to the effort that has been made by producers and breeders, in relation to the characters described. These differences were more evident in the H564C hybrid, which surpassed the rest of the genotypes, including the synthetic VS536, in several of these characters (Table 2).

The hybrid H564C was developed for grain yield; nevertheless, it is a material that showed a very acceptable performance in the humid tropics of Mexico due to its vigor, becoming an option for human and animal feeding (Sierra *et al*., 2008). Note that in the case of the synthetic variety VS536 there was a forage yield of 38.8 t ha^{-1}, which is higher than that obtained with the hybrid H564C (36.6 t ha^{-1}) (Table 2), which even with this yield in fodder surpasses the national yield in forage production estimated at 24.98 t ha^{-1} (SIAP, 2016), the lowest yields in fodder were obtained with the hybrids H520, NH5 and DK357.

The described behavior indicates the wide adaptability that has presented the synthetic VS536 to the diverse conditions of rain, temperature and relative humidity that prevail in the states of Southeast Mexico and that have become an option not only to produce grain, which is the main use that is given to this genotype, but also to produce fodder to feed meat and dairy cattle. For the character forage yield of genotypes considering planting densities, it was found that the synthetic variety VS-536 averaged 49.5 t ha^{-1} in the density of 83 333 plants ha^{-1} (Table 4).

This performance is adequate if one considers that Núñez *et al*. (2001), evaluating maize in the northern region of Mexico, found that forage production in early and intermediate genotypes of tropical and temperate origin under irrigation and in planting densities of 80 to 90 thousand ha^{-1} plants, had forage yields from 52.8 to 75.6 t ha^{-1}, 38.6 to 48.2 t ha^{-1} and 39.0 to 50.3 t ha^{-1}. Planting densities in maize vary according to the production objective, which may be grain, forage or both, and an optimum population density of 39 520 to 98 800 plants ha^{-1} is recommended for forage maize, since in theory the total biomass of forage increases when the density of plants does (Sánchez *et al*., 2013).

The use of high population densities in maize translates into a better use of the land, which together with a large leaf area allow the producer to increase the crop yield per unit area (Reta *et al*., 2000), because photosynthetically active radiation, located at wavelengths of 400 to 700 nm, when it reaches the foliage is better used by the crop (Tinoco *et al*., 2008).

When analyzing the effect of planting density on average of genotypes (Table 3) it was found that in the density of 83 333 plants per ha^{-1} generated a higher precocity reflected as the number of days to male and female flowering, the area increased foliar per plant, number of knots per plant, number of grains per corn and yield in forage per hectare. However, important characters in the production of forage as weight of leaves of the plant, weight of stems, weight of the corn with leaf (bracts), weight of the corn without leaves, length of the corn, number of grains per row and weight of cobs were favored in the planting density of 50 000 plants ha^{-1} (Table 3).

The results derived from the present investigation are explained because the rainfall in the month of October of the year 2012 was of 57.5 mm and in the month of April of 2013 it was of 4.4 mm, presenting therefore a precipitation of 190.7 mm total of the month of October (2012) to April (2013), considering the months in which the present study was carried out, thus the total annual rainfall of 2012 was 1878.9 mm and for 2013 of 1 629.8 mm (FAM, 2015). Quiroz and Douglas (2003) mentioned that high temperatures favor a larger canopy size. Likewise, precipitation and percentage of residual moisture influence the first stages of crop growth.

Conclusions

It was found that there were differences between maize genotypes for twenty studied characters, excelling plant height, foliar area, male and female flowering, number of cobs per plant, length and diameter of corn and yield of forage per hectare. On average three stocking densities the genotypes VS-536 (38.8 t ha^{-1}) and H-564C (36.6 t ha^{-1}) excelled in forage production. The density is sown of 83 333, on average of genotypes of corn, produced the highest yield in forage that was 41.8 t ha^{-1} surpassing the densities of 50 000 and 62 500 plants ha^{-1}. Considering the interaction of genotype by density, a high production of green biomass was observed with the synthetic variety VS-536 (49.5 t ha^{-1}) established at 83 333 plants per hectare.

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