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Article

Characterization of native corns in Tulancingo, Hidalgo

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Abstract

Given the need to propagate productive native corns and preserve *in situ* those from other sites in Mexico, in Tulancingo, Hidalgo, the objective was to assess 23 native Mexican corns in yield, phenology, and characterization of plants and ears of corn in the Highlands of Hidalgo. The sowing was carried out on April 19, 2022, in a completely randomized block design with three replications. Plant height, number of leaves and ears, days to female and male flowering, grain yield, weight of 200 grains, volumetric weight, diameter and length of the ear and number of rows and grains were evaluated. Anova with GLM of SAS and Tukey's test (α= 0.05) were carried out; likewise, a Pearson regression analysis was performed and the Stepwise option of Sas was used to find out which variable is most responsible for yield. The highest grain yield was observed in the genotype from Atlixco, Puebla (6 782 kg ha^{-1}; p< 0.05). The earliest corn were Huitchila and Palomero, with male flowering 75 and 78 days after sowing (das) and female flowering at 80 and 83 das, respectively (p< 0.05). The 200 heaviest corn grains were from Cuetzala, Guerrero with 94.4 g (p< 0.05), whereas the highest volumetric weight occurred in Palomero, 70.7 kg hl^{-1}. Grain yield was influenced by ear diameter by 28% (p< 0.05). The knowledge of native corns in Tulancingo, Hidalgo, allowed the corn from Atlixco, Romita, Tehuacán, Chaltenco, and Huitchila to be highlighted in terms of grain yield.

Keywords:

Zea mays, Ahuehuetitla, flowering in corn, stepwise.

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Introduction

The genotypes of native corn in Mexico have been generated by selection by farmers given each agroecological condition (Vega *et al*., 2022). The evaluation of native corn is important for conserving, characterizing, and providing the basis for genetic improvement (González *et al*., 2013).

The assessment of native corns with desirable potential in an agronomic evaluation allows determining the potential based on their behavior *per se*; in relation to the above, Espinosa *et al*. (2019) evaluated 63 genotypes in two localities in Coahuila, Mexico and reported yields of 6.3 to 8.4 t ha^{-1}, at altitudes of 1 910 m and 1 457 m, respectively; they found eight outstanding corns in each environment.

For their part, Cabrera-Toledo *et al*. (2019) in San José Miahuatlán, Puebla, studied 18 populations of Zapalote chico; the characteristics with the highest descriptive value were ear height, plant height, number of rows, and ear diameter, and they conclude that genetic variability was low between populations of the same altitude.

Given the need to propagate productive corn materials from other sites in Mexico in Tulancingo, Hidalgo, the study aimed to assess and characterize plants of 23 corns in grain yield, phenology, weight of 200 grains, and volumetric weight and also to quantify (%) the influence of these variables in grain yield.

Materials and methods

The research was conducted in Ahuehuetitla, Tulancingo, Hidalgo, Mexico, located at 20° 05’ 04.37” north latitude and 98° 24’ 49.80” west longitude, at an altitude of 2 168 m. The climate is subhumid temperate, with an annual rainfall of 550 mm and an average annual temperature of 16 °C (García, 2004). The soils are vertisols with a clayey texture (INEGI, 2017).

The sowing was carried out on April 19, 2022, and consisted of depositing two seeds per bush at the bottom of the furrow at a depth of 5 cm and 30 cm apart. The sowing land was prepared as follows: plowing, double harrowing, and furrowing with a separation of 0.8 m and separation between genotypes of 2.4 m.

The irrigations were applied on April 19 and 26, May 4, 19, and 26, June 3, 18, and 25, and July 3 and 18, with a 60 cm irrigation sheet. To control weeds, the mixture atrazine + 2,4D-amine was applied at a dose of 1 000 g of each commercial product ha^{-1} 30 days after sowing (das). The formula 120-60-00 was applied with urea and triple super phosphate. Urea was applied 50% at sowing and the rest at 60 das. The corns studied (Table 1) were from different areas of Mexico from the spring-summer 2021 cycle, and the viability of the seeds before sowing was verified according to Álvarez-Vázquez *et al*. (2022); Quero-Carrillo *et al*. (2017) and thus, two viable seeds per plant were deposited.

Table 1. General characteristics of corns evaluated in Ahuehuetitla, Tulancingo de Bravo, Hidalgo, in SS 2022.

Num. material	Code	Color	Locality	Altitude (m)	Municipality	Federal state
1	L1	White	El Abra	2 283	Tulancingo	Hidalgo
2	L2	White	La Lagunilla	2 388	Tulancingo	Hidalgo
3	H1	White	El Canjoy	1 185	San Bartolo Tutotepec	Hidalgo
4	H2	White	San Bartolo	1 430	San Bartolo Tutotepec	Hidalgo
5	HC3	Yellow	Calnalli	1 315	Calnalli	Hidalgo
6	SLP1	White	La Palmita	1 049	Río Verde	San Luis Potosí
7	SLP2	White	La Palmita	1 049	Río Verde	San Luis Potosí
8	SLP3	Black	Pocitos	1 980	Charcas	San Luis Potosí

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Num. material	Code	Color	Locality	Altitude (m)	Municipality	Federal state
9	SLP4	White	Pocitos	1 980	Charcas	San Luis Potosí
10	SLP5	Black	Pocitos	1 980	Charcas	San Luis Potosí
11	P1	Black	San José Miahuatlán	1 105	San José Miahuatlán	Puebla
12	P2	White	San Isidro Tlacxitla	1 966	Tianguismanalco	Puebla
13	P3	White	Rancho Gamboa	1 892	Atlixco	Puebla
14	GS1	Yellow	Apetlanca	1 720	Cuetzala del Progreso	Guerrero
15	GS2	Black	Apetlanca	1 720	Cuetzala del Progreso	Guerrero
16	GH3	Pale yellow	San Francisco Lagunita	692	Cuetzala del Progreso	Guerrero
17	GF4	White	San Francisco Lagunita	665	Cuetzala del Progreso	Guerrero
18	GLS5	White	San Francisco Lagunita	546	Cuetzala del Progreso	Guerrero
19	Palomero	Yellow	Colegio de Postgraduados	2 244	Texcoco	State of México
20	Chaltenco	White	Colegio de Postgraduados	2 244	Texcoco	State of México
21	CMQ	Purple	San Juan del Río	1 925	San Juan del Río	Querétaro
22	Huitchila	Purple	INIFAP Zacatepec	1 187	Zacatepec	Morelos
23	Romita	White	Romita	1 746	Romita	Guanajuato

The study employed a randomized complete block design with three replications. The experimental plots consisted of two furrows 6 m long and 0.8 m wide (9.6 m^2). At 20 das, the population density in each experimental plot was adjusted to 65 000 plants ha^{-1}. At 90 das, 10 representative plants of each genotype were marked and a red and white ribbon was placed on them and measurements were made throughout the experiment. The morphological characterization described by SNICS (2022) was based on the guide for the description of native varieties of corn (*Zea mays* L.).

The variables were: 1) plant height (PH; from ground level to branch apex, cm); 2) ear height (EH; from ground level to the highest ear, cm); 3) number of leaves at 50% anthesis (NL); 4) number of ears per plant (NEP); 5) days to male flowering (DMF; tassel); 6) days to female flowering (DFF; stigma); 7) flower asynchrony between the male and female flowers (FA). Once the ears were harvested, they following was evaluated: 8) grain yield (kg ha^{-1}); 9) weight of 200 grains (g); 10) volumetric weight (hl^{-1}); 11) ear diameter (ED; cm); 12) ear length (EL; cm); 13) number of rows (NR); 14) number of grains per row (NGR) and 15) number of total grains per ear (NGE). For variables 1 to 7, ten plants with full competence were used, whereas for variables 8 to 13, three replications of each block were taken.

The ears were manually harvested on November 20, 2022. Drying was carried out inside a greenhouse, spreading the ears on a double anti-aphid mesh and stirring them every seven days. Once they reached 13% moisture (measured with an LDS-1G® moisture determinator, Beijing, China), 10 ears of each experimental unit were characterized and then manually shelled, and both cobs and grains were weighed on a Truper® 1551 scale.

The grain yield (kg ha^{-1}) per material was determined by cross-multiplication for each experimental plot and block. Subsequently, the grains of each replication were passed through a Boerner-type homogenizer (Seedburo). The volumetric weight (kg hl^{-1}) was calculated by taking 1 L and weighing it on a Truper 1551 digital scale (g). The weight of 200 grains was determined with a Sartorius Entris® digital scale (0.0001 g; Beijing, China). The data on the average, minimum, and maximum monthly temperature, as well as the precipitation were taken from the CONAGUA meteorological station at the La Esperanza Dam, 4 km from the site (Figure 1).

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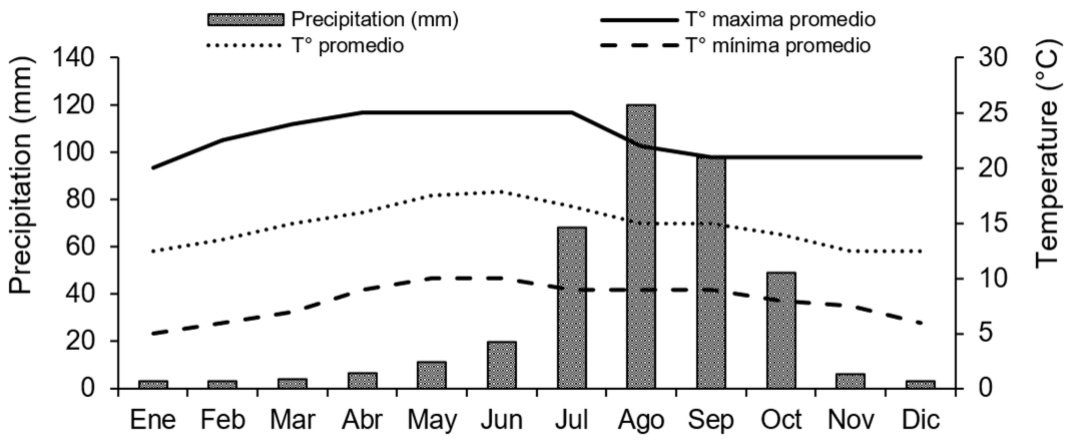
Figure 1. Precipitation and temperatures in Tulancingo, Hidalgo in 2022.



The information was subjected to analysis of variance with GLM of SAS® (2010). The grouping of means was performed with Tukey (α= 0.05). Stepwise of SAS® was also used to determine which ear variable influences yield the most.

A Pearson correlation was performed with the same statistical package to find out if there is a relationship between NL, EH, NE, weight of 200 grains, and volumetric weight with grain yield (α= 0.05).

The multiple regression statistical model was: $Yi= B_0 + B_1 X_1 + B_2 X_2 + B_3 X_3 + B_4 X_4 + B_5 X_5 + B_6 X_6 + \epsilon_i$. Where: Yi = yield; $B_{0,1,2,3,4,5,6}$ = parameters of the regression equation; X_1= independent variables (ear diameter, ear length, grain rows, grains per row, weight of total grains, weight of 200 grains); ϵ_i = random error.

Results and discussion

A difference (p< 0.001) was observed in PH, EH, NL and NEP (Table 2). The genetic materials H2, SLP2, and Chaltenco showed the highest PH, whereas the lowest PH was for Palomero and Huitchila (p< 0.05). No correlation was found between PH and EH (p> 0.05); in large plants, the ear(s) are not higher from the ground level, which differs with Cruz-Lázaro *et al*. (2009) as they observed a linear relationship between older PH and EH.

Table 2. Morphological characteristics and days to flowering of 23 native corns in Ahuehuetitla, Tulancingo, Hidalgo.

Genetic material	Plant height (m)	Plant height from the ground level (m)	Num. of leaves	Num. of ears	Days to male flowering	Days to female flowering	Days of flower asynchrony
L1	3 bcde †	1.65 bcdefg	17 a	1 b	90.2 j	99.1 kl	8.9 fghij
L2	3 bcde	1.59 cdefgh	12 i	1 b	90.6 j	105.8 jk	15.2 bcd
H1	2.9 cdef	1.54 ab	11.9 i	1 b	123.9 a	144.2 a	15.6 bc
H2	3.4 a	1.79 efghij	15.9 bcd	1 b	118.8 b	134.4 b	20.3 a
HC3	3.1 abc	1.84 a	16 abc	1.2 ab	112.9 c	124.7 c	11.8 def

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Genetic material	Plant height (m)	Plant height from the ground level (m)	Num. of leaves	Num. of ears	Days to male flowering	Days to female flowering	Days of flower asynchrony
SLP1	3.3 ab	1.83 a	15.9 bcd	1 b	104.3 ef	125.9 c	18.7 ab
SLP2	3 bcde	1.65 bcdefg	13.9 fg	1.6 a	106.1 de	124.8 c	21.6 a
SLP3	2.5 hi	1.48 hij	16.2 ab	1 b	92.4 ij	108.1 fgh	15.7 bc
SLP4	3.1 bcd	1.66 bcdefg	13.8 gh	1.7 a	107.1 d	116.4 e	9.3 efg
SLP5	-2.8 efg	1.66 bcdefg	16.1 ab	1 b	105.4 de	114.3 e	8.9 fghij
P1	2.4 ij	1.44 hij	12.8 hi	1.4 ab	84.5 k	89.9 l	5.4 ijkl
P2	2.3 ij	1.39 abcde	11.9 i	1 b	111.2 c	120.2 d	9 fghi
P3	2.9 cdef	1.69 jk	12.2 i	1 b	99.4 gh	109.6 fg	10.2 efg
GS1	3.1 abc	1.57 defghij	14 efg	1.2 ab	98.9 h	111 f	12.1 def
GS2	3 bcde	1.66 cdefg	15.6 bcd	1.3 ab	101.6 fgh	121.1 d	19.5 a
GH3	2.9 cdef	1.51 fghij	14 egf	1.2 ab	85.8 k	92.1 l	6.3 hijkl
GF4	3 bcde	1.64 bcdefg	16 abc	1 b	91.4 ij	96.6 k	5.2 jkl
GLS5	2.8 fg	1.5 ghij	15 cde	1 b	92.6 ij	101.5 ij	8.9 fghij
Palomero	2.2 j	1.25 k	12.3 i	1.2 ab	78.3 l	83.1 m	4.8 l
Chaltenco	3.2 abc	1.74 abc	14.9 efg	1.3 ab	93.5 i	107 gh	13.5 cde
CMQ	2.6 gh	1.71 abcd	12.6 i	1.3 ab	101.8 fg	108.9 fg	7.1 ghijk
Huitchila	1.8 k	1.26 k	11.9 i	1 b	75 m	80 n	5 kl
Romita	2.6 gh	1.43 ij	14.9 efg	1.7 a	93.9 i	102.6 i	8.7 fghijk
Average	2.8	1.6	14.2	1.2	98.2	109.6	11.38
MSD	0.239	0.156	1.01	0.554	2.76	2.99	3.7

† = equal lowercase letters by columns are similar averages ($p > 0.05$).

The biggest NL at 50% anthesis was observed in L1, with 17 leaves ($p < 0.05$) and the lowest (with 12.8 leaves) was for P1 ($p < 0.05$), and no correlation was observed between NL with higher grain yield ($p > 0.05$), as reported by Perales and Golicher (2014). The materials with the highest NEP were recorded in SLP4 and Romita (1.7) and they were similar ($p > 0.05$) to SLP2, P1, GS2, GH3, GS1, Palomero, Chaltenco, and CMQ; however, in the analysis of correlation with yield, it had no influence ($p > 0.05$).

Male flowering and female flowering were different ($p < 0.05$) and flower asynchrony was observed from 5 to 22 days (Ángeles-Gaspar *et al*., 2022). The earliest corns were Huitchila and Palomero, with DMF at 75 and 80 das, and DFF at 78.3 and 83.1 das, respectively ($p < 0.05$). FA was observed because there were 40 days between the last irrigation and the rainy season. The genotype with the highest FA was SLP2 at 26 days ($p < 0.05$) and the lowest was Palomero with 5 days.

There was a difference in grain yield in the 23 corn genetic materials evaluated in Tulancingo ($p < 0.05$) (Table 3). The highest grain yield was shown by P3, with 6 782 kg ha^{-1} and it was 1.05, 1.08, 1.13, 1.12, and 1.17 times the grain yield of L2, Romita, P1, Chaltenco, and Huitchila, respectively ($p > 0.05$); L2 (originally from Tulancingo) is among the outstanding materials. Arellano *et al*. (2018) reported 4.3 to 12 t of corn grain in several localities in the state of Mexico and Tlaxcala.

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Table 3. Productive and morphological characteristics of ears and grains of 23 corn genotypes established in Ahuehuetitla, Tulancingo, Hidalgo, Mexico.

Code genotype	Grain yield (kg ha^{-1})	Weight of 200 grains (g)	Volumetric weight (g hl^{-1})	Ear diameter	Ear length	Num. of rows	Grains per row	Total grains per ear
L1	4 323 de †	69.08 ef	61.2 ghi	14.5 bcdefg	11 b	12.9 cdef	22.9 cdef	293 def
L2	6 484 a	83.58 bc	59.6 jk	16 abc	13.3 ab	12.6 cdefg	27.2 abcdef	341 cdef
H1	2 622 i	42.03 jkl	60.2 ijk	12.3 ghi	13.3 ab	10.7 efgh	27.7 abcdef	296 def
H2	3 077 ghi	39.55 lm	61.7 fgh	11.8 i	13.3 ab	10.8 efgh	29.6 abcd	321 def
HC3	3 255 fghi	41.24 klm	66.2 bc	11.9 hi	13.2 ab	10.2 fgh	33.9 a	345 bcdef
SLP1	4 052 de	55.28 hi	60.05 ijk	14.5 bcdef	12.7 ab	12.6 cdefg	23.6 cdef	298 def
SLP2	5 931 de	60.13 hg	61 ghi	16.4 ab	13.8 ab	13.3 cde	29.2 abcd	388 abcd
SLP3	4 138 ef	56.89 hi	64 e	14 cdefgh	11.3 b	13.4 bcde	22.4 def	304 def
SLP4	4 328 ef	66.63efg	60.7 hij	13.99 cdefgh	14.9 a	12.1 cdefg	24.8 bcdef	303 def
SLP5	4 258 efg	48.75 jkl	66.8 b	13 fghi	13 ab	12.1 cdefg	26.2 abcdef	316 def
P1	6 007 abc	80.96 cd	62.6 fgh	16.3 ab	13.2 ab	11.9 cdefg	25.1 bcdef	298 def
P2	4 084 ef	49.74 ijk	61.6 fghi	13.3 defghi	12.7 ab	13.1 cdef	28.4 abcde	371 bcd
P3	6 782 a	60.02 hg	64.7 f	15.1 abcde	13.3 ab	14.4 bc	31.9 ab	461 abc
GS1	3 402 efghi	72.66 de	61.9 gf	13.9 cdefghi	12.9 ab	11.2 defg	20.7 ef	231 fg
GS2	5 455 bc	94.49 a	64.1 e	14.3 bcdefg	12.9 ab	10.1 fgh	22.1 def	224 fg
GH3	5 157 cd	50.92 ij	65.3 bcd	15.9 abc	11.7 b	17.9 a	26.1 abcdef	470 ab
GF4	3 900 efg	70.34 ef	57 i	17.2 a	13.4 ab	13.7 bcde	24.8 bcdef	334 cdef
GLS5	2 703 i	62.94 fgh	56.3 i	15.4 abcde	11.8 b	14.1 bcd	26 abcdef	359 bcde
Palomero	3 813 efgh	32.39 m	70.7 a	13.3 efghi	12.1 ab	16.5 ab	30.8 abc	511 a
Chaltenco	6 067 abc	82.74 c	62.5 f	15.5 abcd	13.8 ab	12.4 cdefg	26.1 abcdef	325 def
CMQ	2 828 hi	89.73 abc	53.8 m	13 fghi	12.8 ab	8.3 h	19.8 f	163 g
Huitchila	5 801 abc	92.33 ab	59.3 k	15.5 abcd	12.4 ab	9.6 gh	24.9 bcdef	242 efg
Romita	6 305 ab	61.65 fgh	61.1 ghi	15.7 abc	13.4 ab	14 bcd	27 abcdef	378 bcd
Average	4 555	63.66	61.9	14.5	12.9	13	26	329
MSD	991	8.94	1.16	2.2	2.95	3.09	7.9	127.1

† Literals with equal lowercase letters per column are similar averages (p> 0.05).

According to Espinosa *et al*. (2019), the yield of corn grain responds differently in contrasting environments due to its wide intra-population genetic variation and good behavior *per se*. Regarding the weight of 200 grains, the highest value was observed in GS2 (94.4 mg) and it was similar to CMQ and Huitchila (p> 0.05), whereas the lowest value occurred for SLP1 and SLP2, with 55.28 and 56.89 mg, respectively. Therefore, Velasco *et al*. (2022) found no relationship between the weight of 200 grains and higher yield; they attributed the higher yield to more ears per plant.

Likewise, Aguilar-Carpio *et al*. (2022) reported 41 g in 100 grains (range of this study) and attributed weight to higher nutrition with N. The highest volumetric weight was observed in Palomero (70.6 kg hl^{-1}; p< 0.05) and the lowest in CMQ (53.8 kg hl^{-1}; p< 0.05); this variable is not correlated with higher yield (p> 0.05), an effect that was related by Velasco *et al*. (2022), which happened in Palomero. According to Widholm *et al*. (2014), the filling of mealy and vitreous endosperm depends on climatic conditions and nutrition.

The highest ED was observed in GF4 (17.2 cm; p< 0.05), but it was similar (p> 0.05) to L2, SLP2, P1, P3, GH3, GLS5, Chaltenco, Huitchila, and Romita; however, the ED of GF4 was 1.08, 1.05, 1.06, 1.08, 1.12, 1.1, 1.11, 1.1 and 1.09 times the ED of the aforementioned genotypes, respectively (p> 0.05), whereas the lowest ED was observed in H2 (11.8 cm).

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The EL was higher in SLP4 (14.8 cm), and the lowest values were in L1, SLP3, GH3 and GLS5, 11.0, 11.3, 11.7, 11.8 respectively ($p > 0.05$). Therefore, Cabrera-Toledo *et al*. (2019) comment that EL and ED have been desirable characteristics that producers have selected for decades since each agroecological site rotates corns due to their productivity in grain or forage (Sánchez-Hernández *et al*., 2021; Hortelano *et al*., 2012); nevertheless, native corns lodge during strong winds and machinery cannot ensilage (Rodríguez Ortega *et al*., 2024).

In the analysis of variance of the stepwise regression for ear variables, the parameters of the independent variables are different ($p < 0.0001$) with $R^2 = 40.6\%$; the variation in grain yield is explained by the model, this percentage can be considered acceptable and confirms the genetic diversity of the 23 native corns.

The influence of ED was 28%, whereas that of NGE and weight of 200 grains was 34%. The prediction equation obtained for grain yield is: y= -2135.77 + 203.96 (diameter) + 4.92 (total grains) + 33.31 (weight of 200 grains). The yield was partly explained by ED, NGE, and weight of 200 grains ($p < 0.0001$). On the other hand, EL, NH NR, and NGR were not important explanatory variables.

Evaluating native corn genetic materials from other sites in Tulancingo made it possible to select and conserve germplasm for future generations. Sánchez-Hernández *et al*. (2021) evaluated native corns from Loma Bonita, Oaxaca, Mexico, and found that native corns outperformed the control in PH, leaf area, stem diameter, and forage, and according to González-Martínez *et al*. (2020), the morphological, phenological, and variability characters of ear support morphological variability, as occurred in this study.

Conclusions

In the assessment of 23 corn genotypes in Tulancingo, Hidalgo, corn from Rancho Gamboa-Atlixco, Huitchila, La Lagunilla, and Romita stands out for grain yield. The yield is influenced by ear diameter by 28%, whereas the number of total grains and weight of 200 grains explain 34%.

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