Article

Behavior of mestizos of corn in three localities of the center of Mexico

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Abstract

To find out if there are useful alleles in native maize for use in a new hybridization program, 52 mestizos trained with 26 collections from the states of Mexico and Tlaxcala and two simple crosses from CIMMYT (CML246xCML242) and (CML457xCML459) were evaluated. They were included as controls to H-40, three experimental hybrid and both testers. The genetic material was evaluated in the field in a series of experiments in randomized complete blocks with two repetitions per site. The grain yield (REND), initial vigor (VIG), male flowering (DFM) and feminine (DFF), plant height (ALP) and cob (ALM), plant (ASP) and cob (ASM) aspects were recorded and percentages of lodging (PACA), tillering (PHI), cob rot (PMP) and twin plants (PPC). For treatments, highly significant differences were determined in all the variables. Among females, there were highly significant differences for most of the variables, indicating that the average behavior of each mestizo was largely due to the genetic contribution of one or the other of these. Among creoles there were highly significant differences in all the variables, except in ASP and PACA, so the native maize had a different behavior in their respective mestizos and there is genetic diversity among them that can be used in a new breeding program based on hybridization. The native maizes that formed the mestizos with the highest yield of grain were 22, 21, 9, 14, 20 and 26. Other important characteristics were percentages of lodging and cob rot.

Keywords: *Zea mays* L., Central Mexican Plateau, crosses line x tester, native maize, outstanding mestizos.

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Introduction

Mexico is considered a center of origin and diversification of maize (*Zea mays* L.) (Sánchez *et al*., 2000; Márquez, 2008; Kato *et al*., 2009). As part of the work on taxonomic classification initiated by Wellhausen *et al*. (1951) and continued by Ortega *et al*. (1991) and Sánchez *et al*. (2000), the 59 races have been defined. The indigenous Mexicans from the teosinte (*Zea mays* spp. *mexicana*) began the selection of plants that offered grain characteristics that could be used as food (Márquez, 2008).

By forming breeds and recombining them they diversified the reservoir of genes that have given rise to millions of landraces. However, few breeds have been used in breeding programs for hybridization (Ramírez *et al*., 2015), perhaps because their use is complex and is determined by multiple factors, such as genetic, environmental, agronomic management, technological packages and their interactions and associations that give rise to each race acquired its own characteristics that differ from others when estimating their means, variances and combining ability, among others. In contrast, most of the native maize have undesirable characteristics, such as plant heights and excessive cob, high susceptibility to lodging, susceptibility to pests and cob rot.

In grain production, early cultivars yield less than late cultivars. In the country in 2013, 7 487 399 ha were planted and 7 095 629 ha were harvested, with a production of 22 663 953 t (3.1 t ha^{-1}). In irrigation the yield of grain was of 7.5 t ha^{-1} and in temporal of 2.2 t ha^{-1}, but only 25% is sowing with improved seed, in High Valley (more than 2 100 only 6% is used (Tadeo *et al*., 2015).

Improved varieties could have a greater productive potential and more profitability in favorable areas; its lower use could be attributed to: a) poor adaptation to the numerous agroecosystems; b) higher cost, poor distribution, technological packages that demand more inputs; and c) the perception of greater economic risk. All these factors are more evident in rainfed or temporary regions, since they are unattractive areas for seed companies (Trejo *et al*., 2004). Therefore, maize has been selected by the environment and by man, resulting in genetic differences that are shown at the level of local farming systems, as a result of the pressure of four factors: 1) ecological pressure: climate, soil and probably quality and quantity of light; 2) physiological pressure: the period of growth of the varieties is especially important for farmers; 3) preference for certain culinary characteristics; and 4) selection based on metaphysical concepts (Gil, 1995).

The creole maize is therefore of patrimonial and strategic nature, recognizing them as living regional genetic systems, or biocentric communities like the milpas, in uninterrupted reproduction, that have been and are recreated in each agricultural cycle and accompanied by diverse species of economic and social interest. From the genetic point of view, for some years there have been works focused on the study and knowledge of the enormous genetic diversity and the possible heterosis that exists between breeds (Bucio, 1959; Paterniani and Lonnquist, 1963; Crossa *et al*., 1990; Barrera *et al*., 2005; Esquivel, 2011).

Some recent efforts for the improvement of native maize are those proposed by Márquez (1990) with the backcross limited method; which was used to improve 50 maize breeds (Márquez *et al*., 1999). Barrera *et al*. (2005) when studying diallel crossbreeds of 10 breeds improved by the method of backcross limited found a reduction in combinatorial aptitude, cob types had more similarity with the donor than the racial type due to the low selection. Romero *et al*. (2005) and Esquivel *et al*. (2011) found that within the Chalqueño race there is diversity and heterosis.

Navas *et al*. (1992) and Carrera and Cervantes (2006) identified tropical interracial crosses adapted to the High Valleys with performance similar to that of commercial hybrids. In the case of the corn genetic improvement program of High Valley of the National Institute of Forestry, Agriculture and Livestock Research (INIFAP, for its acronym in Spanish), the usefulness of local native maize as a source of new alleles in genetic improvement has not been proven. The main objective of this study was to analyze 26 varieties collected in the States of Mexico and Tlaxcala, used as males in the formation of mestizos, considering their grain yield and other agronomic characteristics.

Materials and methods

Description of the study area

This research was carried out in the spring-summer of 2014 in the rainstorm and tip of irrigation in three locations in central Mexico (Table 1).

Table 1. Description of the sites.

Location and state	Location	Climate-rain	Soil
Coatlinchan, Mexico (Santa Lucía)	19° 49’ 05’’ 99° 06’ 39’’ 2 262 masl	mean= 15.7 ºC min= 6.7 ºC max= 24.8 ºC 539 mm	Volcanic, ash between 40 and 60 cm. Textures franc to loamy-clayey. (Magaña and Juárez, 2003).
Zumpango, Mexico	19° 47’ 49’’ 99° 05’ 57’’ 2 261 masl	mean= 14.8 ºC min= -2.3 ºC max= 31 ºC 600-800 mm	Sediments of alluvium and lacustrine deposits (Ramírez, 1999).
Metepec, Mexico	19° 15’ 0.0’’ 99° 36’ 10’’ 2 670 masl	mean= 14 ºC min= 3.5 ºC max= 28 ºC 800 a 1 000 mm	Phaeozem, háplico, luvico or leutric cambisol (Castro, 999).

Genetic material

The 58 treatments were considered: 52 mestizos, two crosses of the International Center of Maize and Wheat (CIMMYT, for its acronym in Spanish) (CML246xCML242 and CML457xCML459) and H-40, H-57E, H-76E, H-77E (Table 2).

Table 2. List of Creoles collected.

No.	Name	Municipality	State	Altitude (m)	North latitude	West longitude
1	ICAMEX M-10	Metepec	Mexico	2 632	19°15’33.16”	99°36’33.53”
2	Avanza B-26	Metepec	Mexico	2 632	19°15’33.16”	99°36’33.53”
3	Creole Tlacotepec	Toluca	Mexico	2 820	19°13’41.69”	99°40’01.49”
4	San Pedro of the Baños	Ixtlahuaca	Mexico	2 540	19°39’47.63”	99°49’55.05”
5	Creole Blanco Tlaxcala	Muñoz of Domingo Arenas	Tlaxcala	2 480	19°28’25.28”	98°12’18.32”
6	Creole Texhuaca	Ozumba	Mexico	2 367	19°02’58.93”	98°47’48.03”
7	Creole The Lomas	Ozumba	Mexico	2 360	19°02’58.93”	98°47'48.03”
8	Creole San Joaquin	Ixtlahuaca	Mexico	2 552	19°33’38.94”	99°45’17.48”
9	Creole Estabilizado	Atlacomulco	Mexico	2 534	19°47’24.65”	99°51’54.75”
10	San Juan Tezontla	Texcoco	Mexico	2 335	19°32’36.54”	98°48’50.15”
11	The Presita Nexini	Jiquipilco	Mexico	2 590	19°40'24.63”	99°40’30.57”
12	Santiago Tepopula	Tenago of Aire	Mexico	2 430	19°08’30.9”	98°51’26.25”
13	Juchitepec	Juchitepec	Mexico	2 539	19°06’02.35”	98°52’43.86”
14	Juchitepec	Juchitepec	Mexico	2 527	19°05’45.42”	98°52’49.18”
15	Huhuecalco, Mexico	Amecameca	Mexico	2 509	19°05’28.83”	98°45’58.98”
16	Huhuecalco, Mexico	Amecameca	Mexico	2 515	19°05’36.43”	98°45’48.25”
17	San Francisco Tetlanocan	San Francisco Tetlanocan	Tlaxcala	2 445	19°15’38.61”	98°09’38.80”
18	Creole Campeón	San Jose Teacalco	Tlaxcala	2 607	19°20’14”	98°03’51.36"
19	Creole Chalco	San Jose Teacalco	Tlaxcala	2 616	19°20’10.29”	98°03’44.79”
20	Creole Tochapa	The Magdalena Talteluco	Tlaxcala	2 326	19°16’41.24”	98°11’49.08”
21	Creole Pilares	San Jose Teacalco	Tlaxcala	2 607	19°20’14”	98°03’51.36”
22	Creole H-33	San Jose Teacalco	Tlaxcala	2 607	19°20’14”	98°03’51.36”
23	Creole Obregón	Españita	Tlaxcala	2 705	19°27’48.69”	98°28’20.22”
24	Creole Monte Alto	Ixtacuixtla of Mariano Matamoros	Tlaxcala	2 430	19°20’49.24”	98°25’38.08”
25	VS-22	INIFAP	Mexico	2 260	19°26’44.74”	98°54’01.43”
26	V-23	INIFAP	Mexico	2 260	19°26’44.74”	98°54’01.43”

Experimental design and size of the plot

The 58 treatments were evaluated in the field in a series of experiments in randomized complete blocks with two repetitions per site. The useful plot consisted of two rows of 5 m in length and 0.8 m in width (8 m^2).

Conduction of experiments

Land preparation, sowing, fertilization and cultural work were carried out in accordance with the technical recommendations of the INIFAP, in 75 000 plants per hectare. Chemical weed control was done at planting and after the second work. The trials were planted on April 30 in Metepec, on May 12 in Zumpango and on June 13, 2014 in Coatlinchan. Irrigation tip was used in Zumpango and Texcoco and in Metepec it was made with residual humidity. The harvest of the biological material was made when it reached physiological maturity.

Data register

The quantified characters were grain yield (REND, kg ha^{-1}, all cobs of the useful plot were weighed and yields were corrected by shelling and moisture (14%) and multiplied by a conversion factor), male and female blooms female (DFM and DFF, days from planting until 50% of the plants in each plot released pollen or emitted stigmas), plant and cob heights (ALP and ALM, average distance of five plants, measured in cm, from the surface from soil to the base of the spike or knot of the cob), aspects of plant and cob (ASP and ASM, visual quality of stem, plant and cob on a scale of 1 to 5: 1 is better and 5 worse), total lodging (PACA, (%) of plants with root and stem lodging), percentages of plants with poor coverage, children, rotten cobs and plants with two cobs (PMC, PHI, PMP and PPC).

Statistical analysis

The data were subjected to a combined analysis of variance and the comparison of means between sites and between treatments was performed with the Tukey test at the significance level of 0.05 (Martinez, 1988). The outputs were obtained with the System for Statistical Analysis or Statistical Analysis System (SAS) version 9.2 for Windows. The program for SAS was prepared by Dr. Fernando Castillo González, professor and researcher of the Postgraduate School-Mexico.

Results and discussion

The localities differed statistically (p= 0.05 or 0.01) in REND, VIG, DFM, DFF, ALP, ALM, PMZ, ASM, PACA, PMC and PPC. This fact underscores the importance of evaluating the genetic material in contrasting sites in rainfall, temperatures and soils (Table 1) to identify the best. González *et al*. (2008); Reynoso *et al*. (2014); Torres *et al*. (2011, 2017) have recognized that in the Central Valley of Mexico, environmental heterogeneity is closely related mainly to differences in altitude, climate and soil.

The significant effects that were observed between treatments (p= 0.01) for all the variables is explained by the differences that existed between mestizos and between hybrids (Table 3). This fact is related to the genetic and geographic diversity of the germplasm available for this region of Mexico. The creoles were collected in the states of Mexico and Tlaxcala, the females of CIMMYT have sources of alleles different from that of the creole, and the hybrids have germplasm from CIMMYT and INIFAP, the latter derived from the Conic and Chalqueño breeds (Table 2). Castellanos *et al*. (1998) evaluated 21 maize lines with seven testers and concluded that simple crosses were the best alternative in plant breeding programs aimed at generating superior trilinear hybrids.

Table 3. Mean squares and statistical significance of the F values.

FV	GL	REND	VIG	DFM	DFF	ALP	ALM	PMZ
Locations (L)	2	21872827*	36.03*	24399.63**	25026.97**	80840.48**	47337**	0.05**
Repetitions/L	3	1546702	2.14	11.82	16.37	1183	262	0.0006
Treatments (T)	57	2996018**	0.98**	40.18**	51.52**	831.15**	592**	0.002**
Crosses (C)	51	2287905**	0.78**	36.1**	48.1**	578.3**	431**	0.001 ns
Females (H)	1	6365033**	8.01**	137.33**	31.41 ns	58.76 ns	1014**	0.011**
Males (M)	25	2661358**	0.66**	62.3**	75.23**	1053.52**	745**	0.001**
H∗M	25	1244565**	0.61**	5.86*	21.64 ns	123.86 ns	94 ns	0.001 ns
Hybrids (HI)	5	4697337**	1**	65.2**	57.1**	104.5 ns	241*	0.004**
C *vs* HI	1	30603194**	10.7**	122.4**	197.8**	17359.7**	10538 **	0.013**
T x L	114	2996018**	0.29 ns	6.48**	14.74 ns	207.34*	124 ns	0.0007 ns
C x L	102	1736383**	0.28ns	5**	14.8 ns	192*	114 ns	0.0007 ns
H x L	2	1854278**	0.69 ns	33.06**	21.7 ns	1462.62**	732**	0.002 ns
M x L	50	1982235**	0.3 ns	5.18**	18.32 ns	203.34*	127 ns	0.0008 ns
H x M x L	50	1255605**	0.24 ns	3.88 ns	11.11 ns	130.01 ns	75 ns	0.0005 ns
HI x L	10	5409005**	0.38 ns	21.8**	15.9ns	243 ns	91 ns	0.0007 ns
C *vs* HI x L	2	1542209*	0.32 ns	0.26 ns	3.1 ns	806.8**	823**	0.004**
Combined error	171	376632	0.24	2.96	13.55	143.56	95	0.0008
CV		9.21	29.89	1.93	4.07	4.61	6.74	5.34

FV= source of variation; GL= degrees of freedom; REND= grain yield; VIG= initial vigor; DFM and DFF= male and female blooms; ALP and ALM= plant and cob heights; PMZ= cob position; *, **= significant at 0.05 or 0.01.

Table 3. Mean squares and statistical significance of the F values (continuation).

FV	GL	ASP	ASM	PACA	PMC	PHI	PMP	PPC
Locations (L)	2	5.86 ns	12.46*	11968.91*	1092.24*	13.69 ns	2479*	2829.23**
Repetitions/L	3	1.47	0.83	547.92	68.31	13.36	120.82	40.01
Treatments (T)	57	1.97**	0.99**	241.18**	121.51**	22.03**	218.68**	96.97**
Crosses (C)	51	1.6**	0.78*	228.5**	125.5**	23.1**	189.9**	59.2**
Females (H)	1	39.13**	0.13 ns	5517.46**	1168.74**	444.25**	1875.57**	324.31**
Males (M)	25	0.97 ns	1.11**	137 ns	130.29**	19.78**	238.69**	73.47**
H∗M	25	0.72 ns	0.47 ns	108.52 ns	79.01*	9.69 ns	73.71 ns	34.36**
Hybrids (HI)	5	3.6**	0.6 ns	136.7 ns	80.8 ns	3.4 ns	258.6**	425.9**
C *vs* HI	1	12.7 ns	13.9**	1407.9**	121 ns	57.6*	1486.2**	377.9**

FV	GL	ASP	ASM	PACA	PMC	PHI	PMP	PPC
T x L	114	0.63 ns	0.75*	131.28 ns	56.76 ns	13.2*	133.7**	56.64**
C x L	102	0.6 ns	0.74*	128 ns	57.4 ns	13 ns	113.2**	33.63**
H x L	2	1.34 ns	5.76**	1668.63**	18.42 ns	31.43 ns	1271.63**	103.55**
M x L	50	0.65 ns	0.78*	116.31 ns	76.57*	13.05 ns	106.6**	40.01**
H x M x L	50	0.57 ns	0.51 ns	78.19 ns	39.95 ns	12.25 ns	73.61*	24.46*
HI x L	10	0.7 8ns	0.9 ns	82.1 ns	38.8 ns	13.4 ns	298.1**	252.8**
C *vs* HI x L	2	0.46 ns	0.22 ns	541.6**	109.8 ns	21.7 ns	353.6**	249**
Combined error	171	0.65	0.51	111.43	47.43	10	46.59	16.47
CV		27.5	24.54	90.38	75.29	74.58	51.54	63.05

FV= source of variation; GL= degrees of freedom; ASP and ASM= aspects of plant and cob; PACA= total lodging; PMC= plants with poor coverage; PHI= percentage of children; PMP, rotten cobs; PPC= plants twin; *, **= significant at 0.05 or 0.01.

The interaction treatments x localities were significant in REND, DFM, ALP, ASM, PHI, PMP, PPC. Hallauer and Miranda (1998); Márquez (1988) emphasized that this type of quantitative characteristics has greater interaction with localities, so it is difficult to identify outstanding materials due to the differential relative behavior they show in contrasting environments and, additionally, has strong implications for programs of plant breeding, generation, validation, application or transfer of technology, as well as seed production programs (González *et al*., 2008; Reynoso *et al*., 2014; Torres *et al*., 2011, 2017).

On the other hand, it stands out the greater phenotypic stability that the treatments showed in the rest of the variables evaluated. In the other interactions a similar trend was observed but grain production was always unstable, perhaps because it is the quantitative characteristic that, when registered shortly after harvest, is affected by all environmental factors that predominated during the crop cycle and, as a consequence of the effect that these also have on the primary components of yield, such as the dimensions of plant and cob (González *et al*., 2008).

The 26 males were stable in ASP and PACA, but in the interaction of these with the localities they were unstable in 50% of the evaluated characteristics (Table 3). These results are similar to those observed by (Mosa *et al*., 2008; Mosa, 2010; Habliza and Khalifa, 2015) and could be related to the greater genetic variability that exists within them, which provides greater ecological plasticity through contrasting sites, compared to hybrids formed from inbred lines (González *et al*., 2008). These results also suggest that there is a fraction of the material that is outstanding, susceptible to self-fertilization to derive new lines and initiate another genetic improvement program to increase grain yield (Carrera and Cervantes, 2002; Mosa, 2010; Ramírez *et al*., 2015).

The yields through the experiments varied from 6 174 to 7 005 kg ha^{-1}. Metepec was the best place to evaluate treatments. This fact is related mainly to the best phenotypic expression observed in VIG, DFM, DFF, ASP, ASM, PACA, PHI, and PPC (Table 4), which can be explained by the climatological, edaphic and favorable altitudinal characteristics shown in the Table 1. González *et al*. (2008) recorded grain yields in Metepec of 7.48 t ha^{-1} and Torres *et al*. (2017) of only 3.4 t ha^{-1}.

Table 4. Comparison of means between sites (Tukey, *p* = 0.05).

Site	REND	VIG	DFM	DFF	ALP	ALM	PMZ	ASP	ASM	PACA	PMC	PHI	PMP	PPC
1	7005.7a	2.3a	105.5a	107a	245b	136.1b	0.55b	3a	3.2a	21.5a	6.6b	4.62a	18.2a	12.1a
2	6807.5ab	1.2b	82.5b	84.36b	243.3b	130.2b	0.53c	3.1a	2.6b	1.2b	12.6a	4.1a	9b	4.1b
3	6174.3b	1.4b	78.6c	79.4c	289.9a	167.8a	0.58a	2.6a	2.8ab	12.1ab	8.19ab	3.9a	12.5b	3.1b
$DSH_{(0.05)}$	682.4	0.8	1.9	2.2	18.9	8.9	0.01	0.7	0.5	12.8	4.5	1.9	6	3.5

Values with the same letter within columns are statistically similar. REND= grain yield; VIG= initial vigor; DFM and DFF= male and female blooms; ALP and ALM= plant and cob heights; PMZ= cob position; ASP and ASM= aspects of plant and cob; PACA= total lodging; PMC= plants with poor coverage; PHI, percentage of children; PMP= rotten cobs; PPC= plants twin; 1= Metepec; 2= Zumpango; 3= Santa Lucía.

The best materials were H-40 and H-76E (8797 and 8095 kg ha^{-1}, Table 5), which was to be expected since both hybrids were previously selected for high yield and better agronomic characteristics. In other studies, carried out in central Mexico, it was observed that H-40 planted at the point of irrigation, residual humidity and favorable temporary humidity yielded 7.36, 7.15 and 7 t ha^{-1}, respectively (Velázquez *et al*., 2005). González *et al*. (2008) evaluated creole from the Palomero Toluqueño, Cacahuacintle, Conic and Chalqueño breeds and commercial hybrids in four Toluca-Atlacomulco Valley locations and concluded that H-40 produced 7.78 t ha^{-1}.

Table 5. Comparison of treatment means.

TRAT	REND	VIG	DFM	DFF	ALP	ALM	PMZ	ASP	ASM	PACA	PMC	PHI	PMP	PPC
H-40	8797	2.5	87.2	88.2	242	136.5	0.6	1.9	1.9	5.6	6.9	3.1	2.4	9.4
H-76E	8095.4	2	83.3	84	233.4	130.1	0.6	2	2.4	3.1	14.1	4	3.4	4.2
19	7816.2	1.3	87.7	89.3	266	157.4	0.6	2.5	2.3	10.6	6.4	4.4	8.8	2.8
20	7755.2	1.3	90.3	91.8	264.8	150	0.6	3	2.3	9.1	4.5	7.1	11.7	6.8
46	7715.9	1.7	93.7	95.5	278.9	157.5	0.6	3.4	2.8	26.8	6	3.9	8.7	7.6
H-77E	7628.1	1.5	83	84.8	239	131.8	0.6	2.3	2.4	2.4	6	3.6	1.7	10.1
45	7413.5	1.7	90	92	269.1	150.5	0.6	3.3	2.5	13.6	15	2.4	7.9	5.5
H-57E	7328.1	2	88.7	88.7	233.5	126.1	0.5	3.8	2.1	15.1	8.8	1.8	5.2	2.5
37	7283.6	1.3	90.7	92.7	265.7	144.8	0.5	3.3	3	23.6	14.9	3.2	10.1	2.3
34	7215.2	1.3	90.3	92.2	269.6	152.5	0.6	3.3	3.2	18.8	14.3	3.6	8.2	8.7
Prob. 1	7183.1	2.5	90.3	91.3	242.6	128.8	0.5	1.7	2.3	3	5	2.9	12.1	5.3
12	7148.9	1.8	90.3	91.8	268.4	151.6	0.6	2.8	3.2	7.9	4.5	4.3	12.6	2.5
5	7066.9	2	86.3	86.7	261.3	146.8	0.6	3.1	2.9	7.6	10.6	4.5	16.1	8.9
30	7007.2	1	88.3	90	258.6	144.4	0.6	3.2	3.3	9.8	12.1	2.4	14.7	7
18	6997.5	1.5	87.3	88.8	249.8	140.5	0.6	1.9	2.8	5.4	6.4	3.9	13.7	4.1
49	6978.4	1.5	87	88.7	251	138.4	0.6	2.8	3	23.6	12.2	2.6	13.8	7.7
13	6972	1.3	90.3	91.7	273.5	157.8	0.6	2.5	3.2	3	3.1	4	22	4.6
8	6954.1	1.7	87.3	89.3	266.3	146.2	0.6	2.2	3	4.6	7.2	4.4	11.6	8.1
27	6903	1.2	85.7	86.7	247.1	133.6	0.5	3.5	2.8	15.5	14.1	2.7	8.9	7.4

TRAT	REND	VIG	DFM	DFF	ALP	ALM	PMZ	ASP	ASM	PACA	PMC	PHI	PMP	PPC
32	6864.8	1.3	91.2	92.7	272.9	156.1	0.6	3.5	2.7	15	6.8	2.7	14.2	6.9
17	6839.7	1.5	92.3	94	275.5	160.7	0.6	2	2.9	9.1	3.1	8.7	24	6
50	6827.9	1.3	89.7	90.3	249.9	141.1	0.6	3.2	3	11.1	12.8	1	8.8	12.7
40	6821.1	1.8	91.7	93.3	265.6	147.6	0.6	3.3	2.8	20.3	11	7.5	14	12.6
33	6820.7	1.2	91	92.3	265.5	148.9	0.6	3.3	2.8	15.8	3.2	1	13.6	3.4
6	6813.9	2.3	90.5	92.7	266.9	154.4	0.6	2.7	2.8	8.7	4	8.1	15.6	4.8
29	6791.9	1	88.7	80.5	254.8	144.3	0.6	3	3.5	10.3	13.1	2.2	15.2	3.8
9	6781.5	2	90.2	91.8	260.4	144.1	0.6	2.4	2.7	6.5	7	5	13.9	7.2
23	6755.3	1.5	85.7	87.5	257.1	145.7	0.6	3.2	2.7	10	9.6	4.6	13.7	1.8
39	6755.2	1.7	91.7	93.3	267.5	148.2	0.6	3.7	3	10.1	6.7	2.7	12.9	6.8
44	6736.4	1	88.8	90.3	259	141.6	0.5	3.7	2.8	20	8.6	4	13.8	5.2
42	6693.7	1.2	91.8	93.7	275.4	151.7	0.6	3.3	3.2	19.8	27.2	2.3	20.1	3.4
43	6692.8	1.2	92.2	93.2	282	158.9	0.6	2.8	2.7	15.5	4.1	5.7	11.5	5.2
47	6593.1	1.3	90.3	91.7	263.6	150	0.6	2.7	2.8	13.9	11.3	4.4	12.3	11.3
26	6577.0	1.8	85.3	87	251.3	142.2	0.6	2.3	2.5	5.1	12	3.4	7.5	8
1	6518.3	1.5	84.7	86	254.4	140.2	0.6	3.3	2.3	17.4	7.4	4.2	8.4	6.1
41	6506.2	1.8	92.3	94	269.3	155.1	0.6	3.7	3.3	22.9	16.7	3.4	17.7	5.9
38	6480	2.2	92.7	93.8	267.1	146	0.5	2.8	3.2	14.7	12.4	3.6	15.1	6.5
16	6431.1	2.3	91.3	93.3	279.5	163.7	0.6	3	2.3	8.1	5	5.4	22.2	2.1
24	6387	2.2	88.5	90.7	254	138.4	0.5	2.3	2.8	9.9	9.2	7.4	12.5	3.6
22	6359.8	1.7	90.7	92.3	260.8	146.7	0.6	3	3	18.2	7.3	8.5	20.4	5.3
28	6347.4	1.5	85.5	87	254.8	129.6	0.5	3.5	3	10.3	8.4	3.8	11.2	7.2
31	6326.4	1.3	91.5	92.8	259.3	149.6	0.6	3.7	2.7	14.5	6	2.3	7.6	3.4
48	6312	1.3	91	92.7	255.3	139.7	0.5	4.3	3	21.3	8.2	3.8	10.8	4
35	6298.3	2.2	90.5	91	251	133.8	0.5	3	3.2	9.7	6.2	3.9	8.3	10.5
Prob. 2	6181.3	2.5	90.3	91.2	241.1	117.6	0.5	2.5	2.8	5.3	3.8	2.9	18.1	25.6
21	6174.4	1.5	90.2	92	265.2	148.8	0.6	2.7	3	3.4	5.4	6.9	17.1	10.7
51	6127.3	1.3	85.8	87.3	250.8	132.2	0.5	3.7	3.3	25	10.1	2.3	5.5	4.3
36	6105.5	1.3	85.2	86.3	243.3	129.7	0.5	3.8	3.5	17	18.9	3.8	7.3	8
15	6006.1	1.5	89.7	91.5	272.6	162.8	0.6	3.3	3.5	12.6	11.1	5.6	21.7	1.6
52	5993.3	1.5	86.3	87.3	248.2	137.8	0.6	3.3	3.2	11.9	13.2	1.7	6.6	17.4
3	5993.1	1.2	87.8	90	268.5	152.6	0.6	2.7	3.5	6.8	9	3.6	23	1.8
7	5896.2	1.7	89	91.3	265	142.2	0.5	2.7	2.7	8	3.3	5.3	12.7	6.1
11	5792.4	2.2	89	90	261.3	152.5	0.6	2.5	3.7	4.7	10.7	6.3	20.8	3.8
2	5646.9	2	85.2	87.3	248.2	137.6	0.6	2.6	3.5	11.4	11.9	5.5	18.4	6.7
14	5644.5	1.8	90.3	92.2	274	153.4	0.6	2.9	3.5	5.9	4.1	6.3	33.1	5.1
10	5305.7	1.8	83.5	86.8	244.2	131.8	0.5	2.7	3.5	5.1	9.4	9	9.9	6.1

TRAT	REND	VIG	DFM	DFF	ALP	ALM	PMZ	ASP	ASM	PACA	PMC	PHI	PMP	PPC
25	5150.6	2.3	88.3	89.5	246.1	140.2	0.6	2.1	2.8	5.3	10.2	5.8	10.3	3.2
4	4816.7	1.7	87.2	89.3	262.9	149.2	0.6	2.7	3.8	7.6	10.2	2.7	24.5	3.7
DSH	1467.5	1.2	4.11	8.8	28.65	23.35	0.07	1.93	1.71	25.24	16.5	7.6	16.3	9.7

REND= grain yield; VIG, initial vigor; DFM and DFF= male and female blooms; ALP and ALM= plant and cob heights; PMZ, cob position; ASP and ASM= aspects of plant and cob; PACA= total lodging; PMC, plants with poor coverage; PHI= percentage of children; PMP= rotten cobs; PPC = plants twin.

Other outstanding materials were H-77E, H-57E and tester 1 (7 628, 7328 and 7 183 kg ha^{-1}), but only the first had a grain production statistically similar to that of H-40 (Table 5). These three materials, H-76E and H-40, have in common the female of CIMMYT, identified as CML246 x CML242; the males of the hybrids were derived from Michoacán 21 and Tlaxcala 151, belonging to the Conic race. These facts strengthen the hypothesis of the existence of heterosis and adaptability in hybrids formed with lines of CIMMYT and INIFAP, in the latter derived from the Conic and Chalqueño races (Velázquez *et al*., 2005; González *et al*., 2008; Reynoso *et al*., 2014; Torres *et al*., 2011, 2017).

Regarding mestizos, it was observed that the most outstanding were 19, 20, 46, 45, 37 and 34, their grain yield varied from 7 215 to 7 816 kg ha and were equal to H-40, H-76E, H-77E, H-57E and the tester 1. The plant and cob bearings and the position of this one were greater in most of the mestizos and in the rest of the variables superiority was observed in the hybrids, even though the differences between both groups were not significant (Table 5). These facts suggest that in these native maize there are genes that can contribute to increase the productive potential of the hybrids, when they manage to incorporate the genes of resistance to lodging and cob rot caused by *Fusarium* spp. (Carrera and Cervantes, 2002; Ramírez *et al*., 2015), since by identifying the best families or lines derived from them, new superior hybrids could be obtained (Hallauer and Miranda, 1988; Márquez, 1988).

The crosses where the female 2 appears had more grain yield, better cob position and were more prolific. They also expressed more flowering days, lower cob heights and less tillering and cob rot, worse plant and cob aspects, more lodging and poor totomoxtle cover (Table 6).

Table 6. Comparison of means between females (Tukey, *p*= 0.05).

HEM	REND	VIG	DFM	DFF	ALP	ALM	PMZ	ASP	ASM	PACA	PMC	PHI	PMP	PPC
2	6715.81a	1.43b	89.75a	90.82a	261.36a	144.76b	0.55b	3.36a	3.01a	16.57a	11.28a	3.19b	11.49b	7.1a
1	6407.71b	1.75a	88.42b	90.19b	262.23a	148.36a	0.56a	2.65b	2.97a	8.16b	7.41b	5.57a	16.4a	5.06b
$DSH_{(0.05)}$	129.14	0.1	0.39	0.85	2.51	2.2	0.006	0.18	0.16	2.44	1.57	0.72	1.59	0.89

Values with the same letter within the column are statistically similar. REND= grain yield; VIG= initial vigor; DFM and DFF= male and female blooms; ALP and ALM= plant and cob heights; PMZ= cob position; ASP and ASM= aspects of plant and cob; PACA= total lodging; PMC = plants with poor coverage; PHI, (%) of children; PMP= rotten cobs; PPC, plants twin.

The males with the highest grain yield (between 6814 and 7735 kg per ha) were those identified as 20, 19, 8, 18, 23, 13, 6 and 12 (Table 7), collected in the municipalities of Magdalena Taltelulco (Tlaxcala), San José Teacalco (Tlaxcala), Ixtlahuaca (Mexico), San José Teacalco (Tlaxcala), Españita (Tlaxcala), Juchitepec (Mexico), Ozumba (Mexico) and Tenango of Aire (Mexico), respectively (Table 2). Even if its genetic origin is unknown, it is inferred that these could belong to the Conic race, since they were collected in the States of Mexico and Tlaxcala, States of Mexico where it is commonly located (Wellhausen *et al*., 1951) and additionally, where the populations of Michoacán 21 and Tlaxcala 151, of the same race, were collected.

The previous results are also related to the following: the upper male fraction had excellent initial vigor, 20 was the latest, but was statistically the same as 12, 13 and 6 and significantly different from 8, 19, 18 and 23. In DFF they were equal statistically. The highest plant height was recorded in male 20 but their differences were not significant with respect to the others. In cob height, there were no significant differences between them, but 6 had the highest value and 18 the lowest. The highest cob position was presented by the male 19 and the lowest was the 18, without both being statistically different. The plant and cob aspects were acceptable and showed no significant differences. In percentage of acame the male 13 excelled, but its average was not statistically different from the others (Table 7).

Table 7. Comparison of means between males.

MALES	REND	VIG	DFM	DFF	ALP	ALM	PMZ	ASP	ASM	PACA	PMC	PHI	PMP	PPC
20	7735.5	1.5	92	93.7	271.8	153.7	0.56	3.2	2.6	18	5.3	5.5	10.2	7.2
19	7614.8	1.5	88.8	90.7	267.5	154	0.57	2.9	2.4	12.1	10.7	3.4	8.3	4.1
8	7084.6	1.5	88.8	90.8	268	149.3	0.56	2.8	3.1	11.7	10.7	4	9.9	8.4
18	6866.9	1.3	88.1	89.6	254.4	141.1	0.55	2.8	2.8	12.7	7.5	3.9	13.7	4.6
23	6866.9	1.5	86.3	88.1	254.1	142.1	0.56	3	2.8	16.8	10.9	3.6	13.7	4.7
13	6863.6	1.5	91	92.5	270.5	153	0.56	3.1	3.1	6.6	4.9	3.3	17.4	5.7
6	6839.3	1.8	90.8	92.7	269.9	155.2	0.57	3.1	2.7	11.8	5.4	5.4	14.9	5.9
12	6814.5	2	91.5	92.8	267.8	148.8	0.56	2.8	3.2	11.3	8.5	4	13.9	4.5
17	6766.2	1.3	92.3	93.6	278.8	159.8	0.57	2.4	2.8	12.3	3.6	7.2	17.7	5.6
1	6710.7	1.3	85.2	86.3	250.7	136.9	0.54	3.4	2.6	16.5	10.8	3.4	8.7	6.7
5	6696.7	1.7	88.9	89.8	260.3	148.2	0.57	3.4	2.8	11	8.3	3.4	11.8	6.1
24	6607.4	1.8	89.1	90.5	252	139.7	0.55	2.8	2.9	10.5	11	4.2	10.7	8.2
16	6562.4	1.8	91.6	93.5	277.4	157.7	0.57	3.2	2.8	14	16.1	3.8	21.2	2.8
9	6539.9	2.1	90.3	91.4	255.7	139	0.54	2.7	2.9	8.1	6.6	4.4	11.1	8.9
11	6538	1.8	89.8	91.3	263.5	148.7	0.56	2.9	3.3	14.2	12.8	4.7	15.5	3
3	6392.5	1.1	88.3	85.3	261.6	148.4	0.57	2.8	3.5	8.6	11	2.9	19.1	2.8
21	6383.7	1.4	90.3	91.8	264.4	149.4	0.57	2.7	2.9	8.6	8.3	5.7	14.7	11
7	6358.4	1.4	90	91.8	265.3	145.6	0.55	3	2.8	11.9	3.3	3.2	13.1	4.8
22	6335.9	1.5	90.8	92.5	258	143.2	0.55	3.7	3	19.7	7.7	6.1	15.6	4.7
26	6285.1	1.7	85.8	87.2	249.7	140	0.56	2.8	2.8	8.5	12.6	2.6	7.1	12.7
15	6256.2	1.7	91	92.8	271	159	0.58	3.5	3.4	17.7	13.9	4.5	19.7	3.8

MALES	REND	VIG	DFM	DFF	ALP	ALM	PMZ	ASP	ASM	PACA	PMC	PHI	PMP	PPC
14	6232.8	1.8	91	92.8	269.8	150.5	0.56	3.1	3.2	13.1	7.5	6.9	23.6	8.8
2	5997.2	1.8	85.3	87.2	251.5	133.6	0.53	3	3.3	10.8	10.2	4.7	14.8	6.9
4	5911.9	1.3	87.8	89.7	260.7	146.8	0.56	2.9	3.6	8.7	11.1	2.5	19.6	5.4
10	5705.6	1.6	84.3	86.6	243.8	130.8	0.54	3.3	3.5	11.1	14.1	6.4	8.6	7
25	5639	1.8	87.1	88.4	248.5	136.2	0.55	2.9	3.1	15.2	10.2	4.1	7.9	3.7
DSH	938.9	0.75	2.63	5.63	18.33	14.94	0.04	1.23	1.09	16.14	10.53	4.83	10.44	6.2

REND= grain yield; VIG= initial vigor; DFM and DFF= male and female blooms; ALP and ALM= plant and cob heights; PMZ= cob position; ASP and ASM= aspects of plant and cob; PACA= total lodging; PMC = plants with poor coverage; PHI, (%) of children; PMP= rotten cobs; PPC, plants twin.

The males 13, 6 and 20 presented low percentages of poor coverage, but their differences were not significant with respect to the others. The percentages of tillering were acceptable and there were no significant differences between them. The males with the highest grain yield and the best cob rot were 19, 8 and 20. In prolificity, the highest values were presented by males 8 and 20.

Conclusions

The differences observed between localities influenced the phenotypic expression of DFM, DFF, ALP, ALM, PMZ, PPC, REND, VIG, ASM, PACA, PMC and PMP. The best location for the evaluation of the trials was Metepec.

The differences that were observed between treatments suggest that there is genetic variability that is susceptible to be used in a breeding program, when from the creoles, new inbred lines are derived.

The interaction treatments x significant localities force the plant breeder to establish trials in several locations to identify a fraction of the material with greater grain yield and stability.

The materials with the highest grain yield were H-40 and H-76-E. The most outstanding mestizos were 19, 20, 46 and 45, whose grain production was statistically equal to that of H-40. In relation to H-76E, 28 mestizos equaled it statistically.

The main characteristics to consider in the use of native maize's in a hybridization program, in addition to their combinatorial aptitude, are the percentages of acame and pod rot, which should be improved; through a program by hybridization.

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