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Analysis of commercial hybrids and maize mestizos formed with germplasm from INIFAP and CIMMYT

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Abstract

In this study, 86 mestizos and 10 hybrids were evaluated in five locations in Central Mexico in randomized complete blocks with two repetitions per site, considering grain yield (REND), male (DFM) and female (DFF) blooms, plant heights (ALP) and cob (ALM), aspects of plant (ASP) and cob (ASM), stem (PAT), root (PAR) and total (PACA), tillering (PHI), cob rot (PMP) and plants cuatas (PPC). There were highly significant differences between females and between males for almost all variables. The female one presented the highest means for most of the variables. The interaction males x females were highly significant for REND, DFF, ASM, PAT, PHI and PMP. Males with higher grain yield and prolificacy 7, 38, 41, 35, 34, 33, 9, 24, 36, 30, 23, 32, 19, 10; of these 7 and 41 were the latest. All the males showed good aspect of plant and cob as well as similar lodging and tillering. The highest percentage of cob rot appcobed in 41, 30 and 27.

Keywords: *Zea mays* L.; Conical Race, mestizos, High Valleys of central Mexico.

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Introduction

In 2012, 7.3 million ha of corn were sown and production of 22.07 million (3.19 t ha^{-1}) was obtained, with 7.5 and 2.2 t ha^{-1}, irrigated and temporary, respectively (SIAP, 2014). In the High Valleys of central Mexico (2 101 to 2 800 meters above sea level), 1 108 267 ha are sown; 134 082 ha in irrigation, 306 828 ha in favorable weather and 667 357 ha in limiting weather (Turrent, 1994).

Since 1950, INIFAP has released more than 40 hybrids and improved varieties (Gámez *et al*., 1996) formed with S_1-S_4 lines derived from creoles and some backcrosses, but with more inbreeding depression caused by the high frequency of deleterious genes (Márquez, 1988). Recently, S_7-S_8 lines have been derived from simple crosses formed with lines from High Valleys and donors from other regions (Velázquez *et al*., 2013), these have been selected *per se* but their combinatorial aptitude has not been evaluated.

The formation and evaluation of mestizos is important to select the best using suitable testers and based on their combinatorial aptitude (Welcker *et al.*, 2005; Lorenz *et al.*, 2009) and this has been the main method (Bernardo, 2001) to select lines that convey desirable characteristics. Varieties, recycled lines, mixtures of varieties or hybrids have been used (Pfarr and Lamkey, 1992). A good tester should allow to classify the merit of each line and maximize the genetic gain (Russell *et al*., 1992; Menz *et al*., 1999). In the previous context, the objective of this work was to analyze mestizos formed with two simple crosses of CIMMYT to identify the most outstanding.

Materials and methods

Description of the study area

This rescobch was carried out in the Spring-Summer of 2013 in the rainforest and tip of irrigation in five localities of the Center of Mexico, differentiable by the characteristics indicated in Table 1.

Genetic material

We included 86 mestizos trained with 43 intermediate cycle lines derived from the Conic race (Michoacan 21, Cuatero of the Virgen and Tlaxcala 151) and two simple crosses from CIMMYT, identified as females 1 (CML 246 x CML 242) and 2 (CML 457 x CML 459). They were also H-40, H-58E, H-76E, H-77E, H-66, H-70, HC-8, AS-722, P1684 and ICAMEX 2010.

Experimental design and size of the plot

The 96 treatments were evaluated in the field in a randomized complete block design with two repetitions per site in a series of experiments in space. The experimental plot consisted of two rows of 5.0 m in length and 0.8 m in width (8 m^2).

Table 1. Description of the localities.

State	Locality	Location	Weather conditions	Predominant soil
Mexico	Coatlinchan, Texcoco, Mexico (Santa Lucia)	Latitude: 19°49’05” Longitude: 99°06’39” Altitude: 2 262 m	T° average= 15.7 T° min= 6.7 T° max= 24.8 Pp annual= 539 mm	Of volcanic origin, with ash cemented between 40 and 60 cm deep. Textural classification: varies from medium to fine textures (franc, loam-clay). (Magaña & Juarez, 2003).
Tlaxcala	Estación Muñoz	Latitude: 19°20’37” Longitude: 98°12’13” Altitude: 2 487 m	T° average= 14.1 T° min= 4.5 T° max= 23.7 Pp annual=626 mm	There are two types: Cambisols and Fluvisols. Cambisols are often soils with duripan or tepetate horizons. Fluvisols comprise poorly developed and deep alluvial sediments (Cuellar, 2012).
Mexico	Almoloya of Juárez	Latitude: 19°22’08” Longitude: 99°45’37” Altitude: 2 613 m	T° average= 13.3 T° min= 4.6 T° max= 22 Pp annual= 744	Sedimented soils predominate with a high proportion of expandable clays (Vertisols) and soils with a dark, shallow surface layer, rich in organic matter and nutrients, but without the lime-rich layers, deep on flat terrain. (Feozem) (Estrada, 2012).
Mexico	Atlacomulco	Latitude: 19°78’83” Longitude: 99°94’25” Altitude: 2538 m	T° average= 13.9 T° min= 5.6 T° max= 22.2 Pp annual= 735 mm	The feozem predominates, brown cobth rich in nutrients. The second type is the Vertisols, which is almost always very fertile soils, because of its hardness it makes it difficult to manage it for farming and it often has floods. The third type is the Planosols, flat but old fertile soils, known as “tepetate”, are easy to erode (Encyclopedia Atlacomulco, 2005).
Mexico	Toluca	Latitude: 19°24’34.17” Longitude: 99°41’21.2” Altitude: 2 614 m	T° average= 13.1 T° min= 4.9 T° max= 21.3 Pp annual= 800 to 1 000 mm	Soils Andosols, Litosols and Regosols, characteristic of the volcanic zones and susceptible to erosion, the north central portion of the municipality presents Feozem, Vertisols and Planosols soils, of medium agricultural fertility, susceptible to cracking and flooding (Hernández, 2012).

Conduction of experiments

Land preparation, sowing, fertilization and cultural work were carried out in accordance with the technical recommendations of INIFAP, 75 000 plants ha^{-1} were managed. Weed control in pre and postemergence was done with atrazine (33.7%) and S-metoloclor (26.1%) in 3 L ha^{-1}. The trials were planted on April 9, 10, 16 and 17 with irrigation tips at Atlacomulco, Toluca, Almoloya of Juárez, and Coatlinchán, respectively, and in strict weather at Estación Muñoz (May 24). The harvest in Santa Lucía was made at the end of November and 2, 4, 5 and 9 December in Toluca, Atlacomulco, Almoloya of Juárez and Estacion Muñoz, respectively.

Data register

The variables of interest were grain yield (REND, weight of all cobs of the useful plot, corrected by percentage of shelling and moisture (14%) and extrapolated to kg ha^{-1}), male and female blooms (DFM and DFF, days from sowing until 50% of the plants released pollen or had stigmata), plant and cob heights (ALP and ALM, measured in cm from the soil surface to the base of the cob or cob insert), aspects of plant and cob (ASP and ASM, visual quality of stem, plant and cob on a scale of 1 to 5, where 1 is better and 5 worse), root lodging (PAR, plants with 35° or more inclination) , lodging of stem (PAT), total lodging (PACA, plants with both acames), plants with poor cover (PMC), percentage of children (PHI), rotten cobs (PMP) and plants cuatas (PPC).

Statistical analysis

The data were subjected to an analysis of variance and to the comparison of means between sites and between genotypes with the tests of Tukey (Martínez, 1988) or Dunnett (p= 0.05). The outputs were obtained with the system for statistical analysis version 9.2 for Windows. The program for SAS was prepared by PhD Fernando Castillo González, professor and rescobcher of the Postgraduate School- Mexico.

Results and discussion

In this study, significant differences were detected (p= 0.05 or 0.01) among localities in the 14 variables. This fact suggests that the environmental heterogeneity that exists in central Mexico forces the rescobcher to establish trials in contrasting sites to identify the most favorable ones (Table 2) Reynoso *et al*. (2014) and Torres *et al*. (2011, 2017) commented on differences in altitude and types of climate and soil are the most important (Table 1).

The significant effects that were observed between treatments (p= 0.01) are explained by the statistical differences between mestizos and commercial hybrids (Table 2). Obaidi *et al*. (1998); Castañon *et al*. (1998); Mihaljevic *et al*. (2005) observed similar results. This fact evidences an outstanding fraction of the germplasm that exists in the central region of Mexico of the Conic and Chalqueño breeds and of other CIMMYT breeds (González *et al*., 2008; Reynoso *et al*., 2014; Torres *et al*., 2001, 2017).

The significant effects that were detected in all the variables between females or between males explain the phenotypic variability that was registered among mestizos (Table 2), the lines evaluated had a different behavior in their respective mestizos and there is genetic diversity (Mosa, 2010). Both females belong to CIMMYT and the 43 lines are from INIFAP, derived from Michoacan 21, Cuatero of the Virgen and Tlaxcala 151. Castellanos *et al*. (1998) concluded that simple crosses were the best alternative as testers to generate superior trilincob hybrids. In other studies, it was concluded that the behavior of the males was different, depending on the female used (Mosa *et al*., 2008; Mosa, 2010; Habliza and Khalifa, 2015).

The 10 commercial hybrids were statistically different in 10 of the 14 variables. The origin of three of them is unknown, but it is inferred that they could have CIMMYT germplasm, such as H-40 and ICAMEX 2010; the female of the first has the same lines of the tester 1 and the female of the second has the same progenitors of the tester 2. H-58E, H-70, H-66, H-76E and H-77E are formed with germplasm of CIMMYT and with lines of Michoacán 21 and Tlaxcala 151, conic race. In other studies, similar inferences have been made (González *et al*., 2008; Quiroz *et al*., 2017). This last situation could explain the cancellation of effects that occurred in crosses vs hybrids; the mean of each group and its average could be considered as an estimator of the mean of the 96 treatments.

Table 2. Mean squares and statistical significance of the F values in the combined Anava.

FV	GL	REND	DFM	DFF	ALP	ALM	ASP	ASM
Locations (L)	4	1150045286^{**}	40511.4^{**}	35668.1^{**}	66628.1^{**}	29662.7^{**}	27.4^{*}	128.5^{**}
Repetitions /L	5	2698533	132.21	258.5	699.5	1005.74	2.63	3.19
Treatments (T)	95	5325781^{**}	47.5^{**}	60^{**}	1568.3^{**}	756.5^{**}	3.8^{**}	1.5^{**}
Crosses (C)	85	5677303^{**}	47.35^{**}	58.68^{**}	1654.2^{**}	783.35^{**}	3.72^{**}	1.45^{**}
Females (H)	1	70431245^{**}	441.22^{**}	77.4^{**}	13476.6^{**}	85.64^{ns}	86.53^{**}	38.89^{**}
Males (M)	42	7759204^{**}	79.29^{**}	106.96^{**}	1894^{**}	1201.43^{**}	4.74^{**}	1.5^{**}
H x M	42	2053642^{**}	6.02^{ns}	9.95^{**}	1132.8^{ns}	381.89^{ns}	0.73^{ns}	0.51^{**}
Hybrids (HI)	9	2581627^{**}	44.16^{**}	66.28^{**}	878.99^{ns}	458.89^{ns}	4.69^{**}	2.31^{**}
C *vs* HI	1	143157^{ns}	94.14^{**}	118.9^{**}	121.6^{ns}	1149.6^{ns}	6.43^{**}	0.53^{ns}
T x L	380	1839167^{**}	5^{ns}	6.9^{*}	917.5^{ns}	400.1^{ns}	1.2^{**}	0.52^{**}
C x L	340	1833634^{**}	4.86^{**}	7.03^{**}	1001.8^{**}	431.59^{**}	1.2^{**}	0.49^{**}
H x L	4	11287051^{**}	27.38^{**}	48.78^{**}	819.9^{ns}	366.5^{ns}	22.91^{**}	3.24^{**}
M x L	168	2109391^{**}	5.6^{**}	7.56^{**}	1023^{**}	475.22^{**}	1.24^{**}	0.56^{**}
H x M x L	168	1332796^{**}	3.59^{ns}	5.51^{ns}	985^{**}	389.5^{**}	0.64^{ns}	0.36^{**}
HI x L	36	1948314^{**}	6.61^{*}	6.48^{ns}	183.45^{ns}	131.13^{ns}	1.1^{**}	0.69^{**}
C *vs* HI x L	4	1327131^{*}	4.2^{ns}	7.5^{ns}	354^{ns}	153.5^{ns}	4.5^{**}	1^{**}
Combined error	475	437453	4.45	5.96	881.61	380.72	0.65	0.32
CV		10.9	2.2	2.5	14.56	19.4	28.5	18.6

REND= grain yield; DFM= male flowering; DFF= female flowering; ALP= plant height; ALM= height of cob; ASP= aspect of the plant; ASM= appcobance of the cob; *, **= significant at the probability level of 0.05 or 0.01, respectively.

Table 2. Mean squares and statistical significance of the F values in the combined Anava (continuation).

FV	GL	PAR	PAT	PACA	PMC	PHI	PMP	PPC
Locations (L)	4	7707**	1799.1**	8410.24**	3823.6**	5000.4**	75127.8**	26876.02**
Repetitions /L	5	323.37	97.16	512.79	95.84	328.5	124.37	411.1
Treatments (T)	95	255.3**	153.79**	584.3**	65.18**	35.6**	187.2**	228.6**
Crosses (C)	85	243.41**	138.6**	534.75**	68.19**	36.71**	179.59**	230.3**
Females (H)	1	3089.41**	2421.89**	10994.19**	2033.72**	288.26**	213.8**	1506.9**
Males (M)	42	333.36**	162.71**	696.75**	62.79**	35.53**	270.5**	335.22**
H x M	42	85.7ns	60.1**	123.72ns	26.79ns	31.9*	87.8**	94.9ns
Hybrids (HI)	9	372.24**	303.74**	1050.74**	30.97ns	26.7ns	239.86**	216.7**
C *vs* HI	1	214.96**	95.16**	596.85*	117.03ns	26.86ns	365.56**	196.69ns
T x L	380	114.5**	72.86**	194.9**	42.03*	26.1*	93**	89.4**
C x L	340	117.8**	71.47**	191.96**	42.75**	26.3**	90.71**	91.32**
H x L	4	376.8**	1361.2**	1210.43**	426.23**	182.39**	1869.14**	700.77**
M x L	168	150.47**	73.6**	252.91**	38.26**	24.4**	90.73**	90.51**
H x M x L	168	78.95**	38.5ns	106.7**	38.1**	24.45**	48.3**	77.62**
HI x L	36	92.78ns	69.68**	200.3**	26.8**	26.33ns	119.96**	78.8ns
C *vs* HI x L	4	30.7ns	219.9**	404.6**	117.4**	8.3ns	44.9ns	26ns
Combined error	475	71.99	39.15	95.9	33.75	21.76	33.92	70.35
CV		116.5	102.45	73.13	72.33	79.38	46.64	60.66

PAR= root encam; PAT= stem house; PACA= both camps; PMC= plants with poor coverage; PHI= percentage of children; PMP= rotten cobs; PPC= plants cuatas; *, **= significant at the 5 or 1% probability levels, respectively.

The interaction treatments x localities significant in 11 variables (p= 0.05 or 0.01) suggests that crosses and hybrids are unstable. In the rest of the interactions presented in Table 2, a similar trend was observed. This condition will make it difficult to identify high-performance genetic material with adaptability to the environmental conditions of the study area. Phenotypic instability forces the plant breeder to choose genotypes with specific adaptation; the generation, validation, application and/or transfer of technology will also be conditioned and there will be side effects in the seed increase and production programs. Mexico could be self-sufficient in corn production by identifying a higher fraction of the germplasm available in different rescobch and teaching institutions (González *et al*., 2010; Franco *et al*., 2016; Torres *et al*., 2011, 2017).

The highest grain yields were observed in Valley Toluca-Atlacomulco (from 6 635 to 8 700 kg ha^{-1}). The greatest biological cycle was also registered, the biggest and the best aspects of plant and cob heights, less acame stem, root and both, and more prolific. Cob rot was less than 6% and there was more tillering (Table 3). Other studies have highlighted the high potential of this region of Mexico, where there are good climate and soil conditions that favor the growth and development of the maize, in the absence of late or cobly frosts and low rainfall; between 4.0 and 10 t ha^{-1} of grain have been recorded (González *et al*., 2008; González *et al*., 2010; Reynoso *et al*., 2014; Quiroz *et al*., 2017; Torres *et al*., 2011, 2017).

Table 3. Comparison of means between evaluation sites (S).

S	REN	DFM	DFF	ALP	ALM	ASP	ASM	PAR	PAT	PACA	PMC	PHI	PMP	PPC
1	8700a	97.3c	97.0b	216.8a	105.7a	2.9a	3b	8.3bc	4.7b	13.1a	14.2a	13.6a	5.5b	30.4a
2	7821b	102.7b	103.5b	226a	115.1a	2.8ab	3b	9.6ab	6.4b	16.1a	10.8ab	5.5b	5.3b	21b
3	6635c	109.7a	111.2a	204.5b	104.5ab	2.1b	2.5bc	0.7d	2.7b	3.4b	6.9bc	7.4ab	3.2bc	10.9c
4	4102d	96.5c	97.3b	179.5d	83.2c	3.1a	2.1c	16.1a	5.5b	21.6a	3.3c	0.7b	0.5c	1.5d
5	2942e	71.3d	74.6c	192.3d	92.6bc	3a	4.3a	1.5cd	11a	12.5ab	4.8c	1.9b	47.6a	5.1cd
M	6040	95.5	96.7	203.8	100.2	2.8	3	7.2	6.1	13.4	8	5.8	12.4	13.8
D	672.5	4.7	6.5	10.8	12.9	0.66	0.73	7.3	4	9.2	4	7.4	4.5	8.3

Values with the same letter within columns are statistically similar. REND= grain yield; DFM= male flowering; DFF= female flowering; ALP= plant height; ALM= height of cob; ASP= aspect of the plant; ASM= appcobance of the cob; PAR= root encam; PAT= stem house; PACA= both camps; PMC= plants with poor coverage; PHI= percentage of children; PMP= rotten cobs; PPC= plants cuatas; M= arithmetic mean; D= significant minimum difference; 1= Atlacomulco; 2= Almoloya of Juárez; 3= Toluca; 4= Estación Muñoz; 5= Santa Lucía.

In relation to the 96 treatments, the grain yield varied from 3 176 to 7 312 kg ha^{-1}; 72 mestizos (83%) were statistically equal to H-40, of these, 33 (38%) exceeded it from 0.5 to 15.8% and 23 or 20 were statistically more precocious in DFM or in DFF and had similar means in ALP, ALM, ASM, PMC, PHI and PMP. Only 41 and 84 presented worse ASP, attributable to their higher PAR, PAT and PACA. Crossing 70 was for PAT and PACA. Crosses 38 and 81 presented higher PPC. In this region of Mexico, hybrids and varieties of high yield and stability, cobly, intermediate plant and cob heights, resistant to lodging are desirable (González *et al*., 2008; González *et al*., 2010; Torres *et al*., 2011, 2017), such as those identified as 81, 34, 41, 10, 33 and 59 (Table 4).

Table 4. Comparison of treatment means.

Trat	REND	DFM	DFF	ALP	ALM	ASP	ASM	PAR	PAT	PAC	PMC	PHI	PMP	PPC
81	7312.7*	96.3	97.5	207.9	99	2	2.7	5.1	3.4	8.5	7	4.7	8.7	25.1*
34	7306.4*	93.4*	95.1*	199.6	91.2	2.4	2.3	4.3	3.1	7.4	9.8	5.2	8.6	12.4
41	7284.1	98.8	100.5	224.9	126.1	4.5*	2.5	20.2*	9.6	29.8*	8.7	5.6	16.1	20
10	7152.2	91.7*	92.4*	193.9	98.2	2.6	2.6	3.1	5	8.1	7.3	5.8	6.3	17
33	7111.7	93.0*	94.1*	202.2	96.7	2.4	2.6	3.6	3.8	7.4	5.4	6.9	7.9	15
50	7066.9	100.3	102.5	215.5	108.2	2.9	3	9.6	8.8	18.3	7.4	3.6	9.7	14
35	6965.8	93.9*	95.1*	202	94.6	2.7	2.4	3.2	7.3	10.5	7.9	5.2	7.1	14.6
H-76-E	6944.8	94.6*	96.1	210.4	103.2	2.5	2.6	5.3	3.4	8.7	8	6.5	14.3	14.8
7	6921.4	99.7	101.5	210.9	105.4	2.2	2.7	14.9	4.2	19.1	6.1	3	10.2	14.5
11	6894	93.3*	94.3*	198.3	97.1	3.4	2.6	6.9	5	11.8	5.4	8.8	6.5	19.1
29	6806.4	93.1*	94.1*	239.4	101.2	2.1	3.1	1.1	3.5	4.7	5.7	4.7	7.1	11.1
23	6796.4	92.7*	95*	208.9	107.2	2.7	2.5	3.6	7	10.6	3.5	6	7.3	9.9
31	6790.2	94.2*	96.1	195.8	86.4	1.7	3	1	1.6	2.6	5.3	8.8	10.8	7.7
12	6750.5	95.1	97.1	197	95	1.8	2.6	1.5	2.3	3.9	7	4.1	5.9	13.3
36	6713.4	93.5*	94.9*	200.8	89.7	2.3	2.9	3.9	4.5	8.4	8.2	7.3	11.2	18.5
13	6693.1	95.2	97.9	197.2	94.4	1.7	2.5	2.1	2	4.1	4.0	7.1	7	10.7
14	6684.1	96.4	97.5	194.2	92.7	1.9	2.4	4.2	2.7	6.8	4.7	4.6	9.1	11.1

Trat	REND	DFM	DFF	ALP	ALM	ASP	ASM	PAR	PAT	PAC	PMC	PHI	PMP	PPC
32	6683.8	93.3*	95.3*	206.3	95.7	2.2	2.9	5.4	2.9	8.3	8.4	4.4	6.6	13.9
H-77-E	6677.7	94.6*	95.3*	212.8	102.2	2.6	2.4	4.5	4.4	8.9	7	6	12.9	18.5
24	6641	92.1*	94.1*	206	100.8	2.7	2.5	3.4	7.1	10.4	4.7	5.9	8.6	8.4
70	6634.1	95.1	95.4*	228.8	93.6	3.6	3.2	10.7	17.9*	28.6*	10.5	5.4	16.7	10.2
38	6626.6	94.1*	95.4*	212.2	99.7	2.2	2.5	6.5	2.4	8.9	2.4	6.1	13.8	25*
30	6610.7	93.1*	95.1*	203	99.4	2.2	3.3	1.5	1	2.5	6.2	5.6	17.2	9.6
78	6556.7	95.7	96.4	205.5	99.1	3.3	3.1	11.2	8.5	19.8	12.1	9	11.8	19.2
9	6530.3	94.3*	95.3*	201.7	101.9	2.8	2.6	3.2	4.1	7.3	10.8	4.4	3.6	15.4
84	6503.5	99.8	101.1	216.3	116	4.8*	3.3	20.7*	25.1*	45.8*	10.9	6.2	15.9	22.8
26	6495.5	92.4*	94.2*	248.1	100.6	2.1	2.6	2.2	1.8	4	5.8	6.7	10.9	9.7
22	6483.1	94.1*	95.1*	207.2	104.4	2.7	2.4	3.5	7.3	10.9	9.2	7.2	11.8	8.6
52	6481.6	96.4	97	198.8	115.9	3.3	3.2	6.6	8.7	15.2	10.3	4.3	10.5	23.7
HC-8	6467.7	95.5	95.8*	187.1	86.7	2.2	2.6	4.5	2	6.5	8.6	4.4	6.4	18.2
28	6454.1	93.9*	96.1	209.6	107.2	2.8	2.3	3.4	7.6	11	5.9	5	8.1	8.5
19	6442.0	93.8*	95.4*	210.8	98.6	2.5	2.7	5.6	2.8	8.4	10.7	5.4	4.4	8
64	6355.1	94.2*	95.1*	197.5	99.5	3	3.3	6.3	9.4	15.8	7.4	4.1	15.5	12.7
67	6353.0	94.2*	94.4*	200.6	101	3.3	3.2	6.9	7.6	14.5	11.3	7.8	12.3	15.3
25	6349.9	93.3*	96	211.5	112.4	2.4	2.7	3.7	8.8	12.5	6	9.4	8.4	12.5
37	6348.1	94.9*	95*	196.5	85.3	2.3	2.9	6.1	5.3	11.4	7.4	8.2	12.2	15
H-40	6314.7	98.1	99.6	206	105.9	2.8	2.6	7.4	3.4	10.8	5	4.6	9.5	12
62	6297.9	96.1	96.5	206.1	96.4	2.9	3.3	9.1	6.3	15.4	16.1*	2.4	9.3	9.4
17	6295.4	95.1	96.4	213.7	101.5	2.4	3.1	4.3	4.2	8.5	8.7	4.4	9.2	11
73	6242.5	93.3*	93.7*	192.7	95.4	3.3	3.4	6.2	9.9	16.2	9.9	4.2	14.1	5.9
76	6228.4	95.2	95.5*	201.5	97.7	3.4	3.2	14.5	7.3	21.8	11.8	3.8	14	18.4
15	6204.6	94.9*	96.8	191	87.3	1.6	2.6	1.7	1.3	3	7.5	6.9	9.6	9.3
65	6177	94.4*	95.2*	191.6	95.9	2.9	3	2.2	10.2	12.4	12.3	5.5	14.4	11.5
68	6168.3	93*	93.5*	194.5	95.9	2.9	3.2	2.6	7.9	10.5	8.1	5.7	15.2	11.3
21	6149.9	92.8*	94.1*	202.4	100.5	2.9	2.7	5.9	4.5	10.3	6.2	10.3	11.7	13.4
79	6148.8	94.3*	94.3*	192.5	86.5	2.6	3.5*	7.3	3.9	11.2	13.6*	7.3	9.5	12.6
77	6143.5	94.3*	94.5*	194.9	89.6	3.2	3.1	11.7	8.4	20	10.8	1.8	11.7	20.2
80	6119.3	94.6*	95.7*	188.1	89.6	2.8	3.7*	11.1	3.6	14.7	8.8	4.6	9	13
75	6082.6	94.3*	94.6*	205.5	96.7	3.4	3.1	11.2	8.5	19.7	7.7	5.8	8.1	9.4
83	6075.6	96.9	97.9	213.6	138.1*	4.1*	3	19.5	11.2	30.6*	7.7	5.5	13.7	19.4
H-66	6043.1	95.9	97.4	203.8	107.8	3.5	3.4	11.5	11.7	23.2	9.7	9.5	13.7	18.6
66	5995.6	94.3*	94.6*	195.3	95.3	2.7	3.3	2	6.1	8.1	9.8	5	18.5*	11.8
71	5977.2	94.3*	94.4*	246	103.3	3.5	3.5*	9.7	7.1	16.7	11.7	5.8	10.7	8.8
69	5958.2	93.9*	95.2*	191.5	105.9	2.7	3.4	4.5	3.2	7.7	8.8	5	14.3	8.3
39	5917	96.8	98	204.3	108.3	3.4	3.3	7.7	7.3	15	5.4	10.5	18.6*	16.3
27	5913.5	92.6*	93.4*	207.3	102.4	3.3	2.9	8.8	6.7	15.5	9.7	5.4	13.6	6
74	5891.3	93.7*	94.3*	188.6	88.6	2.8	3.5*	5.6	4.2	9.8	8.2	4.2	7.8	11.6
16	5889.6	94.9*	96.8	203.7	94.5	2.1	3.1	1.8	2.8	4.6	5.3	6.4	10.9	9.2
3	5879.4	97.5	99.7	250.9*	104.3	2.6	3.1	9.7	5	14.7	4.7	6.2	20.9*	10.4

Trat	REND	DFM	DFF	ALP	ALM	ASP	ASM	PAR	PAT	PAC	PMC	PHI	PMP	PPC
18	5879.0	95.1	97.1	204.3	114.3	1.9	3.1	4.6	2.2	6.7	6.3	6.3	11.3	12.5
42	5855.2	97.9	100.4	212.4	96	2.7	2.7	10.7	2.8	13.4	3.3	6.7	20.7*	13.5
63	5843.3	95.5	96.1	200.0	98.3	3.3	3.3	5.6	11.4	17	6.9	4	11	6.3
H-58-E	5841.8	99.8	101.8	215	107.1	2.6	3.6*	5.7	3.1	8.8	5.4	6.2	18.5*	11.6
54	5829.8	96.4	96.8	186.7	92.7	3.1	3.4	6.8	11.6	18.4	8.8	4.7	10.4	25.5*
20	5790.1	95.9	97.2	211.3	102.6	2.3	3.1	4.8	2.1	7	5.7	5.9	11.6	10.9
6	5765.5	93*	95*	209.8	101.3	2.5	3.3	6.2	4.6	10.8	7	8.5	16.6	10.3
4	5759.8	94.5*	95.8*	208.6	104.2	2.7	3.5*	4.5	4.1	8.6	6.4	9.6	15.2	11.2
82	5739.2	97.2	97.5	211	104	4.1*	3.4	17.3	15.8*	33.1*	6.2	5	17.8	19.2
H-70	5729.9	96.6	97.8	192.6	103.8	4.1*	3.7*	18.5	19.2*	37.7*	7.6	8.4	13.4	11.2
AS-722	5728	94.6*	96.8	210	113	3.8	3.3	6.3	12	18.3	4.0	5.7	24.1*	7.4
60	5713.1	96.2	97.1	202.5	97.4	3.2	3.3	13.9	6.8	20.6	12	4.5	14.2	11.3
72	5711.6	94.3*	94.1*	196	101.1	2.5	3.9*	2.5	5.9	8.4	12.7	4.4	9.3	11.2
61	5680.7	97.7	99.2	195.5	91.2	3.3	3.1	14.5	3.9	18.5	11.1	7.4	12.9	16
57	5680.1	97.3	98	191.5	111.6	2.4	2.9	7.7	6	13.7	8.7	7.1	10.8	17
IC-2010	5667.5	99.9	102.2	215.3	103.1	3.9	2.7	20.24*	5.3	25.5*	7.1	7.4	12.9	16
58	5649.9	96	96.9	181.8	85.4	2.6	3	4.3	5.3	9.6	4.9	3.7	12.4	20
55	5634.4	97.5	98.8	188	88.1	2.9	3.2	5	4.7	9.7	8.8	3.9	9.4	10.9
5	5632.7	93.8*	95.6*	213.2	107.7	2.6	3.4	6.5	4.5	11	9.4	9.4	17.6	14.1
53	5581.5	96.3	97.2	189.3	98.1	3	3.4	5.7	5.4	11.1	8.8	6.2	9.6	26.8*
85	5491.6	100.2	101.9	203.1	110.3	3.6	2.7	27.8*	2.4	30.1*	7.9	8.8	18.5*	18.3
2	5477.3	98.3	100.3	202.8	99.4	2.7	3.1	4.4	4.6	9	4.9	3.7	19.2*	9.8
8	5458.8	93.7*	95.2*	204.3	99.0	2.5	3.5*	4.6	4.4	9	5.8	6.6	15	9.2
49	5367.3	95.4	96.4	194.6	98.8	2.5	3.5*	6.8	9.5	16.2	9.3	5.7	14.4	7.7
P-1684	5346.3	94.9*	95.2*	206.5	101.8	2.9	2.8	2.8	5.9	8.7	8	5.2	17.2	23.1
43	5310.4*	96.6	98.7	191.1	90.5	1.9	3	2.3	2.4	4.8	5.4	6.1	12.7	12.5
1	5086.3*	99.5	101.8	202.1	101	2.7	3.3	7	2.6	9.6	7.9	5.3	21.5*	12.3
40	5057.7*	96.5	98.3	214.9	111.2	3.3	3.4	11	7.1	18.1	8.8	5.5	23.7*	9.7
46	5055.8*	100.6	102.7	199.3	115	3.6	3.1	14.8	4.6	19.4	7.6	4.7	14.8	13.2
56	4955.2*	97.1	97.8	188.2	91.8	2.4	2.7	6.6	4.6	11.1	9.7	10	10.3	21.4
59	4853.5*	96.2	97.4	201	96.9	3	3.4	6.5	8.2	14.7	13.1	9.6	15.5	14.6
86	4852.7*	98.9	100.3	185.7	89.2	3	3.1	10.1	3.3	13.4	8.5	5	7.9	12.7
47	4828.4*	94.4*	94.6*	200.1	101.5	3.2	3.6*	9.8	5.1	14.9	10.6	4	15.6	16
51	4808.6*	95.8	96.5	197	99.6	3.2	3.7*	6.1	7.5	13.6	10.3	6.2	15	10.1
48	4217.5*	95.9	96	201.5	102.8	3.2	3.6*	5.3	7.9	13.2	11	3.4	12.7	16
44	3805*	100.2	101.9	202.2	108.2	3.2	3.5*	8	6	14	10.5	3.8	21.9*	16.5
45	3176.7*	100.6	102.5	197.3	91.4	3.5	3.3	8.4	7.1	15.5	7.2	1.9	13.5	19.9
DMS	976.3	3.1	3.6	43.8	28.8	1.19	0.8	12.5	9.2	14.4	8.5	6.8	8.5	12.3

REND= grain yield; DFM= male flowering; DFF= female flowering; ALP= plant height; ALM= height of cob; ASP= aspect of the plant; ASM= appcobance of the cob; PAR= root encam; PAT= stem house; PACA= both camps; PMC= plants with poor coverage; PHI= percentage of children; PMP= rotten cobs; PPC= plants “cuatas”; *= statistically different from H-40 (Dunnett, *p*= 0.05).

The female one (CML246 x CML242) excelled in grain yield, plant and cob heights, tillering and plant and cob aspects and had lower averages in male and female blooms, root, stem and total lodging, cob cover, cob rot and prolificacy (Table 5). Its superiority has been highlighted in other hybrids of High Valley in Central Mexico (González *et al*., 2008; Torres *et al*., 2011, 2017; Quiroz *et al*., 2017).

Table 5. Comparison of means between females. Tukey (T, 0.05).

	REN	DFM	DFF	ALP	ALM	ASP	ASM	PAR	PAT	PACA	PMC	PHI	PMP	PPC
1	6322a	94.7b	96.3b	207.5a	100a	2.4b	2.8b	5.2b	4.3b	9.5b	6.6b	6.3a	11.7b	12.3b
2	5749b	96.1a	96.9a	199.6b	99.5a	3.1a	3.2a	9a	7.6a	16.6a	9.6a	5.2b	12.7a	14.9a
T	88.7	0.3	0.3	4	2.6	0.1	0.1	1.1	0.8	1.3	0.8	0.6	0.8	1.1

Values with the same letter within columns are statistically similar. REND= grain yield; DFM= male flowering; DFF= female flowering; ALP= plant height; ALM, cob height; ASP= aspect of the plant; ASM= appcobance of the cob; PAR= root encam; PAT= stem house; PACA= both camps; PMC= plants with poor coverage; PHI= percentage of children; PMP= rotten cobs; PPC = plants “cuatas”.

The males with the highest grain yield were 7, 38, 41, 35, 34, 33, 9, 24, 36, 30, 23, 32, 19, 10, 11 (6 362 to 6 994 kg ha^{-1}) only 7 and 41 were later. There were no significant differences in their plant heights, but those of the cob; they also presented good aspect of plant and cob, similar percentages of lodging, tillering and the most prolific were 38, 11, 10, 41, 9, 35, 33, 34 and 36 (Table 6). This upper fraction could be used in this region of Mexico to generate new hybrids of three and four lines with double purpose: production of more grain and green or dry matter.

Table 6. Comparison of means between males.

Male	REND	DFM	DFF	ALP	ALM	ASP	ASM	PAR	PAT	PACA	PMC	PHI	PMP	PPC
7	6994.2	100	102	213.2	106.8	2.6	2.8	12.2	6.5	18.7	6.7	3.3	9.9	14.2
38	6969.7	95.2	96.5	210.1	99.3	2.1	2.6	5.8	2.9	8.7	4.7	5.4	11.2	25.1
41	6893.8	99.3	100.8	220.6	121.1	4.7	2.9	20.5	17.4	37.8	9.8	5.9	16	21.4
35	6761.3	94.8	95.8	203.8	96.9	3	2.7	7.2	7.9	15.1	10	7.1	9.5	16.9
34	6725	93.9	94.8	197.3	90.4	2.8	2.7	8	5.8	13.7	10.3	3.5	10.1	16.3
33	6670	94.1	94.8	201.9	97.2	2.9	2.9	9	5.6	14.6	8.6	5.4	11	16.7
9	6506	95.4	96.2	200.3	108.9	3.1	2.9	4.9	6.4	11.3	10.5	4.4	7	19.5
24	6497	93.2	94.3	203.3	100.9	3	2.8	5.1	7.4	12.5	8	6.9	10.4	11.9
36	6431.1	93.9	94.6	196.7	88.1	2.4	3.2	5.6	4.2	9.8	10.9	7.3	10.4	15.6
30	6426.6	93.2	94.4	197.9	97.4	2.8	3.3	3.8	5.5	9.3	8	4.9	15.6	7.7
23	6396	93.5	94.8	202.1	101.2	2.7	2.9	2.8	6.6	9.3	6.6	5.5	12.9	10.8
32	6383.2	93.8	95	205.9	96.2	2.8	3	8.3	5.7	14	8	5.1	7.4	11.7
19	6370	95	96	208.4	97.5	2.7	3	7.3	4.6	11.9	13.4	3.9	6.9	8.7
10	6366.8	94	94.8	191.6	98.1	2.8	3	4.4	5.2	9.6	8	6	8	22
11	6361.9	94.9	95.6	192.5	94.9	3.3	3	6.9	8.3	15.1	7.1	6.8	8.5	22.3
31	6340.7	94	95.2	192.2	87.5	2.3	3.3	3.3	2.9	6.2	6.7	6.5	9.3	9.6
22	6330	94.3	95.2	199.4	100.2	2.8	2.7	2.9	8.8	11.6	10.7	6.3	13.1	10

Male	REND	DFM	DFF	ALP	ALM	ASP	ASM	PAR	PAT	PACA	PMC	PHI	PMP	PPC
27	6273.8	93.9	94.4	218.1	98	3.4	3.1	9.8	12.3	22.1	10.1	5.4	15.2	8.1
25	6259.1	93.2	94.8	203	104.1	2.7	2.9	3.1	8.4	11.5	7	7.5	11.8	11.9
29	6259	93.7	94.1	217.7	101.2	2.3	3.5	1.8	4.7	6.5	9.2	4.6	8.2	11.1
21	6252.5	93.5	94.6	200	100	3	3	6.1	7	13.1	6.8	7.2	13.6	13
37	6233.7	94.8	95.4	192.3	87.5	2.6	3.3	8.6	4.5	13.1	8.1	6.4	10.6	14
26	6226.8	93.2	94.7	219.8	103.3	2.4	3	3.4	2.5	5.9	7.3	5.8	12.6	9
28	6215.6	94.1	95.3	227.8	105.3	3.2	2.9	6.5	7.3	13.9	8.8	5.4	9.4	8.7
12	6192.4	96.3	98	192.5	91.6	2.4	2.9	3.3	3.5	6.8	7.9	4	7.7	12.1
14	6182.1	96.9	97.8	192.9	102.2	2.1	2.6	6	4.3	10.3	6.7	5.8	9.9	14.1
17	6004.2	95.7	96.8	208.1	99.5	2.8	3.2	9.1	5.5	14.6	10.3	4.4	11.7	11.1
15	5927.2	95.5	96.9	186.4	86.3	2.1	2.8	3	3.3	6.3	6.2	5.3	11	14.6
39	5828.1	97	97.8	207.7	106.2	3.7	3.3	12.5	11.6	24.1	5.8	7.8	18.2	17.7
13	5824.2	96.2	97.9	192.7	93.1	2.1	2.6	4.3	3.3	7.6	6.8	8.5	8.6	16
20	5816.7	95.7	96.7	205.7	100.5	2.8	3.2	5.2	6.8	12	6.3	5	11.3	8.6
18	5779.9	96.4	98.2	199.9	102.7	2.6	3.1	9.6	3.1	12.6	8.7	6.9	12.1	14.2
42	5673.4	99.1	101.2	207.7	103.2	3.1	2.7	19.3	2.6	21.8	5.6	7.8	19.6	15.9
40	5566.6	96.7	98.1	214.2	124.7	3.7	3.2	15.2	9.1	24.4	8.3	5.5	18.7	14.5
6	5566.4	94.2	95.7	202.2	100	2.5	3.4	6.5	7	13.5	8.1	7.1	15.5	9
3	5467.6	99.1	101.2	225.1	109.6	3.1	3.1	12.3	4.8	17	6.2	5.5	17.9	11.8
16	5371.6	95.6	97.1	202.4	95.7	2.5	3.3	4.1	5.5	9.7	9.2	8	13.2	11.9
4	5294.1	94.5	95.2	204.3	102.8	3	3.6	7.2	4.6	11.8	8.5	6.8	15.4	13.6
8	5133.7	94.8	95.9	200.6	99.3	2.9	3.6	5.4	6	11.3	8	6.4	15	9.6
43	5081.6	97.8	99.5	188.4	89.8	2.4	3	6.2	2.9	9.1	6.9	5.6	10.3	12.6
5	4925.1	94.9	95.8	207.4	105.2	2.9	3.5	5.9	6.2	12.1	10.2	6.4	15.2	15
1	4445.7	99.9	101.9	202.2	104.6	3	3.4	7.5	4.3	11.8	9.2	4.5	21.8	14.4
2	4327	99.5	101.4	200.1	95.4	3.1	3.2	6.4	5.8	12.2	6	2.8	16.4	14.9
DSH(0.05)	826.5	2.64	3.05	37.1	24.4	1	0.71	11	7.8	12.24	7.26	5.8	7.28	10

REND= grain yield; DFM= male flowering; DFF= female flowering; ALP, plant height; ALM, cob height; ASP= aspect of the plant; ASM= appcobance of the cob; PAR= root encam; PAT= stem house; PACA= both camps; PMC= plants with poor coverage; PHI= percentage of children; PMP= rotten cobs; PPC= plants “cuatas”.

Conclusions

The best locations for the evaluation of the genetic material were Atlacomulco, Almoloya of Juárez and Toluca.

The interaction between localities and the rest of the interactions was significant in most of the evaluated variables, so the behavior of the genetic material through the evaluation environments is different. It is suggested to give greater importance to specific adaptation.

The female one (CML246 x CML242) contributed to the formation of mestizos of larger dimensions in grain yield, plant and cob heights, tillering and plant and cob aspects; also, had lower averages in male and female blooms, acames of root, stem and total, cob cover, cob rot and prolificacy.

The upper fraction of males recommended for the formation of new double or triple cross hybrids are those identified as 7, 38, 41, 35, 34, 33, 9, 24, 36, 30, 23, 32, 19, 10, 11, 31, 22, 27, 25, 29, 21, 37, 26, 28, 12 and 14.

Cited literature

Bernardo, R. 2001. Breeding potential of intra-and inter heterotic group crosses in maize. Crop Sci. 41(1):68-71.

Castañón, G.; Jeffers, D.; Hidalgo, H. y Tosquy, H. 1998. Prueba de mestizos de maíz en el estado de Veracruz, México. Agron. Mesoam. 9(2):89-96.

Castellanos, J. S.; Hallauer, A. R. and Cordova, H. S. 1998. Relative performance of testers to identify elite lines of corn (*Zea mays* L.). Maydica. 43(1):217-226.

Franco, M. J. R. P.; González, H. A.; Pérez, L. D. J. y González, R. M. 2015. Caracterización fenotípica de híbridos y variedades de maíz forrajero en Valles Altos del estado de México, México. Rev. Mex. Cienc. Agríc. 6(8):1915-1927.

Gámez, V. A. J.; Ávila, P. M. A.; Ángeles, A. H.; Díaz, H. C.; Ramírez, V. H.; Alejo, J. A. y Terrón, I. A. 1996. Híbridos y variedades de maíz liberados por el INIFAP hasta 1996. Publicación Especial Núm. 16. INIFAP, Toluca, México. 16-18 pp.

González, H. A.; Vázquez, G. L. M.; Sahagún, C. J. y Rodríguez, P. J. E. 2008. Diversidad fenotípica de variedades e híbridos de maíz en el Valle Toluca-Atlacomulco, México. Rev. Fitotec. Mex. 31(1):67-76.

González, A.; Pérez, D. de J.; Sahagún, J.; Franco, O.; Morales, E. J.: Rubí, M.; Gutiérrez, F. y Balbuena, A. 2010. Aplicación y comparación de métodos univariados para evaluar la estabilidad de maíces del Valle Toluca-Atlacomulco, México. Rev. Agron. Costarric. 34(2):129-143.

Habliza, A. A. and Khalifa, K. I. 2005. Selection among new yellow maize inbred lines using top cross and stability analysis. Alex. J. Agric. Res. 50(1):41-51.

Lorenz, A. J.; Coors, J. G.; de Leon, N.; Wolfrum, E. J.; Hames, B. R.; Sluiter, A. D. and Weimer, P. J. 2009. Characterization, genetic variation, and combining ability of maize traits relevant to the production of cellulosic ethanol. Crop Sci. 49(1):85-98.

Martínez, G. A. 1988. Diseños experimentales: métodos y elementos de teoría. Editorial Trillas. 756 p.

Márquez, S. F. 1988. Genotecnia vegetal. Métodos, teoría y resultados. Tomo II. AGT Editor. México, D. F. 756 p.

Menz, M. A.; Hallauer, A. R. and Russell, W. A. 1999. Comparative response of two reciprocal recurrent selection methods in BS21 and BS22 maize populations. Crop Sci. 39(1):89-97.

Mihaljevic, R. C.; Schoon, C. C.; Utz, H. F. and Melchinger, A. E. 2005. Correlation and QTL correspondence between line per se and testcross performance for agronomic traits in four populations of European maize. Crop Sci. 45(1):114-112.

Mosa, H. E.; El-Shenawy, A. A. and Motawei, A. A. 2008. Line x tester analysis for evaluation of new maize inbred lines. J. Agric. Sci. Mansoura Univ. 33(1):1-12.

Mosa, H. E. 2010. Estimation of combining ability of maize inbred lines using top cross mating design. J. Agric. Res. Kafer El-Sheikh Univ. 36(1):1-16.

Obaidi, M.; Johnson, B. E.; Van Vleck, L. D.; Kachman, S. D. and Smith, O. S. 1998. Family per se response to selfing and selection in maize based on testcross performance: a simulation study. Crop Sci. 38(2):367-371.

Pfarr, D. G. and Lamkey, K. R. 1992. Comparisons of methods for identifying populations for genetic improvement of maize hybrids. Crop Sci. 32(3):670-677.

Quiroz, M. J.; Pérez, L. D. J.; González, H. A.; Rubí, A. M.; Gutiérrez, R. F.; Franco, M. J. R. P. y Ramírez, D. J. F. 2017. Respuesta de diez cultivares de maíz a la densidad de población en tres localidades del centro mexiquense. Rev. Mex. Cienc. Agríc. 8(7):1420-1431.

Reynoso, Q. C. A.; González, H. A.; Pérez, L. D. J.; Franco, M. O.; Velázquez, C. G. A.; Balbuena, M. A.; Torres, F. J. L.; Bretón, L. C. y Mercado, V. O. 2014. Análisis de 17 híbridos de maíz en 17 ambientes de los Valles Altos del centro de México. Rev. Mex. Cienc. Agríc. 5(5):871-882.

Russell, W. A.; Blackburn, D. J. and Lamkey, K. R. 1992. Evaluation of modified reciprocal recurrent selection procedure for maize improvement. Maydica 37(1):61-67.

Sistema de Información Agroalimentaria y Pesquera (SIAP). 2014. Producción Agropecuaria y Pesquera. http://www.siap.gob.mx/.

Torres, F. J. L.; Morales, R. E. J.; González, H. A.; Laguna, C. A. y Córdova, O. H. 2011. Respuesta de híbridos trilineales y probadores de maíz en Valles Altos del centro de México. Rev. Mex. Cienc. Agríc. 2(6):829-844.

Torres, F. J. L.; Mendoza, G. B.; Prasanna, G. B. M.; Alvarado, G.; San Vicente, F. M. and Crossa, J. 2017. Grain yield and stability of white early maize hybrids in the Highland Valleys of Mexico. Crop Sci. 57:1-14.

Turrent, F. A. 1994. Plan de investigación del sistema maíz-tortilla en la región centro. CIRCE-INIFAP- SARH. Publicación especial núm. 12, Chapingo, México. 55 p.

Velázquez, C. G. A.; Ramírez, D. J. L.; A. Rendón, G. A. y Salinas, M. Y. 2013. Comportamiento de híbridos experimentales de maíz para siembras de riego en la zona de transición (1900 a 2100 msnm). Memoria 58. reunión anual PCCMCA-Honduras. La Ceiba, Atlántida, Honduras. 99 p.

Welcker, C.; Thé, C.; Andreau, B.; de Leon, C.; Parentoni, S. N.; Bernal, J.; Felicite, J.; Zonkeng, C.; Salazar, F.; Narro, L.; Charcosset, A. and Horst, W. J. 2005. Heterosis and combining ability for maize adaptation to tropical acid soils: implications for future breeding strategies. Crop Sci.45(6):2405-2413.