DOI: https://doi.org/10.29312/remexca.v14i3.2829

Article

Adaptability of varietal crosses of corn in the states of Veracruz and Tabasco

Mauro Sierra-Macías[1]
Flavio A. Rodríguez-Montalvo[1]
Alejandro Espinosa-Calderón[2]
Margarita Tadeo-Robledo[3§]
Pablo Andrés-Meza[4]
Noel Gómez-Montiel[5]

[1]Cotaxtla Experimental Field-INIFAP. Veracruz-Córdoba highway km 34.5, Medellín de Bravo, Veracruz, Mexico. CP. 92277. Tel. 800 088222, ext. 87252. (sierra.mauro@inifap.gob.mx; rodriguez.flavio@inifap.gob.mx). [2]Valley of Mexico Experimental Field-INIFAP. Los Reyes-Texcoco highway km 13.5, Coatlinchán Texcoco, State of Mexico. CP. 56250. (espinoale@yahoo.com.mx). [3]Agricultural Engineering-Faculty of Higher Studies Cuautitlán-National Autonomous University of Mexico. Cuautitlán-Teoloyucan highway km 2.5, Cuatitlán Izcalli, State of Mexico. CP. 54714. [4]Veracruz University. (pandres@uv.mx). [5]Iguala Experimental Field-INIFAP. Iguala-Tuxpan highway km 2.5, Iguala de la Independencia, Guerrero. CP. 40000. (gomez.noel@inifap.gob.mx).

[§]Corresponding author: tadeorobledo@yahoo.com.

Abstract

Varietal crosses represent an alternative in the commercial production of hybrid corn due to the heterosis that results from crossing two free-pollinated varieties. Thus, in order to know the yield and adaptability of varietal crosses of corn, during the spring-summer cycles 2016, 2017 and 2018, 20 varietal corn crosses, five experimental synthetics, the varieties VS-536 and V-537C and the hybrid H-520 used as controls, were evaluated in Veracruz and Tabasco. These experiments were distributed under a randomized complete block design with 28 treatments and three repetitions in plots of two furrows 5 m long, 80 cm apart, at a density of 62 500 plants ha^{-1}. From the combined analysis of variance for grain yield, statistical significance at 0.01 probability was found for genotypes (G), for environments (E) and for the GxE interaction. According to the stability parameters, the 28 genotypes were characterized as stable, the varietal hybrids outstanding in yield at 0.01 probability were: SINT-2BxVS-536, SINT-4BxVS-536, SINT-4BxSINT-2B, SINT-5BxVS-537C, VS-536xV-537C, SINT-3BxSINT-1BQ, SINT-2BxVS-537C, SINT-5BxVS-536, SINT-1BQxVS-536, SINT-5BxSINT-1BQ with grain yield of 6.45 to 7.21 t ha^{-1}, which exceeded the commercial control H-520, likewise, the percentages of heterosis with respect to the best parent were: 19.76, 13.46, 11.29, 8.54, 16.9, 5.46, 7.64, 6.24, 6.07, and 5.91%, for each hybrid, respectively, of the comparisons and t-tests, the varietal crosses had an average yield of 6.39 t ha^{-1}, significantly higher by 8% in relation to that of the parents.

Keywords: *Zea mays* L., heterosis, tropics.

Reception date: February 2023
Acceptance date: April 2023

Introduction

In Mexico, corn is the most important crop for being the main food of the population, for its sown area and for generating 36% of the value of agricultural production. The main use is direct consumption in its different forms in human diet. The national area in 2018 was 7.95 million hectares, of which 7.345 million were for grain, with an average yield of 3.748 t ha^{-1} and a production of 26.67 million tonnes, of which 12.6 million tonnes are used for direct consumption, 35% is through the flour industry and 65% through the dough and tortilla industry in the process of nixtamalization. However, during 2018 17.095 million tonnes of yellow grain were imported for the feed industry, which generated an apparent *per capita* consumption of 345.6 kg (SAGARPA 2018).

In the tropical region of the country, 2.8 million hectares are sown with corn, of which one million are located within agronomic provinces of good and very good productivity and 91 000 ha are sown under irrigation conditions (Espinosa *et al*., 2019), in this area the use of improved seed of hybrids and synthetic varieties is feasible since these have good yield potential under favorable conditions of climate, soil and management by farmers (Sierra *et al*., 2019).

In the genetic improvement of corn for the tropics, by-products such as free-pollinated varieties, synthetic varieties and corn hybrids are generated (Sierra *et al*., 2019), in the formation of hybrids it is important to identify parents with good general (GCA) and specific combining ability (SCA), good yield *per se*, tolerance to biotic and abiotic stress, ease and profitability in the commercial production of seed (Tadeo *et al*., 2015a; Tadeo *et al*., 2015b; Trachsel *et al*., 2016; Gómez *et al*., 2017; Sierra *et al*., 2018).

Regarding the use of hybrid seed, the genetic variance, deviation of additivity and the advantages offered by heterosis in the commercial production of corn, given by the heterozygosity when crossing corn parents with relative genetic divergence, are taken advantage of (Reyes, 1985; Esquivel *et al*., 2011; Sierra *et al*., 2018; Sierra *et al*., 2019). Chuquija and Huanuqueño (2015), from a study on the behavior of eight populations of yellow corn, found that populations 28 and 24 were good parents, because their descendants were more yielding, of lower plant height and earlier than the tester.

From a study with corn germplasm adapted to High Valleys, Velasco *et al*. (2019) found that the cross F1p9∗P8 presented the highest value of heterosis (26.19%). Reyes (1971) used the heterotic pattern humid tropics x dry tropics in the formation of the hybrids H-503 and H-507. Córdova *et al*. (2007) report that the cross CML247xCML254 has been used as a control in several experiments in national programs in Latin America, in which it has expressed good yield and favorable agronomic characteristics, it has also been used by several seed producing companies. Sierra *et al*. (2004) used as testers inbred lines of good specific combining ability (SCA), LT154, LT155, CML247 and CML254, which allowed identifying advanced lines and separating heterotic groups. De la Cruz *et al*. (2010), from a study on heterosis and combining ability in tropical corn populations, found that additive effects were the main component in the expression of grain yield. Gómez *et al*. (2015), in crosses of local varieties of temperate climate with adapted varieties of the tropics, found crosses of the Chalqueño race with Tepecintle with the highest values of heterosis.

Varietal crosses represent an alternative in commercial corn production due, among other reasons, to the heterosis that results from crossing two parents free-pollinated varieties, and to the fact that only two parents have to be kept; therefore, commercial seed production is easier and more profitable (Sierra *et al*., 2016; Sierra *et al*., 2018). For their part, Tadeo *et al*. (2015b) mention that although the varieties V-54A and V-55A represent a good option for rainfed producers in the High Valleys of Mexico, the cross 156xV-54A was found, which exceeded by 38.1% the yield of the variety V-54A, which can represent advantages in commercial sowings.

According to the values of Heterosis, GCA and SCA for yield, Palemón *et al*. (2012) selected the varietal crosses VS-529∗VE1 and VS-529∗VE3 for mass promotion in the semi-warm region of the state of Guerrero. The adaptability of genotypes allows knowing the response to different environments defined by climate, soil and agronomic management (Eberhart and Russell, 1966). The environment-genotype interaction is the relative differential behavior exhibited by genotypes across different environments (Reyes, 1990; Andrés *et al*., 2017; Sierra *et al*., 2018).

The model by Eberhart and Russell (1966) uses the regression coefficient to measure the response of a variety to different environments and the regression deviation that measures the consistency of said response, it is necessary to select genotypes that interact as little as possible with the environment. A stable variety is one with a coefficient of variation equal to 1 and regression deviation equal to 0. The statistical model is: $\overline{Y}ij = \mu i + \beta i I_j + \delta_{ij}$. Where, $\overline{Y}_{ij}$= mean of variety i in environment j; μ_i= mean of variety i in all environments; β_i= regression coefficient; I_j= environmental index; δ_{ij}= regression deviation.

The objectives of the research were to know the yield, adaptability and agronomic characteristics of varietal crosses of corn across environments in the states of Veracruz and Tabasco and to determine heterosis with respect to the best parent. The hypotheses were to verify that, in the varietal crosses of corn in evaluation, there are differences in adaptability and agronomic characteristics across environments, as well as values of heterosis with respect to the best parent.

Materials and methods

Location. The formation of varietal crosses of corn was carried out in the Cotaxtla Experimental Field, belonging to the National Institute of Forestry, Agricultural and Livestock Research (INIFAP, for its acronym in Spanish), located in the municipality of Medellín de Bravo, Veracruz, located at 18° 56’ north latitude and 96° 11’ west longitude and an altitude of 15 masl, the climate, according to the Köppen classification modified by García (1981), with area of influence in the humid tropics of Mexico, includes the climatic group A (Aw, Am and Af), humid and subhumid warm with average temperature of 25 °C and annual rainfall of 1 400 mm, distributed from June to November.

The soil is of alluvial origin, deep, with medium texture throughout the profile, slope less than 1%, good drainage and slightly acidic pH (6.6). The evaluation localities of the varietal crosses were: Cotaxtla Experimental Field, CBTA 84 of the municipality of Carlos A. Carrillo in Veracruz and Huimanguillo in the state of Tabasco, with climate Aw1, Aw2 and Am for each locality, respectively.

Germplasm used. The corn germplasm used in the present research is experimental material in different degrees of advance in genetic improvement, particularly they are varietal crosses of corn formed with experimental synthetic varieties belonging to the Tuxpeño race, 28 genotypes were evaluated, of which 20 are varietal crosses, five experimental synthetics, the varieties VS-536 and V-537C and the hybrid H-520, used as controls for their commercial use (Sierra *et al*., 2019).

Description of the experiments. During the spring-summer cycles 2016, 2017 and 2018, 20 varietal crosses of corn, five experimental synthetics, the varieties VS-536 and V-537C and the hybrid H-520 used as controls, were evaluated, which were distributed under a randomized complete block design with 28 treatments and three repetitions in plots of 2 furrows 5 m long, 80 cm apart, at a density of 62 500 plants ha^{-1}, for weed control Atrazine was applied in a pre-emergent way, and the fertilization was carried out with the formula 161-46-00, using urea as a nitrogen source and foliage pests were controlled during the development of the crop.

Variables and data recording. Due to their economic importance and reduction in the risks in production, the main agronomic variables recorded in the experiments were: days to male and female flowering, plant and ear height, rating of appearance and health of plant and ear using a rating scale of 1 to 5, where 1 is the best and 5 is the worst, total number of plants, % of lodged plants, % of ears with poor cover, at harvest the variables of grain yield, total number of ears, % of rotten ears and % of dry matter in the grain were recorded.

Statistical methods. The designs used were randomized complete blocks with 28 treatments and three repetitions in plots of two furrows 5 m long, 80 cm apart, with a density of 62 500 plants ha^{-1}. An individual analysis for each experiment and a combined analysis of the varietal crosses in the six evaluation environments were performed. For the separation of means, the least significant difference (LSD) test was applied, at 0.05 and 0.01 probability (Reyes, 1990).

An analysis of stability parameters was made (Eberhart and Russell, 1966). Comparisons and t-tests at 0.05 and 0.01 probability were made for varietal crosses and their parents' synthetic varieties. Likewise, the percentages of heterosis with respect to the best parent were calculated (Reyes, 1985), as follows: % of heterosis= $\frac{\text{F1- best parent}}{\text{Best parent}}$ x 100.

Results and discussion

From the combined analysis of variance for grain yield in the varietal crosses (Table 1), statistical significance at 0.01 probability was found for genotypes (G), for environments (E) and for the GxE interaction, the significance for the interaction suggests that the genotypes outstanding in one environment are not necessarily outstanding in other environments. In Table 1, it can be observed that the variance due to the factor environments was more important, which means that the environment is important in the expression of varietal crosses; likewise, the coefficient of variation recorded was 13.97%, a relatively low value, which suggests that the management of the experiments and the data obtained are reliable (Reyes, 1990).

Table 1. Combined analysis of variance for grain yield of varietal crosses of corn in six environments of Veracruz and Tabasco. 2016B to 2018B.

Source of variation	DF	SS	MS
Genotypes (G)	27	65.27	2.42^{**}
Environment (E)	5	341.54	68.31^{**}
GxE interaction	135	677.07	5.02^{**}
Error	324		0.7697
CV (%)			13.97

B= spring-summer cycle; DF= degrees of freedom; SS= sum of squares; MS= mean squares; CV= coefficient of variation.

In the genotype-environment interaction and according to the parameters of stability (Eberhart and Russell, 1966), the 28 genotypes were characterized as stable (Reyes 1990; Andrés *et al*., 2017; Sierra *et al*., 2018). The varietal hybrids outstanding in yield at 0.01 probability were: SINT-2BxVS-536, SINT-4BxVS-536, SINT-4BxSINT-2B, SINT-5BxVS-537C, VS-536xV-537C, SINT-3BxSINT-1BQ, SINT-2BxVS-537C, SINT-5BxVS-536, SINT-1BQxVS-536, SINT-5BxSINT-1BQ, with grain yield of 6.45 to 7.21 t ha^{-1} (Table 2). Also, this group of varietal hybrids was superior in yield by 1 to 13% more in relation to the commercial control H-520.

Table 2. Yield of varietal crosses of corn, Veracruz and Tabasco 2016B- 2018B.

Treat	Genealogy	Cot 2016B	Huim 2016B	Carr 2016B	Cot 2017B	Huim 2018B	Cot 2018B	Average	% Rel	% Het	Description
1	SINT-2B XVS-536	7.99	6.34	9.16	6.28	6.55	6.91	7.21^{*}	113	19.76	S
14	SINT-4B X VS-536	8.67	6.05	6.9	6.86	5.47	6.48	6.74^{*}	105	13.46	S
17	SINT-4B X SINT-2B	7.64	5.83	8.11	6.09	5.42	7.1	6.7^{*}	105	11.29	S
9	SINT-5B X V-537C	7.25	5.79	8.3	6.61	5.42	6.32	6.61^{**}	103	8.54	S
20	VS-536 X VS-537C	7.14	5.23	8.13	5.85	5.69	7.36	6.57^{**}	103	16.90	S
18	SINT-3BxSINT-1BQ	7.73	6.01	7.97	3.71	6.36	7.56	6.56^{**}	102	5.46	S
19	SINT-2B X VS-537C	7.75	5.13	6.89	6.51	5.58	7.05	6.48^{**}	101	7.64	S
16	SINT-5B X VS-536	7.03	4.86	8.17	7.65	5.23	5.88	6.47^{**}	101	6.24	S
13	SINT-1BQ X VS-536	6.77	5.39	7.34	6.79	6.15	6.33	6.46^{**}	101	6.07	S
15	SINT-5BxSINT-1BQ	7.01	4.57	8.54	6.82	5.13	6.62	6.45^{**}	101	5.91	S

Treat	Genealogy	Cot 2016B	Huim 2016B	Carr 2016B	Cot 2017B	Huim 2018B	Cot 2018B	Average	% Rel	% Het	Description
6	SINT-3B X VS-537C	6.69	5.42	7.41	6.42	5.24	7.36	6.42	100	3.22	S
28	H-520	7.42	5.92	6.74	6.4	5.16	6.77	6.4	100		S
12	SINT-4B X SINT-3B	7.34	5.02	8.6	6.64	5.43	5.17	6.37	99	2.41	S
3	SINT-5B X SINT-4B	7.1	5.12	7.6	6.32	4.92	6.86	6.32	99	3.78	S
11	SINT-3B X SINT-2B	7.73	6.06	6.06	4.47	6.59	6.87	6.3	98	1.29	S
2	SINT-5B X SINT-2B	7.55	5.71	6.08	6.99	4.35	7.07	6.29	98	3.28	S
23	SINT-3B	7.02	4.36	8.47	6.22	5.76	5.5	6.22	97		S
5	SINT-4B X VS-537C	7.17	5.03	4.97	6.59	5.87	6.99	6.1	95	2.69	S
21	SINT-1BQ	8.18	4.57	7.04	6.09	6.28	4.37	6.09	95		S
8	SINT-4BxSINT-1BQ	7.51	5.03	8.1	4.18	4.66	7.05	6.09	95	0	S
25	SINT-5B	7	4.14	6.07	6.09	6.22	7	6.09	95		S
7	SINT-5B X SINT-3B	7.34	4.91	7.37	6.61	4.51	5.7	6.07	95	-2.41	S
4	V-537C X VS-536	7.12	5.69	4.46	5.85	5.69	7.36	6.03	94	7.29	S
22	SINT-2B	7.35	4.76	6.26	6.02	5.62	6.1	6.02	94		S
24	SINT-4B	6.22	4.56	7.69	5.94	4.94	6.26	5.94	93		S
26	VS-536	6.95	4.62	6.51	5.38	4.65	5.63	5.62	88		S
27	V-537 C	5.22	4.22	8.92	5.08	4.94	5.04	5.57	87		S
10	SINT-2BxSINT-1BQ	7.78	4.82	6.16	4.36	3.49	6.61	5.53	86	-9.19	S
	Average	7.27	5.18	7.29	6.03	5.4	6.48	6.28			
	CV (%)							13.97			
	MSE							0.7697			
	LSD 0.05							0.5732			
	LSD 0.01							0.7545			

B= spring-summer agricultural cycle; */= significance of treatments at 0.05 probability; **/= significance of treatments at 0.01 probability; Treat= treatment; Cot= Field of Cotaxtla, Veracruz; Carr= Carlos A. Carrillo, Veracruz; Huim= Huimanguillo, Tabasco; % Rel= relative % with respect to the control; % Het= % heterosis with respect to the best parent; S= genotype characterized as stable.

These varietal crosses have the additional advantage represented from the point of view of keeping only two parents, which are free-pollinated varieties with greater profitability and ease in the commercial production of seed (Tadeo *et al*., 2015a; Tadeo *et al*., 2015b; Sierra *et al*., 2016; Gómez *et al*., 2017; Sierra *et al*., 2018).

In the best crosses, the presence of VS-536, a variety of greater commercial use in southeastern Mexico (Sierra *et al*., 2016), is observed. Also, the percentages of heterosis with respect to the best parent were: 19.76, 13.46, 11.29, 8.54, 16.9, 5.46, 7.64, 6.24, 6.07 and 5.91% for each varietal hybrid, respectively (Table 2 and Figure 1) (Reyes, 1971; Reyes, 1985; Sierra *et al*., 2004; Córdova *et al*., 2007; De la Cruz *et al*., 2010; Esquivel *et al*., 2011; Palemón *et al*., 2012; Chuquija and Huanuqueño, 2015; Gómez *et al*., 2015; Velasco *et al*., 2019).

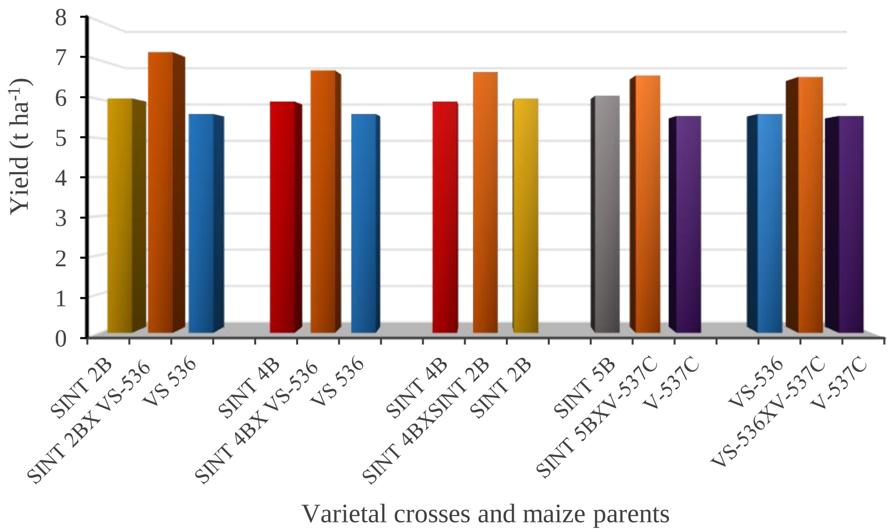

Figure 1. Heterosis in outstanding varietal crosses of corn, Veracruz and Tabasco 2016-2018.

Environmental indices. Regarding the environmental indices, according to Eberhart and Russell (1966), the environments of Carlos A. Carrillo, Veracruz, in 2016B and Cotaxtla, Veracruz in 2016B had significantly higher average yields with 7.29** and 7.27** t ha^{-1} and positive values in the environmental indices with 1.01 and 0.99 for each environment respectively, while Cotaxtla in 2017B and the locality of Huimanguillo, Tabasco in 2018 and 2016B had the lowest average yields with negative environmental indices of -0.25, -0.88 and -1.1 for each environment, respectively (Table 3).

Table 3. Environmental indices of evaluation localities of varietal crosses. CIRGOC 2016B-2018B.

Environment	Yield (t ha^{-1})	Indices
Carlos A. Carrillo, Veracruz, 2016B	7.29**	1.01
Cotaxtla, Veracruz, 2016B	7.27**	0.99
Cotaxtla, Veracruz, 2018B	6.48	0.2
Cotaxtla, Veracruz, 2017B	6.03	-0.25
Huimanguillo, Tabasco, 2018B	5.4	-0.88
Huimanguillo, Tabasco, 2016B	5.18	-1.1
Average	6.28	

B= spring-summer agricultural cycle.

Agronomic characteristics

With regard to agronomic characteristics (Table 4), these varietal crosses showed intermediate biological cycle with 51 to 53 days to male flowering, low height of plant and ear with 217 to 255 cm and 108 to 132 cm for height of plant and ear, respectively. These crosses have good appearance and health of plant and ear, are tolerant to lodging, with good ear cover, have a low percentage of rotten ears and with a ratio of ear height/plant height between 0.49 and 0.58; that is, position of the ear at half the height of the plant, which is reflected in its tolerance to lodging (Tadeo *et al*., 2015a; Tadeo *et al*., 2015b; Trachsel *et al*., 2016; Gómez *et al*., 2017; Sierra *et al*., 2018).

Table 4. Agronomic characteristics of varietal crosses of corn. Cotaxtla 2016B.

Treat	Genealogy	Days to flower	Pl hei (cm)	Ea hei (cm)	Pl app	Ea app	Pl hea	Ea hea	(%) Lodging	(%) Ear	(%) Rot	Ea hei/ Pl hei
1	SINT-2BxVS-536	51	238	130	1.7	2.3	1.8	2.2	7.43	0.79	3.73	0.55
2	SINT-5BxSINT-2B	52	225	117	2.3	2.2	2.5	2.2	8.12	9.41	2.81	0.52
3	SINT-5B X SINT-4B	53	237	128	2.7	2.7	2.3	2.3	12.26	9.15	4.61	0.54
4	V-537C X VS-536	51	227	122	2.2	2.8	2.3	2.3	16.5	2.98	6.39	0.54
5	SINT-4B X VS-537C	51	223	110	2.5	2.5	2.2	2.5	8	4.14	4.59	0.49
6	SINT-3B X VS-537C	52	245	120	2.5	2.5	2.5	2.7	5.03	4.45	4.35	0.49
7	SINT-5B X SINT-3B	52	227	117	2.3	2.7	2.3	2.2	7.05	6.03	5.89	0.52
8	SINT-4B X SINT-1BQ	52	235	118	2	2.2	2	2.2	3.34	0.67	1.33	0.5
9	SINT-5B X VS-537C	51	225	113	2.3	2.2	2.3	2.2	5.9	5.02	3.56	0.5
10	SINT-2BxSINT-1BQ	52	222	112	2.2	2.2	2.3	2.2	5.79	2.9	4.36	0.5
11	SINT-3BxSINT-2B	52	225	132	2.5	2.3	2.2	2.3	1.99	1.39	2.75	0.58
12	SINT-4B X SINT-3B	52	223	117	1.8	2.5	2.2	2.3	5.09	3.35	2.99	0.52
13	SINT-1BQ X VS-536	53	238	130	2.3	2.5	2.5	2.2	37.95	2.54	3.38	0.54
14	SINT-4B X VS-536	51	228	123	2.3	2.2	2.2	2.3	11.36	5	1.74	0.54
15	SINT-5B X SINT-1BQ	52	217	108	2.2	2.3	2.2	2.3	7.79	2.18	3	0.5
16	SINT-5B X VS-536	51	235	132	2.3	2.3	2.2	2.2	20.15	3.69	4.07	0.56
17	SINT-4B X SINT-2B	52	227	115	2.2	2.7	2.3	2.7	13.58	3.29	5.67	0.51
18	SINT-3BxSINT-1BQ	51	230	112	2.3	2.5	2.3	2.3	1.39	2.56	3.89	0.49
19	SINT-2B X VS-537C	51	255	140	2.2	2.2	2.7	2.2	15.26	8.99	4.56	0.55
20	VS-536xVS-537C	52	253	142	2.2	2.8	2.2	2.7	24.66	2.66	5.77	0.56
21	SINT-1BQ	51	220	112	2.3	2.2	2.7	2.2	0	3.27	4.53	0.51
22	SINT-2B	52	212	115	2.7	2.3	2.3	2.3	4.94	1.95	2.53	0.54
23	SINT-3B	51	242	137	2.5	2.8	2.5	2.3	4.77	8.82	4.2	0.55
24	SINT-4B	52	225	118	2.3	2.5	2.3	2.3	2.07	2.38	5.14	0.53
25	SINT-5B	52	223	127	2	2.3	2.3	2	3.98	8.83	2.17	0.57

Treat	Genealogy	Days to flower	Pl hei (cm)	Ea hei (cm)	Pl app	Ea app	Pl hea	Ea hea	(%) Lodging	(%) Ear	(%) Rot	Ea hei/ Pl hei
26	VS-536	52	232	132	2.5	2.7	1.7	2.7	24.83	4.78	3.98	0.57
27	V-537 C	52	225	115	2.3	2.8	2.5	2.5	13.53	5.87	6.98	0.51
28	H-520	51	228	122	2.2	2.3	2	2.2	14.76	4.11	4.04	0.53
	Promedio	51.7	230.07	122	2.28	2.45	2.28	2.32	10.27	4.33	4.04	0.53
	CME	0.97	687.32	589.1	0.27	0.3	0.3	0.25	204.7	42.45	11.8	50.3
	CV (%)	1.91	11.39	19.89	22.79	22.35	24.02	21.55	139.31	150.5	85.03	13.38

Treat= treatment; Pl hei= plant height; Ea hei= ear height; Pl app= plant appearance; Ea app= ear appearance; Pl hea= plant health; Ea hea= ear health; % Ear= percentage of ears with poor cover; % Rot= percentage of rotten ears.

The varietal crosses SINT-2BxVS-536, SINT-4BxVS-536, SINT-4BxSINT-2B, SINT-5BxVS-537C, SINT-3BxSINT-1BQ, SINT-5BxSINT-1BQ, outstanding in yield and favorable agronomic characteristics, can be an alternative in the commercial production of corn because they adapt to the conditions of climate, soil and management by farmers in the tropical region of southeastern Mexico (Sierra *et al*., 2019; Espinosa *et al*., 2019).

From the comparisons and t-tests at 0.05 and 0.01 probability (Table 5), it was found that varietal crosses had an average yield of 6.39 t ha^{-1}, significantly higher by 8% in relation to the average yield of the parents, with a calculated t value of 5.07^{**}; there was also an advantage in the ratings of appearance of plant and ear.

Table 5. Comparisons and t-tests for varietal crosses and their parents. CIRGOC 2016B-2018B.

Comparison	Yield (t ha^{-1})	(%) Rel	t Calc	Pl hei	(%) Rel	t Calc	Pl $app^{2/}$	(%) Rel	t Calc	Ea $app^{2/}$	(%) Rel	t Calc
Crosses	6.39	108	5.07**	231.75	103	0.93ns	2.25	100	0.92ns	2.43	100	0.57ns
Parents	5.93	100		225.57	100		2.37	105		2.51	103	

t0.05 (54 DF)= 2; t0.01 (54 DF)= 2.66. Yield= grain yield; % Rel= relative percentage in the comparison; t Calc= t calculated for the comparison; Pl hei= plant height; Pl app= plant appearance; Ea app= ear appearance; $^{2/}$= rating scale of 1 to 5, where 1 is the best and 5 is the worst.

Conclusions

The outstanding varietal hybrids were: SINT-2BxVS-536, SINT-4BxVS-536, SINT-4BxSINT-2B, SINT-5BxVS-537C, VS-536xV-537C, SINT-3BxSINT-1BQ, SINT-2BxVS-537C, SINT-5BxVS-536, SINT-1BQxVS-536, SINT-5BxSINT-1BQ, with grain yield of 6.45 to 7.21 t ha^{-1} and they were superior to the commercial control H-520. The percentages of heterosis with respect to the best parent in the outstanding varietal crosses were: 19.76, 13.46, 11.29, 8.54, 16.9, 5.46, 7.64, 6.24, 6.07 and 5.91% for each varietal hybrid, respectively.

The crosses had an average yield of 6.39 t ha^{-1}, 8% more in relation to the parents, as well as better rating of appearance of plant and ear. The outstanding crosses showed low plant and ear, good appearance and health of plant and ear, tolerant to lodging, with good ear cover, low percentage of rotten ears. The variety VS-536, of greater commercial use and adapted to the tropical region in southeastern Mexico, participates in five of the 10 outstanding crosses.

Outstanding varietal crosses represent an important advantage from the point of view of keeping both parents, free-pollinated varieties with greater profitability and ease in the commercial production of seed.

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