HV-570, New maize (*Zea mays* L.) varietal prospect hybrid for the humid tropic of México

HV-570, Nuevo Híbrido Varietal de Maíz (*Zea mays* L.) prospecto para el Trópico Húmedo de México

SIERRA-MACIAS, Mauro†*, RÍOS-ISIDRO Clara, GÓMEZ-MONTIEL, Noel Orlando and ESPINOSA-CALDERÓN, Alejandro

Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, INIFAP

ID 1st Author: *Mauro Sierra-Macías* / **ORC ID**: 0000-0001-6476-2192, **CVU CONACYT ID**: 5116

ID 1st Co-author: *Clara Ríos-Isidro* / **ORC ID**: 0000-0003-2148-3745

ID 2nd Co-author: *Noel Orlando Gómez-Montiel* / **CVU CONACYT ID**: 5945

ID 3rd Co-author: *Alejandro, Espinosa-Calderón* / **CVU CONACYT ID**: 78039

DOI: 10.35429/JANRE.2022.11.6.28.35 Received October 14, 2022; Accepted December 23, 2022

Abstract

Varietal hybrids represent an alternative in commercial maize production because of heterosis by crossing two maize varieties with good specific combining ability. The objectives of this research were to know the yield, agronomic traits and adaptability of varietal maize hybrids. Thus, during the spring summer season in 2016, 2017 y 2018 there were evaluated in Veracruz and Tabasco states 20 varietal hybrids, 5 experimental synthetics, the varieties VS-536 and V-537C and the hybrid H-520 used as check. These genotypes were arranged under complete blocks at random, with 28 treatments and three replications in plots of two rows 5m long, and 62,500 plants ha^{-1}. From the combined analysis for grain yield there was found high significant differences for genotypes (G), environments (E) and for the Genotype environment interaction (GE). The best hybrids at 0.05 of probability were: SINT-2BxVS-536 (HV1), SINT-4BxVS-536 (HV-570) and SINT-4BxSINT-2B with yield from 6.70 a 7.21 t ha^{-1}; Besides, the heterosis values with respect to the best parent were: 19.76, 13.46 y 11.29%, for each varietal hybrid, respectively. The varietal hybrid SINT-4BxVS-536 presented high yield, short plant and ear, good plant and ear aspect and good husk cover and it was defined for official registration as HV-570.

***Zea mays* L., Heterosis, Varietal hybrids**

Resumen

Los híbridos varietales representan una alternativa en la producción de maíz debido a la heterosis de cruzar dos variedades con buena aptitud combinatoria específica. Los objetivos de este trabajo fueron conocer el rendimiento, características agronómicas y adaptabilidad de híbridos varietales de maíz. Así, durante los ciclos primavera verano 2016, 2017 y 2018 se evaluaron en Veracruz y Tabasco 20 cruzas varietales de maíz, 5 sintéticos experimentales, las variedades VS-536 y V-537C y el híbrido testigo H-520. Los experimentos se distribuyeron bajo un diseño bloques completos al azar con 28 tratamientos y tres repeticiones en parcelas de 2 surcos de 5 m de largo y densidad de 62,500 pl ha^{-1}. Del análisis combinado para rendimiento, se encontró significancia estadística al 0.01 de probabilidad para Genotipos (G), para Ambientes (A) y para la interacción GxA. Los híbridos sobresalientes fueron: SINT-2BxVS-536 (HV1), SINT-4BxVS-536 (HV-570) y SINT-4BxSINT-2B con rendimiento de 6.70 a 7.21 t ha^{-1}, Heterosis con respecto al mejor progenitor de: 19.76, 13.46 y 11.29%, para cada híbrido, respectivamente. El híbrido varietal SINT-4BxVS-536 registró alto rendimiento, planta y mazorca baja, buen aspecto de planta y de mazorca y buena cobertura de la mazorca por lo que ha sido definido para su liberación oficial como HV-570.

***Zea mays* L., Heterosis, Híbridos varietales**

Citation: SIERRA-MACIAS, Mauro, RÍOS-ISIDRO Clara, GÓMEZ-MONTIEL, Noel Orlando and ESPINOSA-CALDERÓN, Alejandro. HV-570, New maize (*Zea mays* L.) varietal prospect hybrid for the humid tropic of México. Journal-Agrarian and Natural Resource Economics. 2022. 6-11: 28-35

* Correspondence to Author (e-mail: sierra.mauro@inifap.gob.mx)
† Researcher contributing as first author.

Introduction

In Mexico, maize is the most important crop, because is the principal food for people, the planting area and to generate 36% of the agricultural production value. The principal use is the direct consume for human consumption. Thus, during 2018, there were sown in México, 7.95 million of de hectares with maize with an average in yield of 3.75 t ha^{-1}, and a total production of 26.67 million tons, which of them 12.6 million tons are utilized in different ways through the direct human consumption which of them 35% correspond to flour industry and 65% to masa tortilla industry through the nixtamalization process. Besides, in the same year, there were imported 17.095 million tons of maize yellow grain (SIAP, 2018).

In the humid tropic in México, there were sown 2.8 million of hectares with maize, which of them, one million are included in agronomic provinces of good and very good productivity, and 91 thousand hectares were sown under irrigation. In this area is feasible to use improved seed of synthetic maize varieties and hybrids which express their genetic yield potential under favourable conditions in clime, solil and the management by farmers (Sierra *et al*., 2019).

In maize hybridization, is important to identify parentals with high General (GCA) and Specific Combining Ability (SCA), high *per se* yield, tolerant to biotic and abiotic stress, easily in commercial seed production. (Sierra *et al.*, 2018; Gómez *et al.*, 2017; Trachsel *et al.*, 2016; Tadeo *et al* 2015a; Tadeo *et al* 2015b; López *et al.*, 2021; Ramírez *et al.*, 2019; Tadeo *et al.*, 2021).

Improved seeds are the most important input in corn production, they represent the genetic yield potential and quality production (Sierra *et al.*, 2019). In the comercial production of hybrids the kind of gene action is taken advantage, deviation of additivity when crossing different individuals genetically, as long as their genes are compatible, that is to say the yield is greater as the genetic divergence is greater (Reyes, 1985; Sierra *et al.*, 2019; Sierra *et al.*, 2018; Esquivel, *et al.,* 2011 Cordova *et al.,* 2007; Gómez *et al.,* 2015; Chuquija and Huanuqueño 2015; Velasco *et al.,* 2019).

For the tropical region, Reyes (1985), used the heterotic pattern Humid tropic x dry tropic to form the hybrids H-503 and H-507. Sierra *et al.,* (2004), used as testers the inbred lines of High Specific Combinatorial Aptitude (ACE), LT154, LT155, CML247 and CML254, which allowed to identify outstanding advanced lines and to separate heterotic groups to form best hybrids.

Varietal hybrids can be an alternative in the commercial production because of the heterosis of crossing two parents open pollinating varieties; Thus, is easier and cheaper the maintenance of their parents and the commercial seed production because they are synthetic varieties; However, is feasible to increase the use of improved seed. (Sierra *et al.*, 2018; Sierra *et al.*, 2016; Reyes, 1985; Sierra *et al.*, 2014; Tadeo *et al.,* 2016; Tadeo *et al.,* 2015b; Virgen *et al.*, 2016; Espinosa *et al.*, 2012; Cervantes *et al.,* 2016; Palemón *et al.,* 2012).

The adaptability of genotypes permit to know the response to different environments defined by the clime, soil and the agronomic management (Reyes 1990; Andrés *et al.,* 2017; Sierra *et al.,* 2018).

The model of Eberhart and Russell (1966), utilize the coeficient of regresion for measure the response of a variety across of diferent environments and the deviation of the regresion that indicate the consistence of this response. Thus, stable variety correspond to those with a coeficient of regresión equal to 1 and deviation of regression equal to 0.

The statistical model is: $\bar{Y}ij = \mu i + \beta i I_j + \delta_{ij}$,

Where,
$\bar{Y}_{ij}$ = Mean of the variety i in the environment j
μ_i= Mean of the variety i in all environments
β_i=Coeficient of regresion
I_j= Environmental index
δ_{ij}=Deviation of regresión

The objectives of this research were to know the yield, adaptability and agronomic characteristics of the varietal maize hybrids across the six environments in Veracruz and Tabasco states and present to HV-570 as a new varietal maize hybrid prospect for the humid tropic of México.

ISSN 2524-2091

Materials and Methods

Localization

The evaluation of the varietal hybrids was carried out during the spring summer season from 2016 to 2018, in Cotaxtla Experimental Station which belongs to INIFAP, México, and is located at the Km 34 through the public road from Veracruz-Córdoba in the municipality of Medellín de Bravo, Ver., in the 18º 56' North Latitude and 96º 11' West longitude and altitude of 15 masl, Carlos A. Carrillo in Veracruz and Huimanguillo, Tabasco state locations; The clime conditions are Aw1, Aw2 and Am for each location respectively, according with classification by Köppen and modified by García (2004) correspond to humid and subhumid warm conditions.

Germplasm used

The germplasm used in the present research, were 28 genotypes, which of them, 20 varietal crosses, 5 experimental synthetics, the varieties VS-536 and V-537C and the hybrid H-520, used as checks, all of them belong to the Tuxpeño race (Sierra *et al.,* 2019).

Description of the experiment

During the spring summer season in 2016, 2017 and 2018, under rainy conditions, there was carried out an experiment, for evaluating 20 varietal maize hybrids, 5 experimental synthetics the varieties VS-536 and V-537C and the hybrid H-520, used as checks which of them, were distributed in complete blocks at random, with 28 entries and three replications in plots of two rows 5 m long and 80 cm wide in a density of 62,500 pl ha^{-1} (Reyes, 1990).

The weeds were controlled by Atrazine applied before emerging plants. The fertilization was made according to the recommendations by INIFAP; Thus, in Cotaxtla experiment station, this experiment was fertilized using the formula 161-46-00, applying all the Phosphorus and a third part of Nitrogen at sowing moment, the rest of Nitrogen in bunchy stage using Urea as Nitrogen source.

Variables and data recording

During the development of the crop and at harvest time, there were recorded in the experiments the following agronomic variables: Grain yield, days to tassel and silking, Plant and ear height, measured since the base of soil even the highest leaf and the node where is inserted the principal ear, respectively; days to tassel considering 50% of the anthers in anthesis stage, days to silking when stigmas are in receptive stage, total number of plants and ears, qualification of plant and ear aspect and sanity, using a scale from 1 to 5, where, 1 correspond to the best phenotypic expression and 5 for the worst; lodging, ears with bad husk cover, dry matter and ear rot.

Statistical methods

The experimental design used was complete blocks at random with 28 entries and three replications in plots of two rows 5m long and 80 cm wide in a plant density of 62,500 pl ha^{-1}. Individual and combined analysis of variance was made for all variables recorded and were analyzed statistically and for the separation of means, the Significant Minimum Difference test was applied at 0.05 and 0.01 of probability (Reyes, 1990). Besides, there was made an stability parameters analysis (Eberhart y Russell, 1966). On the other hand, comparisons of cross groups and synthetic parent varieties were made and the t-test at 0.05 and 0.01 probability was applied. Also, the percentages of heterosis with respect to the best parent (Reyes, 1985), were calculated as follows:

$$\% \text{ of Heterosis} = \frac{\text{F1}-\text{Best parent}}{\text{Best parent}} \text{ x } 100$$

Resultados y discusión

Grain yield

From the combined analysis for grain yield in the varietal hybrids across the six environments there were found statistical significant differences at 0.01 of probability for Genotypes (G), for Environments (E) and for the interaction VxE; Significance for interaction VxE, suggest that the grain yield in the hybrids across the environments were different (Table 1). (Reyes, 1990; Andrés *et al.,* 2017; Sierra *et al.,* 2018);

The highest variance was recorded for the source of variation environments, factor valued in 68.31**, which means that these environments were different and important in the behavior of the varietal maize hybrids (Reyes, 1990). Besides the Coefficient of Variation registered was 13.97%, value relatively low, and suggest that the results gotten and the management of the experiments are reliable (Reyes, 1990).

Source of Variation	DF	SS	MS
Genotypes (G)	27	65.27	2.42**
Environments (E)	5	341.54	68.31**
Interaction GxE	135	677.07	5.02**
Error	324		0.7697
CV (%)			13.97%

DF=Degree of freedom; SS=Square Sum; MS=Mean Square; CV= Coefficient of variation; **=Significance for source of variation at 0.01 of probability

Table 1 Combined Analysis for grain yield in varietal maize hybrids across six environments in Veracruz and Tabasco states 2016-2018. CIRGOC INIFAP

The best varietal crosses in yield at 0.01 of probability were: SINT2BxVS-536, SINT4Bx VS-536 (HV-570), SINT4BxSINT2B, SINT5Bx V537C, VS-536xV-537C, SINT3BxSINT1BQ, SINT2BxV-537C, with grain yield from 6.47 to 7.21 t ha^{-1} (Cuadro 2). These varietal maize hybrids registered yield from 1 to 13% above than the commercial hybrid H-520 used as check.

These varietal hybrids take the advantage of maintaining only two parents, which are open pollinating maize varieties with greater yield, reliability, and easier for seed production (Espinosa *et al.,* 2012; Cervantes *et al.,* 2016; Sierra *et al.,* 2018; Sierra *et al.,* 2016; Sierra *et al.,* 2014; Gómez *et al.,* 2017; López *et al.,* 2021; Ramírez *et al.,* 2019; Tadeo *et al.,* 2021; Tadeo *et al.,* 2015a; Tadeo *et al.,* 2015b; Tadeo *et al.,* 2016; Virgen *et al.,* 2016).

In the best varietal hybrids participate VS-536, the synthetic maize variety of greater use in the Mexican southeast (Sierra *et al.,* 2016). The heterosis values, with respect to the best parent were: 19.76, 13.46, 11.29, 8.54, 16.9, 5.46 y 7.64%, for each hybrid, respectively, which suggests genetic divergence between the parental varieties (Reyes, 1985; Sierra *et al.,* 2004; Córdova *et al.,* 2007; Esquivel, *et al.,* 2011; Chuquija y Huanuqueño 2015; Palemón *et al.,* 2012; Velasco *et al.,* 2019; Gómez *et al.,* 2015).

In the genotype environment interaction, according with the stability parameters for comparing varieties (Eberhart y Russell, 1966), the 28 genotypes evaluated were characterized as stables (Reyes 1990; Andrés *et al.,* 2017; Sierra *et al.,* 2018).

Environmental indexes

In relation with the environmental indexes by Eberhart and Russell (1966), the environments of the municipality Carlos A. Carrillo and Cotaxtla in Veracruz in 2016B, recorded the highest yield with 7.29** and 7.27** t ha^{-1} and the greatest environmental indexes 1.01** and 0.99** for each environment, respectively.

Entry	Genealogy	Cot 2016B	Huim 2016B	Carr 2016B	Cot 2017B	Huim 2018B	Cot 2018B	Mean	% Rel	% Het	Description
1	SINT2BxVS-536 (HV1)	7.99	6.34	9.16	6.28	6.55	6.91	7.21*	113	19.76	S
14	SINT4BxVS-536 (HV-570)	8.67	6.05	6.90	6.86	5.47	6.48	6.74*	105	13.46	S
17	SINT4BxSINT2B	7.64	5.83	8.11	6.09	5.42	7.1	6.70*	105	11.29	S
9	SINT-5B X V-537C	7.25	5.79	8.30	6.61	5.42	6.32	6.61**	103	8.54	S
20	VS-536xV-537C (HV-3)	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-2BxVS-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-1BQxVS-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
6	SINT-3BxVS-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	6.40	100		S
12	SINT-4B X SINT-3B	7.34	5.02	8.60	6.64	5.43	5.17	6.37	99	2.41	S
3	SINT-5B X SINT-4B	7.10	5.12	7.60	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	6.30	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-4BxVS-537C	7.17	5.03	4.97	6.59	5.87	6.99	6.10	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	8.10	4.18	4.66	7.05	6.09	95	0	S
25	SINT-5B	7.00	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
	MEAN	7.27	5.18	7.29	6.03	5.40	6.48	6.28			
	CV (%)							13.97			
	MSE							0.7697			
	SMD 0.05							0.5732			
	SMD 0.01							0.7545			

* and **= Significance of the treatments at 05 and 0.01of probability; B= Spring Summer season; Cot= Cotaxtla Experimental Station; Carr= Municipality of Carlos A. Carrillo, Ver.; Huim= Huimanguillo, Tab.; MSE= Mean Square Error; CV= Coefficient of Variation; SMD= Significant Minimum Difference; Rel % = Relative percent in relation with the commercial check; % Het= % of heterosis with respect to the best parent; S= Genotype characterized as stable.

Table 2 Grain yield in varietal maize hybrids across the six environments in Veracruz and Tabasco states 2016-2018. CIRGOC INIFAP

On the other hand, the locations Cotaxtla, Ver., in 2017B and Huimanguillo Tabasco en 2018 y 2016B registered the lowest grain yield with 6.03, 5.40 and 5.18 t ha^{-1}, and negative environmental indexes of -0.25, -0.88, and -1.1 (Table 3). It suggest, that there are important differences in these environments in clime, soil and agronomic management for these experiments (Reyes, *et al.,* 1990; Sierra *et al.,* 2018; Sierra *et al.,* 2018).

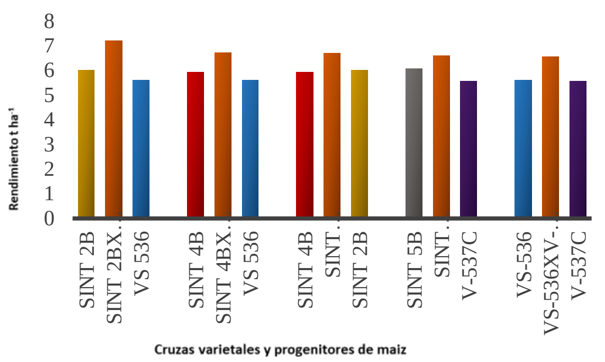

Figure 1 Heterosis in varietal maize hybrids in Veracruz and Tabasco states 2016-2018

Environment	Yield t ha^{-1}	Índexes
Carlos A. Carrillo, Ver 2016B	7.29**	1.01
Cotaxtla, Ver 2016B	7.27**	0.99
Cotaxtla, Ver., 2018B	6.48	0.20
Cotaxtla, Ver., 2017B	6.03	-0.25
Huimanguillo 2018B	5.40	-0.88
Huimanguillo, Tab 2016B	5.18	-1.1
Promedio	6.28	

Yield t ha^{-1}= Grain yield t ha^{-1}; B= spring summer season

Table 3 Environmental indexes in varietal maize hybrids 2016-2018. CIRGOC INIFAP

Agronomic performance and characteristics

In relation with the agronomic characteristics, the varietal hybrids recorded from 51 to 53 days to tassel, short plant height with 217 to 255 cm, and 108 to 132 cm for plant and ear height, respectively (Table 4). These hybrids present good plant and ear aspect and plant and ear sanity, good husk cover and low presence of ear rot; Besides, the relation ear height/plant height was between 0.49 and 0.58, it help to show tolerance to lodging caused by the wind (Sierra *et al.*, 2018; Gómez *et al.*, 2017; Trachsel *et al.*, 2016; Tadeo *et al* 2015a; Tadeo *et al* 2015b).

The best hybrids for yield and agronomic traits were: SINT2BxVS-536, SINT4BxVS-536 (HV-570), SINT4BxSINT-2B, VS-536xV-537C, SINT5BxVS-537C, can be an alternative in commercial maize production because they are adapted to clime and soil conditions and the management by farmers in the southeast of México (Sierra *et al.*, 2019). Thus, considering the yield and agronomic characteristics it is suggested that the varietal cross SINT4BxVS-536, must be libered HV-570, as a commercial new maize hybrid for the humid tropic in México.

The hybrid HV-570, register high yield and adaptation to the humid tropic in Mexico, intermediate biological cicle with 51 days to tassel during the spring summer season under rainy season conditions; This hybrid present short plant an ear height and the leaves above the ear are in semierect position; besides, the position of the ear is desviated to the position of the leaves (Figure 2); HV-570, present good plant and ear aspect and sanity, excellent husk cover, white grain color and semident texture (Figure 3).

Figure 2 HV-570 present short plant and ear and the leaves above the ear are in semierect position

Figure 3 Ears of HV-570 hybrid expressed White grain and semident texture

Entry	Genealogy	Cot 2016B	Huim 2016B	Carr 2016B	Cot 2017B	Huim 2018B	Cot 2018B	Mean	% Rel	% Het	Description
1	SINT2BxVS-536 (HV1)	7.99	6.34	9.16	6.28	6.55	6.91	7.21*	113	19.76	S
14	SINT4BxVS-536 (HV-570)	8.67	6.05	6.90	6.86	5.47	6.48	6.74*	105	13.46	S
17	SINT4BxSINT2B	7.64	5.83	8.11	6.09	5.42	7.1	6.70*	105	11.29	S
9	SINT-5B X V-537C	7.25	5.79	8.30	6.61	5.42	6.32	6.61**	103	8.54	S
20	VS-536xV-537C (HV-3)	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-2BxVS-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-1BQxVS-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
6	SINT-3BxVS-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	6.40	100		S
12	SINT-4B X SINT-3B	7.34	5.02	8.60	6.64	5.43	5.17	6.37	99	2.41	S
3	SINT-5B X SINT-4B	7.10	5.12	7.60	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	6.30	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-4BxVS-537C	7.17	5.03	4.97	6.59	5.87	6.99	6.10	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	8.10	4.18	4.66	7.05	6.09	95	0	S
25	SINT-5B	7.00	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
	MEAN	7.27	5.18	7.29	6.03	5.40	6.48	6.28			
	CV (%)							13.97			
	MSE							0.7697			
	SMD 0.05							0.5732			
	SMD 0.01							0.7545			

B= Spring Summer season; [1/] = Qualification scale from 1 to 5, where, 1 correspond to plants and ears with the best phenotypic expression and 5 for the worst; MSE= Mean square of error; CV= Coefficient of Variation

Table 4 Agronomic characteristics of varietal maize hybrids 2016-2018. Cotaxtla CIRGOC INIFAP

From the comparisons and t test at 0.05 and 0.01 of probability (Table 5), there was found that the varietal hybrids recorded an average grain yield of 6.39 t ha^{-1}, 8% more than the synthetic varieties parents with value for the calculatesd t test of 5.07**; Besides, there was registered advantages in plant and ear aspect (Reyes, 1990). It suggests that there is genetic divergence between the parents, which is also reflected in the values of heterosis with respect to the best progenitor that varied from 5.46 to 19.76%. (Reyes, 1985; Sierra *et al.,* 2004; Córdova *et al.,* 2007; Esquivel, *et al.,* 2011; Chuquija y Huanuqueño 2015; Palemón *et al.,* 2012; Velasco *et al.,* 2019; Gómez *et al.,* 2015).

omparison	Yield t ha^{-1}	% Rel	t Calc	Plant height	% Rel	t Calc	Pl asp[2/]	% Rel	t Calc	Ear asp[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 GL) = 2.00; t0.01 (54 GL) =2.66

% Rel= Relative % in the comparison; t Calc= t calculated for the comparison; Pl asp= Plant aspect; Ear asp= Ear aspect; **[2/]**= Escale of qualifying from 1 to 5, where, 1 is the best and 5 is the worst

Table 5 Comparisons and t test for varietal hybrids and their parents. 2016-2018 CIRGOC INIFAP

Acknowledgment

Authors wish to thank to the National Institute of Forestry Agricultural and Livestock Research (INIFAP), in México for financing and supporting this research.

Conclusions

The best varietal hybrids for grain yield and agronomic characterísticas were: SINT2BxVS-536, SINT4BxVS-536 (HV-570), SINT4Bx SINT2B, VS-536xV537C, with grain yield from 6.57 to 7.21 t ha^{-} 3 to 13% more than the commercial check H-520.

The heterosis with respect to the best parent in the best varietal crosses were: 19.76, 13.46, 11.29, 16.9%, for each hybrid, respectively.

Instead of grain yield and agronomic traits it was suggested the cross SINT-4BxVS-536 for oficial registering as HV-570, new maize hybrid for the humid tropic in México

The varietal hybrid HV-570, present short plant and ear, good plant and ear aspect and sanity and good husk cover

References

Andrés M.,P.; Vásquez C.,G.; Sierra, M.,M.; Mejia C.,A.; Molina G.,J.D.; Espinosa, C.,A.; Gómez M.,N.; López R.,G.; Tadeo R., M.; Zetina C.,P.; Cebada M.,M. 2017. Genotype environment interaction on productivity and protein quality of synthetic tropical maize (*Zea Mays* L.) varieties. *Interciencia* Vol 42(9):578-585 https://www.scopus.com/inward/record.uri?eid=2-s2.0-85033782591&partnerID=40&md5=d68b8c5d0c7654f37fc56f01f3e28aff

Cervantes O., F.; Hernandez E., J.; Rangel L., J.A., Andrio E., E.; Mendoza E., M.; Rodríguez P., G.; *et al.,* 2016. Aptitud combinatoria general y especifica en la calidad de semilla de líneas S3 de maíz. *Rev. Fitotec. Mex.* Vol 39 (3): 259-268. http://www.redalyc.org/articulo.oa?id=61046936011

Córdova O., H.; Trifunovic S.; Ramírez A. y Sierra M., M. 2007. CIMMYT Maize Hybrids for Latin América. Head to Head analysis and probability of outperforming the best check. *Maydica* Vol. 52: 471-476. http://hdl.handle.net/10883/3061

Chuquija, J., Ch.; Huanuqueño C., E.H. 2015. Comportamiento de ocho poblaciones de maíz amarillo (*Zea mays* L.) en cruzas con un probador. *Anales Científicos* Universidad Nacional Agraria La Molina Perú. Vol. 76 (1): 78-86 https://doi.org/10.21704/ac.v76i1.767

Eberhart S.A. and Russell W.A. 1966. Stability parameters for comparing varieties. Crop Sci. 6: 36-40
https://doi.org/10.2135/cropsci1966.0011183X000600010011x

Esquivel E., G.; Castillo G., F.; Hernández C., J.M.; Santacruz V., A.; García S., G.; Acosta G., J.A.; Ramírez H., A. 2011. Heterosis en maíz del altiplano de México con diferente grado de divergencia genética. *Rev. Mex. Ciencias Agríc.* Vol 2(3):331-344
http://www.redalyc.org/articulo.oa?id=263119714003

Espinosa C., A.; Tadeo R., M.; Virgen V., J.; Rojas M., I.; Gómez M., N.; Sierra M., M.; *et al.*, 2012. H-51AE, híbrido de maíz para áreas de humedad residual, buen temporal y riego en Valles Altos Centrales de México. *Rev. Fitotec. Mex.* Vol 35 (4): 347-349. https://doi.org/10.35196/rfm.2012.4.347

García., M.E. 2004. Modificaciones al sistema de clasificación climática de Köppen. 5ª Ed. Universidad Nacional Autónoma de México. Instituto de Geografía. México DF México 246p. https://scielo.org.mx/scieloOrg/php/similar

Gómez, M., N.; Cantú A., M.A.; Vásquez C., G.; Hernández G., C.A.; Espinosa, C., A.; Sierra, M. M.; Coutiño E., B.; Aragón C., F.; Trujillo C., A. 2017. Híbrido de maíz H-568: Nueva opción para las áreas de alta productividad del trópico bajo de México*Rev.Mex.Cienc.Agríc.*Vol8(5):1213-1218
https://doi.org/10.29312/remexca.v8i5.121

Gómez E., A.L.; Molina G., J.D.; García Z., J.J.; Mendoza C., M.C.; De la Rosa L., A. 2015. Poblaciones exóticas originales y adaptadas de maíz. I. Variedades locales de clima templado x variedades tropicales. *Rev. Fitotec. Mex.* Vol 38 (1):57-66
http://www.redalyc.org/articulo.oa?id=61035375008

López L., C.; Tadeo R., M.; García Z., J.J.; Espinosa C., A.; Mejía C., A. 2021. Aptitud combinatoria general y específica de híbridos varietales de maíz amarillo de baja endogamia. *Rev. Mex. Cienc. Agríc.* Vol 12(4):699-711. https://doi.org/10.29312/remexca.v12i4.2786

Palemón A., F.; Gómez, Castillo, Ramírez V., P.; Molina G., J.D.; Miranda C., S. 2012. Potencial productivo de cruzas intervarietales de maíz en la región semicálida de Guerrero. *Rev. Mex.de las Ciencias Agríc.* Vol 3 (1): 157-171. https://doi.org/10.29312/remexca.v3i1.1490

Ramírez D., J.L.; Vidal M., V.; Alemán T., I.; Ledesma M., A.; Gómez M., N.; Salinas M., Y.; *et al.*, 2019. Selección de líneas y cruzas de maíz combinando las puebas de mestizos y cruzas dialélicas. *Rev. Fitotec. Mex.*Vol 42 (4): 335-346.
https://doi.org/10.35196/rfm.2019.4.335

Reyes C., P. 1990. Diseño de experimentos aplicados. Ed. Trillas 3ª Ed. 348p. ISBN: 968240651X, 9789682406515

Reyes C., P. 1985. Fitogenotecnia básica y aplicada. AGT Editor S.A. México. 460p. ISBN: 9789684630215 y 9684630212 Número de OCLC / Identificador único:20071856

Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA). Servicio de Información Agroalimentaria y Pesquera (SIAP) 2018. Servicio de Información Agroalimentaria y Pesquera. Acciones y programas Producción agrícola. Disponible en: http//www.gob.mx/siap/acciones y programas de producción agrícola. (Cons. 22 de noviembre del 2020). s/p. https://nube.siap.gob.mx/cierreagrícola/

Sierra, M. M., Rodríguez, M. F. A., Gómez M., N.; Espinosa, C., A.; Ugalde A., F.J.; Andrés M., P. 2019. Mejoramiento genético de maíz para el trópico húmedo de México. En: Avances en Investigación agrícola, Pecuaria, Forestal, Acuícola, Pesquería, Desarrollo Rural, Transferencia de Tecnología, Biotecnología, Ambiente, Recursos Naturales y Cambio Climático. INIFAP, CP, UACH, INAPESCA, UV, TECNM, Medellín, Ver. p. 482-499. http://rctveracruz.org/doc/AvancesInvestigacionRC2019

Sierra, M. M., Rodríguez, M. F. A., Espinosa, C., A.; Andrés M., P. 2018. Adaptabilidad de híbridos trilineales de maíz en el área tropical de los estados de Veracruz y Tabasco, México. *Rev. de Cienc. Amb. y Rec. Nat.* Vol 4 (11): 15-19. ISSN: 2444-4936

Sierra, M. M.; Rodríguez, M. F. A.; Palafox, C. A.; Gómez M., N.; Espinosa, C., A. 2014. Impacto del H-564C, Híbrido de maíz con alta calidad de proteína para el trópico húmedo de México. *Rev. Biol. y Agrop. Tuxpan* Vol 2(1): 277-282 https://doi.org/10.47808/revistabioagro.v2i1.305

Sierra M., M; Palafox c., A.; Rodríguez M., F.; Espinosa C., A.; Andrés M., P.; Gómez M., N.; *et al.*, 2016. Productividad de semilla y adopción del híbrido de maíz H-520 en el trópico de México. *Rev. Agric. Soc. y Des.* Vol 13(1): 19-32 https://doi.org/10.22231/asyd.v13i1.286

Sierra, M. M., Rodríguez, M. F. A., Palafox, C. A., Espinosa C., A. 2016. Adopción e impacto de la variedad VS-536 en la región tropical del sureste de México *Rev Des.Econ.* Vol 3(9):32-40 http://www.ecorfan.org/bolivia/researchjournals/Desarrollo_Economico/vol3num9/Revista_de_Desarrollo_E con%C3%B3mico_V3_N9_3.pdf

Sierra M., M.; Márquez S., F.; Valdivia B., R.; Córdoba O., H.; Lezama G., R. y Pescador R., A. 2004. Uso de probadores en la selección de líneas para formar híbridos de maíz (*Zea mays* L.). *Agric. Téc. Méx.* México. Vol. 30 (2): 169-181. ISSN: 0568-2517

Tadeo R., M.; Espinosa C., A.; Zaragoza E., J.; López L., C.; Canales I., E.I.; Zamudio G., B.; *et al.*, 2021. Tlaoli Puma, híbrido de maíz para grano y forraje con androesterilidad y restauración de la fertilidad masculina. *Rev. Fitotec. Mex.* Vol 44 (2): 265-267 https://doi.org/10.35196/rfm.2021.2.265

Tadeo R., M.; Espinosa C., A.; García Z., J.J.; Lobato O., R.; Gómez M., N.; Sierra M., M.; *et al.*, 2016. Tsiri Puma, híbrido de maíz para Valles altos de México, con esquema de androesterilidad para producción de semillas. *Rev. Fitotec. Mex.* Vol 39(3): 331-333 https://doi.org/10.35196/rfm.2016.3.331-333

Tadeo R., M.; Espinosa, C., A.; García Z., J.J.; Lobato O., R.; Gómez, M., N., Sierra, M. M.; Valdivia B., R. 2015a. Productividad de híbridos androestériles y fértiles de maíz en cuatro Ambientes de evaluación. *Rev. Mex. de las Ciencias Agrícolas*. Vol 6 (8): 1857-1866. DOI**:** https://doi.org/10.29312/remexca.v6i8.501

Tadeo R., M.; Espinosa C., A.; Guzmán M., R.; Turrent F., A.; Zaragoza E., J.; Virgen V., J. 2015b. Productividad de híbridos varietales de maíz de grano amarillo para Valles Altos de México. *Agron. Mesoam.* Vol. 26(1): 65-72. https://doi.org/10.15517/am.v26i1.16921

Trachsel S.; Leyva M.; López M.; Suarez E., A.; Mendoza A.; Gómez M., N.; Sierra M., M.; Burgueno J.; San Vicente F. 2016. Identification of Tropical Maize Germplasm with tolerance to Drought, Nitrogen Deficiency, and combined Heat and Drought Stresses. *Crop sci.* Vol 56 (6): 3031-3045. doi:10.2135/cropsci2016.03.0182 Crop Science 2016 56:3031-3045

Velasco G., A.M.; García Z., J.J.; Sahagún C., J., Lobato O., R.; Sanchez A., C.; Marín M., I.M. 2019. Rendimiento, componentes del rendimiento y heterosis de germoplasma de maíz adaptado a Valles Altos. *Rev. Fitotec. Mex.* Vol. 42 (4): 367-374 https://doi.org/10.35196/rfm.2019.4.367

Virgen V., J.; Zepeda B., R.; Avila P., M.A.; Espinosa C., A.; Arellano V., J.L.; Gámez V., A.J. 2016. Producción y calidad de semilla de maíz en Valles altos de México. *Agron. Mesoam.* Vol 27 (1): 191-206. https://doi.org/10.15517/am.v27i1.21899