

Three way maize (*Zea mays* L.) hybrids, alternative for producing and using improvement seed

Híbridos trilineales de maíz (*Zea mays* L.), alternativa en la producción y uso de semilla mejorada

SIERRA-MACIAS, Mauro^{†*}, RÍOS-ISIDRO, Clara, FERNÁNDEZ-CARMONA, Elizabeth and GÓMEZ-MONTIEL, Noel Orlando

Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, INIFAP, Mexico.

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: *Elizabeth, Fernandez-Carmona* / ORC ID: 0000-0002-5683-4202

ID 3rd Co-author: *Noel Orlando, Gómez-Montiel* / CVU CONACYT ID: 5945

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Abstract

With the objective of knowing the yield and agronomic characteristics of maize hybrids for the tropical region in México, during the spring summer season in 2021, there were evaluated 27 three way hybrids, on which, there are participating inbred lines of the maize breeding program of Cotaxtla, Ver., and Iguala, Gro., experimental stations of INIFAP and inbred lines from CIMMYT; Besides, there were included the commercial checks H-562, H-565 and H-520. These genotypes were arranged under complete blocks at random, with 30 treatments and three replications in plots of two rows 5m long, and 62,500 plants ha⁻¹. The agronomic traits were: Grain yield, days to tassel and silking, plant and ear height, plant and ear aspect and sanity, lodging, bad husk cover and ear rot. The best 13 maize hybrids at 0.05 of probability were above 7.0 t ha⁻¹, in grain yield and from 5 to 12% more than the commercial check H-520; Among those: (LT155x T48)xCLWN247, (LT156xCML549)xT49, (CML311x T48)xCLWN247, CML549xT49) xCLWN247, (CML549 xLT154)xT48, LT156xLT154) xCLWN247 and (CLWN247xLT154) xT49. The inbred lines LT156, LT154, CLWN247, CML549 and T49 participated in the best hybrids; It suggest that these lines present good General Combining Ability.

Heterosis, Trópic, genotypes, Zea mays L.

Resumen

Con el objetivo de conocer el rendimiento y características agronómicas de híbridos de maíz para la región tropical de México, durante el ciclo primavera verano 2021 se evaluaron 27 híbridos trilineales en los que participan líneas endogámicas de los programas de maíz de los Campos de Cotaxtla, Ver., e Iguala, Gro., del INIFAP y líneas provenientes del CIMMYT; Así también, los testigos H-562, H-565 y H-520. La distribución de tratamientos fue bajo un diseño bloques completos al azar con 30 tratamientos y tres repeticiones en parcelas de 2 surcos de 5 m de largo, en una densidad de 62,500 pl ha⁻¹. Las variables fueron días a floración, altura de planta y de mazorca, calificación de aspecto y sanidad de planta y de mazorca, % de plantas acamadas, % de mazorcas con mala cobertura; % de mazorcas podridas y rendimiento de grano. Un grupo de 13 híbridos, con rendimientos superiores a las 7.0 t ha⁻¹, con 5 a 12% más en relación con el testigo H-520; Entre ellos: (LT155xT48) xCLWN247, (LT156xCML549) xT49, (CML311xT48)xCLWN247, (CML549xT49)xCLWN247, (CML549xLT154)xT48, LT156xLT154)xCLWN247 y (CLWN247xLT154)xT49. Las líneas LT156, LT154, CLWN247, CML549 y T49 participan en híbridos sobresalientes, lo que sugiere que son líneas con buena aptitud combinatoria general.

Heterosis, Trópico, Genotipos, Zea mays L.

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* Correspondence of the Author (E-mail: sierra.mauro@inifap.gob.mx)

† Researcher contributing first author.

Introduction

During 2020, there were sown in México, 7.47 million de hectares with maize with an average yield of 3.83 t ha^{-1} , and a total production of 28.61 million tons, which of them 12.6 million tons are utilized in different ways through the direct consume for human consumption (SIAP, 2020). Improved seeds are the most important input in corn production, they represent the genetic yield potential and quality production (Sierra *et al.*, 2016).

In the humid tropic in México, at the same year there were sown 2.66 million de hectares with maize, which of them, one million are included in agronomic provinces of good and very good productivity, and 100 thousand hectares under irrigation conditions, where is recommended the improved seed of synthetic maize varieties and hybrids (SIAP, 2020; Sierra *et al.*, 2019). In this great area, particularly are recommended hybrid seed, which express their genetic potential because of the heterotic effect by crossing parental lines genetically different (Ramírez *et al.*, 2019; Velasco *et al.*, 2019; Ledesma *et al.*, 2015; Reyes, 1985).

In the maize breeding program of Cotaxtla experimental station, INIFAP, there have been generated maize hybrids and varieties, which expressed good yield and favourable agronomic characteristics through the tropical region in the southeast of México, but above all, they have been adopted by maize farmers (Sierra *et al.*, 2019).

Three way maize hybrids present the advantage of the heterosis (López *et al.*, 2021; Ramírez *et al.*, 2019; Reyes 1985); In the maize commercial production, besides, they represent agronomic and economic advantages in certificated seed production because they use as a female parent a single cross with high yield and complete vigor and as a male parent an inbred line with very good *per se* behaviour, general combining ability and enough pollen production, such as the hybrids H-520, H-567 and H-568, whose specific nomenclature is (LT154xLT155) LT156, LT164xLT165)LT166 y (T47xT48)T49, for each hybrid, respectively (Tadeo *et al.*, 2021; Tadeo *et al.*, 2018; Sánchez *et al.*, 2016; Velez *et al.*, 2018; Sierra *et al.*, 2019; Sierra *et al.*, Sierra *et al.*, 2018; Sierra *et al.*, 2016; Sierra *et al.*, 2014; Sierra *et al.*, 2011; Ramírez *et al.*, 2019; Gómez *et al.*, 2017; Virgen *et al.*, 2016; Espinosa *et al.*, 2012; Cervantes *et al.*, 2016).

Genotypes, fertilizers and bioestimulating treatments are important to increase the grain yield in maize; Particularly, Martínez *et al.*, 2022, found for high valleys in México, that the best hybrids were, H-66, H-50 and H-76; In addition the bioestimulating treatments increased the grain yield from 7.9 to 11.4%. The objective of this research was to know the yield and agronomic characteristics of three way tropical maize hybrids.

Materials and Methods

Localization. The evaluation of the maize hybrids was carried out in Cotaxtla Experimental Station in Veracruz, 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 $18^{\circ} 56'$ North Latitude and $96^{\circ} 11'$ West longitude and altitude of 15 masl. The climate condition is Aw1(w), according with the climate classification described by Köppen modified by García (2004) and correspond to subhumid warm conditions with average annual temperature of 25 °C and annual precipitation of 1400 mm, distributed from June to November with a dry season from December to May. The soil is Vertisol, from alluvial origin, deep, with medium texture throughout the profile, slope less than 1% and good drainage and slightly acid pH (6.6) (INEGI, 2020).

Germplasm used. The germplasm used in the present research, belongs to the Tuxpeño race and there were evaluated 27 experimental maize hybrids, on which, participate inbred lines of the maize breeding program of Cotaxtla, Ver., and Iguala, Gro., experimental stations of the National Institute of Agricultural, Forestry and Livestock Research (INIFAP) in México and inbred lines from The International Maize and Wheat Improvement Center (CIMMYT Int); Besides, there were included the commercial checks H-562, H-565 and H-520.

Description of the experiment. During the spring summer season in 2021, under rainy conditions, there was carried out an experiment, for evaluating experimental maize hybrids, which of them, were distributed in complete blocks at random, with 30 treatments and three replications in plots of two rows 5 m long and 80 cm wide in a density of $62,500 \text{ plants ha}^{-1}$ (Reyes, 1990). The fertilization was made according to the recommendations of INIFAP,

Thus, in this experiment was utilized the formula 161-46-00, applying all the Phosphorus and a third part of Nitrogen at sowing moment, the rest of Nitrogen in bunched stage using Urea as Nitrogen source; The weeds were controlled by Atrazine applied before emerging and there were controlled pests during developing crop.

Variables and data recording. During the development of the crop and at harvest time, there were recorded in the experiment 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 30 treatments and three replications in plots of two rows 5m long and 80 cm wide. Individual analysis of variance was made for each variable 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). There was made an adjust for grain yield by number of plants using the IOWA formula (Reyes, 1990). This formula is described as follow:

$$\text{Corrected weight} = (\text{Weight at harvest time} \times H - 0.3M) / H - M$$

Where:

Weight at harvest time= Weight without correction.

H= Número of plants that the plot must have without fail.

M= Número of lost plants.

0.3= Coefficient for correcting and compensating the lost plants.

Results and Discussion

From the analysis of variance for grain yield and agronomic characteristics (Table 1), There was found statisticall significance differences for treatments, with a Coefficient of Variation of 15.78%, value relatively low, and suggest that the results gotten and the management of the experiments are reliables (Reyes, 1990). Besides, The highest variance was recorded for the source of variation treatments, factor valued in 2.049*, which means that these hybrids were different and important in the yield and the behavior (Reyes, 1990).

For the agronomic characteristics of the maize hybrids, there was found statisticall significance differences at 0.05 of probability of error, in the variables: Plant and ear height, plant and ear aspect and ear sanity. Besides, The Coefficient of Variation were from 2 to 15%, values relatively low, and suggest that the results gotten and the management of the experiments are reliables (Reyes, 1990).

Source of Variation	Degre e Free	Grain Yield	Days to tasse l	Day s to silk	Plant height	Ear height	Plant aspect	Ear aspect	Plant sanity	Ear sanity
Hybrids	29	2.05*	2.178	2.192	449.79	326.8*	0.166*	0.3085*	0.0536	0.305*
Blocks	2	1.18	17.678	18.43	19.21	142.81	0.21	0.71	0.019	0.1
Error	58	1.06	1.39	1.387	113.94	65.13	0.0588	0.113	0.03669	0.1287
Total	89									
CV (%)	15.78		2.09	2.05	6.08	10.6	11.42	15.26	9.65	15.71

1= Qualification scale from 1 to 5 where, 1 correspond to plants and ears with the best phenotypic expression and 5 for the worst; *= Statistical Significance for the Sources of Variation at 0.05 of probability of error; B= Spring Summer season; CV= Coefficient of Variation.

Table 1 Mean square and significance for yield and agronomic characteristics of maize hybrids. Cotaxtla Experimental Station. CIRGOC. INIFAP. 2021B

Grain yield

According with the statisticall test SMD at 0.05 of probability of error (Table 2), there were found 13 three way maize hybrids with yield above 7.0 t ha⁻¹, significant different and higher from 5 to 12% than the commercial check H-520; Among those, the hybrids: (LT155xT48)x CLWN247, (LT156xCML549)x T49, (CML311 xT48)xCLWN247, CML549xT49)xCLWN247, CML549xLT154)xT48, (LT156xLT154)x CLWN247, (CLWN247xLT154)xT49; (T48x T49)xCLWN247; (T47xLT156)x LT154. These hybrids, expressed the maximum genetic potential, due by the heterotic effect of crossing inbred lines genetically different (Ramírez et al., 2019; Velasco et al., 2019; Velez et al., 2018; Sanchez et al., 2016; Ledesma et al., 2015; Reyes, 1985). Besides the agronomic potential in hybrids fertilizers the agronomic management may be increase the grain yield in maize, (Martínez et al., 2022)

Particularly, in these hybrids, participate as parental lines those inbred lines of the maize breeding program of Cotaxtla, Ver., and Iguala, Gro., experimental stations of INIFAP and inbred lines from CIMMYT; The inbred lines LT156, LT154, CLWN247, CML549 and T49 participated in the best hybrids; It suggest that these lines present good General Combining Ability. The three way maize hybrids present the advantage of the heterosis in the maize commercial production, (López et al., 2021; Ramírez et al., 2019; Reyes 1985); Besides, they represent agronomic and economic advantages in certificated seed production because they use as a female parent a single cross with high yield and complete vigor and as a male parent an inbred line with very good per se behaviour, general combining ability and enough pollen production (Tadeo et al., 2021; Tadeo et al., 2018; Velez et al., 2018; Sanchez et al., 2016; Ramírez et al., 2019; Sierra et al., 2019; Sierra et al., 2018; Sierra et al., 2016; Sierra et al., 2014; Sierra et al., 2011; Gómez et al., 2017; Virgen et al., 2016; Espinosa et al., 2012; Cervantes et al., 2016).

Agronomic characteristics

In reference to agronomic characteristics, the experimental hybrids (Table 2), expressed intermediate biological cycle with 56 to 58 days to tassel, short plant and ear height with average values from 175 and 76 cm for plant and ear height, respectively; Besides, they present good qualifications for plant and ear aspect and sanity. It suggest good adaptability to climate, soil and management by maize farmers, principally in good and very good areas and under irrigated conditions in the southeast of México. Thus, there were observed Coeficient of variation relatively low, which suggest that the management of the experiment and the results gotten area reliable (Reyes, 1990). These results indicate the importance of collaboration and the use of the best germplasm of different maize breeding programs.

Entry	Genotype	Grain yield kg/ha ^a	Relative %	Days to tassel	Days to silk	Plant height	Ear height	Plant aspect	Ear aspect	Plant sanity	Ear sanity
19	(LT155xT48)xCLWN247	7.46*	112	56	57	180	87	2.17	2.17	2	2.33
6	(LT156xCLWN247)xCML549xT49	7.42*	111	56	57	180	64	2.5	2.33	2	2.5
20	(CML311xT48)xCLWN247	7.39*	111	56	57	180	84	2.17	2.17	2	2.33
14	(CML549xT49)xCLWN247	7.34*	110	58	59	189	84	2	1.5	1.5	1.83
25	(CML549xLT15)	7.32*	110	57	58	175	67	1.83	2.33	2	2.33
17	(LT156xT48)xCLWN247	7.30**	109	55	56	178	74	1.83	2.33	2	2.33
1	(T48xT49)xCLWN247	7.29**	109	56	57	178	73	2	2	2	2.17
18	(T48xT49)xCLWN247	7.22**	108	58	59	179	84	2.17	2.17	1.83	2.5
11	(T47xLT156)xCLWN247	7.18**	108	57	58	195	84	2	1.83	1.83	2
22	(T47xLT156)xCLWN247	7.18*	108	57	58	182	85	2	2.17	1.83	2
21	(T47xCLWN247)xCLWN247	7.12**	107	57	58	205	98	1.83	1.83	2	1.83
10	(CLWN247xCLWN247)xLT154	7.03**	105	56	57	183	85	1.83	1.83	1.83	1.83
3	(CML549xCLWN247)	7.01**	105	55	56	165	73	2	2	2	2.17
5	(CML549xLT154)xCLWN247	6.75**	101	57	58	166	65	2.33	2.5	2	2.67
8	(CLWN247xT48)	*	6.71	101	55	56	178	77	2.33	2.33	2
30	H-520	6.67	100	54	55	190	81	1.67	1.83	1.83	2
2	(LT156xT48)xCLWN247	6.64	100	56	57	194	96	2	1.83	1.83	2
29	H-562	6.54	98	56	57	159	71	2.33	2.5	2.17	2.33
28	H-565	6.39	96	57	58	171	76	2	2.5	2	2.33
13	(CLWN247xCML549)xLT154	6.29	94	57	58	158	66	2.17	2.17	2	2.17
15	(CML549xLT154)xCLWN247	6.27	94	57	58	182	83	2	1.67	1.67	1.67
26	(CML549xT49)xCLWN247	6.20	93	57	58	164	65	2.17	2.5	2.17	2.83
24	(CML550xCLWN247)xCLWN247	6.13	92	55	56	168	72	2.33	2.33	2	2.33
23	(CLWN247xCLWN247)xCLWN247	6.00	90	56	57	165	74	2.17	2.17	2	2.5
4	(CML311xCLWN247)	5.94	89	56	57	166	70	2.33	2.5	2	2.33
27	(T47xLT154)xLT154	5.69**	85	56	57	161	66	2.17	2.83	2	2.83
12	(CML549xT49)xLT154	5.17	77	57	58	158	57	2.17	2.17	1.83	2.33
16	(T47xLT154)xCLWN247	5.13	77	56	57	187	91	2	2.5	2	2
9	(T47xT49)xLT154	5.06	76	57	58	169	66	2.33	2.33	2	2.5
7	(B49xB47)xCLWN247	4.30	64	57	58	160	63	2.83	2.83	2	3
	Average	6.54		56.38	57.37	175.4	76.08	2.12	2.21	1.94	2.28
	MSE	1.095		1.39	1.39	113.9	65.13	0.059	0.113	0.037	0.129
	CN (95%)	15.78		2.09	2.05	6.08	10.61	11.43	15.27	9.85	15.71
	SMD (0.05)	0.531									
	SMD (0.01)	0.311									

*= Significance of the treatments at 0.05 of probability; 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 worse; MSE= Mean square of error; CV= Coeficient of Variation; SMD= Significative Minimum Difference

Table 2 Grain yield and agronomic characteristics of three way maize hybrids. Cotaxtla 2021B

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Conclusions

The best 13 three way maize hybrids, registered grain yield 5 to 12% over the commercial check H-520. According with the yield and agronomic characteristics the best hybrids were: (LT155xT48)xCLWN247, (LT156xCML549)xT49, (CML311xT48)xCLWN247, CML549xT49)xCLWN247, CML549xLT154)xT48, LT156xLT154)xCLWN247, (CLWN247xLT154)xT49. In the best hybrids participate as parents inbred lines, from Campo Cotaxtla, Ver., and Iguala, Gro., INIFAP, and lines from CIMMYT. The inbred lines LT156, LT154, CLWN247, CML549 and T49 participate in several of the best hybrids and suggest that these lines are characterized with Good General Combining Ability

References

- 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 específica en la calidad de semilla de líneas S3 de maíz. Revista Fitotecnia Mexicana Vol 39 (3):259-268.
<http://www.redalyc.org/articulo.oa?id=61046936011>
- 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. Revista Fitotecnia Mexicana 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. 5^a 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.; *et al.*, 2017. Híbrido de maíz H-568, Nueva opción para áreas de alta productividad del trópico bajo de México. Revista Mexicana de las Ciencias Agrícolas Vol 8 (5): 1213-1218 <https://doi.org/10.29312/remexca.v8i5.121>
- INEGI (Instituto Nacional de Estadística y Geografía). 2020. Edafología. <https://www.inegi.org.mx/temas/edafologia/> (Consulta marzo 2, 2020).
- Ledesma M., A.; Ramírez D., J.L.; Vidal M., V.A.; Peña R., A.; Ruíz C., J.A.; Salinas M., Y.; *et al.*, 2015. Respuesta para integrar un patrón heterótico de maíz de grano amarillo para la zona de transición de México. II. Evaluación de mestizos y cruzas. Revista Fitotecnia mexicana Vol 38(2):133-143. <http://www.redalyc.org/articulo.oa?id=61038806003>
- 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. Revista Mexicana de las Ciencias Agrícolas Vol 12 (4): 699-711. <https://doi.org/10.29312/remexca.v12i4.2786>
- Martínez G., A.; Zamudio G., B.; Tadeo R., M.; Espinosa C., A.; Cardoso G., J.C.; Vazquez C., G.; 2022. Rendimiento de híbridos de maíz en respuesta a la fertilización foliar con bioestimulantes. Revista Mexicana de las Ciencias Agrícolas Vol. 13(2): 289-301. <https://doi.org/10.29312/remexca.v13i2.2782>
- 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. Revista Fitotecnia mexicana Vol 42 (4): 335-346. <https://doi.org/10.35196/rfm.2019.4.335>
- Reyes 1990. Diseño de experimentos aplicados. Ed trillas 3^a Ed. México D.F. 348p
 ISBN: 968240651X, 9789682406515
- Reyes C., P. 1985. Fitogenotecnia básica y aplicada. AGT Editor S.A. México D.F., México. 460 p.
 ISBN: 9789684630215 y 9684630212
 Número de OCLC / Identificador único:20071856
- Sánchez R., F.J.; Mendoza C., M.C.; Mendoza M., C.G. 2016. Estabilidad fenotípica de cruzas simples e híbridos comerciales de maíz (*Zea mays* L.). Revista Fitotecnia Mexicana Vol 39 (3): 269-275. <https://doi.org/10.35196/rfm.2016.3.269-275>
- SIAP (Servicio de información Agroalimentaria y Pesquera). 2020. Servicio de información Agroalimentaria y Pesquera. Acciones y Programas. Cierre de la producción Agrícola. Anuario Estadístico de la producción agrícola. <https://nube.siap.gob.mx/cierreagrícola/> (Consulta: 20 de agosto, 2021).
- Sierra M., M; Palafox c., A.; Rodríguez M., F.; Espinosa C., A.; Vásquez C., G.; Gómez M., N.; *et al.*, 2011. H-564C, Híbrido de maíz con alta calidad de proteína para el trópico húmedo de México. Revista Mexicana de las Ciencias Agrícolas Vol 2(1): 71-84. <http://www.redalyc.org/articulo.oa?id=263119820006>

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. Revista Biológico y Agropecuario 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. Revista Agricultura Sociedad y Desarrollo Vol 13 (1): 19-32. <https://doi.org/10.22231/asyd.v13i1.286>

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. Revista de Ciencias ambientales y Recursos Naturales Vol 4 (11): 15-19.

ISSN: 2444-4936

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. In: 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., México. Año 3, Núm. 1,2488p. <http://rctveracruz.org/doc/AvancesInvestigacionRC2019>

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. Revista Fitotecnia Mexicana 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.; Valdivia B., R.; Turrent F., A.; Zamudio G., B. 2018. Productivity of three maize hybrids under different proportions of male sterile and fertile seeds. Interciencia Vol 43 (12): 852-857. https://www.interciencia.net/wp-content/uploads/2018/12/852-ESPINOSA-43_12.pdf

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

Velez T., M.; García Z., J.J.; Lobato O., R.; Benitez R., I.; López R., J.J.; Mejía C., J., A.; Esquivel E., G. 2018. Estabilidad del rendimiento de cruzas dialélicas entre líneas de maíz de alta y baja aptitud combinatoria general. Rev. Fitotec. Mex. Vol 41 (2): 167-175. <https://doi.org/10.35196/rfm.2018.2.167-175>

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. Agronomía mesoamericana Vol 27 (1): 191-206. <https://doi.org/10.15517/am.v27i1.21899>.