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Agronomic behaviour and population densities of inbred lines to form maize hybrids for Mexican tropic

Comportamiento agronómico y densidades de población de líneas que forman híbridos de maíz para el trópico mexicano

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Abstract

Improved seeds are the most important input in corn production, they represent the genetic yield potential and quality production. The objectives of this research were to know the behavior and seed productivity in maize inbred lines, which participate as parents in three-way hybrids. During spring summer season in 2017, there was carried out in Cotaxtla experimental station, INIFAP, in Veracruz, México, a factorial experiment arranged on split plots design distributed in complete blocks at random, with three replications in plots of one row 5 m long and 80 cm wide. There where evaluated 15 elite inbred lines as Small Plot (SP), with densities of 50,000 and 62,500 pl ha^{-1}, as Big Plot (BP). There were registered treatments: Grain yield, days to tassel and silking, plant and ear height, plant and ear aspect and sanity, plant and ear number, lodging, bad husk cover and ear rot. For grain yield, there were found high signifficant differences for density (D) and lines (L) but there was no found statistical signifficance for interaction DxL. The best yield for lines were: LT160, LT173 and LT166, with 5219, 4225 and 4213 kg ha^{-1}, for each one, respectively; Density of 62,500 pl ha^{-1}, registered grain yield of 3154 kg ha^{-1}, 29% more than 50,000 pl ha-^{1}.

Seed, *Zea mays* L., Parents, Hybrids, Tropic

Resumen

Las semillas mejoradas son el insumo más importante en la producción de maíz, representa el potencial genético para rendimiento y calidad. Los objetivos fueron conocer el comportamiento agronómico y la productividad de semilla de líneas de maíz progenitores de híbridos sobresalientes. Durante primavera verano 2017 se condujo en el Campo Cotaxtla, Ver., INIFAP, México, un experimento factorial con arreglo en parcelas divididas y distribución en bloques completos al azar, con tres repeticiones en parcelas de 1 surco de 5m de largo. Se evaluaron 15 líneas élite como Parcela Chica (PCH), con dos densidades de población 50,000 y 62,500 plantas ha-1, Parcela Grande (PG). Se registraron: Rendimiento, Días a floración, altura de planta y de mazorca, Aspecto y sanidad de planta y mazorca, número de plantas y de mazorcas total, plantas acamadas, mazorcas con mala cobertura y mazorcas podridas. Para rendimiento, se encontró diferencia altamente significativa para Densidades (D) y Líneas (L), no hubo significancia para la interacción DxL. Las mejores líneas fueron LT-160, LT-173 y LT-166, con rendimientos de 5219, 4225 y 4213 kg ha-^{1}, para cada línea, respectivamente; La densidad de 62,500 pl ha-1, registró un rendimiento de 3154 kg ha^{-1}, 29% más en relación con 50,000 pl ha^{-1}.

Semilla, *Zea mays* L., Progenitores, híbridos, trópico

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Introduction

During 2018, there were sown in México, 7.95 million hectares with maize, 7.345 were for grain production with an average in yield of 3.748 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 consume for human consumption (SIAP, 2018). 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 maize breeding program from 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).

The three way maize hybrids present the advantage of the heterosis 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 and (T47xT48)T49, for each hybrid, respectively (Flores and García, 2016; Tadeo *et al*., 2018; Tadeo *et al.,* 2016; Gómez *et al.,* 2017; Sierra *et al*., 2018; Sierra *et al*., 2016; Sánchez *et al.,* 2016; Velez *et al.,* 2018).

For identifying the best inbred lines is necessary to consider their effects of General (GCA) and Specific (SCA) combining ability, the *per se* behaviour and the adaptability (Ramírez *et al.,* 2019; Sierra *et al*., 2018; Sierra *et al*., 2017; Trachsel *et al*., 2016; Cervantes *et al*., 2016; García *et al*., 2018; Rebolloza *et al.,* 2016). Besides, for increasing seed of the parental inbred lines of hybrids, is very important to know the behaviour of these inbred lines under different plant densities, doses of fertilizers for getting the best yield and quality of seed (Reyes, 1990; Tadeo *et al.,* 2018).

The objectives of this research were to know the yield and the agronomic characteristics of the parental inbred lines of élite hybrids, under different plant densities for their maintaining and seed production

Materials and Methods

Localization

This research 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 18º 56' North Latitude and 96º 11' west longitude and altitude of 15 masl. The clime condition is Aw1(w), according with the clime classification described by Köppen modified by García (2004) and correspond to subhumid warm conditions with average annual temperature of 25 ºC 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 troughout the profile, slope less than 1% and good drainage and slightly acid pH (6.6) (INEGI, 2020).

Germplasm used

In the present research, there were evaluated 15 élite inbred lines for the maize breeding program for the humid tropic in the southeast of México, which of them participate on commercial and experimental hybrids and they belong to the Tuxpeño race.

Description of the experiment

During the spring summer season in 2017, under rainy conditions, there was carried out a factorial experiment arranged on split plots design, distributed in complete blocks at random, with three replications in plots of one row 5 m long and 80 cm wide. In this experiment, there were evaluated 15 elite inbred lines as Small Plot (SP), they were sown in two plant densities of 50,000 and 62,500 pl ha^{-1}, that correspond to Big Plot (BP) (Reyes, 1990).

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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 bunchy 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, Plant and ear height, 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 agronomic variables recorded were statistically analyzed according with the factorial experiment arranged on split plots design distributed in complete blocks at random, with three replications in plots of one row 5 m long and 80 cm wide, and for the separation of means there was used the Tukey test to 0.05 of probability (Reyes, 1990; SAS versión 9.3, 2010).

Results and discussion

Agronomic behaviour for élite inbred maize lines

Derived of the analysis of variance for the variable grain yield at 12% of moisture content in élite inbred maize lines (Table 1), there were found statistical significance at 0.01 of probability for big plot (BP), which correspond to plant densities, for inbred lines behaviour as Small Plot (SP); However, there was no statistical difference for interaction BP*SP (Reyes, 1990).

In reference to agronomic characteristics, for plant density (BP), there were only statistical significance in variables ear height and plant sanity; On the other hand, in the factor inbred lines (SP), there were found significant differences for all variables; however, for interaction BP*SP in exception with plant height, there was no significance differences for the rest of variables.

The information above, suggest additive effects for the two factors, it means that the plant density and the inbred lines were expressed as independent factors (Reyes, 1990; Tadeo *et al.*, 2018; Tadeo *et al.*, 2016). For variables: Grain yield, plant and ear height, days to tassel, plant and ear aspect and plant and ear sanity, there were gotten Coefficients of Variation of 26.74, 8.39, 14.92, 1.16, 17.44, 15.90, 17.72 and 14.68% for each variable, respectively, values relatively low that suggest that the management of the experiment and the results gotten are reliables (Reyes 1990; SAS 2010, Version 9.3).

Source of variation	Degree Free	Grain yield	Plant height	Ear height	Days to tassel	Plant aspect1/	Ear aspect1/	Plant sanity1/	Ear sanity1/
Blocks (BL)	2	5740379.9**	1870.27**	1110.27**	3.51**	0.136NS	5.63**	0.58NS	1.53**
Density (BP)	1	11490949.7**	217.77NS	840.27**	0.90NS	0.01NS	0.4NS	0.71*	0.4NS
BL*BP	2	862355.6 NS	1000.7**	436.94*	0.40NS	1.58**	0.13NS	0.036NS	0.41NS
Lines (SP)	14	7199260.4**	2128.49**	579.08**	4.187**	1.04**	2.12**	0.56**	0.61**
BP*SP	14	666395.7 NS	329.68*	137.89NS	0.638NS	0.11NS	0.16NS	0.16NS	0.14NS
MSE	56	559199.8	150.75	96.82	0.396	0.1736	0.22	0.166	0.1359
Average		2796.79	146.22	65.94	53.92	2.38	2.96	2.3	2.51
CV (%)		26.74	8.39	14.92	1.16	17.44	15.90	17.72	14.68

* and **= Statistical Signifficance for the Sources of Variation at 0.05 and 0.01 of probability of error; 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 1 Mean square and significance for evaluation of inbred maize lines and plant densities. Cotaxtla Experimental Station. CIRGOC. INIFAP. 2017B

Plant density (BP)

In relation with plant density factor, with 62,500 plants ha^{-1}, there was registered an average grain yield of 3154 kg ha^{-1}, significantly higher in 29% than 50,000 pl ha^{-1}, Besides, in reference to ear height, this was higher in the greater plant density, because of greater competitivity for light (Table 2); The qualification for plant sanity was better under the lowest density, this is due that in this density plants have the optimum conditions in light, nutrients and humidity. On the other hand, density has no effect in the variables: Days to tassel, height of plant, plant and ear aspect and ear sanity (Reyes, 1990; Tadeo *et al.*, 2018; Tadeo *et al.*, 2016).

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Lines (SP)

The élite lines evaluated (table 3), are the parental lines of the hybrids H-520, H-564C, H-567, HE-3B and HE-4B, the first two hybrids are in commercial use, The rest of them in precommercial stage. For grain yield, the inbred lines LT-160, LT-173 and LT-166 were statistically the best lines according with the tukey test at 0.05 of probability, with yields of de 5219, 4225 and 4213 kg ha^{-1}, for each line, respectively.

Entry	Density	Grain yield	% Relative	Days to tassel	Plant height	Ear height	Plant aspect[1/]	Ear aspect[1/]	Plant sanity[1/]	Ear sanity[1/]
2	62500	3154a	129	54a	148a	69a	2.4a	3.0a	2.39a	2.6a
1	50000	2439b	100	54a	145a	63b	2.4a	2.9a	2.21b	2.4a
	Average	2797		54	146	66	2.4	3.0	2.3	2.5

CV=26.74%

Treatments with the same letter are statisticaly similar, Tukey to 0.05 of probability; 1/ = Qualification scale from 1 to 5, where 1 correspond to plants and ears with the best phenotypic expression and 5 for the worst; CV= Coefficient of variation.

Table 2 Grain yield and agronomic characteristics of élite inbred maize lines in two plant densities. Cotaxtla 2017B

These inbred lines present favourable agronomic characteristics, particulary in qualification of plant an ear aspect and sanity and they participate as parents for prominent maize hybrids; Besides, these lines have been identified and selected considering their *per se* yield and their General (GCA), and Specific (SCA) combining ability, but overall, lines with capacity for producing high yield and quality of seed that permite in efficient way and competitive, their maintenance and the commercial seed production (Sierra *et al*., 2018; Sierra *et al*., 2017; Sierra *et al*., 2016; Sierra *et al*., 2019; Ramírez *et al.*, 2019; Rebolloza *et al.*, 2016; Flores y García, 2016; Gómez *et al.*, 2017; Trachsel *et al*., 2016; Tadeo *et al*., 2018; Tadeo *et al.*, 2016; Sánchez *et al.*, 2016; Cervantes *et al*., 2016; Velez *et al.*, 2018; García *et al*., 2018).

Entry	Line	Grain yield	Days to tassel	Plant height	Ear height	Plant aspect[1]	Ear aspect[1]	Plant sanity[1]	Ear sanity[1]
6	LT160	5219a	53	162	70	1.7	2.1	1.8	2.3
15	LT-173	4225ab	54	156	73	1.8	2.0	1.9	2.1
10	LT-166	4213ab	53	163	74	2.2	2.3	2.3	2.2
11	LT-169	3280 bc	55	158	65	2.0	2.8	2.1	2.7
3	LT-156	3195 bcd	53	164	73	2.2	2.8	2.2	2.4
2	LT-155	3032 bcde	52	159	76	2.6	2.9	2.3	2.5
12	LT-170	2928 bcde	55	163	73	2.5	2.6	2.3	2.3
14	LT-172	2605 cde	54	174	81	1.8	2.8	2.1	2.0
5	LT-159	2509 cde	54	129	64	2.4	3.0	2.2	2.5
4	LT-158	2166 cde	55	118	47	2.6	3.5	2.2	2.8
7	LT-163	1888 cde	53	134	64	2.8	3.2	2.8	2.4
1	LT-154	1752 cde	54	132	56	2.8	3.5	2.6	2.9
9	LT-165	1742 de	54	138	66	2.8	3.3	2.6	2.7
8	LT-164	1604 e	55	124	51	2.8	3.9	2.7	3.1
13	LT-171	1593 e	55	121	57	3.0	3.9	2.7	2.8
	MSE	559199.8	0.396	150.75	96.82	0.1736	0.2226	0.166	0.1359
	Average	2796.79	53.92	146.22	65.94	2.39	2.97	2.30	2.51
	CV (%)	26.74	1.17	8.39	14.92	17.44	15.90	17.73	14.68

Treatments with same letter are statistically similar with the Tukey test at 0.05 of probability; 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 3 Yield and agronomic characteristics for élite inbred maize lines. Cotaxtla 2017B

Interaction plant density - inbred lines

The results for this interaction, for the grain yield variable at 12% in moisture content, are presented in Table 4, which of them register that the best treatments according with the Tukey test at 0.05 of probability, were: 62,500 x LT-160, 50,000 x LT-160, 62,500 x LT-166, 62,500 x LT-173, 50,000 x LT-173 and 62,500 x LT-169 (Sierra *et al*., 2018; Sierra *et al*., 2017; Reyes, 1990; Ramírez *et al.*, 2019; Rebolloza *et al*., 2016; Gómez *et al.*, 2017; Trachsel *et al*., 2016; Sánchez *et al.*, 2016; García *et al*., 2018). The inbred lines LT160 and LT173 expressed high grain yield for the two plant densities, while, LT166 and LT169 were better in the highest density. Such inbred lines present good qualification in plant and ear aspect and sanity, short plant and ear height and intermediate biological cycle with 53 to 55 days to tassel (Reyes, 1990; Sierra *et al*., 2018; Sierra *et al*., 2017; Ramírez *et al.*, 2019; Rebolloza *et al*., 2016; Flores y García, 2016; Gómez *et al.*, 2017; Trachsel *et al*., 2016; Tadeo *et al*., 2018; Tadeo *et al.*, 2016; Velez *et al.*, 2018).

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Entry	Density x Line	Grain yield	Days to tassel	Plant height	Ear height	Plant aspect[1/]	Ear aspect[1/]	Plant sanity[1/]	Ear sanity[1/]
21	62,500 x LT-160	5977a	53	153	67	1.5	2.3	1.7	2.5
25	62,500 x LT-166	5503ab	53	167	73	2	2.2	2	2.2
30	62,500 x LT-173	4709abc	53	165	78	1.7	2	1.8	2.2
6	50,000 x LT-160	4462abcd	53	170	73	1.8	1.8	1.8	2
15	50,000 x LT-173	3741abcde	55	147	68	2	2	2	2
26	62,500 x LT-169	3724abcde	54	153	65	2	2.7	2	2.7
17	62,500 x LT-155	3427 bcdef	52	155	78	2.5	3	2.5	2.7
3	50,000 x LT-156	3282 bcdef	53	170	75	1.8	2.3	2	2.2
18	62,500 x LT-156	3109 bcdef	53	158	72	2.5	3.2	2.3	2.7
27	62,500 x LT-170	3026 cdef	55	172	85	2.5	2.8	2.5	2.7
29	62,500 x LT-172	2946 cdef	54	173	87	2	2.7	2.3	2
10	50,000 x LT-166	2923 cdef	53	158	75	2.3	2.5	2.5	2.2
20	62,500 x LT-159	2899 cdef	53	147	77	2.5	3	2.3	2.5
11	50,000 x LT-169	2836 cdef	55	162	65	2	2.8	2.2	2.7
12	50,000 x LT-170	2830 cdef	55	155	60	2.5	2.3	2	2
2	50,000 x LT-155	2636 cdef	53	163	73	2.7	2.8	2.2	2.3
19	62,500 x LT-158	2364 cdef	55	120	48	2.7	3.5	2.3	2.8
14	50,000 x LT-172	2265 def	54	175	75	1.7	2.8	1.8	2
5	50,000 x LT-159	2119 def	55	112	52	2.3	3	2	2.5
28	62,500 x LT-171	2056 def	55	125	62	3	3.8	3	2.7
16	62,500 x LT-154	2010 ef	54	137	55	2.8	3.7	2.8	3.2
22	62,500 x LT-163	1973 ef	53	123	63	2.8	3.2	2.8	2.3
4	50,000 x LT-158	1969 ef	54	115	45	2.5	3.5	2	2.8
24	62,500 x LT-165	1839 ef	54	142	72	2.7	3.3	2.7	2.5
7	50,000 x LT-163	1804 ef	53	145	65	2.8	3.2	2.8	2.5
23	62,500 x LT-164	1748 ef	55	127	53	2.8	4.2	2.7	3.2
9	50,000 x LT-165	1544 ef	54	133	60	2.8	3.3	2.5	2.8
1	50,000 x LT-154	1493 ef	54	127	57	2.7	3.3	2.3	2.7
8	50,000 x LT-164	1461 ef	55	122	48	2.7	3.7	2.7	3
13	50,000 x LT-171	1130 f	55	117	52	3	4	2.3	3
	MSE	559199.8	0.396	150.75	96.82	0.1736	0.2226	0.166	0.1359
	Average	2796.79	53.92	146.22	65.94	2.39	2.97	2.30	2.51
	CV (%)	26.4	1.17	8.39	14.92	17.44	15.90	17.73	14.68

Treatments with the same letter are statistically similar, Tukey at0.05 of probability, 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 Grain yield and agronomic characteristics of élite inbred maize lines in two plant densities. Cotaxtla 2017B

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Conclusions

The best inbred lines were LT160, LT173, LT166, LT170 and LT169 because they have high yield and favourable agronomic characteristics.

In the 62,500 pl ha^{-1} plant density, the inbred lines registered an average for grain yield of 3154 kg ha^{-1}, value significantly greater in 29% than the 50,000 pl ha^{-1} density.

There are suggest additive effects for the two factors, lines and plant densities, it means lines and densities were expressed as independent factors.

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