Effect of Plant Density on Yield and Plant Characters of Twelve Corn Hybrids and Selections[1]

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ABSTRACT

Twelve corn (*Zea mays* L.) hybrids and selections were evaluated for yield and other plant characters at densities of 45,000 and 90,000 plants/ha. The study showed no yield advantage when densifies were increased to 90,000 plants/ha. Significant differences among entries were observed in time to midsilk, ear height, plant height, test weight, weight of 1000 kernels, rust severity, and yield. No population-density × entry interaction for these characters was observed. Significant differences between population densities and among entries were observed in diameter of the third internode and number of ears per plot. Hybrid Pioneer 304C had the highest yield; Mayorbela, the highest test weight; Diente de Caballo and Pioneer 306B, the highest 1000-kernel weight; and PR-Mp4 and Pioneer 306B, the lowest rust rating. The yields of Pioneer 304C, Pioneer 105A, Pioneer 306B, and PR-3 were very similar at both plant densities, while those of Pioneer 304B and PR-Mo2 were higher by 27 and 20%, respectively, at the higher plant density. In six entries (PR-Mp4, DeKalb B-666, PR-Mo2 × Pr-3, Diente de Caballo, Mayorbela, and DeKalb B-660) yield was from 33 to 14% lower at the higher plant density.

INTRODUCTION

When corn hybrids, varieties, lines, or selections are being evaluated, it is essential to determine their differential response to population densities early in the improvement program. Although most reports tend to indicate a linear increase in yield with an increase in plant density, others have shown the opposite. According to Lang (2), varieties and hybrids of field corn tend to have a differential response to population densities, while Singh and Singh (6) noted that the lack of yield increases in various commercial hybrids at higher plant densities may be attributed to their long history of selection under medium to low densities.

In Puerto Rico, Vázquez (8) studied the effect of three population densities on yields of the local corn variety Mayorbela. He reported a linear increase in yield with an increase in plant population from 25,826 to 51,652 plants per hectare in irrigated plots. Singh and Singh (6) reported maximum grain yield, moisture content, plant height, and ear height when hybrid corn was grown at 100,000 plants/ha. Moll and Kamprath (3) evaluated three strains of corn resulting from recurrent selections at levels of 24,710, 38,300, and 49,420 plants/ha. They reported

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that increased population density resulted in greater yields in the improved strains, but the interaction between strain and density was not statistically significant. Rutger (4) evaluated seven single crosses and their component inbred lines at populations of 37,000, 62,000, and 86,000 plants/ha. Inbreds as a group were more population responsive than hybrids. A population increase from 37,000 to 86,000 plants/ha raised mean yields of inbreds 48% and mean yields of hybrids 37%. In this experiment, there was a significant genotype × population interaction for yield. Rutger and Crowder (5) evaluated six corn hybrids at two locations for 3 years at densities of 40, 50, 60, 70, 80, and 90 thousand plants per hectare. At the high populations, ear height was increased, and stalk diameter decreased. Highest grain yields were obtained at 70,000 plants/ha.

This study was conducted to compare the effect of two population densities on the yield and several morphological characteristics of 12 corn hybrids and selections grown under tropical conditions.

MATERIALS AND METHODS

The 12 corn hybrids and selections included in the experiment were similar to those reported previously by Sotomayor-Ríos (6), except that the seed of local varieties Mayorbela and Diente de Caballo were obtained from the corn improvement program at Mayagüez Institute of Tropical Agriculture (MITA) after one cycle of selection.

The experiment was conducted at the MITA Isabela experiment farm in northwestern Puerto Rico. The farm is 128 m above sea level and the temperature ranges from 18° to 31° C. The soil is a Coto clay (Oxisol). Before planting, a complete fertilizer (15-5-10) was applied to all plots at 560 kg/ha. For control of soil nematodes and insects, carbofuran[3] (2,3-dihydro-2, 2-dimethyl-7-benzofuranyl methylcarbamate) was band-applied at the rate of 6 kg/ha to all rows with the fertilizer. Immediately after planting, propazine [2-chloro-4,6-bis(isopropylamino)-*s*-triazine] was applied to all plots at 2 to 3 kg of active ingredient per hectare to control weeds. Methomyl (*S*-methyl *N*-[(methylcarbamoyl)oxy]thioacetimidate) was sprayed at 0.27 kg of active ingredient per hectare every 10 to 14 days to control insects.

The 12 corn entries (table 1) were grown at two population densities in a split-plot design with three replications. Populations of about 45,000 and 90,000 plants/ha were obtained by hand planting and thinning to one plant per hill in hills spaced at 22 and 11 cm apart, respectively. Each plot consisted of two rows 101 cm apart and 5 m long.

[3] This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation by the USDA or the Agricultural Experiment Station of the University of Puerto Rico, nor does it imply registration under FIFRA.

Data were taken on yield of corn (expressed as kg/ha and adjusted to 15.5% moisture), number of ears per plot, test weight (expressed as kg/hl), and 1000-kernel weight for plants in a 4-m^2 area of each plot. In addition, data were collected on ear height (soil surface to the topmost ear-bearing node), plant height (soil surface to the tip of the tassel), and diameter of the third internode, all for 10 consecutive plants per two-row plot. Time to midsilk and rust severity were recorded on a plot basis. Rust severity was evaluated on a scale of 0 (no lesions) to 5 (75 to 100% of leaf area covered with lesions). Data were subjected to analysis of variance, and significant differences were identified with Duncan's multiple range test.

TABLE 1.—*Yield and other plant characters of 12 corn entries planted on July 8, 1977, at Isabela, P.R.*[1]

Entry	Time to midsilk	Ear height	Plant height	Test weight	Weight of 1000 kernels	Rust rating[2]	Yield
	Days	*Cm*	*Cm*	*Kg/hl*	*G*		*Kg/ha*
Pioneer 304C	55.7 defg[3]	128 cdef	243 ab	78.2 b	282.7 cd	3.0 cd	6,229 a
Pioneer 105A	57.8 bcde	124 ef	237 ab	77.9 b	268.4 de	3.0 cd	5,252 b
Mayorbela	55.0 efg	137 bcd	236 ab	81.4 a	276.2 de	3.3 bc	4,650 bc
Diente de Caballo	56.8 cdef	138 abc	242 ab	74.1 c	337.8 a	3.3 bc	4,489 bcd
DeKalb B-666	59.8 bc	149 a	251 a	79.3 b	291.0 cd	2.6 cd	4,468 bcd
Pioneer 306B	58.8 bcd	135 bcde	242 ab	74.5 c	319.5 ab	2.4 d	3,899 cde
PR-Mo2	54.0 fg	122 f	236 ab	77.6 b	243.4 fg	4.2 a	3,675 cde
PR-Mo2 × PR-3	53.1 g	127 cdef	232 b	74.6 c	257.2 ef	4.0 ab	3,538 de
PR-Mp4	60.3 b	125 def	243 ab	74.2 c	292.3 cd	2.4 d	3,445 de
DeKalb B-660	63.5 a	138 abc	248 ab	73.8 c	229.8 g	3.3 bc	3,280 e
Pioneer 304B	60.0 bc	122 f	215 c	78.7 b	305.3 bc	3.1 cd	3,137 e
PR-3	57.3 bcdef	142 ab	247 ab	70.5 d	236.0 fg	4.0 ab	3,012 f

[1] Data are means for three replicate plots at each of two population densities.

[2] Rating scale: 1 (no infection) to 5 (75 to 100% of leaf covered with lesions).

[3] In each column, means followed by one or more letters in common do not differ significantly at P = 0.05, according to Duncan's multiple range test.

RESULTS AND DISCUSSIONS

The analysis of variance showed that there were significant differences among entries for time to midsilk, ear height, plant height, test weight, 1000-kernel weight, rust severity, and yield, but there was no population-density × entry interaction for these characteristics. Table 1 shows means across the two population densities for these characteristics.

Time to midsilk ranged from 53.1 to 63.5 days. Hybrid PR-Mo2 × PR-3 was the earliest and DeKalb B-660 was the latest to reach midsilk. Pioneer 304C, the best yielder, reached midsilk in about 56 days.

Ear height ranged from 122 to 149 cm, and the average was 132 cm. The greatest ear heights were observed in DeKalb B-666, PR-3, Diente

de Caballo, and DeKalb B-660. Pioneer 304B and PR-Mo2 had the lowest ear height, 122 cm.

Plant height ranged from 215 to 251 cm. Most entires had statistically similar heights, but Pioneer 304B was significantly shorter than all other entries.

Test weight ranged from 70.5 to 81.4 kg/hl, and the average for all entires was 76.2 kg/hl. The highest test weight, that of the local variety Mayorbela, was significantly higher than those of the other entries. This finding is in agreement with results obtained when the same entries were planted on April 21, 1975, at Isabela, P. R. (7); Mayorbela had a higher test weight than the remaining 11 entries.

Weights of 1000 kernels ranged from 229.8 to 337.8 g. The average 1000-kernel weight for all entries was 278.3 g. The local variety Diente de Caballo and Pioneer 306B, produced the highest 1000-kernel weights 337.8 and 319.5 g, respectively. Entries PR-Mo2 × PR-3, PR-Mo2, PR-3, and DeKalb B-660 had 1000-kernel weights ranging from 229.8 to 257.2 g.

Rust ratings ranged from 2.4 to 4.2. The average rating for all entries was 3.2. The best five entries, with ratings of 3.0 or less, were PR-Mp4, Pioneer 306B, DeKalb B-666, Pioneer 304C, and Pioneer 105A. Of all entries tested, PR-Mp4 and Pioneer 306B were the most resistant to rust, with values of 2.4. According to Craig et al. (1), PR-Mp4 "was resistant to *Puccinia polysora* and *Helminthosporium maydis* in Puerto Rico and to *P. polysora* in greenhouse tests in Mississippi." Entry PR-Mp4 should be of extreme value in the breeding and selection of corn genotypes for resistance to rust and southern leaf blight.

Yields ranged from 2,012 to 6,229 kg/ha. The most productive entry was Pioneer 304C, followed by Pioneer 105A, Mayorbela, and Diente de Caballo. Hybrid Pioneer 304C was consistently the most productive entry, as in previous tests conducted by Isabela (7). The local varieties Mayorbela and Diente de Caballo yielded 4,650 and 4,489 kg/ha, respectively, and were among the top producers.

The analysis of variance showed that there were significant differences between population densities and among entries in diameter of the third internode and number of ears per plot. Table 2 shows that the average diameter of the third internode was 2.18 cm at 45,000 plants/ha and 1.90 cm at 90,000 plants/ha. At 45,000 plants/ha the diameter of the third internode ranged from 1.95 to 2.30 cm; all entries except Pioneer 304B had a mean diameter of more than 2.0 cm. At 90,000 plants/ha, the diameter of the third internode ranged from 1.78 to 2.07 cm; local varieties Mayorbela and Diente de Caballo, along with PR-Mo2, had the smallest diameter of the third internode. The diameter of the third internode was significantly different at 45,000 and at 90,000 plants/ha for all entries except DeKalb B-660, Pioneer 105A, and Pioneer 304B.

The average number of ears per plot was 32.3 at 90,000 plants/ha and 25.6 at 45,000/ha, an increase of 26.2% at the higher population density (table 2). The number of ears per plot at 45,000 plants/ha ranged from 20.7 to 28.7, while at 90,000 plants/ha the range was from 26.0 to 40.3 ears. The number of ears per plot was significantly different at 90,000 and 45,000 plants/ha for the following entries: Mayorbela, Pioneer 105A, Pioneer 304C, PR-Mo2, DeKalb B-666, and PR-3.

A separate analysis was conducted to compare yield for each entry at each population density (table 3). The best producers, Pioneer 304C and Pioneer 105A, had similar yields at both population densities. Hybrid Pioneer 304B, however, showed a yield increase of 27% at the higher

TABLE 2.—*Effect of plant density on diameter of the third internode and number of ears per plot of 12 corn entries planted on July 8, 1977, at Isabela, P. R.*

Entry	Diameter of the 3rd internode		Number of ears per plot	
	45,000 plants/ha	90,000 plants/ha	45,000 plants/ha	90,000 plants/ha
	Cm			
DeKalb B-660	2.16_{b}^{NS}	2.07 a	25.7 ab	26.0_{e}^{NS}
PR-3	2.26_{a}^{*}	2.00 a	20.7 c	28.3_{de}^{*}
Pioneer 105A	2.16_{b}^{NS}	1.98 a	28.7 a	39.7_{ab}^{*}
PR-Mp4	2.28_{a}^{*}	1.98 a	24.7 abc	27.3_{e}^{NS}
Pioneer 306B	2.14_{b}^{*}	1.94 a	26.0 ab	31.3_{bcde}^{NS}
DeKalb B-666	2.30_{a}^{*}	1.91 a	26.0 ab	30.7_{cde}^{*}
Pioneer 304C	2.29_{a}^{*}	1.87 a	28.0 a	37.3_{abc}^{*}
Pioneer 304B	1.95_{b}^{NS}	1.84 b	21.7 c	26.3_{e}^{NS}
PR-Mo2 × PR-3	2.07_{b}^{*}	1.84 b	26.0 ab	32.0_{abcde}^{NS}
Mayorbela	2.16_{b}^{*}	1.83 b	28.3 a	40.3_{a}^{*}
Diente de Caballo	2.20_{a}^{*}	1.81 b	26.7 ab	32.7_{abcde}^{NS}
PR-Mo2	2.09_{b}^{*}	1.78 b	25.3 abc	36.0_{abcd}^{*}
$\bar{X}$	2.18	1.90	25.6	32.3

[1] NS—Not significant (comparison between the two densities).

* —Significant at the 5% level, according to Duncan's multiple range test.

[2] In each column, means followed by one or more letters in common do not differ significantly at P = 0.05, according to Duncan's multiple range test.

plant density, although its yield was little more than one half that of the highest yielder (Pioneer 304C).

The yield of hybrids DeKalb B-666 and DeKalb B-660 decreased 28 and 14%, respectively, when the plant density was increased. In local varieties Mayorbela and Diente de Caballo, yield decreases of 16 and 19%, respectively, were observed at the higher plant density. The yield of population PR-Mo2 was 20% higher at the higher plant density, while that of PR-3 was the same at both densities. In contrast, the yield of hybrid PR-Mo2 × PR-3 was 28% lower at the higher plant density.

Although considerable changes in yield resulted from the increase in plant density from 45,000 to 90,000 plants/ha, only in two entries (DeKalb

B-666 and PR-Mp4) were the changes (decreases) significant at the 5% level.

Ear damage on all entries was similar at both population densities; the effect of rust did not appear to be responsible for the reductions in yield at the higher population density. In only one entry, Diente de Caballo, was the rust rating significantly higher at the higher plant density than at the lower plant density (4.0 vs. 2.7).

It is logical that corn yields should increase with increasing populations up to certain densities (8,4). Beyond this, yields may level off or decrease. In this study, the yields of the best hybrids (Pioneer 304C and Pioneer 105A) were similar at densities of 45,000 plants/ha and 90,000 plants/ha. Although there was no increase in yield in these two hybrids at 90,000

TABLE 3.—*Effect of population density on the grain yield of 12 corn entries planted on July 8, 1977, at Isabela, P. R.*

Entry	Grain yield, kg/ha		% change, 90,000 vs. 45,000
	45,000 plants/ha	90,000 plants/ha	
Pioneer 304C	6,178	6,280	+2
Pioneer 105A	5,217	5,286	+1
Mayorbela	5,050	4,250	−16
Diente de Caballo	4,955	4,022	−19
DeKalb B-666	5,188	3,749	−28*[1]
Pioneer 306B	3,866	3,932	+2
PR-Mo2	3,337	4,013	+20
PR-Mo2 × PR-3	4,031	3,044	−24
PR-Mp4	4,131	2,759	−33*
DeKalb B-660	3,533	3,027	−14
Pioneer 304B	2,768	3,505	+27
PR-3	2,008	2,015	+0

[1] Significant at the 5% level, according to Duncan's multiple range test.

plants/ha, apparently they tolerate such high densities better than the entries that were negatively affected by the higher population density. Perhaps more intraspecific competition occurred among entries that showed a yield decrease at the higher plant density than in Pioneer 304C and Pioneer 105A.

RESUMEN

Se observaron diferencias significativas entre 12 selecciones de maíz sembradas en densidades de 45,000 y 90,000 plantas/ha, en términos de los días transcurridos desde la siembra a los días a mitad de la floración, altura de la mazorca, altura de la planta, peso prueba (kg/hl), peso de 1,000 granos, infección de la roya y producción total. No se observó interacción para esos caracteres entre las densidades de siem-

bra y las selecciones, pero sí para el diámetro del tercer entrenudo y número de mazorcas por parcela.

El experimento se llevó a cabo en la finca experimental del Instituto Mayagüezano de Agricultura Tropical del Departamento de Agricultura de los Estados Unidos, localizada en el noroeste de Puerto Rico.

Las 12 selecciones fueron: los híbridos 304B, 304C, 105A, DeKalb B-660 y B-666; las selecciones de PR-Mp4, PR-Mo2, PR-3, y PR-Mo2 ×PR-3; y las variedades nativas Diente de Caballo y Mayorbela.

El experimento se sembró siguiendo un diseño de bloques subdivididos, con tres repeticiones.

El híbrido Pioneer 304C fue el mejor productor (6,229 kg/ha); la variedad local Mayorbela mostró tener el mejor peso prueba (81.4 kg/hl); la variedad local Diente de Caballo y el híbrido Pioneer 304B el mejor peso de 1000 granos (338 y 335 g respectivamente). La selección PR-Mp4 y el híbrido Pioneer 306B mostraron la incidencia más baja de roya (2.4). El rendimiento de Pioneer 304C, Pioneer 105A, Pioneer 306B y PR-3 fue similar en las dos densidades de siembra, mientras que el de Pioneer 304B y PR-Mo2 fue 27 y 20% más alto a 90,000 plantas/ha. Se observó que en seis selecciones (PR-Mp4, DeKalb B-666, PR-Mo2 × PR-3, Diente de Caballo, Mayorbela y DeKalb B-666) la producción fue de 33 a 14% más baja a 90,000 plantas/ha. Los resultados de este estudio indican que en las 12 selecciones de maíz estudiadas, no hay mejora en rendimiento al aumentar la densidad de siembra a 90,000 plantas/ha.

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