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Response of different sowing densities on agronomic parameters in the cultivation of *mejen* corn in Tabasco, Mexico

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ABSTRACT

Objective: To evaluate the response of sowing densities on agronomic parameters in the native *mejen* corn.

Design/Methodology/Approach: A randomized complete block design with four repetitions was used for the treatments: T1 (0.25 m between plants and two seeds per hole (80,000 plants ha^{-1})), T2 (0.50 m between plants and three seeds per hole (60,000 plants ha^{-1})), T3 (0.75 m between plants and four seeds per hole (53,333 plants ha^{-1})), and T4 (1 m between plants and five seeds per hole (50,000 plants ha^{-1})). The following variables were determined: plant height without male flower (PHWMF, cm), ear size (ES, cm), plant, bracts, and rachis dry biomass (t ha^{-1}); number of bracts, rows per ear, grain per row, grains per ear, and grain yield (GY, t ha^{-1}).

Results: Sowing densities influence the morphological response of plants, ears, and GY. The treatment with 80,000 plants ha^{-1} recorded a GY of 4.75 t ha^{-1} in traditional systems in Tabasco —greater than the regional average of 1.94 t ha^{-1}.

Study Limitations/Implications: The architecture of native corn allows an increase in productivity, as a result of the use of high densities.

Findings/Conclusions: Although treatments with greater sowing distances obtained a lower number of grains per ear, this phenomenon is compensated by the greater number of plants per row that leads to higher grain yields.

Keywords: ear, bracts, rachis, grain yield, rows.

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INTRODUCTION

Corn is the most studied crop in Mexico. It is grown in 475,339.43 ha, with an average yield of 3.87 t ha^{-1}. In the case of Tabasco, grain production reaches 149,737.65 t, with a yield of 1.92 t ha^{-1}. Approximately 11,667 ha are cultivated in Huimanguillo, one of Tabasco's municipalities, obtaining a yield of 1.94 t ha^{-1}, which accounts for 14.36% of the state production (SIAP, 2020).

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In these agricultural areas, farmers prefer to use native corn genotypes and implement systems such as the *milpa* (corn associated with horticultural and forestry crops) and low sowing densities, which causes variability in grain yield (Macías *et al*., 2023).

Mejen is one of the most cultivated native corns in different regions of Tabasco, especially as part of the agroecosystem known as *marceño*, which is based on the traditional agriculture of the floodplains of Tabasco (Salgado-Velázquez *et al*., 2021). In the *marceño* system, the *mejen* is grown during the dry season, taking advantage of the residual soil moisture. At its physiological maturity, *mejen* is tolerant to flooding, germinates in humid soils, matures between 2.5 to 3.5 months, and is accepted for human consumption (Narez-Jiménez *et al*., 2015; Peraza-Villarreal *et al*., 2019). However, the current worldwide trend is to implement agricultural practices that increase grain yields, mainly based on genetic improvement and high sowing densities, regardless of the different edaphoclimatic conditions (Aguilar, 2014).

Sowing density affects corn grain production. A wrong decision regarding this factor causes competition for resources within the plot, resulting in small plants, ear malformation, lack of grain filling, and low weight. It also causes an inadequate use of the crop area, as a consequence of greater evaporation, greater lodging, less leaf area, and less light capture. In this respect, it is important to choose an optimal sowing density, especially in native corn, since the increase in leaf decline generates a more homogeneous distribution of solar radiation in the growing area; meanwhile, the time it takes for corn to be covered by the canopy is reduced (Sánchez-Mendoza *et al*., 2017; Salgado-García *et al*., 2021). A recent work about native corn in Tabasco showed that the use of high sowing densities doubles local yields (Ramírez-Gómez *et al*., 2020). Therefore, a greater or lesser regularity in the spatial distribution of plants can generate differences in yield between plots with the same type and population of corn (Chérrez, 2015). Therefore, the spatial arrangement of *mejen* corn sowing should be improved through the evaluation of different sowing densities and their effect on agronomic parameters, with the objective of evaluating which sowing distances can increase the productivity of *mejen* corn.

MATERIALS AND METHODS

Study area

During the spring-summer 2021 cycle, a *mejen* corn experiment was established in the Ranchería de Rio Seco y Montaña 2da section, in Huimanguillo, Tabasco, located at the UTM geographic coordinates X-439240.5 and Y-1985195.9. Corn has been planted in this area for more than 70 years. For this study, the native mejen corn, characterized by thin rachis and semi-toothed grain, was used.

Experimental design and treatment generation

A randomized complete block design was used, with the following treatments under study: T1 (0.25 m between plants and two seeds per hole (80,000 plants ha^{-1})), T2 (0.50 m between plants and three seeds per hole (60,000 plants ha^{-1})), T3 (0.75 m between plants and four seeds per hole (53,333 plants ha^{-1})), and T4 (1 m between plants and five seeds per hole (50,000 plants ha^{-1})).

The experimental plot consisted of three 2-m long furrows. Each treatment had four repetitions, generating 16 experimental plots. The central furrow of each experimental plot was taken as the useful section for data collection. Three plants were chosen at random from each central furrow to collect data, generating a total of 12 repetitions per treatment. The furrows of all experimental units were separated by one meter.

The seeds were placed by hand in each sowing hole, according to the corresponding treatment. Twenty-five days after the plant emerged, the 120N-80P-40K fertilization dose —with the commercial presentations of urea (46% N), triple superphosphate (46% P), and potassium chloride (60% K)— recommended for corn in the tropics (Barrón, 1998) was applied. The agronomic management was based on the technological package developed by INIFAP for corn cultivation (INIFAP, 2015). Hand weeding and insect pest controls were carried out. Pest control was first carried out 25 days after emergence, using 3 mL L^{-1} of cypermethrin; subsequently, it was carried out every eight days. Once the grain began to emerge, common traps (bird scarers) were set up. Finally, relief irrigation was carried out after 45 days of emergence.

Variables

Plant height without male flower (PHWMF, cm) and ear size (ES, cm)

The PHWMF was measured prior to the VT stage (ear emergence) and the ES during the R1 stage (female flowering). Three plants were selected at random from the central furrow of each experimental unit and were measured with a flexometer (Ali *et al*., 2017).

Male flower length (MFL, cm) and number of leaves below the ear (NLBE)

The MFL and NLBE were determined in three plants of the central furrow of each experimental unit.

Yield

Plant, bracts, and rachis dry biomass (t ha-1) and grain yield (GY, t ha^{-1})

The plant, bracts, and rachis fresh weight was determined in the field during stage R6 (physiological maturity), using a grain scale. Three ears of three plants were selected from the central furrow of each experimental unit for their measurement. The samples were placed in manila envelopes and labeled for their identification. The samples were dried in an oven with air flow at 65 °C for 72 h to determine their humidity percentage; subsequently, the plant, bracts, and rachis dry weight was calculated in the Petroleum Chemistry laboratory of the Universidad Popular de la Chontalpa (UPCh).

To determine the grain yield, the total grains per ear were weighed and multiplied by the number of plants in each of the sowing densities.

Number of leaves (bracts), rows, grain per row, and grain per ear

Three ears were chosen at random from the central part of each experimental unit. The number of bracts, the number of rows, and the grains per row were counted for each physiologically mature ear. Finally, the grains per row were multiplied by the number of rows to obtain the total number of grains per ear.

The randomized complete blocks were subjected to an analysis of variance. The variables with statistically significant differences were subjected to a multiple-comparison test of means, using the Tukey method ($P \leq 0.05$). All analysis were performed with SAS 9.3 software.

RESULTS AND DISCUSSION

Plant height without male flower (PHWMF, cm) and ear size (ES, cm)

Based on the analysis of variance (Table 1), the PHWMF and ES did not present statistically significant differences between sowing density treatments. The coefficients of variation (19.53 for PHWMF and 19.51 for ES) are considered admissible.

The results of this study are similar to those reported by Sánchez-Mendoza et al. (2017) in Valles Altos de México and Ramírez-Gómez *et al.* (2020) in Tabasco, both of whom evaluated native corn with different sowing densities. The low PHWMF and ES values were lower than those established by Ramírez-Gómez *et al.* (2020); this low height could be caused by the low soil moisture contents and the scarce precipitation in the period (date) of the field experiment. However, lower height and size values for PHWMF and ES are desirable, since other reports have related these variables to acame (lodging) in native corn (Del Carmen-Bravo *et al.*, 2022). Likewise, the reported ES facilitates the manual harvest of *mejen* corn, especially when it has been established in the lowlands of Tabasco, which face problems from excess humidity (Ramírez-Gómez *et al.*, 2020).

Male flower length (MFL, cm) and number of leaves below the ear (NLBE)

MFL and NLBE did not present statistical differences between sowing densities, according to the analysis of variance (Table 1). These results are contrary to the findings of Cao *et al.* (2021), who point out that the sowing density must be taken into account: a high density reduces the transmission of light within a crop and accelerates the senescence of the leaves, which affects the crop's photosynthesis and the distribution of substances, limiting grain development (Chávez *et al.*, 2021).

Table 1. Analysis of variance and Tukey means of the different sowing densities treatments in the study and their effect on the plant height without male flower, ear, inflorescence, and bracts of *mejen* corn in Huimanguillo, Tabasco.

Treatment (Plants ha^{-1})	PHWMF cm	ES cm	MFL cm	NLBE	
80 000	144.69a	74.28a	37.73a	8.25a	
60 000	147.06a	89.27a	44.75a	9.00a	
53 333	141.48a	79.27a	40.33a	7.50a	
50 000	129.11a	69.99a	30.90a	7.50a	
CV	19.53	19.51	18.09	10.59	
Prob. of F.	0.798		0.357	0.086	0.083
MSD	57.62		32.02	14.58	1.79

PHWMF: plant height without male flower; ES: ear size; MFL: male flower length; NLBE: number of leaves below the ear; CV: coefficient of variation; MSD: minimum significant difference. Values in a column with the same letters have no significant difference (NS), according to Tukey's tests ($p > 0.05$).

Performance variables

According to the analysis of variance (Table 2), the dry biomass of the plant and the bracts did not have statistical differences, unlike the dry biomass of rachis. Tukey's test ($P<0.05$) showed that the sowing density treatment with 80,000 plants ha^{-1} was superior to the others.

The 80,000-plants ha^{-1} sowing density treatment had values of 7.87, 1.21, and 0.68 t ha^{-1}, for the highest plant, bracts, and rachis dry biomass, respectively. These yields were higher than those found by Córdova-Sánchez *et al.* (2012), who reported a production of 3.20 t ha^{-1} of plant dry matter, 0.78 t ha^{-1} of bracts, and 0.68 t ha^{-1} of rachis, with the same variety (*mejen*) and with a sowing density of two seeds per hole, 0.25 cm between plants, and one meter between furrows. In fact, the competition for major growth factors is minimal among more evenly spaced plants. The growth factor that is most affected is light, followed by nutrients and water —a phenomenon which is perhaps related to the dry biomass of the plant and bracts, although it does not influence the biomass of the rachis (Testa *et al.*, 2016).

Grain yield (GY, t ha^{-1})

The analysis of variance (Table 2) showed statistically significant differences between the different sowing density treatments. According to Tukey's test ($P<0.05$), the treatments with 80,000 and 53,333 plants ha^{-1} obtained the best results. Likewise, grain yields and rachis dry weight showed a trend as sowing densities increased.

The highest GY was recorded with the sowing density of 80,000 plants per hectare (4.75 t ha^{-1}) and it was higher than the GY reported by Ramírez-Gómez *et al.* (2020), who used native corn from Tabasco and sowing densities of 0.20 and 0.25 between plants (with GYs of 3.86 and 3.80 t ha^{-1}, respectively), 1.0 m between rows, and two seeds per hole.

The results of this study show that it is possible to increase local yields by 1.94 t ha^{-1} of grain for native corn in the state of Tabasco (SIAP, 2021). Like many native corns, the

Table 2. Analysis of variance and Tukey's test for the different sowing densities treatments under study and their effect on the plant, bracts, and rachis dry biomass (t ha^{-1}) and grain yield (t ha^{-1}) per hectare of *mejen* corn, in Huimanguillo, Tabasco.

Treatments Plants ha^{-1}	**Dry biomass**			
	Plant	**Bracts (Joloche)**	**Rachis (Bacal)**	**Grain Yield (GY)**
	t ha^{-1}			
80 000	7.87a	1.21a	0.68a	4.75a
60 000	6.70a	1.01a	0.46ab	3.56b
53 333	6.63a	0.91a	0.49ab	3.70ab
50 000	5.26a	0.63a	0.36b	2.55b
C.V.	23.02	30.32	24.22	15.49
Prob. of F.	0.174NS	0.081NS	0.01*	0.001**
MSD	3.20	0.60	0.25	1.18

Values in a column with the same letter have no significant difference (NS), *: a highly significant difference.

architecture of the leaf angle is wider than in the hybrids, in which it is more erect and closed. When it is combined with a greater distance between rows, it allows the crop to efficiently take advantage of the solar radiation, assimilating photosynthates, especially in the leaves adjacent to the ear; this phenomenon is reflected in higher grain yields (Sánchez-Mendoza *et al.*, 2017). Table 3 shows that an increase in the sowing density and a shorter distance between plants improves grain yield (Gao *et al.*, 2021), despite its low number of grains per ear (Blanco-Valdés and González-Viera, 2021). Therefore, increasing sowing densities causes a decrease in yield per plant, although the greater number of plants increases grain yield (Getaneh *et al.*, 2016).

Number of bracts, rows per ear, grains per row, and grains per ear

According to the analysis of variance (Table 3), the number of bracts and the number of rows per ear did not have a statistically significant difference, unlike grains per row and grains per ear. According to Tukey's test ($P<0.05$), grains per row and grains per ear had similar values in the treatments with 53,333 plants ha^{-1}.

These results differ from the findings of Jia *et al.* (2018), who reported that the number of rows per ear increased with sowing densities. The highest number of total grains per row and per ear were found with 53,333 plants ha^{-1}, 32.15 total grains per row, and 335.93 total grains per ear. This increase in the number of grains per ear and per plant —when a greater space is established between rows— is attributed to a greater net assimilation rate of corn varieties and to the division and reduction of competition in larger spaces (Shaka *et al.*, 2019). This was the case of the 53,000 and 60,000 plants ha^{-1} sowing densities, which had greater spacing between plants per row.

Consequently, ears with higher grain numbers do not always generate higher grain yields: the treatment with 80,000 plants ha^{-1} recorded the highest grain yield and obtained the lowest number of grains per ear. This phenomenon is attributed to greater competition in the surface of the soil among roots, as a result of shorter distances between plants, which reduces root weight and their correct functioning (Gao *et al.*, 2021).

Table 3. Analysis of variance and Tukey's test for the different densities analyzed and their effect on the number of bracts, rows of grains, grains per row, and grains per ear of *mejen* corn, in Huimanguillo, Tabasco.

Plants ha^{-1}	**Number of brachts (Joloche)**	**Rows per ear**	**Grains per row**	**Grains per ear**
80,000	12.40a	10.25a	23.65b	242.45ab
60,000	10.50a	9.78a	26.25ab	257.98ab
53,333	12.23a	10.43a	32.15a	335.93a
50,000	12.78a	10.23a	22.93b	233.88b
C.V.	12.99	7.31	14.31	17.34
Prob. of F.	0.22NS	0.65NS	0.01*	0.03*
MSD	3.27	1.56	7.89	97.38

Values in a column with the same letter have no significant difference (NS), according to Tukey's test ($P<0.05$).

CONCLUSIONS

Sowing densities influence plant morphological adaptation, ears, and particularly grain yield response. The increase in sowing densities represented an increase in grain yield for native mejen corn. The treatment with 80,000 plants ha^{-1} had a grain yield of 4.75 t ha^{-1} —a value higher than the 1.92 t ha^{-1} regional average in low-density systems in Tabasco. The results indicate that the lower number of grains per ear of the treatments with greater sowing distances is compensated by the higher number of plants per row, given the higher grain yields obtained.

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