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Efecto de la densidad de siembra en la producción de maíz híbrido (Zea mays L.) bajo condiciones de riego en Valle de Santiago, Guanajuato.

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Con el objetivo de evaluar el efecto de la densidad de siembra sobre la producción del híbrido de maíz (Zea mays L.) variedad Samurai de la empresa ASPROS®, se estableció un experimento de mayo a noviembre de 2022 en la parcela experimental de la Universidad Tecnológica del Suroeste de Guanajuato (UTSOE), bajo un diseño experimental simple completamente al azar, con cuatro tratamientos de densidades de siembra y tres repeticiones. Las densidades de siembra evaluadas fueron 80,000, 90,000, 100,000 y 110,000 semillas por hectárea. Se evaluaron el rendimiento, la altura de la planta, el diámetro del tallo y la altura de la primera mazorca. El análisis estadístico mostró que había diferencias significativas para la altura de la planta y la altura de la mazorca; para la altura de la planta, la densidad de 80.000 semillas/ha mostró la altura más baja; mientras que para la altura de la mazorca, las densidades de 80.000 y 90.000 semillas/ha mostraron la altura más baja. El análisis no mostró diferencias significativas para el rendimiento; sin embargo, con la densidad de 90.000 semillas/ha se obtuvo el mayor rendimiento numérico.

Palabras clave: Densidades de siembra, híbrido, rendimiento de grano, maíz.

Abstract

With the objective of evaluating the effect of sowing density on the production of the corn hybrid (*Zea mays* L.) variety Samurai of the company ASPROS®, an experiment was established from May to November 2022 in the experimental plot of the Universidad Tecnológica del Suroeste de Guanajuato (UTSOE), under a simple completely randomized experimental design, with four treatments of sowing densities and three replications. The sowing densities evaluated were 80,000, 90,000, 100,000 and 110,000 seeds for hectare. Yield, plant height, stem diameter and height of the first cob were evaluated. The statistical analysis showed that there were significant differences for plant height and cob height; for plant height, the density of 80,000 seeds/ha showed the lowest height; while for cob height, the density of 80,000 and 90,000 seeds/ha showed the lowest height. The analysis did not show significant differences for yield; however, with the density of 90,000 seeds/ha the highest yield was obtained numerically.

Keywords: Sowing densities, hybrid, grain yield, corn.

1. INTRODUCTION

Maize is one of the most important cereal crops and is used as food, feed and industrial raw material worldwide (Acosta, 2009). In 2012, maize production exceeded that of rice and wheat (Qi et al., 2012). The world's population is estimated to be 9.15 billion, requiring a 70% increase in agricultural production (Kamran et al., 2017). Meeting the demand required by the estimated population is a major challenge for food security. And to meet future needs, productivity per unit area cultivated (in other words, grain yield) must be increased.

Since the development of single-hybrid maize breeding programs launched in the middle of the 20th century (Andorf et al., 2019), maize yields have increased sevenfold, and much of this increase can be attributed to tolerance to higher planting density (Mansfield and Mumm, 2014). Plant density is an energetic method for improving maize production by maximizing the use of energy and nutrients (Cui et al., 2020)[1].

In the municipality of Valle de Santiago, located in the Bajío region, characterized by its climate, soils and technology transfer, suitable for maize production, several white maize hybrids are recommended for each spring-summer agricultural cycle; However, they are recommended based on technical characteristics obtained under experimental conditions; therefore, the aim was to establish the hybrid variety Samurai under real production conditions, so as to subject it to the soil, climate and management conditions present and used in the region, in order to exploit its maximum potential.

Therefore, the effect of four sowing densities (80,000, 90,000, 100,000 and 110,000 seeds/hectare) was evaluated in grain yield, plant height, stem diameter and height of the first ear, during an agricultural cycle of six months from sowing to harvest, so that the producer can make a good choice of the sowing density to be used in the case of acquiring this variety.

2. REVIEW OF LITERATURE

Density tolerance in maize probably involves multiple factors such as:

a) The photosynthetic capacity

The photosynthetic capacity of a maize plant can be interpreted as the amount of sunlight intercepted for conversion into assimilates. It is responsible for higher overall dry matter production (Sinclair, 1998) and higher grain yield (Stewart et al., 2003).

b) The source-demand relationship

This is defined as the supply and demand of assimilates within a maize plant during grain filling (Rajcan and Tollenaar, 1999). A study by Lashkari et al. (2011), found that grains per row, grains per cob and ear diameter decreased as planting density increased; thus there may also be reduction in grain weight and size (Sangoi et al., 2002; Maddonni et al., 2006).

On the other hand, Peña et al. (2010), quantified the variables of grain yield per hectare and dry matter, in three different planting densities (60,000, 80,000 and 100,000 plants ha^{-1}) of the corn hybrids H-376 and Lobo. The increase in population density from 80,000 to 100,000 plants ha^{-1} increased the yield by 1 t ha^{-1} and the increase from 60,000 to 100,000 plants ha^{-1} increased the total dry matter by 3.2 t ha^{-1}.

c) Hormonal balance

Plant hormones have been shown to play an important role in modifying grain filling progress and various other factors that regulate grain filling progress. Yang et al. (2001), have reported that wheat grain filling rate is mediated by the balance between abscisic acid and ethylene, and grain filling rate increases with an increase in the ratio of ABA to ethylene in grains. A concentration of 60 mg L^{-1} of gibberellins is useful for improving grain filling, subtracting senescence and increasing yield in maize[1] (Idem).

d) The architecture of the plant.

Plant architecture plays a role in how the plant intercepts light. The angle of the upright leaf has been related to higher grain yield, particularly as plant density has increased (Hammer et al., 2009). However, intraspecific competition at high densities induces gradual plant stress throughout the growing season that can alter plant growth (Incógnito et al., 2019).

In this way, maize hybrids have been evaluated for many decades grown at different plant densities ranging from 10,000 plants ha^{-1} to 100,000 plants ha -1. It is known that hybrids are evaluated at extremely low plant densities, which represents an almost stress-free environment, where hybrids are allowed to express maximum yield potential (Duvick 2005a). Considering that plants grown in the same agricultural field basically compete for sunlight, moisture and soil nutrients, increasing the plant population would, at some point, induce stress in the hybrids as they compete for the basic requirements for growth.

On the other hand, Duvick, (2005b), mentions that older hybrids have as much yield potential as newer and elite hybrids when grown under stress-free conditions. However, recent hybrids grown under stress conditions (higher plant density) yield significantly more per unit area (Sangoi et al., 2002). In contrast, high plant population density aggravates grain abortion rate, which represents fewer grains per cob[1] (Idem). Therefore, increasing plant density, improving grain filling rate, extending the growing period of individual maize plants and regulating crop senescence would be the first priority.

e) Grain protein quality

According to Vázquez et al. (2013), when evaluating the effect of population density on the commercial and protein quality of the grain and tortillas of three maize hybrids, two of high quality protein (HQP) developed for the High Valleys of Mexico ('H-143C ' and 'H-149C'), and a non- HQP control ('Promesa'), grown at densities of 67,000 and 80,000 plants ha^{-1}, found that the commercial quality and chemical composition of HQP hybrids were affected by planting density and its interaction with the genotype. Crop management with 67,000 plants ha^{-1} allowed the production of HQP maize with quality for the dough and tortilla industries. The hybrid 'H-143C' showed a similar quality in the two population densities studied, while the 'H-149C' planted at 80 000 plants ha^{-1} produced soft endosperm grains, with low protein content (8.6 %) and tryptophan (0.73%).

3. MATERIALS AND METHODS

3.1 Project location

The experiment was established from May to November 2022 in the experimental plot of Sustainable and Protected Agriculture of the UTSOE, in an area of 0.75 ha, located on the road Valle-Huanímaro Km 1.2 in Valle de Santiago, Gto. It is located at coordinates 101º 11' 29" west longitude and 20º 23' 34" north latitude and at an altitude of 1,744 m above sea level.

3.2 Establishment of plant material

The recently commercially released white maize variety Samurai from Aspros®, a single-cross hybrid recommended for the Bajío region of Guanajuato, was established. Sowing was carried out in the second week of May and a background chemical fertilization of 75 % of that commonly used in the region was applied. The crop was established under localized drip irrigation conditions.

3.3 Experimental design and data analysis

The experiment was established under a simple completely randomized experimental design with four treatments and three replications. The treatments consisted of each of the sowing densities used: 80,000, 90,000, 100,000 and 110,000 seeds/hectare. The experimental unit consisted of four 10 m furrows at a distance of 75 cm between them. The data were analyzed using SAS 9.3 statistical software to perform the analysis of variance (Anova), mean comparison test ($p \leq 0.05$) and correlation between the four variables evaluated.

3.4 Variables evaluated

Yield: It was obtained by threshing and weighing with the aid of a granatary scale, the harvested from the total number of plants of the experimental unit at 14% humidity. It was expressed in ton/ha.

Plant height: It was measured with the help of a tape measure from the base of the stem to the spike in a total of 10 plants per experimental unit to obtain an average at the end. It was expressed in meters (m).

Stem diameter: It was measured with the help of a digital vernier below the first ear in a total of 10 plants per experimental unit to obtain an average at the end. It was expressed in centimeters (cm).

Height of the first cob: The height of the first cob was measured with the help of a tape measure from the base of the stem, on a total of 10 plants per experimental unit in order to obtain an average. It was expressed in meters (m).

3.5 Agronomic management

A 75% fertilization of the 260-80-60 formula recommended by INIFAP for maize production in the Bajío region and under irrigation conditions was used. A background fertilization was carried out at the moment of sowing with 97-60-35, the second fertilization was carried out at the V6 stage with 49-00-10 and the third fertilization was carried out at the beginning of flowering with 49-00-00. The irrigations were carried out every third day in the absence of rain. Two foliar applications of amino acids and vitamins were made.

Weed control was carried out manually and with two applications throughout the crop cycle, with contact herbicides and systemic herbicides selective for maize. Pest and disease management was carried out using an integrated scheme, with weeding, the application of organic-biological pesticides, pheromone traps and chemical pesticides, with permanent monitoring.

Harvesting of the entire sown area took place in the last week of November.

4. RESULTS AND DISCUSSION

In the analysis of variance for the yield and morphological variables (Table 1), significant differences ($p \leq 0.05$) were detected for the morphological variables of plant height and cob height, but not for yield, a variable for which statistical significance was assumed. This significance found in the variables indicates the findings of Incógnito et al. (2019), mentioning that as the sowing density is increased, the growth of the plants is modified.

Table 1. Mean squares and statistical significance level for the variables evaluated in the experiment of sowing densities in the production of the maize hybrid variety Samurai in Valle de Santiago, Gto.

FV	REN	AP	DT	AM
Trat	14.8613667	0.18623056*	0.013275	0.18027778*
Error	10.4695083	0.006675	0.016775	0.03304167
CV (%)	22.42	2.328	5.529	11.739
Means	14.428	3.509	2.342	1.548333

FV: source of variation; Trat: Treatment; CV: Coefficient of variation; AP: Height of the plant; REN: Yield; DT: Diameter of stem; AM: height of the first cob * Significant at $p \leq 0.05$.

The comparison of means test ($p \leq 0.05$) in Table 2 shows that there was a statistical difference between treatments in terms of plant height, with the planting density of 80,000 seeds/ha producing plants of lesser height. This reflects what was found by Duvick (2005a), that when plants are in environments of low stress from competition, they do not need to grow, as they intercept and make use of sunlight more efficiently.

Table 2. Comparison of means for yield and morphological variables in the experiment of sowing densities in the production of the maize hybrid variety Samurai in Valle de Santiago, Gto.

Treatment (Density)	Yield (ton/ha)	Height of the plant (m)	Diameter of stem (cm)	height of the first cob (m)
80,000	12.28 a^{z}	3.14 b	2.273 a	1.28 b
90,000	16.48 a	3.56 a	2.373 a	1.43 ab
100,000	16.21 a	3.67 a	2.420 a	1.65 a
110,000	12.74 a	3.65 a	2.303 a	1.61 a
Means	14.428	3.509	2.342	1.548
DSH	8.462	0.21	0.338	0.32

DSH: Significant difference honest. *Same letters within the same column are statistically equal (Tukey $\alpha \leq 0.05$).

The height of the first cob was another variable that showed statistical significance ($p \leq 0.05$), demonstrating the same effect of a crop established in minimum stress conditions due to sunlight competition, knowing that crops grow more when they compete strongly for this factor. Both plant height and height of the first cob presented in the density of 80,000 seeds, correspond with what is reported in the technical data sheet of the variety, but not with the observed yield.

This efficiency of the crop under conditions of low stress in terms of little competition for sunlight, is supposed to be directly related to a higher yield; however, this was not the case, as the density of 80,000 seeds was the one that numerically, but not statistically, produced the lowest yield, demonstrating that this hybrid can tolerate higher sowing densities; the ideal density is 90,000 seeds, technically recommended and in which the highest yield was achieved numerically, which in effect makes it reliable for the producer to acquire it; and with a considerable plant height of 3.56 m, half a meter above the height reported in its technical data sheet.

For the stem diameter variable, there were no significant statistical differences, the average being 2.3 cm, and in general, in the field, the development of vigorous stems resistant to lodging was observed.

In the correlation table (Table 3), the experiment only showed a direct and medium level correlation between the variables plant height and height of the first cob, indicating that this is a genetic characteristic of this variety and well mentioned in its technical data sheet; a characteristic in plant architecture that makes it attractive to the producer.

Table 3. Correlation coefficient between the variables evaluated in the experiment of sowing densities in the production of the maize hybrid variety Samurai in Valle de Santiago, Gto.

	REN	AP	DT	AM
REN	1			
AP	0.18711	1		
DT	0.39644	0.18361	1	
AM	0.17354	0.62488*	0.29186	1

AP: Height of the plant; REN: Yield; DT: Diameter of stem; AM: height of the first cob. * Significant at $p \leq 0.05$.

5. CONCLUSIONS

The different sowing densities did not show statistical differences in grain yield; however, the 90,000 and 100,000 seed densities were numerically the highest yielding, in agreement with what is reported in the variety's technical data sheet.

The density of 80,000 seeds/ha was the one that produced the lowest plant height and height of the first cob according to the technical data sheet of the variety, but not for yield, the density at which the lowest yield was obtained numerically.

The results found for the density of 90 seeds/ha are the most in line with those reported in the technical data sheet of the variety, a density that can be implemented without any problem in the Bajío region, for this and other hybrids of the business house.

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