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Evaluation of the quality of hydroponic tomato in three planting densities

Evaluación de la calidad de jitomate hidropónico en tres densidades de plantación

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Abstract

The objective of this research work was to evaluate the quality and yield of the fruits of a hydroponic tomato crop in a greenhouse for three planting densities. The experiment was established at the facilities of the National Institute of Forestry, Agriculture and Livestock Researchers (INIFAP) San Martinito Experimental Field, Puebla. It was transplanted on April 23, 2021, using "*tepetzil*" (volcanic rock) as a substrate. Three culture densities were evaluated: 2.6, 3.5 and 4.3 plants m^{-2}. Based on the results, it was found that, by increasing the density, the fruits tend to be smaller, directly affecting the yield. On the other hand, it was observed that the ºBrix values increase when working with low densities. In the case of pH, the densities had no effect. In general, the quality variables presented better results for the density of 2.6 plants m^{-2}, only for the size 20, 55 and 25% of fruits were obtained (large, medium and small per plant), respectively, for the weight a value of 107.36 g, ° Brix of 4.0390 and for Titratable Acidity (AT) of .326% and the chromatic values of: L*37.475, b* 26.58 and b*26.57.

***Solanum lycopersicum* L., Density, Quality**

Resumen

El objetivo de este trabajo de investigación fue evaluar la calidad y rendimiento de los frutos de un cultivo de jitomate hidropónico en invernadero para tres densidades de plantación. El experimento se estableció en las instalaciones del Instituto Nacional de Investigadores Forestales, Agrícolas y Pecuarias (INIFAP) Campo experimental San Martinito, Puebla. Se trasplantó el 23 de abril de 2021, usando como sustrato el "*tepetzil*" (roca volcánica). Se evaluaron tres densidades de cultivo: 2.6, 3.5 y 4.3 plantas m^{-2}. Con base a los resultados se encontró que, al aumentar la densidad, los frutos tienden a ser más pequeños afectando de manera directa el rendimiento. Por otro lado, se observó que los valores de ºBrix aumentan cuando se trabaja con densidades bajas. Para el caso del pH las densidades no tuvieron efecto. En general las variables de calidad presentaron mejores resultados para la densidad 2.6 plantas m^{-2}, tan solo para el tamaño se obtuvo 20, 55 y 25% de frutos (grande, mediano y chico por planta), respectivamente, para el peso un valor de 107.36 g, ° Brix de 4.0390 y para Acidez titulable (AT) de.326% y los valores cromáticos de: L*37.475, b* 26.58 y b*26.57.

***Solanum lycopersicum* L., Densidad, Calidad**

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Introduction

The tomato is one of the most widely produced vegetables in Mexico, grown to meet national and international demand. According to data from the Servicio de Información Agroalimentaria y Pesquera (SIAP) (SIAP, 2020), 3.24 million tonnes of tomato were produced. Some of the states with the highest production are Sinaloa, Baja California Sur, Chiapas, Querétaro and Sonora. Puebla is in seventh place nationally with a production of 129,173 tonnes.

Currently, one of the challenges of agriculture is to increase food production for a growing population on a limited amount of agricultural land and at the same time to take advantage of knowledge in production, i.e., to seek new strategies to innovate (IICA, 2014). In recent years, the number of tomato producers in Puebla has increased, as well as the use of greenhouses for the production of this crop, which favours high yields, this is due to the control of biotic and abiotic factors involved in the crop, in addition to the fact that the products obtained are of better quality (UPAEP, 2019; Terrones et al., 2011).

One of the strategies to obtain higher yields is the manipulation of planting density (Grijalva et al., 2010). In order to determine the most recommendable density for tomato cultivation, it is necessary to evaluate the quality of the fruits obtained, and for this purpose some of the measurable parameters are: Size, weight, colour, pH, shape, total soluble solids and titratable acidity (NMX, 1997; San Martín-Hernández et al, 2012; Urieta-Velázquez et al., 2012; Mendoza-Pérez et al., 2018). The objective of this research work was to evaluate some variables that determine fruit quality and yield of a hydroponic tomato crop grown in greenhouses at three planting densities.

Materials and methods

Establishment of the experiment

The present investigation was carried out inside the facilities of the National Institute of Forestry, Agricultural and Livestock Research (INIFAP) in the experimental field San Martinito, Puebla, Latitude 19º 12' 17.96" N and Longitude 98º 20' 8.56" W.

The experiment was set up in a greenhouse with zenithal-natural ventilation, with an E-W orientation, 12 m wide and 56 m long, with a total area of 624 m^2. A semi-automated irrigation system was installed, with stakes and 8 lph self-compensating drippers with a nominal pressure of 1 kg/cm^2. Twelve irrigations per day were programmed, with a duration of 1 minute per irrigation for the initial phenological stage, subsequently increasing by one minute depending on the growth of the plants until 4 minutes of irrigation were given for the stage of maximum growth. The adjustment of the irrigation time was supported by the information collected from the drainage lysimeters installed in each treatment (density). The Steiner's universal solution was applied at 100%, making an adjustment in N and K for the productive stage, increasing by 1 meq L-1 of K and reducing by 1 meq L^{-1} of N. For the management of the pH of the nutritive solution, it was acidified with sulphuric acid and phosphoric acid.

Crop establishment

A Saladette type tomato crop, cv. "Montezuma F1", was evaluated in a hydroponic system using "tepetzil" as substrate in 40 x 40 cm polyethylene bags. The seedlings were transplanted on 27 April 2021 and the cultivation duration was approximately 7 months. The evaluation was carried out for three planting densities.

Experimental design and sampling

A completely randomised block experimental design with four replications was established, where three treatments were evaluated; density 1 (D1) of 2.6 plants m^{-2}, density 2 (D2) of 3.5 plants m^{-2} and density 3 (D3) of 4.3 plants m^{-2}. Each block consisted of 6 beds cultivated in double rows, with a length of 13 m, transplanting was carried out with a planting frame of three bolls (triangle).

For each experimental unit, the fruits of the 1st, 2nd, 3rd and 4th bunches were harvested, with 4 replicates. Sampling was carried out from the beginning of the physiological maturity of the fruits, in which the following variables were measured: size, roundness index, weight, colour, pH, total soluble solids, titratable acidity and yield.

Variables evaluated

Size

This variable was determined according to the Mexican Norm NMX-FF-031-1997, which classifies the saladette tomato crop as elongated, and according to the equatorial diameter the fruits are classified in the category presented in the following table 1.

Size	Diameter	
	Minimum (mm)	Maximum (mm)
Small	38	52
Medium	52	60
Large	60	71
Extra-large	71	From now on

Table 1 Size grading of elongated tomatoes according to NMX-FF-031-1997

Weight: This variable was determined by weighing the fruits of the 1st, 2nd, 3rd and 4th bunches with an analytical balance "KERN EW" model 1500-2M and the data were expressed in grams.

Color: A spectrophotometer model DR-5000 (Konica Minolta inc. Corporation) was used to determine the colour, taking 4 repetitions per fruit, and for the interpretation of the data obtained, the Colour Space model (CIEL* a*b*) proposed by the International Commission on

Illumination (ISO/CIE, 2019) was used. colour: A spectrophotometer model DR-5000 (Konica Minolta inc. Corporation) was used to determine the colour, taking 4 repetitions per fruit, and for the interpretation of the data obtained, the Colour Space model (CIEL* a*b*) proposed by the International Commission on Illumination (ISO/CIE, 2019) was used.).

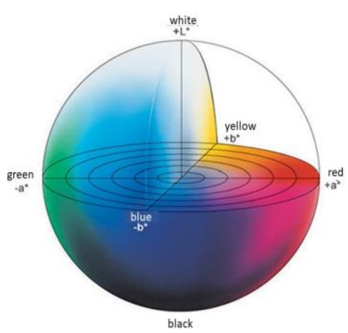

Figure 1 CIELab colour space (L*, a*, b*)
Source: Konica Minolta, 2015.

pH: For this variable, 10 g of each fruit sampled was liquefied with 50 ml of distilled water and the pH was measured directly with an electric potentiometer model Conductronic PC-40.

Total soluble solids: The fruit was cut along the equatorial diameter to extract two drops of juice from the fruit and placed directly on the sensor of a digital refractometer model ATC 81150-36, making 3 repetitions per fruit to have exact values, which was expressed in °Brix.

Titratable acidity: For each fruit a sample of approximately 20 g was taken and the titratable acidity was determined by the method of AOAC (1995). The results were reported as percentage of citric acid, using the equation (1).

$$\%AC. Cítric = \frac{(mL\ NaOH\ worn)x(N\ NaOH)x(VT)x(100)}{(Weight,sample)x(Quota)} \quad (1)$$

Yield: The tomatoes were harvested as they reached their physiological maturity and the weight of the fruits per plant was recorded, at the end of the experiment the weight of each of the measurements recorded during the whole cultivation cycle was integrated, the total weight was considered as the yield value per experimental unit, to obtain the weight an analytical balance brand "KERN EW" model 1500-2M was used.

The data obtained were subjected to an analysis of variance (ANOVA) and the means were compared with the TUKEY test (P≤0.05) with a significance level (α) of 95% with the SAS programme.

Results and discussion

Fruit size

The fruit size classification in the three densities evaluated is presented in Figure 2. In this classification, the density of 2.5 plants m^{-2} was better, obtaining 20, 55 and 25% fruit size (large, medium and small per plant), respectively, for the density of 3.5 plants m^{-2}, with 12, 61 and 28% fruit size (large, medium and small), leaving the high density of 4.3 plants m^{-2} with more fruits of medium size 54%, small 36% and very small 3%.

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As the planting density increases, the size of the fruits in the large category decreases, this is due to the fact that the solar radiation intercepted by the plant is less, causing small, defective flowers and caking of pollen due to the variation of the microclimate in the crop canopy, especially the increase in relative humidity due to the increase in foliage, affecting in some way the number of fruits, weight and size (Grijalva et al, 2010).

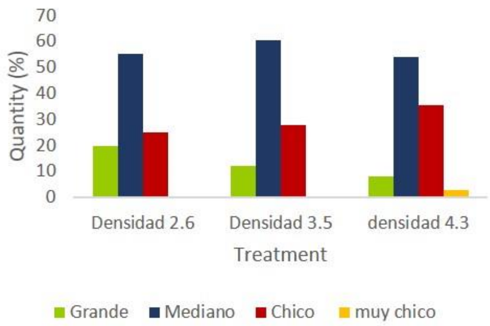

Figure 2 Fruit size classification in the three treatments

Fruit weight is presented in Table 2, where an average value of 107.36 g was obtained for the density of 2.6 plants m^{-2}, which is the highest for this variable and the lowest value was presented in the density of 4.3 plants m^{-2}, with a value of 98.98 g, this indicates a significant statistical difference between the densities. The average value of the fruits in the three planting densities is similar to those found by Sánchez-del Castillo et al. (2017), worked with the cv "Moctezuma F1", evaluating up to the third bunch, found values of 105 g for the lowest density which is 12 plants m^{-2} and 98 g for a high density of 20 plants m^{-2}, from the results found by the authors mentioned above corroborates the effect of the density on the fruit weight of the cv "Moctezuma F1".

The results found by the aforementioned authors corroborate the effect of density on the weight of tomato fruits managed at different planting densities.

The results of the variable equatorial diameter (ED) and polar diameter (PD) are presented in Table 1. The density of 2.5 plants m-2 showed better results in the ED, which has a significant statistical difference with the density of 4.3 plants m^{-2}, which in turn has significant differences with the density of 3.5 plants m^{-2}. Hernández-Leal et al, (2013) evaluated the cv. "Moctezuma F1" and found similar values, DE with 52 mm and DP 76.2 mm.

Based on the results obtained, it was determined that the DE and DP have a close relationship with the planting density, so that the higher the density, the lower the quality of the tomato fruit, in this case the size of the fruit (Grijalva et al., 2010).

The roundness index evaluated presents average values of 0.8 for the density of 2.6 plants m^{-2} and 0.82 for the densities 3.5 and 4.3 plants m^{-2}, which represents a statistically significant difference between the low density and the medium and high densities. Values close to the roundness index were obtained by Cano, (2018) for tomato type Saladette cv "Condor", which presented flattened fruits with values of 0.71 and 0.81. (<1).

Treatment	Weight (g)	Diameters (cm) Equator	Polar	Area (cm^2)	Volume (cm^3)	Roundness index	Aspect ratio
Den_2.6	107.36a	54.74ª	68.20a	29.54a	109.741a	0.803b	1.250a
Den_3.5	104.76a	54.72ª	66.21b	28.62b	105.733a	0.827ª	1.212b
Den_4.3	98.98b	52.96b	65.70b	27.58c	99.192b	0.807b	1.242a
Values with the same letter are not statistically significant ($\alpha = 0.05$).							

Table 2 Mean weight, equatorial diameter, polar diameter, area, volume, roundness index and aspect ratio

Table 2 shows the results of the total soluble solids (TSS), in which it is indicated that the density of 2.6 plants m^{-2} was better with 4.039 °Brix, with a significant statistical difference with the density of 3.5 and 4.3 plants m^{-2}. The result obtained is similar to that found by Hernández-Leal et al, (2013) with a value that ranged between 4.8 and 5.4 % °Brix for indeterminate tomato cv. "Moctezuma F1".

The highest titratable acidity value was obtained for 2.5 plants m^{-2} with a value of 0.326 % slightly lower compared to 0.312% for 4.3 plants m^{-2}, finding significant differences between these two densities (Table 2). Parra-Delgado et al. (2014) working with tomato cv. "Moctezuma F1" for a density of 2.5 plants m^{-2} found values between 0.27 % to 0.32 % titratable acidity in fruits.

The average pH value in the three treatments was 4.5, with no significant differences for this variable. These values are similar to the pH of 4.49 found by Parra-Delgado et al. (2014) for tomato of the same variety evaluated in this research.

Treatments	°Brix	Titratable acidity	pH
Den_2.6	4.039[a]	0.326[a]	4.535a
Den_3.5	3.922b	0.318ab	4.516a
Den_4.3	3.947b	0.312b	4.511a
* Values with the same letter are not statistically significant. (α = 0.05)			

Table 3 Values obtained for total soluble solids, titratable acidity and pH

Table 3 shows the results for fruit colour. The brightness (L*) of the fruit presented visually close values in the three treatments, however, treatment 2 and 3 presented significant differences. For the value a* it was found that statistically the treatment 2 is different from the others to the treatment 1 and 3. And for the value of b* the values found indicate that statistically all the treatments are equal not presenting significant differences between them. The values of the letter L* indicate the luminosity, a* and b* the chromatic coordinates according to Figure 3, indicating a lighter colour for 4.3 plants m^{-2} in comparison with 2.6 and 3.5 plants m^{-2}, following the colour scale, treatment 2 presented a redder colour than the other two treatments. This contrast in colouring may be due to the extinction of light through the canopy as the density increases due to the increase in the leaf area of the crop.

In the final stage of the crop cycle there were low temperatures, which delayed the ripening of the tomato fruits and therefore the values of a* that they present correspond to a faint red colour. On the other hand, for the density of 3.5 plants m^{-2} presented values of light L*, which is due to the fact that the higher the density the solar radiation intercepted by the fruits is lower. López and Gómez (2004) mention that when the fruit does not receive illumination, the synthesis of carotenoids involved in fruit ripening is delayed and also the colour can be significantly affected by air temperature. Padrón et al. (2012), found similar values and concluded that at low temperatures fruit ripening is delayed.

Treatments	L*	a*	b*
Den 2.6	37.475 ab	26.58 b	26.57a
Den 3.5	37.314 b	27.44 a	26.50a
Den 4.3	37.916 a	26.48 b	26.71a
* Values with the same letter are not statistically significant. (α = 0.05)			

Table 4 Colour values, obtained by spectrophotometer

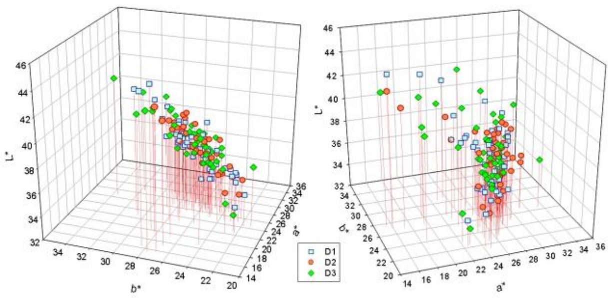

Figure 3 Coordinates and chromatic values L*a*b*

According to the values obtained for yield (Figure 4), the highest yield was obtained at a planting density of 4.3 plants m^{-2}. Similar values were reported by Mendoza-Pérez et al. (2018) who evaluated a tomato crop cv. "CID F1" at a density of 3 plants m^{-2} at two stems per plant. The positive effect on yield increase of density management was also reported by Grijalva et al. (2010).

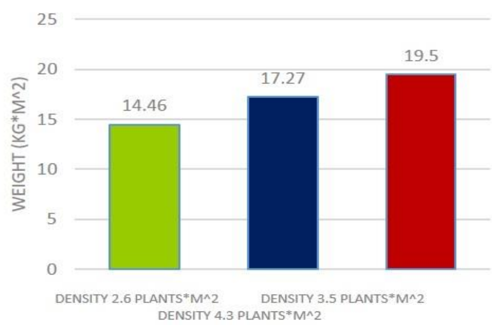

Figure 4 Tomato yields at three planting densities, presented in kg m^{-2}

Conclusions

From this research it is found that when increasing the planting density in the cultivation of tomato, the fruits tend to be smaller, affecting in an important way the weight, this fact leads to take correct decisions at the moment of choosing the planting density, since this will also depend on the commercialisation objective of the product, if a low density is chosen, fruits of greater size and higher quality will be obtained, so their commercialisation destination is for exportation or supermarkets. However, if it is decided to work with high densities, due to the smaller size of the fruits and lower quality, the commercialisation destination may be for local markets, which are less demanding with the quality of the product. It was also found that the °Brix and titratable acidity increase when working with low densities.

However, the densities have no effect on the pH of the fruits. The colour of the fruit is affected by the density, which is reflected in the low quality of the harvested product. The higher the density, the higher the yield, although this implies smaller and lower quality fruits. In general, the density of 2.6 plants m^{-2} showed better quality characteristics according to the variables evaluated.

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