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Effect of the Intraspecific Competition on the Fruit Yield of Guava Trees at High Density

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Abstract: Mexico is one of the main guava producers at the world level with a cultivated area of 21,566 hectares and an annual fruit production of 300 thousand tons. Traditional plantation system at the producing region of Calvillo-Cañones" has been using 204 trees ha^{-1} (7 × 7 m). Nevertheless, it has been observed a tendency to increase plant densities, as a way to increase production per unit area. However, high plant density systems could be affected by intraspecific competition (light, water, nutrients) and do not reflect a greater productivity. The objective of this work was to study the effect of the intraspecific competition on the fruit yield of guava trees established at high density. The study was conducted during three production cycles (2017-2019) at the Experimental Site "Los Cañones" which belongs to the INIFAP, located in Huanusco, Zacatecas. The following variables were registered each cycle: fruit yield, fruit number and average fruit weight. The experimental plot had four lines with 10 guava trees each one, planted at a density of 2,500 trees ha^{-1} (2 × 2 m). Age of trees at the beginning of the study was nine years. All variables were analyzed using a randomized complete block design, as well regression analysis. The results showed that guava trees were very sensible to competition, revealed by a severe reduction on yield and fruit number up to 69%. This was attributed to the effect of the intraspecific competition among guava trees established at high density. Although, fruit size did not show a clear tendency.

Key words: psidium guajava, fruit number, fruit weight

1. Introduction

According to FAO (2020) [1], it was estimated that the world production of guava in 2018 was 7.8 million tons, of which, 5.1 were produced in Asia; 1.25 in Africa and 0.86 in Latin America and the Caribbean. In Asia, the main guava producing countries are India and Pakistan with 4.1 and 0.49 million tons per year, respectively. In Africa, Sudan stands out with 0.47 and Egypt with 0.31 million tons, while in Latin America, Brazil and Mexico are the main guava producers with 0.35 and 0.30 million tons per year, respectively [2]. The foregoing reveals the great importance of this fruit tree around the world, as well in our country. Due to its cultivated area, guava crop is among the first 10 fruit species cultivated in Mexico, with 21,566 hectares on average during the period of 2015-2019 and the main producing states are Michoacán (10,931 hectares), Aguascalientes (6,243 hectares) and Zacatecas (2,892 hectares), which together represent 93% of the total area [3].

In the "Calvillo-Cañones" producing region, which includes the municipalities of Calvillo, Aguascalientes, and Huanusco, Jalpa, Apozol and Juchipila mainly in the state of Zacatecas, guava has a long history of cultivation with more than 100 years, especially in Calvillo, Aguascalientes, from where it extended to the region of "Los Cañones", in Zacatecas. The guava

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orchards were established, using between 204 and 234 trees ha^{-1}, in real frame systems, respectively at a distance of 7.0 × 7.0 m [4], which has prevailed until the last 25 to 30 years. However, at international level, a trend has emerged in the establishment of fruit trees, both in temperate climates, as well as tropical and subtropical climates, with higher tree densities ha^{-1}, as a strategy to increase production per unit area.

Mitra et al. (1984) [5], pointed out that the increase in fruit yield per unit area in guava is possible with high planting densities. In Mexico, the new plantations in the main producing areas have been established 666 trees ha^{-1} [4]. In addition, other studies have been reported in which the fruit yield of guava selections was evaluated, where the density was 1,111 (3 × 3 m) and 5,000 (2 × 1 m) trees ha^{-1} [6, 7].

Singh et al. (2007) [8], reported a study in which they evaluated four planting densities on the development, yield and quality of fruit and the penetration of light in the guava crop. The results showed that the height of the plants was higher, but with a lower crown volume in the density of 2,222 plants ha^{-1}. The fruit yield was higher in the density of 3.0 × 6.0 m, compared to that observed in the highest density. However, the production per unit area was higher in the density of 1.5 × 3.0 m. In the lowest densities (6.0 × 6.0 m and 3.0 × 6.0 m), fruits of greater weight were obtained and with a higher content of total soluble solids and vitamin C. Finally, they point out that photosynthetically active radiation (PAR) was lower in the trees at high density, compared to those more widely spaced trees, and conclude that light penetration was better at lower densities. It is important to mention that in high density systems, various aspects that can affect the production and quality of the fruits must be considered, since there is competition for resources such as: water, light and nutrients. Thus, fruit yield of guava trees at high density could not be reflected in higher productivity.

Therefore, the objective of this study was to evaluate the effect of intraspecific competition on the fruit yield and its components of guava trees established in high density.

2. Materials and Methods

Location and characteristics of the study area:

The study was carried out at the Experimental Site "Los Cañones" of the INIFAP, located in the municipality of Huanuasco, Zacatecas (Latitude 21° 44.7' North; Longitude 102° 58.0' West; Altitude 1,508 meters above sea level). The climate in the region is semi-dry, semi-warm of the BS_1 hw (w) type, according to the classification of García (1981) [9]. The annual average temperature is 20.4°C, the maximum annual average is 31.1°C and the minimum is 9.8°C. Average annual rainfall is from 550 to 650 mm, of which approximately 80% occurs during summer (June to September). Some of the physicochemical characteristics of the soil are: Loamy-clay texture; apparent density of 1.0 g cm^{-3}; alkaline pH of 8.5; low electrical conductivity of 0.74 ds m^{-1} without problem of salts and an average content of organic matter of 2.2%.

Annual crop management and recorded variables:

The irrigation application was carried out through a micro-sprinkler irrigation system, with weekly irrigations during approximately eight months of the crop cycle (March to October). The annual crop cycle is initiated with the tree pruning, which was carried out in March of each year. Fertilization was provided through the irrigation system, with an applied annual dose of 90-90-90 for N-P_2O_5-K_2O, respectively, mainly covering the sprouting, flowering, fruit set and fruit development stages. Manual weeding was carried out to control weeds; the pests and diseases were controlled according to the recommendations for the guava crop in the Calvillo-Cañones region [10]. The traditional management of the guava crop in the study region has an annual production cycle which begins after a period of "calmeo". The calmeo is a common practice during which the application of irrigation is suspended for about 2 to 4 months, inducing the plant to a state of quiescence due to the water stress imposed. The calmeo

period was induced at the end of the harvest of the previous cycle and it is used to schedule the harvest of the new cycle, which is obtained between 7 to 8 months after pruning and application of the first irrigation. Another reason to subject the guava trees to a water stress period (calmeo) is to avoid damage to the trees due to low temperatures mainly during the months of January to February, since frozen temperatures during winter months are not uncommon to occur in the region [11].

The experimental area included four lines with 10 guava trees each, established in a high density system with 2.0 m of separation between lines and 2.0 m between plants (2,500 plants ha^{-1}). The age of the plants at the beginning of the study was nine years. The plants were obtained from material propagated by air layering from the INIFAP guava germplasm bank. The variables recorded in each one of the three production cycles (2017 to 2019) were: fruit yield and number of fruits per tree and the average weight per fruit. The harvest was carried out every week during the months of September to October, when the fruits had a green-yellow or yellow external color that correspond to stages 3-4 of maturation according to the scale for guava proposed by Padilla et al. (2002) [12]. The average variables recorded during the three years of the study were analyzed using a randomized block design with 10 replicates and the experimental unit consisted of a tree. The data were analyzed with the statistical package SAS version 8 [13] and also regression analyzes were performed to estimate the productive behavior due to intraspecific competition between trees. Information on meteorological conditions (maximum and minimum temperatures and precipitation) was also registered in a daily basis from a near weather station to the experimental site.

3. Results and Discussion

Meteorological conditions at the experimental site:

The average maximum temperature ranged from 27.0°C occurring during the months of December and January, up to 37.0°C in May, which is the hottest month, prior the rainfall season starts. The lower average minimum temperatures occurred in December and January with values from 3.0 to 4.5°C, although temperatures below 0°C can occur during some days in those months. These chilly temperatures during the winter months may decrease growth of guava trees or even may cause damage to fruits or to trees, therefore the "calmeo" practice contribute to reduce damages [11]. Monthly average precipitation showed that the dryer months were from January to May, as well as from October to December with less than 40-50 mm per month, indicated that irrigation is need to achieve the water requirements of guava trees. In the other hand, precipitation from June to September represented almost 80% of the total annual rainfall (Table 1).

Table 1 Monthly average of Maximum and Minimum temperatures and accumulated precipitation at the Experimental Site "Los Cañones" of INIFAP at Huanusco, Zacatecas, Mexico, from 2017 to 2019.

	--------TMax. °C --------			--------TMin.°C --------			--------Prec.mm --------		
Month	2017	2018	2019	2017	2018	2019	2017	2018	2019
J	30.1	27.5	27.7	3.1	3.3	3.5	0.0	36.0	9.0
F	29.3	28.8	30.3	4.1	7.7	5.9	4.0	25.0	0.0
M	32.2	32.8	33.3	7.9	6.8	8.7	3.0	0.0	0.0
A	34.0	33.6	33.3	9.5	9.6	10.4	0.0	11.5	0.0
M	36.6	35.0	35.6	12.7	12.7	10.5	0.0	26.1	0.0
J	36.1	32.4	34.9	15.9	14.6	15.6	14.0	166.0	59.0
J	30.3	31.1	32.3	14.0	12.6	14.2	287.9	94.0	206.0
A	30.5	30.0	30.7	15.3	13.4	14.0	145.5	124.0	89.0
S	29.9	29.5	31.1	13.8	14.3	13.2	118.0	128.5	92.0
O	29.6	29.1	30.1	10.7	10.0	12.5	29.0	63.5	55.0
N	32.0	27.7	28.8	4.7	5.6	10.2	0.0	34.5	44.4

D	28.4	26.7	28.0	4.1	4.6	4.4	28.0	0.0	14.0
Annual	**31.6**	**30.4**	**31.3**	**9.7**	**9.6**	**10.3**	**629.4**	**709.1**	**568.4**

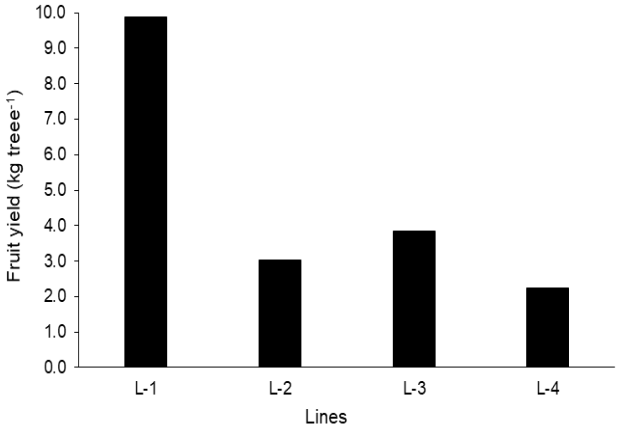
The ANVA of the fruit yield and fruit number showed significant differences ($p \leq 0.01$) between lines and between trees within each line, while in the average fruit weight, no statistical significance was observed at any of the variation factors. Results for each variable is discussed at the following paragraphs.

Fruit yield:

The average fruit yield was higher in the trees of line 1, compared to the rest of the trees on lines towards the interior of the experimental plot, which showed an average reduction of 69%. Fruit yield was from 9.9 kg tree^{-1} in the first line to only an average of 3.0 kg tree^{-1} in the rest of the lines (Fig. 1, left). This response is attributed to the fact that line 1 did not have complete competition, while the other three lines were subjected to intraspecific competition on both sides. Regarding the average yield of fruit per tree, a reduction was also observed in the trees in the center of the lines due to competition, with a very marked reduction in the third and fourth trees, without showing recovery at the end of the line. The regression analysis was performed using a second degree polynomial equation, which showed an R^2 of 0.54 (Fig. 1, right). The percentage of reduction estimated with respect to tree 1, varied from 22 to 68% due to the effect of intraspecific competition, depending on the position of the tree within the line. These results agree with those reported by Brar et al. (2009) [14], where they evaluated the distribution of solar radiation in guava plants established at different densities, indicating that a lower density of 420 trees ha^{-1} (6 × 4 m) it was the best with respect to radiation interception and that higher densities decreased yield and fruit quality.

Fruits per tree:

The average number of fruits tree^{-1}, followed a similar trend to that of fruit yield. The average number of fruits in the trees of line 1 was 174 fruits tree^{-1}, compared to an average of only 53 fruits tree^{-1} in lines 2 to 4 (Fig. 2, right). This meant a reduction of more than 65% in the production of fruits tree^{-1} due to intraspecific competition, since, as indicated above, line 1 did not have full competition, while the rest of the lines did. The average number of fruits tree^{-1} showed a pattern similar to that of the fruit yield, with a greater average number of fruits in tree^{-1} (204 fruits tree^{-1}) and a marked reduction in the following trees towards the interior of the line, mainly starting from the third and fourth tree. Pal and Lal (2015) [15], reported similar results, where high-density guava plants had lower fruit set and fruit retention, mainly attributed to competition for light, due to the overlapping of branches, which can reduce the photosynthetic activity of the plants. The polynomial regression equation had an R^2 of 0.55, and estimates the greatest reduction in the number of fruits in the middle trees of up to 70% compared to tree 1 (Fig. 2, left).



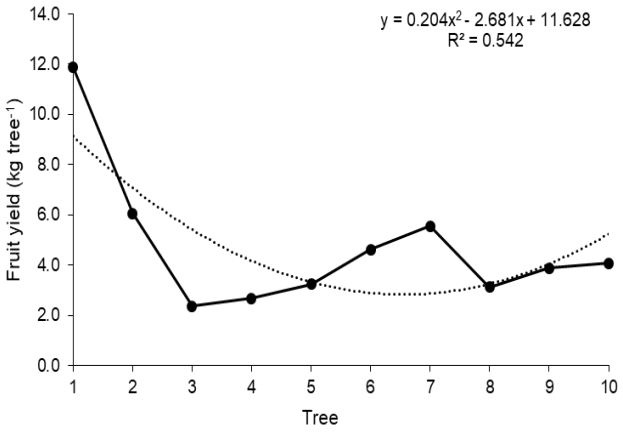


Fig. 1 Fruit yield average per line (left) and per tree (right) of guava trees established in a high density system (2 × 2 m), during three production cycles (2017-2019). Experimental Site "Los Cañones". INIFAP. Huanusco, Zacacatecas, Mexico.

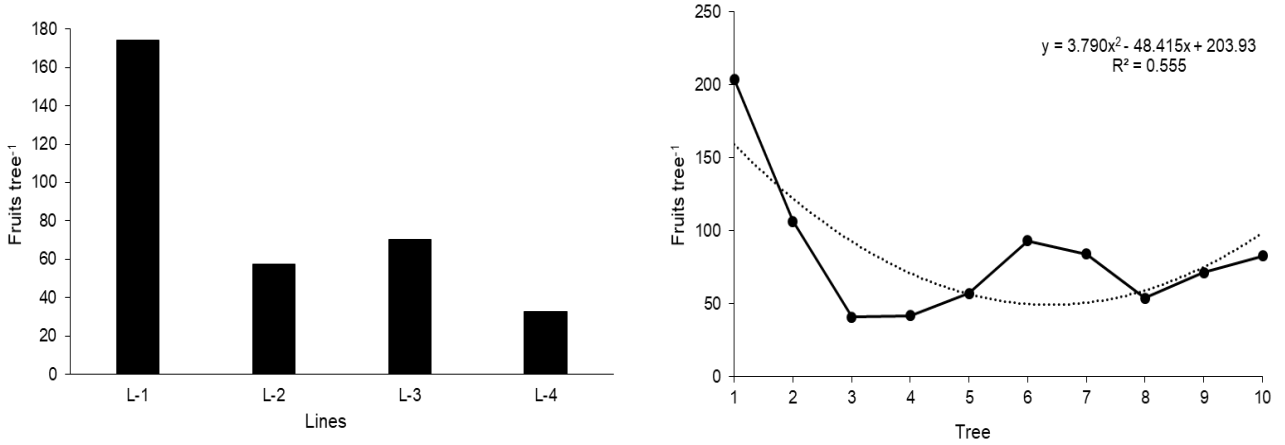


Fig. 2 Average number of fruits tree^{-1} per line (left) and per tree (right) of guava trees established in a high density system (2 × 2 m), during three production cycles (2017-2019). Experimental Site "Los Cañones". INIFAP. Huanusco, Zacacatecas, Mexico.

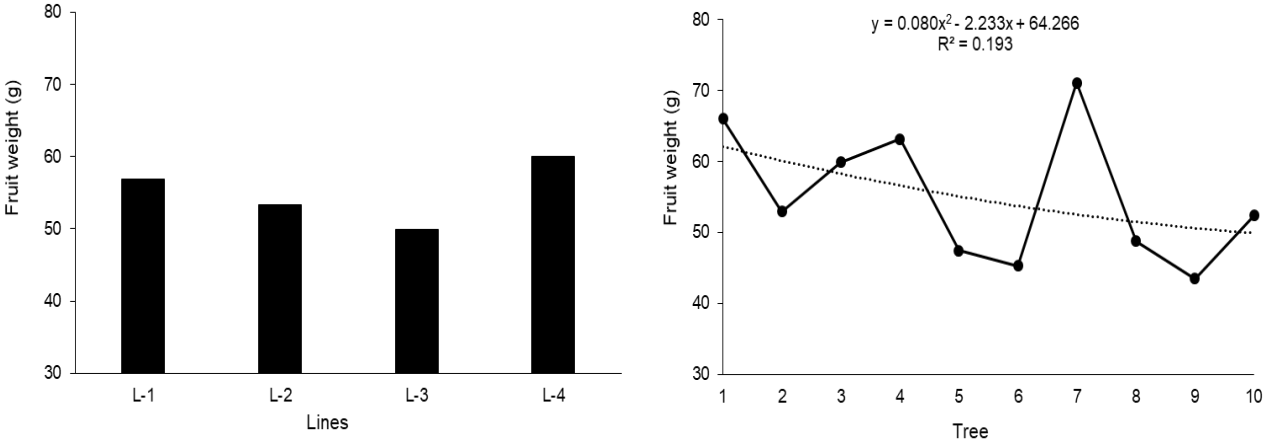


Fig. 3 Average fruit weight per line (left) and per tree (right) of guava trees established in a high density system (2 x 2 m), during three production cycles (2017-2019). Experimental Site "Los Cañones". INIFAP. Huanusco, Zacacatecas, Mexico.

Fruit weight average:

Regarding the average fruit weight, no significant effects were observed due to intraspecific competition among guava trees. The average fruit weight in the four lines varied from 50 to 60 g fruit^{-1} (Fig. 3, left), being even slightly higher in line 4, which is attributed to the fact that this line showed the lowest number of fruits, which may had compensated fruit growth, thus fruits achieved a slightly larger size, despite the competition. In contrast, Singh et al. (2007) [8] reported smaller fruits in guava trees at high densities, where the penetration of solar radiation was lower. The average weight of the fruits per tree did not reveal a clear trend of the effect of competition between trees, which was manifested in the low value obtained from the R^2 (0.19) of the polynomial equation (Fig. 3, right). The trees with the lowest values of fruit weight were: A-5, A-6, A-8 and A-9 with an average of 46.3 g fruit^{-1}, while the trees that had the largest fruits were: A-1, A-3, A-4 and A-7 with an average of 65.0 g fruit.

4. Conclusions

Guava trees showed high sensitivity to competition. The intraspecific competition generated among guava trees established in high density (2,500 trees ha^{-1}), considerably affected the fruit yield and fruit number, up to 70%, with respect to the trees subjected to less competition. The average weight of the fruit did not

show a clear trend of the effect of competition. It is suggested that in order to establish a high-density system in guava, specific agronomic management practices must be integrated (nutrition, pruning, irrigation), as well as the use of genotypes with a more compact development, in order to obtain higher productivity.

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References

[1] FAO, Las principales frutas tropicales. Análisis del mercado 2018, Roma, 2020, pp. 18.

[2] P. F. Mendes, M. Usman, N. A. Mayer, N. J. Costa, M. O. R. Mbongeni and S. Willemse, Advances in guava propagation, *Rev. Bras. Frutic.* 39 (2016) (n.4) (e-358), doi: 10.1590/0100-29452017358.

[3] SIAP, Consultada el 28 de julio de 2020, available online at: https://www.gob.mx/siap/acciones-y-programas/ produccion-agricola-33119.

[4] G. E. González, C. M. A. Perales de la and V. F. Esquivel, Establecimiento de la Huerta, in: González G. E., Padilla R. J. S., Reyes M. L. Perales de la C. M. A. and Esquivel V. F. (Eds.), G*uayaba. Su cultivo en México*, Libro Técnico No. 1, INIFAP-CIRNOC. Campo Experimental Pabellón, 2002, pp. 58-64.

[5] S. K. Mitra, S. K. Sen, S. C. Maiti and T. K. Bose, Effect of plant density on growth, yield and fruit quality in guava, *Bangladesh Hort.* 12 (1984) 7-9.

[6] R. J. S. Padilla, G. E. González, C. M. A. Perales de la, A. F. Gutiérrez and P. N. Mayek, Fruit yield of twelve outstanding selections of guava (*Psidium guajava*) from the Calvillo-Cañones region, Mexico, *Acta Hort.* 735 (2007) 25-30.

[7] R. J. S. Padilla, M. V. M. Rodríguez, G. E. González, C. E. S. Osuna and B. M. H. Pérez, Influencia de paclobutrazol en el crecimiento de brotes y rendimiento de *Psidum guajava* L. en alta densidad, *Rev. Mex. Cienc. Agríc. Pub. Esp. Núm.* 19 (2017) 3965-3977.

[8] G. Singh, A. K. Singh and D. Mishra, High density planting in guava, *Acta Hort.* 735 (2007) 235-241.

[9] E. García, Modificaciones al sistema de clasificación climática de Köppen (para adaptarlo a las condiciones de la república mexicana). Instituto de Geografía. Universidad Nacional Autónoma de México (UNAM), DF. México, 1981, p. 246.

[10] G. E. González, Control de plagas insectiles, in: González G. E., Padilla R. J. S., Reyes M. L. Perales de la C. M. A. y Esquivel V. F. (Eds.), *Guayaba. Su cultivo en México*, Libro Técnico No. 1, INIFAP-CIRNOC. Campo Experimental Pabellón, 2002, pp. 86-109.

[11] C. M. A. Perales de la, R. J. S. Padilla, V. F. Esquivel and G. E. González, Manejo agronómico, in: González G. E., Padilla R. J. S., Reyes M. L., Perales de la C. M. A. y Esquivel V. F. (Eds.), *Guayaba. Su cultivo en México*, Libro Técnico No. 1, INIFAP-CIRNOC, Campo Experimental Pabellón, 2002, pp. 65-85.

[12] R. J. S. Padilla, Cosecha y postcosecha, in: González G. E., Padilla R. J. S., Reyes M. L. Perales de la C. M. A. y Esquivel V. F. (Eds.), *Guayaba. Su cultivo en México*, Libro Técnico No. 1, INIFAP-CIRNOC, Campo Experimental Pabellón, 2002, pp. 134-144.

[13] Statistical Analysis System. Institute (SAS), User’s guide: Statistics, Version 8, SAS Inst, Cary, NC. USA, Quality, and elemental removal, *J. Environ. Qual.* 19 (1999) 749-756.

[14] J. S. Brar, J. S. Bal and S. P. Singh, Radiant energy distribution in guava (*Psidium guajava* L.) plants at different spacings, *J. of Agrometeorology* 11 (2009) (2) 135-139.

[15] M. Pal and S. Lal, Effect of different high density planting on growth and yield of guava (*Psidium guajava* L.) cv. Pant Prabhat, *Int. J. of Basic and Applied Agricultural Research* 13 (2015) (3) 420-425.