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Agronomic behavior and fruit quality in habanero peppers (*Capsicum chinense* Jacq.) as a response to formative pruning

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ABSTRACT

Objective: To evaluate the effect of pruning on the agronomic variables and fruit quality of habanero peppers (*Capsicum chinense* Jacq.).

Methodology: Habanero peppers were pruned with two intensities, two shoots and three shoots. The control plants were not pruned. The experiment had a randomized block design with four replications. The experimental plots consisted of 50 plants established in rows at a distance of 1.2 m and 0.3 m among plants within a row. The evaluated variables were fruit yield, number of fruits per plant, fruit weight, fruit length and fruit diameter. Data were obtained from 10 harvests. For the analysis, the fruit quality, ash content, moisture, protein and crude fiber were determined.

Results: Plants with two and three shoots produced fruits of 4 and 3.99 cm in length. Plants with two and three shoots produced 42 and 48% first quality fruits, whereas control plants produced only 10% first quality fruits. The highest protein content in fruits at physiological ripeness (14%) and commercial maturity (12%) was observed in plants pruned to two shoots.

Implications: These results show the importance of crop management on the fruit quality of habanero peppers. Further studies are needed to have more information on the effects of crop management on the nutritional content of fruits.

Conclusion: The pruning of habanero pepper plants significantly influenced the fruit size, crude fiber and protein content in their fruits.

INTRODUCTION

Habanero peppers (*Capsicum chinense* Jacq.) are in demand in the national and international market. In this sense, it is sown in 20 states in Mexico, with a total of 971.45 ha and a production of 16,306.31 t. The largest planted area is mainly found in the southeast region the country. The state of Yucatán is the main producer of habanero peppers, with 243.24 planted ha and a production volume of 3,222.84 t, and an average yield of 13.69 t ha^{-1}. Followed by the states of Tabasco, Quintana Roo, Campeche and Chiapas. In Yucatán, 40 municipalities produce habanero peppers,

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of which ten are the ones with the largest planted area. The municipalities of Tahdziú, Halachó, Yaxcaba, Tekax, Peto and Tizimín stand out, concentrating 60% of the production of habanero peppers in the state of Yucatán (SIAP, 2019). Even though it is the region with the largest cultivated area of habanero peppers, its yields do not cover the overall demand, mainly for sauces and condiments production, since the crop is strongly affected by inadequate planning, which limits the production and quality of their fruits (Reyes-Ramírez *et al*., 2014). The three main factors that must be taken into account when planning a crop are: pest and disease control, nutrition and agronomic management (Reyes-Pérez *et al*., 2019). Within the latter, training pruning allows to define the plant development according to the number of stems that it is desired to have, which facilitates cultural operations, treatments, harvesting, staking and can influence the yield and quality of the fruits (Villa *et al*., 2014). The cultivation of habanero peppers is generally sown following a traditional open-field system. However, with this system, the crop is negatively affected on the quality and yield of their fruits due to the fact that agronomic management given in the field is sometimes limited (Lugo-Jiménez *et al*., 2010). In this way, it is important to identify the factors that influence the production and quality of the habanero peppers, in such a way that yields increases are guaranteed and with it, its commercialization. The yield and quality of the habanero pepper fruits were evaluated as a response to formation pruning.

MATERIALS AND METHODS

Establishment and crop management

The work took place at Conkal, Yucatán (21° 15' N and 83° 32' W). The region›s climate is AW0 type, warm subhumid with an annual mean rainfall of 984.4 mm and an annual mean temperature of 26.8 °C. The experimental habanero pepper variety H-241 with orange fruits was assessed. The sowing was carried out in 200 cavities polystyrene trays, previously disinfected with 5% chlorine. Cosmopeat® was used as a substrate. The seedlings management consisted of daily irrigation, in addition to the application of fungicide, insecticide and foliar fertilizer according to their needs.

The experiment was carried out in a greenhouse 40 m long by 18 m wide. The sowing was in 12 L capacity polyethylene bags filled with a substrate (soil + gravel) at a 10: 2 ratio. Substrate disinfection was carried out with hydrogen peroxide. Transplantation was carried out when the seedlings reached a height between 15 to 20 cm, approximately 42 days after sowing (dds). A completely randomized block with four repetitions was used. The useful plot was n=50 habanero pepper plants and the treatments consisted of three types of pruning: two-branch pruned per plant (T1), three-branch pruned plant (T2) and non-pruned plants (four branches) which was the control. Pruning was carried out 45 days after transplant (DDT). For irrigation, self-compensating and anti-draining drippers were used at a 4 L h^{-1} rate, with tees, tubines and irrigation stakes. The irrigations were daily applied, with a 40 min duration, divided into four irrigation frequencies of 10 min (9:00 am, 11:00 am, 1:00 pm and 3:00 pm).

Fertigation was applied using a 100 times concentrated stock solution through four tanks: A (acid), B (sulfates and phosphates), C (nitrates) and D (microelements). The used fertilization formula was: NO_3=12 meq, H_2PO_4=1.5 meq, K=7 meq, Ca=5 meq, Mg=2.5 meq, SO_4=2.5 meq, NH_4=1.7 meq, Fe=17 ppm, Zn=20 ppm, B=5 ppm and Mn=5 ppm per plant (Soria, 2002).

Agronomical variables

Fruit yield. It was determined in g per plant for 10 fruit cuts. **Number of fruits per plant**. Number of total fruits harvested in 10 plant cuts. **Individual fruit weight**. The average fruit weight (g) was obtained by dividing the fruit yield by the number of fruits per plant, the average fruit weight was reported throughout the harvest period. **Fruit length and diameter**. Ten fruits taken at random from each cutting were measured with a digital vernier (Figure 1).

Figure 1. Habanero pepper plants pruned to two branches with fruits at two maturity stages (green and orange color).

Fruit quality variables

Analyses were carried out at two stages of the fruit's maturity, taken from the experiment established under controlled conditions. For each variable, there were three replicates. The first analysis was made with green fruits (physiological maturity) taken from the fourth cut, approximately at 105 DDT. The second analysis was made with mature fruits (orange color) taken from the sixth cut, approximately at 125 DDT. For the analyses, 250 g of fruit were harvested per repetition, which resulted in 1.0 kg of fruit, before the chemical analyses, the samples were washed in running water and 1% sodium hypochlorite, allowed to dry at room temperature and then placed in an air convection oven at 60 °C for 72 h, after removing the peduncles. The whole fruits were crushed in a mill (Ika® Werke mod Mf 10 basic) and kept in a desiccator with silica until the corresponding analyses were done.

Moisture, ash, protein and crude fiber content were determined via bromatological analysis following the official methods of the AOAC (2000). Moisture was determined by gravimetric measurement using an air convection oven at 105 °C for 4 h, ash content was determined by muffle calcination at 600 °C for 4 h, while the amount of protein was calculated from the total nitrogen content with the Kjeldahl method (nitrogen to protein conversion factor 6.25). Crude fiber content was determined by the filter paper bag method, which uses acid digestion with H_2SO_4 (1.25%) and alkaline digestion with NaOH (1.25%) in a ANCON fiber analyzer.

Data analysis

An analysis of variance (ANOVA) was performed with the data, followed by a Tukey mean test at $p<0.05$.

RESULTS AND DISCUSSION

Agronomic performance

Differences ($p<0.05$) were observed in the fruit length, moisture, protein and crude fiber variables; while fruit yield, number of fruits per plant, weight, diameter and ash content were statistically equal. Based on the mean yield behavior, the three-branch pruning treatment numerically stood out with 1357 g per plant (Table 1). In this sense, Villa *et al*. (2014) evaluated the yield of habanero peppers with three training pruning (two, three and four stems). Plants pruned to three branches had yields of 5.37 kg m^{-2}, while unpruned plants (four branches) had yields of 4.59 kg m^{-2}. In contrast to the above, Monge-Pérez (2016) reported higher yields when bell chili pepper plants were not pruned.

For the number of fruits per plant, numerically, the highest value (165.57 fruits per plant) was recorded in plants pruned to three branches, while unpruned plants (four branches) obtained an average of 152.60 fruits per plant (Table 1). In this regard, for individual fruit weight, little variation was observed, which was not significant, where plants pruned to two branches had an average weight of 8.83 g per fruit and unpruned plants (four branches) 8.65 g per fruit. In contrast, Monge-Pérez (2016) found differences ($p<0.05$) in two pruning intensities (Spanish and Dutch) for the quality of square bell pepper (*C. annuum* L.).

Spanish pruning (two guides) increased 10% fruit weight (180 g), while with Dutch pruning (no pruning) the weight was 163.96 g. Villa *et al*. (2014) mentioned that the average fruit weight is higher as the number of stems per plant decreases, which constitutes a quality improvement. Likewise, Gómez *et al*. (2020) confirmed the aforementioned by evaluating the effect of different pruning intensities on two types of chili peppers (*C. annuum* and *C. chinense*); they reported an increase in the fruit weight.

The longest fruits were recorded in plants with two and three branches, in contrast to the unpruned plant, which had shorter fruits. For fruit width, numerically, the fruits in three-branch plants stood out with 3.11 cm, while the plants without pruning presented fruits 3.06 cm wide (Figure 2). In this regard, Gómez *et al*. (2020) found no differences ($p<0.05$) in habanero peppers regard the pruning treatments. However, in plants with two and

Table 1. Mean behavior and significance of agronomic variables as a response to pruning in habanero pepper plants.

Pruning system	Fruit yield (g $plant^{-1}$)	Number of fruits per plant	Individual fruit weight (g)
Two branches	1279.70±42.29a	148.03±6.69a	8.83±0.31a
Three branches	1357.00±33.24a	165.57±5.16a	8.24±0.13a
Four branches	1293.07±33.85a	152.60±5.23a	8.65±0.37a

Data include mean ± S.E., n=3. Means with the same letter are not statistically different between treatments, Tukey ($p\leq0.05$).

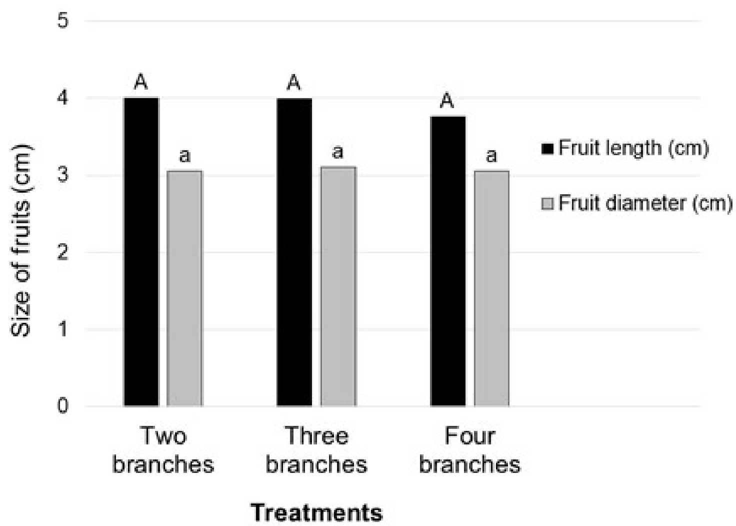

Figure 2. Size of habanero pepper fruits (length and diameter) according to formation pruning. Means with the same letter are not statistically different between treatments (p≤0.05).

three stems, the length and width of their fruits tended to be greater compared to those of unpruned plants.

In the present study, the quality of the fruit, regard their size was better than that reported in other research. In plants with two and three branches, fruits of 4.0 and 3.99 cm in length, respectively, and diameters of 3.11 and 3.06 cm, each, were produced. Overall, several studies have confirmed an increase in the size of the fruits in peppers when the plants are subjected to intensity of pruning, such is the case of Villa *et al*. (2014). The classification of the Official Mexican Standard NOM-189-SCFI-2017, defines three categories for the length of fruits: small (<2 cm), medium (2 to 3.9 cm) and large (>4 cm). In the present work, the plants pruned to two branches produced 42% first quality fruits (large fruits) and 48% second quality fruits (medium fruits); Regard the plants pruned to three branches, they produced 48% first quality fruits and 42% second quality (medium fruits), while the un-pruned plants (control) produced only 6% first quality fruits. The above indicates the importance of pruning on the quality of the fruits (Figure 3).

Fruit quality analysis

The results show that the humidity in green (physiological maturity) and orange (commercial maturity) fruits war not different ($p<0.05$) between pruned and un-pruned plants. The fruits at physiological maturity presented a higher percentage of humidity than those at commercial maturity (Table 2).

The humidity percentage results coincide with that reported by Morales-Guzmán (2013), who indicates that the humidity value of the chili fruits varies between 82% and 92%. High levels of humidity indicate that fruits are not adequate for long-term storage, because, during storage in low light conditions fungi growth and tissue decomposition favors by the activity of microorganisms and enzymes, affecting the nutritional and sensory properties. Additionally, the high water content in the fruits influences the

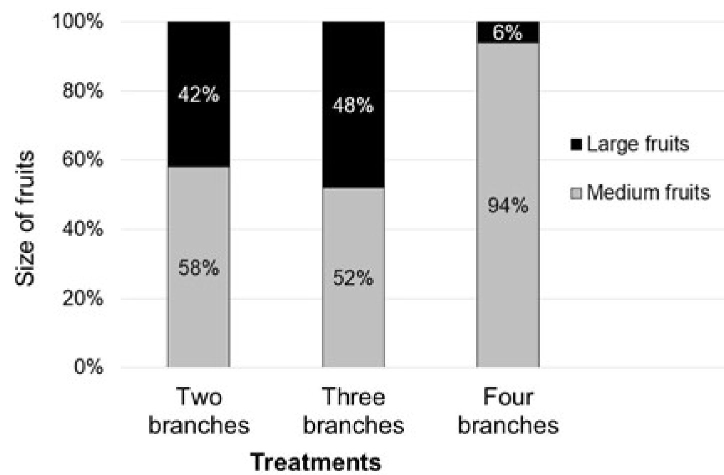

Figure 3. Percentage of first and second quality habanero chili fruits regard formative pruning.

Table 2. Bromatological analysis (humidity, ash, protein and crude fiber) of habanero pepper fruits as a response to formative pruning.

Ripening stage of fruits	Pruning system	Humidity (%)	Ash (%)	Crude protein (%)	Crude fiber (%)
Physiological ripeness	Two branches	91±0.002a	1±0.000a	14±0.000a	2±0.001a
	Three branches	90±0.000b	2±0.005a	13±0.003ab	2±0.001a
	Four branches	91±0.001ab	2±0.100a	13±0.000b	2±0.001a
Commercial ripeness	Two branches	86±0.010a	1±0.001a	12±0.003a	2±0.001b
	Three branches	86±0.010a	1±0.001a	12±0.002a	3±0.001a
	Four branches	86±0.003a	2±0.001a	10±0.010b	2±0.001b

†Means include ± S.E., n=3, means followed with the same letter are not statistically different between treatments (p≤0.05).

bioavailability of nutrients, since at high water content the nutrients contents can decrease (Solís-Marroquín *et al.*, 2017).

Regard the ash content of the fruits at physiological and commercial maturity as a response to pruning, no differences were found ($p>0.05$) (Table 2). In this regard, Solís-Marroquín *et al.* (2017) found higher ash values (6.5% in green fruits and 5.9% in orange fruits) in pepper (*C. annuum*) fruits of the cv. "siete caldos" grown in open field conditions at Comitán, Chiapas, Mexico. Although minerals were not quantified in this study, the *Capsicum* genus is considered an important and balanced source of a large number of essential nutrients, including mineral elements. The presence of minerals in the fruits could play a key role in the decrease of micronutrient deficiencies in humans (Olatunji & Afolayan, 2018). In this sense, Castillo *et al.* (2012) also confirm that a high ash content allows inferring that chili peppers are rich in mineral elements. Due to the obtained results in the ash content in the present study, it would be advisable to expand the analysis on minerals identification in habanero pepper fruits.

Differences ($p<0.05$) were observed for protein content due to pruning. It was observed that the fruits in physiological maturity showed a higher protein content than those at commercial maturity. Pruning management in plants with two and three branches statistically surpassed the non-pruned plants in their protein percentage. In fruits at physiological maturity of two pruned branches per plants, the protein content (14.0%) was statistically higher than in non-pruned plants; while in fruits at commercial maturity, the two pruning treatments statistically surpassed the protein content (12.0%) compared to the non-pruned ones (10.01%). This concurs with that reported by Alsadon *et al.* (2013) who argue that the competition for nutrients availability and other factors is lower in plants with fewer branches compared to plants with more branching. In this sense, Emmanuel *et al.* (2014) reported levels of 11.67% and 11.97% protein in *C. annuum* and *C. frutescens*, respectively. Rebouças *et al.* (2013), reported 4.8% protein content in *C. frutescens*, lower values than those found in the present study due to the pruning effect. Solís-Marroquín *et al.* (2017) reported a protein content of 13.9% in chili pepper fruits (*C. annuum*) and in habanero peppers (*C. chinense*). Likewise, Pino *et al.* (2010) found protein values of 14.92%, results that are similar to that found in this study.

In the crude fiber content, the effect of pruning was only different ($p<0.05$) in fruits at physiological maturity. An increase in the crude fiber content was observed in plants pruned to three branches (3.0%) compared to plants with two and four branches, which had 2.0% (Table 2). In this regard, Sandoval-Rangel *et al.* (2011) recorded 33.59% of fiber in "chile piquín" peppers (*C. annuum* var. *glabriusculum*) and Emmanuel *et al.* (2014) recorded 13.22% fiber in *C. annuum*, while Solís-Marroquín *et al.* (2017) reported 15.70% of crude fiber in green fruits of chile peppers cv. siete caldos, in the same way, they mention that a high content of crude fiber in chile peppers could reduce constipation in humans due to its water retention capacity, which causes an increase in the volume of intestinal waste.

CONCLUSIONS

Pruning in habanero pepper plants significantly influenced their fruit size (length and diameter), achieving a higher percentage of first quality fruits compared to unpruned plants. Yet, pruning did not affect the yield and number of fruits per plant. Based on the results of the fruit quality analysis, the habanero peppers are nutritionally valuable due to their mineral, protein and crude fiber content. Additionally, with the management of formation pruning, the protein content tends to increase.

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