

Thinning intensities to increase the size and weight of mangosteen fruits (*Garcinia mangostana* L.)

Abstract

Mangosteen (*Garcinia mangostana* L.) is a tropical tree native to Southeast Asia. The main mangosteen producing countries are Thailand, Indonesia, Malaysia, Vietnam and Philippines. Lower scale is cultivated in Singapore, Ivory Coast, Madagascar, Sri Lanka, India and Australia. In America countries like Costa Rica, Puerto Rico, Dominican Republic, Jamaica, Panama, Honduras, Guatemala, Cuba, Brazil, and Mexico also cultivate mangosteen in low scale. In recent years, its demand in international markets has increased due to the discovery of its multiple medicinal and nutraceutical properties. However, in mangosteen producing countries a high percentage of production corresponds to small fruits weighing less than 76 g, which do not fit the weight and size requirements for export purposes. The objective of the present work was to determine the response of mangosteen trees to thinning intensities to increase the weight and size of the fruit, according to the standards of international markets. Three thinning intensities (TI) 10, 30 and 50% and control without thinning (C) were evaluated, in trees with three initial fruiting ranges (IFR): 40-80; 81-120 and > 120 fruits per tree, prior to thinning. A significant difference was found ($P \leq 0.05$) between treatments for weight, diameter, fruits per tree, and fruits ha⁻¹. Non-significant difference in yield was found. TI 50% and TI 30% increase from 55.3 to 79.2 the percentage of fruits with a weight ≥ 76 g. The highest crop value is obtained with TI 30%. Thinning is a viable practice to increase the weight and size of the mangosteen fruit and its crop value.

Keywords: mangosteen, cropload management, fruit export, standards quality

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Introduction

The mangosteen (*Garcinia mangostana* L.) native to Southeast Asia, was introduced to Mexico in the 70s. The Soconusco Chiapas region concentrates 99% of the area sown with this fruit in Mexico, estimated at approximately 720 ha.¹ Most of this area corresponds to plantations established during the 2013-2017 period, which have just started their productive life.² Even though the current production volumes are small, Mexico already appears positioned in the world as a mangosteen producing country in Latin America. In this context and due to the increase in demand in international markets, this fruit tree represents a viable alternative as an export product. However, for this the fruits must comply with the quality standards required by international markets. The quality of the mangosteen fruit is evaluated using the Standard Codex Stan 204-1997.³ Besides the features related to the physical appearance of the fruits (whole fruit, with intact calyx and peduncle, without damage by pests and diseases and free of latex), the standard uses the size (weight and diameter of the equatorial section of the fruit) according to the classification indicated in Table 1.

Table 1 Classification of mangosteen fruits by size according to the Standard Codex Stan 204-1997³

Size Code	Weight (g)	Diameter (mm)
A	30 - 50	38 - 45
B	51 - 75	46 - 52
C	76 - 100	53 - 58
D	101 - 125	59 - 62
E	> 125	> 62.4

Sizes C, D and E (Table 1) are considered suitable for export. However, in many mangosteen producing countries, a high percentage of the production is small fruits corresponding to classes A and B (weighing less than 76 g) that do not fit the weight and size requirements for export purposes. In Indonesia, only 5 to 10% of the fruit fit the quality standards for export.⁴ Setiawan⁵ report that a study carried out in orchards in Bogor and Purwakarta, Indonesia, class E fruit was less than 15%. Masri,⁶ in a study carried out in Malaysia to determine the effect of soil moisture on the flowering, yield and size of the mangosteen fruit, found that more than 70% of the harvested fruits registered a weight of less than 80 g, attributable among other reasons to water stress. In a study carried by Díaz et al.² on the productive behavior of the mangosteen in the Soconusco Region, Chiapas, México, it was found that during the first four harvests (corresponding to the period 2015 - 2018), between 52 and 92% of the harvested fruits registered a weight of less than 80 g. As in other fruit trees, in the case of the mangosteen, the weight and size of the fruit are closely related to the cropload (number of fruits on the tree). The higher cropload, the smaller the fruit size and vice versa. In an experiment conducted in southern Thailand to evaluate the effect of cropload on physiological responses, yield and fruit quality in 14-year-old mangosteen trees, Sdoodee et al.⁷ report that excessive crop load caused an adverse effect on fruit size. Díaz, et al.² in the aforementioned study on the productive behavior of the mangosteen in Soconusco Chiapas, reports that in the harvest of 2018 there was an increase of 81.7% in the number of fruits produced in relation to the immediate year before, with predominance of small fruits, weighing less than 80 g, and representing 61% of the total fruits harvested during that year. As it occurs in other fruit species, mangosteen has a severe alternate bearing. This is a biannual productive pattern where one year the trees emit abundant flowering and production, mainly of small fruits. However, the following year the fruit production is considerably

lower, but larger. In the case of mangosteen, Díaz and Picón⁸ reported that at the individual tree level the differences of production between years is in a range of 4 to 35%. This means that in the same year the yield between trees is quite variable, with differences of up to 200% between the most productive tree and the least productive one within the same plantation. In this context, thinning is considered a viable alternative to increase the size and weight of fruits and reduce the productive alternation in mangosteen.

Thinning is a practice that consists of the manual, mechanical or chemical removal of the fruits to regulate the crop load in trees. With the opportune thinning, the competition for carbohydrates between the fruits that remain on the tree is reduced, which have a greater amount of reserves for their development, promoting cell division and elongation, which translates into greater growth of the fruits with a greater accumulation of sugars.^{9,10} Thinning allows the production of fruits with a higher quality in terms of weight, size, color, internal quality, and the alternation of production is controlled by promoting greater flowering in the following year.¹¹⁻¹³ The moment of thinning is a determining element in the effectiveness of this practice. Earlier thinned, translates in greater benefits effects on the size and quality on the remaining fruits. In most of the fruit trees, thinning is carried out during the first phase of fruit development known as the cell multiplication phase, which coincides with the highest demand for carbohydrates.¹⁴ Due to the multiple advantages that thinning offers, it is a routine practice in many fruit trees such as apple, pear and peach, where producers recognize that the value of production increases.¹⁵ However, there is little technical information about thinning in the case of tropical fruit trees. In the specific case of mangosteen, the technical-scientific evidence reported on the advantages and disadvantages of thinning is minimal. Sdoodee et al.⁷ indicates that in 14-year-old mangosteen trees with a crop load of 1001 to 1500 fruits/tree, up to 66% of fruits with a weight greater than 70 g are obtained. Sacramento et al.¹⁶ indicates that production of 600 fruits per plant is a good productivity for plants with 15 years of age, which provides a high proportion of fruits with a weight greater than 100 g. For plants 20 years of age or older, the number of fruits per plant can be 800. In this context, the objective of the experiment described here was to determine the response of mangosteen trees with different initial fruiting conditions, to different thinning intensities to increase the weight and size of the fruit according to the requirements of international markets.

Materials and methods

The experiment was carried out in the 8.5-year-old mangosteen plantation, established in the Rosario Izapa Experimental Station, dependent on the National Institute of Forestry, Agriculture and Livestock Research (INIFAP), located in the municipality of Tuxtla Chico, Chiapas, Mexico, at an altitude of 460 m. The predominant climate in the area is warm humid with rains in summer. The topography of the land is flat and the andosol mollic soil, with a loamy texture and pH 5.0. The average annual temperature in the area is 26.6 °C, with a minimum annual average of 17.7 °C and a maximum annual average of 34 °C. The minimum temperature values are recorded during the months of December and January. The maximum temperature values are recorded during the month of March. The average annual rainfall is 4,311.7 mm and relative humidity is 80.12%. The rainy season begins in April and ends in November, with a short dry period of 10 to 15 days in August. The highest volumes of precipitation are recorded in September and October, representing approximately 40% of the total annual precipitation. The dry period runs from December to March. The plantation was established in December 2010, at distances of 7 x 7 m between lines and plants, with a plant density of 196 trees ha⁻¹.

Three thinning intensities (TI) were evaluated: 10, 30, 50% and a control (without thinning) applied to trees with three initial fruiting ranges (IFR) prior to thinning: 40-80 fruits per tree; 81-120 fruits per tree and > 120 fruits per tree. The thinning intensities treatments were applied manually at 42 days after fruit set. Small fruits, with weight less than 20 g were eliminated until an average crop load of 4 leaves per fruit per branch was adjusted and the number of fruits per tree according to intensities thinning treatments under evaluation. The study variables recorded were fruits per tree, fruits-ha⁻¹, weight and diameter of fruits and yield (kg ha⁻¹). The percentage of fruits with export quality (with weight > 76 g) was quantified and the crop value was calculated. The harvest was carried out twice a week during the period from May 04 to September 03, 2019. Fruits per tree were quantified as the accumulated of ripe fruits harvested every four days during the harvest period. The weight of the fruit was estimated with a precision digital electronic scale to centigram. The diameter of the fruit was estimated in the equatorial region of the fruit, with a vernier caliper with graduation in millimeters. The harvest was carried out when 90 and 100% of the pericarp of the fruit showed red tones, which correspond to the stages of maturity 5 and 6 described by Díaz et al.¹ A completely randomized design with four replications was used. The experimental unit was a tree. The data were analyzed using the standard procedure of analysis of variance and Tukey's multiple comparison test of means ($P \leq 0.05$) using the statistical software InfoStat 2020. To determine the crop value the fruits were grouped into two ranges according to their weight and commercial category: a). Fruits with weight ≥ 76 g (with export quality) and, b). Fruits with weight < 76 g. The yield obtained in both categories was added and multiplied by the average prices in the region of Soconusco, Chiapas (\$ 5.95 dollars/kg of fruits with weight ≥ 76 g and \$ 4.28 dollars/kg of fruits with weight < 76 g), during the years 2018- 2019, according to the data provided by mangosteen producers and buyers.

Results and discussion

Trees with initial fruiting range (IFR) 40-80 fruits

In trees with IFR 40-80 fruits, significant difference was found between TI treatments for the fruit weight and diameter. TI 50% treatment is statistically superior to other treatments (Tukey $P \leq 0.05$), with average values of 82.3 g and 53.9 mm in weight and diameter, respectively (Table 2). The lowest average values correspond to the control treatment, without thinning. Non-significant difference was found between treatments for fruits per tree, fruitsh⁻¹ and yield. The control treatment recorded the highest number of fruits per tree (96 fruits) and fruitsh⁻¹ (18,767 fruits). The highest yield (1295 kg ha⁻¹) was registered in TI 30%. The differences in the yield of the treatments with thinning and the control without thinning are less than 40 kg ha⁻¹ (Table 2).

Trees with initial fruiting range (RFI) 81-120 fruits

In trees with RFI 81-120 fruits, a significant difference was found between treatments for weight and diameter of the fruit, fruits per tree and fruits-ha⁻¹. TI 50% treatment is superior (Tukey $P \leq 0.05$), to other treatments in weight and diameter, with averages of 83.8 g and 55.7 mm, respectively, and is 31% higher than control treatment without thinning, which registered the lowest values of weight (63.5 g). In fruits per tree and fruits-ha⁻¹, the control treatment is statistically superior to all treatments with thinning in its different modalities (Table 3). Non-significant difference in yield was found between treatments. Differences registered are less than 100 kg ha⁻¹ between the treatment with the highest yield (control) and with the lowest yield (TI 10%).

Table 2 Weight, diameter, fruits per tree, fruits-ha⁻¹ and yield averages of thinning intensities treatments in mangosteen trees with initial fruiting range of 40-80 fruits

Thinning intensity (%)	Weight (g)	Diameter (mm)	Fruits per tree	Fruits-ha ⁻¹	Yield (kg ha ⁻¹)
50	82.3 a ^z	53.9 a	80 a	15827 a	1281 a
30	79.7 ab	53.4 a	83 a	16219 a	1295 a
10	75.5 ab	52.6 ab	86 a	16709 a	1256 a
Control (without thinning)	68.1 a	49.5 b	96 a	18767 a	1277 a
DMS	13.89	3.49	50.23	9845	711.5
CV	8.66	3.17	27.78	27.28	26.53

^zDifferent letters in the same column indicate significant differences according Tukey's test ($P \leq 0.05$). Values are the average of total fruits of four trees (replications). DMS, minimal significant difference. CV, coefficient of variation

Table 3 Weight, diameter, fruits per tree, fruits-ha⁻¹ and yield averages of thinning intensities treatments in mangosteen trees with initial fruiting range of 81-120 fruits

Thinning intensity (%)	Weight (g)	Diameter (mm)	Fruits per tree	Fruits-ha ⁻¹	Yield (kg ha ⁻¹)
50	83.8 a ^z	55.7 a	121 b	23765 b	1981.7 a
30	77.0 ab	52.9 ab	133 b	26166 b	2015.9 a
10	71.9 b	52.1 b	139 ab	27195 ab	1955.2 a
Control (without thinning)	63.5 c	52.6 b	165 a	32291 a	2050.0 a
DMS	8.96	2.86	29.02	5668.1	386.3
CV	5.77	2.56	9.91	9.91	9.2

^zDifferent letters in the same column indicate significant differences according Tukey's test ($P \leq 0.05$). Values are the average of total fruits of four trees (replications). DMS: Minimal Significant Difference. CV: Coefficient of variation

Trees with initial fruiting range (RFI) > 120 fruits

In trees with RFI > 120 fruits, a significant difference was found between treatments for weight and diameter of the fruit. In both variables, TI 50% (76.7 g and 55.1 mm, respectively) and TI 30% (75.8 g and 54.6 mm, respectively), are superior (*Tukey* $P \leq 0.05$) to others treatments. The lowest values in weight and diameter correspond to control treatment. Non-significant difference was found between

treatments for fruits per tree, fruits-ha⁻¹ and yield. In control treatment the highest values of fruits per tree (216 fruits) and fruits ha⁻¹ (42,385 fruits) were recorded. The lowest values were recorded in TI 50% treatment. The highest yields were recorded in control treatment and TI 30% treatment, which are relatively similar (2738.1 and 2677 kg ha⁻¹, respectively). Lowest yield (1893.5 kg ha⁻¹) was recorded in TI 50% treatment (Table 4).

Table 4 Weight, diameter, fruits per tree, fruits-ha⁻¹ and yield averages of thinning intensities treatments in mangosteen trees with initial fruiting > 120 fruits

Thinning intensity (%)	Weight (g)	Diameter (mm)	Fruits per tree	Fruits-ha ⁻¹	Yield (kg ha ⁻¹)
50	76.7 a ^z	55.1 a	171.5 a	33614 a	1893.5 a
30	75.8 a	54.6 a	180.0 a	35280 a	2677.0 a
10	67.4 b	50.4 b	173.2 a	33957 a	2290.6 a
Control (without thinning)	64.8 b	49.8 b	216.2 a	42385 a	2738.1 a
DMS	6.87	3.9	90.64	17766	1829
CV	4.6	3.54	23.3	23.3	36.3

^zDifferent letters in the same column indicate significant differences according Tukey's test ($P \leq 0.05$). Values are the average of total fruits of four trees (replications). DMS: Minimal Significant Difference. CV: Coefficient of variation

As it is observed in Tables 2, 3 and 4, regardless of the initial fruiting condition, in all treatments that include the practice of thinning, the weight and diameter of the fruits are greater than the control treatment without thinning. This corroborates, for mangosteen what has been indicated for other fruit species by various authors¹¹⁻¹³ who indicate that thinning in different fruit species is a practice that allows obtaining fruits of greater weight and size. Although, in the three initial fruiting conditions, highest fruits per tree and fruits-ha⁻¹ were recorded in the control treatments without thinning, were recorded too in all cases, the lowest values in weight. This shows relationship between the number of fruits and their weight. These results corroborate that, as reported by various authors for other fruit trees^{10,11,14,17} like in mangosteen the higher crop load has a negative effect in the size and weight of the fruit. This is according to Sdoodee et al.⁷ where an experiment carried out to evaluate the effect of the crop load on the yield and quality of the mangosteen fruit, found that an excessive crop load (more than 1500 fruits per tree), resulted in a higher yield, but with an adverse effect on the size of the fruit. However, not in all cases the higher crop load is reflected in higher yield as observed when comparing the average yield values found in the present study and recorded in Tables 2, 3 & 4.

Percentage of fruits according to weight category

The highest percentage of fruits with weight ≥ 76 g was recorded in TI 30% and TI 50% treatments. (Figure 1). In trees with RFI 40-80 fruits, both treatments produced from 5 to 6 out of 10 fruits recorded a weight ≥ 76 g, comparatively higher than the control treatments were only 3 of every 10 fruits recorded a weight ≥ 76 g. Similar situation is observed in trees with RFI > 120 fruits. In trees with RFI 81-120 fruits, the percentage of fruits is even higher, where 6 to 7 out of 10 fruits recorded a weight ≥ 76 g. These results are relatively similar as reported by Sdoodee et al.⁷, in evaluation of different crop load

ranges in mangosteen trees (from <500 to > 1500 fruits), found that in trees with intermediate crop load (from 1001 to 1500 fruits), 66% of the fruits recorded a weight ≥ 70 g. These results also confirm the positive effect of thinning on the increase in the weight of mangosteen fruits and consequently, on the increase in the percentage of fruits with weight characteristics in accordance with the requirements of international markets. In synthesis, as it can be seen in Figure 1, with TI 50% treatment the percentage of fruits with weight ≥ 76 g is in a range between 53.0 to 65.6%, and with TI 30% treatment between 51.9 to 60.9%, both comparatively higher than the control treatments were recorded a range between 31.8 to 37.6% of fruits with weight ≥ 76 g.

Production value

In all RFI conditions, the highest crop value was recorded in the TI 30% treatment (Table 5) which exceeds by 9.9, 6.0 and 5.6% the value of the production of the control treatments with RFI 40-80, 81-120 and >120 fruits respectively, with increases in net income per ha⁻¹ of \$610; \$629 and \$738 dollars respectively, in comparison with the control treatments. In trees with RFI of 40-80 fruits and IR 10% treatment, the production value is relatively like that of the control treatment and even lower in trees with RFI greater than 81 fruits. This is attributable to the high percentage of small fruits, with low weight, as observed in Figure 1. These results suggest that low intensity thinning has little impact and even it negatively affects the yield and consequently the value of mangosteen production. On the contrary, even though with TI 50% treatment a greater production of fruits with a weight ≥ 76 g is obtained, the yield and crop value are lower than those corresponding to the IR 30% treatment, this is the low crop load of fruits per tree and fruits-ha⁻¹, as a result of the high intensity of thinning corresponding to previously mentioned treatment.

Table 5 Percentage by weight category, yield, and value of mangosteen production with three treatments of thinning intensity (TI) in trees with different initial fruiting ranges (RFI)

RFI (Fruits)	TI (%)	Fruits with weight ≥ 76 g (%)	Fruits with weight < 76 g (%)	Yield (k ha ⁻¹)	Crop value (Dollars ha ⁻¹)
40-80	Control	31.8	68.2	1277	6152
	10	43.3	56.7	1256	6324
	30	55.9	44.1	1295	6762
	50	57	43	1281	6705
81-120	Control	37.6	62.4	2050	10071
	10	49.4	50.6	1955	9990
	30	60.9	39.1	2015	10700
	50	65.6	34.4	1981	10662
> 120	Control	33.4	66.6	2738	13033
	10	38.2	61.8	2290	11248
	30	51.9	48.1	2677	13771
	50	53	47	1893	13314

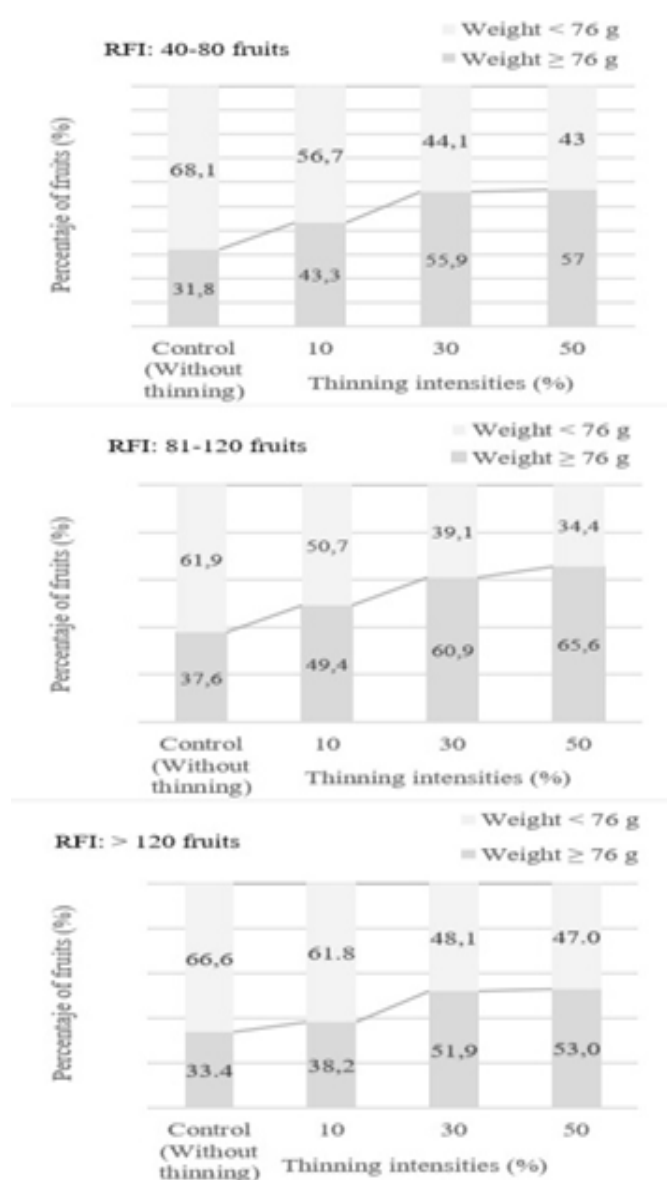


Figure 1 Percentage of mangosteen fruits *G. mangostana* by weight category (g), corresponding to three initial fruiting ranges (RFI) and thinning intensity (%) treatments.

Conclusion

By applying 50 and 30% of fruit thinning in mangosteen trees the percentage of fruits with weight ≥ 76 g is in a range between 53.0 to 65.6%, and 51.9 to 60.9% respectively. Both treatments are comparatively higher than the control treatments were recorded a range between 31.8 to 37.6% of fruits with weight ≥ 76 g. The highest value of production in trees with initial fruiting of 40 to more than 120 fruits, prior to thinning, is obtained with the thinning of 30% of the fruits. Thinning increases the weight of mangosteen fruits and the percentage of fruits with weight characteristics in accordance with the requirements of international markets.

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None.

Conflicts of interest

Authors declare no conflict of interest exists.

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