Revista Mexicana de Ciencias Agrícolas
REMEXCA

DOI: https://doi.org/10.29312/remexca.v16i1.3301

Article

Flower and vegetative stimulation of soursop with summer pruning

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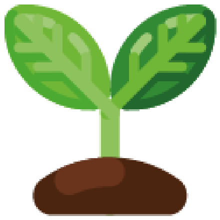
Abstract

Soursop (*Annona muricata* L.) is an important cultivation alternative. Nayarit produces 75% of national production. Nonetheless, this fruit crop is severely affected by phytosanitary problems, causing low yields and fruit quality. The study was conducted in August 2020 in El Capomo, Compostela; pruning treatments at 100%, 75%, 50%, 25% and 0% were assessed for the flower and vegetative stimulation of soursop. The shoots with 100% pruning showed greater vigor in diameter (0.34 cm) and length (11.8 cm) of the branch; likewise, the number of fruits per m^2 increased by 62.5% compared to the treatment with 0% pruning. In 50% pruning, the number of flower buds per m^2 increased by 60% and inflorescences increased 80% compared to the 0% pruning treatment. In primary branches (trunk), an average of 1.82 shoots, 0.85 flower buds, 0.09 inflorescences, 0.11 brown fruit buds, and 0.09 fruits were recorded. Secondary branches with 100% pruning showed the highest number of shoots (1.98), whereas flower buds, inflorescences, brown fruit buds, and fruits reached averages of 0.4, 0.05, 0.13 and 0.09, respectively. The use of pruning at different intensities has a positive effect on the vegetative and reproductive vigor of soursop.

Palabras clave:

intensidad, producción, tecnología.



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Introduction

Soursop (*Annona muricata* L.) is an important cultivation alternative; it has acquired social and economic importance mainly due to its commercial and industrial value (Jiménez *et al*., 2017; Ortiz and Campos, 2018; Nolasco *et al*., 2019). In Mexico, 30 791 t are produced per year; Nayarit is the state with the highest production, with 75% (23 230 t) (SIAP, 2022). This fruit crop is severely affected by phytosanitary problems that compromise the quality of the soursop, hindering the marketing of fresh fruits in the international market (Anaya *et al*., 2021).

Pests and diseases contribute to the early fall of flowers and fruits, reducing yield and fruit quality by up to 90% (Alberto and Otanes, 2016; Cambero *et al*., 2019). The seed borer, *B. cubensis*, affects about 72% of Nayarit's soursop production; likewise, the pink hibiscus mealybug and the Annonaceae weevils also affect it (Coto and Saunders, 2001; Hernández *et al*., 2013). Diseases such as fruit spots and rot (anthracnose) (Alberto and Otanes, 2016) have a great economic impact due to the losses they cause in fruit volume and quality (Betancourt *et al*., 2019; Cambero *et al*., 2019).

In addition, the production of the soursop is severely affected by the poor pollination of its flowers. In most orchards, the yields obtained are incompatible with the total number of flowers produced by the plant (Rebolledo *et al*., 2009). This is due to the late nature of the pollination process, inducing early flower fall or drying (Escobar *et al*., 1986).

In young soursop trees (5-6 years), the flowers appear solitary in thin branches and throughout the crown of the tree, causing the branches to break due to lack of load-bearing capacity during the fruiting period, so yields are severely affected (Escobar *et al*., 1986). Soursop in Nayarit is produced with little or no technology regarding irrigation, pest management, disease management, pollination techniques, nutrition, and pruning, which results in low yields.

Pruning is one of the most relevant agronomic management factors in the production of fruit crops, rejuvenates plant tissue, removes damaged or diseased branches, allows greater aeration and light penetration into the tree, and avoids conditions conducive to the development of pests and diseases; it also allowed the increase of its biomass.

Likewise, pruning generates sustained production in the orchard in terms of health, yield, and fruit quality, which is largely determined by the size of the fruits, the color and firmness of the pulp, and the concentration of soluble solids (Ojer *et al*., 2006; Jaimes and De Vidal, 2014; Pérez *et al*., 2016). As a result, pruning can increase yield and fruit quality.

In states such as Campeche in orchards with high density (2 222 trees ha^{-1}), pruning has contributed to maintaining optimal conditions for good management in fertilization, irrigation, identification of sanitary problems and production of 12.79 kg per tree and yield of 28.42 t ha^{-1} as well as facilitating harvesting work in an 8-year-old orchard (Reyes *et al*., 2018). Given the production problems faced by this fruit crop, it is important to increase the production and productivity of its orchards in the state. Therefore, different pruning percentages were evaluated to determine the best response in the flower and vegetative stimulation of soursop in Nayarit, Mexico.

Materials and methods

Study area

The study was carried out in a 1 ha, unirrigated, five-year-old commercial soursop orchard. It is located in the ejido El Capomo, Las Varas, municipality of Compostela, Nayarit, at 80 masl with coordinates 21° 7' 39" north latitude and 105° 10' 6" west longitude. Before selecting the experimental plot, the leaf was isolated in the drip zone of each tree and it was broadcast-fertilized on July 7, 2020, with 1 kg tree^{-1} of a compound mixture (ammonium sulfate, DAP, potassium sulfate, boron, magnesium sulfate, manganese sulfate, and zinc sulfate) and a second fertilization was performed on September 1, 2020, with 300 g tree^{-1} of Terratec original (urea, Man, DAP, Sam, phosphonitrate, KCL, Sop, sulfomag).

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The following insecticides were applied prior to the start of flowering (July 31 and August 20, 2020): copper oxychloride (2.5 ml L^{-1}), permethrin (0.36 ml L^{-1}), and imidacloprid (1 ml L^{-1}). The pruning was carried out on August 7, 2020, 33 days after the first fertilization, five treatments were established, the experimental unit was of one tree with eight replications, so there was an experimental plot of 40 trees.

In each tree, prior to pruning, the existing branches were counted to determine the number of branches to be pruned. Five treatments were evaluated (Table 1). In all treatments, dry, broken, and diseased branches were removed, leaving branches with a better angle and load-bearing capacity. The wounds were covered with the help of a brush with a mixture of copper sulfate (200 g), lime (500 g), and table salt (50 g) in 5 L of water in order to create a barrier and prevent diseases.

Table 1. Pruning treatments evaluated on soursop trees.

Treatment	Pruning and health	Removed branches
Treatment 1	100% formation and health pruning	8 to 10 branches
Treatment 2	75% formation and health pruning	6 to 8 branches
Treatment 3	50% formation and health pruning	4 to 6 branches
Treatment 4	25% formation and health pruning	2 to 4 branches
Treatment 5	Control without pruning	0 to 1 branches

Vigor of vegetative shoots

Four shoots were randomly marked on the outside of the tree crown (middle part), one for each cardinal point (N, S, E, W) in each of the 40 trees; a mark (rope) was placed to later measure with a vernier the diameter and length of each shoot. The first measurement was made 20 days after pruning. The following measurements were made monthly from the first date until completing one year. The data obtained in millimeters were transformed into centimeters.

Number of vegetative shoots per m^2

A 3/8 steel quadrant of 50 cm^2 was placed in the middle part of each shoot previously selected per cardinal point; the new shoots that were found inside it were counted. The first count was made 20 days after pruning. The following counts were made monthly from the first count until completing one year.

Number of flower buds, inflorescences, brown fruit buds and fruits per m^2

Using the method and area measured in the previous variable, the flower buds, inflorescences, brown fruit buds, and fruits per m^2 that were found within the quadrant were counted for one year.

Number of vegetative shoots per linear meter in primary and secondary branches

In all trees, the trunk (primary branch) was measured 2 m from the ground to the top of the tree with a tape measure. Four branches of the second axis were selected, one for each cardinal point; they were measured 1.5 m from the bottom to the outside of the crown, marked with aerosol and identified with a ribbon in consecutive order. The first count in primary and secondary branches was made 20 days after pruning. The following counts were made monthly from the first count until completing one year.

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Number of flower buds, inflorescences, brown fruit buds, and fruits per linear meter in primary and secondary branches

Using the method and area measured in the previous variable, the flower buds, inflorescences, brown fruit buds, and fruits that were found in the primary (trunk) and secondary branches were counted for one year.

Statistical analysis

The data were analyzed with a mixed linear model considering the treatments as fixed effects and the parameters evaluated for the vigor of vegetative shoots, number of flower buds, inflorescences, brown fruit buds and fruits per m^2, and the number of flower buds, inflorescences, brown fruit buds and fruits per linear meter in primary and secondary branches were assessed as random parameters. Multiple comparisons between means of the evaluated parameters of the Fisher's LSD type (test based on a Wald test) were performed. The statistical software of Infostat 2020 was used (Di Rienzo *et al*., 2020).

Results and discussion

Vigor of vegetative shoots

A significant difference (p= 0.001) was found in the vigor of the shoots per treatment; treatment 1 (100% formation and health pruning) was the best in diameter and length of the vegetative shoots, with means of 0.34 cm and 11.8 cm, respectively, being 20.59% more vigorous in diameter and 39.92% longer compared to treatment 5 (control with 0% pruning) with 0.27 cm in diameter and 7.09 cm in length (Table 2).

Table 2. Flower buds, inflorescences, fruits, brown fruit buds, shoots, and vigor of vegetative shoots per square meter.

Treat	Variables assessed (m^2)						
	Dia (cm)	Len (cm)	Sho	Bud	Inf	Bfd	Fru
1	0.34 a	11.8 a	4.28	0.4 ab	0.02 b	0.08	0.08 a
2	0.28 b	7.67 b	4.48	0.3 bc	0.02 b	0.03	0.04 b
3	0.28 b	6.75 b	4.19	0.5 a	0.05 a	0.07	0.04 b
4	0.27 b	6.72 b	4.28	0.26 bc	0.02 b	0.05	0.05 ab
5	0.27 b	7.09 b	4.37	0.2 c	0.01 b	0.04	0.03 b

Treat= different pruning percentages; Bud= flower buds; Inf= inflorescences; Fru= fruits; Bfb= brown fruit buds; Sho= shoots; Dia= diameter of vegetative shoots; Len= length of vegetative shoots. Means with a common letter in columns are not significantly different ($p \leq 0.05$).

According to Pérez *et al*. (2016), obtaining flushes with a larger diameter favors the outer branches to be strengthened and have a greater load-bearing capacity. In turn, it will intervene in the number of leaves that can develop, increasing the biomass of the tree, providing greater sunlight capture and photosynthetic capacity. In addition, Rebolledo *et al*. (2009) report that, by removing the apical part, regrowth of the thick branches is stimulated, therefore, resistance to high fruiting.

In cherimoya, with rejuvenation pruning, an average of 22.85 leaves was obtained in branches of indeterminate growth, with a leaf blade biometrics of 18.56 cm (Jaimes and De Vidal, 2014). Rani *et al*. (2018), with spring pruning in lemon (*Citrus limon* Burn.), recorded maximum lengths of 20.37 cm and 17.63 cm in new shoots in summer. For their part, Bhagawati *et al*. (2015), with severe pruning in guava (*Psidium guajava* L.), reported lengths of 32.81 cm.

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Number of vegetative shoots per m^2

There was no significant difference (*p*= 0.993) between treatments. An average of 4.32 shoots per m^2 was found (Table 2). In lemon, with summer pruning, Rani *et al*. (2018) registered 3.56 shoots. On the other hand, Thakre *et al*. (2016), with the manual removal of leaves and flower buds in guava, obtained a maximum of 93.31 new shoots and with light pruning, Bhagawati *et al*. (2015) obtained 7.1 shoots per pruned shoot. According to Pérez *et al*. (2016), with pruning, a greater number of shoots are obtained, helping to have an adequate flowering and fruit mooring.

Number of flower buds per m^2

In the appearance of flower buds, there is a highly significant difference (*p*= 0.001); treatment 3 (50% formation and health pruning), with 0.50 buds per m^2, was 60% better than treatment 5 (control with 0% pruning), with an average of 0.20 buds per m^2 (Table 2). With summer pruning in lemon, Rani *et al*. (2018) recorded 59.44 clusters of flower buds in the middle part of the treetop. According to Guzmán (1982), it is important to program the pruning period so that the number of flower buds increases and there is a greater flowering.

Number of inflorescences per m^2

In inflorescences, there is a significant difference (*p*= 0.001). Treatment 3 (50% formation and health pruning) registered 0.05 inflorescences per m^2, being 80% better than treatment 5 (control with 0% pruning), with an average of 0.01 inflorescences per m^2 (Table 2). According to Pérez *et al*. (2016), health pruning, in addition to maintaining the health of the tree, also leads to an increase in its biomass, leading to greater sunlight capture and photosynthetic activity.

With this, more energy is captured to benefit metabolic processes that are transformed into flowers and fruits; Basto *et al*. (2018) recorded up to 16 flowers with progressive reductions in treatments without crown pruning and with the application of growth inducers, whereas in treatments with crown pruning and application of inducers, an average of 14 flowers was recorded.

Number of brown fruit buds per m^2

For brown fruit buds, there is no significant difference between treatments (*p*= 0.103), with an average of 0.54 brown fruit buds per m^2. Treatment 1 (100% formation and health pruning) registered the highest number of brown fruit buds, 0.08 per m^2, whereas treatment 2 (75% formation and health pruning), with 0.03 brown fruit buds per m^2, was the one with the lowest number (Table 2).

Number of fruits per m^2

For fruits per m^2, there is no highly significant difference (*p*= 0.01) between treatments. In the appearance of fruits per m^2, treatment 1 (100% formation and health pruning) registered an average of 0.08, whereas treatment 5 (control with 0% pruning) had 0.03 fruits per m^2 (Table 2). Rani *et al*. (2018), with summer pruning and paclobutrazol in lemon, cite yields of 27.87 kg tree^{-1}. For their part, Thakre *et al*. (2016), in guava with pruning of a couple of leaves of fruited shoots, reported maximum yields of 55.3 kg tree^{-1}.

In peach trees with green pruning (removal of suckers), quality fruits have been obtained since, with pruning, it is possible that the maximum photoassimilates goes to the fruit and not to the shoots in active growth (Ojer *et al*., 2006). Asrey *et al*. (2013), on the other hand, mentions that in pruned mango fruits, a slower ripening and lower respiration, ethylene rate and enzymatic activity were observed.

Number of shoots per linear meter in primary and secondary branches

In primary branches, there was no significant difference (*p*= 0.808); on average, 1.82 shoots per linear m were recorded (Table 3). In secondary branches (*p*= 0.021), treatment 1 (100% formation

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and health pruning) presented 1.98 shoots per linear m, with a 42.42% higher incidence of shoots compared to treatment 5 (control with 0% pruning), with an average of 1.14 shoots per linear meter (Table 4). In ilama (*Annona diversifolia* Saff.) with pruning and defoliation, Otero *et al*. (2006) recorded 140.8 shoots per tree, registering the highest appearance of shoots in June.

Table 3. Flower buds, inflorescences, fruits, brown fruit buds, and shoots per linear meter in primary branches.

Treat	Variables assessed (linear meter in primary branches)				
	Shot	Bud	Inf	Bfb	Fru
1	2.53	0.62	0.1	0.12	0.05
2	1.86	0.91	0.05	0.13	0.12
3	1.73	0.78	0.09	0.11	0.08
4	1.61	0.73	0.08	0.14	0.12
5	1.37	1.21	0.15	0.08	0.12

Treat= different pruning percentages; Sho= shoots; Bud= flower buds; Inf= inflorescences; Bfb= brown fruit buds; Fru= fruits. Means with a common letter in columns are not significantly different ($p \leq 0.05$).

Table 4. Flower buds, inflorescences, fruits, brown fruit buds and shoots per linear meter on secondary branches.

Trat	Variables assessed (linear meter in secondary branches)				
	Sho	Bud	Inf	Bfb	Fru
1	1.98 [a]	0.37	0.05	0.09	0.13
2	1.17 [b]	0.35	0.05	0.12	0.06
3	1.28 [b]	0.53	0.06	0.17	0.12
4	1.28 [b]	0.41	0.05	0.14	0.09
5	1.14 [b]	0.38	0.04	0.13	0.06

Treat= different pruning percentages; Bud= flower buds; Sho= shoots; Inf= inflorescences; Bfb= brown fruit buds; Fru= fruits. Means with a common letter in columns are not significantly different ($p \leq 0.05$).

Works such as that of Parés *et al*. (2005) mention that, in soursop, the formation of shoots increases gradually after pruning, and may be of less intensity in secondary branches. In cherimoya (*Annona cherimola* M.), Jaimes and De Vidal (2014), with rejuvenation pruning, achieved the differentiation of vegetative and flower buds at 8.97 days and 11.67 days with mixed pruning.

Number of flower buds per linear meter in primary and secondary branches

In primary branches, there were no significant differences (p= 0.34); on average, 0.85 flower buds per linear meter were recorded (Table 3). In secondary branches (p= 0.134), an average of 0.4 flower buds per linear meter was recorded (Table 4).

Number of inflorescences per linear meter

There were no significant differences in primary branches (p= 0.505); there was an average of 0.094 inflorescences per linear meter (Table 3). In secondary branches (p= 0.836), 0.05 inflorescences per linear meter was recorded on average (Table 4). Otero *et al*. (2006), with pruning and irrigation, recorded 21.5 flowers per branch in ilama (*Annona cherimola* M.), a situation that is explained by the importance of water availability in vegetative and reproductive growth, during flower formation, a critical phase in ilama and other Annonaceae (George and Nissen, 1987; George *et al*., 1990).

The findings by Jaimes and De Vida (2014) with rejuvenation, mixed, and fruiting pruning showed a flowering of 93.3%, 66.7% and 60%, respectively, in cherimoya trees (*Annona cherimola* M.). With pruning and irrigation, Otero *et al*. (2006) recorded 21.5 flowers per branch in ilama (*Annona*

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cherimola M.), a situation that was explained due to the importance of water availability in vegetative and reproductive growth, during flower formation, a critical phase in ilama and other Annonaceae (George and Nissen, 1987; George *et al*., 1990). Jaimes and De Vida (2014), with rejuvenation, mixed, and fruiting pruning, achieved a flowering of 93.3%, 66.7% and 60%, respectively, in cherimoya (*Annona cherimola* M.).

Number of brown fruit buds per linear meter in primary and secondary branches

In primary branches, there is no significant difference (*p*= 0.951); on average, 0.11 brown fruit buds per linear meter were recorded (Table 3). Likewise, in secondary branches, there is no significant difference (*p*= 0.256), with an average of 0.13 brown fruit buds per linear meter (Table 4). In cherimoya (*Annona cherimola* M.), Jaimes and De Vidal (2014), with rejuvenation, mixed, and fruiting pruning, recorded 6.47, 5.27, 5.17 active meristems and 3.6, 3.37, 2.11 latent meristems, respectively.

Number of fruits per linear meter in primary and secondary branches

In primary branches, there was no significant difference (*p*= 0.895); on average, 0.098 fruits per linear meter were recorded (Table 3). In secondary branches (*p*= 0.125), an average of 0.09 fruits per linear meter was recorded (Table 4). Reyes *et al*. (2018), with the use of pruning in plantations with high density (2 222 plants ha^{-1}), reported an average production of 28.42 t ha^{-1}, compared to the yield of a traditional plantation, it was 566% higher.

In cherimoya, Jaimes and De Vidal (2014) mention that, with the use of rejuvenation and mixed pruning, 66.7% and 43.3% of fruiting were achieved in the trees, respectively. In ilama, Otero *et al*. (2006) recorded 8.5 fruits tree^{-1}, with an average yield of 4.987 kg tree^{-1}; they also mention that it is important that there is water availability during pruning. In guava, they cite a yield of 11.66 kg tree^{-1} and 18 t ha^{-1} with severe pruning, 9.6 kg tree^{-1} and 15.31 t ha^{-1} with light pruning, and 8.7 kg tree^{-1} and 13 t ha^{-1} with moderate pruning. Asrey *et al*. (2013) cite that, in fruits of pruned mangos, anthracnose and rot of the peduncle decreased.

Conclusions

The application of 100% formation and health pruning favors the development of the diameter (0.34 cm) and length (11.8 cm) of vegetative shoots, as well as a greater appearance of fruits (0.08) per m^2. Pruning can increase the appearance of inflorescences and flower buds on primary and secondary branches, modifying the flowering and fruiting site, which increases the load-bearing capacity. A penological event that favors flowering and production peaks in soursop orchards.

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Flower and vegetative stimulation of soursop with summer pruning

Journal Information
Journal ID (publisher-id): remexca
Title: Revista mexicana de ciencias agrícolas
Abbreviated Title: Rev. Mex. Cienc. Agríc
ISSN (print): 2007-0934
Publisher: Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias

Article/Issue Information
Date received: 01 November 2024
Date accepted: 01 February 2025
Publication date: 27 February 2025
Publication date: Jan-Feb 2025
Volume: 16
Issue: 1
Electronic Location Identifier: e3301
DOI: 10.29312/remexca.v16i1.3301

Categories

Subject: Articles

Keywords:

Keywords:

intensity

production

technology

Counts

Figures: 0

Tables: 4

Equations: 0

References: 27

Pages: 0