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Article

Pruning modifies vegetative shooting and flowering process in 'Ataulfo' mango

María Verónica Santos-Cárdenas[1]
María Hilda Pérez-Barraza[2,§]
Gelacio Alejo-Santiago[1]
Circe Aidin Aburto-González[1]
Beatriz Guillermina Arrieta-Ramos[1]

1 Maestría en Ciencias Biológico-Agropecuarias-Universidad Autónoma de Nayarit. Carretera Tepic-Compostela km 9, Xalisco, Nayarit, México. CP. 63780. Tel. 311 2112478. (verosantos676@gmail.com; gelacioalejo@hotmail.com; Beatriz-arrieta@uan.edu.mx; circe.aburto@uan.edu.mx).

2 Campo Experimental Santiago Ixcuintla-INIFAP. Carretera Internacional México-Nogales km 6, Entronque a Santiago Ixcuintla, Nayarit, México. CP. 63300. Tel. 55 38718700, ext. 84416.

Autora para correspondencia: perez.mariahilda@inifap.gob.mx

Abstract

Pruning trees improves light penetration, optimizes production and photoassimilation, and allows harvesting out of season without affecting fruit quality. The objective was to evaluate the effect of the pruning time (T) and intensity (I) on the differentiation and flowering process. Three pruning times: early, intermediate, and late, with two intensities: 50 and 75 cm of trimming, plus an unpruned control were evaluated in a commercial orchard in Santiago Ixcuintla, Nayarit, during 2019-2020 and 2020-2021. The experimental design was completely randomized with a 3*2 factorial arrangement. The variables evaluated were number and length of shoots, bud development stage, percentage of differentiated bud, flowering percentage, and days of flowering delay. The results indicated that, in both cycles, there was a significant effect due to the intensity and time of pruning and due to the T*I interaction on some variables. It is concluded that severe pruning, in the two cycles, regardless of the time, increases the number of shoots per pruned branch by more than 100% compared to the control; in contrast, early pruning in its two intensities increased the number of differentiated buds in both cycles, which led to greater flowering; however, with late and severe pruning, this variable drastically decreased, with percentages between 8 and 19% in the first and second cycles, respectively.

Keywords:

Mangifera indica L., anthesis, flower differentiation, vegetative shoots.

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Introduction

Mango (*Mangifera indica* L.) is one of the three most important tropical fruits in Mexico, with a production of 2.18 million tons in an area of 206 000 ha and an average yield of 10.7 t ha^{-1} (SIAP, 2021). In Nayarit, it is the main crop within the fruit crops with an area of 28 329 ha; the production volume exceeds 322 000 t and the average yield is 12 t ha^{-1} (SIAP, 2021).

In Mexico, most mango producing areas are located in tropical regions, which have favorable conditions for the development of tall trees with excessive vegetative growth. Under these conditions, it is essential to prune to control the size of the trees at a height that allows the plantation to be efficiently managed, maintain the productivity of the orchard and improve the quality of the fruit (Pérez, 2015).

One of the main problems in the crop is the susceptibility of mango varieties to climatic variability; flower differentiation is stimulated by cool temperatures (20/18-15 °C; day/night), which results in abundant flowering but causes concentration of harvest and low price of the product in the market. On the other hand, warm autumns (>30/>20 °C; day/night) impair flower differentiation, leading to irregular flowering (Pérez, 2015).

It has been found that production pruning that is carried out after harvest, in addition to reducing the crown of the tree, helps to standardize flowering (Carvalho *et al*., 2021). There are reports that show that pruning improves light penetration, optimizes the production of photoassimilates, and allows harvesting out of season, without affecting fruit quality (Sarkhosh *et al*., 2018).

Light pruning carried out in the period of natural flower induction favors the emission of shoots in axillary buds of pruned branches as a result of the breaking of apical dominance due to pruning carried out (Galán, 2017).

Based on the above, this research aimed to evaluate the effect of pruning on the process of flower differentiation and flowering in order to avoid irregular flowering and modify flowering in the assumption that the time or intensity with which it is carried out influences these processes towards an increase, delay or even inhibition.

Materials and methods

This work was carried out in the municipality of Santiago Ixcuintla, Nayarit, during two production cycles (2020-2021 and 2021-2022). It has a warm subhumid climate (AW1) and an altitude of 25 m. A commercial orchard of mangoes of the Ataulfo cultivar grafted on regional landrace rootstock was used; the age of the trees was 20 years, established at a planting distance of 8 x 8 m for a planting density of 156 trees ha^{-1}. In this orchard, trees of uniform vigor were chosen.

The management of the orchard consisted of a soil fertilization of 2 kg $tree^{-1}$ of phosphonitrate (31-04-00) in July. To prevent diseases, applications of copper octanoate 1.5 L ha^{-1} (three applications) were made. Regarding pests, the protocol for the control of the fruit fly of the program of the State Committee of Plant Health was followed.

Treatments. Two pruning intensities were evaluated: light pruning, cut 50 cm in length from the apex of the terminal shoot towards the center of the tree, and severe pruning, cut of 75 cm. Each type of pruning was carried out in three periods. Early pruning was applied immediately after harvest (July 5 in the first cycle and July 7 in the second cycle), intermediate pruning two months after the first pruning, and late pruning, two months after the second pruning. Unpruned trees were used as a control.

Experimental design

The experimental design was completely randomized with a 3 x 2 factorial arrangement. Factor 1 refers to the pruning time with three levels (early, intermediate, and late) and factor 2 corresponds to the pruning intensity with two levels: light and severe (50 cm and 75 cm trimming, respectively).

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Their combination gives a total of six treatments plus the control without pruning, all with six replications and a tree as an experimental unit.

Response variables

Number and length of shoots. Four pruned branches were labeled in the middle part of the tree, one for each cardinal point; once the branch stopped producing the vegetative shoots after pruning, these were counted. When the shoots matured, 30-45 days after early and intermediate pruning, the length of each emitted flush (two flushes) was measured with a tape measure; in late pruning, it was measured 60 days after pruning.

Bud development. The development of the flower bud was recorded from vegetative bud to reproductive bud and later to anthesis using the scale proposed by Pérez *et al*. (2009). Where: stage 1 (S1) corresponds to the vegetative bud and stage 12 (S12) to anthesis. The record was carried out every eight days from mid-October and from December, the record was kept every five days until flowering. Percentage of differentiated bud. It was evaluated by considering the number of buds that reached stage 4 (S4) divided by the total sampled.

Flowering delay (FD). For this variable, the days from the last pruning date until the tree entered full flowering were counted and then the days in which the control reached this stage were subtracted, with the following formula: FD (days)= (dlp- dff)-dffc). Where: FD= flowering delay expressed in days; dlp= date of last pruning; dff= date of full flowering of treatments; and dffc= days elapsed to full flowering in the control.

Flowering percentage (FP). To evaluate this variable, in each experimental unit (tree), the crown was divided into two sections, front and dorsal, in the direction of the rows in the orchard. On both sides, the proportion of inflorescences covering each side of the tree was estimated weekly from the beginning (5%) to full flowering (between 80 and 100%) or anthesis; 100% was considered in each section and then divided by two using the following formula: FP= (% of flowering in frontal area + % of flowering in dorsal area)/2.

Analysis of results

An analysis of variance and means test by Tukey ($p \leq 0.05$) were performed. The statistical analysis system (SAS, 9.3) program and multiple comparisons of means of Tukey's test (*p*# 0.05) were used.

Results and discussion

The results of the first evaluation cycle in the analysis of variance showed that there was an effect of the pruning time factor on the variables studied, except for the percentage of flowering ($p= 0.0712$); similarly, the intensity of pruning influenced most of the variables, except for the length of shoot ($p= 0.2441$). Regarding the Time*Intensity (T*I) interaction, an effect was found on the variables of bud development (0.001) and flowering delay ($p= 0.0031$). In the second production cycle (2021-2022), the variables were affected by pruning time, except for shoot length ($p= 0.894$), and by intensity and T*I interaction, except for flowering delay ($p= 0.1851$) in the latter.

Number and length of shoots

In the first cycle, regardless of the factors, the number of shoots was higher in all treatments compared to the control (between three and five shoots per pruned branch, compared to two in the control) (Figure 1). The most notable effect was observed with severe pruning regardless of the time; but the T*I interaction had a higher number than the rest of the treatments with almost 6 shoots branch^{-1}.

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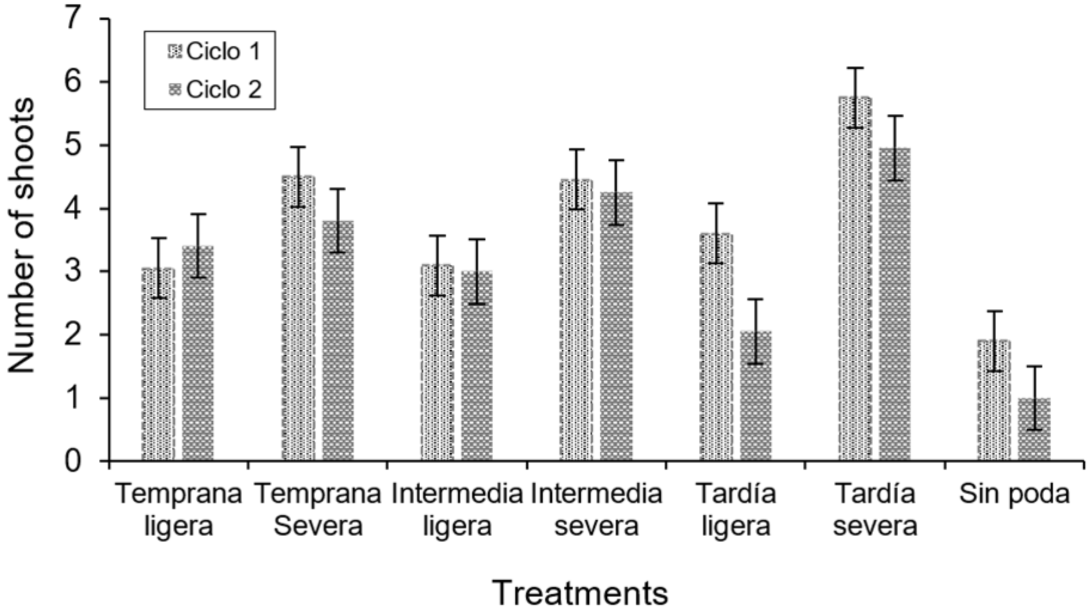
Figure 1. Number of vegetative shoots in 'Ataulfo' mangoes because of pruning intensity and time in two production cycles. Santiago Ixcuintla, Nayarit, 2022. The bars in the columns represent the average of 24 shoots per treatment ± the standard error.



In the second productive cycle, the emission of vegetative shoots was higher in trees with severe pruning regardless of the time; statistically, there were no differences between these treatments. Light pruning in all three times promoted the emergence of vegetative shoots in smaller numbers compared to severe pruning, but this was superior when compared to the control that only produced a shoot in the apical bud.

According to Persello *et al*. (2019), the increase in the number of shoots per pruned branch is due to the fact that pruning breaks the apical dominance. The breakdown of dominance results in the reduction of the auxin content in the branches and an increase in the content of gibberellins (Rademacher, 2015). On the other hand, in Litchi cv. Brewster, it is due to nutrient redistribution (Aburto *et al*., 2017).

Shoot length (Figure 2), in the first evaluation cycle, early and intermediate pruning were statistically equal in any of their intensities, similar to the control. The longest shoots were obtained with severe late pruning, with 25 cm. In the second productive cycle, high values were achieved when pruning was severe in the early and intermediate times, to such an extent that they equalized the size of the shoots of the control trees. In the rest of the treatments, there were no statistically significant differences and it varied between 23 and 26 cm.

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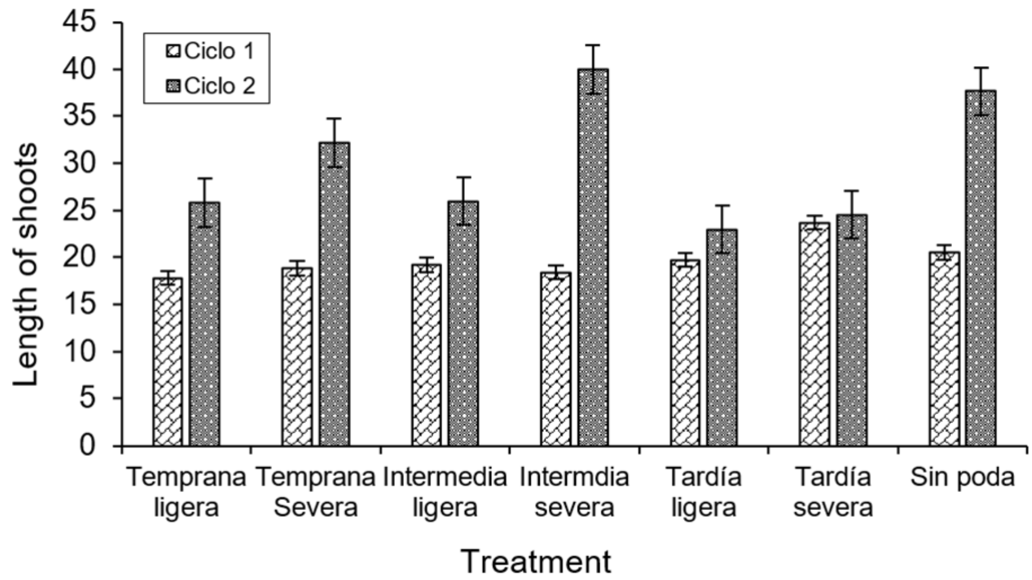
Figure 2. Length of shoots in 'Ataulfo' mango trees due to the effect of pruning intensity and time in two production cycles. Santiago Ixcuintla, Nayarit, 2022. The bars in the columns represent the average of 24 shoots per treatment ± the standard error.



In this study, the longest shoots were obtained with severe pruning regardless of the time; in this regard, Taiz *et al*. (2017); Tiwari *et al*. (2018) mention that severe pruning stimulates the production of higher-growth shoots by the supply of carbohydrates. This coincides with what was pointed out by Solanki *et al*. (2016) because pruning improves light penetration. In mangoes of the Palmar cultivar, a longer shoot length was found at 30 days after pruning and, although the intensity of pruning is not mentioned, the results are attributed to a high concentration of carbohydrates recorded in these growths (Cavalcante *et al*., 2020).

Bud development stage

The results in the first evaluation cycle showed that early pruning, both light and severe, advanced the state of bud differentiation (between 6.5 and almost 8). With intermediate pruning, the buds developed up to stage 3 in both trimmings (50 and 75 cm), whereas with late pruning in November, the buds did not develop and remained in a stage between 1 and 1.5 regardless of the intensity of pruning. The trees without pruning were in stage 7 (Figure 3).

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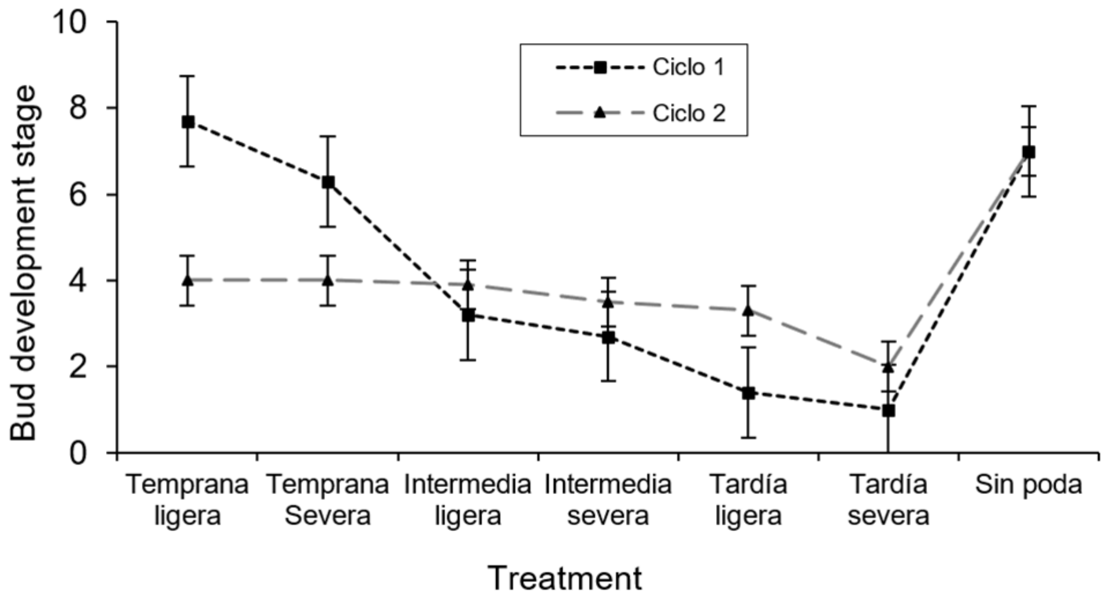
Figure 3. Bud development stage in 'Ataulfo' mango trees because of pruning intensity and time. Santiago Ixcuintla, Nayarit, 2022. The bars in the columns represent the average of 24 apical buds per treatment ± the standard error.



Flower induction in buds is stimulated by low nighttime temperatures below 20 °C (Pérez *et al*., 2018). Surely, the stage of bud development in the shoots derived from early pruning and the control was induced to differentiation by this type of temperature.

In the second production cycle, the buds of shoots with early and intermediate pruning, regardless of their intensity, developed up to stage 4; that is, they had differentiated buds, whereas those with late pruning remained vegetative (stage 1). In trees without pruning, an advanced stage of differentiation (stage 7) was achieved.

With the results obtained, it is inferred that, with early and intermediate pruning, the emission of flower shoots is favored, which agrees with Galán (2017), where he reports that the emission of shoots may be due to the effect of pruning at a time when the factors that favor flower induction and differentiation are present.

In the present study, the vegetative shoots of early pruning matured approximately between mid and late August, which allows them to have the physiological maturity to be stimulated or induced to flower at temperatures > 20 °C (nighttime) that occur from October to November (Pérez *et al*., 2018), whereas with intermediate pruning, physiological maturity is reached at the end of October and they can be induced with temperatures below 20 °C during autumn; nevertheless, the shoots that result from late pruning are in a condition to flower as long as there are cool temperatures in January and February.

Percentage of differentiated bud

In relation to the percentage of buds that differentiated themselves in the first evaluation cycle, averages between 5 and 75% were achieved, but the highest percentage was obtained with light and early pruning (75%); being statistically equal to the percentage achieved with severe pruning at the same time (55%) and the control (65%); treatments with late pruning presented few or no differentiated buds (Table 1).

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Table 1. Percentage of differentiated buds in response to pruning intensity and time in two productive years.

Time	Intensity (cm)[1]	Differentiated buds (%)	
		Cycle 1	Cycle 2
Early	Light	75 a	100 a
Early	Severe	55 abc	100 a
Intermediate	Light	20 bcd	93.8 a
Intermediate	Severe	15 bcd	50 bc
Late	Light	5 dc	60 ab
Late	Severe	0 d	10 c
Without pruning	Without pruning	65 ab	100 a
CV		78.1	28.16
LHSD		3.49	3.49

Light= 50 cm trimming from the apex of the shoot towards the center of the tree; severe= 75 cm trimming; CV= coefficient of variation; LHSD= least honest significant difference. Means with the same letters are not statistically different (Tukey, p= 0.05).

Regarding the percentage of differentiated buds in the second evaluation cycle, this varied from 10 to 100%. Again, the trees pruned in the early time, regardless of the intensity, achieved the highest percentage; they were statistically equal to the control and to the treatments with intermediate and late light pruning. In the last year of evaluation, late pruning showed values between 10 and 60% of differentiated buds.

Table 1 shows that the percentage of differentiated buds; in general, was higher than in the first cycle. McConchie (2018) mentioned that, in late pruning in mangoes of the Honey Gold and B74 cultivars, there was no differentiation because the vegetative shoots stimulated at that time of pruning did not coincide with cold temperatures below 20 °C; on the contrary, in this study, there was differentiation, although in a lower percentage compared to early and intermediate pruning.

In this study, the presence of inductive temperatures was probably lower in shoots with late pruning compared to those obtained with early and intermediate pruning; however, the temperature condition was not studied in the present work, suggesting that they should be included in future studies.

Delayed flowering

In the first evaluation cycle, all pruning treatments, regardless of the time and intensity, delayed flowering in relation to the control. With intermediate pruning, a delay of 34 and 31 days in flowering was observed with light and severe pruning, respectively, but the greatest delay was obtained with late light pruning (52 days delay). There were similar results in the second cycle, where the delay varied between 14 and 29 days. Early pruning treatments delayed flowering by 14 to 18 days, whereas late light pruning delayed it by 29 days as did the treatment with severe intermediate pruning (Figure 4).

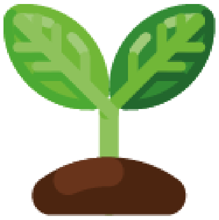

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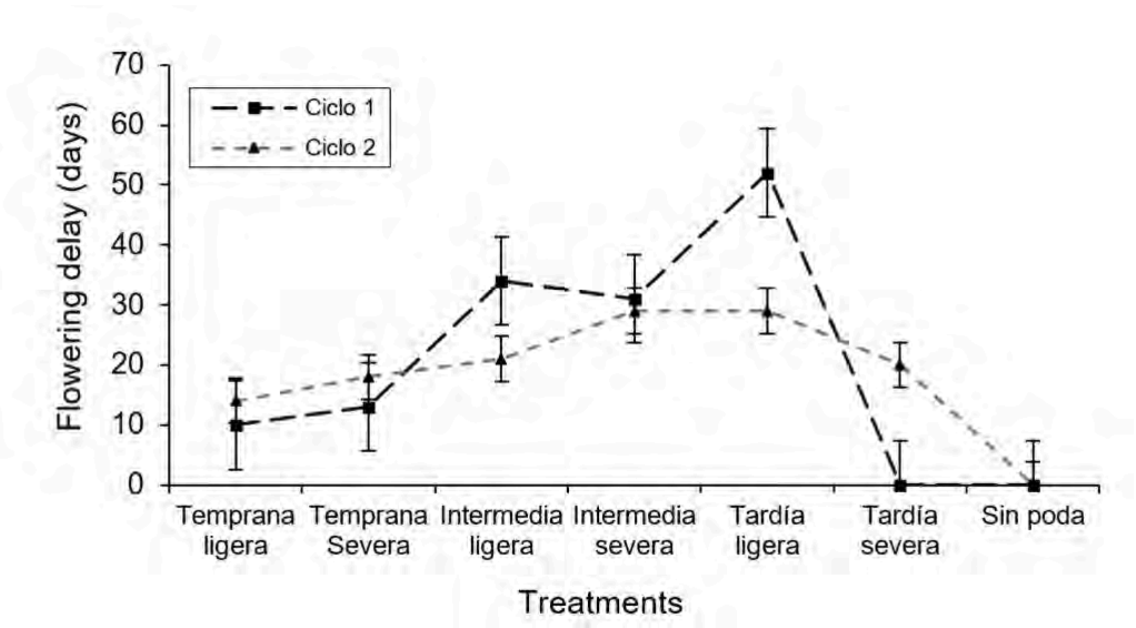
Figure 4. Days of delay in flowering in 'Ataulfo' mango trees because of early, intermediate, and late pruning. Santiago Ixcuintla, Nayarit, 2022. The bars in the columns represent the average of six trees per treatment± the standard error.



Flowering percentage

In the first cycle, it was observed that the percentage of flowering tends to decrease according to the pruning time; the later the pruning is carried out, the lower the incidence of flowering. Flowering decreased dramatically with late pruning, by 17% with light pruning and by 8% with severe pruning. Similar results were found in the second cycle, with flowering percentages between 19 and 99%. The highest value was obtained in trees without pruning and in those pruned in the early stage, both statistically equal to the percentage with light intermediate pruning. Again, late and severe pruning reduced flowering by up to 19% (Figure 5).

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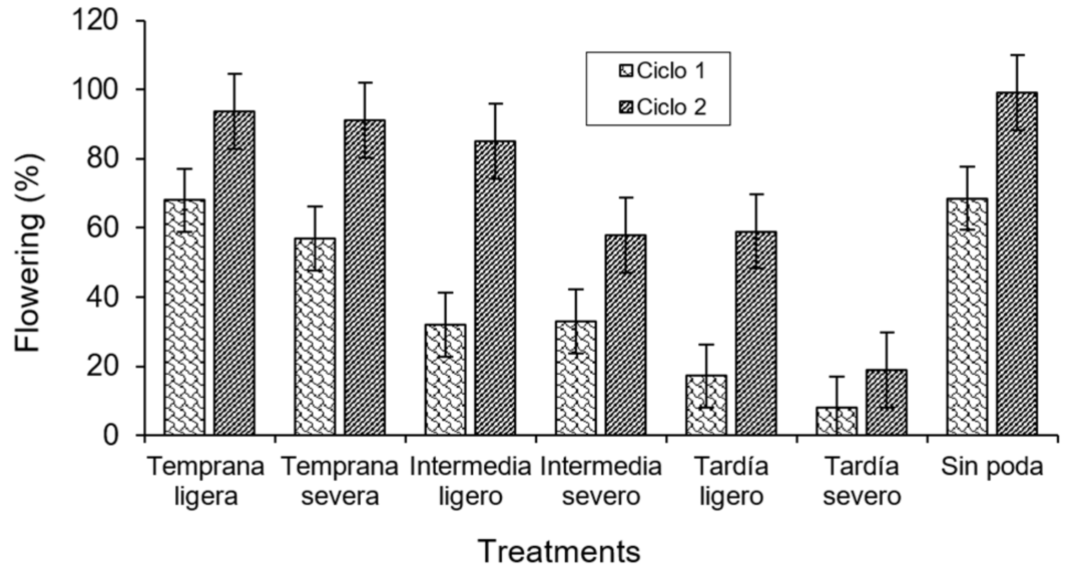
Figure 5. Flowering percentage in 'Ataulfo' mango trees and their pruning effects in two flowering cycles. Santiago Ixcuintla, Nayarit, 2022. The bars in the columns represent the average of six trees per treatment ± the standard error.



The results obtained in the first production cycle evaluated indicate that if pruning is carried out lightly, the flowering percentage of the trees is not affected; nevertheless, if pruning is done intensively, flowering is reduced by up to 40%, which can be negative for fruit production. In both evaluation cycles, flowering was affected by late severe pruning, as flowering was only 8 and 19% in the first and second cycles, respectively.

The results are similar to those reported by Vázquez *et al*. (2009), who report that pruning of 100 cm presented the lowest percentage of flowering. Davenport (2006) points out that the flowering of these shoots with severe pruning only occurs if favorable temperature conditions for flowering are present once they have reached maturity.

Conclusions

Regardless of the time and intensity, pruning increases the number of shoots per pruned branch, mainly with severe pruning, which also gives rise to longer shoots. Flower differentiation and flowering density were favored by early pruning regardless of severity, as well as by intermediate and light pruning, avoiding irregular flowering. Flower differentiation and shooting is negatively affected with late and light pruning, but with late and severe pruning, it was drastically reduced and could even be inhibited.

The delay in the differentiation of the bud and therefore flowering depends on the time and intensity of pruning, so it is recommended to trim in the early and intermediate times and with light intensity because the intermediate and late pruning in their severe intensity and late light pruning affect the flowering process and can inhibit it. Future studies should focus on the interaction between late times with their two intensities and the use of gibberellin inhibitors that ensure delayed flowering, which would benefit producers economically.

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