FINAL REPORT

PROJECT

DEVELOPMENT AND VALIDATION OF TECHNIQUES TO MODIFY THE PRODUCTION OF PARTHENOCARPIC FRUITS IN ATAULFO MANGO IN THE STATES OF NAYARIT, CHIAPAS AND GUERRERO



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Title: Development and validation of techniques to modify the production of parthenocarpic fruits in Ataulfo mango in the states of Nayarit, Chiapas and Guerrero

Project Period

Start: 1st. May 2107 **Term: July 31, 2019**

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General objective

Increase productivity and improve the quality of the 'Ataulfo' mango fruit, by studying and validating techniques related to growth regulators in flowering, fruit-set and development of the 'Ataulfo' mango fruit in Nayarit, Chiapas and Guerrero. As well as to validate the mathematical model under other environmental conditions in order to design adaptation strategies to face future climate variability.

Particular objectives

1. Determine the impact of climate vulnerability on the development of the inflorescence, as well as on the production of seedless fruits.
2. Validate a mathematical model based on meteorological conditions that relates to the development of inflorescence and the production of seedless fruits in 'Ataulfo' mango.
3. Evaluate and validate the effect of growth regulators and nutrition on the incidence and size of mango fruit 'Ataulfo'.

Activities performed

The study was carried out in commercial mango orchards in the states of Nayarit, Chiapas and Guerrero, with significant production of 'Ataulfo' mango and with a high presence of parthenocarpic fruits. For this, the following subprojects were executed.

Subproject 1. Validation of the mathematical model and its relationship with the development of inflorescence and the production of parthenocarpic fruits.

In each producing State (Nayarit, Guerrero and Chiapas), an 'Ataulfo' mango orchard with a high incidence (≥80%) of seedless fruits was selected. In each orchard 10 trees of uniform vigor were selected and in each of them 10 inflorescences emerged at the beginning of flowering and 10 in the second flowering (if present) distributed around the tree and in the middle part of the canopy were marked. In each inflorescence, the date and stage of development of the same were recorded considering the scale developed by Perez *et al*. (2009), where E3 is equal to bulky bud and E14 is fruit-set (fruits between 1 and 2 cm in length).

The climatic characterization of the producing areas was carried out with data from the National Meteorological Service. The monthly indicator used was the Climatological Standards (http://smn.cna.gob.mx/es/climatologia/informacion-climatologica). The selected stations were the closest to the site under study. Additionally, in order to relate the phenological data with the meteorology, a portable climate station (with temperature and relative humidity sensors) was installed in each orchard, which recorded data every hour from E-3 to E-14.

Mathematical models of floral development

Using the standard stepwise regression model in Minitab, models were generated for each temperature threshold (Minitab, 2019). The four criteria used to select the best model that described the relationship between the accumulation of days with temperatures below the threshold and floral development, were: a) Value close to 1 of R^2; b) Value close to zero of the mean square of the error; c) Near zero value of the Mallows CP and d) Near zero value of the variance.

Statistical analysis

The statistical analysis of the inflorescences development and incidence of parthenocarpic fruits data was carried out in the Minitab 17 program. The data on the status of the development of the inflorescences were grouped by sampling date and a cash chart was prepared by flowering and producing region. For the analysis of the incidence data of parthenocarpic fruits, the incidence data of normal and parthenocarpic fruits were grouped by inflorescence, floral flow and producing region, generating a box plot for each region.

Subproject 2. Studies on pollination, fertilization and fruit-set in 'Ataulfo' mango: Floral biology.

This work was carried out in Nayarit, in a commercial de 'Ataulfo' mango orchard with a high presence of parthenocarpic fruits (80% or more). In that orchard, doses of cytokinin (0 and 50 $mg \cdot L^{-1}$), and gibberellins (0 and 50 $mg \cdot L^{-1}$) were evaluated in single and combined applications at different phenological stages. Studies on pollinators, pheromones and embryo development were also carried out.

Experiment 1. Effect of thidiazuron (TDZ) and gibberellic acid in pollination (GA_3), fruit fertilization and fruit-set. Realized in 2018.

Applications of TDZ (50 mg L^{-1}) were made alone and combined with GA_3 with the same dose. The sprays were applied eight days before full flowering, in full bloom and fifteen days later, seeking the effect on cell division, as well as replacing and/or promote pollination and fertilization. The number of parthenocarpic and pollinated fruits was evaluated by inflorescence at the initial fruit-set (45 days after full flowering) and final (fruit close to harvest).

Experiment 2. In 2019, the following experiment was included in this same subproject: Studies on pollination, fertilization and fruit-set through pollinators and pheromones.

The work was carried out in commercial de 'Ataulfo' mango orchards with a high incidence of parthenocarpic fruits (80%). Two pollinators were used (Haden and Tommy Atkins) and a pheromone (Splat Bloom©) of the nasonov gland of worker bees that contains 10% Geranicol/CAS #106-24-1/3,7-Dimethyl- 2,6-octadien-1-ol/C10H80.

The procedure was as follows: In two locations, six orchards (three in each) of Ataulfo were selected. The orchards at Nanchi Station had been managed with paclobutrazol (PBZ)

Locality Nanchi Station in the municipality of Santiago Ixcuintla

Orchard 1. 'Ataulfo' close to 'Tommy Atkins' as a pollinator, with pheromone application on Ataulfo trees (Ataulfo + Pheromone + Tommy Atkins).

Orchard 2. 'Ataulfo' with pheromone application (Ataulfo + pheromone).

Huerto 3. 'Ataulfo' without pheromone, not close to Tommy Atkins (Ataulfo).

Locality La Cofradia in the municipality of San Blas

Orchard 1. 'Ataulfo' (with pheromone) interspersed with 'Haden' as a pollinator. A row of 'Haden' for three of 'Ataulfo'. (Ataulfo + Pheromone + Haden).

Orchard 2. 'Ataulfo' with pheromone application, without pollinator (Ataulfo + pheromone).

Orchard 3. 'Ataulfo' without pheromone and without pollinator, (Ataulfo).

When both Ataulfo and pollinator trees were in full bloom, the Splat Bloom pheromone was applied using a caulking gun and approximately 3 g were placed on three main branches of the 'Ataulfo' trees, except in the 'Ataulfo' orchard without pheromone.

Initial and final set of pollinated (POL) and parthenocarpic (PRT) fruits and tree yield (number of fruits/tree and kg of fruit/tree, both of POL and PRT fruits were evaluated.

Experiment 3. Embryo development. In the search for the causes of parthenocarpy in 'Ataulfo' mango or to define what damage or effect the extreme temperatures (<15 and/or >33 °C) had on the floral development or fruit growth, a study was conducted on embryo development.

In 10 selected trees, fruits with parthenocarpic appearance were sampled every 15 days from fruit set, set and fruit development when it reached 5 cm in length. In each sampling 20 fruits were collected, the seeds were extracted and placed in a FAA fixative (50% at 100% ethanol + 5% glacial acetic acid + 10% formaldehyde + 35% distilled water) for 8 days, then rinsed with ethanol at 50 and 70% (4 hours each) and placed in a GAA fixative (25% glycerol + 50% ethanol + 25% distilled water). Once in the laboratory its dehydration with ethanol, transparency with xylene and inclusion in paraffin was carried out and anatomical cuts were made in rotary microtome (8 micrometers), they were observed under a microscope to follow the development of the embryo in three stages of the development of the fruit 1) fruit-set, between 3 and 5 mm in length, 2) fruit-tie, between 1 and 2 cm in length and 3) fruits in development with a length between 4 and 5 cm.

Subproject 3. Validation of techniques generated to increase fruit-set and size of parthenocarpic fruits in Ataulfo mango.

In this subproject, the technologies generated in previous studies in 'Ataulfo' mango orchards with high incidence (80% or more) of parthenocarpic fruits in the states of Nayarit and Chiapas were validated.

Technology 1. TDZ + GA_3 4X applied at 15, 30, 45 and 60 DDF.

Four applications of TDZ mixed with GA_3 in doses of 50 mg L^{-1} each. The first application was made in fruit set (fruits with 3-5 mm in length) or fall of petals, approximately 15 days after full flowering (DAF), the second application 30 days DAF, third application at 45 days DPF and fourth application at 60 days DPF.

It was carried out in Nayarit during two years 2018 and 2019 in a commercial orchard of 'Ataulfo' mango of 15 years, established at 8 x 8 m between row and tree (156 trees/ha) and with an incidence of 80% of fruits parthenocarpic. The trees were under drip irrigation conditions.

Technology 2. TDZ 1X in full bloom and GA_3 4X at 15, 30, 45 and 60 days DPF.

One application of 50 mg L^{-1} of TDZ in full bloom and then three to four applications of 50 mg L^{-1} of GA_3 at 15, 30, 45 and 60 days DAF.

It was carried out in Nayarit in an 'Ataulfo' mango orchard with an incidence of 80% of parthenocarpic fruits. The trees were 8 years old, established at 6 x 4 m (416 trees/ha) and managed under conditions of drip irrigation. In both technologies, initial and final set of pollinated (POL) and parthenocarpic (PRT) fruits, the yield per tree (number of fruits/tree and kg of fruit/tree of POL and PRT fruits and fruit size were evaluated.

In Nayarit, a completely randomized design was used evaluating two treatments with 20 repetitions and a tree as a useful plot. Variance analysis of the results was performed and the Tukey test ($P \leq 0,05$) was used to compare means. The SAS version 9.2 program was used.

In Chiapas, the work was carried out in the "Las Andreas" orchard with more than 80% of parthenocarpic fruits and is located at Km. 11.5 of the Airport-Ciudad Hidalgo highway, in the municipality of Tapachula, Chiapas. The orchard has agronomic management (pruning, fertilization, sanitation, etc.) and irrigation. In this orchard the two technologies mentioned above were applied.

The application dates were as follows:

The First application, December 5, 2018 (Technology 2), in three applications, as well as for technology 1 (TDZ + AG_3) in four applications. Second application on December 20, 2018, third application on January 4, 2019 and fourth application on January 19, 2019

To observe the results of this validation, 25 trees of 30 were considered, to which the technologies were applied by sprinkling the foliage of the trees. Thus, there were two rows of 30 trees to which the corresponding treatment was applied. Each row was separated by a row without treatment, and the control row was two rows away from the target treatments.

In both technologies, the percentage of pollinated fruits (POL) and parthenocarpic fruits (PRT) was evaluated in physiological maturity, as well as their size in a sample of 100 fruits per technology.

The analysis of the evaluated variables was carried out by means of a univariate statistic and later by means of the randomized complete block design (RCBD) with three treatments and 4 repetitions (each repetition with a random sample of 25 fruits). The analysis revealed a highly significant difference, and on this basis, a separation of means was carried out by the strict Tukey method at 5% acceptance

Subproject 4. Effect of nutrition on the production of parthenocarpic fruits in 'Ataulfo' mango.

It was carried out in Nayarit (two experiments) and Guerrero (one experiment) in cultivating 'Ataulfo'. In Nayarit, orchards were selected with high incidence of parthenocarpic fruits or "mango niño" (80%) located in the municipality of Tepic (locality 5 de Mayo) and San Blas (Locality Cofradia and Las Palmas).

Experiment 1. Various treatments were applied, in full bloom and 15 days later depending on the combination of nutrients that favor pollination and fertilization. The treatments were as follows: T1, calcium + nitrogen; T2, boron; T3, calcium; T4, nitrogen + boron; T5, boron + calcium and T6, control (without application of nutrients). Calcium nitrate, foliar urea was used as a source of nitrogen and a soluble source of boron was the calcium source. All nutrients were applied at 1%, making two applications, one in full bloom and the other 15 days after full flowering (fruit-set; fruits between 4 and 5 mm in length).

The number of fruits retained in the initial set and retained until harvest (final set), the production considering the number of pollinated (POL) and parthenocarpic (PRT) fruits per tree and the kg of fruit were evaluated, the fruit size was also evaluated in terms of fresh weight, length and diameter.

A completely randomized design was used evaluating six treatments with 6 repetitions and a tree as a useful plot. Variance analysis of the results was performed and the Tukey test (P≤0,05) was used to compare means. The SAS version 9.2 program was used.

Experiment 2. Sustainable strategies of physio-nutritional replacement to increase fruit size in 'Ataulfo' mango pollinated and parthenocarpic.

Work was done on 'Ataulfo' mango with irrigation, clay soils and moderately high OM, in the town of 5 de Mayo and Cofradia, municipality of San Blas, in plantations 5 X 4 and 10 X 10 m, 5 and 20 years of age, neutral pH (7.1) and slightly acid. In 2019, the study was continued at the two sites, 5 de Mayo and Cofradia. In 2018, in the town of 5 de Mayo, the control (Tfi) was 2 kg per triple 17 tree in fruit-set. Tfi + four applications of mixed organic fertilizer (Om, identified as Balmix in 2019) were compared with: two applications (1 kg tree^{-1}) of solid Balmix from fruit-set + 15% Balmix leaching, biweekly application; + two leachate only applications. In Cofradia they do not fertilize (T = control). It was compared with a similar application of Balmix, increasing the solid to 2 kg tree^{-1}. Experimental unit: a tree, 12 repetitions in blocks. They were harvested by tree, intermediate part, by cardinal point: four fruits of pollinated or normal mango and eight of parthenocarpic. Weight (g), volume (cc) and SST (°Bx) were recorded.

In 2019, the study was continued on the 2018 sites: 5 de Mayo and Cofradia. In this year, the main modifications were that two more treatments were added and that the applications began a few days later, in advance of fruit-set. The treatments evaluated were:

T1 Balmix: 2 kg per tree of mixed organic fertilizer in solid state, one week after fruit-set) + leachate of mixed organic fertilizer (identified as Om in 2018, Balmix (B) in 2019) at 15%, four applications between fruit-set and fruit tie, in biweekly application.

T2 B + *A. nodosum*: T1 without solid Balmix + *Ascophyllum nodosum* (A. nod) algae extract as a biostimulant, in doses of 2 L ha^{-1}, mixed in Balmix applications. In the last two applications, Ca-B-Zn was added in doses of 1.5 L ha^{-1}

T3 Aminoac cR: Amino acid and nutrient complex in doses of 1.5 L ha^{-1}, three applications, one per fortnight, from match fruit.

T4 Control. At 5 de Mayo, the grower annually applies 2 kg of triple 17 per tree at the time of fruit-set, which was considered as a control treatment (Tfi). In Cofradia, it is not fertilized, which was considered as a control treatment.

The soil fertilizer was applied in 3 to 4 holes, approximately 1-1.5 m from the trunk. The sprays were made in a gentle breeze, covering the tree evenly to the point of runoff, by means of a motorized backpack pump. The experimental unit was a tree, 6 repetitions, selected in blocks. Previously, soil and leaf sampling were performed to diagnose soil and orchard conditions.

The variables evaluated were: Nutrient concentration in leaves and fruits (% and/or ppm), fruit-set, weight, volume and total soluble solids, yield (number and kg of fruits/tree).

The data of the variables under study were interpreted through on-site factor analysis (four treatments and two types of mango: normal and parthenocarpic) and between sites (two sites, four treatments and two types of mango) at $p \leq 0.05$. will be correlated, foliar concentration levels mainly with the type of mango: normal and parthenocarpic.

Statistical analysis

The data of the variables under study were interpreted by means of factor analysis: two sites (5 de Mayo and Cofradia), four treatments (three alternatives of fissionutricional replacement and one control), and two types of fruit (pollinated and pathenocarpic), with the corresponding mean tests $p \leq 0.05$.

Experiment 3. In Guerrero, the work was carried out in a commercial orchard of cv. Ataulfo with a high incidence of “mango niño” (parthenocarpic fruits) (> 80%), in the municipality of Atoyac, in the region of the Costa Grande. The treatments were: integrated management (MIM1), modified integrated management (MIM2) and the Control (the grower’s way). MIM1 included the application of water-soluble fertilizer of N, P, K and Mg with the formula 30-13-20-6 divided into two applications, prefloration and growth of fruit; dolomite (Ca 53% and Mg 44%) 500 kg ha^{-1}; foliar fertilizer, 2 L ha^{-1} of chelated boron micronutrient, with two applications; two sprays of 2% phosphonitrate during pre-flowering; Pest and disease management with seven applications of chemical fungicides and insecticides. MIM2 included the application of water-soluble fertilizer of N, P, K and Mg with the formula 30-13-20-6 divided into two applications, flowering and fruit-set; dolomite (Ca 53% and Mg 44%) 250 kg ha^{-1}; compost (bovine) 500 kg ha^{-1}; foliar fertilizer, 2 L ha^{-1} of chelated boron, with one application, as well as 2 L ha^{-1} of chelated micronutrients, with two sprays; two sprays of 2% phosphonitrate during pre-flowering; pest and disease management with seven applications of chemical fungicides and insecticides. Control was the usual management of the grower. The number and production (kg) of POL and PRT fruits per tree were evaluated, as well as the fruit size. Production was estimated at one hectare (ha).

An experimental design was used in randomized blocks, evaluating three treatments, with 10 repetitions for MIM1, MIM2 and Control. The useful plot was a tree. The data were subjected to analysis of variance and when the average of the treatments was with a significant F value ($P < 0.05$), the Tukey multiple comparison tests were performed using the SAS statistical analysis system (SAS, 2010).

Results

Subproject 1. Validation of the mathematical model and its relationship with the development of inflorescence and the production of parthenocarpic fruits.

This work was carried out in the states of Nayarit, Guerrero and Chiapas under the responsibility of M.C. Arturo Álvarez Bravo, the collaboration of Dr. Maria Hilda Pérez Barraza in Nayarit, Dr. David H. Noriega Cantú in Guerrero and Dr. Moisés Alonso Báez in Chiapas

Climatic characterization

A synthesis of the climate regions is as follows: The average monthly maximum temperature is presented in the absence of floral development (April-June). The minimum temperature is shown during January-March, being in Nayarit where it coincides during the floral development (in Guerrero and Chiapas this process has already concluded). Although the annual average temperature oscillation is only a couple of degrees between the three regions, however, the greatest contrasts occur in winter (<5 ºC average monthly temperature between Nayarit and the rest of the producing regions). Precipitation occurs mainly in summer (when there is no floral or fruit development) with very similar temporal values and distribution between regions. There are two contrasting climatic conditions (Nayarit and Guerrero - Chiapas) the difference lies mainly in the temperature during the period of floral development and winter.

Inflorescence development

In Nayarit the floral development of 'Ataulfo' mango presented two "flows". The first began in mid-December and concluded at the beginning of March (approximately 90 days), the second with an approximate duration of 70 days began at the end of January and ended at the beginning of April (Figures 1A and 2B). In the Guerrero producing region, only a "flow" of floral development was presented, which required approximately 20 days (from the beginning of October until the first week of November) (Figure 2). In Chiapas there were two flows, the first one began on December 13 until the end of January (45 days) and the second flow from mid-January to the first week of February (approximately 20 days) (Figure 3A and 3B).

In the three regions and in all the identified flows, it is observed how the first stages develop faster, particularly the separation, elongation and development of the secondary axes of future inflorescences. In contrast to the last stages of floral development (emergence and opening of flowers or antecedents) where the process is slower.

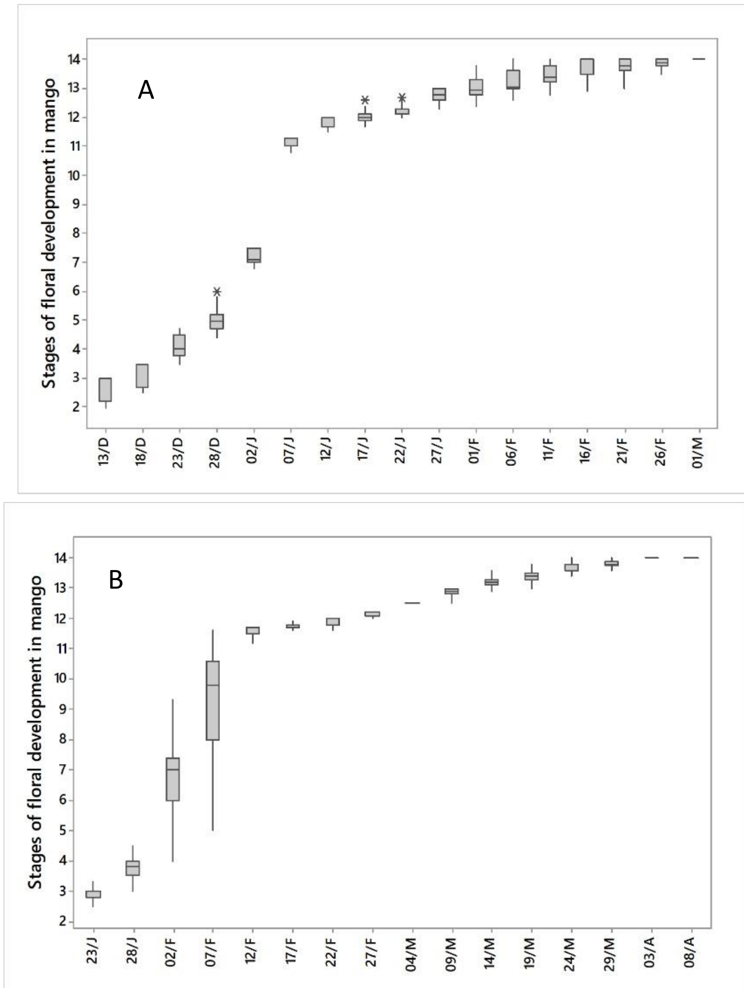

Figure 1. Floral development in Nayarit, a) first flow and b) second flow.

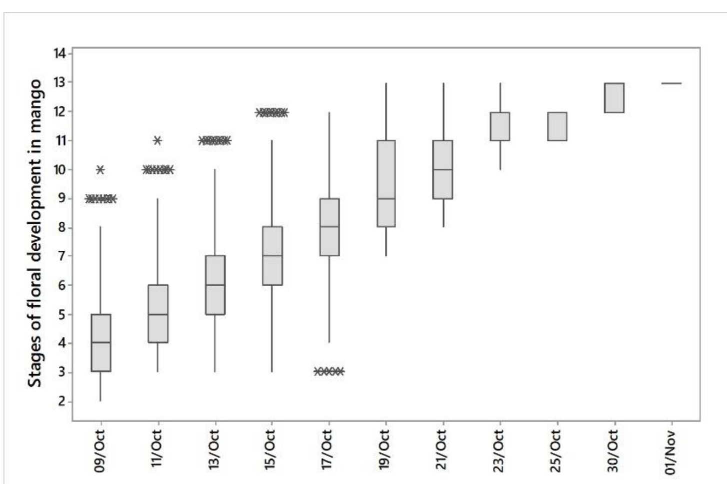

Figure 2. Floral development in Guerrero.

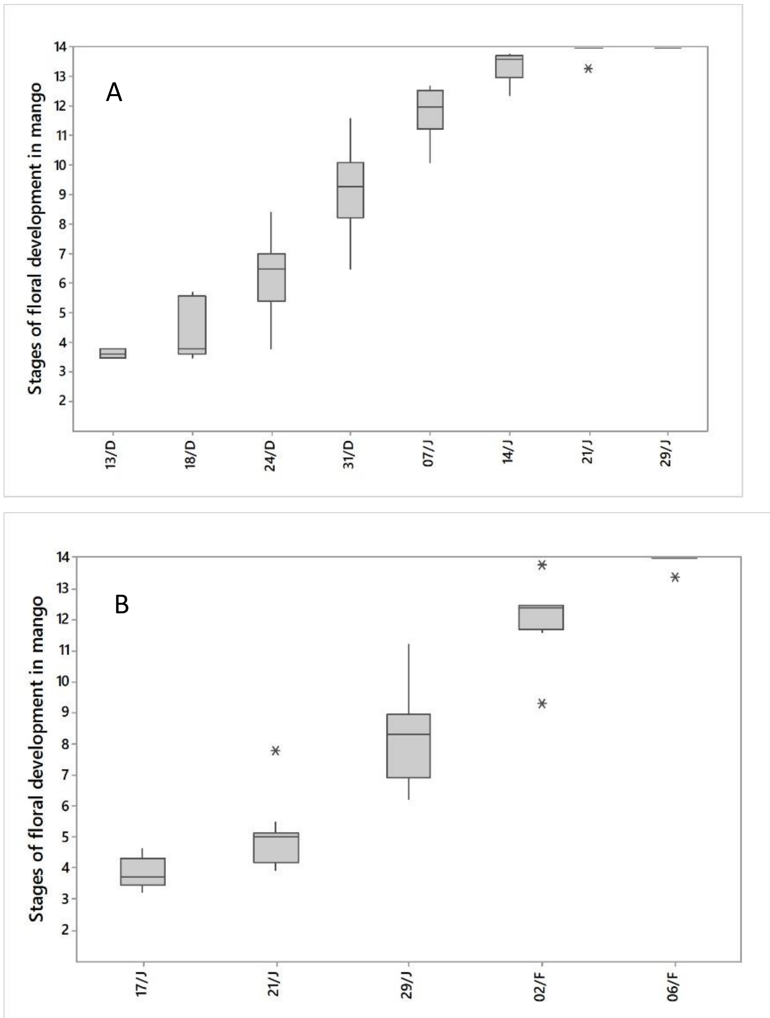

Figure 3. Floral development in Chiapas, a) first flow and b) second flow.

Mathematical models of floral development

Mathematical models based on the accumulation of cold days were generated. For Nayarit the minimum temperatures with the best ratio were ≤12 °C for the first "flow" and ≤15 °C for the second, while for Guerrero it was ≤24 °C. In Chiapas, the first flow was better related to a minimum temperature ≤23 °C and the second flow was ≤21 °C.

Nayarit's model for the first "flow" resulted in a third order polynomial $y=1.4251 + 0.736x + 0.0146x^2 - 1E\text{-}04x^3$ with an excellent fit (0.97) (Figure 4A). The second flow with a fit of 0.97 and a third order polynomial $y=1.6719 + 0.6211x + 0.0114x^2 - 7E\text{-}05x^3$ (Figure 4B). The resulting model for Guerrero presented an excellent fit (0.98) using a third order polynomial $y=3.3168 + 0.1246x - 0.0117x^2 + 0.0001x^3$ (Figure 5). Finally, the models for Chiapas $y=3.6738 + 0.0257x - 0.0341x^2 + 0.001x^3 - 9E\text{-}06x^4$ (adjustment of 0.94) as well as $y=3.9398+ 0.042x - 0.0431x^2 + 0.0009x^3$ (adjustment of 0.96) corresponding to the first and second flow respectively (Figure 6A and 6B).

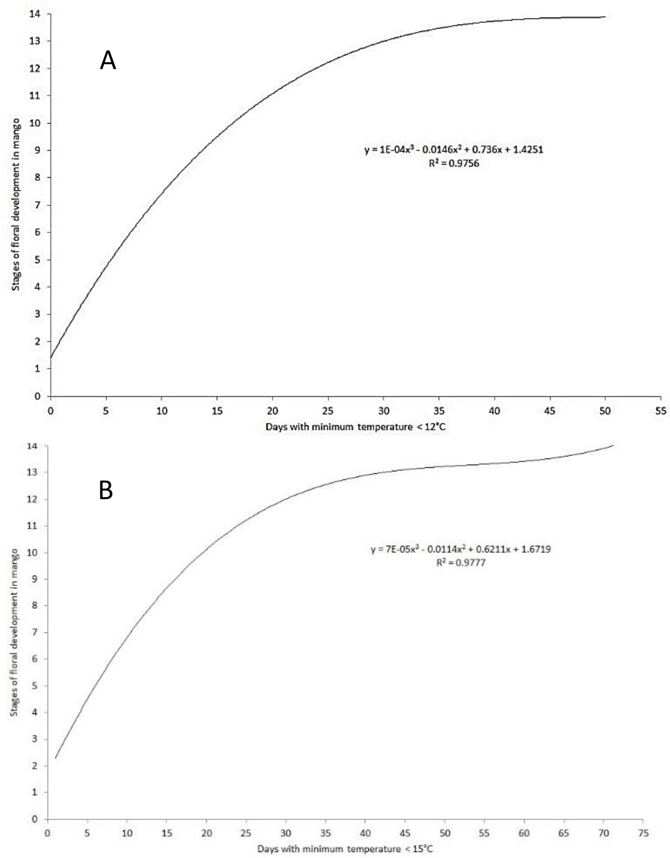

Figure 4. Mathematical models of floral development in Nayarit: a) first flow and b) second flow.

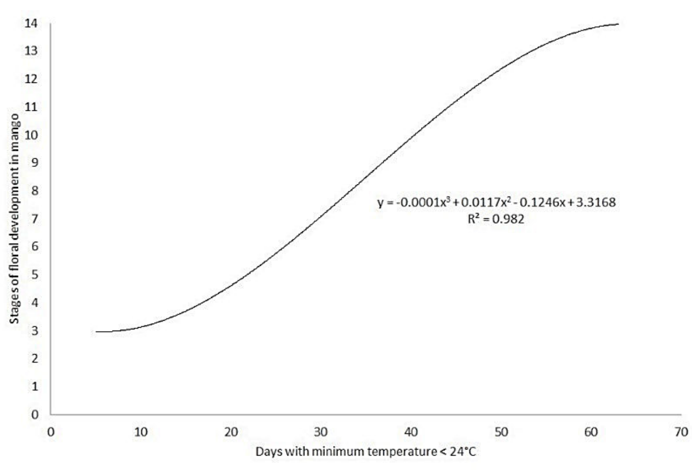

Figure 5. Mathematical models of floral development in Guerrero.

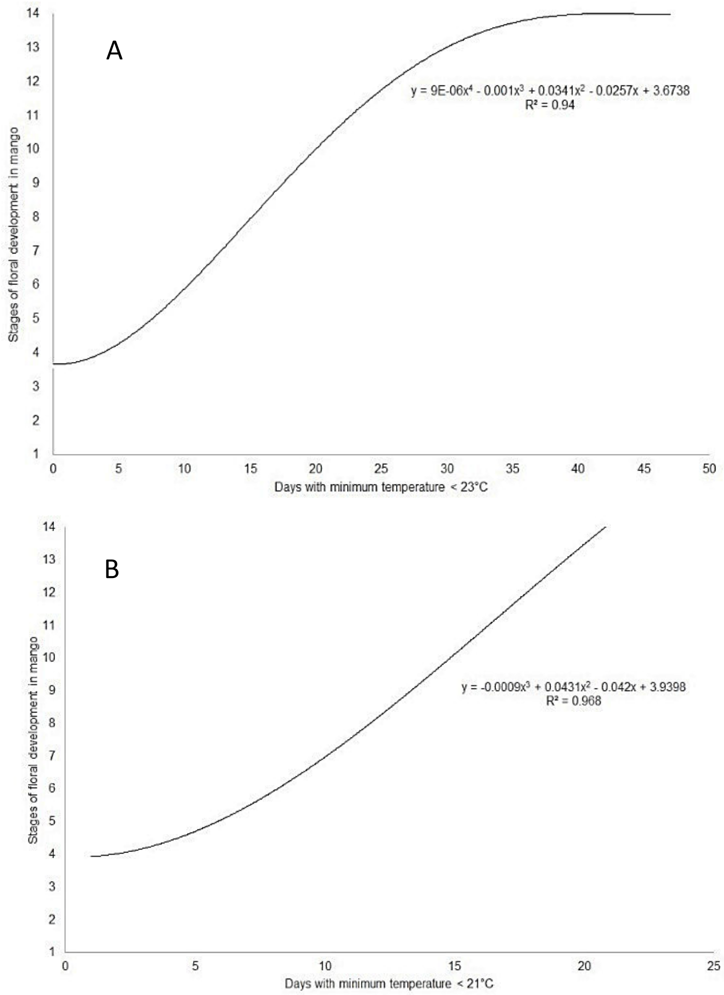

Figure 6. Mathematical models of floral development in Chiapas: a) first flow and b) second flow

Incidence of parthenocarpic fruits

The Figure 7A shows how the incidence of parthenocarpic fruits in Nayarit for the first flowering was 13.7% in contrast to the second flowering (75.1%) which resulted 5.5 times more than the first flowering. In Guerrero (Figure 9B) the incidence was higher than 82% (the highest incidence of the three producing regions). While in Chiapas the first flowering exceeded 80% and the second flowering reached 78.9% of parthenocarpic fruits (Figure 8).

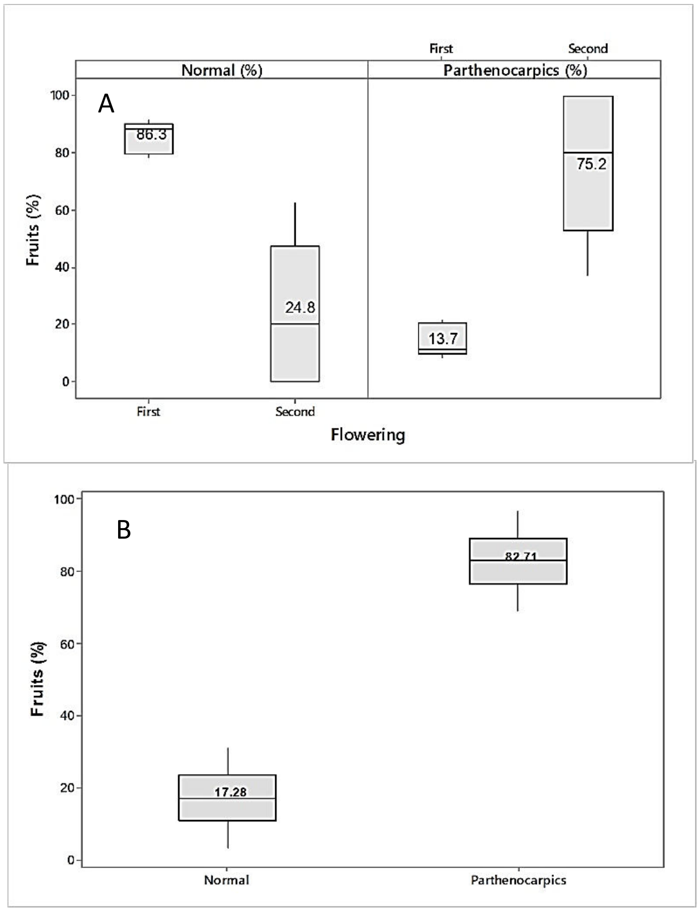

Figure 7. Incidence of parthenocarpic fruits a) Nayarit and b) Guerrero.

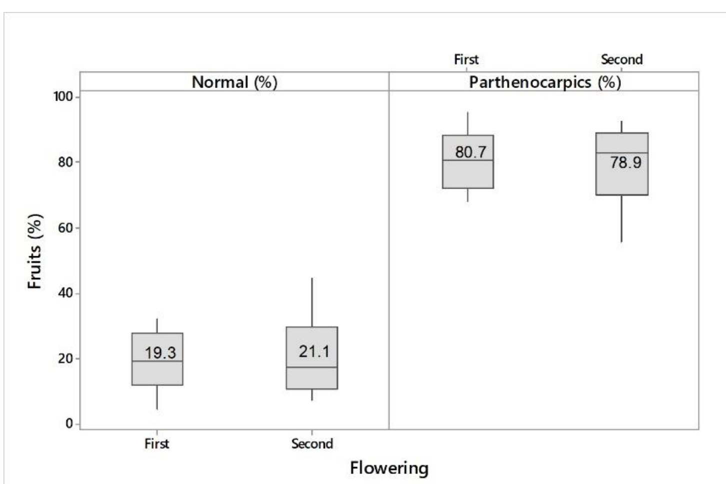

Figure 8. Incidence of parthenocarpic fruits in Chiapas.

Thermal thresholds

The first flowering was characterized by the greater differences between regions in the thermal thresholds identified, especially in the minimum temperature. On the other hand, the second flowering was characterized by the most extreme thermal thresholds particularly in Nayarit, that is, the second flowering was exposed to higher (maximum temperature) and lower (minimum temperature) thresholds in Chiapas and Nayarit (In Guerrero no second bloom was presented).

For the minimum temperature in the first flowering, 48 events less than 25 °C were recorded in Chiapas, 24 events with a temperature lower than 26 °C in Guerrero and 78 events with 16 °C (Figure 9A). In the second flowering 21 events with less than 21 °C in Chiapas and 74 events with less than 15 °C in Nayarit (Figure 9B).

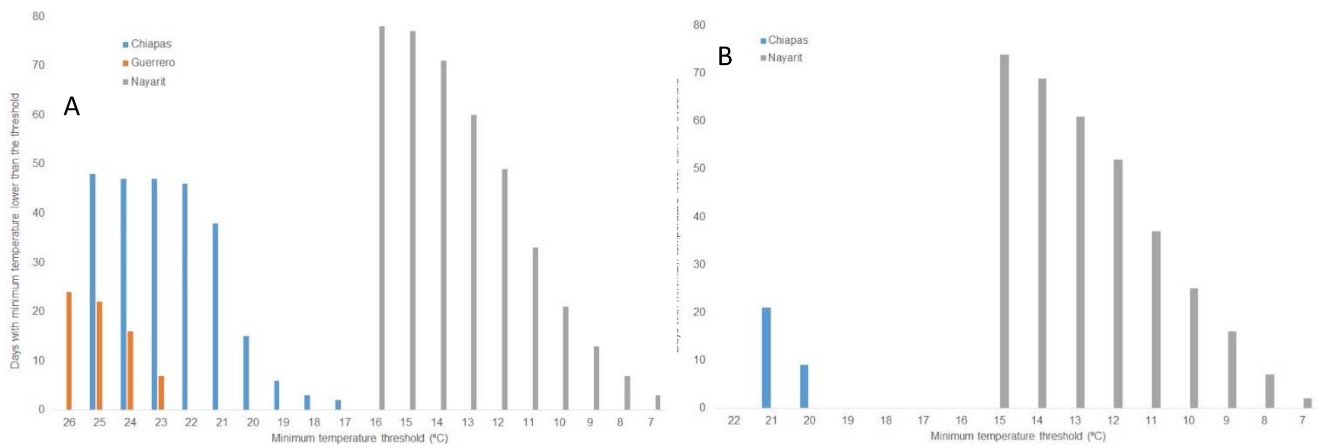

Figure 9. Accumulation of days with minimum temperature below the thermal threshold, a) first flowering in Nayarit, Guerrero and Chiapas and b) second flowering in Chiapas and Nayarit.

The events recorded under the maximum temperature thresholds for the first flowering were 48 in Chiapas and 24 in Guerrero (34 °C), while in Nayarit 78 events with a maximum temperature below 35 °C (Figure 10). On the second flowering, 21 events less than 34 °C in Chiapas and 74 events in Nayarit less than 37 °C were accumulated (Figure 11).

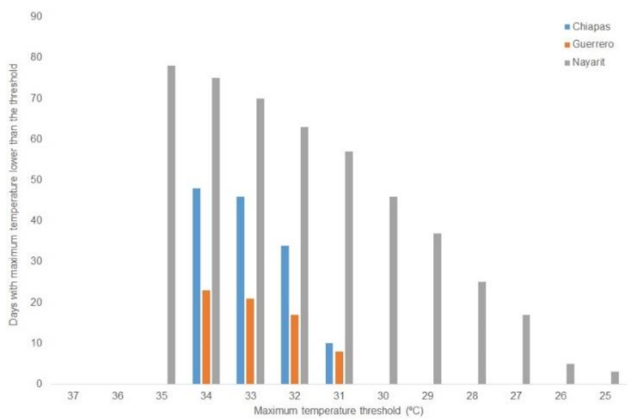

Figure 10. Accumulation of days with maximum temperature below the thermal threshold, first flowering in Chiapas, Guerrero and Nayarit.

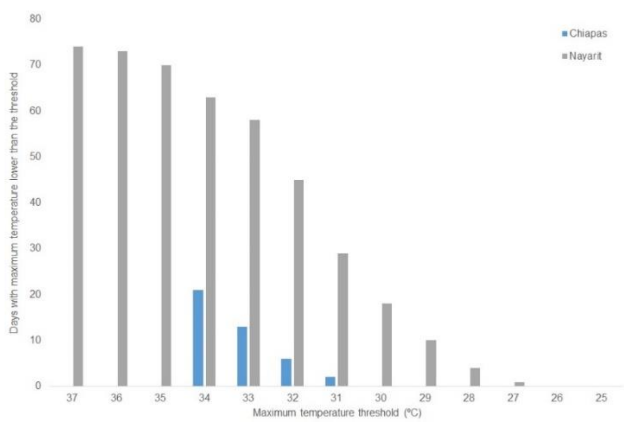

Figure 11. Accumulation of days with maximum temperature below the thermal threshold, second flowering in Chiapas and Nayarit.

Conclusions

1. The temperatures associated with floral development allowed the development of mathematical models of floral development with a high predictive power in the three states.

This will allow the creation of forecasting systems and early warning of extreme temperature events that could affect its development.

2. The climatic conditions that occur during the floral development of ‘Ataúlfo’ in Nayarit, Guerrero and Chiapas are contrasting, therefore, the problem of parthenocarpy in this cultivar is not due to a fixed temperature threshold.

3. In Nayarit the second flowering is the most exposed to thermal thresholds that affects the floral structures or the fruit (both at maximum and minimum temperature; < 15 and/or > 33 °C).

4. In Guerrero and Chiapas, high thresholds, especially at maximum temperatures (> 33 °C), could be associated with parthenocarpy.

Subproject 2. Studies on pollination, fertilization and set of fruit in 'Ataulfo' mango: Floral biology. Dr. Maria Hilda Pérez Barraza

Experiment 1. Effect of thidiazuron (TDZ) and gibberellic acid in pollination (AG_3), fruit fertilization and set. 2018.

The number of fruits produced by treatment is reflected in Table 1. The treatments applied before full flowering did not produce any type of fruit, in the rest of the treatments the production of parthenocarpic fruits (PRT) varied between 4 and 8 fruits per branch treated; The lowest production was with the TDZ + GA_3 treatment (50 mg L^{-1} of each) applied in full bloom. Regarding the production of pollinated fruits, the highest number was obtained in the TDZ + GA_3 treatment (50 mg L^{-1} of each) applied after full flowering with 19 fruits/branch treated. However, it was not significantly different from the treatments applied in full bloom as TDZ (50 mgL^{-1}) and TDZ + GA_3 (50 mg L^{-1} of each one). Similar results were obtained in the total number of fruits between TDZ + AG_3 treatments (50 mg L^{-1} of each one) and TDZ (50 mgL^{-1}) applied after full flowering.

Table 1. Number of parthenocarpic (PRT) and pollinated (POL) fruits per branch treated in 'Ataulfo' mango obtained by the effect of treatments. 2018

Treatments	Yield (No. of fruits/branch)		
	PRT	POL	Total
TDZ^{z} BFF^{y}	0.0 c^{x}	0.0 c	0.0 c
TDZ FF	6.0 a	8.0 b	14.0 b
TDZ AFF	8.0 a	15.0 ab	23.0 ab
TDZ + AG_3 BFF	0.0 c	0.0 c	0.0 c
TDZ + AG_3 FF	4.0 b	12.0 ab	14.0 b
TDZ + AG_3 AFF	7.0 a	19.0 a	26.0 a
Control	5.0 ab	9.0 b	14.0 b

^{z} Dose; TDZ 50 mgL^{-1}; TDZ + AG_3 50 mgL^{-1} of each one
^{y} BEF before full flowering; FF full flowering; AFF after full flowering
^{x} Mean with the same letter inside columns, are not significantly different. Tukey P≤ 0.05.

The tendency towards a greater number of fruits at the time of harvest, in the treatments applied with TDZ, is related to the initial set and the fruits retained until harvest. This explains the non-production of fruits in the treatments applied before full flowering, where the initial set was very low and no fruits were retained until the time of harvest. In the treatments applied in full bloom, from the initial set the TDZ seems to have an effect on fertilization and fruit-set, these treatments retained their fruits until the time of harvest, as well as those treatments applied after full flowering. Several studies show that cytokinins regulate cell division so it is possible to associate them with set and fruit growth by increasing the number of cells (Jun-hu *et al.*, 2013). On the other hand, it seems that the application of gibberellins is necessary for the development of the fruit.

Conclusion. The application of TDZ + AG_3 15 days after full flowering, improved the pollinated and parthenocarpic fruits.

Experiment 2. Studies on pollination, fertilization and set of fruit through pollinators and pheromones. 2019

Locations X Production systems

The effect of the interaction of 2 Localities (Nanchi Station and Cofradia) X 2 Production Systems (A + P + F and A + F), was studied only for the variables fresh weight (g), of pollinated fruits, number of fruits per tree and fruit production per tree (kg). Iodine variables were superior in Cofradia, without the presence of the pollinator cultivar (A + F) (Figures 12 and 13). While, in Nanchi Station, only the weight (g) of pollinated fruits was higher under pheromones (A + F), the remaining performance components were statistically equal under A + P + F or A + F. The above suggests that the pollinator cultivar was not relevant to improve the production components in quantity or quality.

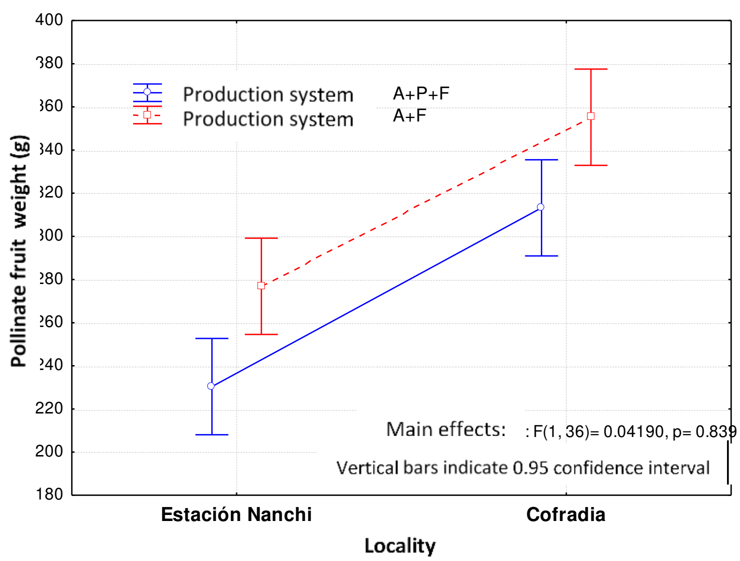

Figure 12. Graphical statistical analysis of the weight (g) of pollinated fruits in the interaction of 2 Localities (Nanchi Station and Cofradia) X 2 Production systems (A + P + F and A + F). 2019

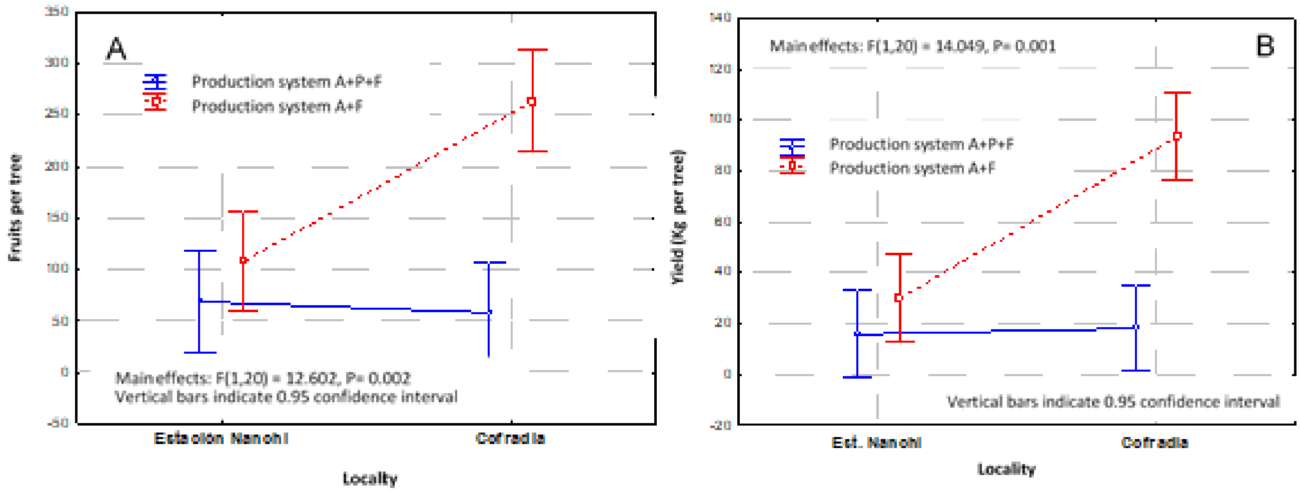

Figure 13. Graphical statistical analysis of the number of fruits per tree (A) and Kg/tree (B) in the interaction of 2 Localities (Nanchi Station and Cofradia) X 2 Production Systems (A + P + F and A + F). 2019

Separate effects

The effect of treatments (production systems with or without pollinator and/or pheromones) on yield (number of fruits and kg/tree), by location, is shown in Figure 14. In Nanchi Station, the highest production of pollinated fruits was obtained, both in number and in kg/tree, with 'Ataulfo with pheromone, although it was statistically equal to the production of the system with Ataulfo without pollinator, or pheromone (Figure 14A). The same results were obtained in the locality of Cofradia, and even in the Ataulfo system near Tommy Atkins as pollinator plus pheromone (A + P + F) obtained the lowest yield (Figure 14B). These results indicate that, in both locations, the pollinator, either close to Ataulfo or interleaved, did not help the production of pollinated fruits. Apparently the application of pheromone in both locations contributed to higher performance.

Regarding the effect on the production of parthenocarpic fruits (PRT), the results are shown in Figure 15 for both locations. At Nanchi station, at the time of harvest, the trees did not show parthenocarpic fruits, which can probably be attributed to the application of PBZ in all these Ataulfo production systems (A + TA + F; A + F and A).

While in Cofradia the greatest production in both number and kg of fruit per tree was the Ataulfo + Pheromones and Ataulfo systems alone (Without pollinator, without pheromones). The lowest production of this type of fruit was with Ataulfo interspersed with Haden + pheromones; however, it was also the one that had less production of pollinated or normal fruits. Statistically there were no differences in the production of parthenocarpic fruits with or without the use of pheromones. However, Ataulfo with pheromones produced the greatest amount and Kg of both pollinated and parthenocarpic fruit.

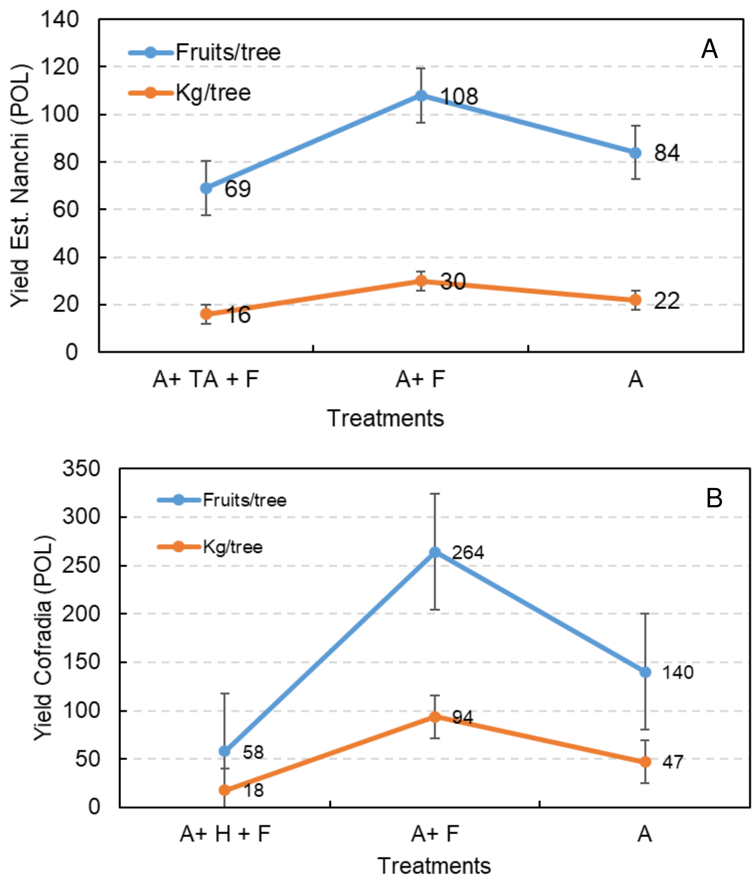

Figure 14. Production of pollinated fruits (PRT) in different production system and two locations, nanchi station (A) and Cofradia (B). 2019

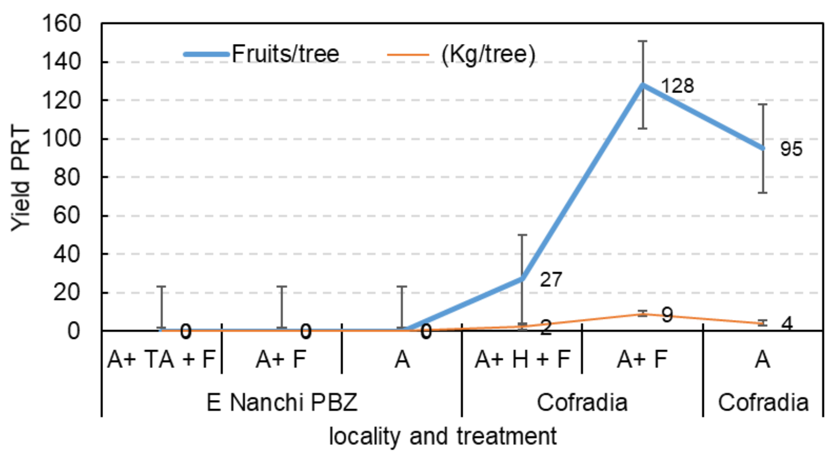

Figure 15. Production of parthenocarpic fruits (PRT) in different production system and two locations. 2019

The weight of the pollinated fruit (POL) at Nanchi Station ranged from 230 to 277 g, the Ataulfo trees near Tommy Atkins + pheromones had the smallest fruits (Figure 16). In the same Figure, the results for Cofradia are shown, the weight of the POL fruit varied from 284 to 355 g; the smallest size was obtained in 'Ataulfo' trees without pollinator or pheromones (A).

There were no differences in the size of the parthenocarpic fruit. The site effect can be attributed to the management of the orchard, since in Cofradia the producer promptly watered, which favored the production of fruits with better quality, but not at Nanchi Station. On the other hand, the climate and the altitude of the orchards are different, which conditioned the differential response of the production components by location.

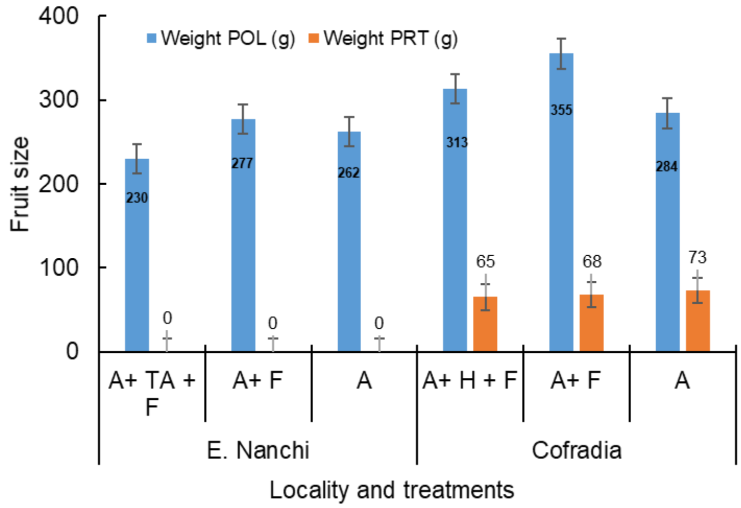

Figure 16. Fresh weight of the pollinated fruit (POL) and parthenocarpic (PRT) in different production system and two locations in Nayarit. 2019

Conclusion.

1. There is an effect of the locality attributed to soil and climate management and environment. Cofradia registered greater weight, number of fruits per tree and kg of fruit per tree.
2. Pollinators was not a decisive factor in improving yield and fruit quality for either pollinated or parthenocarpic.
3. The use of pheromones improved the production and quality of pollinated fruits, and decreased the number of parthenocarpic fruits, but did not increase their size.

Experiment 3. Embryo development.

The results obtained in fruits collected in the different stages of development are shown in Figure 17. The fruits presented an anotropic ovule with the degenerated embryo sac; however, the aborted embryo was observed from the early stage of fruit development; in fruit control (E 13) with fruits between 4 and 5 mm in length (Figure 4A and B); in set or E 14 (Figure 4C and D), even the aborted embryo was observed in the globular stage (fruits with a length between 1 and 2 cm). Finally, in developing fruits with a length between 4 and 5 cm, the presence of numerous embryos was observed (Figure 4E and F).

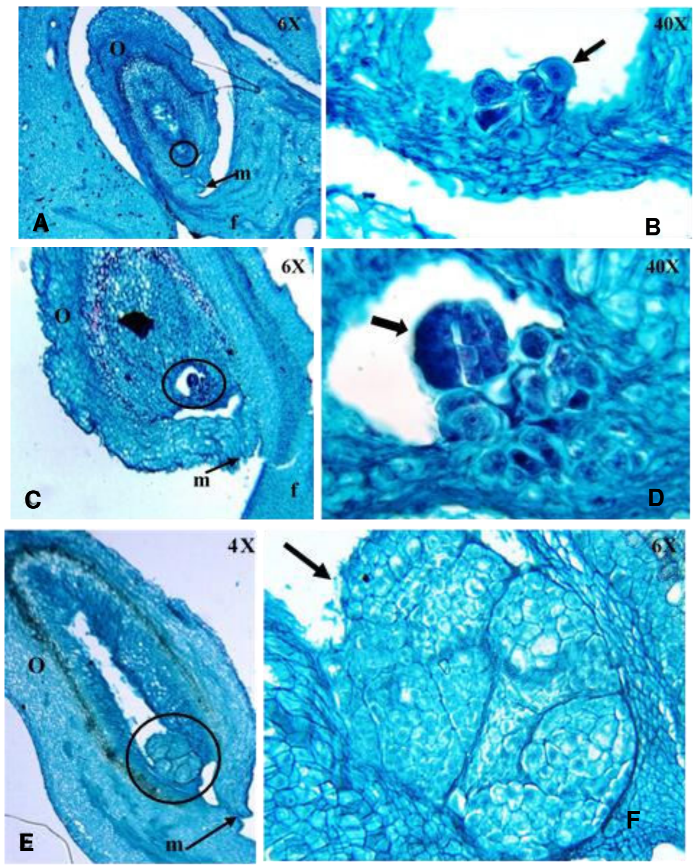

Figure 17. Embryo abortion observed, in three stages of development of parthenocarpic fruits. **A**, Curd stage (fruits between 3 and 5 mm in length), the circle indicates the presence of the aborted embryo (6X); **B**, aborted embryo observed on a larger scale (40X). **C**, set (fruits between 1 and 2 cm), the circle indicates the presence of the embryo in the aborted globular state (6X); **D**, aborted globular embryo (40X). **E**, fruits in development (between 4 and 5 cm), the circle indicates the presence of numerous aborted embryos (4X) and **F**, same larger-scale embryos (6X), corroborating that ul Ataulfo 'is a type of poly-embryonic fruit. **O**, anthropogenic ovum; **m**, micropyl; **f**, funicular. Nayarit 2018.

The aborted embryos found in the different stages of development of mango fruits 'Ataulfo', indicates that in these, there was pollination and fertilization and that possibly the embryo was damaged by temperatures below 15 °C and greater than 35 °C presented from E 13 to E 14, which coincides with that reported by Whiley *et al*. (1988) and Sukhvibul *et al*. (2000a) defining these fruits as stenospermocarpics, a type of parthenocarpy in which there is pollination and fertilization but the newly fertilized embryo is aborted (Vardi, *et al*., 2008). Contrary to this, Salazar-Garcia *et al*. (2016) found no evidence of stonospermocarpia in fruits without mango seeds ‘Ataulfo’; however, in their work they did not perform histological studies and only observed macroscopic characteristics of longitudinally sectioned seedless fruits.

On the other hand, Huang *et al*. (2010) mention that there was no sexual reproduction in mango fruits ‘Tainong 1’ when they develop at maximum daytime temperatures <20 °C, due to a slow growth of the pollen tube and low fertilization rate. In fruits with seeds, through histological studies of high quality, they observed the development of the embryo in its different stages of development, from globular to torpedo form. In this study, in seedless fruits of 'Ataulfo', embryos were observed in globular state in the early stages of development, but aborted, and even observed in degenerated ovules, multiple aborted embryos, which is related to the type of polyembryonic fruit to which the cultivar 'Ataulfo' belongs.

Conclusion

In Nayarit the cause of the production of parthenocarpic fruits is due to embryo abortion.

Subproject 3. Validation of techniques generated to increase fruit-set and size of parthenocarpic fruits in Ataulfo mango. Dr. Maria Hilda Pérez Barraza and Dr. Moisés Alonso Báez.

Results in Nayarit. Dr. María Hilda Pérez Barraza

Technology 1. TDZ + GA_3 (3X) applied at 15, 30 and 45 days after full flowering.

Set of fruits

The selected orchards presented an abundant flowering of more than 90% and it happened at the end of January in the orchard where the TDZ + GA_3 (4X) was applied.

The Table 2 shows the results obtained in the initial Fruit-set. In 2018, the number of fruits pollinated by inflorescence was 1.8 in trees with the application of technology and 0.9 fruits/inflorescence in trees without regulator. For 2019, the trees where TDZ + GA_3 (4X) applied produced an average of 2 fruits pollinated by inflorescence and up to 2.9 parthenocarpic fruits; while the trees without regulator, in that same orchard, had 1 fruit with seed for inflorescence and 1.3 fruits without seed.

The results indicate that in trees where the technology was applied, they retain a greater number of fruits with seeds, as well as parthenocarpics, compared to trees without regulators. A greater set was observed in 2019 in both types of fruits. These results coincide with those reported by other authors. Singh (2009), showed that the application of GAs in the cultivation of mango 'Kensington Pride', is important to ensure the set of fruit and production in places with low temperatures during flowering. Other authors report similar results in the increase in set due to the effect of regulators on mango 'Srisaket 007', 'Kensington Pride' and 'Irwin' (Chutichudet *et al.*, 2006; Singh, 2009; Ogata *et al.*, 2010).

Table 2. Number of pollinated (POL) and parthenocarpic (PRT) fruits by inflorescence, by effect of the treatments applied. 2018-2019

Technology	**Fruits/inflorescence (No.)**			
	POL		**PRT**	
	2018	**2019**	**2018**	**2019**
TDZ + G_3 (4X)^z	1.8 a^y	2.0 a	2.5	2.9 a
Without regulator	0.9 b	1.0 b	1.2	1.3 b

^{z}4X, four applications of GA_3 at 15, 30, 45 and 60 days after full flowering.

^{y}Means with the same letter inside columns, are not significantly different. Tukey P≤ 0.05.

Yield

Figure 18 shows the results obtained in the number of fruits and kg of fruit per tree in 2018. In trees where the validated technology was applied consisting of one application of TDZ + four applications of GA_3 in doses of 50 mgL^{-1} each, a greater number of pollinated fruits was obtained. The amount of fruits obtained per tree (172 fruits) exceeds that obtained in trees by more than 100% without the application of regulators (48). This led to an increase of up to 76% in the yield of trees treated with regulators compared to those without application thereof, which produced approximately 17 kg/tree against almost 70 kg in trees with regulator application.

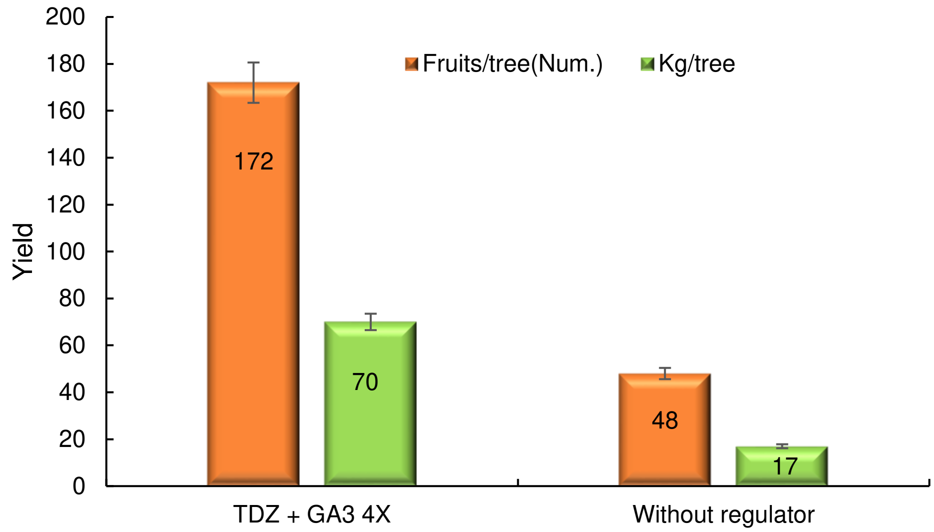

Figure 18. Fruit yield with seed obtained in mango trees 'Ataulfo' with or without application of the technology, expressed in number and kg of fruit/tree. The bars at each point represent the average of 20 trees per treatment ± standard error. 2018.

In 2019, the number of fruits per tree in trees with TDZ + GA_3 (4X) was 360 fruits pollinated against 320 fruits in trees without technology. The amount of fruit retained per tree resulted in a yield of 123 kg of fruit per tree with application of the technology; while trees without technology produced 103 kg/tree (Figure 19).

Regarding the production of parthenocarpic fruits, trees with technology (TDZ + GA_3, 4X) produced a large amount of fruits (522), which led to a production of 68 kg of parthenocarpic fruits per tree. In trees without technology, the production of this type of fruit was 250/tree with a yield of almost 15 kg (Figure 20).

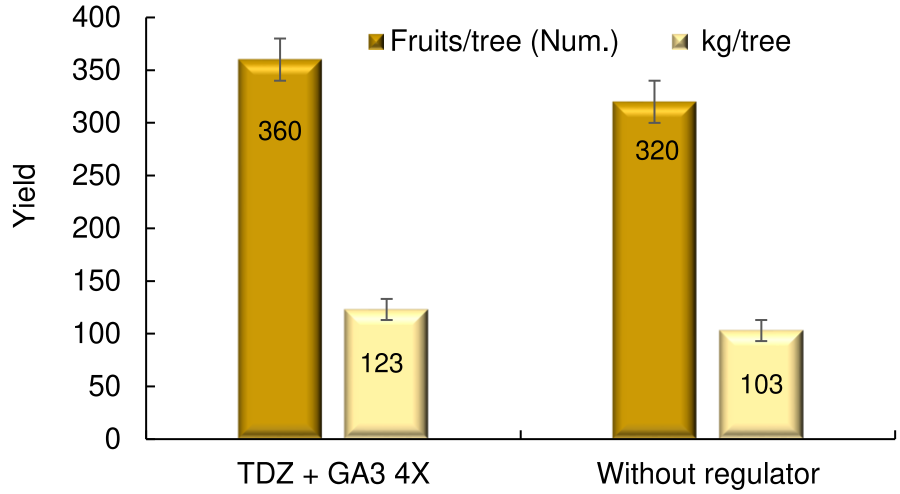

Figure 19. Fruit yield with seed obtained in mango trees 'Ataulfo' with or without application of the technology, expressed in number and kg of fruit/tree. The bars at each point represent the average of 20 trees per treatment ± standard error. 2019

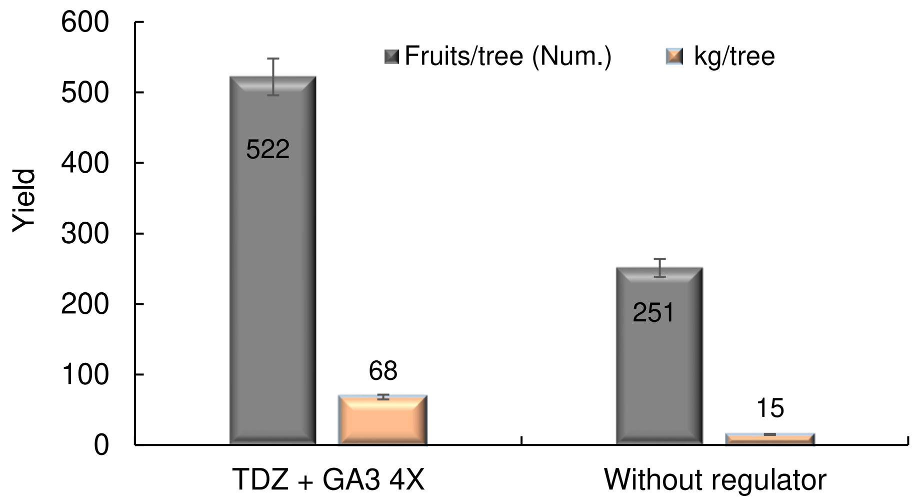

Figure 20. Yield of fruits without seeds obtained in mango trees ´Ataulfo’ with or without application of the technology, expressed in number and kg of fruit/tree. The bars at each point represent the average of 20 trees per treatment ± standard error. 2019.

In 2019 the amount of fruits pollinated by tree and the production of fruit exceeded that obtained in 2018, both in trees with application of technology and those where it was not applied; however, the latter do not exceed the trees with regulator. In this same year (2019), the production of parthenocarpic fruits in trees with technology exceeded that of the control trees, going from 14.8 kg (controls) to 68 kg in treated trees. Despite this, the production of pollinated fruits exceeds that of the parthenocarpic by almost 15%, which makes the orchard more profitable for the price reached by the pollinated fruit (between 3 and 9 pesos per kg of fruit).

Fruit size

Regarding the size of the fruit, it was possible to increase the fresh weight of the parthenocarpic fruit with the application of technology (Table 3). For 2018, in trees where the technology was applied, the weight of the parthenocarpic fruit was 160 g on average, increasing more than twice the weight in relation to the fruits of un-sprinkled trees (61 g). In the length and diameter of these fruits, the results showed an increase of 31 and 28%, compared to the fruits of trees that did not receive the application of the technology. Similar results were obtained in the size of the pollinated fruit (with seed), in which it was possible to increase both the fresh weight, as the length and diameter (14, 9 and 6%, respectively) in relation to the size of the fruit of trees without technology (Table 3). Figure 21 shows the differences in the size of the parthenocarpic fruit due to treatments.

Table 3. Fruit size, expressed in fresh weight, length and diameter, with and without seed due to the effect of the treatments applied. 2018-2019

Technology	Weight (g)		Length (cm)		Diameter (cm)	
	2018	2019	2018	2019	2018	2019
Fruits with seed						
TDZ + GA_3 (4X)[z]	405 a[y]	342 a	12.3 a	11.3 a	7.9 a	7.0 a
Without regulator	347 b	322 a	11.5 b	11.3 a	7.5 b	6.6 b
Seedless Fruits						
TDZ + GA_3 (4X)	160 a	134.0 a	8.8 a	8.3 a	5.8 a	4.8 a
Without regulator	61 b	59.0 b	6.1 b	6.0 b	4.2 b	3.7 b

[z]3X, three applications of GA_3 at 15, 30 and 45 days after full flowering.

[y]Means with the same letter inside columns, are not significantly different. Tukey P≤ 0.05.

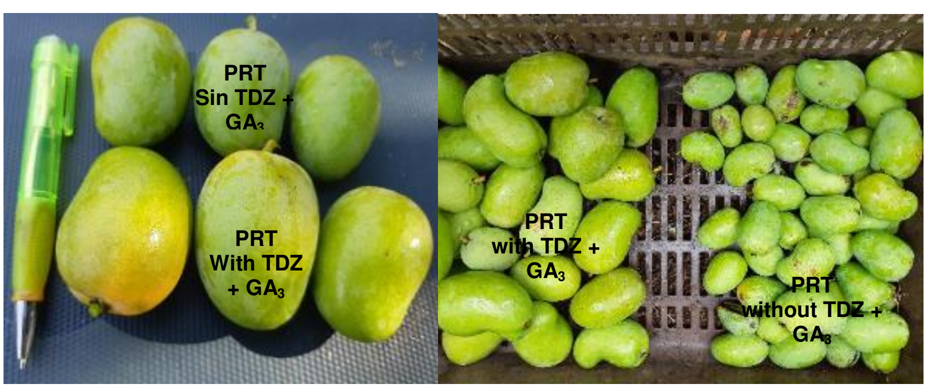

Figure 21. Parthenocarpic fruit size applied with 50 mgL^{-1} of TDZ + GA_3 (3X) from fruit control and without application.

Similar results were found in 2019, achieving a 56% increase in the weight of the parthenocarpic fruit (134 g) with respect to the weight obtained in fruits without the technology (59 g), the length and diameter of parthenocarpic fruits with technology exceeded that of fruits without application (Table 3). In the pollinated or seeded fruits, there were no significant differences in their weight between those treated with technology and those not treated; although there is a tendency to produce slightly larger fruits with technology (342 g) than without its application (322 g). The length and diameter were greater in fruits with technology (Table 3).

The size of the fruit obtained in 2019 was smaller both in weight and in length and diameter in both types of fruit, compared to the size achieved in 2018. The above can be attributed to the large amount of fruit retained by tree in 2019, which caused greater competition for photosynthates and nutrients in the tree giving it a smaller size.

On the other hand, the results obtained in the increase in size in this study are probably because the application of this technology coincides with the development of the fruit. At this stage and until harvest the most active process is cell elongation (Varoquaux *et al*., 2000) and the content of cytokinins and gibberellins is high in pericarp according to Ram (1992) and Jun-hu *et al*. (2013), respectively, suggesting a relationship between these two hormones; apparently both are required for cell elongation. In this study the increase in size achieved in the last stage of growth was greater with the combined technology (TDZ + AG_3), which confirms the above. On the other hand, Perez *et al*. (2017) found that the increase in size of parthenocarpic fruits treated with regulators is due to an increase in the number and size of cells, physiological processes (cell division and elongation) that are regulated by cytokinins and gibberellins, respectively.

Similar results in increase in size were obtained in 'Irwin' handle with the application of AG_3 (Ogata *et al*., 2010) and with two and four applications of CPPU + AG_3 when applied at the end of Stage I (Sasaki and Utsunomiya, 2002).

Technology 2. TDZ 1X in full bloom and GA_3 4X at 15, 30, 45 and 60 days AFF.

With an application of TDZ in full bloom and four applications of AG_3 at 15, 30, 45 and 60 days after full flowering, the trees retained an average of 1.6 fruits with seeds and 1.2 parthenocarpic, in trees without regulators the number of fruits was of 0.9 with seed and 1 fruit without seed per inflorescence (Table 4).

Table 4. Number of fruits per inflorescence retained in the initial set (45 days after full flowering) by effect of the treatments. 2019.

Technology	Fruits/inflorescence (No.)	
	POL	PRT
TDZ (1X) y AG_3 (4X)[z]	1.6 a[y]	1.2 a
Without regulator	0.9 b	1.0 a

[z]1X, an application of 50 mgL^{-1} of water in full bloom; 4X four applications of GA_3 (50 mgL^{-1} water) at 15, 30, 45 and 60 days after full flowering.

[y]Means with the same letter inside columns, are not significantly different. Tukey $P \leq 0.05$.

Regarding the yield, the results on number and kg of fruits pollinated per tree are shown in Figure 22. Trees with the application of technology produced 70 fruits/tree against 48 of trees without technology; this resulted in a yield of 26 kg of fruit/tree in tree with technology and 15 kg in those without technology.

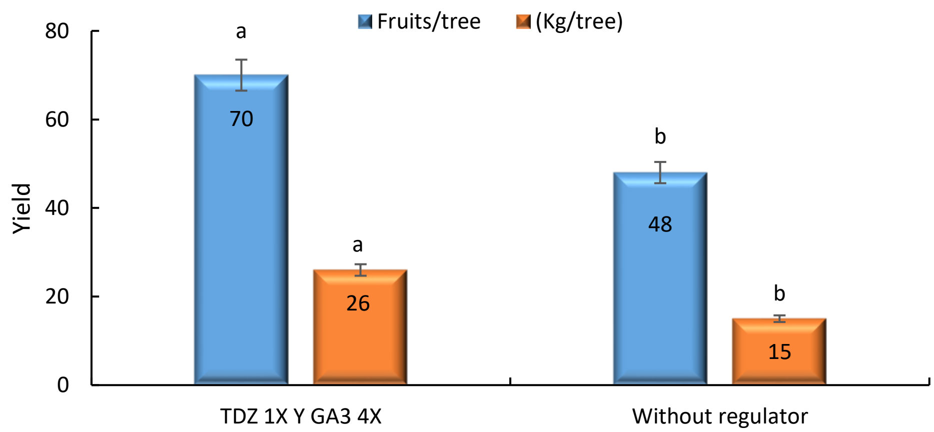

Figure 22. Fruit yield with seed obtained in mango trees 'Ataulfo' with or without application of the technology, expressed in number and kg of fruit/tree. The bars at each point represent the average of 20 trees per treatment ± standard error. 2019

In relation to parthenocarpic fruits, trees with technology produced 96 fruits/inflorescence, while in control (without technology) the production was 56 fruits and the yield was 13 kg/tree with the application of technology against 4 kg in untreated trees (Figure 23).

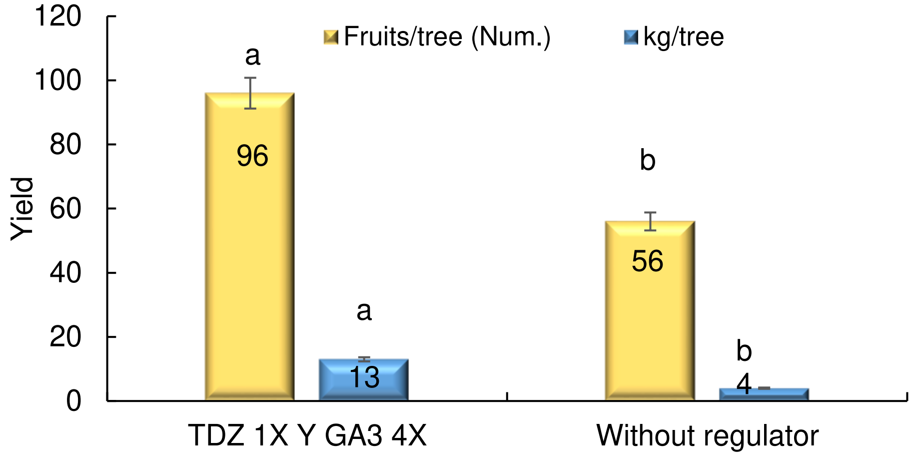

Figure 23. Yield of fruits without seeds obtained in mango trees ´Ataulfo' with or without application of the technology, expressed in number and kg of fruit/tree. The bars at each point represent the average of 20 trees per treatment ± standard error. 2019.

It was possible to increase the weight of the parthenocarpic fruit by more than 50% with one application of TDZ in full bloom and four applications of AG_3 (133 g) in relation to the fruits without application that had fruits of 65 g, also obtained greater length and diameter in fruits treated with untreated regulators (Table X). In the same way, the weight and diameter of the pollinated fruit increased by 15 and 8%, respectively with the application of technology, in relation to the fruits of trees without application (Table 5).

Table 5. Size of pollinated (POL) and parthenocarpic (PRT) fruits expressed in fresh weight, length and diameter, in mango trees 'Ataulfo' by effect of treatments. 2018-2019

Technology	**Weight (g)**	**Length (cm)**	**Diameter (cm)**
	Fruits POL		
TDZ 1X + GA_3 (4X)[z]	373 a[y]	11.5 a	7.1 a
Without regulator	317 b	10.0 a	6.5 b
	Fruits PRT		
TDZ 1X + GA_3 (4X)	133 a	7.8 a	4.9 a
Without regulator	65 b	6.1 b	3.8 b

[z]1X, an application of 50 mgL^{-1} of water in full bloom; 4X four applications of GA_3 (50 mgL^{-1} water) at 15, 30, 45 and 60 days after full flowering.

[y]Means with the same letter inside columns, are not significantly different. Tukey P≤ 0.05.

The results obtained in the experimental phase, in increasing the size of the parthenocarpic fruit (weight, length and diameter), are corroborated with the application of regulators in its commercial phase, in addition to favoring the production of pollinated fruits. These results coincide with those reported by several authors. Singh (2009), showed that the application of GAs in the cultivation of mango 'Kensington Pride', is important to ensure the set of fruit and production in places with low temperatures during flowering. On the other hand, Ogata *et al.* (2010) found an increase in set and size of the parthenocarpic fruit in mango 'Irwin' with the application of gibberellins. Similar results were obtained in mango 'Srisaket 007' with the application of 50 ppm of GA_3 in Stage 1 of fruit development (Chutichudet *et al.*, 2006). On the other hand, the application of hormones such as cytokinins in Stage 1 of the development of the fruit, has been effective in increasing its size by stimulating cell division and elongation in species such as mango (Perez *et al.*, 2017). Therefore, it is possible that the size achieved with this technology may be due to the fact that the TDZ and GA_3 stimulated the number and size of the cells.

Conclusions

1. The results obtained in the experimental phase, in increasing the size of the parthenocarpic fruit (weight, length and diameter), are corroborated with the application of regulators in its commercial phase, in addition to favoring the production of pollinated fruits.

2. Both technologies increased the size of the parthenocarpic fruit and the production of normal fruit,

3. The technology based on a mixture of TDZ + GA_3 in doses of 50 mg L^{-1} of water of each regulator and making four applications from fruit set and subsequently every 15 days gave better results.

Results in Chiapas. Dr. Moisés Alonso Báez

On the results of the first validation cycle (2017 - 2018), it was observed that the production of parthenocarpic mangos (S/S) by inflorescence was 86% with the application of the mixed regulators (TDZ + GA_3, 4X) (Figure 24) due to its efficient agronomic management: tree health, flowering and fruits, in addition to its fertilization and micro-spray irrigation, during the AW cycle: 2017-2018 an average yield of 5.3 tons per hectare was obtained This result is acceptable from an economic point of view in this region of Soconusco, Chiapas, which indicates that the production of fruits with seeds also increased.

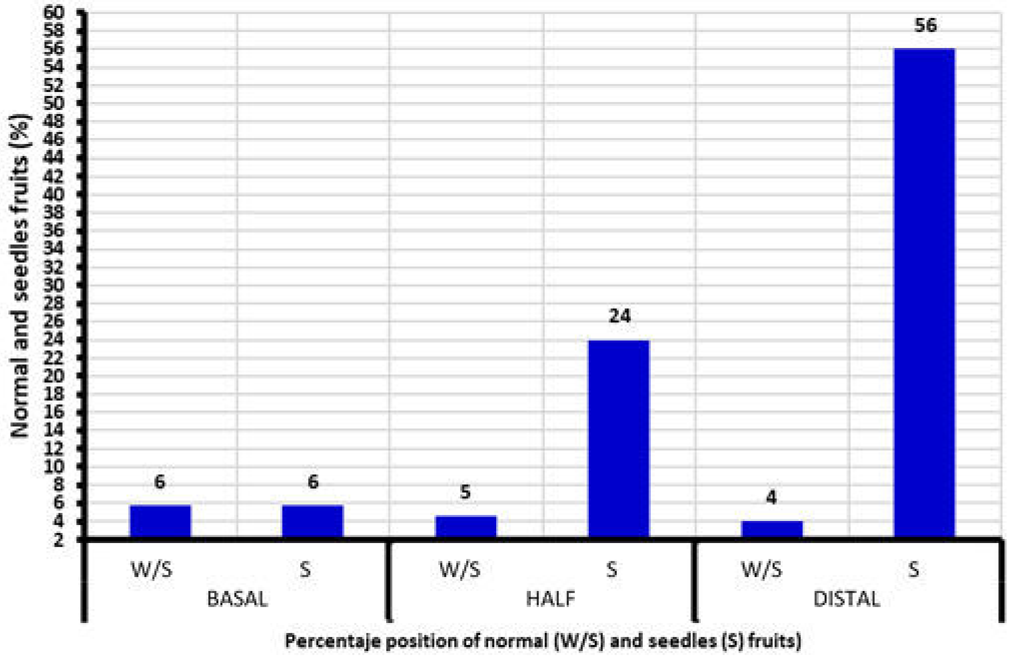

Figure 24. Percentage ratio of normal or seed fruits (C/S) on parthenocarpic fruits, children or seedless (S/S). TDZ + GA_3 (4X). Orchard "Las Andreas" municipality of Tapachula, Chiapas. 2017-2019 cycle.

In relation to the validation results of TDZ + GA_3 (3X) treatments, as well as TDZ 1X and GA_3 4X treatments and the control treatment (T), of the 2018-2019 cycle, these are presented in Table 6.

Using a univariate statistic with an acceptable variation coefficient, the mixture treatment (TDZ + GA_3) presented an average in weight and length of fruit, superior to the TDZ 1X and GA_3 4X treatments and the control; since the fruit size exceeded the official size indicated as a Standard of 118 g in the Official Gazette of the Federation (OGF). These results indicate that there was a significant effect of phytohormones treatments on the control treatment. Based on these results, it is suggested to continue one more year with this validation, in particular with the treatment of the mixture (TDZ + GA_3, 4X), in order to specify the validation and its adoption in the short term to increase the size of parthenocarpic fruits in the region of Soconusco, Chiapas.

In order to specify in the validation results of the mentioned treatments and highlight their effect on the induction of the growth of parthenocarpic fruits in relation to the control treatment, the values of the weight and length of 25 fruits selected at random by four repetitions are presented, same to which an analysis of variance was applied through the randomized complete block design (RCBD). This analysis revealed a highly significant difference, and on this basis a separation of means was carried out by the strict Tukey method at 5% of acceptance. This indicates that, from a statistical point of view, treatment 1 exceeded the other treatments (Table 4).

Likewise, these results confirm that the mixture (TDZ + GA_3) in three applications had a significant effect on the induction of the growth of parthenocarpic fruits or “mango niño” in the Ataulfo cultivar in Soconusco, Chiapas.

Table 6. Results of the ANVA of TDZ + GA_3, 3X treatments; TDZ 1X and AG_3 4X and control for the variables weight and length. Tapachula, Chiapas. 2018-2019.

Treatment	Length (cm)	Tukey (P<0.05)	Weight (g)	Tukey (P<0.05)
	Ŷ		Ŷ	
TDZ + GA_3, 4X	8.3	A	130.08	A
TDZ 1X y GA_3, 4X	7.0	B	82.03	B
CONTROL	6.3	C	67.06	C
CV (%)	2.19		4.52	

Conclusion. The TDZ + GA_3 mixture treatment in four applications through the indicated doses and its scheduled application every 15 days from full flowering on Ataulfo mango trees in Soconusco, Chiapas., Increased the growth of parthenocarpic fruits above the official size indicated as 118g Standard in the Official Gazette of the Federation (DOF).

Subproject 4. Effect of nutrition on the production of parthenocarpic fruits in 'Ataulfo' mango. The work is carried out in Nayarit and Guerrero.

Results in Nayarit.

Experiment 1. Effect of boron, urea and calcium nitrate on the incidence, size of parthenocarpic fruits and mango yield 'Ataulfo'. Dr. Maria Hilda Pérez Barraza

Fruit-set

The results of both years (2018 and 2019) on the number of fruits per inflorescence in the final set (fruit with physiological maturity), are shown in Table 7.

In both years, the number of fruits pollinated by inflorescence did not show significant differences between treatments; However, the treatment with boron + calcium had 1.5 fruits/inflorescence in 2018 and 3.1 fruits in 2019 and the control presented 1.0 and 2.3 fruits/inflorescence in 2018 and 2019, respectively. Regarding the number of parthenocarpic fruits per inflorescence, this varied from 1 to 1.6 fruits in 2018, surpassing all the treatments with nutrients to the control. In 2019 the number of fruits varied between 1.3 and 5.4 fruits, treatments with boron + calcium (T5), calcium (T3) and nitrogen + boron (T4) retained a greater number of fruits (4.2, 5 and 5.1 fruits, respectively), although they were statistically equal to the control with 3.1 fruits.

Table 7. Final set of parthenocarpic (PRT) and pollinated (POL) fruits in mango trees due to treatments applied to foliage. 2018-2019

Treatment	Product[z]	Fruits/inflorescence (No.)			
		POL 2018	POL 2019	PRT 2018	PRT 2019
1	**$CaNO_3$ + N**	1.4 a	**3.0 a**[y]	1.5 a	2.5 ab
2	**Boron**	1.4 a	2.9 a	1.3 a	**1.3 b**
3	**$CaNO_3$**	1.4 a	2.8 a	1.1 a	5.0 a
4	**N + B**	**1.5 a**	1.9 a	1.6 a	5.1 a
5	**B + $CaNO_3$**	**1.6 a**	**3.1 a**	1.9 a	4.2 ab
6	**Control**	1.0 a	2.3 a	0.7 b	3.1 ab

[z] $CaNO_3$ = Calcium nitrate; N = nitrogen; B = Boron; applied to 1%.
[y] Means with the same inside columns, are not significantly different Tukey, $P \leq 0.05$.

Yield

The yield obtained in fruits pollinated by the effect of treatments, is shown in Figure 25. In 2018, the treatments T5 (boron + calcium nitrate; both at 1%), T3 (1% calcium nitrate) and T2 (Boron) stand out with a production of 105, 95 and 89 kg/tree of pollinated fruits, respectively, far exceeding the control trees (45 kg), the largest increase in yield was 57% in the T5 treatment, which produced twice as much as the control (T6) (Figure 25A). For 2019, treatments T5, T3 and T4 exceed the control in the production of pollinated fruits (kg/tree), the production obtained was 172, 130 and 122 kg against 94 kg of the control (Figure 25B).

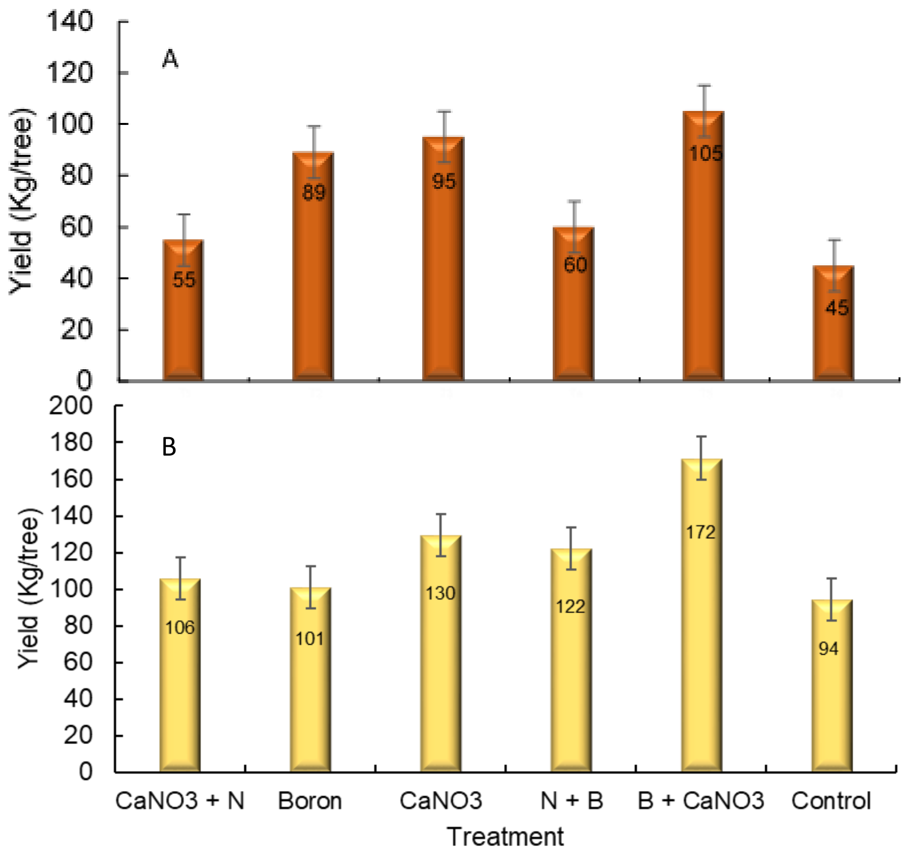

Figure 25. Yield obtained in kg of fruits pollinated in mango trees ‘Ataulfo’ due to the effect of nutrition in 2018 (A) and 2019 (B). The bars at each point represent the average of 6 trees per treatment ± standard error.

Regarding the production of parthenocarpic fruits in 2018, it is observed in Figure 26A, as treatments T5, T3 and T2 had a low production of fruits without seeds or parthenocarpic, the yield was between 7 and 9 kg/tree; while in the control trees the production of this type of fruit per tree was 12 kg. However, by 2019, the trees of the calcium and boron + calcium based treatments had a production of 12 and 13 kg of fruit/tree, surpassing the rest of the treatments including the control (Figure 26B).

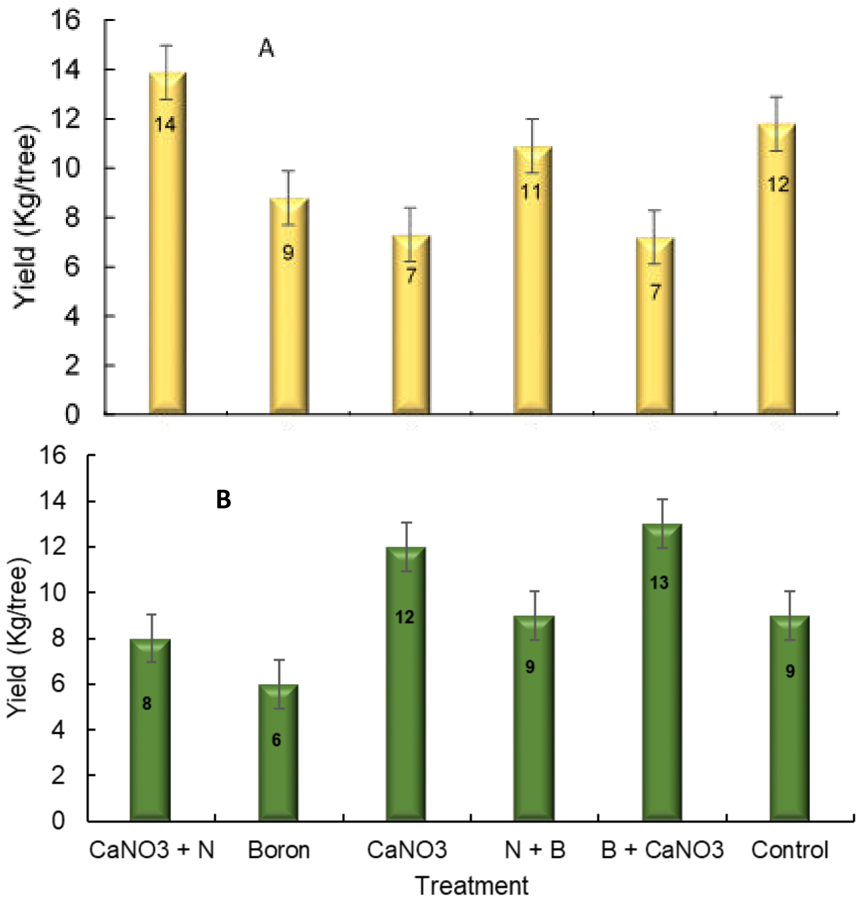

Figure 26. Yield obtained in kg of parthenocarpic fruits 2018 (A) and 2019 (B) in mango trees 'Ataulfo' due to the effect of nutrition. The bars at each point represent the average of 6 trees per treatment ± standard error.

The production of pollinated fruits obtained in 2019, exceeds that of 2018 in all treatments. The production obtained in both years exceeds that achieved in trees without the application of nutrients. In both years, the treatment based on boron + calcium with the highest production of pollinated fruits stands out, although in 2019 it produced a greater amount of parthenocarpic fruits with 13 kg/tree, despite this result, the production of pollinated fruits in both years with this treatment, the benefit achieved is greater due to the price achieved by the pollinated fruit (between 3 and 9 pesos per kg of fruit), compared to the parthenocarpic that often does not have a commercial value (0.50 and 1.0 peso per kilogram of fruit). The results of two years in nutrition, indicate that this has a positive effect on the production of pollinated fruits and shows a tendency to decrease the incidence with the foliar application of B + Ca in a dose of 1% in full flowering and fruit control (15 days after full flowering). In this regard, Hernandez-Maruri *et al.* (2015) found in 'Ataulfo' mango, that the dose of 50 and 100 g of B decreased 45 and 35%, respectively, the number of seedless or parthenocarpic fruits and improved the concentration of B in reproductive and leaf buds at the end of fruit development. This same author, found the low amount of nutrients present in the parthenocarpic fruits, since they do not contain seed are at a disadvantage with the pollinated ones, since they cannot demand the photosynthates produced by the leaves, nor the nutrients that the root absorbs from ground.

Fruit size

In 2018, the weight of the pollinated fruits (with seed) varied between 323 and 380 g, highlighting the fruits of T5 with an average fresh weight of 380 g, although statistically it was equal to the weight obtained in treatments T3 and T4. The average weight of the pollinated fruits of control trees was 343 g, this indicated a 10% reduction in size compared to the fruits of T5. In that same year, the T5 parthenocarpic fruits showed an increase of 21% in strawberry weight compared to the fruits of the control trees (Table 8). The same table shows the results for 2019. The fresh weight of parthenocarpic fruits varied from 228 to 283 g, being statistically the same between treatments, except for the nitrogen + boron treatment that showed the lowest fruit weight with 228 g, with respect to the parthenocarpic fruit

Table 8. Size of pollinated (POL) and parthenocarpic (PRT) fruits expressed in fresh weight, in mango trees 'Ataulfo' by effect of treatments. 2018-2019.

Treatments[z]	Fresh weight POL (g)		Fresh weight PRT (g)	
	2018	2019	2018	2019
$CaNO_3$ + N	335 ab[y]	255 ab	81 ab	55 c
Boron	323 b	255 ab	79 ab	73 ab
$CaNO_3$	368 a	254 ab	78 ab	79 ab
N + B	363 ab	228 b	79 ab	78 ab
B + $CaNO_3$	**380 a**	249 ab	**86 a**	**87 a**
Control	343 ab	283 a	68 c	64 bc

[z] $CaNO_3$ = Calcium nitrate; N = nitrogen; B = Boron; applied to 1%.
[y] Means with the same inside columns, are not significantly different Tukey, $P \leq 0.05$.

Conclusion. Two applications of calcium + boron sprinkled on the foliage, one in full bloom and the second 15 days later (fruit control), increase the production of pollinated fruits and improve the size of the parthenocarpic fruits.

Experiment 2. Nutritional strategies and sustainable integral management to increase fruit size in 'Ataulfo' mango. Dr. Irma Julieta González Acuña.

The results in weight (g), volume (cc) and SST (°Bx), are presented in Table 9. At 5 de Mayo they indicate that in normal mango, the mixed organic treatment + inorganic fertilization (TOm + fi), with an average of 299.24 ± 29.08 g and 271.04 ± 31.32 cc exceeded ($p \leq 0.01$) in weight and volume in 24.13 and 28.81% the control with only inorganic fertilization (Tfi); however, in SST they were similar with an average of 12.57 °Bx. In parthenocarpic mango the response was similar, since TOm + fi obtained an average weight of 84.54 ± 54.80 g and volume of 54.80 ± 12.38 cc, greater in 45.30 and 43.72% respectively to the control; however, in SST the control registered 25.73% more than TOm + fi.

At the Cofradia site, in normal mango mixed organic treatment (TOm) an average weight of 253.99 ± 28.56 g higher ($p \leq 0.05$) was obtained in 26.27% to the control without fertilizer (T). however, both volume and SST were similar with average values of 168.02 ± 24.82 g and 10.49 ± 1.15 °Bx. In parthenocarpic management TOm weighed 83.48 ± 17.47 g with a volume of 50.06 ± 15.84 cc, surpassing ($p \leq 0.05$) at T in 55.311 and 31.74% respectively. For SST they showed no differences, the average value was 10.29 ± 1.21 °Bx.

Table 9. Average and standard deviation of weight (g), volume (cc) and total soluble solids (°Bx) in normal Ataulfo ' and parthenocarpic mango by orchard in San Blas, Nayarit. 2018.

Level of factor			**Weigth (g)**			**Volume (cc)**			**°Bx**		
Location	**Fruit**	**Treatment**	**Mean**		**Std. Dev.**	**Mean**		**Std. Dev.**	**Mean**		**Std. Dev.**
5 de Mayo	Pollinated	Mixed organic + inorganic	299.24	a	29.08	271.04	a	31.32	12.31	b	1.13
5 de Mayo	Pollinated	Test*	241.07	b	12.52	210.42	b	14.80	12.82	b	1.64
5 de Mayo	Parthenocarpic	Mixed organic + inorganic	84.64	c	11.73	54.80	c	12.38	12.53	b	1.88
5 de Mayo	Parthenocarpic	Test*	58.25	d	5.99	38.13	d	3.13	16.87	a	1.99
Cofradía	Pollinated	Mixed organic	253.99	a	28.56	177.71	a	25.39	10.15	a	1.12
Cofradía	Pollinated	Test	201.15	b	12.61	158.33	a	20.94	10.83	a	1.13
Cofradía	Parthenocarpic	Mixed organic	83.48	c	17.47	50.06	b	15.84	9.71	a	0.83
Cofradía	Parthenocarpic	Test	53.75	d	11.72	38.00	c	4.92	10.87	a	1.27

*Control with inorganic fertilizer application

Equal literals indicate statistical equality ($p \leq 0.05$)

On the other hand, in Figures 27 to 29, the interaction between sites, by type of mango and treatments is shown. In weight (g) (Figure 1), it was notorious ($p \leq 0.05$) that in both locations the treatment with mixed organic fertilizer exceeded the control in normal and parthenocarpic mango. However, in normal mango, the highest weights in each treatment, were always obtained in the locality of 5 de Mayo with respect to Cofradia. While parthenocarpic mango by treatment, presented similar weight in one place or another, without leaving the NOM "mango niño" scale. This behavior may be due to the fact that no treatment provided enough carbohydrates and/or amino acids at the right time for the division and cell expansion of the fruit.

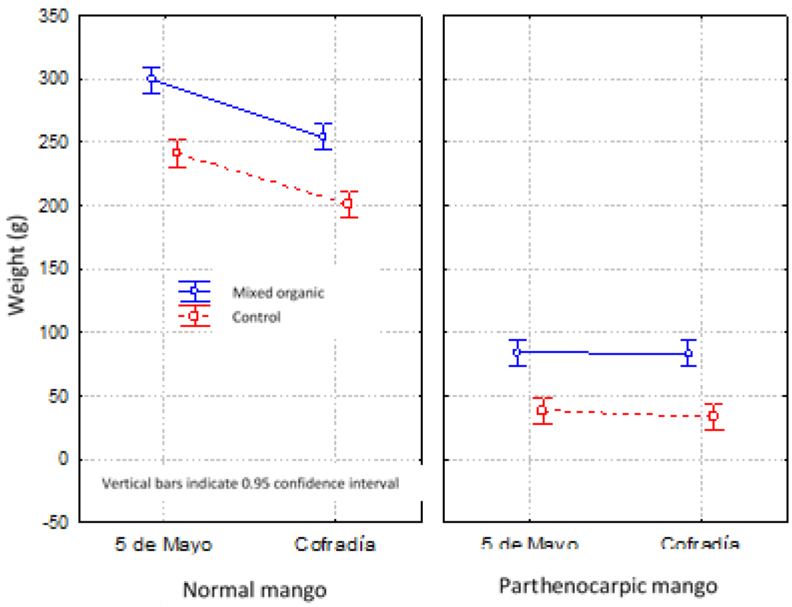

Figure 27. Response of the interaction of sites, type of mango and treatments for the weight (g) of the fruit in the cultivar 'Ataulfo'. 2018

In volume (Figure 28), the response was similar with the exception that in Cofradia, the normal mango volume was similar by applying organic fertilizer or not applying, which is explained because the data from this site correspond to the second crop.

In SST (Figure 29), a trend of higher Brix grades was observed in the control compared to the comparative treatment with organic fertilizer. Subject to its corroboration, this tendency could suggest that the organic fertilizer could be extending the period at maturity of the parthenocarpic mango, especially since the control showed a more mature visual color.

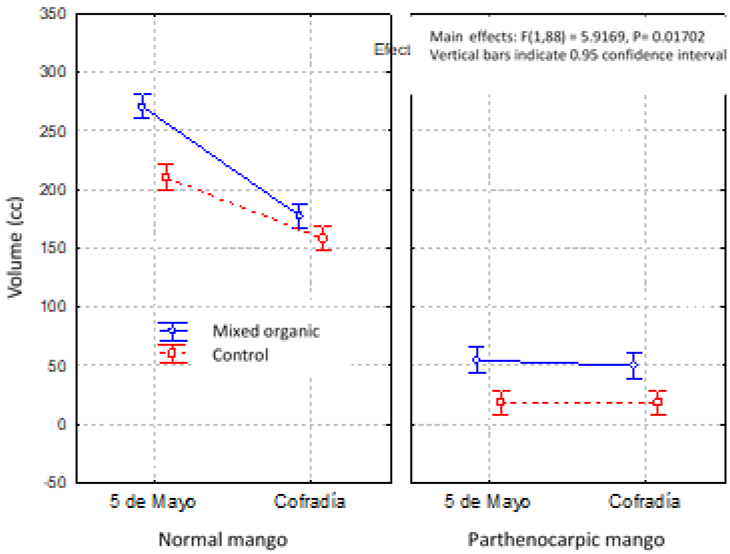

Figure 28. Response of the interaction of sites, type of mango and treatments for the volume (cc) of the fruit in the cultivar 'Ataulfo'. 2018.

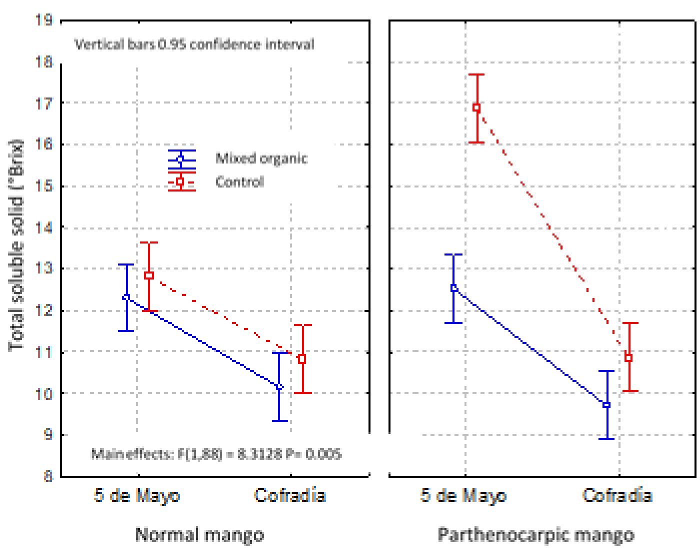

Figure 29. Response of the interaction of sites, type of mango and treatments for total soluble solids (°Bx) of the fruit in the cultivar 'Ataulfo'. 2018.

In 2019, results were obtained on pollinated and parthenocarpic fruit variables: fruit size, weight (g), total soluble solids (SST, °Brix), as well as percentage of pollinated and parthenocarpic mango.

In length (Figure 30), it was observed that, by type of fruit, in pollination, with an average of 11.36 ± 0.16 cm on 5 de Mayo, the length was greater than in Cofradia, with 10.70 ± 0.08 cm, attributable to that in

This town harvested fruits of the second flow. As for parthenocarpic fruit, the values were similar with a mean of 6.74 ± 0.10 cm in length. By treatment, in pollinated fruit, in both locations, Balmix and Aminoác cR, with an average length of 11.30 ± 0.55 cm significantly exceeded the control by 5.50%. While for parthenocarpic, in Cofradia significant differences were observed in favor of Balmix that with 6.92 ± 0.24 cm was 5% greater than the control. However, there are no significant differences at 5 de Mayo, the highest numerical value corresponds to Balmix.

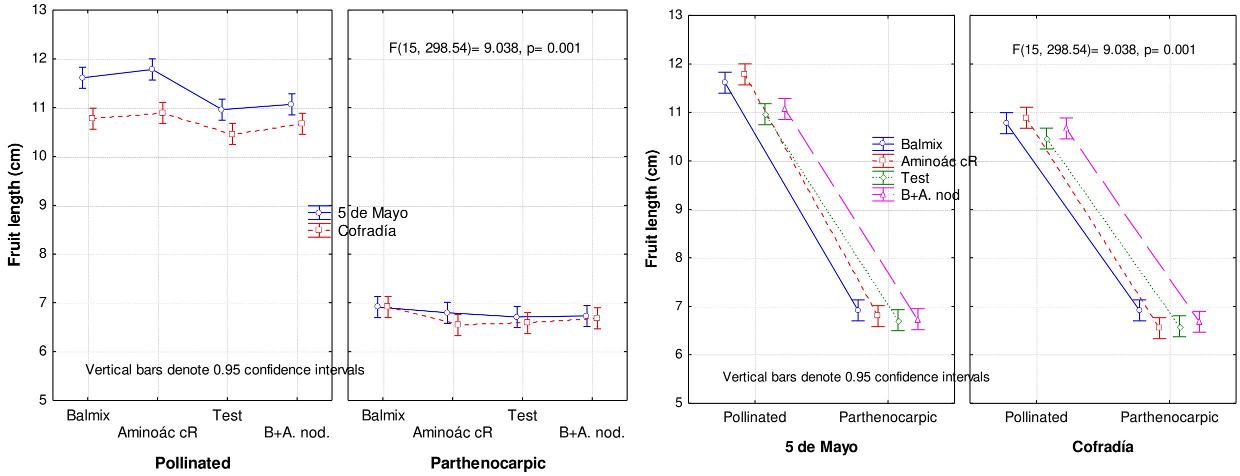

Figure 30. Response of the interaction of localities, type of mango and treatments for the length (cm) of the fruit in the cultivar 'Ataulfo'. 2019.

The results of weight (g) of the pollinated and parthenocarpic fruit, in their individual effects and their interaction are presented in Figure 31. The weight of the fruit was observed differently ($p \leq 0.001$) in both locations, larger in 5 de Mayo, where the pollinated fruit registered a weight of 368.81 ± 6.15 g and 78.95 ± 1.27 g for parthenocarpic fruits. While in Cofradia, fruits of the second crop, weights of 277.23 ± 16.40 g were obtained in pollination and 40.37 ± 2.79 g in parthenocarpic.

By treatments, in pollinated fruit, locality 5 de Mayo, Aminoác cR and Balmix with an average weight of 378.32 ± 2.57 g exceeded the control by 5.05%. While in Cofradia, only the Aminoác cR treatment showed an effect on the weight of the pollinated fruit harvested from the second flow, with an increase of 32.21% compared to the control. In parthenocarpic fruit, locality of Cofradia, contrary to the response in pollination, the treatment that showed effect was Balmix, with a weight of 51.18 ± 4.31 g exceeded the control by 54.93%. In relation to 5 de Mayo, there were no significant differences in the weight of the parthenocarpic fruit as a result of the treatments. The tendency was that Aminoác cR and Balmix with an average weight of 79.91 ± 3.03 g numerically exceeded the control by 3.81%.

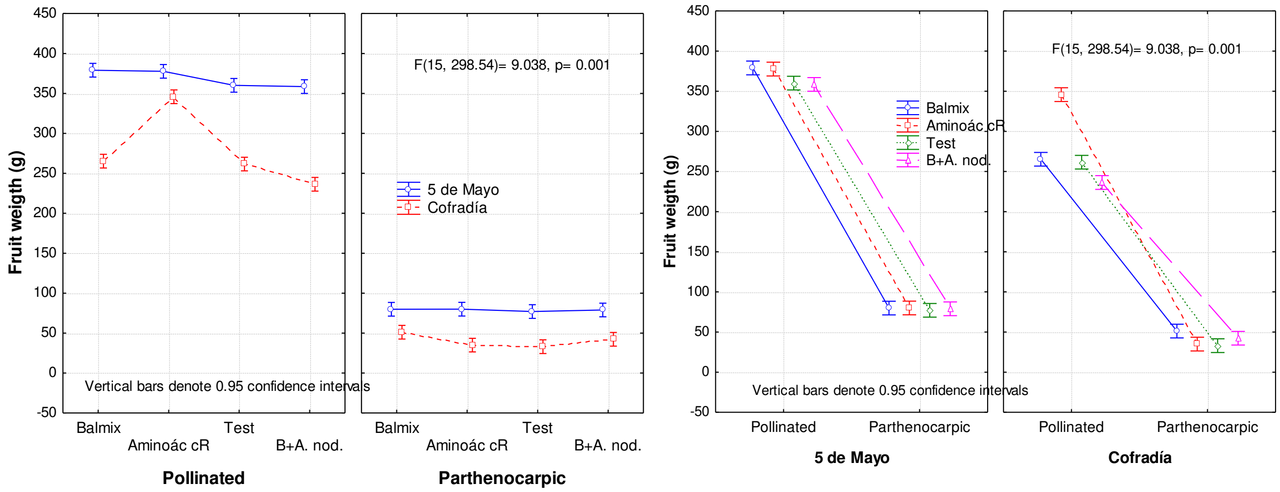

Figure 31. Response of the interaction of localities, type of mango and treatments for the weight (g) of the fruit in the cultivar ‘Ataulfo’. 2019.

In relation to SST (°Brix) (Figure 32), it was observed that at 5 de Mayo, average values of 8.25 ± 0.09 °Brix were recorded in pollinated fruits and of 8.88 ± 0.12 °Brix in parthenocarpic fruits. In Cofradia, 8.94 ± 0.10 °Brix and 9.58 ± 0.18 °Brix respectively. In both locations, °Brix were higher in parthenocarpic fruits.

By treatments, in pollinated fruit it was observed that on 5 de Mayo, the application of Aminoác cR with 8.50 ± 0.23 °Brix, exceeded the control by 4.14%. However, in Cofradia, it showed no effect, since statistically, together with Balmix, the same values were obtained as the control, with an average of 9.02 ± 0.18 °Brix. Regarding parthenocarpic fruit, Aminoác cR and Balmix in both Cofradia (9.88 ± 0.34 °Brix) and 5 de Mayo (8.93 ± 0.17 °Brix) recorded 3.3 and 5.0% more soluble solids than the control.

The percentage of pollinated and parthenocarpic fruits per tree is generally presented by location. Statistics (Mean, standard deviation, standard error and confidence intervals) of the percentage of pollinated and parthenocarpic fruits of 'Ataulfo' mango (Table 10, Figure 33) indicate that at 5 de Mayo, the pollinated fruit was produced in 80.78% of the fruits per tree, with 95% confidence intervals that the pollinated fruit was between 78.60 and 82.95% in the orchard. In Cofradia, the percentage was lower ($p \leq 0.001$), 71.36%, with a probability that at the orchard level it was produced between 67.86 and 74.87% of pollinated fruits. This indicates that in this locality, there was a higher percentage of mango (28.64%), which could have varied in the orchard, from 25.13 to 32.14% of parthenocarpic fruit. at 5 de Mayo, the percentage of “mango niño” was lower ($p \leq 0.001$), from 19.22%, between 17.05 and 21.40% at the orchard level.

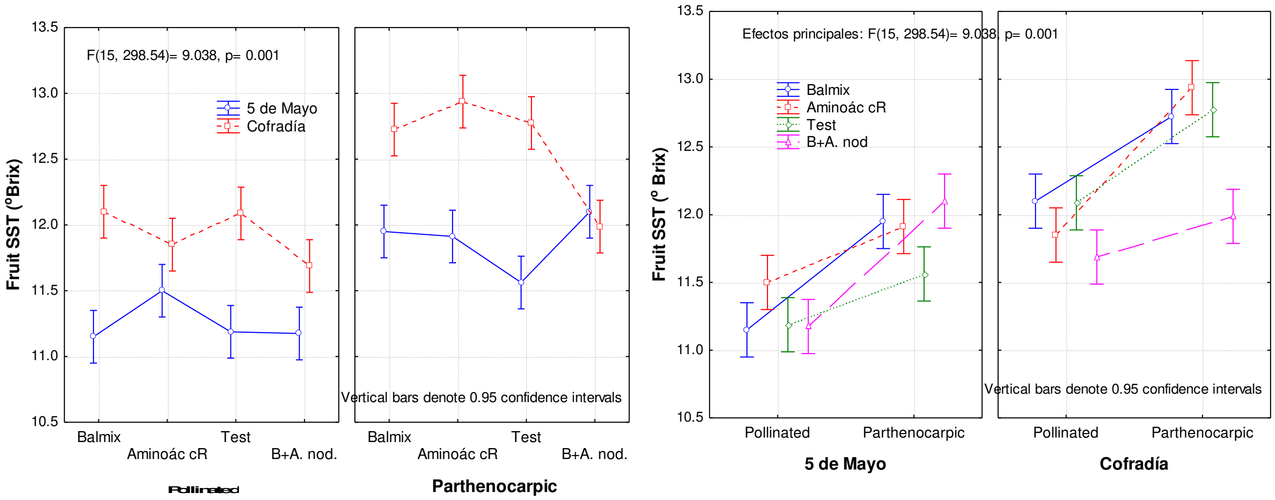

Figure 32. Response of the interaction of localities, type of mango and treatments for SST (°Brix) of the fruit in the cultivar 'Ataulfo'. 2019.

Table 10. Statistics (Mean, standard deviation, standard error and confidence intervals) of the percentage of pollinated and parthenocarpic mango fruits 'Ataulfo', by tree. 2019.

Level of factor		**N**	**Percentage of fruits by tree (%)**				
			Mean	**Std. Dev.**	**Std. Err.**	**-95%**	**95%**
		96	50.00	27.48	2.81	44.43	55.57
5 de Mayo		48	50.00	31.52	4.55	40.85	59.15
Cofradía		48	50.00	23.10	3.33	43.29	56.71
Pollinated		48	76.07	8.32	1.20	73.65	78.49
Parthenocarpic		48	23.93	8.32	1.20	21.51	26.35
5 de Mayo	Pollinated	24	80.78	5.15	1.05	78.60	82.95
5 de Mayo	Parthenocarpic	24	19.22	5.15	1.05	17.05	21.40
Cofradía	Pollinated	24	71.36	8.29	1.69	67.86	74.87
Cofradía	Parthenocarpic	24	28.64	8.29	1.69	25.13	32.14

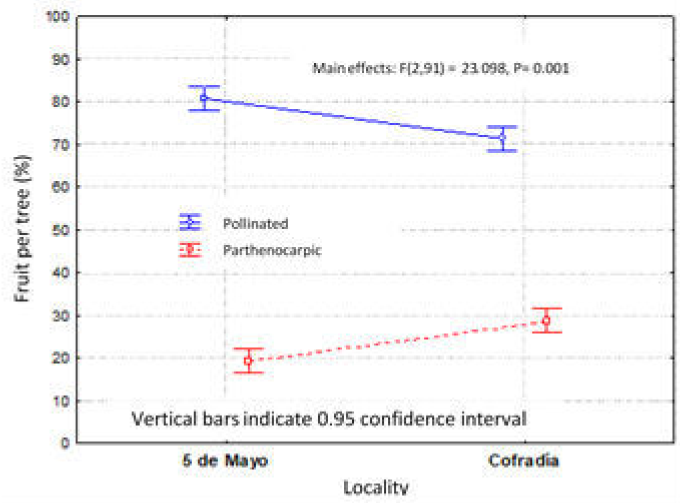

Figure 33. Percentage (%) of pollinated and parthenocarpic fruits by location, in the 'Ataulfo' cultivar. 2019.

Conclusions

A greater increase in size, weight and quality of pollinated and parthenocarpic fruit was achieved with two alternatives of physio-nutritional replacement: 1) mixed organic fertilizer whose source is a vermicompost enriched type Bocashi, identified as Balmix: four applications of leaching at 15%, from match fruit, in biweekly application + two biweekly applications of solid fertilizer, 2 kg per tree, from the first one of the leachate, and 2) Amino acid and nutrient complex identified as Aminoác cR, in doses of 1.5 L ha^{-1}; four applications, one per fortnight, from match fruit.

In pollinated fruit the increases were 6.3% in diameter (cm), 5% in length (cm), 11.2-18.6% in volume (cc), 5% in weight (g) and 4.14% in SST. While in parthenocarpic fruit, the increases were 8.4% in diameter (cm), 5% in length (cm), 20-40% in volume (cc), 55% in weight (g) and 4.00% in SST.

It was not possible to increase the weight of parthenocarpic mango to the value proposed by NOM 188-SCFI-2012 (it was 47% lower), or to the increases achieved with synthetic hormone applications.

The incidence of pollinated fruit was 71 and 81% and the incidence of parthenocarpic was identified in 19-29%.

Results in Guerrero. Dr. David H. Noriega Cantú

Experiment 3. The results of yields of pollinated fruits of the 2017 cycle showed no significant statistical differences (P≤ 0.05), in number and weight of fruits per hectare of the MIM1, MIM2 and the Control treatments (Table 11). The POL fruits of MIM1 and MIM2 weighed an average of 312 g, while the average weight of the Control was 208 g. It is worth mentioning that the fruit size of the MIM1 and MIM2 treatments were classified as large fruits (269 to 323 g), while Control were medium fruits (239 to 268 g) according to NOM-188-SCFI-2012 (Secretary of Economy, 2012). On the other hand, there was a minimum difference in the number of mango fruits POL of the Control and MIM2 with 60 fruits; however, when comparing the weights, the MIM2 exceeded the Control by 4 796 kg ha^{-1}. While MIM1 was the treatment with the highest number of fruits (87 570) and with the highest yield (27 367 kg ha^{-1}).

Table 11. Production of mango fruits cv. 'Ataulfo' in three ways, counting the number and weight of pollinated fruits (POL) and parthenocarpics "mango niño" (PRT) ha^{-1}. 2017 cycle, Atoyac, Guerrero

TREATMENTS[1]	POL				PRT			
	No. ha^{-1}		Kg ha^{-1}		No. ha^{-1}		Kg ha^{-1}	
MIM1	87,570	a[2]	27,367	a	4,184	b	754	a
MIM2	76,990	a	24,059	a	5,206	ab	869	a
Control	77,050	a	19,263	a	8,917	a	597	a

[1] Integrated handling (MIM1), modified integrated handle handling (MIM2) and control
[2] Values with the same letter are statistically equal (P≤ 0.05)

The yields of pollinated fruits in the second cycle 2018 showed significant statistical differences (P≤ 0.05), both in number and weight of fruits per hectare of the MIM1 treatments compared to the MIM2 and Control (Table 12). The POL fruits of MIM1 and MIM2 weighed on average ≥400 g, while the average weight of the Control was 318 g. In this second cycle the MIM2 treatment surpassed the Control with 10 860 fruits; and when comparing the weights, the MIM2 exceeded 4 926 kg ha^{-1} to the Control. The best treatment was MIM1 with the highest number of fruits (46 600) and with yields of 19 942 kg ha^{-1}. The production of normal fruits, POL, was lower compared to the previous cycle.

Regarding the production of "mango niño" (parthenocarpic fruits=PRT), in the 2017 cycle, there were significant differences (P≤ 0.05), in number of fruits per hectare in the MIM2 and Control treatments with respect to MIM1. The Control treatment had the highest PRT incidence with 8 917 fruits ha^{-1}, followed by MIM2 with 5 206 fruits ha^{-1} respectively. The MIM1 treatment had a lower incidence of PRT with 4 184 fruits ha^{-1}. Regarding the yield of "child mango" per hectare, the three treatments (MIM1, MIM2 and

Control) were statistically equal (P≤ 0.05). However, MIM1 and MIM2 contributed greater weight of these fruits compared to the Control.

Table 12. Production of mango fruits cv. 'Ataulfo' under three management, counting the number and weight of pollinated fruits (POL and parthenocarpics ("child mango") (PRT) ha^{-1}. Cycle 2018, Atoyac, Guerrero

TREATMENTS[1]	POL				PRT			
	No. ha^{-1}		Kg ha^{-1}		No. ha^{-1}		Kg ha^{-1}	
MIM1	46,600	a[2]	19,942	a	62,240	b	10,166	b
MIM2	26,540	b	10,920	b	59,400	b	9,702	b
Control	15,680	b	5,994	b	88,320	a	14,426	a

[1] Integrated handling (MIM1), modified integrated handle handling (MIM2) and control
[2] Values with the same letter are statistically equal (P≤ 0.05)

This was due to the fact that the PRT fruits of MIM1 weighed 180 g on average, while MIM2 and Control were 167 and 67 g respectively. It should be noted that the MIM1 and MIM2 treatments produced small fruits (119 to 238 g); the Control registered a greater presence of "child mango" PRT (<118 g) according to NOM-188-SCFI-2012 (Secretary of Economy, 2012). Therefore, when the trend of MIM1 and MIM2 treatments was expressed in weight, they had 754 and 869 kg ha^{-1} of PRT fruits, respectively, while the Control was lower with 597 kg ha^{-1}.

In the 2018 cycle, the production of parthenocarpic fruit increased with respect to the previous cycle, however, the statistical analyzes detected significant differences (P≤ 0.05), in number and weight of fruits per hectare in the MIM1 and MIM2 treatments with respect to the Control. The highest incidence of PRT was again with the Control treatment with 88 320 fruits ha^{-1} with a weight of 14 426 kg ha^{-1}, while MIM1 had 62 240 fruits ha^{-1} and 10 166 kg ha^{-1}, while MIM2 treatment had 59 400 fruits ha^{-1} and 9 702 kg ha^{-1}. In this second cycle, a greater number of PRT fruits was registered compared to the first cycle and in general terms, these fruits weighed an average of 163 grams in the three treatments, which is in accordance with NOM-88SCFI-2012 (Secretary of Economy, 2012).

The results of the present work of two cycles indicate that, under a balanced nutrition, applied in pre-flowering and fruit growth, as well as an adequate management of pests and diseases (MIM1) it was possible to reduce the number of "mango niño" (parthenocarpic fruits) , which may be an indicator that under the conditions where the investigation was conducted the presence of PRT is influenced by some environmental factor (minimum daytime temperature <20 °C) coupled with the physiological factor (nutrition), the latter may decrease its incidence under An integrated management system. In this regard, in Nayarit, Salazar *et al.*, (2016) evaluated the influence of three soil fertilization treatments on the presence of parthenocarpic fruits: 1) normal dose, which considered the demand and foliar nutritional condition of the tree, the contribution of nutrients by the soil and the efficiency of fertilization and consisted of applying per tree, according to the orchard, from 349 to 360 g N, 139 to 147 g P2O5, 163 to 296 g K2O, 13 to 24 g Mg, 11 a 12 g Fe, 6 to 12 g Mn, 2 to 5 g Zn and 4 to 7 g B; 2) 1.5 times the normal dose; and 3) control, without fertilization. These fertilization treatments did not change the proportion of "child mango" that reached harvest maturity.

Conclusion. Balanced nutrition, applied in pre-flowering and adequate management of pests and diseases (integrated management) favors the reduction of the number of parthenocarpic mangos and increases the production of pollinated fruits.

Achievements

Subproject 1. Validation of the mathematical model and its relationship with the development of inflorescence and the production of parthenocarpic fruits.

1. Five mathematical models were generated that explain the dynamics of floral development in Chiapas (two), Guerrero (one) and Nayarit (two) with high predictive power.
2. Mathematical models could be integrated into an early temperature warning system
3. Knowledge about the temperature thresholds that cause the production of parthenocarpic fruits in Chiapas, Guerrero and Nayarit.

Subproject 2. Growth regulators and their effect on pollination, fertilization and set of fruit in 'Ataulfo' mango.

1. Basic knowledge about the role of thidiazuron (cytokinin) and gibberellic regulators in fruit fertilization and set.
2. Basic knowledge about the abortion of the embryo, which corroborates the cause of the parthenocarpy in 'Ataulfo' mango.
3. The fact that, at least in Nayarit, pollination is not involved in the production of seedless fruits is corroborated, although the use of pheromones increased the production of pollinated fruits.

Subproject 3. Validation of techniques generated to increase set and size of parthenocarpic fruits in Ataulfo mango.

1. A technology to be transferred based on a mixture of TDZ + AG_3 in doses of 50 mg L^{-1} of each regulator in four applications at 15, 30, 45 and 60 days after full flowering, to increase the size of the parthenocarpic fruit and increase the production of normal or pollinated fruits in Nayarit.
2. Technology validated based on a mixture of TDZ + AG_3 (50 mgL^{-1}, for each one) in four applications at 15, 30, 45 and 60 days after full flowering, to increase the size of the parthenocarpic fruit in Chiapas.

Subproject 4. Effect of nutrition on the production of parthenocarpic fruits in 'Ataulfo' mango.

1. Technology based on two applications of calcium + boron (1%) sprinkled on the foliage, one in full bloom and the second 15 days later (fruit control), to increase the production of pollinated fruits and improve the size of the parthenocarpic fruits in Nayarit.
2. Technology on balanced nutrition to reduce the number of parthenocarpic fruits in Guerrero

Plans

Submission of articles, summaries and technical publications once they are published.

Problems or delays:

There were no unexpected delays, impediments or challenges during the conduct of this study, except for an extension requested to deliver the final report considering the harvest and yield variables for July 31. But this was due to the same productive cycle of this cultivar, since the harvest will take place between the months of May and June.

The final report of the project is delivered in a timely manner, with respect to the extension granted.

Financing spent to date: Summarize the level of grant funds spent to date.

	Funds received ($) MX	Funds exercised	Concept
1st. Ministering	640 456.00	640 456.00	Useful office supplies, printing, Pesticides, fertilizers and growth regulators, laboratory materials and reagents, fuel, outsourcing of services (assistants), per diem and tickets, maintenance and conservation of vehicles, laboratory and computer equipment, congresses and conventions.
2nd. Ministering	720 513.00	720 513.00	
Total	1 360 969.00	1 360 969.00	

Presentations (oral presentation and Poster).

1. Participation with the exhibition of a Poster at the XX International Congress on Agricultural Sciences, held from October 26 to 27, 2018 in Mexicali, Baja California.

"Relationship between temperature, development of inflorescence and production of parthenocarpic fruits in 'Ataulfo' mango"

2. Participation with poster in the XXVII National Congress and VII International of Plant Genetics, held from September 24 to 28, 2018 at the Graduate College, Campus Montecillo, State of Mexico.

Growth regulators and their effect on pollination, fertilization and set of parthenocarpic fruits in 'Ataulfo' mango.

3. Participation with oral presentations and posters in the Congress of the Mexican Society of Horticultural Sciences (SOMECH) that will take place at the end of October this year in Michoacán.

Works submitted:

1. Temperature and floral development in mango cultivate Ataulfo. Extensive work. In Review. Arturo Álvarez
2. Incidence of parthenocarpic fruit in 'Ataulfo' mango. Extensive work. In Review. Arturo Álvarez

3. Boron, calcium and nitrogen in the production of child mango. Summary. In Review. Maria Hilda Pérez Barraza.
4. Studies on pollination with pheromones in 'Ataulfo' mango. Summary. In Review. Maria Hilda Pérez Barraza.
5. Increase in size of parthenocarpic fruit and mango production 'Ataulfo', through cytokinins and gibberellins. Extensive work under review. Maria Hilda Pérez Barraza.

Peer review articles or summary

- **In process**

1. Technical brochure "Integrated management to increase size of parthenocarpic fruits and increase production in 'Ataulfo" Mango. In review by CESIX Technical Committee. Maria Hilda Pérez Barraza.
2. Effects of temperatures on the production of parthenocarpic mango and its management. Technological publication in preparation. David H. Noriega Cantú.

- **Submitted**

Scientific article "Temperature and floral development in the formation of parthenocarpic fruits in 'Ataulfo' mango, Accepted by the Mexican Journal of Agricultural Sciences (acceptance annexed)

- **Published**

1. Scientific article published in the Mexican Journal of Agricultural Sciences "Effect of chemical nutrition in the production of parthenocarpic fruits in 'Ataulfo' mango. Irma Julieta González Acuña. (annexed).
2. Summary published in memoirs of the XX International Congress on Agricultural Sciences, held from October 26 to 27, 2018 in Mexicali, Baja California.
3. Summary published in Phytogenetic Record Vol 5 No. 1 October 2018.
4. Thesis at the Bachelor's level, with the obtaining of the degree in May 2019 by María Verónica Santos Cárdenas.
5. Thesis at the Bachelor's level in the process of presenting the exam by Javier de Jesús Mercado Banda.

Other products

- Presentation Workshop of producers and extension 2018 Los Mochis, Sinaloa Mexico.
  Mango parthenocarpy 'Ataulfo' research advances.
- Presentation Workshop of producers and extension 2018 Mazatlan, Sinaloa Mexico.

Mango parthenocarpy ‘Ataulfo’ research advances

- Presentation Workshop of producers and extension 2019 Guayaquil Ecuador.
- Training course for producers and technicians “Pruning of cup reduction and integrated management of mango (child mango). David Noriega Warrior.
- Training course for producers and technicians: Advancement of results of child mango (parthenocarpic fruits) and white scale (*Auslacpis tubercularis*) mango on the coast of Guerrero. David Noriega

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carbohidratos número y tamaño de células. Revista Mexicana de Ciencias Agrícolas 19: 3855-3868.
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