Techniques to advance flowering in export mangoes

Técnicas para adelantar floración en mango de exportación

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Centrosur
Instituto Superior Edwards Deming, Ecuador
ISSN-e: 2706-6800
Periodicity: Trimestral
vol. 1, no. 13, 2022
centrosuragraria@gmail.com

Received: 09 April 2021
Accepted: 25 November 2021

URL: http://portal.amelica.org/ameli/journal/646/6463152008/

Abstract: Ecuador has been exporting mango since the 1990s, however, there is currently no established agricultural methodology to help farmers increase productivity and lower production costs while maintaining mango quality and safety; therefore, it is necessary to develop sustainable and sustainable methodologies for the benefit of mango producers. This research seeks to develop procedural techniques that benefit the agroexport sector through the use of mango production strategies to advance harvests, based on an exhaustive review of books and scientific articles. The various activities carried out in mango cultivation, pruning, fertilization, irrigation, phytosanitary controls, among others, are cultural tasks that will determine the productivity and quality of the fruit. All the activities carried out in mango cultivation are links that form the productive chain of the agroexport activity.

Keywords: Cultural activities, Mangifera indica, production.

Resumen: El Ecuador inicia la exportación de mango desde los años 90, sin embargo en la actualidad no hay una metodología agrícola establecida que ayude a los agricultores a elevar la productividad y bajar costos de producción, manteniendo la calidad e inocuidad del mango; por lo tanto, es necesario desarrollar metodologías sustentables y sostenibles en beneficio de los productores de esta fruta. La presente investigación busca desarrollar técnicas de procedimientos que beneficien al sector agroexportador mediante el uso de estrategias de producción de mango para adelantar cosechas, a partir de una exhaustiva revisión de libros y artículos de carácter científico. Las diversas actividades realizadas en el cultivo de mango, poda, fertilización, riego, controles fitosanitarios, entre otras; son labores culturales que determinarán la productividad y calidad de la fruta. Todas las actividades que se realizan en el cultivo de mango son eslabones que forman la cadena productiva de la actividad agroexportadora

Palabras clave: Labores culturales, Mangifera indica, producción.

Introduction

Globally, pineapple, avocado and mango are the three most traded tropical fruits, excluding bananas. Because of the rapid increase in global demand (FAO, 2018).

In Ecuador, the mango varieties exported are Tommy Atkins, Kent, Ataulfo, Haden, Keitt, Nam Doc Mai, Madame Francis, Osteen. Being the Tommy, Kent and Ataulfo with the highest percentage of kilos exported respectively, consequently represents the largest areas planted with mangoes for export, totaling 7,700 hectares of mango for export. (Fundación Mango Ecuador, n.d.-a).

In the 2020-2021 mango season, 12,250,228 4kg boxes were exported, the main exporters as fresh fruit were; the United States of America representing 94.10%, Canada with 2.59% and Europe with 1.33%.(Fundación Mango Ecuador, n.d.-b). In the domestic market it is marketed as fresh fruit, jam, dehydrated and pulp, its exquisite flavor and high content of vitamins and minerals make the consumption of this fruit year after year increases its demand in the domestic and foreign markets.

The beginning of the harvest starts in the month of October and generally ends in the month of December, being this window of production attractive in terms of prices since in the international market, Brazil is finishing its export and Peru starts its harvest in the month of December. This is the export behavior to our main mango market, which is the United States.

The main mango-producing areas are in the province of Guayas, in the canton of Balzar, Palestina, Nobol, Pedro Carbo, Lomas de Sargentillo, Boliche, Chongon, and Cerecita. In the province of Los Ríos, mainly Vinces. In El Oro, the Machala canton (Fundación Mango Ecuador, n.d.-a).

When deciding to plant mango, the planting frame, the relief of the terrain, the variety and the climatic conditions of the place are determined. Being higher in the dry tropics due to the slower growth of the trees. (Galán Saúco, 2009).

In the beginning of mango planting for export, the distances were 10m X 10m, 9m X 9m, 8m X 8m; then preceded the use of high planting density, to increase productivity, with orientation from north to south to take advantage of daylight. Mango farmers do not agree on the various planting densities, which range from 200 to 4000 trees; however, it is not possible to increase productivity without greater effort. (Menzel y Le Lagadec, 2017).

In research conducted by Luis et al. (2008)the Springfiels and Tommy Atkins varieties of low and medium size, respectively, were those that obtained the highest productivity, followed in decreasing order by Haden and Edward characterized, respectively, by high and intermediate vegetative vigor with a planting distance of 6m X 6m and a density of 278 plants per hectare.

Several types of pruning are carried out in mango cultivation, starting with formation pruning, which begins when the plants settle in the final soil and is crucial to obtain trees with a good architecture at the time of harvesting and phytosanitary controls, since these tasks represent significant items when managing an export plantation.

Generally the first cut is made in the form of bevel at knee height or 50 cm from the ground up, then the development of leaf growth is chosen two to three branches, choosing those that are more vigorous and to be seen in balance the two or three vegetative buds that will remain, then after the vegetative growths have reached the necessary maturity (2 to 3 months) is made another cut at 25 to 30 cm giving the same height to the top of the small tree, After the vegetative buds of the last growth have matured again, continue with the bevel cut and with the same criteria that started at 25 to 30 cm, but here also cut the branches that

cross inside the crown and the tree begins to form a balanced shape giving shape to the upper part of the tree (crown).

Fruiting pruning , this is generally done annually after harvest, where the foliar growth of one or two internodes is cut, depending on the size of the same, or at the same time the top of the tree is cut from 20 cm to 40 cm, verifying that the top of the trees do not touch each other, as for the height is sought to reach 3.5 m to 4 m maximum, this facilitates the harvest lowering costs, phytosanitary controls are more efficient and the implementation of technology to improve the quality of the fruits. In recent years, pruning is carried out with machinery, calculating the centimeters that need to be cut from the tree to be pruned and the pruning is carried out. Here the intertwined branches are also cut and a 30% crown opening is left, in order to allow air to circulate and the sun's rays to enter, which contributes to improve coloring, especially in red varieties.

In research conducted in Venezuela, on haden cultivar, observing the effects of pruning on reproductive variables, it was concluded that "Intermediate pruning (30 cm) tends to stimulate flowering and fruit set. Light pruning (20 cm) and severe pruning (40 cm) adversely affected the total soluble solids content of the fruit. Likewise, light pruning affects fruit color, and heavy pruning affects flesh firmness. It is recommended to use an intermediate pruning (30 cm) in December to improve flowering and fruit set. (P. y Leal, 1998, p. 22)

Phytosanitary pruning , this is done at any time of the year depending on the damage that some branches present, here the branches that are damaged by insects or any disease are cut. This pruning is also done at the time of fruiting pruning.

Rejuvenation pruning , is carried out when trees generally have not been pruned for years, harvesting and phytosanitary controls become difficult, affecting fruit quality. According to Davenport (2011)According to Davenport, these trees are cut at breast height or lower, regardless of trunk diameter, and the cuts should be treated with white water paint or lime (calcium hydroxide solution).

Fertilization is one of the most complex tasks in mango cultivation because of the diversity of genotypes, planting density, environmental factors, phenological phases, and rootstocks, among others. The literature does not reflect precise specifications on fertilization programs, so it is necessary to establish a fertilization plan for each particular site through a previous analysis of the aforementioned characteristics.

The mango producing zones are well defined, a dry tropical climate zone and a rainy tropical climate zone, therefore soils and soil fertility are very different. In the rainy zone, leaf growth is more aggressive than in the dry zone.

Table 1. *Appropriate values for a soil intended for mango plantation.*

Table 1
Appropriate values for a soil intended for mango plantation.

Element	Range
pH	5.5-7.0
C Organic	1-2%
CE	<0.2 (dSm)
N	<10 mg/kg
P	60-80 mg/kg
K	0.25-0.40 meq/100g
Ca	3-5 meq/100g
Mg	0.75-1.25 meq/100g
S	>12 mg/kg
Na	<1.0 meq/100g
Cl	<2.50 mg/kg
B	1-2 mg/kg
Zn	2-15 mg/kg
Mn	4-50 mg/kg
Faith	4-100 mg/kg
Cu	0.3-10 mg/kg
Cation exchange	≈5
% Na	>1%
% K	5 %
% Ca	65-80 %
% Mg	15-20 %

Table 2. *Optimum nutrient levels in* mango*leaves.*

Table 2
Optimum nutrient levels in mangoleaves

Nutrient	Unit	Desired range
Nitrogen	(% N)	1 - 1.5
Sulfur	(% S)	0.1 - 0.2
Phosphorus	(% P)	0.1-0.2
Potassium	(% K)	0.75 - 1.2
Calcium	(% Ca)	2.0 - 3.5
Magnesium	(% Mg)	0.15 - 0.4
Sodium	(% Na)	<0.20
Chlorine	(% Cl)	<0.25
Boron	(ppm B)	50 - 70
Zinc	(ppm Zn)	20 - 100
Copper	(ppm Cu)	10 - 20
Iron	(ppm Fe)	30 - 120
Manganese	(ppm Mn)	60 - 500
Molybdenum	(ppm Mo	(0.05-1.0)

Source: QDALF (2015)

Nutrient extraction by the plant is something to consider, since the extracted elements must be replaced in order to achieve adequate crop development; in studies conducted by Mellado-Vázquez et al. (2012) in mango varieties cv. Haden and cv. Tommy Atkins the approximate amounts of the following macronutrients are required in kg t-1 of fresh fruit: N 1.03-1.11, P 0.22-0.24, K: 1.88-2.14, Ca: 0.21-0.31, Mg: 0.14-0.15, S: 0.28-0.33 and in g t-1 of fresh fruit the micronutrients: Fe: 3.52-3.87, Cu: 1.02-1.17, Mn: 3.22-4.80, Zn: 2.06-2.88 and B:1.55-1.66.

Table 3 shows the results obtained by Cruz-Barrón et al. (2014) on the macronutrient requirements of 'Ataulfo' mango, managed with annual or biannual pruning, where it can be observed that the values obtained are higher than those mentioned above for the Haden and Tommy Atkins cultivars.

Table 3. *Macronutrient requirements of 'Ataulfo' mangoes, managed with annual or biannual pruning.*

Table 3

Macronutrient requirements of 'Ataulfo' mangoes managed with annual or biannual pruning

Nutrient	Kg
N	4.19
P	0.79
K	7.19
Ca	3.67
Mg	0.93

Source Cruz-Barrón et al. (2014)

Another aspect to consider is the time of application, which should be done according to the phenological stages of the crop. The use of N is recommended at the beginning of vegetative growth, beginning of fruit growth and after harvest to enhance new sprouting growth (Galán Saúco, 2009). Phosphorus is of special relevance during the period of root development and at the time of flowering and the beginning of fruit growth, so it should be applied at these times as long as there are not sufficient quantities in the soil. Potassium should be supplied one month before flowering, or when there is a deficiency in the leaf. Boron, sulfur and magnesium should be incorporated one month before flowering, the rest of the micronutrients can be foliar applied during flowering as this is the most effective method. (Ram et al., 2019).

Farmers usually fertilize twice a year, with N, P and K, after harvest or at the time of pruning and at flowering time of the mango plantation. All mango plantations are technified with various irrigation systems, mainly micro-sprinkler and drip irrigation. For logistic reasons and to lower costs, most of the plantations have fertigation systems. Farmers who do not use fertigation apply fertilizers by broadcasting or simply bury them in the soil, in the middle part of the canopy projection towards the outside.

In general terms, the following infographic can be used to program fertilization of the four elements that most influence mango productivity.

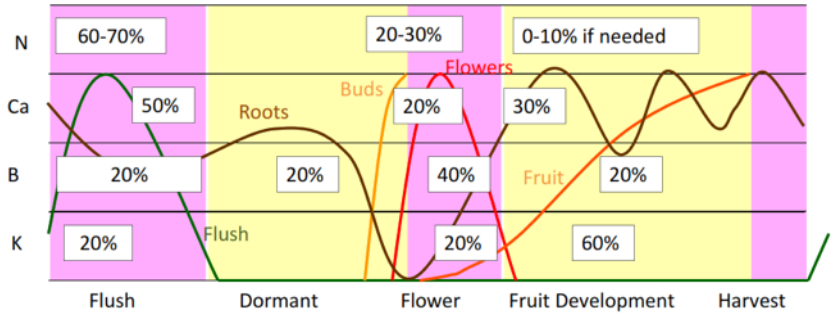

FIGURE 1

Nutrient requirements as a function of the phenological stage of the mango crop.

Nitrogen plays a very important role when you want to bring forward the harvest. Excess nitrogen causes vegetative growth not to stop and ignores flowering even when climatic conditions are favorable for anthesis.

Phosphorus , is an important component in the nutritional part since it is essential in the growth and development of plants, therefore phosphorus fertilizer applications are required to achieve good productivity, considering that most soils do not have assimilable phosphorus. (María Teresa Fernández, 2007).

Potassium . Undoubtedly one of the most essential elements required by the mango tree to obtain high yields and fruit quality. (Galán Saúco, 2009).

Magnesium. Along with nitrogen, potassium, calcium and magnesium, mango extracts significant amounts of these elements. (Galán Saúco, 2009).

Boron and zinc . According to (Huete y Arias, 2007) quoting Tom Davenport writes that the soils of Central and South America lack trace elements (zinc and boron are the most important elements responsible for the development of fruit color and texture). He recommends that these elements be maintained at a concentration of 100 pm each in the leaves.

Calcium . In research conducted in Mexico by Romero et al. (2006) in cv. Haden, the trees that received calcium applications increased their productivity versus the control that did not receive Ca, likewise the nutritional demand in mango fruits was K>N>Mg> Ca. Calcium in fruit trees in optimal amounts can be better transported and maintained in better condition for a longer period of time. Therefore, optimal amounts can improve the postharvest life of mangoes. (Agust, 2010).

Materials and methods

A systematic review (scientific articles, indexed journals, books (according to the subject matter) from recognized international publishers) was used as an exploratory and analytical technique for the collection of relevant information on existing, updated and effective procedures to advance flowering in mango for export.

In general, we used the procedure for reviewing articles proposed by Codina (2020)The following meta-search engines were consulted: science direct (Scopus), Google academic, Springer, Scielo, Redalyc, latindex.

Key words related to mango flowering and the various techniques that exist internationally and nationally to accelerate flowering were used. The information

was systematized using criteria based on the reliability of the research, logical reasoning, results achieved by the authors and novelty (articles from the last 5 years were considered as the most relevant). With the information selected, the most relevant results were chosen, which were compared and discriminated according to the research objectives. The results and ideas were condensed and a conceptual map was prepared to facilitate the writing of the document. The analysis and consultation of experts contributed to the writing and completion of this research article.

Result

Mango farmers are accustomed to make applications of paclobutrazol (PBZ), in the month of February in order to induce early flowering, treatments with PBZ, decrease gibberellin contents, increasing abscisic acid and cytokinin contents accompanied with C: N ratio and leaf . w in mango shoots to stimulate flowering responses. (Upreti et al., 2013).

PBZ applications are generally accompanied by fulvic acids in order to improve the absorption of the product in the roots of the plant. The addition of fulvic acid to paclobutrazol improves the absorption of this molecule by the plant, with superior inhibition of vegetative development of 'Keitt' mango and minimal remnants in the soil. (Silva et al., 2020).

The recommended dose of PBZ (at 25%) is 1 g of active ingredient per linear meter of canopy, mainly with the Tomy atkins variety. This application is related to the capacity of vegetative sprouting such as the Haden and Kent varieties that need to increase the dose. Many times the dose will depend on the vigor of the tree and the variety, the most efficient way to apply the product is to dilute it in 2 liters of water and place it uniformly on the ground around the trunk. It is very important to apply this product after pruning when there are at least two vegetative flows. Likewise, when there were satisfactory results in the first year of application of PBZ, the second year the dose is lowered by 70% to 50% of the dose used in the previous year. (Embrapa, 2010). Low temperatures, water stress together with the maturity of the last leaf growth are conditions that must be met to initiate the flowering process in mango, foliar spraying of potassium sulfate has been normalized in mango growers in order to stop leaf growth, with doses of 2% and 2.5%. The use of foliar etephon also participates in the maturation process of the last foliar growth and promotes flowering. The application should be foliar at doses of 200 to 300 ppm. (Embrapa, 2010).

In recent years, the use of mineral broths such as sulfocalcic, is being used to help mature the last leaf growth, to control mites in case of presence in the crop and as a preventive control of diseases. The low cost of making this mineral broth has led to its normal use in a mango production program for export. The dose used is 1% of the mineral broth solution. Flowering begins when temperatures start to drop from 22 oC. at the end of May with early varieties such as ataulfo and haden, followed by the tomy atkins variety in June, then kent in July. In studies carried out by Puche et al, (2012), Castillo-Morales (2000)Avilan et al, (2002) refers that flowering is determined by water stress, crop management and in a natural way, with low temperatures.

In tropical climate regions, flower induction in mango trees is a practice that is carried out in plantations dedicated to the export of this fruit, with the purpose of obtaining it out of season and gaining economic returns at the time of selling the fruit. The use of 2% to 4% ammonium nitrate, 2% to 4% calcium nitrate and 2% to 6% potassium nitrate is very common to induce flowering. However, research conducted by Castillo-Morales, (2000)However, research carried out by the company, determined that applications of PBZ followed by foliar sprays of potassium nitrate at 2%, 4% or 6% caused anthesis 16 days after treatment. Also, the highest number of emerging flowers was obtained with PBZ and 6% potassium nitrate.

When flowering begins it is necessary to take into account the irrigation, this is done in varieties such as tommy atkins, at the time that the flowering is defined. In varieties such as kent and ataulfo, if the flowering is not defined, mixed flowers and vegetative flows can occur.

The mango crop is attacked by some diseases and pests that affect the production and quality of the fruit, to the detriment of farmers' income. It is useless to make a good management in all the cultural labors of the crop if there is no efficient management of these pests.

Colletotrichum gloeosporioides, considered one of the main diseases present in mango, generally present in all phenological stages of the crop, attacks panicles, fruits in growth and postharvest, causing preharvest losses. (Gil et al., 2013), (Gómez-Lim et al., 2011) citing (Cook, 1975). Generally, chemical synthesis fungicides and biofungicides are used to control this disease, mainly in flowering and fruit growth.

It appears as a white powder composed of conidia and mycelium is one of the only pathogens that can have sporadic incidence, but can generate losses up to 90% of production. The most susceptible phenological (critical) stages were in full bloom and at the beginning of fruit set at 8-15 mm. Optimum conditions for powdery mildew development, which maximizes the density of spores in the air, are temperatures above 30°C and relative humidity above 90%. (Pérez-Rodríguez et al., 2017). Sulfur-based fungicides and fungicides of the propiconazole family are mainly used to control this disease.

Growing fruits with exudates and some with the appearance of rot are attributed to this disease. In research conducted in Mexico, in kent, ataulfo and tommy atkins varieties. The symptoms of mango fruits and branches were described. Fruit rot, light to dark brown in color, originated around the peduncle and extended along it with wavy margins. In the trees sampled, branches were observed with downward drying that started at the apex and advanced towards the base of the branch, contrasted with branches of normal appearance, and showed necrotic vascular bundles and reddish gummy exudates. In an advanced stage of downward dieback, the trees exhibited drying with partial defoliation and branches with dry, green leaves. (Sandoval-Sánchez et al., 2013), (Paola Alejandra Picos-Muñoz, Raymundo Saúl García-Estrada, Josefina León-Félix, 2015). This disease is controlled with the same products used for anthracnose.

Among the main pests affecting mango production, we found thrips, this insect increases in mango panicles and when it is in pin point(8mm), it damages fruit quality; however, when the availability of flowers and tender fruits ended, the populations decreased (Trujillo et al., 2017).

Mites are one of the factors that affect mango production; sulfur applications are recommended because of their low cost and environmental friendliness. (Trujillo et al., 2017). The symptoms of mites are evidenced by denitrification of their leaves in some varieties such as tommy atkins, their leaves turn silver color in other varieties such as kent and ataulfo the leaf takes an appearance of burned by fire; in the fruits there is a loss of color giving an opaque appearance, damaging the quality of mangoes. (Flores Canales et al., 2011)

Two fruit flies are present in the country: ceratitis capitata or Mediterranean fruit fly and the anastrpha genus. The damage they cause to fruit makes this pest the number one enemy of growers. Exports are affected in the absence of efficient control, due to the quota measures imposed by the main export markets. The monitoring of this pest by the Agrocalidad authorities ensures that there is efficient control with Integrated Pest Management of this pest using products such as Spinosad, ceratrap and malathion, together with other cultural measures such as harvesting of ripe fruit in the field, weed control, etc.(Valarezo, 2011).

After approximately 120 days after the panicle was 10 cm long, the harvesting process begins, the field is walked and the shape of the mango is observed. Among the morphological characteristics of the mango fruit, it is observed that it has shoulders and in some cases in the peduncle area may be sunken, after visually identifying the mangoes, we proceed to make a longitudinal cut near the testa(pepa) to observe the physiological maturity, a yellow coloration should be observed that comes from the contour of the testa outward. Physiological maturity can be judged by a combination of factors, including internal factors such as color change, firmness, SSC (Brix percentage) and fruit shape. (Mango Board, n.d.).

Conclusions

The study explained that the IV-range products are currently in good use of the applied method, since they have been declared as the food of the future since they maintain the freshness of fruits and vegetables, improving the convenience for consumers and encouraging the consumption of fruits and vegetables based on these processes in order that people eat healthily and thus avoid diseases.

It is necessary that, when using the type of packaging material for fourth range and IV-range products, they are specifically designed to facilitate sealing and thus achieve a better balance of reliability, firmness to slipping and resistance to the type of material; and especially to humidity. The packaging, whether plastic bags, trays or tubs, can prevent water loss, thus avoiding the loss of vitamins and minerals in packaged foods.

They are also considered to maintain the relative humidity in the container, thus extending the volume of processed vegetables and fruits helping to maintain the freshness of the product.

Regarding the growth of microorganisms, it can be considered that the conditions of fresh-cut products are mainly composed of water, resulting in a high water activity (> 0.99). Intracellular pH is another important intrinsic factor and varies for most of these minimally processed products from 4.9 to 6.5. The bruised areas of the plant tissue facilitate a better substrate for microbiological growth by providing nutrients and the properties of the tissue

check which microorganisms will be active and which allow the growth of these at the time nutrients are available resulting in a risk of microbiological contamination especially to these products passed through this minimally processed medium.

Finally, one of the advantages and disadvantages of fresh-cut products are the technologies applied to extend the shelf life of the product, but it will depend on many factors. It is also necessary to know that these products can last up to 21 days according to a study, after that time they tend to degrade, but not by microorganisms but by volatile substances and enzymatic and non-enzymatic browning.

The technologies applied in the production of fresh-cut foods are products whose shelf life will depend on many factors, among them: the quality of raw materials, the technology used in their production, the incidence rate and the interaction with sources of microbial contamination.

The disadvantage is during misuse in processing, as well as controlling the temperature during storage of the products, not allowing acceptance by consumers due to irradiation and physical and chemical changes during food processing.

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