Influence of solar radiation on mango fruit growth and its biological optimum (Mangifera indica) through regression in Cerecita exporting zone, Guayas Province

Influencia de la radiación solar sobre el crecimiento de frutos de mango y su optimo biológico (Mangifera indica) a través de regresión en Cerecita zona exportadora, Provincia del Guayas

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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: 13 May 2021
Accepted: 27 October 2021

URL: http://portal.amelica.org/ameli/journal/646/6463152001/

Abstract: This research work analyzed the influence of solar radiation on the growth of mango fruits (Mangifera indica L.) in the province of Guayas. This project was carried out in the following mango exporting zones of the Tommy Atkins variety: Balzar - Producer A, Nobol: Producer B and C, Palestina - Producer D and Cerecita: Producer E, F and G, where only the information particular to Cerecita was analyzed. The methodology was descriptive analytical; the results were obtained using statistical methods of regression and multiple linear correlation. The variables taken were: solar radiation, precipitation, relative humidity, average temperature and fruit size in the area under study. The values of the climatic factors were defined with the help of data obtained from INAMHI from 1984 to 2018; likewise, it was determined that there is no variation in climate change in the variables mentioned above, except for the average temperature, which indicates that it increases about 0.03 degrees Celsius with each elapsed year; finally, the influence between solar radiation and fruit size was analyzed, finding that there is no correlation between the variables. Concluding this research, several authors stated that, with an adequate integrated management of the crop and soil (nutrition, water, relevant cultural tasks, etc.), it would be sufficient to increase the size of the fruits of the Tomy Atkins mango variety.

Keywords: climatic factors, Guayas, mango, Tommy Atkins, solar radiation. 23.

Resumen: En este trabajo de investigación se analizó la influencia de la radiación solar sobre el crecimiento de frutos de mango (*Mangífera indica L.)* en la provincia del Guayas. Este proyecto se lo realizó en las siguientes zonas exportadoras de mango variedad Tommy Atkins: Balzar- Productor A, Nobol: Productor B y C, Palestina – Productor D y Cerecita: Productor E, F y G, donde solo se analizó la información particular de Cerecita. La metodología fue analítica descriptiva; los resultados se obtuvieron mediante métodos estadísticos de regresión

y correlación lineal múltiple. Las variables tomadas fueron: radiación solar, precipitación, humedad relativa, temperatura media y calibre de frutos de la zona en estudio. Se definieron los valores de los factores climáticos con ayuda de datos obtenidos del INAMHI desde 1984 hasta 2018; así mismo, se determinó que no existe variación en el cambio climático en las variables antes mencionadas, a excepción de la temperatura media, el cual indica que aumenta unos 0,03 grados centígrados con cada año transcurrido; por último, se analizó la influencia entre la radiación solar y el calibre de los frutos, encontrándose que no existe correlación entre las variables. Concluyendo esta investigación, según diversos autores manifestaron que, con un adecuado manejo integrado del cultivo y del suelo (nutrición, agua, labores culturales pertinentes, etc.), sería suficiente para incrementar el tamaño de los frutos de mango variedad Tomy Atkins.

Palabras clave: factores climáticos, Guayas, mango, Tommy Atkins, radiación solar. 23.

Introduction

In Ecuador, the cultivation of mango (*Mangifera indica L*), Tommy Atkins is one of the main varieties of mango grown, is of great importance due to its nutritional source of vitamins, mainly rich in beta-carotene and vitamin A, essential for development and growth, favor the body's immune system, and have antioxidant properties. It also provides vitamin C, necessary for the growth and repair of body tissues, healing, promotes the absorption of iron, among other functions; folic acid, especially important in pregnant women for the normal development of the baby and to prevent anemia. (Vargas-Salgado et al., 2022 p .461)

Mangoes are one of the most demanded fruits worldwide by exporting countries. Due to its color, flavor and for being a shock resistant fruit, the Tommy Atkins mango is a very desirable fruit for the international market. In the 2018 season, producers in all export zones indicated that one of the main production problems was the size of the fruit, since around 50% of the production, the average fruit weight was less than 333g, that is, an irregular year due to the low weight of the fruit. (Llamas-Molina et al., 2022)

During the mango harvest season, farmers indicated that the size of the mango fruit is very small, which caused mango exports to decrease and therefore prices to drop, causing losses to the export sector. Some farmers attribute this anomaly to low solar radiation and various climatic factors.

Table 1. *Main* mango *growth stages*

Table 1
Main mango growth stages

Stadium	Description
0	Germination, sprouting, bud development
1	Leaf development (shoot or main stem)
	Formation of lateral shoots / tillering (tillering)
	Stem longitudinal growth or rosette growth, shoot development (shoots)/candleshoot (main stem)
	Development of harvestable vegetative parts of the plant or vegetative organs for propagation/embudding
5	Inflorescence (main stem) emergence / spiking
	Flowering (main stem)
	Fruit development
	Coloration or ripening of fruits and seeds
	Senescence, onset of dormancy

Novartis and Dachler, 1998

Materials and methods

The work was carried out in exporting areas of Tommy Atkins mango in Guayas, in the Cerecita area, producers E, F and G.

The research was carried out using descriptive analysis of inferential statistics, correlation and multiple linear regression, more than one explanatory variable was used; this offered the advantage of using more information in the construction of the model.

Independent variables

Cerecita Export Zone

Dependent variables

The corresponding data were obtained from the Inamhi database for the last 34 years.

· Solar radiation· Precipitation· Average temperature· Relative humidity· Fruit sizes: Fundación Mango Ecuador was asked for the records of the number of boxes exported in the last 5 years from each producer under study, detailing the quantity of fruit and size.

Outline Of Regression And Linear Correlation Analysis

Multiple linear regression model $Y = \beta 0 + \beta 1X1 + - - - - + \beta pXp + \varepsilon$

Where:· $\beta 0$ is the independent term. It is the expected value of Y when X1, . . ., Xp are zero.· $\beta 1, \beta 2, \ldots, \beta p$ are the partial coefficients of the regression:

· $\beta 1$ measures the change in Y for each unit change in X1, holding X2, X3, . . ., Xp constant.

· $\beta 2$ measures the change in Y for each unit change in X2, holding X1, X3, . . ., Xp constant.

· βp measures the change in Y for each unit change in Xp, holding X1, . . . , Xp-1 constant.

· ε is the observation error due to uncontrolled variables.

Multiple Linear Correlation Model

The multiple correlation coefficient R is a dimensionless parameter, whose absolute value can be between 0 and 1. The closer it is to unity, the greater the

degree of associativity between the variables and. As it approaches zero, the linear relationship tends to disappear. This coefficient is calculated with the formula:

Fermin, 2017

Where:

· ###: correlation coefficient for the # and # series,
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· ###: correlation coefficient for the # and # series.

Result

Multiple Linear Correlation

tabla 2

Table 2. Pearson's Correlation: Coefficients of Probabilities

Regression statistics	
Multiple correlation coefficient	0,4636744
Coefficient of determination R^2	0,1405443
R^2 adjusted	0,1387427
Standard error	8,019988
Remarks 35	

Rad Solar (MJ/M²) Prec (mm) RH (%) Mean Temp. (°C)
Solar Rad. (MJ/M²) 1.00 0.47 0.36 0.03
Prec (mm) 0.13 1.00 0.00 0.00 1.7E-03
HR(%) 0.16 0.93 1.00 1.7E-04
Mean Temp. (°C) -0.36 -0.51 -0.59 1.00

Variance Of Climatic Factors In Cerecita

Table 3, 4 and 5 show the means obtained when evaluating the variance of the climatic factors such as: solar radiation, precipitation, relative humidity and average temperature; throughout the years from 1984 to 2018 in the Cerecita area. According to the analysis of variance, a coefficient of determination closer to zero was observed in all the variables, so the variables do not have a relationship between them, that is to say, the climatic factors vary very little according to the years since they are maintained in a uniform straight line. (See figure 1, 2, 3). Except for the average temperature, which shows a moderately positive regression in which it can be seen that as the years go by, the average temperature increases in this area. (See figure 4).

Table 2. *Solar radiation - cerecite*

Table 2
Solar radiation cerecite

Regression statistics	
Multiple correlation coefficient	0,4636744
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Remarks 35	

Table 2
Solar radiation cerecite

Sources	Gl	SC	MC	Fc	F-value
Regression	1	1447,4	1447,4	22,503	0,3033
Waste		2122,56	64,3202		
Total		3570			

Moise, 2021

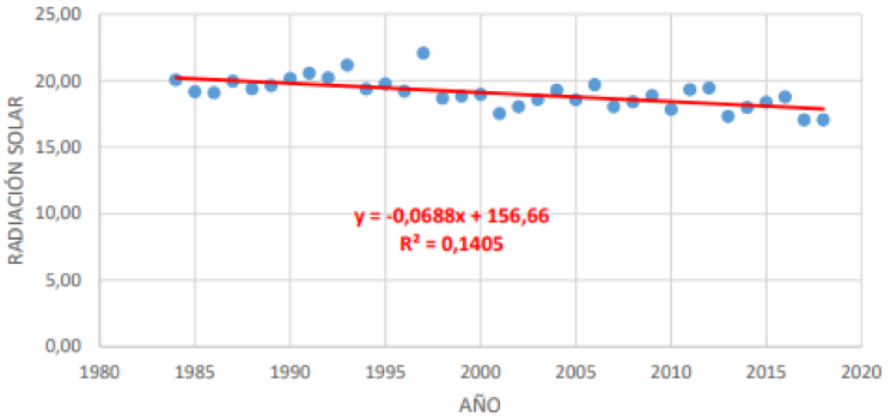

FIGURA 1
Scatter plot for solar radiation at Cerecita.

Moise, 2021
Table 3. *Precipitation - Cerecite*

Table 3
Precipitation Cerecite

Regression statistics	
Multiple correlation coefficient	0,042139
Coefficient of determination R^2	0,0017176
R^2 adjusted	-0,02847
Standard error	10,39181
Remarks 35	

Table 3
Precipitation Cerecite

Sources	gl	SC	MC	Fc	F-value
Regression	1	6,3392	6,3392	0,058	0,8100
Waste		3563,6	107,989		
Total		3570			

Moise, 2021

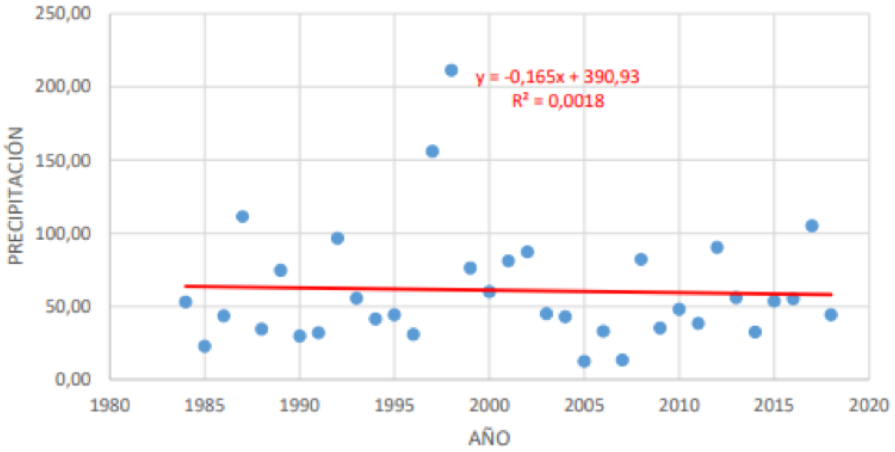

FIGURA 2
Scatter plot for precipitation in Cerecita.

Moise, 2020
Table 4. *Relative Humidity- Cerecite*

Table 4
Relative Humidity Cerecite

Regression statistics	
Multiple correlation coefficient	0,039987
Coefficient of determination R^2	0,001599
R^2 adjusted	-0,02866
Standard error	10,39273
Remarks 35	

Table 4
Relative Humidity Cerecite

Sources	gl	SC	MC	Fc	F-value
Regression	1	5,7081	5,7081	0,0528	0,819597
Waste		3564.292	108,0088		
Total		3570			

Moise, 2021

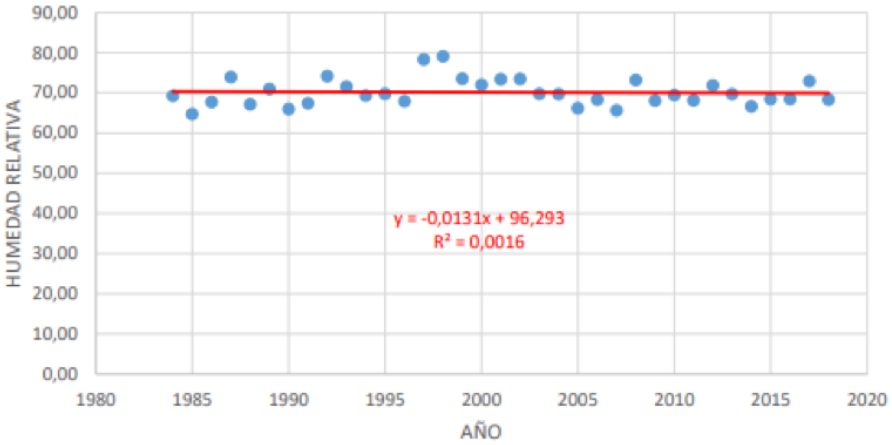

FIGURA 3
Scatter plot for relative humidity in Cerecita.

Moise, 2021
Table 5. *Average temperature - Cerecita*

Table 5
Average temperature Cerecita

Regression statistics	
Multiple correlation coefficient	0,573815
Coefficient of determination R^2	0,629264
R^2 adjusted	0,308938
Standard error	8,518303
Remarks 35	

Table 5
Average temperature Cerecita

Sources	gl	SC	MC	Fc	F-value
Regression	1	1175,471	1175,471	16,19966	0,000313
Waste		2394.529	72,56148		
Total		3570			

Moise, 2021

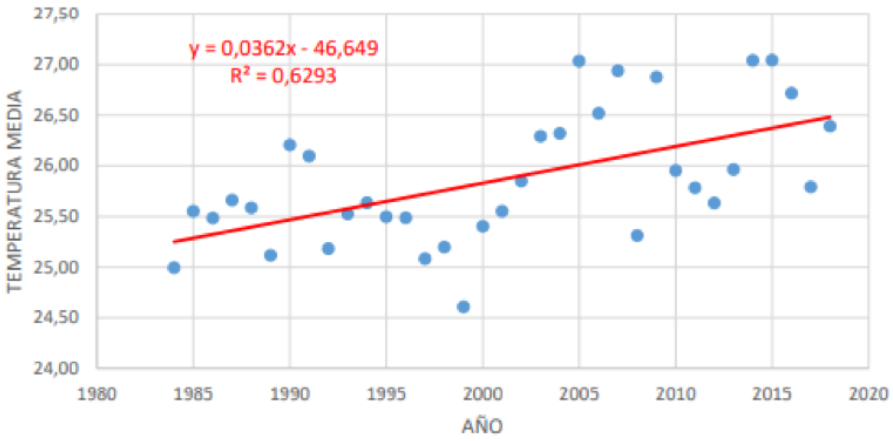

FIGURA 4

Scatter plot for mean temperature in Cerecita.

Cerecita - Producer E

In the analysis of variance of the fruit size calibers of the Tommy Atkins mango variety for the Cerecita zone, producer E, it was determined that no statistical significance was found between solar radiation and the different fruit calibers, since in all the variables the p-value was greater than 0.05 of significance. Likewise, in the regression and multiple linear correlation, determination coefficients closer to zero were found, so that the variables have very little relationship between them or there is no correlation between them in some cases.

For the influence of solar r. on 6-gauge fruit in Producer E., a p-value of 0.5233 was determined, greater than 0.05 probability, so no statistical significance was found between the variables.

For the influence of solar r. on 7-gauge fruit in Producer E., a p-value of 0.4660 was determined, greater than 0.05 probability, so no statistical significance was found between the variables.

Cerecita- Producer F

In the analysis of variance of the fruit size calibers of the Tommy Atkins mango variety for the Cerecita zone, producer F, it was determined that no statistical significance was found between solar radiation and the different fruit calibers, since in all variables the p-value was greater than 0.05 of significance. Likewise, in the regression and multiple linear correlation, determination coefficients closer to zero were found, so that the variables have very little relationship between them or there is no correlation between them in some cases.

Cerecita- Producer G

In the analysis of variance of the fruit size calibers of the Tommy Atkins mango variety for the Cerecita zone, producer G, it was determined that no statistical significance was found between solar radiation and the different fruit calibers, since in all the variables the p-value was greater than 0.05 of significance. Likewise, in the regression and multiple linear correlation, determination coefficients closer to zero were found, so that the variables have very little relationship between them or there is no correlation between them in some cases.

After having carried out the analysis and interpretation of data in the mango crop, it was possible to define the values of different climatic factors from

1984 to 2018, for each area studied, by means of the National Institute of Meteorology and Hydrology (INAMHI, NASA POWER), climatic factors such as: solar radiation, precipitation, relative humidity and average temperature. That according to Boada Garcia et al., (2021)who indicates that this is a public entity of scientific and technical character that serves to obtain, compile, process and publish data that allow to obtain a detailed knowledge of the meteorological, climatic and hydrological conditions of the country.

It also indicates that it is necessary to have climatic data from at least 25 years ago in order to Morgado-Carrasco et al., (2021) indicates that it is necessary to have climatic data from at least 25 years ago in order to be able to carry out a more precise analysis of the alteration of these data. The respective data tabulation was carried out to determine the variance in the climatic factors of the different zones studied and it was found that all the factors of the zones under study had no variance in relation to the time elapsed, except for the mean temperature factor, which indicates that the temperature rises 0.03 degrees Celsius for each year elapsed.

According to Cifuentes & Amariles, (2017) plant growth and fruit formation are closely related to the use of solar radiation. Thus, a reduction in light intensity affects above all the induction of the flower bud, its differentiation, fruit set, size, color and fruit quality and to a lesser degree growth. Therefore, according to Flórez et al., (2021)the current average global surface temperature is about 15 degrees Celsius. Between 1906 and 2005, the temperature of the planet rose by 0.74 degrees. And from 2005 to the present day, this process has experienced an upward evolution, placing the increase in the temperature of the Earth at approximately one degree since 1850. This information coincides with the UN, which establishes that solar radiation is a factor that influences the high land and ocean temperatures, and also states that the high temperatures we are going through are caused by the wear of the ozone layer due to contamination by oil combustion processes, machinery, animals, etc.

Emitting the so-called greenhouse gases that raise temperatures in the atmosphere. However, the results of the research indicate that there was no correlation between the variables solar radiation and fruit size by size of the Tommy Atkins variety in any of the zones, and that no statistical significance was found between the variables of fruit size and solar radiation, possibly due to the climatic conditions of the zone: hours of daily light.

Low solar radiation can cause stress resulting in elongation of internodes, thinner stems, broad and thin leaves, and poor development of the root system. In addition, it can cause smaller fruits, due to deficient photosynthesis in the leaves near them; and in general, poor coloration and reduced skin brightness, according to studies carried out by (Morgado-Carrasco et al., 2022)

Likewise with Romero et al., (2022) (2014), indicates that sunlight is important for the process of plant photosynthesis, since the assimilated light is transformed into energy; and according to what was observed in the study area, the farmer can also provide this energy through an adequate mineral nutrition, through the correct fertilization according to the previous results of the soil and plant analysis, as well as the necessary water supply for the optimal growth of the plant. It also mentions that a plant can grow under Cossoli et al., (2014) It also mentions that a plant can grow in shaded conditions, in greenhouses

or nurseries and be even more vigorous than one planted in open fields, since these are highly influenced by the integrated management of the crop, which includes the contribution of elements necessary for the life of the plant and good agricultural practices.

According to Farhat et al., (2015)Solar radiation not only affects plant development, but can also affect fruit growth and quality. The high temperatures produced by solar radiation on the field during the production stage can reach up to 15°C above the air temperature (especially in temperate zones with dry climates).

Such high temperatures not only cause thermal stress in the plant, but also deteriorate the quality of the fruit, causing the so-called scald or sunburn. The average temperature of the study areas was 26.25°C, according to the information collected from the 34 years, there was only a variance of 0.03°C, so it is presumed that this data does not affect the growth of mango fruits.

Conclusions

According to the results obtained from the research, the following conclusions can be drawn: Based on the first specific objective it was achieved: to define the values of the main climatic factors that could affect the mango crop in the Cerecita area (warm climate).

Data were obtained for 34 years from 1984 to 2018 for solar radiation, precipitation, relative humidity and average temperature for each zone, which were then correlated with fruit size. Based on the second specific objective, the variance of climate change in each zone was evaluated; it can be indicated that in the variables such as solar radiation, precipitation and relative humidity no variation was found over the years, while in the mean temperature variable, it was determined that its value increased by 0.03°C for each year elapsed.

This increase was due to an imbalance of these factors, such as light levels, carbon dioxide, air humidity, water and nutrients, which influenced plant growth and mango fruit size to the point of affecting crop productivity. Likewise, based on the third specific objective, no statistical differences or correlation were found between the variables solar radiation and the size of the Tommy Atkins mango fruit produced in the area under study.

Therefore, it is concluded according to the results obtained that solar radiation does not have a significant effect on fruit size since the increase of 0.03°C over the years did not affect the growth of mango fruit, and that this is mostly affected by the crop management carried out by each producer, according to the authors cited above.

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