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Effects of pruning and fertilization on the yield of cocoa (*Theobroma cacao* L.) in Guayas, Ecuador

Efectos de la poda y fertilización sobre el rendimiento en el cultivo de cacao (*Theobroma cacao* L.) en Guayas, Ecuador

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Abstract

Ecuador is one of the largest producers of fine and aromatic cocoa whose flavor has been recognized for centuries in the international market. To increase production and yield, producers rely on agricultural practices such as pruning and the use of soil and foliar fertilization. The effects of these

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amendments on crops of Theobroma cacao L were analyzed using a Latin square design in triplicate with four treatments including the control with 48 experimental units, divided into 16 units for each replicate. The treatments evaluated were T1 (pruning), T2 (pruning plus foliar fertilization), T3 (pruning plus soil fertilization) and T4 (control). The variables evaluated in this study were: fruit diameter (cm), fruit length (cm), seed per ear, weight of 100 seeds (gr), yield (kg/ha/year), as well as a cost/benefit analysis. Statistical analyses were carried out using ANDEVA and Tukey's test at 5% probability was used for the comparison of means. The variable of greatest interest was yield, in which T2 obtained an average of 2355.9 kg/ha/year. In addition, the cost/benefit analysis showed that for each dollar invested in T2 yields $2.21, being superior to the other treatments. In conclusion, small and large farmers should adopt these agricultural practices to improve their profitability and quality of life.

Key words: Productivity, agricultural practices, sustainability, economic benefit.

Resumen

El Ecuador es uno de los mayores productores de cacao fino y de aroma cuyo sabor es reconocido durante siglos dentro del mercado internacional, para aumentar su producción y rendimiento los productores se basan en prácticas agrícolas como la poda y el uso de fertilización edáfica y foliar. Se analizaron los efectos de estas enmiendas en cultivos de Theobroma cacao L mediante el diseño de un cuadro latino por triplicado con cuatro tratamientos incluido el testigo con 48 unidades experimentales, divididos en 16 unidades por cada replica. Los tratamientos evaluados fueron T1 (Poda), T2 (Poda más fertilización foliar), T3 (Poda más fertilización edáfica) y T4 (Control). Las variables evaluadas en este estudio fueron: el diámetro del fruto (cm), longitud del fruto (cm), semilla por mazorca, peso de 100 semillas (gr), rendimiento (kg/ha/año), además de un análisis costo/beneficio. Se realizaron los análisis estadísticos mediante ANDEVA y se utilizó el test de Tukey al 5% de probabilidad para la comparación de medias. La variable de mayor interés fue el rendimiento, en el cual el T2 obtuvo un promedio de 2355,9 kg/ha/año. Además, el análisis costo/beneficio mostró que por cada dólar invertido en el T2 da como resultado $2,21 siendo superior a los demás tratamientos. Concluyendo que los pequeños y grandes agricultores deben adoptar estas prácticas agrícolas para mejorar su rentabilidad y calidad de vida.

Palabras clave: Productividad, prácticas agrícolas, sostenibilidad, beneficio económico.

Introduction

Cacao (*Theobroma cacao* L.) belongs to the Malvaceae family (alternatively Sterculiaceae), with physiological characteristics distinguished by three groups or types of cultivars: Criollo, Forastero and Trinitario all of American origin, which have spread to the (sub) humid tropics. (Jürgen & Díaz , 2010). Cocoa is one of the most important crops in the world, produced in about 8.2 million hectares globally, being one of the most important items in the social and economic sphere of producing countries. (Sánchez, Zambrano, & Iglesias, 2019, p 90)

Cocoa has great relevance in the world market, according to the International Standard Industrial Classification (ISIC, revision 4) of all economic activities prepared by the Statistics Division of the United Nations Organization, the cultivation of cocoa is within class 0127 "Cultivation of plants from which beverages are prepared" and the manufacture of the final product corresponds to class 1073 "Manufacture of cocoa and chocolate and confectionery products". (Acebo , 2016 p. 493).

Among the countries with the highest production are listed Ivory Coast, Ghana, Nigeria, Indonesia and Brazil being the most important producers of cocoa; in addition, 58 producing countries are registered and its value exceeds 4 billion US dollars per year to the world economy. The quality of cocoa production will depend on genetic elements, natural conditions of the area where the plantations are located and the integral management of the crop. (Sánchez, Zambrano, & Iglesias, 2019 p. 49)

The cultivation of cocoa is traditional in Ecuador began with the establishment of national type cocoa plantations, the new owners at that time established more productive varieties of cocoa and with greater tolerance to new diseases. Quiroz (2009). In 1994 the International Cocoa Organization decided that only 75% of Ecuadorian cocoa could be recognized as fine and aromatic, since the quality of Ecuadorian cocoa provided organoleptic characteristics above the international competition, despite not being among the world's largest producers, it is the largest producer of quality cocoa (fine and aromatic), whose flavor has been recognized for centuries. Freire (2009)The flavor has been recognized for centuries in the international market, due to the fact that this type of bean is used in most of the refined chocolates. (Abad, Acuña, & Naranjo, 2020 p. 434).

One of the existing practices to manage the caco canopy is pruning, which is a procedure that has the purpose of stimulating the development of new buds, increasing flowering and fruit production. Pruning prolongs the useful life of the tree and increases yields, and is generally carried out according to the age and condition of the plant. Gutiérrez, Leiva, & Ramírez (2019). Currently, three types of pruning are practiced: training pruning, which is performed in the first two years of life to adopt the shape of the plant; maintenance pruning, which consists of eliminating fruit and diseased parts due to pests; and rehabilitation pruning, which is aimed at generating new terminal buds. (Arvelo, Gonzáles, Maroto, Delgado, & Montoya, 2017 p. 44)

In addition to pruning to improve cocoa productivity, foliar fertilization has become a common and important practice for producers, because it corrects micro-nutrient deficiencies favoring the good development of the crop, improves the yield and the quality of the corncob. Trinidad & Aguilar (1999). Authors such as Uribe, Méndez, & Mantilla, (1999). reported the increase in cocoa production with fertilizer treatments in solar exposure carried out in 10 experimental units of cocoa cultivation in Colombia from October 1990 to January 1996, applying annual doses of N, P, K in the agro-ecological zone and harvesting the fruit every two weeks and monthly.

In the same way, soil fertilization in cocoa cultivation has been extensively studied. The application of fertilizers should be done based on a soil analysis, because due to the origin of the same have minerals and nutrients that are rich to be absorbed by plants, but often over time the sources are weakened by losing important nutritional values that crops need. It is now known that the integrated application of organic and inorganic fertilizers in crop production increases growth more than either used alone. Likewise, the application of organic fertilizers in combination with inorganic fertilizers increases plant uptake of N, P and K compared to the single application of organic or inorganic fertilizers. Therefore, an integrated application of organic and inorganic fertilizers seems to be a suitable technique to meet the nutrient requirements of cocoa grown on marginal soils for improved and sustainable growth. Jerome, et al. (2021).

The objective of this research is to determine the effects of pruning and fertilization on the yield of cocoa (*Theobroma cacao* L.) in Guayas.

Materials and methods

The present research is experimental and exploratory, conducted in the cocoa-growing area of the Chan-Chan precinct belonging to the parish Roberto Astudillo, Milagro canton of the province of Guayas, whose UTM coordinates are X: 66470.27 E Y: 9751576.81 S, Zone 17S; the altitude ranges between 24 to 50 m.a.s.l. with average daily temperatures between 24 to 27°C, annual rainfall between 1300 to 1800 mm, flat topography, soil variability in which predominate deep clay loam soils with neutral pH and high base saturation and moderately deep silty clay loam soils, with poor drainage and high fertility as established by the national information system (2015) in its diagnostic report for the Roberto Astudillo parish. Based on the conditions of the trial, a Latin square experimental design with 3 replicates was carried out in which 4 treatments were established, as summarized in Table 1.

Table 1. *Distribution of treatments*

No.	Treatment	Description	Home
1	Pruning	Maintenance and phytosanitary pruning	End of rainy season
	Pruning + Foliar Fertilization	Maintenance and phytosanitary pruning + Evergreen (1 lt/ha)	Appearance of fruit
	Pruning + Edaphic Fertilization	Maintenance and phytosanitary pruning + Ferticacao (389 g/plant)	Appearance of

		fruit
Absolute witness	-	-

For the statistical analysis, an analysis of variance was performed, the scheme of which can be seen in Table 2. For the comparison of means, a Tukey test was used with a value of $P<0.05$, therefore, it will have a significance of 95%.

Table 2. *Outline of the analysis of variance (ANAVA*).

Source of Variation	Degrees of freedom
Treatments	
Row Column	
Replicas	
Experimental error	
Total	

The variables evaluated were: fruit diameter (cm), fruit length (cm), fruit weight (gr), seeds per cob, 100-seed weight (g) and yield. The characteristics of the plots were 24 m long and 24 m wide, giving a total of 576 m^2 , replicated on three occasions by choosing plants randomly, the distribution can be seen in Figure 1.

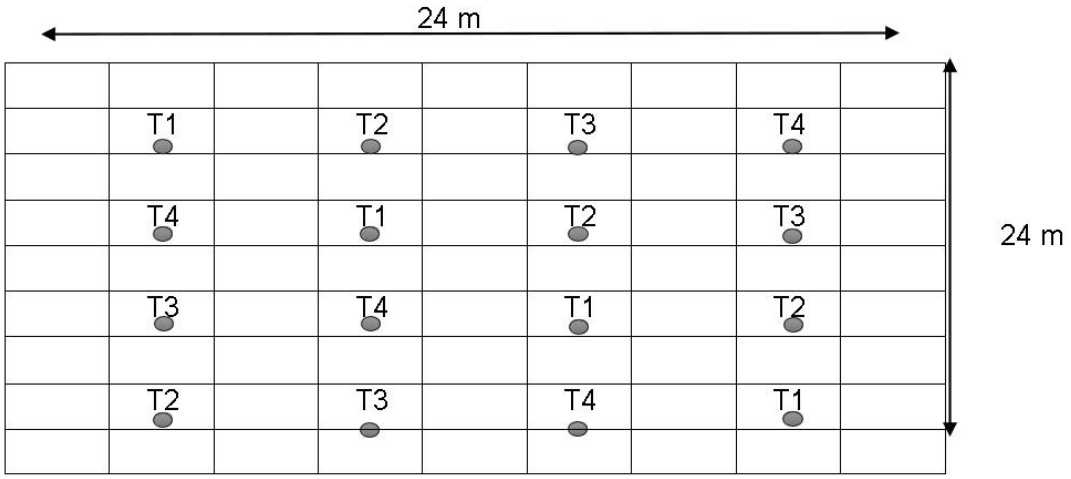

Figure 1. Distribution of treatments within the plots.

Result

Based on the research, a soil analysis was carried out, which yielded the data shown in Table 3.

Table 3. *Summary of the soil analysis performed in the trial.*

Lot	pH	NH_4	P	K	Ca	Mg	S	Zn	Cu	Faith	Mn	B
Sample 1	7,5	6,0	20,0	246,0	431,0	480,0	9,0	2,2	6,5	78,0	11,0	1,8

Units: µg/ml

Source: Soil, Plant Tissue and Water Laboratory (INIAP) Cod. 68538

Chemical properties suitable for cocoa cultivation are evident, based on this basis, the treatments were analyzed in each of the replications.

Fruit diameter (cm)

A coefficient of variation of 3.62% was obtained for the aforementioned variable without showing a level of statistical significance when comparing the means obtained by Tukey's test, as shown in Table 4.

Table 4. *Comparison of means in fruit diameter (cm)*

N°	Treatments	Averages	Significance
1	Pruning	10,0	**A**
	Pruning+Fert. Foliar	9,9	**A**
	Pruning+Fert. Edaph.	9,9	**A**
	Absolute witness	**9,7**	**A**

Equal letters show non-significant differences according to Tukey's test at 5%.

Fruit length (cm)

The fruit length analyzed in the different treatments shows that treatment 2 presented an average fruit length of 23.6 cm, being superior to treatment 1, with similarities to treatments 3 and 4.

Table 5. *Comparison of means in fruit length (cm)*

N°	Treatments	Averages	Significance	
1	Pruning	22,6		**B**
	Pruning+Fert. Foliar	23,6	A	
	Pruning+Fert. Edaph.	23,4	A	**B**
	Absolute witness	**23,1**	**A**	**B**

Equal letters show non-significant differences according to Tukey's test at 5%.

Fruit weight (gr)

In the analysis of fruit weight (gr), it can be observed that treatment 2 obtained the highest average, reaching 924.3 gr, being superior and statistically significant in the comparison of means of the other treatments, as summarized in Table 5.

Table 6. *Comparison of means for fruit weight (gr)*

N°	Treatments	Averages	Significance		
1	Pruning	743,4		B	**C**
	Pruning+Fert. Foliar	924,3	A		
	Pruning+Fert. Edaph.	801,7		B	
	Absolute witness	**712,5**			**C**

Equal letters show non-significant differences according to Tukey's test at 5%.

Seeds per ear

With a coefficient of variation of 8.09%, it was determined for this variable that the treatment with the highest average reached was treatment 2 with a value of 54.9 grains per ear, being

higher and statistically significant than the control treatment and the other treatments. The summary of the comparison can be seen in Table 6.

Table 7. *Comparison of means in number of seeds per ear.*

N°	Treatments	Averages	Significance		
1	Pruning	46,8		B	**C**
	Pruning+Fert. Foliar	54,9	A		
	Pruning+Fert. Edaph.	51,1	A	B	
	Absolute witness	**43,6**			**C**

Equal letters show non-significant differences according to Tukey's test at 5%.

Weight of 100 seeds

In the evaluated variable, which presented a coefficient of variation of 3.72%, there was a significant statistical difference, being treatment 3 the one that reached the highest average weight with a value of 149.3 gr, followed by treatment 2 that reached 149.0 gr, both results do not represent significance, therefore, we infer in this variable that the two treatments were the best in comparison to the control and treatment 1. It is important to emphasize that the weight variable is crucial for the economic importance of cocoa cultivation; the greater the weight, the greater the economic returns.

Table 8. Comparison of means in the weight of 100 seeds (gr).

N°	Treatments	Averages	Significance	
1	Pruning	132,8		B
	Pruning+Fert. Foliar	149,0	A	
	Pruning+Fert. Edaph.	149,3	A	

Absolute witness	**123,7**		**C**

Equal letters show non-significant differences according to Tukey's test at 5%.

Performance

The analysis of variance for this variable showed a significant difference with a coefficient of variation of 5.19%. The comparison of means showed that the treatment with the highest yield was treatment 2, with an average yield of 2355.6 kg/ha/year, which was different from the other treatments evaluated.

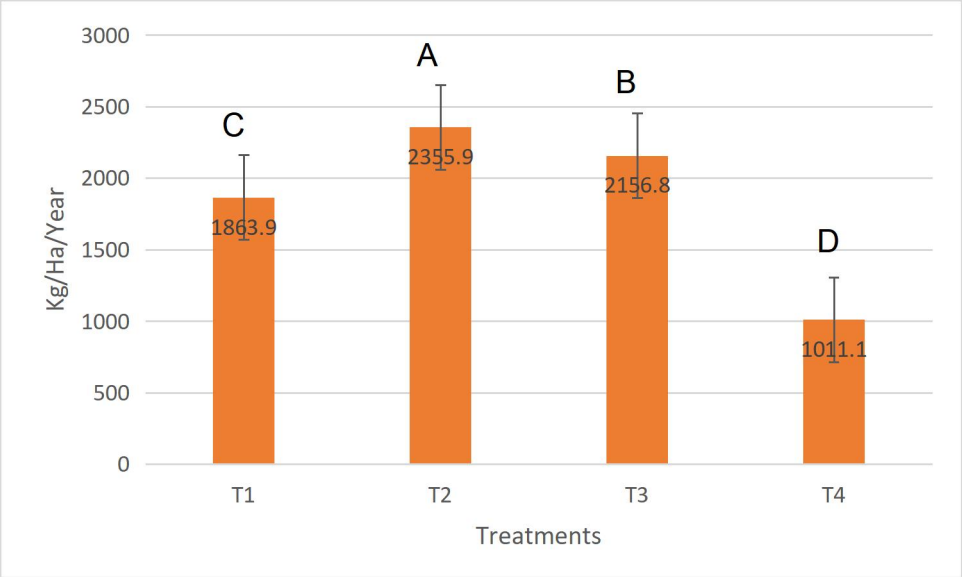

Figure 2. Equal letters show non-significant differences according to Tukey's test at 5%.

Yield in kg/Ha/year in each treatment**.**

Finally, an economic analysis was carried out to determine whether it is feasible to implement pruning and fertilization in the cocoa crop in the study area, obtaining favorable results for treatment 2. With an adjustment in the yield considering a 10% reduction, it is evident that an average cost/benefit of 2.21 was achieved, compared to the control treatment that obtained 1.39 respectively.

Based on the results obtained in the present investigation, we can point out that there is evidence of satisfactory results in comparison with investigations of similar characteristics.

According to the research conducted by Solorzano (2017) the use of Leonardite plus three levels of N-P-K, B and Zn obtained favorable results in fruit development both in length and

diameter. In comparison with this research there is coincidence in relation to fruit diameter as a function of fertilization.

Continuing with other evaluated parameters, the most relevant one is yield, where authors such as Pinargote (2014) state that the use of different fertilizers such as "Evergreen" plus pruning obtained a yield of 2355.6 Kg/Ha/Year, being lower than the yields obtained by Alvarez and Mendoza (2013) who obtained a yield of 3346.30 kg/ha/year. The yield of this research was higher with an average of (insert average annual yield).

Regarding the weight per 100 seeds, the research by Pazmiño (2016) where the implementation of edaphic fertilization plus pruning managed to obtain weights of up to 177.83 gr being superior to that presented in this trial where values of up to 149.3 gr were obtained. Consequently, the variable of grains per ear, where researchers such as Chinin (2015) in his research on three types of pruning plus irrigation obtained averages of up to 59 seeds per ear, being very similar to those obtained in the present research, which reached 54.9 seeds per ear. In addition, the same research analyzed the weight of the fruit, whose average was an average of 1109 gr. per ear, being similar to those obtained in this trial, which corresponds to an average of 924.3 gr. per ear.

Conclusions

Based on the study of the effects of pruning plus fertilization in the commercial cultivation of cocoa in the parish Roberto Astudillo of Milagro canton belonging to the province of Guayas. Statistically significant results were obtained in terms of the agronomic response of the crop, showing higher yields of cocoa per hectare per year compared to the control treatment. Significance was also found in other variables such as seed weight, fruit weight, seeds per cob and economic benefit. Small farmers in the area do not implement these practices in their crops because they are unaware of the positive effects and the economic benefits they can obtain. This research presents the response of the cocoa crop to two basic practices in the concept of agricultural production that should be disseminated and applied in rural areas, in order to improve the quality of life of the families that benefit economically from this crop.

References

Abad, A., Acuña, C., & Naranjo, E. (2020). Cocoa on the Ecuadorian coast: a study of its cultural and economic dimension. *Management Studies: international journal of management, No. 7*, 59-83.

Acebo , M. (2016). *Industrial studies and strategic guidance for decision making for the cocoa industry.* Guayaquil: ESPAE-ESPOL.

Arvelo, M., Gonzáles, D., Maroto, S., Delgado, T., & Montoya, P. (2017). *Technical manual of cocoa cultivation: Latin American practices.* San José, Costa Rica: Inter-American Institute for Cooperation on Agriculture.

Chinin, R. (2015). *Evaluation of three forms of pruning in cocoa CCN-51 and subfoliar irrigation system with SENNINGER 3012 gun.* University of Guayaquil, Guayaquil. Retrieved from http://repositorio.ug.edu.ec/bitstream/redug/8645/1/Chinin%20Macias%20Roberto%20Manuel.pdf.

Freire, J. (2009). *Cocoa marketing: Training program for facilitators and farmers of the cocoa chain.* Quito: Iniap.

Gutiérrez, E., Leiva, E., & Ramírez, R. (2019). Pruning and its effect on cocoa bean (Theobroma cacao L.) quality. *Agronomía Costarricense*, 167-176.

Jerome, A., Alfred, A., Godfred, K., Amos, K., Sampson, K., & Andres, A. (2021). Effects of Organic and Inorganic fertilizers on Growth and nutrient uptake by young cacaco (Theobroma cacao). *International journal of Agronomy, 2021*, 10. doi:https://doi.org/10.1155/2021/5516928

Jürgen, H., & Díaz , V. (2010). Growth and production of cocoa. In W. Verheye (Ed.), *SOILS, PLANT GROWTH AND CROP PRODUCTION* (Vol. III, p. 10).

Pazmiño, A. (2016). *Effects of phosphorus and sulfur on the yield of cobs, in a cocoa plantation (Theobroma cacao L.) ccn-51, in the area of Babahoyo.* Universidad Ténica de Babahoyo, Babahoyo. Retrieved from http://dspace.utb.edu.ec/handle/49000/3358

Pinargote, M. (2014). *Cocoa (Theobroma cacao L.) CCN-51 production performance under different fertilization formulations. Quevedo, 2014.* Graduate thesis, University of Guayaquil, Guayaquil. Retrieved from http://repositorio.uteq.edu.ec/bitstream/43000/334/1/T-UTEQ-0020.pdf.

Quiroz, J. (2009). *Cocoa production: Training program for facilitators and farmers in the cocoa chain.* Quito: Iniap.

Sánchez, V., Zambrano, J., & Iglesias, C. (2019). *The Cocoa Value Chain in Latin America and the Caribbean (*Vol. I). Quito: INIAP.

National information system (NIS) (2015). *General characterization of the Roberto Astudillo parish.* Milagro. Obtenido de http://app.sni.gob.ec/sni-

link/sni/PORTAL_SNI/data_sigad_plus/sigadplusdiagnostico/0968554860001_DIAGN%C3%93STICO%20ROBERTO%20ASTUDILLO_17-06-2015_09-46-28.pdf

Solorzano, O. (2017). *Effects of Leonardite application with three levels of N, P, K, B andZn on national cocoa (Theobroma cacao L.) in Vuelta Larga, Yaguachi.* Graduate thesis, University of Guayaquil, Guayaquil. Retrieved from http://repositorio.ug.edu.ec/bitstream/redug/20972/1/Tesis%20OMAR%20SOLORZANO.pdf

Trinidad, A., & Aguilar, D. (1999). Foliar fertilization, an important support in crop yield. *Terra Latinoamericana*, 247-255.

Uribe , A., Méndez, H., & Mantilla, J. (1999). Effects of nitrogen, phosphorus and potassium on cocoa production in Colombia. *Equatorial Soils*, 31-36.