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INFLUENCE OF RAINFALL ON THE YIELD OF *Coffea canephora* Pierre ex Froehner CULTIVATED IN CAMBISOL SOILS OF THE EASTERN REGION OF CUBA

Influencia de las precipitaciones en el rendimiento de *Coffea canephora* Pierre ex Froehner cultivado en suelos Pardos de la región oriental de Cuba

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ABSTRACT. In order to evaluate the effect of rainfall on the yield of the species *Coffea canephora* Pierre ex Froehner cultivated in brown soils in two coffee areas of eastern part of Cuba (Cruce de los Baños site, located in the municipality Tercer Frente, Sierra Maestra hills and Alcarraza site, located in the municipality of Sagua Tánamo, Nipe-Sagua-Baracoa hills). Data from two production cycles of this specie were used in an experiment of study of nitrogen fertilizer dose, planted in 1996 and pruned in 2003. Regressions between yields and annual rainfall were established. Different mathematical models were used, selecting the highest coefficient of determination (R^2). A strong relationship between annual rainfall and maximum stable yields at both sites and cycles (R^2> 90%) was found. With rainfall in the range of 1 400 mm – 1 600 mm in "Tercer Frente" and "La Alcarraza", were not obtained more than 1,30 t ha^{-1} green coffee year^{-1}, while annual rainfall values from 1 750 mm to 1 900 mm allowed yields from 1,4 t ha^{-1} to 1,8 t ha^{-1} of green coffee. When rainfall amounted to 2 000 mm at both sites, 2 t ha^{-1} green coffee year^{-1} were obtained.

Key words: *Coffea canephora*, clime, rainfall, yield, correlation

RESUMEN. El trabajo se realizó con el objetivo de evaluar el efecto de las precipitaciones sobre el rendimiento de la especie *Coffea canephora* Pierre ex Froehner cultivada en suelos Pardos en dos macizos cafetaleros de la región oriental de Cuba (sitio Cruce de los Baños, situado en el municipio Tercer Frente, macizo Sierra Maestra y sitio La Alcarraza, situado en el municipio Sagua de Tánamo, macizo Nipe–Sagua–Baracoa). Se utilizaron datos de dos ciclos productivos de esta especie dentro de un experimento de estudio de dosis de fertilizantes nitrogenados plantado en 1996 y podado en el 2003. Se establecieron regresiones entre los rendimientos y las precipitaciones anuales. Se utilizaron diferentes modelos matemáticos, seleccionándose el de mayor coeficiente de determinación (R^2). Se encontró una fuerte relación entre las precipitaciones anuales y los rendimientos máximos estables, en ambos sitios y ciclos (R^2 > 90 %). Con precipitaciones en el rango entre 1 400 y 1 600 mm en "Tercer Frente" y "La Alcarraza", no se obtuvieron más de 1,30 t ha^{-1} de café oro año^{-1}; mientras que valores de lluvias anuales entre 1 750 y 1 900 mm permitieron alcanzar rendimientos anuales entre 1,4 a 1,8 t ha^{-1} de café oro. Cuando las precipitaciones ascendieron a 2 000 mm en ambos sitios, se obtuvieron 2 t ha^{-1} de café oro año^{-1}.

Palabras clave: *Coffea canephora*, clima, precipitación, rendimiento, correlación

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INTRODUCTION

Due to the wide geographical distribution of coffee plots, the response to different management systems among countries and regions within one country is different. The dissimilar of ecology in world coffee growing areas suggests this crop is not identical everywhere, and therefore, frequent experimental results do not match amongh themselves or are diametrically opposed (1).

It has been stated that the ecological requirements are better studied in the region of origin of the specie, other authors express that sometimes is more useful to study plant growth in areas where the specie has been distributed, particularly if the plants show good growth in those sites (1). Out of the *Coffea* species cropped in Cuba, *canephora* has been less studied, hence why it is essential to conduct investigations with this specie in the pre-mountainous areas where it is grown in the country.

The climatic characteristics expressed through temperature, rainfall and rainy days in addition to those relative to landscape and soil properties, interact and decisively influence on growth and yield of the plot and therefore, on the nutritional requirements (2, 3). Thus, it has been established that climate in subtropical regions has a greater importance on the growth and fruting of coffee trees than in the warm areas of the tropics, regardless the studied varieties (4)

Coffee trees productivity depends on a complex system of interelated environmental and social factors. Temperature and rainfall distribution are two of those factors affecting crop phenology, yield and quality, and even the composition of the organic compounds of the beverage (5, 6, 7). At the same time, when estimating the climatic impact over production, the fertilization effect on increased CO_2 in the atmosphere should be considered[A].

At present, there studies on the threats of climate change on crops have boomed and governments are creating scenarios to mitigate its effects. As to coffee trees are concerned, studies have focussed on the agroforestry management as an adaptation strategy against microclimate extremes (8). There are reports from Brazil on the relationship between coffee planted areas and climatic vulnerability and also for the climatic context of 2080, the displacement of suitable coffee growing areas to the South and Southeast states is being thought of (4), and even increased areas of the specie *canephora* (9).

In Camerun (10) a relationship was found between the increased severity of Coffee Berry Disease and the fall of temperatures (minimum or maximum). Likewise, a strong relationship was found between the attack of the disease and the quantity of rainy days, however, no correlation was found with the total rainfall of the years under study. Authors suggest the use of both indicators to establish predictive models to optimize the effective control of the disease.

Out of the environmental elements associated to climate system, the commonly recognized critical variable for the plants is water availability, because it is the determining factor for growth (11). Rainfall, temperature and sun radiation are climatic elements of major importance in coffee production. Water deficits are necessary for flowering, but if it lasts too much, flower opening does not take place, vegetative growth and fruit filling are limited. On the other hand, water excesses reduce flower induction (12) and the formation of reproductive structures, favor the presence of diseases, promote soil nutrients leaching and losses by erosion (13).

Coffee from the *arabica* specie responds with sensitivity to temperature increase and it occurs with a higher intensity during flowering and fruiting. Much less information is available regarding temperature impact and rainfall distribution in plants of the Robusta cultivar, which could be related to a lesser interest on climate change impact over this specie, but it can also be related to the lower volume of this variety in the world market (30 %) compared to *arabica* (70 %) (4).

In Cuba, growing areas of *Coffea canephora* Pierre ex Froehner, have been increased mainly in the Eastern region of the country. For this reason, this research has aimed at evaluating rainfall effect over the yield of this specie grown on Brown soils of two coffee growing areas in this region.

MATERIALS AND METHODS

In order to establish a relationship between rainfall and yields, this research was done from 1995-2007 in two sites of the Sierra Maestra and Sagua-Nipe-Baracoa Mountain ranges, in which increasing nitrogen fertilizer rates were studied.

The location of Tercer Frente (*site Cruce de los Baños*): located in the municipality Tercer Frente, Sierra Maestra Mountain Range, at 20º09´ N lat and 76º16´ O long, and at 135 km North West of Santiago de Cuba city, at a height of 150 m a. s. l., with an annual mean temperature of (13 years- average) of 24,5 ºC, minimum temperature of 15,5 ºC, maximum temperature 31 ºC, rainfall of 1 654 mm in 112 days with rains and relative humidity of 79,8 %. Landscape: Pre-mountain. Predominant shade*: Samanea saman* (Jacq) Merril. Soil type: Ocric brown without carbonates

[A] Haggar, J. y Schepp, K. Coffee and Climate Change Impacts and options for adaption in Brazil, Guatemala, Tanzania and Vietnam [en línea], [Climate Change, Agriculture and Natural Resources, 4], Natural Resources Institute, University of Greenwich, 2012, p. 47, [Consultado: 5 mayo 2015], Disponible en: <http://www.nri.org/images/documents/promotional_material/D5930-11_NRI_Coffee_Climate_Change_WEB.pdf>.

(14) with a slightly acid pH (6.3), low contents of assimilable phosphorus (8,7 mg 100 g^{-1} of soil) and a high capacity of cationic exchange 44,6 cmol kg^{-1}.

The location La Alcarraza: located in the municipality Sagua de Tánamo, Nipe-Sagua-Baracoa Mountain Range, at 20º35´ N lat and 75º15´ West long, at 118 km to the south East of Holguín city. With a height of 300 m a. s. l. The main climatic variables are: annual mean temperature (13 years- average): 24,1 ºC. Rainfall (13 years-average): 1 773 mm and 120 days of rain. Landscape: Pre-mountain. Predominant shade: *Gliricidia sepium* (Jacq) Walp. Soil type: Glay brown without carbonates (14) with a slightly acid pH (5,8), low contents of assimilable phosphorus (9,72 mg 100 g^{-1} of soil) and a high capacity of cationic exchange 34,7 cmol kg^{-1}.

During 12 years, the response to five nitrogen fertilization systems was studied (Table I), using a random block design with four replicates. The first productive cycle extended from planting till low pruning and the second one included three harvests after pruning coffee trees. The agronomical effects of this experiment are detailed in Vol 38 No. 4 of C Centro Agrícola magazine, the results of the first productive cycle (15) and the results of the second one can be found in Vol 46, No. 8 of the Pesquisa Agropecuaria Brasileira magazine (16).

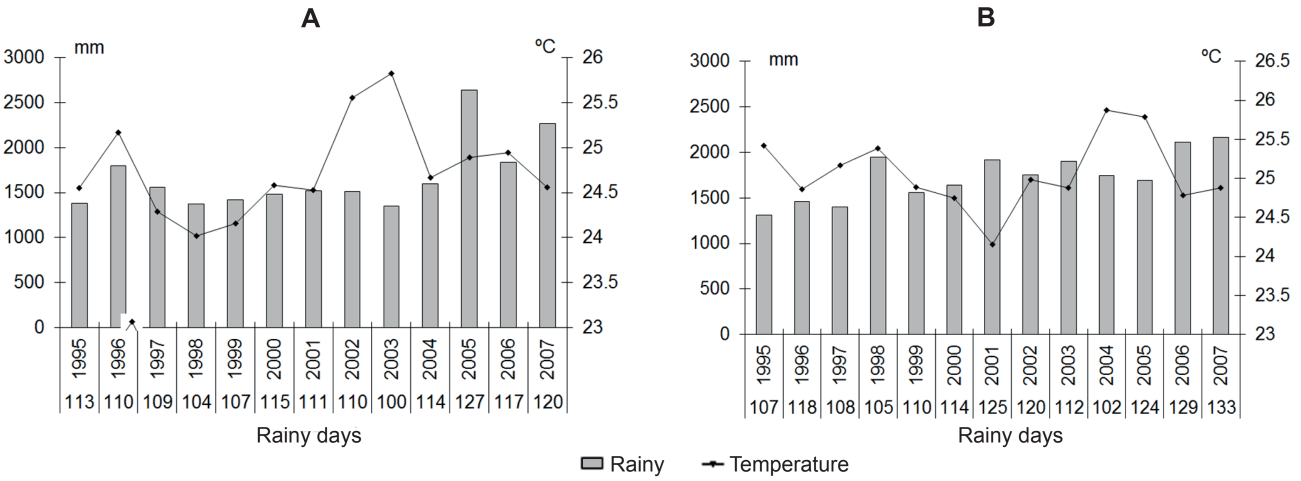
All treatments included a bottom fertilization with P_2O_5 and K_2O. Simple superphosphate and potassium chloride were used as carriers. The 100 % of phosphorus was applied together with 50 % of the potassium in May, and the rest of the latter one in September, both around the trunk following a half moon pattern.

The behavior of climatic variables like rainfall, mean temperature and monthly rainy days are shown in Figure 1. Rain values are within the range of 1 400 mm to 2 900 mm exclusing values considered as threats for the crop under Colombia's conditions (17).

Table I. Nitrogen rates (kg ha^{-1}) used under the two fertilization studied systems

Treatments	First productive cycle			Second productive cycle		
	1996	1997	1998-2002	2003	2004	2005-2007
N_0	0	0	0	0	0	0
N_1	30	45	50	50	75	100
N_2	60	90	100	100	150	200
N_3	90	135	150	150	225	300
N_4	120	180	200	200	300	400

N carrier: urea. Splitted nitrogen fertilizer at 50 %, first application between March and June, second application: September-November



Data from the Meteorological Stations of Cruce de los Baños, Tercer Frente municipality and Sagua de Tánamo, municipality of Sagua de Tánamo[B]

Figure 1. Annual behavior of meteorological variables rainfall, rainy days and mean temperatures in both sites of the Tercer Frente (A) and La Alcarraza (B) during the execution of the experiments

[B] Instituto de Meteorología. *Hojas de asentamiento de las variables meteorológicas diarias. Estaciones meteorológicas de Sagua de Tánamo, Holguín y Tercer Frente, Santiago de Cuba*, Ministerio de Ciencia, Tecnología y Medio Ambiente, Cuba, 2011.

A study of the relationship between rainfall and yield of *Coffea canephora* Pierre ex Froehner was conducted. In so doing, maximum stable yields in each cycle and location were considered (15, 16) and regression equations were established taking as independent variables rainfall values. The equation of the highest coefficient was determined (R^2) and the one of the least standard error of estimation (Esŷ). From this analysis, model of better adjustment was selected. The whole statistical procedure was done using the software Statgraphics Centurión XV, version 15.2.14.

RESULTS AND DISCUSSION

In order to adequately understand the relationship between annual maximum yield, nitrogen fertilization and rainfall, it should be known that coffee yield depends on the variety, the quantity of new shoots at flowering, planting density, rainfall level, intensity of the previous harvest, soil type and landscape[C] in such a way that these variables predetermine the yield level.

In relation to the above, the rainfall effect was evaluated over the yield of *C. canephora* plots with an adequate nutrients supply and it was found that with rainfall of 1 400 mm –1 600 mm in both locations, more than 1,30 t ha^{-1} of green coffee per year was harvested; while with rainfall of 1 750 –1 900 mm allowed to reach annual yields of 1,4 t ha^{-1} to 1,8 t ha^{-1} of green coffee (Figure 2).

However, when rainfall increased to 2 000 mm in both sites, 2 t ha^{-1} of green coffee per year were reached. The above led to stand out the importance of the annual rainfall level over the yield.

This is a frequent characteristic of the site La Alcarraza, historical records show that in 52 % of the years, rainfall of around 2 000 mm were recorded, unlike Tercer Frente, where only 20 % of those years recorded such annual rainfall values[B].

Table II shows the comparison of different mathematical models to establish the regression analysis between total annual rainfall (independent variable) and the yield reached in both experimental sites.

The integration of the results from different harvests into the productive stages of the two cycles in both sites, showed a strong positive relationship between annual rainfall and maximum stable yields, with a high association between variables (R^2>90 %), which explains, to a great extent, the differences found in annual yields between the sites (Figure 3).

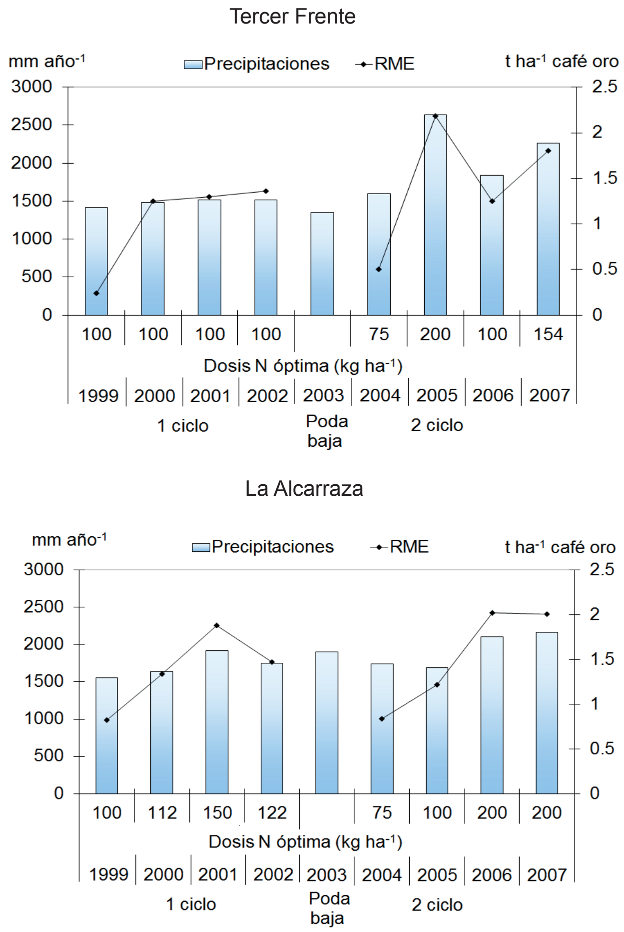


Figure 2. Behavior of maximum stable yields (MEY) and annual rainfall during the two coffee cycles studied in both experimental sites

This analysis determined that the existence of favorable conditions of humidity make possible for *Coffea canephora* to show a good growth and productivity in any of the productive cycles.

The evaluation of climatic variability in Eastern Cuba showed that total annual rainfall is the variable determining most of yield variations which confirms that rainfall is the climatic element of greatest variability in the country. The same is not true with tempetrature due to the predominating warm nature of the climate[D]. Figure 1 show that mean temperature showed little variations in its monthly values in years.

[C] Rivera, R. *Nutrición, fertilización y balance del fertilizante nitrogenado (15N) para el cafeto en un suelo Ferralítico Rojo compactado* [Tesis de Doctorado], Instituto Nacional de Ciencias Agrícolas, Mayabeque, Cuba, 1988, 110 p.

[D] Palacios, J.R. y Palacios, A.V. "Evaluación de la variabilidad climática interanual en el oriente cubano con el uso de la clasificación climática de Köppen", *Resúmenes Convención Trópico. II Congreso de Meteorología Tropical*, 2008, 337 p.

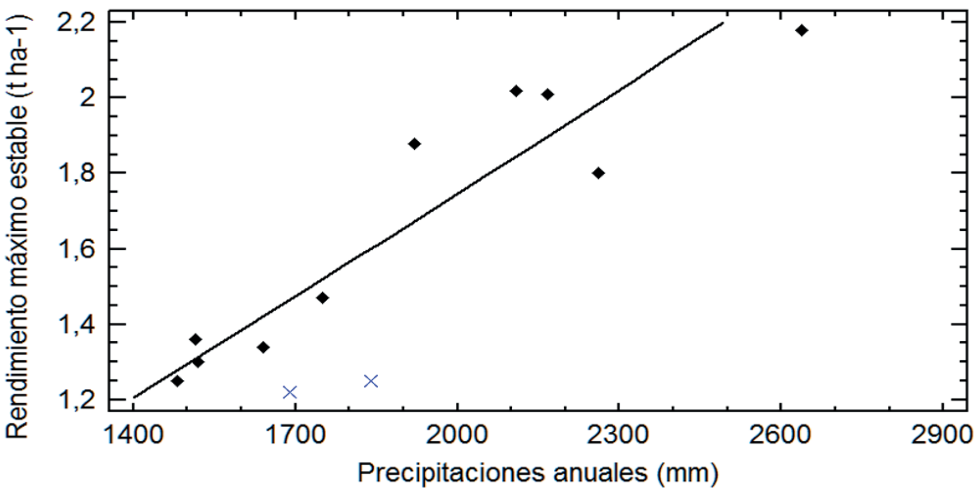
The fact of obtaining a high relation between the annual precipitations and the maximum yields stable, as well as that the species canephora in Cuba is harvested from October, suggests that the growth of the fruit is going to extend from May to December and therefore Can take advantage of both the annual rainfall and the fertilizer that was applied at the beginning of October.

These results coincide with those obtained in research carried out in Mexico, where it was found that the rainfall included in the period from May to December, ensure the growth of Coffea fruit. Canephora Pierre ex Froehner, beginning the harvest from the month of January, with the beginning of the maturing phase of the grain.

It is worth noting that the yield - precipitation ratio is not so simple and here the rainfall distribution depends on the phenological stage of the crop, the number of rainy days, and the crop 's alternation (18). Investigations in Colombia showed that in the shade coffee plantations there is a double interception of rainfall, a smaller proportion due to the aerial part of the vegetation and the other by the superficial rasping layer in which a high proportion of water is retained (19). An example of this positive interaction occurs in the conditions of Pinares de Mayarí, province of Holguín on Ferritic Soils (Rhodic - Ferric Ferralsols), where plantations of *Coffea arabica* L. are obtained with an adequate supply of nutrients, related to an adequate Temperature, rainfall (1 650 mm annually), with 180 days of rain.year^{-1} and in a plateau relief, all of which conditions an adequate water supply for coffee[E].

Table II. Comparison of Alternate Models for the relationship between yields and total annual rainfall in both experimental sites

Model	Correlation	R^2	Esŷ
Inverse double	0,9516	90,55 %	0,04
Inverse of X	-0,9487	90,00 %	0,12
Logarithm of X	0,9430	88,93 %	0,12
Multiplicative	0,9421	88,75 %	0,08
Square root of X	0,9376	87,90 %	0,13
Double square root	0,9364	87,68 %	0,05
Square of Y	0,9330	87,05 %	0,45
Lineal	0,9302	86,53 %	0,14
Square root of Y	0,9281	86,13 %	0,05
Exponential	0,9254	85,64 %	0,09
Inverse of Y	-0,9188	84,42 %	0,06
Double Square	0,9170	84,09 %	0,50
X square	0,9100	82,81 %	0,16



$y = 1/(-0{,}0242012 + 1194{,}68/x)$ $R^2 = 90{,}55$ % Esŷ = 0,04

Figure 3. Relationship between maximum stable yields (y) found and annual rainfall (x) in both experimental sites

[E] Ochoa, M. *Nutrición y fertilización fosfórica del cafeto* (*Coffea arabica* L.) *cultivado sobre suelo Ferrítico Rojo oscuro* [Tesis de Maestría], Instituto Nacional de Ciencias Agrícolas, Mayabeque, Cuba, 2000, 80 p.

In these conditions of Ferritic soils and for 18 years, with total lower pruning every four harvests, annual yields were obtained between 1,5 and 2,5 t ha $^{-1}$ of gold coffee, with doses varying between 164 kg ha $^{-1}$.year^{-1} and 240 kg ha^{-1} year^{-1} N, depending on the level of yield, precipitation and fractionation used.

Under Veracruz's conditions in México, it is said that rainfall and temperature related to the subperiods of the phenological stages, affect differently coffee production cycles and for those conditions it is explained that excess rains do not allow the optimum development of flowers and fruting causing early wilt[F].

The situation found in these experimental sites lead to state that *Canephora* specie, can reach yields from 1 5 t.ha^{-1} of green coffee to 2 t ha^{-1} when favored with rains, regardless the location and soil type.

CONCLUSIONS

A strong relationship between annual rainfall and maximum stable yields was found in both sites and cycles (R^2>90 %); and due to the eminent predominating nature of the annual variation of rainfall, it is necessary to consider this variable in the harvest estimates to guarantee stability in coffee production in addition to an adequate nutrients supply and good cultural practices.

BIBLIOGRAPHY

1. Maestri, M. y Barros, R.S. "Ecofisiología de cultivos tropicales", *Serie publicaciones misceláneas. Instituto Interamericano de Cooperación para la Agricultura*, vol. 288, 1981, p. 50, ISSN 0534-5391.
2. Soto, F. "Crecimiento y requerimientos ecológicos del cafeto", en: Rivera, R. y Soto, F., *El Cultivo del cafeto en Cuba. Investigaciones y Resultados*, edit. Ediciones INCA, San José de las Lajas, Cuba, 2006, p. 500, ISBN 959-7023-37-7.
3. Alves, M.C.; Silva, F.M. da.; Sanches, L.; Carvalho, L.G. de. y Ferraz, G.A. e S. "Geospatial analysis of ecological vulnerability of coffee agroecosystems in Brazil", *Applied Geomatics*, vol. 5, no. 2, 1 de febrero de 2013, pp. 87-97, ISSN 1866-9298, 1866-928X, DOI 10.1007/s12518-013-0101-0.
4. Rodríguez, D.; Cure, J.R.; Cotes, J.M.; Gutierrez, A.P. y Cantor, F. "A coffee agroecosystem model: I. Growth and development of the coffee plant", *Ecological Modelling*, vol. 222, no. 19, 10 de octubre de 2011, pp. 3626-3639, ISSN 0304-3800, DOI 10.1016/j.ecolmodel.2011.08.003.
5. Fournier, L.A. y Di Stefano, J.F. "Variaciones climáticas entre 1988 y 2001, y sus posibles efectos sobre la fenología de varias especies leñosas y el manejo de un cafetal con sombra en Ciudad Colón de Mora, Costa Rica", *Agronomía Costarricense*, vol. 28, no. 1, 2004, pp. 101–120, ISSN 2215-2202.
6. Ruiz, L.V.; Arizpe, N.; Orellana, R. y Hernández, J. "Impactos del cambio climático en la floración y desarrollo del fruto del café en Veracruz, México", *Interciencia: Revista de ciencia y tecnología de América*, vol. 34, no. 5, 2009, pp. 322-329, ISSN 0378-1844.
7. Bertrand, B.; Boulanger, R.; Dussert, S.; Ribeyre, F.; Berthiot, L.; Descroix, F. y Joët, T. "Climatic factors directly impact the volatile organic compound fingerprint in green Arabica coffee bean as well as coffee beverage quality", *Food Chemistry*, vol. 135, no. 4, 15 de diciembre de 2012, pp. 2575-2583, ISSN 0308-8146, DOI 10.1016/jfoodchem.2012.06.060.
8. Lin, B.B. "Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture", *Agricultural and Forest Meteorology*, vol. 144, no. 1–2, 14 de mayo de 2007, pp. 85-94, ISSN 0168-1923, DOI 10.1016/j.agrformet.2006.12.009.
9. Andrade, G.A.; Ricce, W. da S.; Caramori, P.H.; Zaro, G.C. y Medina, C. de C. "Zoneamento agroclimático de café robusta no Estado do Paraná e impactos das mudanças climáticas", *Semina: Ciências Agrárias*, vol. 33, no. 4, 28 de agosto de 2012, pp. 1381-1390, ISSN 1679-0359, DOI 10.5433/1679-0359.2012v33n4p1381.
10. Mouen Bedimo, J.A.; Cilas, C.; Nottéghem, J.L. y Bieysse, D. "Effect of temperatures and rainfall variations on the development of coffee berry disease caused by *Colletotrichum kahawae*", *Crop Protection*, vol. 31, no. 1, enero de 2012, pp. 125-131, ISSN 0261-2194, DOI 10.1016/j.cropro.2011.09.010.
11. Pallardy, S.G. *Physiology of Woody Plants* [en línea], edit. Academic Press, 20 de julio de 2010, p. 470, ISBN 978-0-08-056871-3, [Consultado: 5 de mayo de 2015], Disponible en: <http://books.google.com.cu/books?hl=es&lr=&id=lErfWWicYb4C&oi=fnd&pg=PP2&dq=Physiology+of+woody+plants&ots=ViN-NL2hRA&sig=Qz3Ej-Rwsw7eVUdI0LF9xAyTtXA&redir_esc=y#v=onepage&q=Physiology%20of%20woody%20plants&f=false>.
12. Ramírez, B.V.H.; Arcila, P.J.; Jaramillo, A.; Rendón, J.R.; Cuesta, G.; García, J.C.; Menza, H.D.; Mejía, C.G.; Montoya, D.F.; Mejía, J.W.; Torres, J.C.; Sanchez, P.M. y Baute, J.E. "Variabilidad climática y la floración del café en Colombia", *Avances Técnicos Cenicafé*, no. 407, 28 de enero de 2013, ISSN 0120-0178, [Consultado: 5 de mayo de 2015], Disponible en: <http://biblioteca.cenicafe.org/handle/10778/333>.

[F] Rosales, G.T. *Evaluación de los impactos potenciales de la variabilidad y cambio climáticos en la producción de café* (*Coffea arabica* L.) *en Coatepec, Veracruz* [Tesis de Maestría], UNAM, 2013, 111 p.

13. Ramírez, V.H.; Jaramillo, A. y Arcila, J. ‘‘Rangos adecuados de lluvia para el cultivo de café en Colombia’’, *Avances Técnicos Cenicafé*, no. 395, 7 de mayo de 2013, ISSN 0120-0178, [Consultado: 5 de mayo de 2015], Disponible en: <http://biblioteca.cenicafe.org/handle/10778/364>.
14. Hernández, A.; Pérez, J.; Bosch, D. y Castro, N. *Clasificación de los suelos de Cuba 2015*, edit. Ediciones INCA, Mayabeque, Cuba, 2015, p. 93, ISBN 978-959-7023-77-7.
15. Pérez, A.; Bustamante, C.; Rivera, R. y Martín, G.M. ‘‘Efecto del nitrógeno sobre los rendimientos y contenido foliar de *Coffea canephora* en un suelo Pardo ócrico sin carbonatos’’, *Centro Agrícola*, vol. 38, no. 4, 2011, pp. 37–44, ISSN 2072-2001.
16. Díaz, A.P.; González, C.A.B.; Alonso, G.M.M.; Espinosa, R.A.R.; Núñez, R.V. y Castro, M.I.R. “Nitrogen fertilization after robusta coffee pruning in Cambisols’’, *Pesquisa Agropecuária Brasileira*, vol. 46, no. 8, agosto de 2011, pp. 935-943, ISSN 0100-204X, DOI 10.1590/S0100-204X2011000800021.
17. Peña, Q.A.J.; Ramírez, B.V.H.; Valencia, A.J.A. y Jaramillo, R.A. “La lluvia como factor de amenaza para el cultivo del café en Colombia”, *Avance Técnicos Cenicafé*, no. 415, 28 de enero de 2013, pp. 1-8, ISSN 0120-0178.
18. Rivera, R. ‘‘Nutrición y fertilización de *Coffea arabica* en Cuba” [en línea], en: Rivera, R. y Soto, F., *El cultivo del cafeto en Cuba. Investigaciones y resultados*, La Habana, Cuba, 2006, p. 500, ISBN 959-7023-37-7, [Consultado: 16 de mayo de 2015], Disponible en: <http://www.researchgate.net/profile/Ramon_Espinosa/publication/271763850_Nutricin_y_fertilizacin_del_coffea_arbica_en_Cuba/links/54d0dcb00cf20323c219fce5.pdf>.
19. Velásquez Franco, S.; Jaramillo Robledo, A.; Acosta, L.; Louman, B.; Galloway, G.; Varón, E.H.; Hanson, P.; Longino, J.T.; Borbón, O.; Carballo, M. “Redistribución de la lluvia en diferentes coberturas vegetales de la zona cafetera central de Colombia’’, *Cenicafé*, vol. 60, no. 2, 2009, pp. 148–160, ISSN 0365-9372.

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