Cultivos Tropicales, 2015, vol. 36, no. 1, pp. 28-34 January-March

ISSN print: 0258-5936
ISSN online: 1819-4087

Ministry of Higher Education. Cuba
National Institute of Agricultural Sciences
http://ediciones.inca.edu.cu

BIOMASS PRODUCTION BY *Coffea canephora* Pierre ex Froehner IN TWO PRODUCTIVES CYCLES

Producción de fitomasa por *Coffea canephora* Pierre ex Froehner en dos ciclos productivos

Carlos Bustamante González[1✉], Alberto Pérez Díaz[2], Rolando Viñals[3], Gloria M. Martín Alonso[4], Ramón Rivera[4] and Maritza I. Rodríguez[1]

ABSTRACT. In areas of the Estación Central de Investigaciones de Café y Cacao located in La Mandarina, Tercer Frente municipality, Santiago de Cuba province, and La Alcarraza, municipality Sagua de Tánamo, Holguín province, the biomass production of *Coffea canephora* Pierre ex Froehner var. Robusta was assessed from planting until the fourth year in both locations and after pruning until the fourth year in Alcarraza. The coffee trees were planted at 3 x 1,5 m in Cambisol under *Samanea saman* Jerr shade in the first town and *Leucaena leucocephala* Lam de Wit in the second. The biomass was separated into: leaves, branches, stems, fruits and roots. From 24 months and one year after pruning, leaflitter was collected monthly. For the study of the root system soil blocks of 25 x 25 x 25 cm were extracted, in an area formed by 1,5 m (distance to the street) and 0,75 m (between plants), centered relative to the coffee plant and up to a meter deep. The extracted soil represented ¼ of the volume occupied by the plant. The dry mass of each organ was determined. Dry matter production reached values of 25 t dry mass ha^{-1} regardless of the stage of the plantation. Until the fourth year the root system dominated the biomass, followed by the leaves and then the stems. The participation of the fruits in the biomass increased in the crop stage and when concluding the experiment the coffees had dedicated for its formation among the 16-20 % of the total dry mass, independently of the development cycle.

Key words: *Coffea canephora*, biomass, growth

RESUMEN. En áreas de la Estación Central de Investigaciones de Café y Cacao ubicadas en La Mandarina, municipio Tercer Frente, provincia Santiago de Cuba y La Alcarraza, municipio Sagua de Tánamo, provincia Holguín, se evaluó la producción de biomasa de *Coffea canephora* Pierre ex Froehner var. Robusta desde la plantación hasta el cuarto año en ambas localidades y luego de la poda baja y hasta el cuarto año en la Alcarraza. Los cafetos fueron plantados a 3 x 1,5 m en suelos Pardos bajo sombra de *Samanea saman* Jerr en la primera localidad y *Leucaena leucocephala* Lam de Wit en la segunda. La fitomasa se separó en hojas, ramas, tallos, frutos y raíces. A partir de los 24 meses y al año después de la poda se recolectaron mensualmente las hojas del cafeto caídas. Para el estudio del sistema radical se extrajeron bloques de suelo de 25 x 25 x 25 cm, en un área formada por 1,5 m (distancia hacia la calle) y 0,75 m (entre plantas), en todos los casos centrado en relación con la planta y hasta un metro de profundidad. El volumen del suelo extraído representó ¼ del volumen ocupado por la planta. Se determinó la masa seca de cada órgano. La producción de fitomasa alcanzó valores de 25 toneladas de masa seca ha^{-1} independientemente de la fase de la plantación. Hasta el cuarto año el sistema radical predominó en la fitomasa, seguido de las hojas y luego los tallos. La participación de los frutos se incrementó en la etapa de cosecha y al concluir el experimento los cafetos habían destinado para su formación entre el 16-20 % de la masa seca total, independientemente del ciclo de desarrollo.

Palabras clave: *Coffea canephora*, biomasa, crecimiento

[1] Instituto de Investigaciones Agroforestales. UCTB Tercer Frente Santiago de Cuba. CP 92700.

[2] Universidad de Guantánamo, Facultad Agroforestal de Montaña. carretera a Santiago de Cuba, km 2 ½, Guantánamo. CP 95 300.

[3] Instituto de Investigaciones Agroforestales. UCTB Velasco. Holguín.

[4] Instituto Nacional de Ciencias Agrícolas (INCA), carretera Tapaste, km 3 ½, gaveta postal 1, San José de las Lajas, Mayabeque, CP 32700.

✉ marlonalejandro2012@gmail.com; nutricion1@tercerfrente.inaf.co.cu

INTRODUCTION

The paradigm governing the soil-plant relationship focused on the exogenous process of the soil and paid less attention to endogenous processes, which should be known better and more extensively used (1).

In the last two decades, a new plant production paradigm has evolved to get crop yields involved and integrating resources, productive factors and interactions among processes that manage the soil-plant system. It provides special importance to biological processes that serve to improve nutrients recycling, minimize external entries and increase the effectiveness of its use to the maximum[A] (2, 3).

Genetics focuses on the quest for more productive and better adapted plants to the different types of soils and technologies that match the characteristics of production ecosystems; however, today it is not possible to improve varieties without a deep knowledge of the physiological and biochemical processes governing yield formation. It has been established that as higher dry matter production is, so the yield of the crop will be, so dry mass distribution within the plant plays an important role in yield (4) and in the selection of cultivars (5).

The growth analysis technique has shown to be important in dry matter production studies in relation to varietal differences in cultivated plants or affected by cultural practices (fertilization, irrigation, among others) or subjected to different environmental conditions (6). In Brazil, it was shown that up to the fifth year of planting coffee trees, total dry matter increase is conditioned to higher dry mass production of coffee tree leaves (7).

The biomass production of a plant is an important variable to characterize its productivity, since it reflects the biological yield of the plant. Yield is the final result of several interactions where the genotype, climate, soil and crop management are involved (4, 5). The impact of these different parameters defines crop phenology and yield (5).

Coffea canephora Pierre ex Froehner var. Robusta was introduced in Cuba since the decade of the 30's of the XX century. Its crop can be found in those areas where the arabica specie cannot express its full potential for ecological restrictive factors like (temperature, mainly) or for being affected by the soil or by nematodes[B].

The early research on *Coffea canephora* Pierre ex Froehner in Cuba were aimed towards cultural practices with studies on the leaf surface (8), planting densities (9) and more recently on the effect of shoot education (10).

Wordwide research on these topics are not so wide and in Cuba, only one study on phytomass production in coffee has been published (11) made with the arabica specie as the case of *Coffea canephora* related to pruning wastes biomass (12), so there is not information of this indicator for this specie. It is highly known that phytomass contributes information on the functioning and productivity of the plot, and permits to evaluate the use of the ecosystem by the crop.

Coffea canephora is characterized by a different management compared to that of *Coffea arabica* due to its different size, its capability of forming multiple stems, lower density planting, different edapho-climatic demands, so it is necessary to establish phytomass production in this specie and its composition in two agro-ecosystems of the Eastern region of the country as the essential element to know its nutrient requirements.

MATERIALS AND METHODS

In order to characterize phytomass production of *Coffea canephora* Pierre ex Froehner on Brown soils, evaluations of coffee trees planted in two experimental locations of the Central Research Station for Coffee and Cocoa, were made: one at La Mandarina Farm (20°09'N, 76°16'W at 150 m of altitude), in the Tercer Frente municipality, Santiago de Cuba province and the other one in La Alcarraza (20o35'N, 75015'W at 300 m of altitude) Sagua de Tánamo municipality, Holguín province.

Coffee trees were planted at 3 x 1,5 m with cutting from a clonal mixture of the above-mentioned station. Seedlings were planted at the shadow of Samanea saman Jerr in October 1995, Tercer Frente and in December that year in La Alcarraza under the shadow of Leucaena leucocephala Lam de Wit. On February 2003, low pruning was practiced in both plots.

Evaluations were made annually during the first productive cycle (1995-2002) in both sites, while in the second cycle (2003-2006) they were only made in "La Alcarraza".

The extraction area was made up of 60 plants, distributed in three plots of 41 m2. Twenty plants were planted in each plot and were left to free growth till the fourth year. Every year, two plants at random were extracted per plot for a total of six per year.

Plants were fertilized in the first cycle with 60, 90 and 100 kg of N ha^{-1} $year^{-1}$ (for the first, second, third and fourth consecutive year respectively) and as bottom fertilization with 40 kg of P O ha^{-1} per $year^{-1}$ and 160 kg of KO ha^{-1} per $year^{-1}$. In all the cases, dry mass was determined (drying each organ at 70 °C till the second cycle. Nitrogen was then applied at the rates of 100, 150 y 200 kg ha^{-1} for the first, second and third year, respectively. Phosphorus was applied at 50 kg ha^{-1} in 2004. Potassium (KO) was applied at a constant weight and was expressed in t ha^{-1}.

[A] Blanco, A. Manejo de la sombra en la regeneración de la variedad Robusta (*Coffea canephora* Pierre). Su influencia en el desarrollo vegetativo y la producción de café oro. [Tesis de Doctorado]. Universidad Agraria de La Habana, 2005. 100 pp.

[B] Díaz W.; Bustamante, C.; Caro, P.; Cumbá, Bárbara /et al./. Establecimiento y manejo de plantaciones de *Coffea canephora* var. Robusta (Pierre ex Froehner). [Informe final Proyecto Nacional 007-03-016]. Estación Central Investigaciones de Café y Cacao, Cruce de los Baños, 2003. 352 pp.

Phytomass production was calculated (t ha^{-1}) in each extraction date. Annual extractions of phytomass were estimated by the difference between accumulated extractions of consecutive sampling. In all evaluated variables, the mean and standard deviation were determined.

Phytomass production was determined, both in the areal system as in the root system; the first one was separated in different parts: leaves, branches (lignified and growing), stems (lignified and growing), fruits and roots.

The root system was also studied by extracting soil blocks of 25 x 25 x 25 cm, from an area of 1,5 m (distance to the row middle) and 0,75 m (between plants), centered in all cases in relation to the plant and up to 1 meter deep till finding roots. Total soil volume extracted accounted for ¼ of soil volume occupied by the plant according to the spacing used.

After 24 months and one year after pruning, plant material fallen into the soil was collected monthly using polyurethane sheets that covered ¼ of the vital area of coffee trees (0,75 x 1,5 x 1,0 m), in the plants to be extracted. Results were expressed as leaf drops (t ha^{-1}). Samples were clean from soil wastes and leaves were separated from the rest of accumulative fractions of further sampling. The mean and standard deviation were determined to all evaluated variables.

RESULTS AND DISCUSSION

First Production cycle

In both sites, annual phytomass production in the aereal system showed a different behavior between the initial stage of plot establishment (till 12 months) and a later productive stage, which coincides with other authors (13) who confirm a marked effect of edapho-climatic conditions on dry mass production.

The accumulated production of phytomass in both locations ranged from 5.4 to 6.0 t ha^{-1} of dry mass and increased to 10 t ha^{-1} in the second year (Table I). In the productive stage, at the third year, phytomass reached 18 t ha^{-1} at “Tercer Frente” and increased to 19 t ha^{-1} of dry mass at “La Alcarraza”. In the fourth year, coffee plots accumulated 25 t ha^{-1} of dry mass (Table I).

These results were higher than those of *Coffea arabica* L. “Isla 5-16” variety under the same edapho-climatic conditions of Tercer Frente, where phytomass reached 4.16 t ha^{-1} in the second year and increased to 8.2 t ha^{-1} of dry mass at the third year (13). In Brazil, in studying 13 elite clons of the “Vitoria Incaper 8142” variety, lower dry mass values were found (14).

From the fourth year on, annual dry mass reductions were found as compared to the third year, which could be equivalent to less primary branches and having relatively high harvests three years in a row.

Table I. Accumulative dry mass production (t ha^{-1}) in *Coffea canephora* plots on brown soils

Phytomass	1996	1997	1998	1999	2000
	Tercer Frente				
Leaves	1,25 (± 0,18)	2,25 (± 0,37)	3,90 (±1,18)	3,80 (± 1,25)	3,70 (± 1,52)
Accumulated leaf fall	-	0,35	1,58	3,2	4,75
Branches	1,61 (± 0,22)	1,94 (± 0,17)	3,60 (± 1,33)	3,49 (± 1,16)	3,38 (± 1,28)
Stms	1,84 (± 1,38)	2,43 (± 1,25)	3,50 (± 1,27)	4,91 (± 1,37)	4,80 (± 1,10)
Fruits	-	0,71 (± 0,16)	1,60 (± 0,66)	1,70 (± 0,68)	1,60 (± 0,35)
Accumulated fruits	-	0,71	2,31	4,11	5,91
Aereal system	4,70	8,84	14,89	19,51	22,54
Root system	1,37 (± 0,44)	1,47 (± 0,43)	3,54 (± 1,21)	4,75 (± 0,82)	5,70 (± 0,29)
Total phytomass	6,07	10,31	18,43	24,31	27,24
	La Alcarraza				
Leaves	1,20 (± 0,64)	2,72 (± 1,20)	3,80 (± 1,62)	3,68 (± 1,73)	3,60 (± 1,63)
Accumulated leaf fall	-	0,36	1,72	3,47	5,12
Branches	1,24 (± 0.55)	2,65 (± 1,03)	3,50 (± 1,11)	3,38 (± 1,59)	3,30 (± 1,24)
Stems	1,73 (± 1,48)	2,43 (± 1,12)	4,30 (± 1,20)	4,85 (± 1,16)	4,90 (± 1,61)
Fruits	-	0,60 (± 0,29)	1,95 (± 0,14)	2,16 (± 0,26)	1,90 (± 0,35)
Accumulated fruits	-	0,6	2,55	4,71	6,61
Aereal system	4,17	9,12	15,87	20,09	23,51
Root system	1,26 (± 0,96)	1,43 (± 0,26)	4,10 (± 2,23)	5,35 (± 1,63)	5,80 (± 1,65)
Total phytomass	5,43	10,55	19,97	25,44	29,31

Planting density: 2222 plants per ha^{-1}
Numbers between parentheses: standard deviation of the mean values

Annual dry mass gradually increased till reaching 4,24 t ha^{-1} inthe third year at Tercer Frente and 5,12 t ha^{-1} at "La Alcarraza". In the third year, the increase was 8 and 9 t ha^{-1} respectively, while in the fourth year it fell to 7,03 and 5,47 t ha^{-1}, influenced by reduced leaves and branches involvement in the total composition of the plant biomass which might be related to the productive level of the plot. The production of the specie *C. canephora*, is directly related to node formation in branches (15).

In general, annual absolute increase of phytomass were similar in both locations but the analysis of the relative annual increase against th biomass of the base year reflected the growth of this indicator in "La Alcarraza" was higher than Tercer Frente's and in the fourth year it was 368 % as compared to the first year in the first location and 321 % in the second location. This behavior could be related to differences in climate of these sites.

In Tercer Frente, annual mean temperature (average of 13 years) was 24,5 ºC, and rainfall was 1 654 mm in 112 days with rain. While in "La Alcarraza" annual mean temperature was lower than 24,1 ºC, and rainfall higher, 1 773 mm, and more days with rains 120.

It has been established that plant growth shows different behavior as a response to climatic conditions which may vary from one site to another (16). Rain quantity and distribution during the year are very important factors for a good development of coffee trees. Rainfall below 1000 mm per year, limits plant growth and therefore, next year harvest (17). High temperatures inhibit coffee trees growth because at 24 ^{o}C, photosynthesis starts decreasing and turns almost imperceptible at 34 ^{o}C (18).

The annual dry mass production found in *Coffea arabica* L. (13) on a Brown soil of Tercer Frente, increased per year, but it did below *C. canephora* specie with only 3.96 t ha^{-1} at the third year. It is related to the edapho-climatic demands of each specie. It is known that *Coffea canephora* is native from the low and hot jungles of Guinea and Congo (18) with similar conditions to this site's regarding rainfall and temperature, while the arabica specie, for being native from Ethiopia, requires lower temperatures for its optimum development.

Branches at the fourth year, accounted for 13 and 14 % of the total biomass of the plots and stems accounted for 19 %. These values are similar to the values of 15 and 20 % respectivelye, found in Colombia for *Coffea arabica* L. (6). Leaves contribution (including fallen ones) accounted for 26 and 27 % of the total phytomass production of the plots. In Costa Rica, branch share in the production of the total biomass under an agroforestry system and under sun exposure was 22 %, while leaves share was 16 % (19).

In nutrient accumulation studies done in Brazil with this specie, it was reported that leaves, after 72 months of planting coffee trees, accounted for 17 % of the total biomass of the plants (20), while in Nicaragua, Balladares and Calero[C], in studies on the management system of coffee plots, found that leaves accounted for 25 and 27 % of the biomass, irrespective of the management and sampling time.

Fruits share as reservoir of the annual aereal phytomass, increased as coffee trees approached harvest. In the second year, it accounted for 6-8 % of the aereal dry mass produced by coffee plots. At the third year, fruit contribution was from 11 to 12 % in both plots, while at the fourth year it was 9 % in Tercer Frente and reached 10 % in "La Alcarraza". Both conditions were similar in the distribution of the dry mass for the harvest. The plot in Tercer Frente used 17% of the total dry mass till the fourth year of the first productive cycle to form fruits; while in "La Alcarraza" it was 19 %.

Canephora plots located in "La Alcarraza" produced more efficiently under these conditions. Fruits contribution to the annual phytomass of the plot at the third year of the second cycle was similar to the first cycle's, with 21 %; however, at the fourth year it reached 45 % of the annual phytomass of the plots. The results were similar to those of *Coffea arabica* L. in Kenia (21), where it was reported that coffee trees used up to 36% of the dry mass to form fruits.

In *Coffea arabica* L. planted in Cuba, the contribution of the dry mass to fruit formation was 32.5 % in plots on Red Ferralitic Soil of San José de las Lajas and on Lixiviated Red Ferralitic Soils of Topes de Collantes mountains it reached 45,8 % (22), which confirmed that this indicator (production/phytomass) expresses the efficiency attained in coffee plots located in more favorable conditions for the development of the specie.

The root system contribution to total phytomass production ranged from 18 to 20 %, higher than 3,8 t ha^{-1} of dry mass (10 % of the total phytomass produced in *C. arabica* (23). It has been confirmed that root activity of *Coffea canephora* Pierre ex Froehner is higher than *C. arabica* and therefore, it makes easier the effective use of applied fertilizers and soil nutrients (24).

Under lab conditions in Brazil, the involvement of the root system in 13 elite clons of *Coffea canephora* ranged from 18 to 22 % (14), while in the same country, field experiments with two genotypes of *C. canephora*, showed this specie was able to produce 77,39 % of dry mass in the aereal part and 22,61 % in the root system (25).

[C]Balladares, D. D. y Calero, J. M. Efecto de la sombra y fertilización sobre el crecimiento, estructura productiva, rendimiento y calidad del café (*Coffea arabica*) vr. Costa Rica 95. [Tesis de Ingeniería]. Managua. Universidad Nacional Agraria. 2005. 82 pp.

In Costa Rica, when comparing *Coffea arabica* under the sun and under an agroforestry system, they found that the contribution of the root system to the total biomass of the plant ranged from 21 to 22 % (19).

Root growth of *Coffea canephora* was higher than *Coffea arabica* in high density plots of the Tercer Frente and under similar edaphoclimatic conditions, an indication of the better adaptation of this specie to such conditions[D].

The root system of *Coffea canephora* changes according to the clon. At the same time, extension, distribution, architecture, depth and efficiency of the water uptake, can be affected by different factors, genetic ones included (15). In Togo, root biomass from *Coffea canephora* trees showed values from 4 to 5 tonnes ha^{-1} (26).

The balance between the roots and the aereal part is closely linked to the development of coffee trees and their productivity. The ideal clons are those showing a high aereal biomass production followed by a great development of the root system.

The root mass / aereal mass relationship of 13 clons in Brazil ranged from 0,23 to 0,32 (14), while under experimental conditions similar values were found from 0,16 to 0,3.

The greatest phytomass contribution was made by the aereal system as compared to the root system. At the fourth year, accumulated aereal phytomass production in *C. canephora* accounted for 77 and 78 % of total phytomass (Table I).

The relationship of the dry mass from the vegetative system / root system, ranged from three to four and although they fall in the range for *C. arabica* (27), they indicate a high development of the root system in *C. canephora*, since a relationship of three are considered as high values of the root system and four is considered as typical for coffee trees.

[D] Bustamante, C. /*et al*./. Efecto de los tratamientos sobre el crecimiento e índices agroquímicos en el período. Proyecto Nacional 003-046. [Informe final de etapa]. Estación Central de Investigaciones de Café y Cacao, Cruce de los Baños, 1989. 30 pp.

Similar results are true for *C. arabica* grown on Red Ferralitic Soils (11).

Second productive cycle

Accumulated phytomass values in the second cycle at “La Alcarraza” were similar to those attained in the first one, which indicates that cycles similarly managed show a similar growth.

The total biomass production of the plot in the first year was 7,6 t ha^{-1} of dry mass; the second one witnessed an increase of 7 t ha^{-1} and reached 23 t ha^{-1} of total accumulated phytomass at the third year. In the fourth year, phytomass increased in 4 t ha^{-1} and reached 27 t ha^{-1} of dry mass (Table II), two tonnes more than the previous cycle.

In Togo, there are reports of total biomass values in *Coffea canephora* close to 20 t ha^{-1} (26).

Fruit contribution in the second cycle increased and from 11 % total phytomass, reached 15% at the third year and then increased again to 20% of the total phytomass of the plots at the end of the trial (Table II).

Branches accounted for 13 % at the third year and went down to 11 % of the total phytomass at the fourth year. Stems contributed from 21 to 23 % of the total accumulated dry mass, while the share of the leaves, including fallen leaves, accounted for 21- 29 % of the total phytomass production in the *C. canephora* plot.

Annual dry mass production at the first and second year was higher in the first and second year and slightly higher to the first cycle; it was around 7 tonnes ha^{-1}. At the third year, annual increase was lower to that of the first cycle in approximately 2 t ha^{-1} of dry mass (Table II).

Total phytomass production in both plots were similar to estimated values for characterizing evergreen forests of Sierra del Rosario in Pinar del Río, which ranged from 1,86-9,64 t ha^{-1} of dry mass (28).

In general, phytomass production increased as coffee trees came into bearing. The aereal system provided the highest phytomass as compared to the root system, but both showed a different behavior between the initial stage of the plot and the further productive stage.

Table II. Accumulated production of dry phytomass (t ha^{-1}) in *Coffea canephora* plots at “La Alcarraza”. Second productive cycle

Phytomass	2002	2003	2004	2005
Leaves	1,38 (± 0,49)	2,22 (± 0,24)	3,00 (± 0,33)	3,24 (± 1,14)
Leaf fall	0,24	1,56	3,09	4,69
Branches	1,13 (± 0,24)	2,02 (± 1,45)	2,95 (± 1,24)	2,80 (± 1,04)
Stems	1,68 (± 1,10)	3,08 (± 1,25)	5,41 (± 2,72)	5,76 (±1,18)
Fruits	-	1,62 (± 0,61)	1,93 (± 0,93)	1,86 (± 0,59)
Accumulated fruits	-	1,62	3,55	5,41
Total aereal phytomass	4,43	10,5	18,00	21,9
Root system	3,17 (± 1,38)	3,65 (± 1,93)	5,03 (± 1,61)	5,20 (± 1,11)
Total phytomass	7,60	14,15	23,03	27,10

L.F. leaf fall. Planting density 2222 plants ha-1
Numbers between parentheses: standard deviation of the mean values

During the first cycle, phytomass production did not differ among plots from the experimental sites. “La Alcarraza”, stands out for the fact that in the first and second cycles, annual production of dry mass at the third year was similar 9 t ha^{-1}.

C. canephora specie used from 16 to 20% of the total dry mass to fruit formation. In the aereal system, leaves (including fallen leaves) provided the highest phytomass production followed, in order of importance, fruits, stems and branches.

Accumulated phytomass in the second cycle at “La Alcarraza” were similar to those of the first cycle, which indicates that similarly managed cycles showed similar growth, yield, and efficiency indicators.

These results show that *C. canephora* specie under the study conditions shows an intensive production pace of annual dry mass which surpasses *C. arabica*. Such pace is annually increased till the third year and then stabilizes in the fourth one.

Brazilian researchers have reported that *C. canephora* specie is very efficient in dry mass production since it has a high uptake and transfer rate of light energy, a wider foliar area to attract light and high photosynthetic, transpiration and stomatic conductance rates (29).

CONCLUSIONS

- Coffee trees from the *Coffea canephora* specie undr the study conditions produced values of 25 t of dry mass per ha^{-1} irrespective of the planting stage.
- Untirl the fourth year, root system predominated in the phytomass, followed by the leaves and then by the stems.
- Fruit participation in the phytomass increased when coffee trees came into the harvest stage; at the end of the experiment *C. canephora* specie had used from 16 to 20 % of the total dry mass of the plot, regardless their development cycle.

BIBLIOGRAPHY

1. Martínez Viera, R. y Dibut, B. Utilización de nuevos paradigmas que permitan profundizar los conocimientos sobre las relaciones suelo-planta en condiciones tropicales. *Cultivos Tropicales,* 2009, vol. 30, no. 2, pp. 5-9. ISSN 1819-4087.
2. Maqueira, L. A.; Torres, W. y Miranda, A. Crecimiento y rendimiento de dos variedades de arroz de ciclo corto en época poco lluviosa. *Cultivos Tropic*ales, 2009, vol. 30, no. 3, pp. 28-31. ISSN 1819-4087.
3. Gama, A. Soil organic matter, nutrient cycling and biological dinitrogen-fixation in agroforestry systems. *Agroforest Syst*., 2011, vol. 81, pp. 191-193. DOI 10.1007/s10457-011-9372-9. ISSN 1572-9680.
4. Soto, F.; Plana, R. y Hernández, Naivy. Influencia de la temperatura en la duración de las fases fenológicas del trigo harinero (*Triticum aestivum* ssp aestivum) y triticale (x *Triticum secale* Wittmack) y su relación con el rendimiento. *Cultivos Tropicales,* 2009*,* vol. 30, no. 3, pp. 32-36. ISSN 1819-4087.
5. Kufa, T. Biomass production and distribution in seedlings of *Coffea arabica* genotypes under contrasting nursery environments in southwester Ethiopia. *Agricultural Science,* 2012, vol. 3, no. 6, pp. 835-843. ISSN 2156-8561.
6. Riaño, N.; Arcila, J.; Jaramillo, A. y Chaves, B. Acumulación de materia seca y extracción de nutrimentos por *Coffea arabica* L. cv. Colombia en tres localidades de la zona cafetera Central. *Cenicafé,* 2004*,* vol. 55, no. 4, pp. 265-276. ISSN 0120-0275.
7. Pereira, F. M. Crescimento e desenvolvimento do cafeeiro sob efeito da adubação nitrogenada. [Tesis Doutorado]. Piracicaba. Escola Superior de Agricultura Luis de Querioz. 2006. 81 pp.
8. Ortiz, E. Crecimiento y desarrollo del *Coffea canephora* con diferentes marcos de plantación. *Cultivos Tropicales*, 1993, vol. 14, no. 1, pp. 48-51. ISSN 1819-4087.
9. Arias, L.; Sánchez, O. y Aldazabal, M. Influencia de diferentes densidades de plantación sobre el rendimiento y algunos de sus componentes en el cultivo de *Coffea canephora* Pierre. *Revista Alimentaria, Tecnología e higiene de los alimentos*, 2002, Año XXXIX, no. 332, pp. 49-51. ISSN 0300-5755.
10. Molina, G.; Díaz, W.; Vázquez, E. y Reyes, R. Influencia de la poda en el número de vástagos de *Coffea canephora* Pierre. *Café Cacao*, 2002, vol. 3, no. 2, pp. 23-25. ISSN 1680-7685.
11. Rivera, R. Crecimiento y producción de fitomasa de una plantación de cafeto a plena exposición solar sobre suelo Ferralítico Rojo Compactado. *Cultivos Tropicales,* 1982, vol. 13, no. 2-3, pp. 60-68. ISSN 1819-4087.
12. Bustamante, C. y Grave de Peralta, G. Producción de biomasa y retorno de nutrientes al ecosistema por *Coffea canephora* Pierre bajo diferentes sistemas de poda. En: Congreso Científico del INCA (14: 2004, nov 12-15, La Habana) Memorias, CD ROM. Instituto Nacional de Ciencias Agrícolas, 2004. ISBN 959-7023-27x.
13. Rodríguez, Maritza I.; Bustamante, C. y Grave de Peralta, G. Crecimiento y requerimientos nutrimentales del cafeto *(Coffea arabica*) var. Isla 5-16 hasta el tercer año de plantación en suelo Pardo sin carbonatos. *Café Cacao*, 1998, vol. 1, no. 1, pp. 10-15. ISSN 1680-7685.
14. Contarato, C. C.; Moreira, S. F.; Tomaz, M. A.; Cintra de J. J., Waldir; Almeida da Fonseca, A. F.; Gava F., Maria Amélia y Gava F., R. Evaluation of the initial development of conilon coffee clones (*Coffea canephora*). *Scientia agrária*, 2010, vol. 11, no. 1, enero-febrero, pp. 65-71. ISSN 0103-9016.
15. Da Matta, F. M. /*et al*./. Ecophysiology of coffee growth and production. *Brazilian Journal of Plant Physiology*, 2007. vol. 19, no. 4, pp. 485-510. ISSN 1677-0420.
16. Nortcliff, S. y Gregory, P. J. The historical development of studies on soil–plant interactions. En: *Soil Conditions and Plant Growth.* Edited by Gregory, Peter J. and Nortcliff, Stephen. Published by Blackwell Publishing Ltd. 2013. 21 pp.

17. Duicela, L. A. Manejo sostenible de fincas cafetaleras. Buenas prácticas en la producción de café arábigo y gestión de la calidad en las organizaciones de productores. Portoviejo: Fondo Común para los productos básicos y Consejo Cafetalero Nacional. 2011. 306 pp.
18. Coffee: growing, processing, sustainable production-a guidebook for growers, processors, traders, and researchers. Nicolas, Jean. Wintgens (Ed). Wiley-VCH Verlag, Weinheim, 2004. 976 pp, ISBN 3-527-30731-1.
19. Siles, P.; Harmand, J. M. y Vaast, P. Effects of Inga densiflora on the microclimate of coffee (*Coffea arabica* L.) and overall biomass under optimal growing conditions in Costa Rica. *Agroforest Syst.*, 2010, vol. 78, pp. 269-286. ISSN 1572-9680. DOI 10.1007/s10457-009-9241-y.
20. Bragança, Scheilla Marina; Prieto, Herminia Emılia; Garcia, H.; Pereira, L.; Sigueyuki, C.; Alvarez, V. y Lani, J. Accumulation of Macronutrients for the Conilon Coffee Tree. *Journal of Plant Nutrition*, 2008, vol. 31, pp. 103-120. ISSN 1532-4087.
21. Cannell, M. G. R. Production and Distribution of Dry Matter in Trees of *Coffea arabica* L in Kenya as affected by seasonal climate differences and the presence of fruits. *Ann. Appl. Biol.*, 1971, vol. 67, pp. 99-120. ISSN 1744-7348.
22. Rivera, R. Nutrición y fertilización de *Coffea arabica* en Cuba. En: Rivera, R. y Soto, F. (editores). El Cultivo del cafeto en Cuba. Investigaciones y Resultados. 2006. pp. 500. ISBN 959-7023-37-7.
23. Rivera, R.; Bustamante, C. y Ochoa, M. La fertilización nitrogenada del cafeto en diferentes condiciones edafoclimáticas de Cuba. *Cultivos Tropicales,* 1994, vol. 15, no. 1, pp. 5-11. ISSN 1819-4087.
24. Jayarama, R. P.; Ananda, A. y Naidu, R. Latest concept of fertiliser usage in coffee plantations with respect to Nitrogen, Phosphorus and Potassium. *Indian Coffee,* 1994, vol. LVIII, no. 9, pp. 9-12. ISSN 0975-2404.
25. Mattiello, J. B.; Gervasio, E. M.; Zonta, E.; Mauri, J. y Matiello, J. B. Produção de material seca, crescimento radicular en absorção de calcio, fósforo e aluminio por *C. canephora* e *C. arabica* sob influenciada da atividade do aluminio. *Rev. Bras. Ci. Solo*, 2008, vol. 32, pp. 425-434. ISSN 0100-0683.
26. Dossa, E. L.; Fernandes, E. C. M.; Reid, W. S. y Ezui, K. Above- and belowground biomass, nutrient and carbon stocks contrasting an open-grown and a shaded coffee plantation. *Agroforest Syst.,* 2008, vol. 72, pp. 103-115. DOI 10.1007/s10457-007-9075-4. ISSN 1572-9680.
27. Muller, L. E. Coffea Nutrition. En: Temperate to Tropical Fruit Nutrition. Sommerville: Somerst Press. 1966. pp. 685-776.
28. Menéndez, Leda /*et al*./. Estructura y productividad del bosque siempre verde de la Sierra del Rosario, Cuba. Proyecto MAB, No.1. 1974-1987. La Habana: Oficina Regional de Ciencia y Tecnología de la UNESCO para América Latina y el Caribe. 1988. 212 pp.
29. Marques de Calvalho, Luciana; Monteiro da Silva, E.; Azevedo, A.; Mosquin, P y Cecon, P. R. Aspectos morfosisiológicos dos cultivares de cafeeiro Catuai-Vermilho e conilon. *Pesquisa Agropecuaria Brasileira*, 2001, vol. 36, no. 3, marzo. ISSN 1678-3921.

Received: December 25th, 2013
Accepted: September 9th, 2014