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COFFEE (*Coffea arabica* L.) SEEDLING GROWTH WITH FOUR SHADE LEVELS UNDER TWO SOIL AND CLIMATE CONDITIONS OF ECUADOR

Crecimiento de posturas de cafeto (*Coffea arabica* L.) con cuatro niveles de sombra en dos condiciones edafoclimáticas de Ecuador

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ABSTRACT. An experiment was developed under two soil and climate conditions of Ecuador: "Chaguarpamba" and "Yantzaza", with the aim of studying the effect of four shade levels: 0, 30, 50 and 80 % on coffee seedling growth in the nursery. A sample experimental design was used in stripes. Destructive samplings were performed from the first pair of true leaves every 25 days, evaluating height, dry mass and leaf area. Data were processed through a one-way classification variance analysis. To study growth dynamics of the total dry mass and leaf area, data were fitted to a second-degree polynomial exponential function for calculating absolute growth rate. Concerning the indicators evaluated, it was generally observed that the best treatments were 80 and 50 % shade, whereas less developed seedlings were grown at full solar exposure. Furthermore, treatments of 80 and 50 % had a greater growth and reached its maximum values before the others in both sites. Regarding sites, plant growth at the early stage was faster in "Yantzaza" than in "Chaguarpamba", which was related to temperature that was higher at growth beginning in the first site with a trend to decrease over time. However, the opposite occurred in "Chaguarpamba", where temperature gradually increased towards the end of the nursery period.

Key words: shade, coffee plant, growth, temperature, *Coffea*

RESUMEN. Se desarrolló un experimento en dos condiciones edafoclimáticas de Ecuador, en los sitios "Chaguarpamba" y "Yanzatza", para estudiar el efecto de cuatro niveles de sombra, 0, 30, 50 y 80 % en el crecimiento de posturas de cafeto en vivero. Se utilizó un diseño experimental muestral en franjas. A partir del primer par de hojas verdaderas y cada 25 días se realizaron muestreos destructivos, evaluándose la altura, la masa seca y el área foliar. Los datos se procesaron mediante un análisis de varianza de clasificación simple. Para estudiar la dinámica de crecimiento de la masa seca total y el área foliar, se ajustaron los datos a una función exponencial polinómica de segundo grado, a partir de la cual se calculó la Tasa Absoluta de Crecimiento. En los indicadores evaluados, de manera general, se observó que los mejores tratamientos fueron el 80 y 50 % de sombra, las posturas con menor desarrollo fueron las crecidas a plena exposición solar. Así mismo, los tratamientos del 80 y 50 % tuvieron un mayor crecimiento y alcanzaron los valores máximos de este indicador con anterioridad, en relación con los otros tratamientos en ambos sitios. Respecto a los sitios, se observó que el crecimiento en la fase inicial fue más rápido en "Yantzaza" que en "Chaguarpamba", lo que tuvo relación con el comportamiento de la temperatura, que en el primer sitio fue mayor al inicio del crecimiento, con tendencia a ir disminuyendo con el tiempo. Lo contrario sucedió en "Chaguarpamba", donde la temperatura fue aumentando hacia el final del período de aviveramiento.

Palabras clave: sombra, cafeto, crecimiento, temperatura, *Coffea*

INTRODUCTION

Coffee plants are grown in different regions of the world, due to its wide range of adaptation to ecological conditions, particularly *Coffea arabica* L. species, which represents 67 % of the overall worldwide crop (1).

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Although Ecuador is a small coffee-producing country, its production, marketing, processing and exportation are relevant in the economy, social development and environmental preservation, since it can be grown in various regions of the country, taking up 193,000 ha and approximately 105,000 families depend on it, 70 % out of them are small coffee producers (2).

Low productivity has always been a problem to face, and one of the main elements to manage changing that reality in coffee plantations is the use of good quality seedlings, defined as their ability to get adapted to the environmental conditions under which they will be finally planted to ensure successful plantations (3, 4).

Coffee seedlings traditionally grow under shade, either natural or artificial, so that they have the required conditions to be further taken to the field (5). In order to ensure these conditions expressed in biomass, it is necessary to efficiently use environmental factors, particularly light, which allows a better use of available solar radiation during growth cycle (6), taking advantage of plant ability to acclimatize to a certain light intensity that can be variable, both between species and among populations of the same species (7).

The coffee plant, like any living organism, keeps relations with the surrounding environment that consists of a group of elements, climate and soil being outstanding (8); thus, it is necessary to study its influence on the site where this crop is grown.

It is important to note that there are only few studies published on this subject in recent years and, particularly in Ecuador, there are no previous studies on shade in coffee nurseries.

Therefore, the present work was carried out with the aim of studying the influence of four shade levels on coffee seedling growth under two soil and climate conditions of Ecuador.

MATERIALS AND METHODS

To comply with the proposed goal, an experiment was conducted in two sites with the following characteristics:

Chaguarpamba: it is located in the western foothills of Los Andes mountains, northwest of Loja province, with semi-humid mesothermal climate, at 760 m over sea level, annual rainfall between 1200 and 1400 mm, annual mean temperature of 23,5 °C and Oxic Distrudept soils.

Yantzaza: it is located in the eastern foothills of Los Andes mountains, to the south of Ecuadorian Amazon, with humid mesothermal climate, at 810 m over sea level, annual mean rainfall of 1400-2000 mm, annual mean temperature of 22,5 °C and Typic Tropaquept soils (USDA taxonomy) (9).

Four shade levels were studied in the experiment: 0, 30, 50 and 80 % using a black polyshade. The shade started to be regulated in three stages from the third pair of leaves until seedlings were left in full sunlight, one month before the end of the nursery period. A sampling design in stripes was used, where each stripe corresponded to a shade level with *Coffea arabica* L. species, Caturra cultivar.

In the first site, seeding was carried out in July 2011 whereas in the second one, it was held in October 2011, considering that seedlings were ready to be taken to the field at the optimum period, according to each site rainfall regime. Seeding substrate consisted of a mixture of agricultural soil from coffee plantation, taken within the first 10 cm plus vermicompost in ratios of 3:1 (5).

Five seedlings were evaluated per treatment every 25 days from the appearance of the first pair of leaves until they reached seven pairs of leaves, determining total dry mass and leaf area. Dry mass was obtained by separating different organs, which were dried in a forced circulation oven at 80 °C up to constant weight; leaf area was determined through linear measurements of leaves (10). Plant height was evaluated at the end of the nursery period.

Data were processed by one-way classification variance analysis; the dynamics of dry mass and leaf area was established by fitting data to a second-degree polynomial exponential function, using Statgraphics plus 5.0 statistical program; absolute growth rate (AGR) was calculated from the equations obtained (8).

Data from monthly mean temperature were taken at the following meteorological stations: small farms in “Chaguarpamba” and Yanzatza in “Yanzatza”.

Substrate characteristics of both sites are presented in Table I, where it can be observed that even though soils are not the same, its characteristics in both sites are suitable for coffee growth. Cultural attention to the crop was applied according to the technical manual for special coffee production (5).

Table I. Analysis of each site substrate

Site	pH	MO (%)	N	P_2O_5 (ppm)	K_2O	Ca (meq 100 mL)	Mg
Chaguarpamba	5,9	11,4	66,9	113,5	321,1	7,97	0,86
Yantzaza	5,6	14,4	123,8	129,5	490,9	8,30	0,83

RESULTS AND DISCUSSION

Table II shows that treatments of 80 and 50 % shade, at the end of the nursery period, reached the greatest height values, without significant differences between them; the lowest values corresponded to full sunlight treatment, although neither it differed from that of 30 % shade in Chaguarpamba nor with that of 30 and 50 % in Yanzatza. In addition, the treatment of 50 % shade was not different from that of 30 % in Chaguarpamba.

Something similar happened with total dry mass (Table III), since in Chaguarpamba the treatment of 80 % shade reached the greatest development, without significant differences with that of 50 %; likewise, the highest light treatment reached the lowest dry mass values without any difference with that of 30 %; in the case of Yantzaza, there was a greater dry mass accumulation than in that of 80 % shade.

In the case of leaf area (Table IV), plants grown at 80 and 50 % shade, at the end of the nursery period, reached the highest values without significant differences between them in both sites. Even the lowest values were recorded with 0 % shade there, although in Yantzaza, it did not differ from that of 30 % shade.

Table II. Seedling height (cm) at the end of the nursery period with four shade levels under two soil and climate conditions

Shade (%)	Chaguarpamba	Yantzaza
80	22,4 a	19,7 a
50	21,2 ab	16,7 ab
30	18,2 bc	15,8 b
0	14,9 c	15,5 b
ES	1,9	1,17
VC (%)	10,7	12,0

Table III. Total dry mass (g) of seedlings at the end of the nursery period with four shade levels under two soil and climate conditions

Shade (%)	Chaguarpamba	Yantzaza
80	3,83 a	3,90 a
50	3,26 a	3,12 b
30	2,38 b	2,64 b
0	2,38 b	1,90 c
ES	0,07	0,16
VC (%)	4,2	9,3

Table IV. Leaf area (cm^2) of seedlings at the end of the nursery period with four shade levels under two soil and climate conditions

Shade (%)	Chaguarpamba	Yantzaza
80	479,21 a	362,77 a
50	438,62 a	370,09 a
30	362,92 b	227,28 b
0	189,59 c	268,19 b
ES	13,67	25,89
VC (%)	6,44	14,6

Regarding the indicators evaluated, it was generally observed that the best treatments were 80 and 50 %, showing a greater plant photosynthetic efficiency under higher shade levels; on the other hand, the lowest values were recorded in full sunlight seedlings, proving that increased radiation induces the formation of smaller plants (11).

Concerning dry mass, it is related to the other indicators evaluated, which is explained because plant production results from crop leaf efficiency at the interception and use of available solar radiation during growth cycle (6, 12, 13, 14).

Shaded plants invest a relatively higher photoassimilate ratio to increase leaf area linearly, according to higher shade levels, in order to maximize available light uptake (15); however, specific leaf area decreases with high radiation values (16).

Seedling growth has demonstrated to result from using sunlight to manufacture constituent and functional components of different plant organs; therefore, such growth is directly related to the ability of plant canopy to capture light (14, 17); that is, to the amount of photosynthetically active radiation (PAR) that could intercept its leaves, which affects its dry mass accumulation (18, 19).

Figure 1 (A and B) shows that levels of 80 and 50 % shade had greater growth and reached maximum values of this indicator earlier, in relation to the other treatments in both sites, which is also demonstrated in Figure 2 (A and B), where seedlings of these treatments attained a faster growth rate.

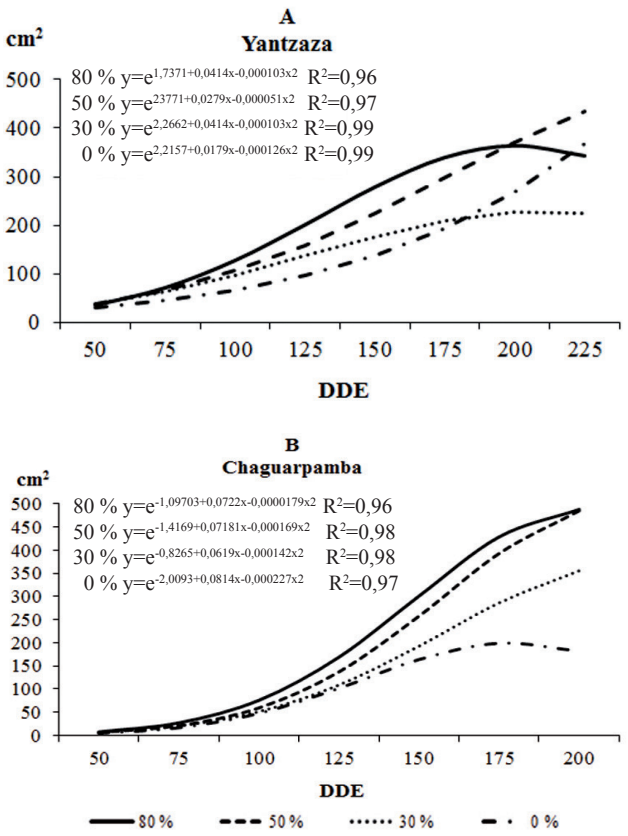

Figure 1. Leaf area dynamics of seedlings with four shade levels in two sites

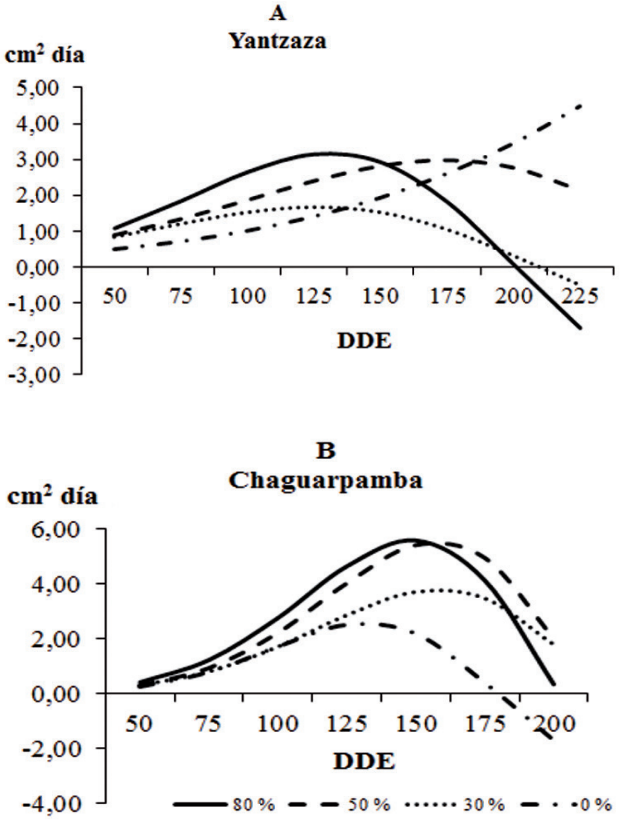

Figure 2. Absolute leaf area growth rate of seedlings with four light levels in two sites

The behavior of 0 % shade treatment in Yanzatza was notable, since plants had a slow growth from the beginning up to approximately 125 days after emergence (DAE), when it accelerated, reaching the end of the period with similar values to the rest. It did not occur in Chaguarpamba, as seedlings grown at 0 % level obtained the lowest values.

In the case of total dry mass (Figure 3 A and B), a similar leaf area behavior was observed in seedlings grown at 80 and 50 % shade, which had a faster growth since the early days, so that they reached their maximum values prior to the rest. It is interesting to remark how seedlings developed in Yantzaza had a quicker growth rate at the beginning than in Chaguarpamba, promoting to reach its maximum rate in less time, but with lower values (Figure 4 A and B).

By analyzing both sites, regardless of shade treatments, the evaluated indicators showed how growth was faster at the beginning in Yantzaza than in Chaguarpamba, so that the maximum values were achieved earlier in the first site, which are generally lower. This is explained in Figure 5 (A and B) that presents the behavior of mean temperature in both sites during the experiments. In Yantzaza, within the early seedling growth stages, the highest temperatures were recorded, showing a marked tendency to decrease over time, whereas in Chaguarpamba quite the opposite occurred, as temperatures were lower at the beginning and gradually increased towards the end of the nursery period, proving the importance of temperature for plant growth.

In general, the best treatments were 80 and 50 % shade for the three indicators evaluated, which is demonstrated by a higher plant photosynthetic efficiency under these conditions (20); less developed seedlings were those grown in full sunlight. Likewise, treatments of 80 and 50 % reached maximum values earlier than the others in both sites.

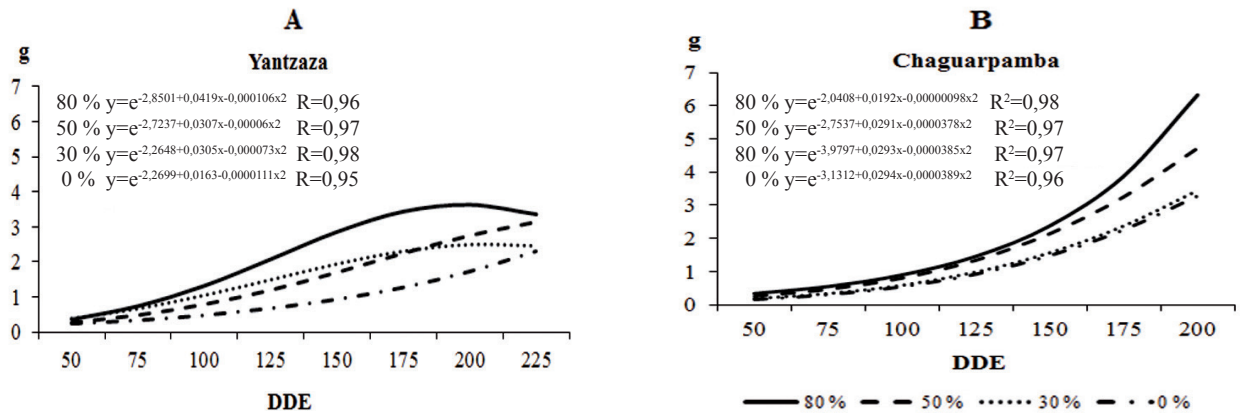

Figure 3. Total dry mass dynamics of seedlings with four shade levels in two sites

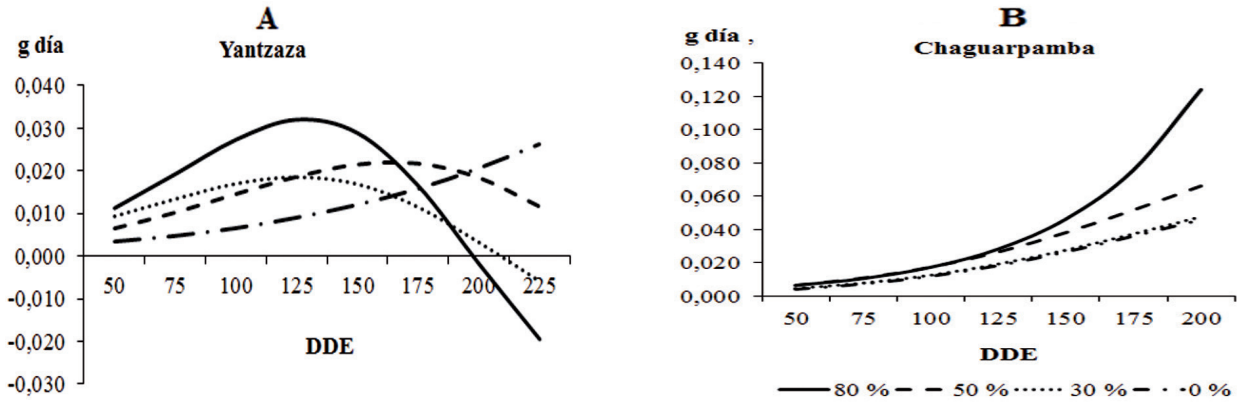

Figure 4. Absolute total dry mass growth rate of seedlings with four shade levels in two sites

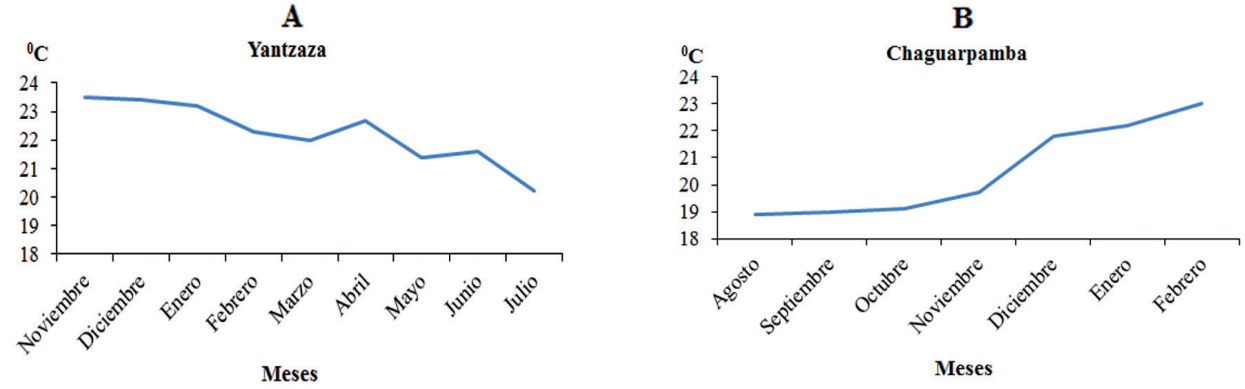

Figure 5. Monthly mean temperature from plant emergence until the end of the nursery period in two sites

Comparing sites by the indicators evaluated, plant growth was faster at the beginning in Yantzaza than in Chaguarpamba, because of the highest temperatures recorded at the early plant stages, with a marked trend to decrease with time. The opposite occurred in Chaguarpamba, as temperatures were lower at the beginning and gradually increased towards the end of the nursery period.

This confirms that crop productivity has a close relationship between climate and physiological processes; therefore, a successful production not only depends on the intensity of climatic stimuli but also on its temporary sequence along crop life cycle (21).

Crops should reach a fast increase of leaf area within its early stage, which may lead to a higher sunlight interception (22), so that along with temperature that controls developing rates of many organisms (23, 24) and increases photosynthesis (14), will imply a greater dry mass accumulation (19).

Results of this work allow considering that coffee is defined as a C_3 plant, since it has, among other features, better ability to live under climatic variation and shade conditions, although its growth may be affected at certain levels (25); seedling behavior, with a level of 80 and 50 % shade during the early stages, proves this statement.

CONCLUSIONS

- According results of this work it can be considerate that coffee is defined as C_3 plant that have among other characteristics a better capacity to live is shadow conditions and climatic variations, although in different levels it can be affected its growth. The seedling behavior, with a level of 80 and 50 % of shadow in the first stages confirm the above exposed.
- These elements suggest the need to conduct more research works, in order to evaluate other physiological indicators that permit to deepen on coffee seedling behavior at different shade levels.

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