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Morpho-agronomic characterization of genotypes of Conilon coffee intercropped with dwarf coconut palms

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Abstract

The study of *Coffea canephora* genotypes at different environments, and the various edaphoclimatic characteristics and techniques used in the cropping systems is an important tool in the process of identifying those with higher adaptability to a particular scenario. The objective of this study was to characterize the development of Conilon coffee genotypes in an intercropping system with dwarf coconut palms. The experiment was carried out in the municipality of Colatina (Espírito Santo, Brazil), studying agronomic traits of genotypes of Conilon coffee in a completely randomized design and six repetitions. The eight treatments were composed by eight Brazilian improved genotypes of Conilon coffee and traits of growth, leafiness and fruit bearing were measured. It was possible to verify different behaviors among genotypes regarding tree architecture and fruit production. The genotypes 83 and 48 presented higher number of fruits per branch, besides vigorous growth, along with genotype 153 which presented larger leaves and higher content of chlorophyll *b*. Genotype 02 also had higher chlorophyll *b* content, but did not develop large leaves. The genotypes 16 and 100 presented lower levels of chlorophyll *b* but greater leaf development. Genotypes 03 and 76 are characterized by lower harvest yield. The biomass and the number of fruits per plagiotropic branch seem to be especially useful to study the variability and may ease future studies of variability among genotypes in intercropping systems.

Keywords: *Cocos nucifera*; *Coffea canephora*; genetic variability; intercropping.
Abbreviations: PLH_plant height; NPB_number of plagiotropic branches; NFB_number of fruits per plagiotropic branch; LPB_length of the plagiotropic branches; NNB_number of nodes per plagiotropic branch. CL_a_content of chlorophyll *a*; CL_b_content of chlorophyll b; CL_{a+b}_total chlorophyll content; ULA_unitary leaf area; SLA_specific leaf area; ALA_available leaf area per fruit in the plagiotropic branch; LAR_leaf area ratio; DMP_dry matter of plagiotropic branches; SMR_stem mass ratio; LMR_leaf mass ratio; HAI_harvest index.

Introduction

Brazil is the largest producer of coffee worldwide, cultivating both main species of coffee (*Coffea arabica* Lineu and *Coffea canephora* Pierre ex A. Froehner). The Conilon coffee (*C. canephora*) is considered one the most important Brazilian agricultural commodities and presents a high financial value for trade (Sunarharum et al., 2014).
The cultivation of coconut (*Cocos nucifera* L.) is also an important economic activity in Brazil, mainly aimed to the production of coconut water. The crops are mainly located along the coast and both main coconut varieties are explored (giant and dwarf), as well as several sub-varieties and ecotypes (Farias Neto et al., 2009).
Intercropping with arborous species is an interesting alternative for the coffee cultivation, offering protection and mitigating harmful effects from events of climatic stress, which have been more common due to climate change, and climatic vulnerability in several regions where coffee is cultivated. This system also may allow the cultivation of coffee in regions where the hydric and climatic conditions are unfavorable, in addition to the diversification of production and improvement of family income for smaller farmers (Camargo, 2010; Silva et al., 2013).
The cultivation of coffee in intercropped systems also offers other benefits, such as improving the conservation of soil humidity and decrease in wind damage (DaMatta and Ramalho, 2006; Pezzopane et al., 2010), as well as improving soil fertility (Vaast et al., 2005), decreasing coffee bienniality and occurrence of spontaneous plants (Silva et al., 2013), improving familiar labor and land use (Aparecido et al., 2014), and promoting financial return (Chung et al., 2013).
Coconut palms from the dwarf group have been successfully used in intercropped coffee plantations. In these systems, it has been observed that coconut palms can modify the incidence patterns of photosynthetically active radiation over the coffee plants, decrease wind speed inside the

system, and also buffer air temperature and relative air humidity (Pezzopane et al., 2011). Additionally, as long as the intercropping evades excessive shading of coffee plants, it may not have any negative effect over the crop yield when compared to conventional unshaded systems (Pezzopane and Camargo, 2007).
The Conilon coffee has high genetic variability as result of its high natural rate of crossbreeding caused by its gametophytic auto-incompatibility (Lashermes et al., 1996). It has been observed that genotypes of Conilon coffee present different responses when cultivated in shaded systems (Cavatte et al., 2013). But there is still a lack of scientific information about the potential selection of genotypes or expression of morpho-agronomic traits in these systems (DaMatta et al., 2007b).
Due to this lack of information about the divergence of responses of improved genotypes of Conilon coffee to the intercropped cultivation in stablished productive systems with coconut palms. The objective of this study was to characterize the growth, fruit bearing, leafiness and agronomic traits of Conilon coffee genotypes (*Coffea canephora* Pierre ex Froehner) in an intercropping system with dwarf coconut (*Cocos nucifera* L. var. *nana*).

Results and Discussion

Meteorological events during the phenological cycle

The average air temperature during the evaluated cycle was about 2.1 ºC above the local normal standards of 24.2 ºC (Feitosa et al., 1979; Pezzopane et al., 2012). The rainfall data indicate a strong event of water deficit, it was observed only 215.2 mm of accumulated rainfall while the expected average for the region is 1,147 mm (Feitosa et al., 1979; Pezzopane et al., 2012). This fact characterizes an atypical event of higher temperate and drought, which should be enough to affect the normal development of the coffee plants. The supplementary irrigation was used in critical periods of high water demand by the plants, as usually adopted in the region.
The occurrence of low rainfall and high temperatures, as observed, may promote considerable physiological and biochemical changes that will negatively affect the coffee crop (DaMatta and Ramalho, 2006). However, the results of the present study show that, even under adverse conditions of low precipitation and high temperature which occurred in the region during the study, the coffee plants presented suitable vegetative and reproductive development. In that sense, the results of this study corroborate with scientific studies which suggest that shaded plantations, such as this intercropped system, are especially useful to mitigate the effects of stressful weather fluctuations (DaMatta and Ramalho, 2006; Pezzopane et al., 2010; 2011).
Studies carried out by Pezzopane et al. (2003; 2005; 2007) showed positive changes in meteorological elements in intercropping systems in relation to unshaded cultivation. These authors observed microclimatic differences for solar radiation, air temperature, wind speed and vapor pressure deficit. Cavatte et al. (2013) observed that when the coffee tree is intercropped with tree species, the damages caused by frost, excessive radiation, winds and extreme temperatures are considerably diminished.

Photosynthetically active radiation inside the intercropping

In the intercropping system, the coconut palms generated a shaded environment and decreased the incident radiation over the coffee plants. The overall photosynthetically active radiation over the coconut palms was approximately 1,250 µmol (photons) m^{-2} s^{-1} while the peak radiation that reached the coffee plants was 750 µmol (fótons) m^{-2} s^{-1}. This decrease of 40% in the photosynthetically active radiation is an important factor in the regulation of growth and development of coffee plants. The photosynthetic apparatus of some C3 species, such as coffee and coconut, may become saturated even at low levels of radiation (Larcher, 2000); therefore, the intercropping of such species becomes interesting as a strategy to improve the metabolic efficiency of the shaded crop.
Since the coconut crop is considered secondary, and therefore less economically interesting in this intercropping system, the palms will be used to partially absorb the total radiation. The shaded coffee, of higher economical interest, will receive a decreased photon flux which will help attenuating photooxidative stresses and mitigating the photorespiration, favoring the efficiency in converting the radiation in biomass (Alvarenga et al., 2004; Cavatte et al., 2012, Larcher, 2000; Kirschbaum, 2011).
Since the plant growth depends directly on intrinsic genetic factors and environmental complex interactions which will modulate the conversion of light into chemical energy (Silva et al., 2005), it is important to quantify morphological variables to identify genotypes capable of expressing higher efficiency in shaded systems.

Stem architecture and fruit bearing of coffee plants

Genotype 83 stood out regarding morphological and production characteristics (NPB, NFB, LPB and NNB), since it showed higher means for all variables (Table 1). This genotype presented vigorous plants, with relatively high capacity of generating and sustaining vegetative structures and higher number of fruits per plagiotropic branch.
Genotype 48 showed good results for the number of fruits per plagiotropic branch and number of nodes per branch, which usually correlates with the plant yield capacity (Partelli et al., 2013). However, this genotype did not surpass the beforementioned genotype 83, due to its lower number and of plagiotropic branches per plant and their shorter length (Table 1).
Since the number of fruits and nodes per branch were statistically similar for the genotypes 83 and 48, regardless of the differences in their plagiotropic branch length, these genotypes didn't express significant differences in the variables directly related to their overall yield per branch. However, the total number of plagiotropic branches per plant may accentuate the differences between them, since it is directly related to the total yield per plant.
In general, genotype 16 showed intermediate results in the analyzed characteristics; however, it presented considerable high number of plagiotropic branches and number of fruits per branch, which can positively affect the productivity of this genotype (Table 1).
The behavior of genotypes 02, 100 and 153 was similar for morphological traits and fruit bearing variables, but had lower values than those observed for genotypes 83 and 48

Table 1. Morphological and fruit bearing characteristics of genotypes of C*offea canephora* intercropped with *Cocos nucifera* (Colatina, Espírito Santo, Brazil, 2015-2016).

Genotypes	PLH[1] (cm)	NPB[2] (Unit)	NFB[3] (Unit)	LPB[4] (cm)	NNB[5] (Unit)
02	226.33 a	40.83 b	75.83 c	52.50 b	18.83 a
03	197.67 a	49.33 a	59.83 d	43.50 b	15.00 b
48	231.83 a	43.00 b	147.67 a	59.50 b	19.00 a
16	214.83 a	45.17 a	112.67 b	53.50 b	14.83 b
83	229.67 a	47.83 a	161.00 a	84.50 a	18.67 a
76	215.50 a	49.17 a	58.83 d	47.33 b	14.67 b
100	197.67 a	41.33 b	76.67 c	59.67 b	12.33 b
153	210.67 a	37.83 b	93.00 c	52.33 b	16.83 a

[1]plant height, [2]number of plagiotropic branches, [3]number of fruits per plagiotropic branch, [4]length of the plagiotropic branches, [5]number of nodes per plagiotropic branch. Means followed by the same letter do not differ from each other according to the Scott-Knott test, at 5% of probability.

Table 2. Chlorophyll contents and leafiness of genotypes of C*offea canephora* intercropped with *Cocos nucifera* (Colatina, Espírito Santo, Brazil, 2015-2016).

Genotypes	CL_a[1] (ICF)	CL_b[2] (ICF)	CL_{a+b}[3] (ICF)
02	40.93 a	16.62 a	57.55 a
03	38.78 a	14.00 b	52.78 a
48	41.48 a	17.77 a	59.25 a
16	40.38 a	12.30 b	52.68 a
83	40.85 a	17.18 a	58.03 a
76	40.47 a	14.92 b	55.38 a
100	38.70 a	12.60 b	51.30 a
153	39.98 a	16.22 a	56.20 a
Genotypes	**ULA[4] (cm^2 per leaf)**	**SLA[5] ($cm^2\ g^{-1}$)**	**ALA[6] (cm^2 per fruit)**
02	35.68 b	116.94 a	6.24 b
03	49.57 a	152.84 a	11.49 a
48	44.32 a	118.99 a	3.87 b
16	46.26 a	131.77 a	3.80 b
83	53.37 a	98.58 a	5.29 b
76	40.62 b	126.52 a	9.68 a
100	49.10 a	121.42 a	6.08 b
153	44.80 a	132.94 a	6.40 b

[1]content of chlorophyll *a*, [2]content of chlorophyll *b*, [3]total chlorophyll content, [4]unitary leaf area, [5]specific leaf area, [6]available leaf area per fruit in the plagiotropic branch. Means followed by the same letter do not differ from each other according to the Scott-Knott test, at 5% of probability.

Table 3. Biomass ratios of genotypes of C*offea canephora* intercropped with *Cocos nucifera* (Colatina, Espírito Santo, Brazil, 2015-2016).

Genotypes	LAR[1] ($cm^2\ g^{-1}$)	DMP[2] (g)	SMR[3] ($g\ g^{-1}$)	LMR[4] ($g\ g^{-1}$)	HAI[5] ($g\ g^{-1}$)
02	18.21 b	25.07 c	0.14 b	0.15 b	0.71 a
03	36.54 a	18.79 d	0.13 b	0.24 a	0.63 b
48	17.18 b	33.04 b	0.15 a	0.14 b	0.70 a
16	16.20 b	26.96 c	0.13 b	0.12 b	0.76 a
83	19.28 b	44.31 a	0.17 a	0.19 b	0.64 b
76	31.64 a	17.84 d	0.12 b	0.25 a	0.63 b
100	18.82 b	24.65 c	0.14 b	0.16 b	0.71 a
153	21.58 b	27.39 c	0.12 b	0.17 b	0.71 a

[1]leaf area ratio, [2]dry matter of plagiotropic branches, [3]stem mass ratio, [4]leaf mass ratio, [5]harvest index. Means followed by the same letter do not differ from each other according to the Scott-Knott test, at 5% of probability.

Table 4. List and description of the genotypes of *Coffea canphora* Pierre ex Froehner used in the experiment.

Genotype	First available in cultivar	Ripening cycle	Source
02	Emcapa 8111	Early	Bragança et al. (2001)
03	Emcapa 8111	Early	Bragança et al. (2001)
48	Incaper 8142 – Conilon Vitória	Early	Fonseca et al. (2004)
16	Emcapa 8121	Intermediate	Bragança et al. (2001)
83	Incaper 8142 – Conilon Vitória	Intermediate	Fonseca et al. (2004)
76	Incaper 8142 – Conilon Vitória	Intermediate	Fonseca et al. (2004)
100	Emcapa 8131	Late	Bragança et al. (2001)
153	Emcapa 8131	Late	Bragança et al. (2001)

(Table 1). This behavior is possibly due to their lower emission of fruits per branch in the intercropping system with dwarf coconut.

The genotypes 03 and 76 showed the lowest number of fruits per branch, shorter branch length and lowest number of nodes per plagiotropic branch. However, it was observed high number of plagiotropic branches (Table 1), indicating that these genotypes invested in vegetative growth rather than fruit production (lower NFB values).

Populations of *Coffea canephora* naturally presents high heterogeneity originated from the reproductive process of the species (allogamy). Studies conducted with Conilon coffee highlight the expression of diversity among genotypes of this species, which allow to identify and cluster some genotypes regarding several agronomic traits (Rodrigues et al., 2012; 2016). The similarity between the results for the genotypes 02 and 153 found in this study corroborates others researches that show these genotypes having similar behavior regarding growth rate (Contarato et al., 2008; Couvre et al., 2013), root growth (Martins et al. 2013a), biomass accumulation and nutritional parameters (Colodetti et al., 2014; Martins et al. 2016).

Based on the morphological and production characteristics, a different behavior is observed among the genotypes, making it possible to identify groups with different responses to the cultivations in the intercropped system with dwarf coconut palms.

Chlorophyll content and leafiness of coffee plants

The content of chlorophyll *a* and the total chlorophyll content did not differ statistically among the genotypes (Table 2). Such fact corroborates the results of Gonçalves et al. (2007), which studied conilon coffee trees with partial shading. Also corroborate the results of Araújo et al. (2015), which describe a homogeneous behavior for conilon coffee intercropped with banana trees.

The content of chlorophyll *b*, however, presented relevant differences among the genotypes. The genotypes 02, 48, 83 and 153 formed a homogeneous group with superior mean (Table 2). This plasticity in the concentration of chlorophyll in the green tissues of coffee plants was also observed by Araújo et al. (2015), corroborating with the results of amount of chlorophyll *b* of the present study. Chlorophyll *b* constitutes an accessory pigment related to absorption and transference of energy from the antenna complex to reaction centers, which are constituted by chlorophyll *a* (Streit et al., 2005). Therefore, variations in the content of chlorophyll *b* in shaded conditions constitute a plastic adaptive response of the genotype to increase the efficiency of light use (Lee et al., 1990; Cao, 2000; Feng et al., 2004). The content of chlorophyll *b* is a valuable descriptor for the identification of genotypes with adaptation potential to shaded environments, such as the intercropped cultivation.

In order to improve their adaptation to shaded conditions, it is noted that, besides being able to change the content of chlorophyll *b*, some genotypes (03, 48, 16, 83, 100 and 153) also developed larger leaves, which can directly affect the amount of light intercepted by the plant (Table 2). The increase of the leaf area in shaded environments is normally a morphological response to optimize the light interception and keep the photosynthesis apparatus working under the condition of lesser available radiation, as found for shaded conilon coffee trees in the observations of Ricci et al. (2013) and Partelli et al. (2006). The specific leaf area is directly related to the thickness of the leaf blade as higher values of specific leaf area are resulted from slender or less dense leaves. Matos et al. (2009), studying the morphoanatomical plasticity of coffee plants in response to changes in the irradiance, noticed that under lesser irradiance, such as in the shaded growth, the coffee leaves presented thinner parenchymas and more intercellular spaces than unshaded leaves, resulting in higher specific leaf areas. Under the same shaded conditions, it was not observed variety of responses among genotypes regarding the changes in specific leaf area, showing that the studied genotypes may respond in a similar way to this variable (Table 2). The available leaf area of the genotypes 03 and 76 were larger than the others (Table 2), indicating a larger leaf area in the plagiotropic branches available to sustain its production of fruits. Larger available leaf area means higher availability of tissues acting as source of metabolic assimilates that can be directed to the formation of fruits, making it possible to sustain higher yield without an excessive metabolic exhausting of the branches, which could lead to losses in filling and formation of fruits as well as increase the bienniality affects (Laviola et al., 2007; Rodrigues et al., 2014; 2016).

As the genotypes 03 and 76 also presented lower production of fruits per plagiotropic branch, this result indicates that these genotypes presented high metabolic investment in the development of leaves in detriment of fruits. The vigorous vegetative growth of these genotypes may be a response to the shading of the intercropping system, some genotypes are less plastic to adapt to the shaded conditions and may suffer a change in the differentiation of the nodes, favoring the development of vegetative structures while restricting the differentiation of reproductive buds (DaMatta et al., 2004).

Production and allocation of biomass

Genotype 83 presented higher accumulation of biomass in its branches, followed by genotype 48 (Table 3). Both genotypes presented the highest proportion of branch biomass allocated to the stem (SMR), however, lower leaf allocation and leaf area ratio (Table 3). The harvest index of genotype 48 was higher, while the lowest result was observed for 83 (Table 3). It is noteworthy that these genotypes showed the highest number of fruits and nodes (vegetative and reproductive) per plagiotropic branch (Table 1). This characteristic directly influences the plant productive capacity and resulted in considerable accumulation of biomass in fruits, as well as high harvest indexes from the genotypes 48 and 83 (even though genotype 83 presented a slightly lower harvest index). The genotypes 02, 16, 100 and 153 were similar in the capacity to allocate biomass in the branches, leaf area ratio, stem mass ratio, leaf mass ratio and harvest index (Table 3). Also, they showed smaller results for leaf area ratio, stem mass ratio and leaf mass ratio; intermediate results for dry matter of plagiotropic branches; and higher results for the harvest index (Table 3). This shows that, even though they are not very prominent genotypes to form lengthier branches with many fruits (Table 1), they showed good results in the proportion of the branch mass allocated in fruits, which resulted in good harvest index (Table 3).

The genotypes 03 and 76 presented plagiotropic branches with lesser accumulation of biomass, and the biomass

seemed to be directed to the development of leaves instead of fruits or stems.
Therefore, it was observed that genotypes 03 and 76 were materials that invested in leaf biomass (Table 3) and in leaf area relationships (Table 2). This may be due to the low luminosity available within the intercropping system, causing these genotypes to present differences in the leaf structures, which is commonly found in intercropping systems.
Colodetti et al. (2014) also observed variability in different Conilon genotypes for various plant growth traits and biomass production. Genotypes 02 and 153 showed similar behavior for biomass production, as noted in the present study, together with genotypes 16 and 100.
In another study, Martins et al. (2013b) verified that Conilon coffee genotypes have different behavior in relation to the accumulation of dry matter, and this fact is also due to nutritional aspects being related to the accumulation and absorption of phosphorus.
It was commonly observed a different accumulation of dry matter between the Conilon genotypes. This behavior is due to the intrinsic characteristics of each genotype, depending on the genetic and phenotypic variability (Fageria, 1998). According to Fonseca et al. (2004) and Ferrão et al. (2008), the coffee genotypes have a wide phenotypic and genetic variability, which allows different behaviors, indicating the need the genotypes have to adapt and stabilize in different management conditions.

Materials and Methods

Experimental design and plant materials

The experiment followed a completely randomized design, with eight genotypes of conilon coffee randomly distributed under the evaluation lines and using six repetitions. The genotypes were selected to sample genotypes from different groups regarding ripening cycle (Rodrigues et al., 2012). The genotypes used in this study were: 02, 03 and 48 of early cycle; 16, 76 and 83 of intermediate cycle; and 100 and 153 of late cycle, regarding the duration of their ripening cycle. These genotypes are improved and adapted to cultivation in the region, being part of clonal cultivars widely used in the Espírito Santo state (Table 4).
The genotypes received individual identifications plates and were randomized along the crop lines. The randomized placement of genotypes is used as a strategy to promote cross-pollination in the system (Conagin and Mendes, 1961; Ferrão et al., 2007).

Characterization of the experimental field

The study was done in the municipality of Colatina, Northwest region of the Espírito Santo state, localized in Southeast Region of Brazil (19°19’5.61”S, 40°36’13.64”W), in a traditionally coffee producing region. The intercrop is located at 116 m above sea level and the soil was classified as Oxisol. The climate, according to the Köppen classification, is classified as “Aw” type, with two well defined seasons: hot and rainy from November to February, and cold and dry from March to September.
The conilon coffee plants (*Coffea canephora* Pierre ex Froehner) were cultivated with a 3 × 1 m spacing, keeping four orthotropic stems per plant. The lines of coffee plants were intercropped under lines of dwarf green coconut palms (*Cocos nucifera* L. var. nana), cultivated in a 10 x 5 m spacing. The coffee lines were placed 2 m away from the coconut lines. The system was composed by the sequential distribution of three lines of coffee and one line of coconut.
The crop was irrigated using aspersion system only in order to meet the hydric demand of the plant in critic periods of drought. The coffee cultivation followed the actual recommendations from the conilon coffee in the Espírito Santo state (Prezotti et al., 2007; Ferrão et al., 2007; 2012).
The weather conditions were monitored using an automatic meteorological station localized near the experimental field (data provided by the Instituto Capixaba de Pesquisa, Assistencia Técnica e Extensão Rural). The photosynthetically active radiation over each species of the intercrop was measured during a day with clear sky, at midday, using a portable irradiance bar of 1 linear meter of length (Irradiance Bar, Li-cor, Li-250A, precision: 1 µmol m^{-2} s^{-1}).

Evaluated characteristics

The intercrop was cultivated until the stabilization of the reproductive phenological cycles of both species and evaluated during the eighth year. The canopy architecture and morphology parameters were evaluated during the end of the fruit ripening phase. The evaluations were performed in average orthotropic stems and plagiotropic branches selected at the medium portion of the canopy, selecting branches which represented the overall growth and yield of the current cycle.
The plant height and the length of the plagiotropic branches were determined using a ruler. The number of plagiotropic branches, fruits and nodes per plagiotropic branch were obtained through direct counting.
The unitary leaf area was estimated using a non-destructive method, using measurements of the linear dimensions of the leaf blade, following the methodology proposed by Barros et al. (1973), proven efficient for conilon coffee (Brinate et al., 2015). The specific leaf area was obtained by the ratio between the leaf area and its dry matter, with the result expressed in cm^2 of leaf area per gram of biomass. The available leaf area was determined by the ratio between the leaf area available in the plagiotropic branch to sustain the number of fruits grown in the same branch (cm^2 $fruto^{-1}$).
The chlorophyll contents (*a*, *b* and total content) were evaluated in the third and fourth pair of leaves from the apex of the plagiotropic branch. The determination of the contents was done using a portable chlorophyll analyzer (Electronic Chlorophyll Analyzer, Falker, ClorofiLOG FL1030).
After measuring, the plagiotropic branches were collected and separated in leaves, stems and fruits; packed in paper bags and dried in laboratory oven, with forced air circulation, at a 65 °C until the plant tissues achieve constant mass. The total dry matter of the plagiotropic branches were determined as sum of leaves, stems and fruits. The leaf area ratio was determined through the relation between the leaf area and the dry matter of the plagiotropic branch (cm^2 g^{-1}). The stem mass ratio was calculated as the relation between the stem dry matter and the total matter of the plagiotropic branch (g g^{-1}). The leaf mass ratio was obtained through the leaves dry matter and the total dry matter of the plagiotropic branch (g g^{-1}). The harvest index was determined as the ratio between the fruits dry matter and the total dry matter of the plagiotropic branch (g g^{-1}).

Statistical analysis

The data were submitted to analysis of variance and, following the occurrence of significance for the variation source, the Scott-Knott criteria was applied to study the means of the genotypes. The statistical analysis was done considering a 5% of probability and using the statistical software GENES (Cruz, 2013).

Conclusion

Among the evaluated genotypes, it is possible to identify genotypes with different responses regarding their growth, architecture and fruit bearing traits, showing that some improved genotypes with high yield in unshaded crops are also showing desirable characteristics to support a possible selection for intercropping systems. In intercropping systems with dwarf coconut palms, the genotypes 83 and 48 presented higher number of fruits per branch, besides vigorous growth, and, together with genotype 153, presented larger leaves and higher content of chlorophyll *b*. Genotype 02 also had higher chlorophyll *b* content, but did not develop large leaves. The genotypes 16 and 100 presented lower levels of chlorophyll *b* but greater leaf development. Genotypes 03 and 76 are characterized by lower harvest yield. The biomass and the number of fruits per plagiotropic branch seems to be especially useful to study the variability and may ease future studies of variability among genotypes in intercropping systems.

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References

Alvarenga AP, Vale RS, Couto L, Vale FAF, Vale AB (2004) Aspectos fisiológicos da cultura do café e seu potencial produtivo em sistemas agroflorestais. Agrossilv. 1(2):195-202.

Aparecido LEO, Rolim GS, Souza OS (2014) Épocas de florescimento e colheita da nogueira-macadâmia para áreas cafeícolas da região Sudeste. Rev Bras Fruti. 36(1):170-178.

Araújo AV, Partelli FL, Oliveira MG, Pezzopane JRM, Falqueto AR, Cavatte PC (2015) Microclima e crescimento vegetativo do café conilon consorciado com bananeiras. Coffee Sci. 10(2):214-222.

Barros RS, Maestri M, Vieira M, Braga-Filho LJ (1973) Determinação de área de folhas do café (*Coffea arabica* L. cv. "Bourbon Amarelo"). Rev Ceres. 20:44-52.

Braganca SM, Carvalho CHS, Fonseca AFA, Ferrão RG (2001) Variedades clonais de café Conilon para o Estado do Espírito Santo. Pesq Agrop Bras. 36(5):765-770.

Brinate SVB, Martins LD, Rodrigues WN, Colodetti TV, Amaral JFT, Tomaz MA (2015) Accuracy of linear methods to estimate the leaf area of genotypes of Conilon coffee. Afr J Agr Res. 10:2955-2960.

Camargo M (2010) The impact of climatic variability and climate change on arabic coffee crop in Brazil. Bragantia. 69(1):239-247.

Cao KF (2000) Leaf anatomy and chlorophyll contente of 12 woody species in contrasting light conditions in Bornean heath forest. Canad J Bot. 78(10):1245-1253.

Cavatte PC, Oliveira AAG, Morais LE, Martins SCV, Sanglard LMVP (2012) Could shading reduce the negative impacts of drought on coffee? A morphophysiological analysis. Physiol Plant. 114:111-122.

Cavatte PC, Rodrigues WN, Amaral JFT, Pereira SMA, Venancio LP (2013) Arborização em café conilon: aspectos microclimáticos, fisiológicos e nutricionais. In: Tomaz MA, Amaral JFT, Oliveira FL, Coelho RI (eds) Tópicos especiais em produção vegetal IV. Caufes, Alegre.

Chung KH, Shin KO, Hwang HJ, Choi KS (2013) Chemical composition of nuts and seeds sold in Korea. Nutrit Res Prac. 7(2):82-88.

Colodetti TV, Rodrigues WN, Martins LD, Tomaz MA (2014) Differential tolerance between genotypes of conilon coffee ('*Coffea canephora*') to low availability of nitrogen in the soil. Aust J Crop Sci. 8(12):1648-1657.

Conagin CHTM, Mendes AJT (1961) Pesquisas citológicas e genéticas em três espécies de *Coffea*. Auto-incompatibilidade em Coffea canephora. Bragantia. 20(34):787-804.

Contarato CC, Sobreira FM, Modolo EP, Tomaz MA, Jesus Junior WC, Ferrão MAG, Fonseca AFA, Volpi OS (2008) Taxa de crescimento de plantas de café conilon. Paper presented at the 12th Encontro Latino Americano de Iniciação Científica, UNIVAP, São José dos Campos, 26-27 October 2008.

Covre AM, Partelli FL, Mauri AL, Dias MA (2013). Crescimento e desenvolvimento inicial de genótipos de café Conilon. Rev Agro@mbiente. 7(2):193-202, 2013.

Cruz CD (2013) GENES: a software package for analysis in experimental statistics and quantitative genetics. Act Sci Agr. 35(3):271-276.

DaMatta FM (2004). Ecophysiological constraints on the production of shaded and unshaded coffee: a review. Field Crop Res. 86:99-114.

DaMatta FM, Ramalho JDC (2006) Impacts of drought and temperature stress on coffee physiology and production: a review. Braz J Plant Physiol. 18(1):55-81.

DaMatta FM, Ronchi CP, Sales EF, Araújo JBS (2007) O café conilon em sistemas agroflorestais. In: Ferrão RG, Fonseca AFA, Bragança SM, Ferrão MAG, DeMuner LH (eds) Café Conilon. Incaper, Vitória.

Farias Neto JT, Lins PMP, Resende MDV, Muller AA (2009) Seleção genética em progênies híbridas de coqueiro. Rev Bras Frut.31:190-196.

Feitosa LR, Scárdua JA, Sediyama GC, Valle SS (1979) Estimativas das temperaturas médias mensais e anuais do Estado do Espírito Santo. Rev Cent Ciênc Rur. 9(3):79-91.

Feng YL, Cao KF, Zhang JL (2004) Photosynthetic characteristics, dark respiration and leaf mass per unit area in seedlings of four tropical tree species grown under three irradiances. Photosynthetica. 42(3):431-437.

Ferrão RG, Fonseca AFA, Bragança SM, Ferrão MAG, DeMuner LH (2007) Café conilon. Incaper, Vitória.

Ferrão RG, Fonseca AFA, Ferrão MAG, Verdin Filho AC, Volpi OS, DeMuner LH, Prezotti LC, Ventura JA, Martins DS, Mauri AL, Marques EMG, Zucateli F (2012) Café conilon: técnicas de produção com variedades melhoradas, 4th edn. Incaper, Vitória.

Fonseca AFA, Ferrão MAG, Ferrão RG, Verdin Filho AC, Volpi OS, Zucateli F (2004) 'Conilon Vitória - Incaper 8142': improved *Coffea canefora* var. kouillou clone cultivar for the State of Espírito Santo. Crop Breed Appl Biotech. 4:503-505.

Gonçalves GC, Gallo LA, Favarim JL (2007) Assimilação do carbono por plantas de cafeeiro (*Coffea arabica* L. var. Obatã) crescendo a pleno sol e com sombreamento parcial. Rev Agricult. 82(1):35-46.

Kirschbaum MUF (2011) Does enhanced photosynthesis enhance growth? Lessons learned from CO_2 enrichment studies. Plant Physiol. 155:117-124.

Larcher W (2000) Ecofisiologia vegetal. Rima, São Carlos.

Lashermes P, Couturon E, Moreau N, Paillard M, Louarn J (1996) Inheritance and genetic mapping of self-incompatibility in *Coffea canephora* Pierre. Theor Applied Gen. 93(3):458-462.

Laviola BG, Martinez HEP, Salomão LCC, Cruz CD, Mendonça SM, Neto AP (2007) Alocação de fotoassimilados em folhas e frutos de cafeeiro cultivado em duas altitudes. Pesq Agrop Bras. 42(11):1521-1530.

Lee DW, Bone RA, Tarsis SL, Storch D (1990) Correlates of leaf optical properties in tropical forest sun and extreme-shade plants. Am J Bot. 77(3):370-380.

Matos FS, Carretero DM, Martins S, Chaves A, Cavatte PC, DaMatta FM (2009) Plasticidade morfo-anatômica de folhas de *Coffea arabica* L. em resposta à irradiância. Paper presented at the 6th Simpósio de Pesquisas dos Cafés do Brasil, Embrapa café, Vitória, 2-5 June 2009.

Martins LD, Rodrigues WN, Machado L, Brinate SVB, Colodetti TV, Ferreira DS, Cogo AD, Apostolico MA, Teodoro PE, Tomaz MA, Amaral JFT, Partelli FL (2016) Genotypes of conilon coffee can be simultaneously clustered for efficiencies of absorption and utilization of N, P and K. Afr J Agr Res. 11(38):3633-3642.

Martins LD, Tomaz MA, Amaral JFT, Christo LF, Rodrigues WN, Colodetti TV, Brinate SVB (2013a) Alterações morfológicas em clones de cafeeiro conilon submetidos a níveis de fósforo. Sci Plena. 9(4):1-11.

Martins LD, Tomaz MA, Amaral JFT, Bragança SM, Rodrigues WN, Reis EF. Nutritional efficiency in clones of conilon coffee for phosphorus (2013b) J Agr Sci. 5(1):130-140.

Partelli FL, Marré WB, Falqueto AR, Vieira HD, Cavatti PC (2013) Seasonal vegetative growth in genotypes of Coffea canephora, as related to climatic factors. J Agr Sci. 5(8):108-116.

Partelli FL, Vieira HD, Detmann E, Campostrini E (2006) Estimativa da área foliar do cafeeiro Conilon a partir do comprimento da folha. Rev Ceres. 53(306):204-210.

Pezzopane JRM, Camargo MBP (2007) Arborização de cafezais: Informações técnicas. O Agron. 59(1):28-29.

Pezzopane JEM, Castro FS, Pezzopane JRM, Cecílio RA (2012) Agrometeorologia: aplicações para o Espírito Santo. Caufes, Alegre.

Pezzopane JRM, Marsetti MMS, Ferrari WR, Pezzopane JEM (2011) Alterações microclimáticas em cultivo de café conilon arborizado com coqueiro-anão-verde. Rev Cien Agron. 42(4):865-871.

Pezzopane JRM, Marsetti MMS, Souza JM, Pezzopane JEM (2010) Condições microclimáticas em cultivo de café conilon a pleno sol e arborizado com nogueira macadâmia. Ciên Rur. 40(6):1257-1263.

Pezzopane JRM, Pedro Júnior MJ, Gallo PB (2003) Caracterização microclimática em cultivo consorciado café/coqueiro-anão verde. Rev Bras Agromet. 11(2):293-302.

Pezzopane JRM, Pedro Júnior MJ, Gallo PB (2007) Caracterização microclimática em cultivo consorciado café/banana. Rev Bras Agromet. 11(3):256-264.

Pezzopane JRM, Pedro Júnior MJ, Gallo PB (2005). Radiação solar e saldo de radiação em cultivo de café a pleno sol e consorciado com banana 'Prata Anã'. Bragantia. 64(3):485-497.

Prezotti LC, Gomes JA, Dadalto GG, Oliveira JA (2007) Manual de recomendação de calagem e adubação para o Estado do Espírito Santo: 5ª aproximação. Seea/Incaper/Cedagro, Vitória.

Ricci MSF, Cocheto Junior DG, Almeida FFD (2013) Condições microclimáticas, fenológicas e morfologia externa de cafeeiros em sistemas arborizados e a pleno sol. Coffee Sci. 8(3):379-388.

Rodrigues WN, Tomaz MA, Ferrão RG, Ferrão MAG, Fonseca AFA, Miranda FD (2012) Estimativa de parâmetros genéticos de grupos de clones de café Conilon. Coffee Sci. 7:177-186.

Rodrigues WN, Tomaz MA, Amaral JFT, Ferrão MAG, Colodetti TV, Apostólico MA, Christo LF (2014) Biometrical studies on characteristics of plagiotropic branches in *Coffea arabica* L. cultivated with high plant density. Aust J Crop Sci. 8:1239-1247.

Rodrigues WN, Tomaz MA, Ferrão RG, Ferrão MAG, Fonseca AFA, Martins LD (2013) Crop yield bienniality in groups of genotypes of conilon coffee. Afr J Agr Res. 8:4422-4426.

Rodrigues WN, Tomaz MA, Ferrão MAG, Martins LD, Colodetti TV, Brinate SVB, Amaral JFT, Sobreira FM, Apostólico MA (2016) Biometry and diversity of Arabica coffee genotypes cultivated in a high density plant system. Gen Mol Res. 15:1-12.

Silva DKT, Daros E, Zambon JLC, Weber H, Ido OT, Zuffelatoribas KC, Koehler HS, Oliveira RA (2005) Análise de crescimento em cultivares de cana de açúcar em cana soca no noroeste do paraná na safra de 2002/2003. Sci Agr. 6:47-53.

Silva VA, Colares MFB, Andrade FT, Lima LA (2013) Viabilidade técnica e econômica da cafeicultura consorciada com mamão no norte de minas gerais. Coffee Sci. 8(4):519-529.

Silva VC, Perdoná MJ, Soratto RP, Negrisoli E (2013) Ocorrência de plantas daninhas em cultivo consorciado de café e nogueira-macadâmia. Pesq Agr Trop. 43:441-449.

Streit NM, Canterle LP, Canto MWD, Hecktheuer LHH (2005) The chlorophylls. Ciênc Rur. 35(3):748-755.

Sunarharum WB, Williams DJ, Smyth HE (2014) Complexity of coffee flavor: a compositional and sensory perspective. Food Res Int. 62, 315-325.

Vaast P, Bertrand B, Perriot JJ, Guyot B, Génard M (2005) Fruit thinning and shade improve bean characteristics and beverage quality of coffee (*Coffeaarabica* L.) under optimal conditions. J Sci Food Agr. 86(2):197-204.