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Agronomic, anatomic and physiological characterization of *Coffea arabica* L. genotypes on irrigated system in the Central Cerrado

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ABSTRACT

Due to climatic conditions and the possibility of using machineries, coffee has a potential to achieve high yields with reduced costs, in the biome of Cerrado. Leaf anatomy and physiology can help in the identification of more adapted cultivars to a given environmental condition. The objective is to verify the behavior of *Coffea arabica* L. genotypes in the Cerrado of the Brazilian Central Plateau through anatomical and physiological characterization and yield. Ten coffee genotypes from the Active Germplasm Bank located in the municipality of Planaltina, Distrito Federal, were evaluated. The genotypes evaluated were: Araponga MG1, Catiguá MG2, Catiguá MG3 P23, Catiguá MG3 P7, Catiguá MG3 P51, Catiguá MG3 P, Catuaí Amarelo IAC 62, Catuaí Vermelho IAC 15, Paraíso MG1 and Topázio MG 1190. The phenotypic characteristics evaluated were the thickness of: adaxial cuticle surface, adaxial and abaxial epidermis surfaces, the palisade and spongy parenchyma, the mesophyll layer, the phloem, number and diameter of the xylem vessels, stomatal density, relationship between the polar and equatorial diameter of the stoma, specific leaf area, stomatal conductance, transpiration rate, net photosynthetic rate, water use efficiency, intercellular carbon concentration and yield. Genotypes of *Coffea arabica* L. presented a distinction between the characteristics evaluated when grown under climatic conditions of the Brazilian Central Plateau Cerrado, highlighting the variations in the behavior and distinguished adaptation in this environment. The Araponga MG1 genotype stood out for anatomical and physiological characteristics of higher values, such as net photosynthetic rate, stomatal conductance, intercellular carbon concentration, abaxial and adaxial epidermis thickness, stomatal density and number of xylem vessels. The genotype Paraíso MG1 stands out for higher grain productivity. The genotype Catuaí Vermelho IAC 15 stands out for anatomical and physiological characteristics such as higher stomatal density, greater number of xylem vessels and greater efficiency in water use, resulting in improved productivity.

Key words: Adaptability; Coffee tree; Morphology; Grain yield; Gas exchange.

1 INTRODUCTION

The coffee growing has a major social and economic importance in Brazil. For 2022, the estimated coffee production scored 55.7 million of processed bags, in which 38.7 million processed bags are *Coffea arabica* and 17.0 million processed bags are *Coffea canephora*. The main producing states are Minas Gerais, Espírito Santo, São Paulo, Bahia, Paraná, Rondônia, Goiás, Mato Grosso and Rio de Janeiro (Companhia Nacional de Abastecimento - CONAB, 2022).

In the Region of Cerrado, coffee production is favored by some aspects such as topography and temperature allied with irrigation, fertilization and production technologies (Fernandes et al., 2012). The Brazilian Cerrado Biome represents approximately 23% of the national territory and constitutes the second largest biome in the country, distributed in several States, among them is the Distrito Federal (Instituto Brasileiro de Geografia e Estatística - IBGE, 2004). This biome is characterized by a rainy summer, with high radiation and insolation, frequent incidence of “veranico” (Indian summer), low temperatures during the winter and absence of rainfall (Moreira, 1995).

The Cerrado coffee region presents favorable conditions for high yields, characterized by average temperatures in an optimum range, higher difference in thermal amplitudes, defined hydric regime and fundamentally a high number of sunlight hours (Fernandes et al., 2012).

High environment temperatures, even above 30 ºC, may not change the net photosynthetic rate of coffee species (Martins et al., 2016; Rodrigues et al., 2016), giving them greater survival and adaptation under those conditions (Rodrigues et al., 2018). Both *Coffea canephora* and *Coffea arabica* species are recommended for some regions of Cerrado in an irrigated system, showing high grain yields and cup quality (Fernandes et al., 2012; Moreira, 1995; Veiga et al., 2021). However, despite the recommendation of the *Coffea arabica* cultivars Catuaí and Mundo Novo for being more productive (Fernandes et al., 2012; Moreira, 1995), there is a requirement for studies that evaluate the performance of cultivars under these conditions, which combine agronomic characteristics of interest such as high yield and tolerance to orange rust, along with favorable expression of anatomical and physiological characteristics, to improve the recommendation of cultivars for the Cerrado of Central Plateau.

Through genetic breeding of coffee trees, cultivars with characteristics of agronomic interest were developed, such as productivity, resistance to pathogens and beverage quality. However, there is a constant search for genotypes adapted to different environments with great agronomic characteristics (Coltri et al., 2019; Purba; Sukartiko; Ainuri, 2019).

Studies on the leaf anatomy coupled with the physiology of coffee trees can help in the identification of cultivars with tolerance to environmental stresses, resistance to pathogens, among others, besides helping the exploration of a higher number of genotypes in genetic breeding programs (Castanheira et al., 2016; Giles et al., 2019; Queiroz-Voltan et al., 2014).

In this regard, the objective was to verify the behavior of *Coffea arabica* L. genotypes in the Cerrado of the Brazilian Central Plateau through anatomical and physiological characterization and yield.

2 MATERIAL AND METHODS

Coffee plants of the species *Coffea arabica* L. were used, from the Embrapa Cerrados's Active Germplasm Bank of Coffee, settled in October of 2010, located in Planaltina, Distrito Federal, Brazil, with the following Cartesian coordinates: South latitude: 15º35'30', West longitude: 47º42'47'. The spacing used was 3.8 x 0.7 m. The crop traits followed the usual technical recommendations for coffee lands in the region (fertilization, phytosanitary management, sprout thinning, mechanical and / or manual control of weeds). The irrigation was made by a central pivot system, with an irrigation frequency of every 5 days, the irrigation management criteria was based on the soil water balance, from the Cerrado Irrigation Monitoring System (Rocha et al., 2006), which provided the water depth, timing of irrigation.

The climate of the area, according to the classification of Köppen (1948) is the Aw type and has 1000m of altitude. The area is a flat dark red latosol with clay texture and presents an average annual rainfall of 1200 mm, two typical seasons of rainy and dry periods and an average of annual temperature of 22 ºC.

The climatic condition of the year where the current work was evaluated (2015) was characterized by low relative air humidity in the winter season, mainly in the months of August and September, high temperatures for most part of the year, and hardly any rain from May to September Figure 1. The annual maximum and minimum average temperature, radiation and the average and minimum relative humidity were 29 ºC, 16 ºC, 19.12 MJ m-2, 65.96% and 39.64%, respectively.

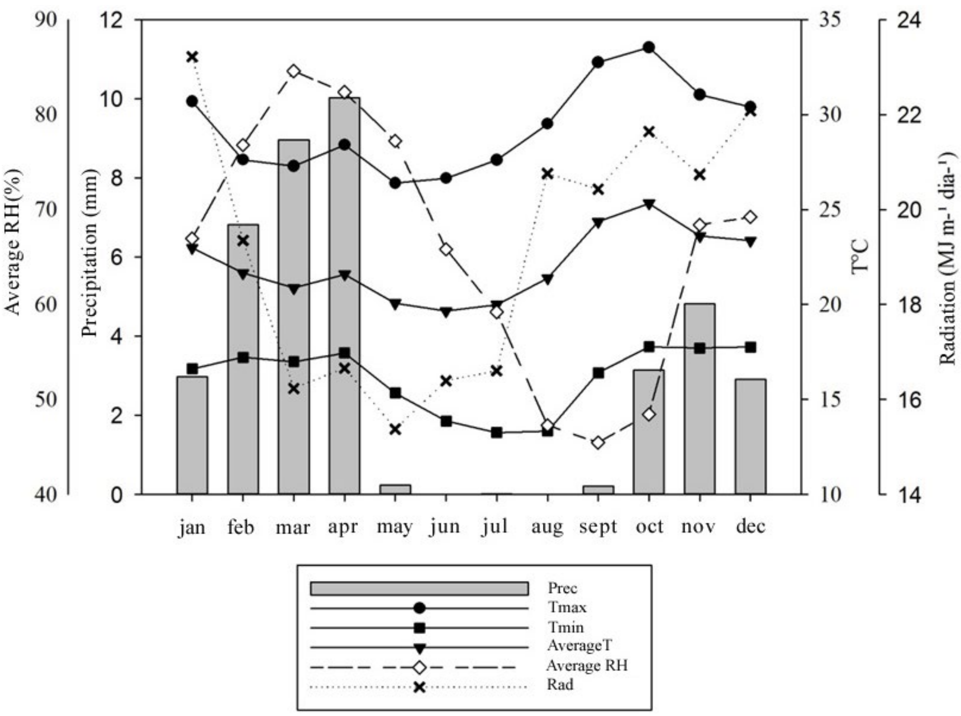

Figure 1: Graphic representation of the climatic variables: maximum, minimum and average temperatures, average relative humidity, radiation and precipitation, recorded during 2015 at Embrapa Cerrados.

The following genotypes of *Coffea arabica* L. were evaluated: Araponga MG1, Catiguá MG2, Catiguá MG3 P23, Catiguá MG3 P51, Catiguá MG3 P51, Catiguá MG3 SM, Catuaí Amarelo IAC 62, Catuaí Vermelho IAC 15, Paraíso MG1 and Topázio MG-1190, all belongs to Empresa de Pesquisa Agropecuária de Minas Gerais - EPAMIG, in which are being characterized in active germplasm banks. The progenies identified as Catiguá MG3, followed by the letter "P" and "SM" correspond to the descendants of individual plants selected in an experiment settled in Turmalina-MG.

For the analysis of anatomical and physiological characteristics, in September of 2015, were selected "fully expanded" leaves, from the third or fourth leaf pair, in the mid-third position of the plagiotropic branches of three plants for each genotype.

The collected leaves were fixed in 70% alcohol (v v^{-1}) (Johansen, 1940) and after 72 hours it was placed in a new 70% alcohol solution (v v^{-1}) aiming to preserve the material at room temperature until the evaluation day. The cross-sections were obtained in a bench-top microtome (LPC type) and the free hand paradermic sections using a steel blade.

The sections were clarified in 50% sodium hypochlorite solution followed by a triple wash in distilled water. Then, the cross-sections were stained with safranin solution (1%) and astra blue (0.1%) in the proportion of 7: 3. The paradermic sections were stained with safranin (1%) (Kraus; Arduin, 1997). As for the cuticle staining, it was made using 2% sudan IV in 92% ethanol (Gerlach, 1984). Subsequently, the sections were mounted on semi-permanent slides with 50% glycerol (v v^{-1}) (Kraus; Arduin, 1997).

The slides were observed and photographed in an optical microscope, Olympus BX 60 model, coupled to a Canon A630 digital camera to capture images. For each treatments replication, three images of each evaluated tissue were taken. The images were analyzed through a specific software for image analysis UTHSCSA-Imagetool, 3.0 version.

The characteristics evaluated in the cross-sections were: adaxial cuticle thickness (cut- µm), adaxial epidermis thickness (ade- µm), palisade parenchyma thickness (pp- µm), spongy parenchyma thickness (sp- µm), abaxial epidermis thickness (abe- µm), number of xylem vessels (nxv), diameter of the xylem vessels (dxv- µm) and phloem thickness (phl- µm).

For the paradermic sections, the polar diameter (pd) and equatorial diameter (ed) of the stomata (µm) were analyzed to obtain the pd/ed ratio (pded) and stomatal density (sd - number of stomata mm^{-2}).

To analyze the leaf gas exchange parameters, a portable infrared gas analyzer (IRGA LICOR - 6400XT) was used. Were measured the stomatal conductance (gs - mol H_2O m^{-1} s^{-1}), transpiration rate (E - mmol m^{-2} s^{-1}), net photosynthetic rate (A - µmol CO_2 m^{-2} s^{-1}), water use efficiency (WUE - µmol CO_2 / mol H_2O^{-1}) (A/gs) (Hetherington; Woodward, 2003; Yan et al., 2015), intercellular carbon concentration (Ci - µmol CO_2 mol H_2O^{-1}) and carbon use effeciency (CUE - µmol CO_2 m^{-2} s^{-1} / µmol CO_2^{-1} mol H_2O^{-1}) (A/Ci) (Silva et al., 2015). The evaluations were performed between 8 and 11 in the morning, under saturating light (1000 µmol m^{-2} s^{-1}).

In June of 2015, the genotypes were harvested by mechanical stripping, then the coffee cherries were dried until the moisture content reached 12%, the yield data was obtained, measured in grain production of 60 kg bags of processed coffee per hectare (bags ha^{-1}). It is important to note that as the trial was settled in 2010, in 2012 the plants had their first production and in 2013 their first most considerable production. Due to the biennial pattern of coffee yield, in 2014 there was a decrease in grain production and for the year of 2015, the second highest and significant productivity was achieved for the assessed genotypes.

A completely randomized design was used, with 10 genotypes and 3 replications, one plant per replication and 15 plants per plot. Data were analyzed using the software Genes (Cruz, 2013) and the obtained means were compared by the Scott-Knott test at 5% of probability.

To study the clustering of the evaluated genotypes, as well as their most relevant characteristics, the physiological and anatomical variables were analyzed on a Canonical Variable Analysis performed by the R program (R Core Team, 2021), using the Candisc package (Friendly, Fox; 2021). For the study of genetic divergence between genotypes, a genetic distance-matrix was performed, based on the generalized *Mahalanobis* distance. Afterward, clustering was proceeded using the *Tocher's* optimization clustering method (Rao, 1952) in the Genes program (Cruz, 2013).

3 RESULTS

The anatomical and physiological results of this current work were assessed in *Coffea arabica* L. genotypes, in an irrigated production system, evaluated after a period of natural stress, which precedes the blooming, on a high temperature, low precipitation and low relative air humidity environment (Figure 1). However, the yield data for 2014/2015 harvest were taken before this period of natural stress, reflecting the reproductive period from September 2014 to June 2015. In response to the environmental conditions in which they were installed, the genotypes showed high variability regarding the evaluated characteristics, some of which were more important when distinguishing them.

Table 1 displays the contribution of each characteristic for the canonical variable 1 and 2. For canonical variable 1, which explains most part of the data variation (85%), the parameters net photosynthetic rate (A), stomatal conductance (gs), intercellular carbon concentration (Ci), spongy parenchyma thickness (sp) presented a greater negative contribution for the observed variation (Table 1). Water use efficiency (WUE) was the characteristic that showed the highest positive correlation with the canonical variable 1. The canonical variable 2 represented 6.71% of the data variation and the parameters that most contributed negatively to this variation were stomatal density (sd), spongy parenchyma thickness (sp) and number of xylem vessels (nxv). Abaxial and adaxial epidermis thickness (abe and ade) were the variables that showed the greatest positive contribution to the canonical variable 2 (Table 1).

Table 1: Contribution of the characteristics evaluated for the first two canonical variables, assessed in *Coffea arabica* L. genotypes from the Embrapa Cerrados Active Germplasm Bank.

Characteristic	Can1	Can2
ade	0.07	0.36
abe	-0.04	0.40
pp	0.07	0.12
sp	-0.46	-0.45
phl	0.002	0.28
dxv	0.05	0.10
nxv	0.12	-0.33
cut	0.12	-0.06
pded	0.10	-0.12
sd	0.14	-0.51
A	-0.59	-0.15
gs	-0.57	-0.09
Ci	-0.52	0.05
E	-0.26	0.02
WUE	0.48	-0.03
CUE	-0.34	-0.18

Figure 2A displays the dispersion of the genotypes as per the characteristics evaluated. According to the clustering by *Tocher's* method, using as a measure of dissimilarity the generalized *Mahalanobis* distance, 4 distinct clusters were generated.

Higher mean values of the variables abe and ade, as well as lower mean values of sd contributed to the dispersion of the genotypes Catiguá MG2, Catiguá MG3 P7, Topázio and Paraíso MG1. In contrast, the genotypes Catiguá MG3 P51, Catiguá MG3 SM, Catiguá MG3 P23 and Catuaí Vermelho IAC 15 showed the opposite pattern (Figure 2A and B, Table 2). Interestingly, the genotypes Catiguá MG2 and Catiguá MG3 P7 presented high mean values of net photosynthetic rate Figure 2 and Table 3.

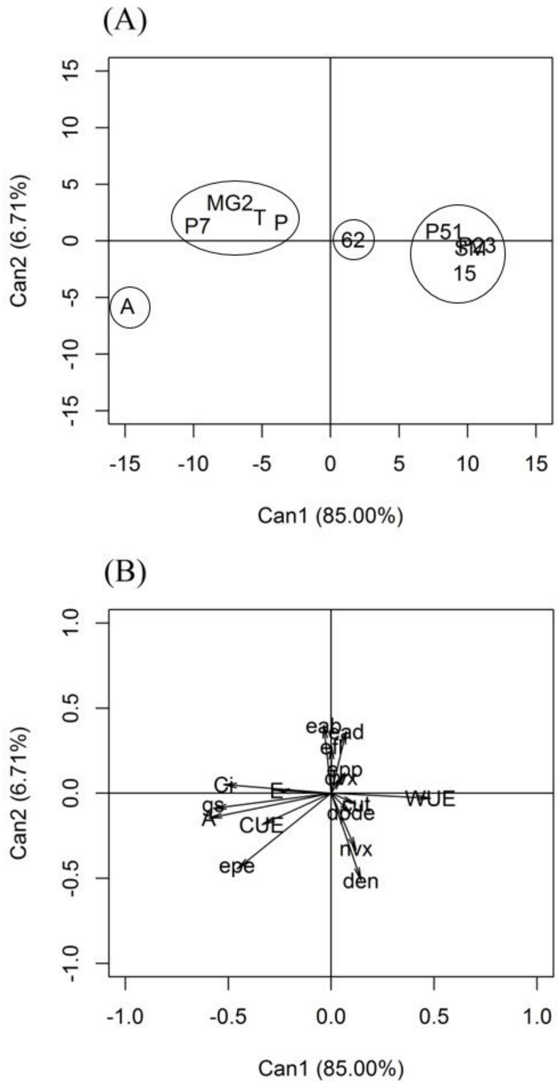

Figure 2: Dispersion plot (A) of *Coffea arabica* L. genotypes from the Embrapa Cerrados Active Germplasm Bank and (B) spatial vector projection of physiological and anatomical leaf characteristics regarding the first two canonical variables.

Tables 2 and 3 presents the mean values of leaf anatomical and physiological characteristics that contributed the most on distinguishing the genotypes (Table 1 and Figure 2), respectively.

The Araponga MG1 genotype presented an isolated dispersion from the others, being observed for it, high mean values of the physiological characteristics A, gs, Ci, sp, nxv and sd, also the lowest mean value of WUE Figures 2A and B, Tables 2 and 3.

The cluster of genotypes Catiguá MG3 P23, Catiguá MG3 SM and Catuaí Vermelho IAC 15 highlighted from the others by the WUE parameter Figure 2 and Table 3. Besides WUE and stomatal density, the Catuaí Vermelho IAC 15 genotype stood out due to the high mean value of number of xylem vessels, which may promotes the translocation of water and mineral salts in the plant.

Table 2: Mean values of the anatomical leaf characteristics evaluated, adaxial epidermis thickness (ade), abaxial epidermis thickness (abe), spongy parenchyma thickness (sp), number of xylem vessels (nxv), stomatal density (sd) of *Coffea arabica* L. genotypes from to the Active Germplasm Bank of Embrapa Cerrados.

Genotype	ade	abe	sp	nxv	sd
Araponga MG1	24.94b	19.47a	253.36a	127.83a	244.64a
Catiguá MG2	30.99a	23.87a	205.82c	117.91a	190.82b
Catiguá MG3 P7	29.90a	21.20a	208.47c	90.91b	187.88b
Catiguá MG3 P23	28.37a	21.70a	205.94c	124.91a	211.37b
Catiguá MG3P51	30.97a	20.81a	206.51c	100.91b	196.69b
Catiguá MG3 SM	27.22b	21.20a	183.02c	118.33a	206.48b
Catuaí Vermelho IAC15	26.89b	19.67a	218.42c	134.83a	287.70a
Catuaí Amarelo IAC62	26.94b	19.62a	204.07c	117.91a	214.31b
Paraíso MG1	28.49a	20.83a	229,95b	109.61b	170.27b
Topázio MG1190	25.54b	21.09a	209.49c	123.42a	207.45b

Means followed by the same lower case letters in the vertical belongs to a statistically homogeneous cluster.

Table 3: Mean values of the physiological characteristics evaluated, net photosynthetic rate (A- μmol CO_2 m^{-2} s^{-1}), stomatal conductance (gs- mmol H_2O m^{-2} s^{1}), intercellular carbon concentration (Ci- μmol CO_2 mol^{-1}) and water use efficiency (WUE- A/gs ratio) of genotypes of *Coffea arabica* L. from the Active Germplasm Bank of Embrapa Cerrados.

Genotype	A	gs	Ci	WUE
Araponga MG1	10.82a	0.1361a	247.28a	82.74b
Catiguá MG2	8.90a	0.1067a	233.94a	92.13b
Catiguá MG3 P7	8.70a	0.0831b	202.17b	112.76a
Catiguá MG3 P23	6.95b	0.0573b	175.81b	126.65a
CatiguaMG3P51	5.61b	0.0522b	205.09b	109.19a
Catiguá MG3 SM	6.56b	0.0545b	171.04b	129.65a
Catuaí Vermelho IAC15	4.91b	0.0385b	172.58b	130.02a
Catuaí Amarelo IAC62	6.35b	0.0694b	195.73b	116.53a
Paraíso MG1	6.87b	0.073b	212.37b	106.66a
Topázio MG1190	7.12b	0.0944a	237.29a	91.27b

Means followed by the same lower case letters in the vertical belongs to a statistically homogeneous cluster.

The Catuaí Amarelo IAC 62 genotype presented an intermediate behavior in comparison to the other clusters of genotypes, pointing that among the analyzed variables, no specific characteristic contributed to its dispersion Figure 2.

The grain yield of the evaluated genotypes, in 60 kg bags of processed coffee per hectare, obtained in the 2015 harvest, represents the second highest and significant yield of the studied genotypes, due to the “biennial effect” of coffee trees Figure 3. The highest yield estimated belongs to the Paraíso MG1 genotype, with 63.96 bags per hectare.

The second cluster with the highest yield was composed by the genotypes Catuaí Vermelho IAC 15, Catiguá MG 3 SM, Catiguá MG3 P23, Catiguá MG3 P7 and Topázio MG 1190, with a yield between 44 and 51 bags per hectare Figure 3. The genotypes Catuaí Amarelo IAC 62 and Araponga MG1 are remained in the third cluster with a yield between 31 and 32 bags per hectare, followed by the genotypes Catiguá MG2 and Catiguá MG3 P51, which had lower yields Figure 3.

4 DISCUSSION

Studies report that the coffee tree may present alterations in its anatomical and physiological characteristics due to environmental factors, also, these characteristics might be important to distinguish between genotypes of the same species (Baliza et al., 2012; Batista et al., 2010; Castanheira et al., 2016; Queiroz-Voltan et al., 2014).

Based on the results above, the dispersion of the genotypes Catiguá MG2, Catiguá MG3 P7, Topázio and Paraíso MG1 was due to the higher mean values of abe and ade, just as lower mean values of sd. In contrast, the genotypes Catiguá MG3 P51, Catiguá MG3 SM, Catiguá MG3 P23 and Catuaí Vermelho IAC 15 presented an opposite pattern Figure 2A and B; Table 2. It is particular interesting that the Catiguá MG2 and Catiguá MG3 P7 genotypes presented high mean values of net photosynthetic rate Table 3, as the result observed in the Catiguá MG2 genotype corroborates the work of Batista et al. (2010), who noted that Catiguá MG2 was in the cluster of genotypes that exhibit higher adaxial epidermis thickness.

In *Coffea racemosa*, a species known as resistant to the leaf miner (Alves et al., 2011; Ramiro et al., 2004) and drought (Medina Filho; Bordignon; Carvalho, 2008), compared to *C. arabica* (Ramiro et al., 2004) the adaxial and abaxial surfaces of epidermis were thicker. The thickness of the epidermis can vary depending on the environmental condition, particularly the conditions of strong solar radiation and water content in the soil (Baliza et al., 2012; Castanheira et al., 2016). The species *C. arabica* has a great phenotypic adaptation to changes in radiation intensity, as a lower epidermis thickness have been observed in coffee plants grown in full sunlight (Baliza et al., 2012). The increase in the thickness of these anatomical characteristics might be related to characteristics of interest for coffee breeding programs.

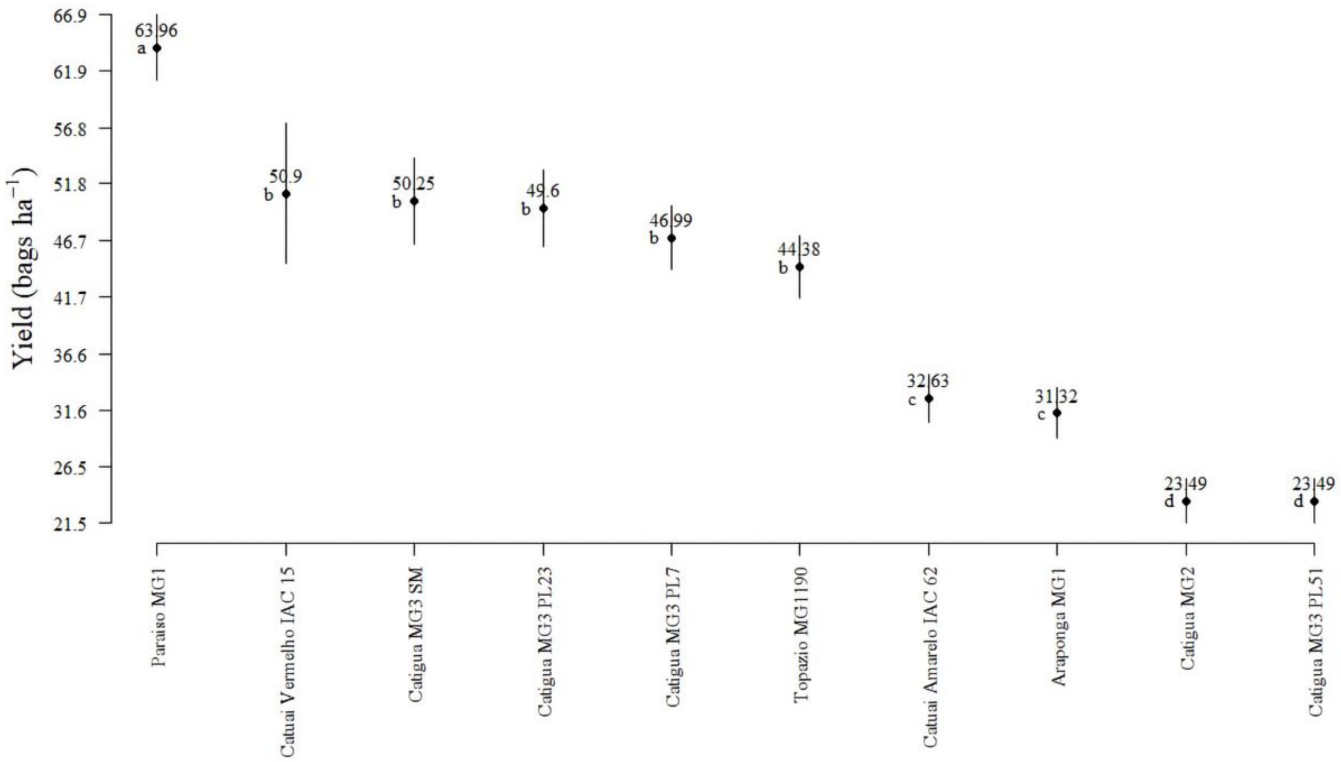

Figure 3: Yield in 60 kilogram bags per hectare of different genotypes of *Coffea arabica* from Embrapa Cerrados's Active Germplasm Bank, 2015 harvest.

The period of natural stress that affected the year of evaluation of the current study Figure 1 might have influenced adaptations on some genotypes. For example, the Araponga MG1 genotype, that remained isolated from the others Figure 2A due to the high mean values of the physiological characteristics A, gs and Ci and anatomical sp, nxv and sd, as well as a lower mean value of WUE Figure 2A and B, Tables 2 and 3. The higher intercellular carbon concentration observed in this genotype might be associated with greater stomatal conductance and stomatal density, once a higher number of stomata per area improves conductance (Dubberstein et al., 2020; Nóia Júnior et al., 2020). In addition, the higher spongy parenchyma thickness, an existing characteristic in this genotype, may help in the diffusion of CO_2 of the sub-stomatal cavities, contributing to the accumulation and storage of CO_2 necessary to complete the photosynthesis (Castanheira et al., 2016; Terashima et al., 2011). Higher frequency and smaller diameter of xylem vessels contribute to the efficient transport of water and mineral salts, avoiding the occurrence of embolism (Hacke et al., 2017; Queiroz-Voltan et al., 2014).

Although the Araponga MG1 genotype remained in the cluster with the highest net photosynthetic rate Table 3, it presented lower water use efficiency, showing a negative correlation, displayed in Figure 2A. This is probably due to higher CO_2 assimilation, linked with a higher conductance that promotes higher transpiration, whereas for a plant to be efficient in the use of water, the increase of photosynthesis must be combined to a decrease in transpiration (Fares et al., 2016).

An inverse behavior was noticed in the genotypes Catiguá MG3 P23, Catiguá MG3 SM and Catuaí Vermelho IAC 15, which were clustered due to their higher WUE Figure 2A and B; Table 2. This characteristic, combined with lower stomatal conductance, characterizes plants with some climate change tolerance mechanism (Dubberstein et al., 2018; Rodrigues et al., 2018), showing its efficiency in reducing water loss while allowing enough CO_2 absorption for photosynthesis. In this study, the plants from the cluster above mentioned were grown in Brazilian Cerrado conditions and a several abiotic factors, such as low precipitation and relative air humidity Figure 1, might have induced this mechanism on them.

An important characteristic when evaluating genotypes is the grain yield, being consistently pursued in coffee breeding programs and critical for the recommendation of a material to a specific region (Pavan et al., 2021). The greater yield of Paraíso MG1 genotype, 63.96 bags ha^{-1} Figure 3, can be justified by the good vegetative vigor, which is related to the adaptation on different environments (Carvalho et al., 2012). Other researchers have found great yield for this genotype in coffee-growing areas in the state of Minas Gerais. In the south of Minas Gerais, Reis et al. (2018) reported an annual yield of 77.63 bags ha^{-1} for this genotype, a value that is similar to what was found in this current study and, in Alto do Paranaíba region, considering the biennial, Carvalho et al. (2017) found an average yield of 37 bags ha^{-1}.

The yield of the Topázio MG 1190 genotype, which composes the second highest cluster in terms of yield Figure 3, corroborates with results reported by Carvalho et al. (2012), who found an average yield of 43.6 bags ha^{-1} in Patrocínio-MG, which is located in Cerrado Mineiro region.

In a trial conducted on a coffee-growing region, Lavras-MG, the Catiguá MG3 genotype showed good annual yield (55.73 bags ha^{-1}) (Reis et al., 2018), being close the values obtained for most genotypes of the Catiguá MG3 group assessed in the current study Figure 3. However, in another trial carried out in the cities of Patrocínio-MG and Lavras-MG, a low average yield (23.6 bags ha^{-1}) was reported for this genotype (Carvalho et al., 2017).

The genotype Catuaí Vermelho IAC 15, just as in the current study Figure 3, also stood out in the Cerrado Mineiro region, Campos Altos-MG and in the Triângulo Mineiro region, Uberlândia-MG where it exhibited high average yield (Andrade; Melo; Paula, 2007; Botelho et al., 2010).

Low yield and high net photosynthetic rate were observed in the genotype Araponga MG1 Figure 3 and Table 3 in relation to the other genotypes, corroborating with the current study, Carvalho et al (2012) found low average yield (32,60 bags ha^{-1}) for this genotype. However, Araponga MG1 proved to be highly responsive to framework pruning, presenting high yield (96.90 bags ha^{-1}) in the year evaluated, along with a high net photosynthetic rate (8.35 μmol m^{-2} s^{-1}) (Reis et al., 2018). In the current work, the photoassimilates produced by the Araponga MG1 genotype could have been translocated to other regions, once plants with low grain yield may invest in vegetative growth (Reis et al., 2018).

Overall, *Coffea arabica* proved to be a species with good adaptability regarding the environment in which it is grown, modifying anatomical structures of the leaves and physiological characteristics, resulting in mechanisms of adaptation to the Cerrado environment. There are evidences that environmental factors, such as radiation levels, water availability and temperature might cause anatomical, morphological and physiological modifications, therefore characterization of the genotypes is an important tool on the identification of the most adapted ones (Araújo et al., 2021; Baliza et al., 2012; Oliveira et al., 2018; Queiroz-Voltan et al., 2014; Zulfiqar et al., 2020).

5 CONCLUSIONS

Genotypes of *Coffea arabica* L. presents a distinction between anatomical and physiological characteristics and grain yield when grown under the climatic conditions of the Brazilian Central Plateau Cerrado, highlighting variations on the behavior and differentiated adaptation in this environment.

The Araponga MG1 genotype stood out for anatomical and physiological characteristics of higher values, such as net photosynthetic rate, stomatal conductance, intercellular carbon concentration, abaxial and adaxial epidermis thickness, stomatal density and number of xylem vessels. The genotype Paraíso MG1 stands out for higher grain productivity. The genotype Catuaí Vermelho IAC 15 stands out for anatomical and physiological characteristics such as higher stomatal density, greater number of xylem vessels and greater efficiency in water use, resulting in improved productivity.

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7 AUTHORS' CONTRIBUTION

CSS; JM; GCR; ADV; GFB and MAFC designed the study and supervised the experiments, CSS and TTR contributed in data analyses, CSS; NMS; JM; GCR and MAFC made contributions in data acquisition, GCR; ADV; GFB and MAFC was responsible for design of methodology, and CSS; NMS, JM; GCR; ADV and MAFC assisted in writing and editing.

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