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BASIC AREAS
Article

Initial vegetative development and early selection of arabica coffee cultivars in a low-altitude region

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ABSTRACT: The cultivation of *Coffea arabica* L. in a low-altitude region is a sustainable alternative for diversifying the income of farmers. On account of the variability of available cultivars, the use of indirect selection through initial vegetative development may be an auxiliary tool for identifying the most suitable genotypes for this environment. This study aimed to identify the dwarf Arabica coffee cultivars with better initial development in a low-altitude region and the morphological traits with greater relevance for the early selection of cultivars with high yield potential. The experiment was installed in the northeast of São Paulo, Brazil. The experimental design used was randomized blocks with four replications. The treatments consisted of 17 dwarf Arabica coffee cultivars. There is variability among dwarf Arabica coffee cultivars for initial vegetative development. The growth and increase in the number of nodes of the plagiotropic branch can be used in early selection to identify cultivars with greater yield potential. The cultivars IAC Obatã 4739, Obatã IAC 1669-20, and Tupi IAC 1669-33 present higher initial vegetative performance in low-altitude environments. The results obtained are useful to breeders and producers for choosing the cultivars best adapted to cultivation in this environment.

Key words: *Coffea arabica* L., yield, high temperatures, morphological traits, indirect selection.

INTRODUCTION

Brazil is the main world producer of *Coffea arabica* L., whose production is concentrated in the state of Minas Gerais, which holds 70% of the areas with Arabica coffee cultivation in the country (Conab et al. 2022). The demand for coffee grew, even during the crisis that occurred during the COVID-19 pandemic (ABIC 2021), demonstrating the value of this product on the table of Brazilians and for the national industry.

The crop is little explored in low-altitude regions due to its greater adaptation to higher regions, especially in São Paulo and Minas Gerais states. Although the crop is adapted to places with a milder climate, studies demonstrate the achievement of high yields of *C. arabica* lines and cultivars in regions with high temperatures (Carvalho et al. 2022a; Teixeira et al. 2015).

Coffee is a crop with the potential to obtain a product with high added value, especially in the specialty coffee market. Coffee production does not require large areas for economically viable and sustainable production, being an alternative for job creation and income diversification for producers in the Média Mogiana Paulista region. However, there is a high diversity of cultivars available, with around 140 coffee cultivars currently registered in the country (Brazil 2022), and few studies covering the performance of these materials in places with lower altitudes and higher temperatures.

The evaluation of the initial vegetative performance of the coffee plant is a useful tool in the early selection and identification of materials with greater adaptation to the environment and, consequently, with greater expected yield potential in future harvests (Carvalho et al. 2022a; Romano et al. 2022; Teixeira et al. 2012).

Identifying the most relevant morphological traits for selecting the most responsive genotypes is one of the objectives of coffee breeding programs. This is because the process of developing a new cultivar is costly and takes a long time. Consequently, identifying the most relevant morphological traits provides greater security, precision, and economy in the elaboration of indexes for selecting and identifying cultivars with greater yield potential for each environment.

This study aims to identify the dwarf Arabica coffee cultivars with better initial development in a low-altitude region and the morphological traits with greater relevance for the early selection of cultivars with high yield potential.

MATERIAL AND METHODS

Description of the experimental area and agroclimatic characterization

The experiment was conducted at São Paulo State University (Unesp), School of Agricultural and Veterinarian Sciences, Jaboticabal - SP, at 21°14'30.23"S, 48°17'51.66"W, with an altitude of 565 m (Fig. 1). The climate is classified as Aw-type (humid tropical with rainy season in summer and dry winter), according to the Köppen classification (Rolim et al. 2007).

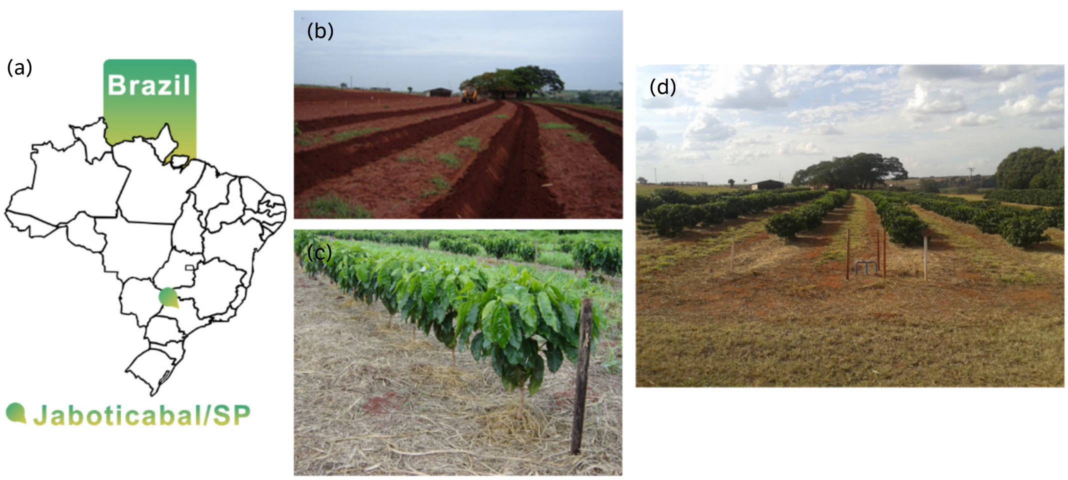

Figure 1. Geographic location of the experimental area (a); preparation of furrows for transplanting (b); growing coffee seedlings (c); coffee plants 14 months after transplanting (d).

Source: Elaborated by the authors

Based on average data from 1971 to 2014, the average annual temperature (Tm) in the site is 22.3 °C, the average temperature in November (Tn) is 24 °C, and annual precipitation is 1417 mm. It can be seen from the average data presented a limitation to the cultivation of coffee in this region, which would be the thermal restriction. The Tm is in the restriction range, according to the criteria by Pinto et al. (2001), between 22 and 23 °C. The Tn is within the limit adopted by the Agricultural Climatic Risk Zoning (ACRZ) of 24 °C (Brazil 2011). The classification of the region would change from "fit", according to Pinto et al. (2001), to "marginal with thermal restriction". Temperature and precipitation data for the first four coffee harvests are shown in Fig. 2.

The average annual water deficit in Jaboticabal between 1971 and 2000 was 56 mm, with no water restriction for cultivation, according to the criteria used in agroclimatic zoning for coffee crops (Brazil 2011; Pinto et al. 2001). However, during the initial vegetative development (April/2013 to May/2015), the average water deficit was 149 mm (Fig. 3), being in the water restriction range (between 100 and 150 mm of average water deficit), characterizing, as indicated, the supply of water by irrigation (Matiello et al. 2008). The high value concerning the historical average is due to the drought condition in 2014, when an annual water deficit of 372 mm was recorded.

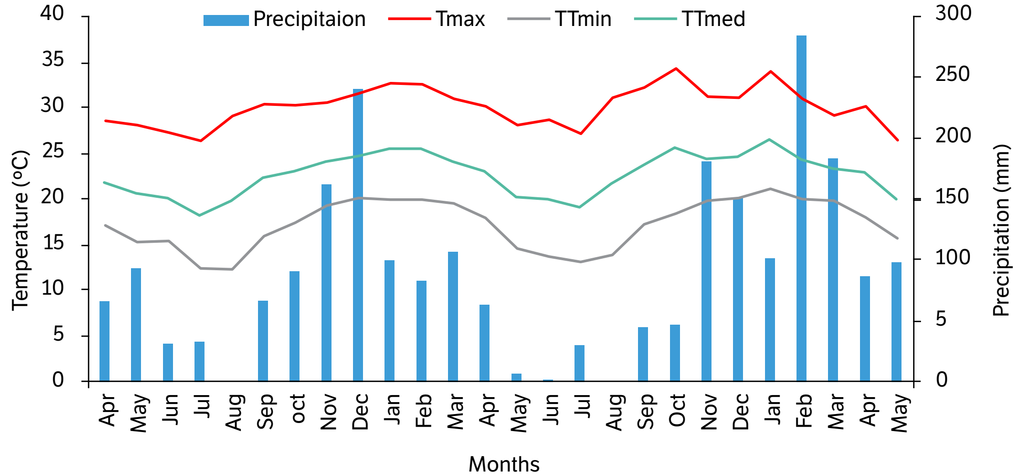

Figure 2. Maximum, minimum, and average temperatures (Tmax, Tmin, Tmed) and precipitation during the coffee development phase (April/2013 to May/2015).

Source: Elaborated by the authors

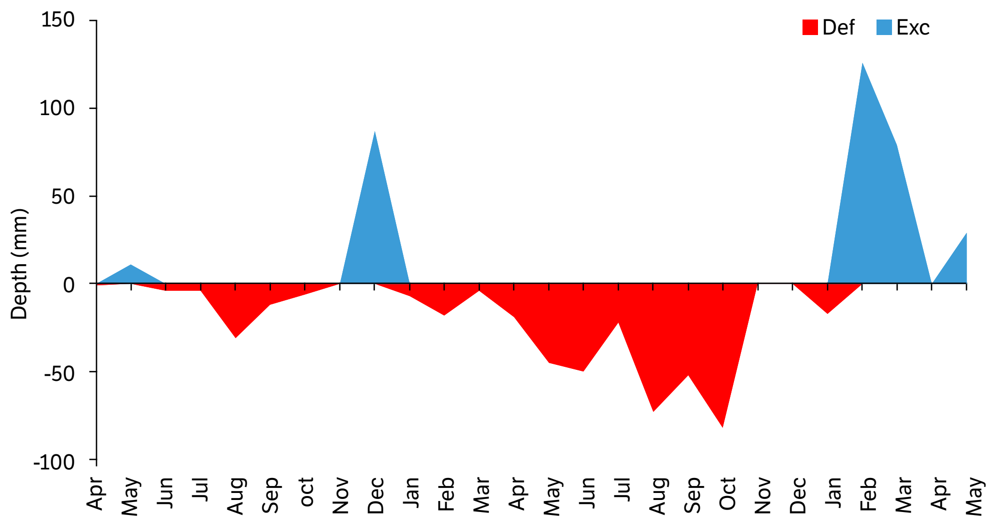

Figure 3. Climatological water balance during the initial vegetative development. Def: water deficit; Exc: excess water.

Source: Elaborated by the authors

The soil in the experimental area was classified as *Latossolo Vermelho eutroférrico* (Oxisol) (Santos et al. 2018). Its texture is classified as clayey, with clay, silt, and sand content of 533, 193, and 274 $g \cdot kg^{-1}$, respectively. The experimental area was previously occupied by the crop of sunn hemp (*Crotalaria juncea*) for two years. In July 2012, soil sampling was conducted in 0-20 and 20-40 cm layers to evaluate the chemical attributes (Table 1).

Table 1. Soil chemical attributes in the experimental area before the implantation of dwarf Arabica coffee cultivars.

Layer (cm)	pH ($CaCl_2$)	O.M. ($g \cdot dm^{-3}$)	P resin ($mg \cdot dm^{-3}$)	K	Ca	Mg	H+Al	SB	CEC	BS (%)
				($mmolc \cdot dm^{-3}$)						
0 – 20	5.5	14	48	1.7	27	16	20	44.7	64.7	69
20 – 40	5.3	14	44	2.1	20	14	22	36.1	58.1	62

OM: organic matter; SB: sum of basis; CEC: cation exchange capacity; BS: base saturation. Source: Elaborated by the authors.

Experimental design and treatments

The experimental design used was randomized blocks, with four replications, where the treatments consisted of 17 dwarf Arabica coffee cultivars, as follows: IAC Catuaí SH3, Catuaí Amarelo IAC 62, Catuaí Vermelho IAC 99, IAC Ouro Verde, IAC Ouro Amarelo, Obatã IAC 1669-20, IAC Obatã 4739, Tupi IAC 1669-33, IAC 125 RN, Catiguá MG1, Oeiras MG 6851, Pau-Brasil MG1, Sacramento MG1, IPR 99, IPR 100, IPR 103, and Sabiá Tardio. The seedlings were produced in a tube system with an artificial substrate based on coconut fiber, peat, and slow-release fertilizer and were planted with five pairs of leaves.

Each experimental plot consisted of a four-meter-long coffee row, with eight plants spaced 0.50 m between plants and 3.5 m between rows. The cultivar Acauã was used throughout the border of the experiment. Throughout the experiment, brachiaria (*Urochloa ruziziensis*) was sown between the rows to form vegetation cover on the soil surface to mitigate erosion and benefit the soil environment.

Crop practices

According to Raij et al. (1997), there was no need for lime and gypsum application. Conventional soil tillage was conducted by scarifying, plowing, and harrowing in September and October 2012. In November 2012, the soil was furrowed at a depth of 0.40 m, and organic and chemical fertilizers were distributed and homogenized in the furrow. For this, the recommendations of Raij et al. (1997), using cattle manure at a dose of 20 $L \cdot m^{-1}$, 15 g of $P_2O_5 \cdot m^{-1}$ (85 g of Yorin® Master), and 10 g of $K_2O \cdot m^{-1}$ (17 g of KCl).

The experiment was implemented (seedling planting) in April 2013. A drip irrigation system was used in the experimental area, with self-compensating emitters spaced 0.50 m apart, a working pressure of 150 kPa (15 mca), and a flow rate of 1.6 $L \cdot h^{-1}$. The irrigation management adopted was supplementary. During the dry season, the irrigation shift lasted seven days, with a water depth of 15-20 mm per week. The system was also activated in the drought periods during the rainy season. In the production phase, irrigation was suppressed from July until the first half of August to promote controlled water stress before anthesis.

Integrated weed management was conducted through manual weeding, mechanical control (weed cutter and plant disintegrator), and chemical control. Phytosanitary treatment was conducted by applying products recommended for coffee cultivation.

Field and laboratory evaluations

The traits evaluated were the Insertion height of the first plagiotropic branch (IHFB), measured with a graduated ruler from the ground, near the base of the plant, to the insertion of the first plagiotropic branch of the plant; plant height growth (PHG), measured with a graduated ruler from the ground, close to the stem of the plant, to the apical meristem; stem diameter growth (SDG), measured with a digital caliper at 10 cm above the ground; canopy diameter growth (CDG), using two wooden rods to mark the end of the most distant branches of the plant and a measuring tape to measure the internal distance of the rods, passing through the apical meristem in the perpendicular direction to the planting row; plagiotropic branch growth (PBG), being marked and measured with a measuring tape, in four plagiotropic branches in the middle third of the plants; increase in the number of nodes in the plagiotropic branch (NNI), being in the same plagiotropic branches marked for length analysis, the number of nodes was counted.

The presented vegetative traits data correspond to growth between the 1st and 2nd evaluations, except for IHFB, which was obtained 12 months after planting (MAP). PHG and SDG evaluations were performed at 2 and 24 MAP (June/2013 and April/2015). CDG, BLG, and NNI were obtained at 12 and 24 MAP (April/2014 and April/2015).

The harvest was carried out by manually stripping on cloth in a staggered way to obtain the time each cultivar obtained the highest number of fruits at the cherry stage. After harvesting and homogenizing the cherry, the total volume of coffee beans in each plot was measured, in which 10 L of raw coffee from the field were collected for drying in the sun on a concrete floor, using suitable sieves to separate the fruits of each experimental plot, until they reached moisture content in a wet basis in the range between 11 and 12.5%. After drying, the dry cherry was peeled, passing each sample five times through a Pinhalense® huller. From the weight of raw coffee beans obtained after processing and correcting moisture in the wet base for 12.5%, yield (YLD) was determined in bags of 60 $kg \cdot ha^{-1}$, and processing income was determined by the ratio between straw and green coffee. The first four harvests occurred in the agricultural years 2014/2015, 2015/2016, 2017/2018, and 2018/2019.

Data analysis

The data were submitted to outlier analysis using the generalized ESD test (Rosner 1983), and it was verified whether the assumptions of the analysis of variance (ANOVA) (normality of the residues, using the Levene test and homogeneity of variances, using the Jarque-Bera) were met. When one of the assumptions was violated, the data was transformed to meet the ANOVA requirements. Data were analyzed using one-way ANOVA. When the F test was significant ($p < 5\%$), the Scott-Knott cluster test was performed to compare means. Analyzes were performed using the SpeedStat® software (Carvalho et al. 2020). Data were also submitted to statistical analysis and Pearson's correlation using the AgroEstat® software (Barbosa and Maldonado Júnior 2009).

Due to the dependency structure of the variables analyzed, exploratory multivariate principal component analysis was applied (Hair Jr. 2009) to plot the distribution of arabica coffee cultivars in two dimensions and group the traits into new latent variables (principal components). This analysis was conducted to identify the cultivars that differed from the others regarding morphological traits. The analysis was performed using the average of the repetitions of each variable for each cultivar.

All traits evaluated were used in the multivariate analysis. Before analysis, all variables were standardized, generating zero mean and unitary variance. The number of principal components was chosen based on the Kaiser criterion, using those with eigenvalues above 1.0 (Kaiser 1958). The eigenvalues were extracted from the covariance matrix of the original variables. Variables with scores greater than 0.600 were considered relevant for explanation within each principal component.

For the identification of cultivars with specific traits, ellipses were plotted, covering the values of the X and Y axes ranging from -1.96 to 1.96. These values refer to the Z value of the normal distribution, in which values less than -1.96 and greater than 1.96 indicate points with specific traits at 5% probability. Thus, it was possible to identify cultivars with specific traits for each principal component, as performed by Romano et al. (2022). Multivariate statistical analyses were performed using the Statistica® software, version 7.0 (StatSoft, Tulsa, USA).

RESULTS AND DISCUSSION

The cultivars had significant differences for all vegetative traits during initial vegetative development (Table 2). Considering the PHG, the cultivars were separated into two groups, and most of the genotypes were allocated to the group with the highest averages. Obatã IAC 1669-20 and IAC Obatã 4739 had the highest averages of CDG, while Oeiras and Sabiá Tardio tended to develop more compact canopies, with lower CDG.

Cultivar IAC Obatã 4739 showed higher means for all vegetative traits during the growth period except for IHFB (Table 2). The lower averages of Oeiras MG 6851 and Pau-Brasil MG1 for BLG and NNI indicate low yield potential since the number of nodes is one of the main yield components (Carvalho et al. 2017). Oeiras MG 6851 showed the worst initial vegetative development for all traits except for IHFB, followed by Pau-Brasil MG1.

Based on the correlations between the traits, it is observed that the trait with the highest number of significant correlations was PHG (Table 3). This evidenced a greater association with SDG, followed by CDG, BLG, and NNI. SDG also correlated with CDG, BLG, and NNI. The highest correlation was obtained between BLG and NNI (0.78).

Table 2. Mean values of initial vegetative development of dwarf arabica coffee cultivars.

Cultivar	PHG cm	SDG mm	IHFB	CDG	BLG	NNI	PROD 1S	PROD 4S
			----------------cm -------------			nº	bags·ha-1	
SH3	99.47 b	26.52 c	18.27 b	72.24 b	19.00 b	11,00 a	32,2 b	43,6 b
CA62	105.63 a	28.81 b	23.66 a	71.12 b	17.56 b	8,56 b	48,0 a	46,0 a
CV99	103.08 a	28.51 b	22.89 a	72.09 b	15.81 b	9,88 b	47,6 a	48,8 a
OrV	106.74 a	28.22 c	19.63 b	74.21 b	18.22 b	9,20 b	43,1 a	44,8 b
OrA	102.53 a	28.85 b	19.44 b	63.06 c	17.75 b	9,62 b	44,9 a	48,9 a
ObV	101.50 a	29.58 b	20.63 b	89.68 a	20.69 a	11,06 a	51,9 a	49,1 a
ObA	105.20 a	31.69 a	19.13 b	83.98 a	26.50 a	11,50 a	24,1 c	47,0 a
Tupi	94.01 b	27.23 c	18.84 b	73.26 b	23.05 a	10,56 a	42,0 a	50,2 a
IAC125	91.23 b	26.93 c	19.38 b	61.29 c	13.38 c	9,06 b	44,6 a	46,8 a
Catiguá	103.24 a	27.39 c	20.16 b	69.58 b	16.25 b	9,00 b	13,6 d	29,1 d
Oeiras	96.78 b	27.38 c	22.60 a	48.12 d	8.69 d	6,00 c	38,9 b	34,7 c
PBr	93.87 b	25.99 c	19.68 b	59.98 c	9.63 d	7,00 c	41,4 a	37,3 c
Sacr	109.30 a	30.77 a	21.03 b	75.83 b	21.25 a	9,44 b	16,3 d	26,7 d
IPR99	108.83 a	30.40 a	19.29 b	78.42 b	17.06 b	9,63 b	41,4 a	40,2 b
IPR100	106.08 a	26.70 c	18.19 b	70.98 b	18.81 b	10,81 a	45,5 a	51,6 a
IPR103	102.99 a	26.17 c	17.69 b	68.28 b	14.88 c	9,13 b	32,8 b	41,6 b
Sabiá	100.99 a	27.19 c	20.50 b	45.42 d	9.56 d	8,50 b	39,0 b	36,7 c
F	3.39**	4.38**	5.41**	12.99**	7.52**	5.59**	18.72**	13.72**
CV	5.64	5.67	7.22	8.40	20.30	12.84	17.0	9.4
Mean	101.85	28.14	20.06	69.27	16.95	9.41	38.1	42.5

PHG and SDG evaluations were performed 2 and 24 months after planting (MAP, June/2013 and April/2015). CDG, BLG, and NNI were obtained at 12 and 24 MAP (April/2014 and April/2015). PHG: plant height growth; SDG: stem diameter growth; IHFB: insertion height of the first plagiotropic branch; CDG: canopy diameter growth; BLG: plagiotropic branch length growth; NNI: increase in the number of nodes of the plagiotropic branch; YLD 1S: yield of the 1st harvest; YLD 4S: average yield of the first four harvests. SH3: IAC Catuaí SH3; CA62: Catuaí Amarelo IAC 62; CV99: Catuaí Vermelho IAC 99; OrV: IAC Ouro Verde; OrA: IAC Ouro Amarelo; ObV: Obatã IAC 1669-20; ObA: IAC Obatã 4739; Tupi: Tupi IAC 1669-33; IAC125: IAC 125 RN; Catiguá MG1; Oeiras: Oeiras MG 6851; PBr: Pau-Brasil MG1; Sacr: Sacramento MG1; IPR99: IPR 99; IPR100: IPR 100; IPR103: IPR 103; Sabiá: Sabiá Tardio. Means followed by the same letter belong to the same cluster by the Scott-Knott clustering algorithm at a 5% probability level. * and ** Significant at 5% and 1% probability, respectively. Source: Elaborated by the authors.

Table 3. Pearson correlation coefficients between the morphological traits and yield of the first harvest (YLD 1S), the average yield of the first two harvests (YLD 1B), and the average yield of the first four harvests (YLD 4S) of dwarf arabica coffee cultivars.

Traits	PHG	SDG	IHFB	CDG	BLG	NNI
SDG	0.53***	-	-	-	-	-
IHFB	0.009NS	0.09NS	-	-	-	-
CDG	0.33**	0.38**	-0.14NS	-	-	-
BLG	0.37**	0.46***	-0.17NS	0.60***	-	-
NNI	0.28*	0.25*	-0.32**	0.50***	0.78***	-
YLD 1S	-0.002NS	0.01NS	0.12NS	-0.04NS	-0.12NS	-0.01NS
YLD 1B	0.15NS	0.01NS	-0.19NS	0.18NS	0.28*	0.39**
YLD 4S	0.04NS	0.05NS	-0.09NS	0.27*	0.32**	0.43**

PHG: plant height growth; SDG: stem diameter growth; IHFB: insertion height of the first plagiotropic branch; CDG: canopy diameter growth; BLG: plagiotropic branch length growth; NNI: increase in the number of nodes of the plagiotropic branch. YLD 1S: yield of the first harvest; YLD 1B: average yield of the first two harvests. YLD 4S: average yield of the first four harvests. *, **, and *** significant at 5%, 1%, and 0.1% probability, respectively. Source: Elaborated by the authors.

Regarding the yield of the 1st harvest, no correlations were obtained with any growth variable. However, this does not indicate that the evaluation of the increment of the growth traits is not related to the future yield performance of the cultivars. Considering the average yield of the first four harvests (YLD 4S), significant correlations were obtained with NNI (0.43**), BLG (0.32**), and SDG (0.27*). This indicates that both traits have greater relevance in the indirect selection of arabica coffee cultivars. The association between traits obtained by Pearson's correlation can be used as a tool to help select cultivars with better agronomic performance.

The length of the first plagiotropic branch 12 months after planting showed a high correlation and direct effect on the yield of *C. arabica* in Patrocínio (MG) at about 1,000 m altitude (Teixeira et al. 2012). Carvalho et al. (2010), when evaluating morphological traits of coffee plants at 12 months of age, obtained genotypic and phenotypic correlations between all the evaluated traits and the yield of the first harvest, except for the number of nodes of the plagiotropic branch, differing from the results of the present study.

Stem diameter is also an important trait in the selection of cultivars for low-altitude regions, as it is related to the development of the root system (Rena and Maestri, 1998). Although no significant correlation was obtained between SDG and yield (Table 3), it was associated with BLG and NNI, which showed significant correlation coefficients with YLD 4S.

Two first principal components (PC) were sufficient to explain 74.79% of the data variability (Fig. 4 and Table 4). The relevant traits for PC1 were SDG, CDG, BLG, and NNI. All the traits of this PC had the same sign; that is, they had a direct correlation with each other. Within PC2, the relevant traits were PHG, STG, and YLD 4S. PHG and STG were inversely correlated with YLD 4S. It is important to emphasize that the PCs are independent; consequently, one PC does not interfere with the other.

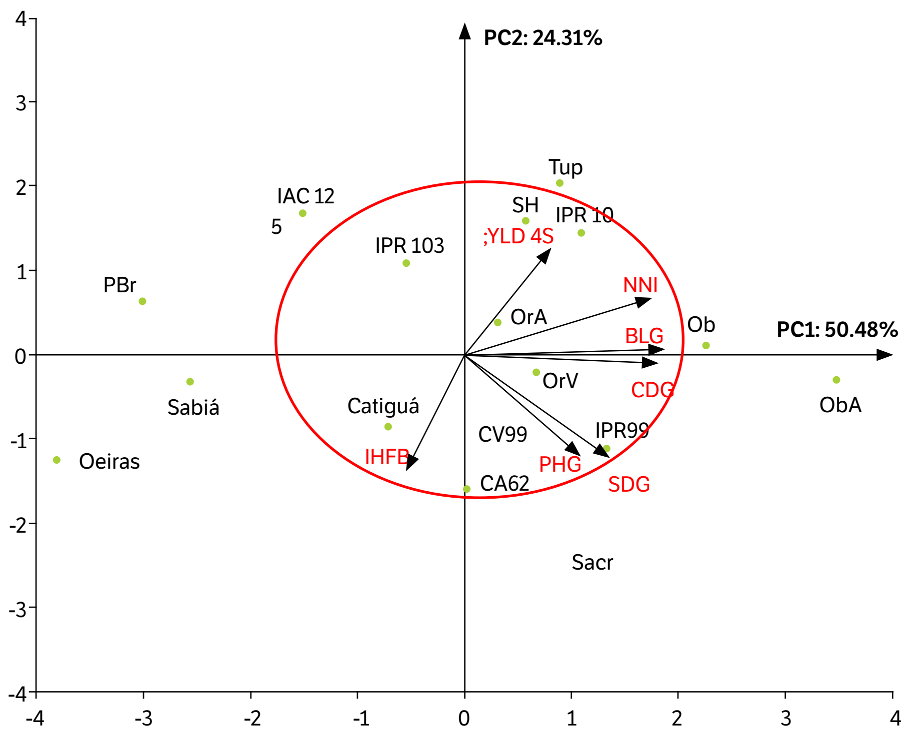

Figure 4. Biplot of principal components to evaluate the dispersion of vegetative traits and average yield of the first four harvests of dwarf arabica coffee cultivars at low altitude region. SH3: IAC Catuaí SH3; CA62: Catuaí Amarelo IAC 62; CV99: Catuaí Vermelho IAC 99; OrV: IAC Ouro Verde; OrA: IAC Ouro Amarelo; ObV: Obatã IAC 1669-20; ObA: IAC Obatã 4739; Tupi: Tupi IAC 1669-33; IAC125: IAC 125 RN; Catiguá MG1; Oeiras: Oeiras MG 6851; PBr: Pau-Brasil MG1; Sacr: Sacramento MG1; IPR99: IPR 99; IPR100: IPR 100; IPR103: IPR 103; Sabiá: Sabiá Tardio. PHG: plant height growth; SDG: stem diameter growth; IHFB: insertion height of the first plagiotropic branch; CDG: canopy diameter growth; BLG: plagiotropic branch length growth; NNI: increase in the number of nodes of the plagiotropic branch. YLD 4S: average yield of the first four harvests.

Source: Elaborated by the author

Table 4. Factor loadings of principal components (PC) variables.

Variables	PC1	PC2
PHG	0.559	**-0.598**
SDG	**0.670**	**-0.616**
CDG	**0.911**	-0.038
IHFB	-0.260	-0.699
BLG	**0.943**	0.048
NNI	**0.894**	0.331
YLD 4S	0.430	**0.602**

PHG: plant height growth; SDG: stem diameter growth; CDG: canopy diameter growth; IHFB: insertion height of the first plagiotropic branch; BLG: plagiotropic branch length growth; NNI: increase in the number of nodes of the plagiotropic branch. YLD 4S: average yield of the first four harvests. Source: Elaborated by the authors.

Teixeira et al. (2013), when using principal component analysis, identified that the length of the first plagiotropic branch, vigor, and number of nodes of the first plagiotropic branch were the most important traits in the distinction of arabica coffee genotypes among the morphological traits evaluated.

By analyzing the biplot, it is possible to identify the cultivars with the best initial vegetative development and yield (Fig. 4). Outside the ellipse are cultivars with specific traits for each PC. In PC1, IAC Obatã 4739 and Obatã IAC 1669-20 cultivars stood out, with higher CDG, SDG, BLG, and NNI. The IAC Obatã 4739 cultivar also showed high yield in the Registro region, southwest of the state of São Paulo, at just 25 m altitude (Carvalho et al., 2022a); Obatã IAC 1669-20 also stood out in yield in Rondônia (Teixeira et al. 2015), a place with high temperatures (annual average temperature of 25.6 oC), even though it is an environment considered unsuitable for the cultivation of *C. arabica*. On the opposite side, the genotypes with inferior vegetative development were distributed: Oeiras MG 6851, Sabiá Tardio, Pau-Brasil MG1, and IAC 125 RN.

Sacramento MG1 is described as a cultivar with high vegetative vigor (Carvalho et al., 2022b), which was also observed in this study, standing out in terms of growth in PHG and SDG. These traits were strongly associated (Fig. 4). However, it showed low YLD 4S, while more compact cultivars, such as Tupi IAC 1669-33 and IAC 125 RN, with lower vegetative growth, showed higher yields.

Although Tupi IAC 1669-33 presents lower growth in PHG (Table 2), its high yield can be explained by the greater growth of plagiotropic branches (greater BLG) and the number of nodes in these productive branches. The high average yield achieved by IAC 125 RN, despite the lower vegetative growth, can be attributed to the good development of other traits not evaluated, such as the number of plagiotropic branches and the number of flowers per node, traits that are also related to yield (Adepoju et al. 2020; Carvalho et al. al. 2010), in addition to this cultivar being characterized by the production of large beans (Fazuoli et al. 2018).

The examples of the two cultivars above indicate, therefore, that the lowest initial vegetative growth of the coffee plant does not necessarily imply low adaptation and yield potential and vice-versa. To make safer decisions when choosing cultivars, studying other traits related to agronomic performance throughout the cycle is necessary. However, the assessment of initial growth already provides useful information in identifying cultivars with greater adaptation and response potential in the study environment.

The PC analysis was complementary to the results of the analysis of variance and Pearson's correlation. It can be used as an auxiliary tool to identify the cultivars with the best initial vegetative development. Due to the many traits that can be evaluated, prior selection of the most relevant traits reduces labor costs and increases the efficiency of breeding programs (Teixeira et al. 2012).

CONCLUSION

There is variability among dwarf Arabica coffee cultivars for vegetative development. The growth of the plagiotropic branch and the increase in the number of nodes in the plagiotropic branch can be used in early selection to identify cultivars with greater yield potential. The cultivars IAC Obatã 4739, Obatã IAC 1669-20, and Tupi IAC 1669-33 present higher initial vegetative performance in low-altitude environments. The obtained results are useful to the producers for choosing cultivars more adapted to low-altitude environments.

AUTHORS' CONTRIBUTION

Conceptualization: Filla, V. A. F., Morello, O. F. and Lemos, L. B.; **Methodology:** Filla, V. A. F., Coelho, A. P. and Lemos, L. B.; **Investigation:** Filla, V. A., Grossi Terceiro, M., Morello, O. F. and Lemos, L. B.; **Data curation:** Filla, V. A. and Coelho, A. P.; **Formal analysis:** Filla, V. A., Coelho, A. P. and Morello, O. F.; **Funding Acquisition:** Filla, V. A. and Lemos, L. B.; **Resources:** Lemos, L. B.; **Supervision:** Coelho, A. P. and Lemos, L. B.; **Writing – Original Draft:** Filla, V. A. and Coelho, L. B.; **Writing – Review and Editing:** Grossi Terceiro, M.; Morello, O. F. and Lemos, L. B.

DATA AVAILABILITY STATEMENT

All dataset were generated and analyzed in the current study.

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