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PLENA: Conilon coffee cultivar with average productivity of over 100 bags per hectare per year, obtained in six harvests

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Abstract: Cultivar PLENA is composed of six *Coffea canephora* Pierre ex A. Froehner genotypes, derived from clones discovered and bred by farmers, which were reproduced in Nova Venécia, in the North of Espírito Santo State, Brazil (18°39′43″ S, 40°25′52″ W; 200m asl). The selected genotypes (A1, AD1, Bicudo, L80, LB1 and Peneirão) were superior to the others evaluated, with an average productivity in six harvests above 100 bags of processed coffee per hectare.

Keywords: *Coffea canephora*, genetic improvement, genetic diversity.

Introduction

Coffee growing is one of the most important activities in the social and economic aspects, both worldwide and in Brazil, generating employment and income, and settling farmers in the most rural areas. Brazil stands out worldwide as the largest producer and exporter of coffee (*Coffea* sp.), followed by Vietnam

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and Colombia (ICO, 2025), and Espírito Santo State leads the national production of the species *C. canephora*, with a production of 9.8 million processed bags in 2024 (CONAB, 2025).

Among the 130 species of coffee known in the genus *Coffea* (Davis and Rakotonasolo, 2021), two are widely cultivated (*C. arabica* and *C. canephora*). The *C. canephora* are highlighted due to their adaptation to tropical regions, expressive genetic and phenotypic diversity, and high productive potential (Partelli et al., 2022; Santos et al., 2024; Silva et al., 2024c;). It has approximated the percentage of Arabica produced in recent years worldwide (Salvador et al., 2024).

This level of production, as well as crop productivity, can be attributed to the development and adoption of new technologies, such as the selection of genotypes with high production potential, efficiency in irrigation management, advances in nutrition and plant health, pruning and densification, among other technologies, making the production process more efficient.

The conilon coffee plant is characterized as a diploid plant (2n=2x=22 chromosomes) and its reproductive system shows a gametophytic self-incompatibility mechanism, which favors alogamy and provides high genetic variability among individuals of this species (Carvalho et al., 1991; Nowak et al., 2011; Vázquez et al., 2019; Silva et al., 2024a). This genetic variability allows the identification of individuals with different characteristics (Giles et al., 2018, Giles et al., 2019; Martins et al., 2019; Partelli et al., 2021,;Santos et al., 2024; Silva et al., 2024b). Thus, the characterization and exploration of genetic variability within the species *Coffea canephora* can provide novel materials with promising characteristics.

The selection of new genetic materials of conilon coffee is crucial, as it can enable coffee producers to plant genotypes with superior productive potential under these conditions, leading to greater profitability combined with improved sustainability.

Breeding process

The planting was composed of 42 genotypes propagated by cutting, in the municipality of Nova Venécia, Espírito Santo State, at approximately 200 m altitude. The experimental area is located at Latitude: 18° 39′ 43″ S, Longitude: 40° 25′ 52″ W. The region is characterized by a climate classified as Aw, that is, tropical with dry winter and rainy summer (Alvares et al., 2013). The average minimum temperatures are above 16°C (July and/or August) and average maximum temperatures up to 32°C in January and/or February. Occasionally, there are days with temperatures below 13°C or above 36°C (Figure 1). The soil of the site is classified as a dystrophic Red-Yellow Latosol with a clayey texture and undulating topography (Santos et al., 2018).

The experimental design was in randomized blocks, with three field replications, with each replication consisting of seven plants. Fertilization was carried out according to soil analysis. The spacing used for planting was 3 × 1 m, occupying 3 m^2 per plant. Pruning was performed to control excessive branches, maintaining the standard of 12,000 to 15,000 stems per hectare. In all experimental years, manual weeding (treading at the fertilization site), mechanized weeding, and chemical weeding were carried out. Nutrients, insecticides, and fungicides were applied during the years of study. The experimental area was irrigated during all years.

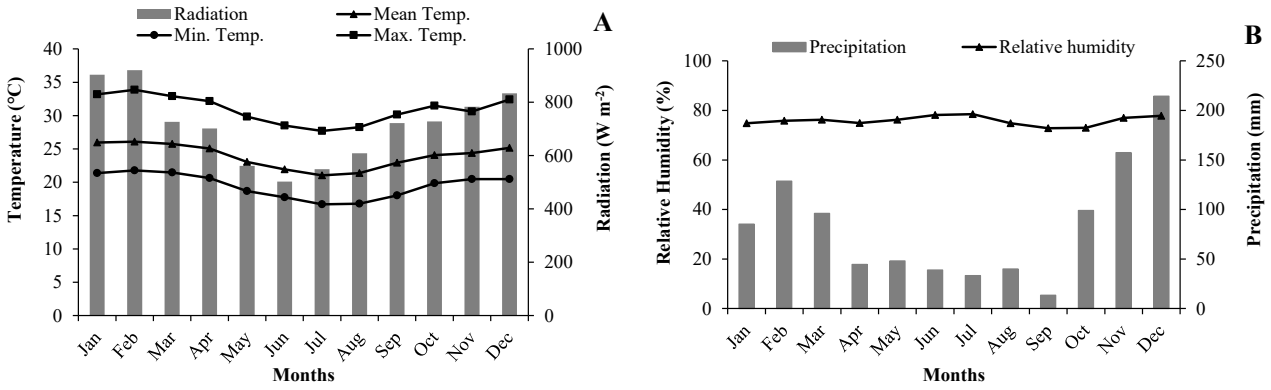

Figure 1. Mean values of solar radiation and maximum, mean and minimum air temperature (A) and relative air humidity and precipitation (B) in the years 2014 to 2022, recorded at the meteorological station of Nova Venécia county, Espirito Santo State.

To analyze the stability and adaptability of the genetic materials evaluated in this study, yield data corresponding to six harvests (2016, 2017, 2018, 2019, 2020, and 2021) were used. In addition to productivity, other characteristics were evaluated, such as plant architecture, some chemical contents of the leaves, beans, and fruit husks, sensory analysis of the beverage, plant height, among many other characteristics presented in Tables 1 to 7.

Table 1. Average productivity from the 2016 to 2021 harvests, the yield in liters of ripe coffee needed to produce a 60 kg bag of processed coffee, and the maturation period of the genotypes that compose the cultivar.

Genotypes	Prod. 1	Prod. 2	Prod. 3	Prod. 4	Prod. 5	Prod. 6	* Yield Ripe/Processed Liters bag^{-1}	Maturation
	sac ha^{-1}							
A1	93.4	85.9	108.8	108.2	106.4	103.6	365.4	Early/Medium
AD1	123.7	136.6	126.7	128.9	115.6	111.2	303.5	Early
Bicudo	106.3	91.6	109.7	93.1	103.3	111.8	366.2	Medium
L80	95.1	76.2	104.6	105.5	103.1	101.4	364.7	Early
LB1	125.6	126.7	135.4	118.1	124.0	119.6	312.2	Medium
Peneirão	128.3	93.2	109.0	99.2	100.6	105.8	326.6	Medium
Average of the PLENA Cultivar						**108.91**	**339.77**	**-**
Average of the other genotypes evaluated						**83.84**	**348.85**	**-**

* Dados completos publicados por Partelli et al. (2021).

Table 2. Root system at six soil depths, 50 cm from the trunk of the adult plant of the genotypes that compose the cultivar.

Genotypes	0 – 10 cm	10 – 20 cm	20 – 30 cm	30 – 40 cm	40 – 50 cm	50 – 60 cm	Total	0-20 cm	40-60 cm
	Root length in mm cm^{-3}							%	
A1	870.2	408.0	317.7	232.6	224.7	167.0	2220	57.57	17.64
AD1	577.5	270.0	200.3	297.5	375.7	320.3	2041	41.52	34.09
Bicudo	958.9	753.3	392.2	253.4	152.6	154.1	2664	64.26	11.51
L80	954.7	902.6	654.8	610.6	410.5	419.4	3952	46.99	21.00
LB1	710.5	405.3	235.7	192.6	137.1	184.3	1865	59.82	17.23
Peneirão	924.9	532.4	155.4	108.9	99.0	125.6	1946	74.88	11.54
Average of PLENA	**832.8**	**545.3**	**326.0**	**282.6**	**233.2**	**228.4**	**2448**	**57.51**	**18.83**
Average of others genotypes	**818.6**	**340.9**	**227.4**	**173.3**	**150.8**	**138.3**	**1849.2**	**62.29**	**15.98**

Data published by Silva et al. (2020).

Table 3. Some characteristics of the plant and leaves of the genotypes that compose the cultivar.

Genotypes	PH (cm)	DBNP (cm)	LA (cm²)	LL (cm)	LW (cm)	NS (per mm²)	PDS (µm)
A1	226.2	3.89	67.43	16.10	6.70	34.4	25.5
AD1	198.8	3.97	38.96	12.40	5.00	35.0	25.3
Bicudo	253.7	4.01	65.95	14.98	6.77	27.6	23.6
L80	214.3	4.49	60.21	15.91	6.29	37.4	28.0
LB1	198.2	3.86	60.24	14.76	6.39	29.5	26.2
Peneirão	226.5	3.4	59.42	14.54	6.33	26.3	27.0
PLENA average	**219.61**	**3.94**	**58.70**	**14.78**	**6.25**	**31.70**	**25.93**
Other genotypes	**211.91**	**3.78**	**58.49**	**14.56**	**6.29**	**30.96**	**25.63**

PH: plant height; DBNP: distance between nodes of plagiotropic branches; LA: leaf area; LL: leaf length; LW: leaf width; NS: number of stomata; PDS: polar diameter of stomata. Complete data published by Dubberstein et al. (2020 and 2021).

Table 4. Some characteristics of the fruit and beans of the genotypes that compose the cultivar.

Genotypes	BQ 2018-2020 Score	*Bean in fruit %	PB 2019 %	PB 2020 %	*RFW / 60Kg PC Kg	*RFW / DBW Relation	*RV / RFW Relation
A1	77.8	53.8	28.4	28.3	240	4.00	1.52
AD1	78.5	60.9	30.3	30.9	192	3.20	1.58
Bicudo	78.3	55.3	40.0	43.1	231	3.85	1.58
L80	79.4	53.7	34.4	29.0	233	3.88	1.57
LB1	79.6	63.2	4.2	5.4	203	3.39	1.54
Peneirão	78.6	57.1	13.0	15.6	215	3.59	1.52
PLENA average	**78.71**	**57.33**	**25.05**	**25.38**	**219.0**	**3.65**	**1.55**
Other genotypes	**77.82**	**57.34**	**16.74**	**15.78**	**224.1**	**3.74**	**1.78**

BQ: beverage quality; PB: peaberry bean; RFW/60kg PC: ripe fruit weight/60 kg of processed coffee; RFW/DBW: ripe fruit weight/dry bean weight; RV/RFW: ripe volume/ripe fruit weight. * Complete data published by Partelli et al. (2021).

Table 5. Some characteristics of traditional beans of the genotypes that compose the cultivar.

Genotypes	Bean weight g	Area cm²	Max. Diameter cm	Min. Diameter cm	Edges number	Perimeter cm
A1	0.140	0.40	0.85	0.59	161.9	2.95
AD1	0.155	0.40	0.81	0.63	207.3	2.73
Bicudo	0.170	0.49	0.97	0.63	316.2	3.20
L80	0.141	0.40	0.80	0.62	201.5	2.51
LB1	0.147	0.39	0.82	0.60	165.6	2.94
Peneirão	0.204	0.50	0.91	0.69	259.5	3.53
PLENA average	**0.159**	**0.43**	**0.86**	**0.62**	**218.7**	**2.98**
Other genotypes	**0.137**	**0.38**	**0.81**	**0.59**	**187.4**	**2.75**

Table 6. Nutrient concentration in leaves collected at the fruit development stage, in beans, and in fruit husks of the genotypes that compose the cultivar.

	Genotypes	N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mn	B
		(g Kg⁻¹)						(mg Kg⁻¹)				
*Nutrient concentration in the leaves collected at the fruit development stage	A1	28.9	1.18	13.3	16.0	4.23	2.09	82.3	7.33	13.3	461	63.3
	AD1	28.4	1.14	14.0	20.2	5.48	2.06	74.0	8.00	17.0	442	61.3
	Bicudo	28.6	1.18	16.0	18.9	5.40	2.17	99.0	7.67	15.3	446	81.0
	L80	27.2	1.24	12.9	14.0	5.15	1.59	73.7	7.33	20.0	323	57.3
	LB1	30.5	1.33	12.9	15.5	5.27	2.09	77.3	7.67	21.3	661	56.7
	Peneirão	27.4	1.07	13.3	16.7	4.48	2.06	72.3	7.33	16.0	348	51.3
	PLENA average	**28.5**	**1.19**	**13.8**	**16.9**	**5.00**	**2.01**	**79.8**	**7.56**	**17.2**	**447**	**61.8**
	Other genotypes	**28.3**	**1.17**	**14.0**	**16.2**	**4.76**	**2.30**	**78.7**	**7.65**	**16.7**	**473**	**58.3**

(to be continued)

Table 6. Nutrient concentration in leaves collected at the fruit development stage, in beans, and in fruit husks of the genotypes that compose the cultivar (Continuation).

	Genotypes	N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mn	B
		(g Kg^{-1})						(mg Kg^{-1})				
Nutrient concentration in beans	A1	27.6	1.43	15.4	1.64	1.67	1.30	47.3	4.67	9.67	36.3	16.3
	AD1	26.3	1.58	15.4	1.46	1.77	1.26	55.3	6.67	11.3	29.0	15.3
	Bicudo	27.4	1.42	16.5	1.46	1.96	1.33	54.3	6.33	10.3	33.0	16.7
	L80	26.6	1.34	15.2	1.75	1.75	1.18	50.0	7.00	13.3	45.0	14.7
	LB1	24.9	1.39	15.8	1.48	1.69	1.15	37.3	4.33	13.7	138	13.7
	Peneirão	28.0	1.39	15.0	1.70	1.65	1.23	49.7	6.00	10.3	44.0	15.0
	PLENA average	**26.8**	**1.43**	**15.6**	**1.58**	**1.75**	**1.24**	**49.0**	**5.83**	**11.4**	**54.3**	**15.3**
	Other genotypes	**27.2**	**1.42**	**15.2**	**1.61**	**1.81**	**1.29**	**48.8**	**5.81**	**13.5**	**55.1**	**16.4**
	Genotypes	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Fe**	**Zn**	**Cu**	**Mn**	**B**
		(g Kg^{-1})						(mg Kg^{-1})				
Nutrient concentration in fruit husks	A1	13.3	0.46	18.5	3.68	0.88	1.05	29.3	2.33	4.67	75.3	44.7
	AD1	12.6	0.56	20.4	2.56	0.75	0.73	53.7	3.33	9.33	106	43.3
	Bicudo	13.3	0.51	22.5	3.64	0.90	0.87	35.0	5.67	7.33	84.0	46.0
	L80	15.8	0.46	17.9	3.85	1.02	0.90	30.7	4.33	10.7	61.0	36.0
	LB1	13.0	0.51	15.8	5.51	1.33	1.11	31.3	3.67	10.3	275	43.0
	Peneirão	14.7	0.52	20.0	3.83	1.02	1.14	81.7	5.00	11.0	104	37.7
	PLENA average	**13.8**	**0.50**	**19.2**	**3.84**	**0.98**	**0.97**	**43.6**	**4.06**	**8.89**	**118**	**41.8**
	Other genotypes	**14.7**	**0.53**	**19.4**	**4.14**	**1.10**	**1.15**	**42.8**	**3.84**	**9.01**	**123**	**42.4**

* Data published by Silva et al. (2021).

Table 7. Contents of trigonelline, caffeine, CQA, FQA, diCQA, CGA, phenolic acids, and soluble solids in beans, fruit husks, and dried coffee leaves (two-year average) of the genotypes that compose the cultivar.

	Genotypes	Trigonelline g 100g^{-1}	Caffeine g 100g^{-1}	CQA g 100g^{-1}	FQA g 100g^{-1}	diCQA g 100g^{-1}	CGA g 100g^{-1}	Phenolic acids mg 100^{g-1}	Soluble solids °Brix
Contents in beans	A1	0.87	1.82	4.76	1.23	1.01	6.99	9.39	3.95
	AD1	0.88	1.57	3.77	1.17	0.60	5.53	9.78	3.25
	Bicudo	0.98	1.83	5.99	0.97	0.88	7.83	9.58	4.20
	L80	1.01	1.33	2.36	1.11	0.37	3.83	9.11	3.25
	LB1	1.03	1.82	4.41	1.41	0.76	6.58	10.8	3.30
	Peneirão	1.05	1.77	5.62	1.14	1.04	7.80	8.99	4.35
	PLENAaverage	**0.97**	**1.69**	**4.48**	**1.17**	**0.77**	**6.42**	**9.60**	**3.72**
	Other genotypes	**0.97**	**1.90**	**4.98**	**1.19**	**1.03**	**7.19**	**9.06**	**3.99**
	Genotypes	**Trigonelline g 100g^{-1}**	**Caffeine g 100g^{-1}**	**CQA g 100g^{-1}**	**FQA g 100g^{-1}**	**diCQA g 100g^{-1}**	**CGA g 100g^{-1}**	**Phenolic acids mg 100^{g-1}**	**Rutin mg 100^{g-1}**
Contents in fruit husks	A1	1.91	0.24	0.51	0.06	0.31	0.88	19.7	60.7
	AD1	2.25	0.87	0.63	0.08	0.37	1.09	11.0	63.5
	Bicudo	1.93	0.62	0.30	0.04	0.43	0.75	15.2	88.0
	L80	1.98	0.61	0.43	0.05	0.26	0.74	20.9	57.3
	LB1	2.01	1.01	0.36	0.05	0.20	0.60	11.2	53.7
	Peneirão	2.08	1.07	0.37	0.04	0.18	0.58	18.3	68.2
	PLENA average	**2.02**	**0.73**	**0.43**	**0.05**	**0.29**	**0.77**	**16.0**	**65.2**
	Other genotypes	**2.04**	**0.83**	**0.48**	**0.06**	**0.35**	**0.90**	**17.9**	**74.3**

(to be continued)

Table 7. Contents of trigonelline, caffeine, CQA, FQA, diCQA, CGA, phenolic acids, and soluble solids in beans, fruit husks, and dried coffee leaves (two-year average) of the genotypes that compose the cultivar (Continuation).

	Genotypes	Trigonelline g 100g^{-1}	Caffeine g 100g^{-1}	CQA g 100g^{-1}	FQA g 100g^{-1}	diCQA g 100g^{-1}	CGA g 100g^{-1}	Phenolic acids mg 100^{g-1}	Rutin mg 100^{g-1}
Contents in coffee leaves	A1	0.90	1.10	1.56	0.07	0.27	1.89	14.2	135
	AD1	1.43	0.98	0.88	0.07	0.28	1.22	8.4	438
	Bicudo	0.99	0.93	1.05	0.01	0.25	1.31	11.8	175
	L80	1.04	0.90	1.48	0.04	0.18	1.69	16.3	311
	LB1	0.81	1.00	1.11	0.03	0.25	1.39	10.9	73,6
	Peneirão	0.89	0.87	0.97	0.01	0.09	1.07	14.6	81,4
	PLENA average	**1.01**	**0.96**	**1.17**	**0.04**	**0.22**	**1.43**	**12.7**	**202**
	Other genotypes	**0.82**	**1.16**	**1.10**	**0.05**	**0.20**	**1.34**	**11.9**	**119**

*CQA: chlorogenic acids; FQA: feruloylquinic acids; diCQA: dicaffeoylquinic acids; and CGA: total chlorogenic acids (sum of CQA, FQA, and diCQA).

Performance

The Federal University of Espírito Santo (UFES) registered the PLENA cultivar, of the species *Coffea canephora* Pierre ex A. Froehner. The cultivar registration was conducted with the Brazilian Ministry of Agriculture, Livestock, and Supply (MAPA), and was registered as PLENA No. 50300, which represents another contribution to coffee growing. It is a cultivar of *Coffea canephora* Pierre ex A. Froehner (Conilon or Robusta), composed of six genotypes with an average productivity of over 100 bags per hectare.

Over the years that preceded this trial, a work team began the process of identifying Conilon/Robusta coffee plants, which showed promise under field conditions. Genotypes of varieties already known and registered were also studied in the same trial.

Among all the materials evaluated in the trial, considering characteristics such as yield (of six harvests), plant architecture, vigor, and resistance to pests and diseases, six genotypes were selected (A1, AD1, Bicudo, L80, LB1, and Peneirão) to constitute the new clonal cultivar, called PLENA (Figures 2 to 7). On average, the six harvests of the six genotypes yielded 108.91 bags per hectare per year, whereas the average of the other genotypes was lower than 83.84 bags per hectare per year (Table 1). The data on the genotypes, both individually and as averages for the cultivar and the other evaluated genotypes, can be found in the tables below (Tables 1 to 7).

Figure 2. Flowers, foliage, green fruits, ripe fruits, and beans processed from the A1 genotype of the PLENA cultivar.

Figure 3. Flowers, foliage, green fruits, ripe fruits, and beans processed from the Bicudo genotype of the PLENA cultivar.

Figure 4. Flowers, foliage, green fruits, ripe fruits, and beans processed from the AD1 genotype of the PLENA cultivar.

Figure 5. Flowers, foliage, green fruits, ripe fruits, and beans processed from the L80 genotype of the PLENA cultivar.

Figure 6. Flowers, foliage, green fruits, ripe fruits, and beans processed from the Peneirão genotype of the PLENA cultivar.

Figure 7. Flowers, foliage, green fruits, ripe fruits, and beans processed from the LB1 genotype of the PLENA cultivar.

During the eight years of evaluation, the genotypes showed a good adaptation to the cultivation conditions, considering their performance in growth and production. No severe attacks from the main pests and diseases was found, with the plants remaining vigorous and with good foliage. In 2015, the crop received limited irrigation due to one of the most severe droughts in history, which occurred in 2014 and 2015 (Salvador et al., 2024). The farmers had limited water availability for irrigation, which also significantly impacted the productivity of the 2017 second harvest.

Thus, the new cultivar shows desirable characteristics, particularly high productivity for the conditions of Northern Espírito Santo State, which leads to great acceptance among coffee growers. It can be cultivated under climatic conditions similar to those of its original location (at approximately 200 m of altitude). Therefore, it is recommended for Espírito Santo State at an altitude of less than 500 meters. All genotypes showed average productivity above 100 bags per hectare per year. Notably, several leaves, fruits, roots, and other aspects were analyzed, resulting in a comprehensive characterization.

Clone maintenance and distribution

Cultivar PLENA was registered in 2022 by the National Registry of Cultivars (RNC, nº. 50300) of the Brazilian Ministry of Agriculture, Livestock and Food Supply. The Federal University of Espírito Santo (UFES) is in charge of maintaining the six genotypes that constitute cv. PLENA.

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