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SALUTAR: FIRST CULTIVAR BRED FOR SOLUBLE COFFEE PRODUCTION AND HEALTH

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Abstract: Salutar is a cultivar composed of five *Coffea canephora* genotypes, derived from clones discovered and bred by farmers, in Espírito Santo, Brazil. A group of 42 promising *C. canephora* genotypes was selected. These genotypes were propagated by cuttings and planted in an experimental area for selection for high yield potential and agronomic traits of interest. A design in randomized blocks with three field replications and seven plants per replication was used and the laboratory analyses were replicated three times. The cultivar produces high yields and the contents of total soluble solids, caffeine and chlorogenic acids in the green beans are higher than the traditional mean contents of *Coffea canephora* grown in Brazil. It was the first study focused on developing a cultivar with high levels of soluble solids and chlorogenic acids in green Conilon coffee beans. Cultivar Salutar is suitable for climatic conditions similar to those of this study, in other words, recommended for the State of Espírito Santo, south of Bahia and east of Minas Gerais, at less than 600 m asl.

Keywords: *Coffea canephora*, chlorogenic acids, soluble solids, coffee robusta.

Introduction

With a long-standing history, coffee is extremely important on the world market. Among the 124 species of the genus *Coffea* (Davis et al., 2011, 2019), *C. arabica* L. and *C. canephora* Pierre ex A. Froehner are the most commercially relevant ones. Brazil is the largest *C. arabica* Lproducer and the second producer of *Coffea canephora* worldwide, with 16.3 million bags produced produced in 2021 (ICO 2022; CONAB 2022). Espírito Santo is the leading producer of this species, with Conilon being the variety grown in the country. *C. canephora* has particularly high levels of soluble solids, responsible for the sensory attribute of full body and bioactive compounds, mainly caffeine and chlorogenic acids. The latest are phenolic compounds with antioxidant and anti inflamatory activities. This species has low acidity, neutral characteristics and contribute to coffee flavor (Farah and Lima 2019).

Currently, given the refinement of Conilon coffee through the development of post harvest methods market acceptance and demand are increasing. The relevance and market potential of conilon and robusta (another *C. canephora* variety) coffees have increased further in Brazil after their acceptance in the Brazilian Association of Specialty Coffee (BSCA).

Additional outstanding features of this species are high yield potential, pest and disease resistance and a good development in areas with hot and humid climates. The latter aspect has aroused growing interest of producers in areas affected by climate change, jeopardizing the *C. arabica* plantations, which depend on mild temperatures. In view of all the above factors, quality Conilon coffee is seen as seminal for the future of coffee production. Therefore, studies that make possible breeding and selection of the most promising lines for cultivation in terms of increased yields and better-quality beans are needed, enabling greater economic returns.

Breeding methods

The Conilon coffee tree is a diploid plant (2n = 2x = 22 chromosomes) and the reproductive system has a gametophytic mechanism of self-incompatibility, which favors allogamy and provides high genetic variability among plants of the species (Nowak et al., 2011; Vázquez et al., 2019). This genetic variability allows the identification of plants with different characteristics (Giles et al., 2018, 2019; Martins et al., 2019; Dubbersteinet al., 2020; Partelliet al. 2021; Silva et al., 2021) and enables the selection of genotypes for different cultivation purposes.

A group of 42 promising *C. canephora* genotypes was selected, mostly by coffee growers in the State of Espírito Santo, Brazil. These genotypes were propagated by cuttings and planted in an experimental area for selection for high yield potential and agronomic traits of interest. Planting was carried out in April 2014, at spacing of 3.0 x 1.0 m and a density of 3333.3 plants ha^{-1}, in an area with a flat topography in a district of Nova Venécia, Espírito Santo, Brazil (18°39′43″S, 40°25′52″ W), at approximately 200m asl. According to Köppen's classification, the regional climate is tropical Aw, with dry winters and rainy summers (Alvares et al., 2013). In general, the mean minimum temperature is above 16°C (July - August) and the mean maximum up to 32°C (January - February). Occasionally, there are days with temperatures below 13°C or above 36 °C (Figure 1).

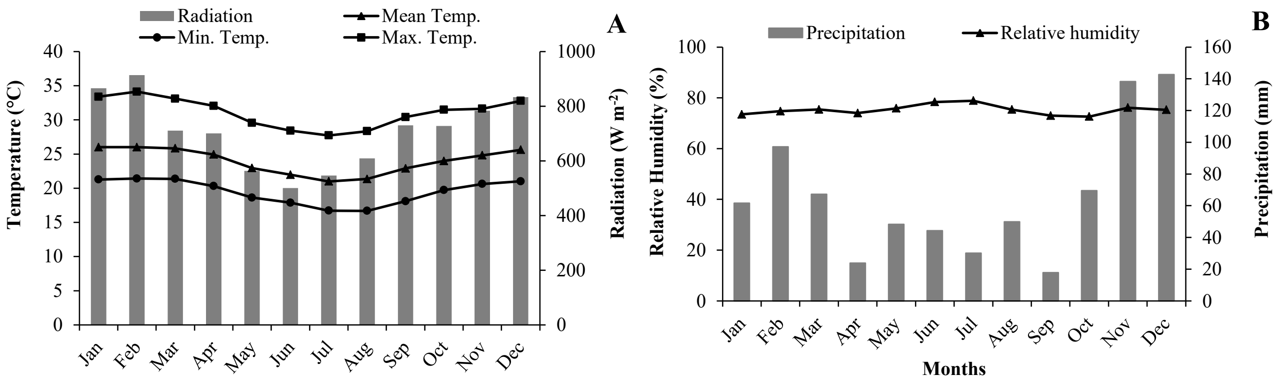

Figure 1. Mean values of solar radiation and maximum, mean and minimum air temperature (A) and relative air humidity and precipitation (B) in six growing seasons (2014, 2015, 2016, 2017, 2018 and 2019), recorded at the meteorological station of Nova Venécia-ES.

A design in randomized blocks with three field replications and seven plants per replication was used and the laboratory analyses were replicated three times. Fertilization was applied according to soil analysis and excessive branches were pruned to maintain a standard of 12,000 to 15,000 stems per hectare.

In all growing seasons, weeds were controlled by hand weeding (along the planting line), in addition to mechanical and chemical weeding. During the study years, nutrients, insecticides and fungicides were applied as typically recommended for this crop. In all growing seasons, the experimental area was irrigated with a drip irrigation system.

To analyze the stability and adaptability of the genetic material evaluated in this study, yield data of the four growing seasons (2016, 2017, 2018 and 2019) were used. For the chemical characteristics, two growing seasons (2018 and 2019) were taken into consideration, with data variation between the two years below 10%, indicating stability of the compositional traits over the years and a genetic nature of these traits.

Conilon coffee seed extracts (10%) were prepared and filtered through Whatman paper number 1. Soluble solids were determined using a digital refractometer (Atago, PAL-1, Japan) by the modified method no. 15,034, AOAC (1997) and the results expressed in °Brix. Chlorogenic acid contents were determined by high performance liquid chromatography, as suggested by Farah et al. (2006).

All procedures were carried out based on the criteria defined by law (Lei Federal n° 10.711, 2003; Decreto nº 10.586, 2020), so that the request for registration was approved by the Ministry of Agriculture, Livestock and Establishment – MAPA.

Performance

The five genotypes were selected for vigor and resistance to pests and diseases. Compared to other genotypes of the same species, their yields are satisfactory and the levels of chlorogenic acids and soluble solids are higher, which motivated the request for registration of the new cultivar. The individual data and means of the five genotypes that comprise cv. Salutar (Graudão HP, Emcapa 02, Tardio C, Tardio V and Z 37) and the other evaluated genotypes are listed in Tables 1, 2 and 3.

Table 1. Contents of soluble solids (SS) and chlorogenic acids (CGA) in beans of *Coffea canephora* Pierre ex A. Froehner cv. Salutar (means of 2018 and 2019) and mean yield of four growing seasons (2016 - 2019).

Genotypes	SS (°Brix)	CQA (g 100g^{-1})	FQA (g 100g^{-1})	diCQA (g 100g^{-1})	CGA (g 100g^{-1})	Yield bags ha^{-1}
Graudão HP	4.40	6.77	1.22	1.32	9.31	86.1
Emcapa 02*	4.85	6.88	1.04	1.16	9.07	97.1
Tardio C	4.65	5.75	1.10	2.02	8.87	74.7
Tardio V	4.35	5.66	1.70	1.54	8.89	69.8
Z 37	4.40	6.20	1.59	1.06	8.84	86.8
Meanof cv. Salutar	4.53a	6.25a	1.33a	1.42a	9.00a	82.93a
Meanof Other Genotypes**	**3.87b**	**4.72b**	**1.17a**	**0.94b**	**6.82b**	**84.36a**

SS: soluble solids; CQA: caffeoylquinic acids; FQA: feruloylquinic acids; diCQA: dicaffeoylquinic acids and CGA: total chlorogenic acids (sum of CQA + FQA + diCQA). Means followed by the same letters in a column do not differ by the Dunnett testat 5% probability.*Genotype 02 of cultivar Emcapa 8111 (Bragança et al. 2001).**18, 122, 700, A1, AD1, Alecrim, AP, B01, Bamburral, Beira Rio 8, Bicudo, CH1, Clementino, Cheique, Emcapa 143, Emcapa 153, Imbigudinho, L80, LB1, Ouro Negro, Ouro Negro 1, Ouro Negro 2, P1, P2, Peneirão, Pirata, Semente, Valcir P, Verdim D, Verdim R, Z18, Z21, Z29, Z35, Z36, Z38, Z39, Z40.

Table 2. Contents of soluble solids and chlorogenic acids in the husk of *Coffea canephora* Pierre ex A. Froehner cv. Salutar cherries (mean 2018 and 2019) and mean yield of four growing seasons (2016 - 2019).

Genotypes	CQA g 100g^{-1}	FQA g 100g^{-1}	diCQA g 100g^{-1}	CGA g 100g^{-1}	Yield Dry cherry/ green coffee L bags^{-1}	Maturation
Graudão HP	0.39	0.04	0.22	0.65	317.6	Medium
Emcapa 02*	0.38	0.04	0.28	0.69	323.2	Early/mean
Tardio C	0.67	0.08	0.79	1.57	345.1	Super late
Tardio V	0.53	0.07	0.56	1.16	329.9	Super late
Z 37	0.44	0.05	0.28	0.75	363.8	Medium
Meanof cv. Salutar	**0.480a**	**0.054a**	**0.424a**	**0.961a**	**335.9a**	**-**
Meanof Other Genotypes	**0.473a**	**0.057a**	**0.334b**	**0.867a**	**349.1a**	**-**

CQA: caffeoylquinic acids; FQA: feruloylquinic acids; diCQA: dicaffeoylquinic acids and CGA: total chlorogenic acids (sum of CQA + FQA + diCQA). Mean values followed by different letters in a column differ by the Dunnett test at 5% probability. *Genotype 02 of cultivar Emcapa 8111 (Bragança et al. 2001).

Table 3. Important traits of the five genotypes of *Coffea canephora* Pierre ex A. Froehner cv. Salutar (branches, leaves and root system).

Genotype	DNPB cm	LL cm	LW cm	LA cm^{-2}	NS n mm^{-2}	PD µm	SI %	SFU -
Graudão HP	3.78a	14.33b	5.76c	53.27b	26.7c	26.0c	21.3c	1.55b
Emcapa 02*	3.44b	13.20c	6.07b	51.25c	27.9c	26.8b	23.4b	1.52b
Tardio C	3.58a	14.76b	5.78c	55.76b	27.4c	25.7c	20.7c	1.50c
Tardio V	3.63a	15.70a	6.54a	61.10a	30.1b	25.1d	22.9b	1.51c
Z 37	3.44b	14.63b	5.99b	53.33b	32.0a	28.0a	24.7a	1.63a
Mean	**3.574**	**14.52**	**6.028**	**54.94**	**28.82**	**26.32**	**22.6**	**1.542**

Genotype	SA 0-10 cm^2 dm^{-3}	SA 10-20 cm^2 dm^{-3}	SA 20-30 cm^2 dm^{-3}	SA 30-60 cm^2 dm^{-3}	SA 40-50 cm^2 dm^{-3}	SA 50-60 cm^2 dm^{-3}	SA 0-60 cm^2 dm^{-3}	SA 0-20 %
Graudão HP	1511.61 Aa	599.40Bba	240.40Cb	310.70 Ca	249.68 Ca	189.45Cb	516.87a	68.07a
Emcapa 02*	1161.38 Aa	462.23 Bb	198.85Cb	131.95Cb	117.55Cb	252.56 Ca	387.42b	69.85a
Tardio C	1418.18 Aa	671.54 Ba	415.63 Ca	191.43Cb	233.44 Ca	249.29 Ca	529.92a	65.72a
Tardio V	578.51 Ac	382.57 Ab	215.90Bb	212.17Bb	189.10Bb	70.72 Cb	274.83c	58.28b
Z 37	779.34 Ab	210.92 Bc	169.13Bb	185.81Bb	166.28Bb	97.03 Bb	268.09c	61.56a
Mean	**1089.80**	**465.33**	**247.98**	**206.41**	**191.21**	**171.81**	**395.43**	**64.70**

DNPB: Distance between nodes of plagiotropic branches; LL: Leaf length; LW: Leaf width; LA: Leaf area; NS: Number of stomata; PD: Stomatal polar diameter (µm); SI: Stomatal index; SFU: Stomatal functionality; SA 0-60: Surface area of the root system within a distance of 30 cm from the plant and down to a depth of 60 cm; SA 0-20% of surface area in the 0 - 20 cm soil layer, all parameters evaluated in Nova Venécia-ES. Means followed by the same uppercase letter in rows and lowercase letter in columns do not differ by the Scott-Knott test at 5% probability. *Genotype 02 of cultivar Emcapa 8111 (Bragança et al. 2001). DNPB, LL, LW and LA (Dubbersteinet al. 2020); NS, PD, SI and SFU (Dubberstein 2019); SA (Silva et al. 2020).

The five genotypes of cv. Salutar have higher levels of soluble solids and chlorogenic acids than the remaining tested genotypes (Tables 1 and 2). For soluble solids and chlorogenic acids, Aguiar et al. (2005) had previously reported genetic variability in *Coffea canephora,* indicating the potential of the species for breeding for these characteristics. Maximized levels of soluble solids in coffee are desirable, both with regards to high yelds for the soluble coffee industry and to promote a full-bodied flavor (Mendonça et al., 2005).

The antioxidant effect of coffee results mainly from the presence of chlorogenic acids and free phenolic acids caffeine, trigonelline, Maillard reaction products and volatile compounds, e.g., furans and pyrroles (Castilho et al., 2002). The contents of phenolic compounds, particularly of chlorogenic acids and related compounds in coffee, have also a significant influence on the aroma and peculiar flavor of the beverage (Farah and Donângelo 2006).

Phenolic compounds are widely distributed in nature, representing the largest group of bioactive compounds that comprise plants. Among the phenolic-rich foods, coffee is one of the main contributors to the consumption of phenolic compounds by the Brazilian population (Corrêa et al., 2015; Torres and Farah 2017). The main representatives of the phenolic fraction in raw coffee beans are chlorogenic acids and related compounds. These compounds have beneficial health properties, not only due to their strong antioxidant activity, but also as hepaprotective, hypoglycemic and antiviral agents (Farah and Donangelo 2006).

Thus, under the studied conditions, the new cultivar has desirable characteristics, above all, high levels of soluble solids and total chlorogenic acids and satisfactory yield, which increases the chances of acceptance by coffee growers. Cultivar Salutar is suitable for climatic conditions similar to those of this study, in other words, recommended for the State of Espírito Santo, south of Bahia and east of Minas Gerais, at less than 600 m asl. It is worth mentioning that this was the first study focused on developing a cultivar with high levels of soluble solids and chlorogenic acids in green (unroasted) Conilon coffee beans. In most cases, the promising and registered clones were “discovered” by farmers; therefore, the information about the origin of the genotypes that compose the new cultivar has been included:

Graudão HP: Plant found by Hermes Joaquim Partelli, on his property, Sítio Araripe, in Paraíso Novo, district of Vila Valério-ES. The plant was discovered in 1998, in a seed-propagated plantation.

Emcapa 02: Genotype 02 of Cultivar Emcapa 8111 (Bragança et al., 2001).

Tardio C: “Tardio dos Covre”, coffee genotype found in a seed-propagated plantation in the 1990s, on a property of the Covre brothers (Carlos, Isaac and Moyses), district of Pinheiros-ES.

Tardio V: “Tardio do Vinin”, plant found by farmer Alvino Figueira de Barros (known as Vinim), on his property in Paraíso Novo, district of Vila Valério-ES. Plant selected around 1995, in a seed-propagated plantation.

Z 37: Plant found on a seed-propagated plantation and multiplied by Amistrong Luciano Zanottiinn his property located in Patrimônio do XV, Nova Venécia-ES.

Conclusion

Based on the great genetic diversity and chemical characteristics of the grains, it was possible to obtain the registration of the first Conilon coffee cultivar focused on materials with high contents of soluble solids and chlorogenic acids in the grain, with satisfactory yield levels, called Salutar.

Clone maintenance and distribution

Cultivar Salutar was registered in 2021 by the National Registry of Cultivars (RNC, no. 45722) of the Brazilian Ministry of Agriculture, Livestock and Food Supply. The Federal University of Espírito Santo (UFES) is in charge of maintaining the five genotypes that constitute cv. Salutar.

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