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Characterization of Yellow Bourbon coffee strains for the production of differentiated specialty coffees

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ABSTRACT: The demand for specialty coffees in the national and international market grows and generates an excellent opportunity for the exploration of new business. The cup quality of coffee is defined by the genetic predisposition of varietal groups, effects of the production environment, crop management, and form of post-harvest processing. Genotypes of Yellow Bourbon have already shown a predisposition to the production of excellent cup quality, but it may differ in sensory attributes and cup quality. The aim of this article was to evaluate the agronomic and qualitative performance of Yellow Bourbon strains from the Active Germplasm Bank of the Agronomic Institute of Campinas, in order to identify the best genotypes for the production of specialty coffees. The experiment was conducted in São Sebastião da Grama, SP, Brazil, at 1,100 meters of altitude in a medium-textured Ultisol. Treatments consisted of 14 strains of Yellow Bourbon, arranged in a randomized block design with three replicates. Field, post-harvest and laboratory evaluations were carried out. The strains IAC J3-1, IAC J9-16 and IAC J19-18-10 stood out in terms of yield values and sensory quality above the average of the studied group. The strains IAC J9-16 and IAC J19-18-10 showed predominance of floral and honey nuances, respectively, indicating that they may have high potential to express these characteristics in the beverage. The results suggested that there are Yellow Bourbon strains suitable for production and with superior cup quality, which highlights the importance of the appropriate choice of genotypes for the production of differentiated specialty coffees.
Key words: *Coffea arabica* L., genotypes, lineages, yield, beverage sensory profile.

INTRODUCTION

Due to the growth of the specialty coffee segment in Brazil, there has been an increase in demand by producers for differentiated coffee varieties that meet the requirements of this market. Currently, coffee growers from various production regions are in search of ancient varieties and non-traditional varieties, such as Maragogipe and Laurina, or imported varieties such as Geisha, Rume Sudan and Pacamara. These varieties are recognized internationally for having differentiated sensory profile in the cup, often acquiring the status of exotic coffee due to the great differentiation of their sensory profile (Fazuoli et al. 2007, Malta et al. 2020).

Although foreign varieties are cultivated in Brazil, it is important to highlight that Brazilian legislation considers any coffee propagative material as a regulated article, with specific standards for importing cultivars (Brasil 2016, 2017). Thus, it can be inferred that the use of imported material without proper authorization from the Ministry of Agriculture, and especially without regulatory quarantine, can compromise the sustainability of Brazilian coffee production given the risk of introducing pests and/or diseases not yet existing in the country.

In this context, it is fundamental to intensify national scientific and technological research for identifying coffee varieties with desirable characteristics to meet the growing demand of the production sector for differentiated specialty coffees in Brazil. Figueiredo et al. (2013) demonstrated the potential of strains of the Yellow Bourbon group to produce beverages with excellent sensory characteristics. The factors with the greatest impact for the recommendation of new coffees are related to agronomic characteristics, such as yield, vegetative vigor, and seed characteristics. In view of the need to increase the production of specialty coffees in Brazil, there is an opportunity for exploring the Yellow Bourbon strains from the Active Germplasm Bank of the Agronomic Institute of Campinas (IAC). This is main for investigate whether, when quality is prioritized, there is the possibility of recommendations of the existing strains for commercial use.

Yellow Bourbon is native to Brazil and was found in the middle of crops in São Paulo. The characteristics that led it to stand out from the other coffee strains of the time were the notoriously higher yield and a lower biennial effect in comparison to the other ones from the same period. Thirty plants, considered as 30 strains of Yellow Bourbon, were studied and selected, and then seven were registered by IAC (Carvalho et al. 1957, MAPA 2021). Yellow Bourbon coffee is highly susceptible to rust and nematodes with tall plants, yellow fruits, and early maturity. The average expected yield is 25 bags per hectare, the plants are considered of low vigor, and cultivation is recommended for regions with more than 1,000 meters of altitude (Fazuoli et al. 2007, Consórcio Pesquisa Café 2011).

Coffee cup quality and yield are two factors that interfere with the profit obtained by producers, because the price paid for coffee is directly affected by the quality of the beverage. In this context, studies that evaluate the production of specialty coffee, that is, with high quality of beverage, associated with high yields, are necessary to support the recommendation of cultivars more appropriate for each cultivation situation.

Therefore, the hypothesis was that there are differences in the agronomic characteristics and in the cup quality of Yellow Bourbon strains. The aim of this article was to evaluate the agronomic and qualitative performance of Yellow Bourbon strains from the Active Germplasm Bank of the IAC, trying to identify the genotypes that stand out in terms of grain yield and specialty coffees production.

MATERIAL AND METHODS

The experiment was installed in January 2016 at Recreio Estate Coffee Farm in São Sebastião da Grama, São Paulo state, Brazil. The experimental area is located at 1,100 meters of altitude, close to the geographical coordinates 21º41’54.26”S and 46º41’41.56”W. According to Köppen’s classification, the climate of the region is Cwb, tropical of altitude, with average temperature of 19.5°C and average annual rainfall of 1,510 mm. The soil is a medium-textured Ultisol, and its chemical attributes prior to planting in the 0.00-0.20 m layer were:

- pH ($CaCl_2$): 5.4;
- Organic matter content: 24 g·dm^{-3};
- P (resin): 21 mg·dm^{-3};
- K: 6.6 mmolc·dm·;
- Ca: 62 mmolc·dm^{-3};
- Mg: 18 mmolc·dm^{-3};
- H+Al: 29 mmolc·dm^{-3};
- Sum of bases: 86.6 mmolc·dm^{-3};
- Cation exchange capacity: 115.6 mmolc.dm^{-3};
- Base saturation: 75%.

The average climatic conditions of monthly temperatures and precipitations of the last 30 years are described in Fig. 1. The design used was randomized blocks with three replicates, and the treatments consisted of 14 Yellow Bourbon strains selected by the IAC, as described in Table 1; genotype 5 was considered a reference for yield, for being a registered cultivar. The experimental plots consisted of 32-m-long coffee rows, containing 40 plants spaced at 0.8 m between plants and 3.5 m between rows, and the 15 central plants were considered as useful area.

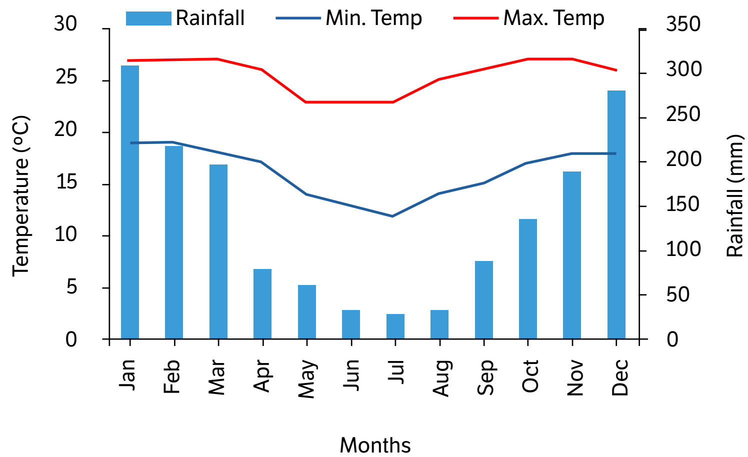

Figure 1. Average data of a 30-year series of maximum and minimum temperatures and accumulated monthly rainfall of the municipality of São Sebastião da Grama, SP, Brazil.

Source: Clima Tempo (2021).

Table 1. 14 Yellow Bourbon strains from the Germplasm Bank of the Agronomic Institute of Campinas used in the experiment located in the municipality of São Sebastião da Grama, SP, Brazil.

Strains	Genotypes	Strains	Genotypes
1	B.A. IAC J3-1	8	B.A. IAC J26-8
2	B.A. IAC J4-10	9	B.A. IAC J19-18-10
3	B.A. IAC J6-9	10	B.A. IAC J20-17
4	B.A. IAC J8-2	11	B.A. IAC J24-6
5	B.A. IAC J9-16	12	B.A. IAC J26-6
6	B.A. IAC J14-20	13	B.A. IAC J28-8
7	B.A. IAC J15-16-5	14	B.A. IAC J30-20

Soil tillage for planting included the correction of acidity with the application of 4 t·ha^{-1} of dolomitic limestone and 491 kg·ha^{-1} of P_2O_5, followed by 60 kg·ha^{-1} of N and 60 kg·ha^{-1} of K_2O in 2016; 228 kg·ha^{-1} of N and 120 kg·ha^{-1} of K2O in 2017; 120 kg·ha^{-1} of N and 180 kg·ha^{-1} of K_2O, 1.5 kg·ha^{-1} of S, 3 kg·ha^{-1} of B and 6 kg.ha^{-1} of Zn in 2018; 400 kg·ha^{-1} of N, 50 kg·ha^{-1} of P_2O_5 and 200 kg·ha^{-1} of K_2O, 0.45 kg·ha^{-1} of S, 0.9 kg·ha^{-1} of B and 1.8 kg·ha^{-1} of Zn in 2019.

In the pre-harvest stage, in 2019, the following morphological attributes were evaluated in three random plants out of the 15 of the useful area of each plot:

- Plant height (cm), measured from the soil level to the apical meristem;
- Height of the first pair of plagiotropic branches (cm), measured from the soil level to the first pair of branches;
- Stem diameter (mm), measured with a digital caliper 10 cm from the soil surface;
- Canopy diameter (cm), measured transversely in the middle third of the plants with a wooden ruler;
- Number of nodes on the orthotropic branch;
- Number of pairs of productive branches, considering the plagiotropic branches that produced coffee in the agricultural season;
- Plagiotropic branch length (cm), measured in a pair of branches in the middle third per plant;
- Number of productive nodes on the plagiotropic branch, using the same branches analyzed for length.

Sprout color and vegetative vigor were recorded at the time of field evaluation to contribute to the characterization of each strain. To determine vegetative vigor, scores from 1 to 10 were assigned to each experimental plot, according to the vegetative performance of the plants, being 1 to little vigorous strains and 10 to those with excellent performance (Nogueira et al. 2005). The average of the treatments was calculated, and it was proposed a classification to the vigor, which was considered low for values up to 4, medium for values from 4.01 to 7, and high for values between 7.01 and 10.

Harvest was carried out in May 2019, manually and by strip-picking the fruits on appropriate cloth, after cleaning the ground around the plants. The volume and total mass of harvested fruits were quantified, and then the fruits were subjected to post-harvest processing by the natural coffee method, with hydraulic separation of fruits and manual picking of unripe fruits in the fraction of higher density. Ripe fruits were dried in the sun in a suspended terrace for 30 days, until they reached the water content of 12% (w.b.).

From each experimental plot, 1 L of fruits was separated to constitute the working sample to quantify the percentages of green, ripe, and dry fruits. The over-ripe fruits were considered as dry fruits. These samples were dried as previously mentioned and, after processing, were used to obtain the technical coefficients to calculate grain yield. To estimate coffee grain yield, the entire useful plot was harvested, and the 1-L sample was used to calculate the fruits ripeness degree and the benefit yield, as performed by Morello et al. (2020).

After reaching 12% of water content, the coffee samples were weighed, processed, and weighed again. The relationship between dried coffee mass of the 1-L sample and raw coffee mass was used to establish the processing yield (%). Subsequently, the yield of each plot was estimated in bags of 60 $kg{\cdot}ha^{-1}$, based on the mass of harvested fruits, mass of processed grains and on the plant stand (3,571 $plants{\cdot}ha^{-1}$).

Laboratory evaluations were performed using 300-g samples of raw grains from ripe fruits, which were dried separately. Grains were classified according to size and shape, by passing 100 grams of the sample in a set of 10 sieves, seven sieves of round hole to retain flat grains (sieves 18, 17, 16, 15, 14, 13 and 12) and three of oblong holes to retain peaberry grains (sieves 12, 11 and 10). To determine the 100-grain weight, we used only flat grains retained in sieves above 16. For this determination, four subsamples of 100 grains were used in each plot, calculating the 100-grain weight average.

Sensory analysis was performed according to the methodology proposed by Lingle (2011) and recommended by Specialty Coffee Association of America, in which individual scores from 6 to 10 are assigned for each of the following attributes: fragrance/aroma, flavor, acidity, body, finish, balance, and overall impression. For uniformity, absence of defects, and sweetness, two points were attributed for each cup. This assessment was carried out by three Q-graders. Grain roasting was moderately mild, with color corresponding to a 58 score on the Agtron scale for the whole grain and a 63 score for the ground grain. The final scores of each plot were constituted by the sum of the average scores of all attributes.

To identify the strains with specific characteristics for yield and cup quality, a figure was plotted relating the values of yield (x-axis) and coffee beverage scores (y-axis). The intersection between the axes was the average values of yield and beverage scores of the 14 strains. The strains with above-average yields were located in the two quadrants above the x-axis, while the strains with above-average cup quality were located in the two quadrants on the right side of the y-axis. Thus, the strains with above-average beverage quality and yield were located in the quadrant to the right of y and above x.

The obtained data were subjected to statistical analysis in AgroEstat® software (Barbosa and Maldonado Júnior 2009). Analysis of variance (ANOVA) was performed using the F-test ($p < 0.05$), and, when significant, the means of the treatments were grouped by the Scott-Knott test ($p < 0.05$).

Due to the dependence structure of the variables analyzed, multivariate principal component analysis (Hair Júnior 2009) was applied in order to plot the distribution of variables and strains of Arabica coffee, Yellow Bourbon, in two dimensions, and group the variables into new latent variables (principal components). This analysis was performed with the objective of identifying the strains that differed from the other ones for the morphological and production attributes of coffee, except for yield and cup quality. The analysis was performed using the mean of the replicates of each variable for each strain. The variables used in this analysis were plagiotropic branch length (PBL), canopy diameter (CaD), number of productive nodes on the branches (NPN), number of productive branches (NPB), stem diameter (StD), number of nodes on the orthotropic branch (NNOB), plant height (PH), processing yield (PY), above sieve 16 (16, 17 and 18), first node height (FNH) and 100-grain weight (100GW). Prior to the analysis, all variables were standardized, generating 0 mean and unit variance. The number of principal components was chosen according to the Kaiser criterion, using those with eigenvalues above 1 (Kaiser 1958). The eigenvalues were extracted from the covariance matrix of the original variables. Variables with scores higher than 0.600 were considered relevant for the explanation within each principal component.

To identify strains with specific characteristics, ellipses encompassing the values of the X and Y axes ranging from -1.96 to 1.96 were plotted. These values refer to the Z value of the normal distribution, in which values lower than -1.96 and higher than 1.96 indicate points with specific characteristics at 5% of significance level. For the ellipse elaboration, the normal distributions on the X and Y axes were plotted, in which the Z value of -1.96 and 1.96 coinciding with the same values of the axes of the biplot graph. Thus, it was possible to identify the strains with specific characteristics for each principal component, as performed by Bertasello et al. (2020). Multivariate statistical analyses were performed in Statistica® software, version 7.0.

RESULTS AND DISCUSSION

The morphological attributes of the 14 strains of Yellow Bourbon did not show significant mean differences from one another (Table 2). In commercial cultivars of Arabica coffee, Carvalho et al. (2010) and Morello et al. (2020) verified differences in the morphological attributes, which occurred possibly due to genetic expression in the environment due to the use of cultivars with lower genetic proximity, which possibly results in greater variability between them. In this study, the similarity of morphological development among the evaluated genotypes may have occurred due to the close genetic relationship between the Yellow Bourbon strains, since it is a single varietal group.

Table 2. Mean values of plant height (PH), height of the first pair of plagiotropic branches (FNH), stem diameter (StD), canopy diameter (CaD), number of nodes on the orthotropic branch (NNOB), number of pairs of plagiotropic branches that produced coffee in the season (NPB), plagiotropic branch length (PBL), and number of productive nodes on the plagiotropic branches (NPN) in different strains of Yellow Bourbon coffee in São Sebastião da Grama, SP, Brazil, 2019.

Strains	PH (cm)	FNH (cm)	StD (cm)	CaD (cm)	NNOB (n)	NPB (n)	PBL (cm)	NPN (n)
1	162.22	25.56	4.49	170.56	32.67	19.44	83.33	12.28
2	150.56	26.67	4.13	176.11	30.67	18.44	87.50	11.17
3	167.22	28.33	4.42	161.67	33.22	19.56	80.83	12.44
4	168.33	32.78	4.01	153.89	32.78	19.11	77.22	11.67
5	163.89	28.89	4.09	155.56	33.56	19.78	75.28	12.11
6	161.67	27.22	4.41	163.89	32.22	19.33	81.11	10.61
7	170.00	28.89	4.32	162.78	33.78	18.11	76.11	10.72
8	158.33	30.00	4.12	162.22	30.78	17.67	75.28	10.00
9	165.00	30.56	3.97	150.56	27.78	15.67	74.72	10.61
10	173.89	31.67	4.41	158.33	34.00	18.22	80.56	10.44
11	157.50	25.83	4.08	156.67	31.67	17.00	75.00	9.25
12	171.11	28.89	4.48	158.89	34.00	18.67	72.22	9.22
13	162.22	31.67	4.04	153.33	31.56	17.67	74.17	10.50
14	165.55	27.77	4.08	159.44	34.22	19.00	71.67	11.33
F value	1.51ns	1.97ns	1.12ns	1.57ns	1.86ns	0.96ns	1.94ns	1.01ns
CV (%)	5.24	9.5	7.41	5.89	6.96	10.9	7.26	16.11
Overall mean	164.11	28.91	4.22	160.27	32.35	18.40	77.50	10.88

CV: coefficient of variation; ns: not significant.

For the agronomic characterization of the strains in the experiment, the sprout colors were recorded. Nine strains, 1, 2, 3, 4, 5, 7, 9, 10 and 13, showed a green color for new sprouts and five other strains, 6, 8, 11, 12 and 14, showed bronze color for this characteristic (Table 3). Under the local conditions of this experiment, prior to the first harvest, strains 4, 9 and 13 showed medium vegetative vigor, while the other ones showed high vegetative vigor.

Table 3. Sprout color and medium vegetative vigor in Yellow Bourbon coffee strains in São Sebastião da Grama, SP, Brazil, 2019.

Strains	Sprout color	Vegetative vigor	Vegetative vigor	Strains	Sprout color	Vegetative vigor	Vegetative vigor
1	Green	7.67	High	8	Bronze	7.44	High
2	Green	8.56	High	9	Green	7	High
3	Green	7.11	High	10	Green	7.78	High
4	Green	6.78	Medium	11	Bronze	6.83	Medium
5	Green	7.11	High	12	Bronze	7.89	High
6	Bronze	8.22	High	13	Green	6.89	Medium
7	Green	7.33	High	14	Bronze	7.44	High

The 100-grain weight and the processing yield (Table 4) showed significant differences, separating the strains into two groups: strains 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14, with mass ranging from 13.68 to 14.59 grams, whose values were higher than those of strains 2 and 3. All strains had 100GW above the average described for Yellow Bourbon, which was 11.85 g (Fazuoli et al. 2007). For the processing yield, it was observed that strains 2 and 14 showed values of 47.11 and 49.77%, respectively, lower than the values of the other ones, which were between 51.59 and 54.88%. These values were within the yield range from 45 to 55% cited by Krug et al. (1965) as adequate for Arabica coffee.

Table 4. Mean values of 100-grain weight (100GW), processing yield (PY), yield (Y) and relative yield (RY) in strains of Yellow Bourbon coffee in São Sebastião da Grama, SP, Brazil, 2019#.

Strains	100GW (g)	PY (%)	Y (bg·ha^{-1})	RY (%)
1	13.84 a	51.72 a	41.26 a	130.74
2	12.90 b	47.11 b	26.82 b	84.98
3	13.40 b	53.66 a	21.52 b	68.19
4	13.74 a	54.88 a	43.09 a	136.53
5	13.89 a	51.79 a	31.56 a	100.00
6	13.85 a	52.07 a	26.95 b	85.39
7	13.68 a	53.60 a	24.57 b	77.85
8	14.59 a	51.59 a	31.75 a	100.60
9	14.18 a	52.68 a	33.39 a	105.80
10	14.12 a	51.72 a	21.82 b	69.14
11	13.80 a	53.81 a	25.86 b	81.94
12	14.10 a	53.17 a	24.78 b	78.52
13	14.11 a	53.32 a	24.79 b	78.55
14	14.08 a	49.77 b	22.98 b	72.81
F value	4.48**	3.10**	2.21*	-
CV (%)	2.35	3.66	27.61	-
Overall mean	13.88	52.21	28.65	-

#Means followed by the same letter in the column do not differ from each other by the Scott-Knott test ($p \geq 0.05$); *$p < 0.05$; **$p < 0.01$; ns: not significant.

The strains with highest yields were 1, 4, 5, 8 and 9, ranging from 31.56 to 43.09 bg·ha^{-1} (Table 4). These values were higher than those found by Ferreira et al. (2013) for Yellow and Red Bourbon in Campos Altos (MG), Lavras (MG) and Três Pontas (MG), Brazilian cities that are above 900 meters of altitude, where the highest average yields were 34.87, 32.81 and 26.51 bg·ha^{-1}, respectively. The results were also higher than the values observed by Rodrigues et al. (2012) for Red Bourbon CJ10, 26.91 bg·ha^{-1}. It is worth noticing that these five strains showed yield averages higher than the Brazilian national average in 2019, which was 27.92 bg·ha^{-1} (CONAB, 2020). The difference in yield between the two groups separated by the means comparison test was 48%, demonstrating the importance of the correct choice of cultivars and strains for commercial cultivation. It is emphasized that, unless there is a qualitative differential that allows greater value addition to coffee, the use of less productive cultivars may not be feasible.

When comparing the yield of the first season of these strains with the yield of strain 5 (Yellow Bourbon J9), which is the reference commercial cultivar or control, the genotypes could be grouped into two groups. Strains 1, 4, 8 and 9 were more productive than the reference and, along with strain 5, they are the genotypes that statistically showed higher yield (Table 4).

The strains presented a significantly different maturation behavior and can be separated into two distinct maturation groups (Table 5). Group 1, with early maturation, considering the high percentage of dry fruits, covers strains 3 with 93.33%, 10 with 84.17%, 13 with 81.67%, 12 with 80%, 7 with 76.67%, 8 with 71.67% and 5 with 70% of dry fruits. Group 2, with average maturation, considering a high percentage of ripe fruits, covering strains 1 with 46.67% ripe and 16.67% green, 14 with 40% ripe and 10.83% green, 6 with 35% ripe and 11.67% green, 4 with 34.17% ripe and 15% green, 9 with 31.67% ripe and 11.67% green, and 11 with 30% ripe and 10% green and 2 with 30% ripe and 43.33% green. It is worth pointing out that, when considering the percentage of green fruits, strain 2, with 43.33% of green fruits, was the only one with a significantly higher amount compared to the other ones, which indicates that this strain was later than the other ones.

Table 5. Percentage of fruit maturation in Yellow Bourbon strains at harvest in São Sebastião da Grama, SP, Brazil, 2019#.

Strains	Green (%)	Ripe (%)	Over-ripe/Dry (%)
1	16.67 b	46.67 a	36.67 b
2	43.33 a	30.00 a	26.67 b
3	3.33 b	3.33 b	93.33 a
4	15.00 b	34.17 a	50.83 b
5	6.66 b	23.33 b	70.00 a
6	11.67 b	35.00 a	53.33 b
7	5.83 b	17.50 b	76.67 a
8	8.33 b	20.00 b	71.67 a
9	11.67 b	31.67 a	56.67 b
10	2.50 b	13.33 b	84.17 a
11	10.00 b	30.00 a	60.00 b
12	2.00 b	18.00 b	80.00 a
13	6.67 b	11.67 b	81.67 a
14	10.83 b	40.00 a	49.17 b
F value	4.32**	2.26*	4.04**
CV (%)	77.76	54.84	26.02
Overall mean	11.03	25.33	63.63

#Means followed by the same letter in the column do not differ from each other by the Scott-Knott test ($p \geq 0.05$); *$p < 0.05$; **$p < 0.01$; ns: not significant.

For the large grains, the strains were divided into two groups, and the group with the highest percentage of retention on sieve 17 or greater comprised ten strains, namely 4, 5, 7, 8, 9, 10, 11, 12, 13 and 14, with values between 59.99 and 66.69% (Table 6). It was observed that the same strains showed high values of grain retention on sieves above 16, being higher than those obtained by Ferreira et al. (2013), reaching up to 91.53% for strain 9. Only strain 2, which had 79.22% retention of grains on sieves above 16, obtained a value lower than those of Ferreira et al. (2013), which is a relevant information and with possible effect on the value addition to the product, since larger grains have higher value in the market.

Table 6. Mean values of retention of large flat grains (above sieve 17), medium flat grains (sieves 15 and 16), small flat grains (sieves 12, 13, and 14), peaberry grains (sieves 10, 11 and 12) and above-sieve-16 grains (above 16), in different strains of Yellow Bourbon coffee in São Sebastião da Grama, SP, Brazil, 2019#.

Strains	Large (%)	Medium (%)	Small (%)	Peaberry (%)	Above 16 (%)
1	52.95 b	37.85 a	3.34	5.86 c	85.03 b
2	44.87 b	42.76 a	5.26	7.12 c	79.22 b
3	54.23 b	33.33 a	3.02	9.41 b	86.17 b
4	61.59 a	29.36 b	2.38	6.66 c	89.52 a
5	64.22 a	27.79 b	1.59	6.40 c	90.25 a
6	53.23 b	35.92 a	4.08	6.77 c	84.62 b
7	60.22 a	30.28 b	2.67	6.83 c	88.61 a
8	60.51 a	28.33 b	2.79	8.37 c	89.69 a
9	66.69 a	23.42 b	1.96	7.92 c	91.53 a
10	64.47 a	23.37 b	1.92	10.24 b	90.58 a
11	62.52 a	21.57 b	2.77	13.14 a	89.65 a
12	64.63 a	23.13 b	2.31	9.93 b	91.23 a
13	65.16 a	22.48 b	2.16	10.20 b	90.44 a
14	59.99 a	26.59 b	3.53	9.89 b	87.69 a
F value	2.76*	4.63**	1.64ns	7.80**	2.40*
CV (%)	10.79	17.85	46.37	15.04	4.29
Overall mean	59.66	29.01	2.84	8.48	88.16

#Means followed by the same letter in the column do not differ from each other by the Scott-Knott test ($p \geq 0.05$); *$p < 0.05$; **$p < 0.01$; ns: not significant.

The results obtained in the sensory analyses (Table 7) indicate that all Yellow Bourbon strains studied scored above 80 on the Specialty Coffee Association scale, suggesting that all produced specialty coffees. Among the 14 strains, 12 had an average sensory score above 85, which classifies these coffees as of excellent cup quality, compatible with the soft beverage classification mentioned in the Brazilian Official Classification (Brasil 2003). Strains 9 and 12, with scores of 90.58 and 90.50, respectively, fall as coffees of exceptional quality or coffees of strictly soft beverage, being differentiated specialty coffees and very rare to be found in Brazil. It is also observed that some sensory perceptions of flavors and aromas, with nuances of uvaia in strain 1, tutti-frutti in strains 3, 9 and 13, red fruits in strains 6 and 9 and lemon balm in strain 12 are very desired and considered exotic nuances for the Brazilian coffee beverage, which confirms the high potential of Yellow Bourbon to produce excellent quality coffees in the studied region.

The average sensory score of the experiment, of 87.09 SCA score (Table 7), is very high for Brazilian coffee standards, being even higher than the maximum score of 85.67 cited by Carvalho et al. (2016) when they evaluated the commercial strain LCJ10 of Yellow Bourbon in the municipalities of Lavras and Patrocínio (MG), indicating that in fact there may be Yellow Bourbon genotypes that are superior for cup quality and more suitable for the production of specialty coffees in the studied environment. These data corroborate those reported by Borém et al. (2020), who found scores above 85, when studying the qualitative performance of several coffee cultivars, in environments above 1,050 meters of altitude.

It can be noted that there was a greater repeatability of sensory characteristics for some strains of Yellow Bourbon (Table 8), indicating a probable stronger genetic expression for these characteristics in the studied environment. Sensory notes with nuances of fruits, honey, flowers and caramel were predominant throughout the experiment. Strains 9, 12 and 13 stood out for the honey nuance, 5 and 12 for the floral nuance, 6 for the fruity nuance and 4 by the caramel nuance in all replicates.

Figure 2 shows the dispersion of the mean values of yield and sensory quality of the 14 Yellow Bourbon strains. The part of the graph that represents the best associated characteristics is the upper quadrant of the right side, because it expresses the strains that are above the average of the experiment for yield (28.65 bg-1) and sensory quality (87.09 score), comprising strains 1, 5 and 9. It is also emphasized that strains 5 and 9 had floral and honey nuances in the three blocks evaluated, respectively.

Table 7. Evaluation score and description of the sensory profile of Yellow Bourbon strains from the 2019 season, cultivated in the municipality of São Sebastião da Grama, SP, Brazil, 2019#.

Strains	Score	Sensory description
1	88.50 a	floral, caramel, fruity, honey, citric, uvaia
2	84.83 b	fruity, floral, dried banana, chocolate
3	85.92 b	caramel, vanilla, tutti-frutti, berries, honey, citric, floral
4	85.58 b	caramel, citric, floral, honey, fruity, herbaceous
5	87.92 a	fruity, vanilla, floral, citric, berries, honey, caramel
6	88.33 a	fruity, vanilla, molasses, herbal, floral, chocolate, red fruits, honey, citric
7	87.92 a	fruity, honey, floral, chocolate, caramel, citric, jasmine, vanilla
8	84.25 b	caramel, fruity, herbal, chocolate
9	90.58 a	honey, red fruits, vanilla, tutti-frutti, citric, dried fruits, lemon balm, fruity, floral
10	85.67 b	caramel, fruity, honey, floral, herbaceous, vanilla, chocolate
11	85.00 b	fruity, honey, caramel, vanilla, chocolate, citric, herbal
12	90.50 a	lemon balm, fruity, floral, honey, vanilla, caramel, citric, fruit compote, jataí bee honey
13	88.08 a	fruity, caramel, honey, tutti-frutti, floral
14	86.17 b	fruity, vanilla, dried fruits, honey, caramel, floral
F value	2.20*	
CV (%)	2.73	
Overall mean	87.09	

#Means followed by the same letter in the column do not differ from each other by the Scott-Knott test ($p \geq 0.05$); *$p < 0.05$; **$p < 0.01$; ns: not significant.

Table 8. Compilation of adjectives that were used in all replicates of the same coffee strain to characterize the sensory profile.

Adjectives	Strains
Fruity	6
Honey	9, 12, 13
Floral	5, 12
Caramel	4

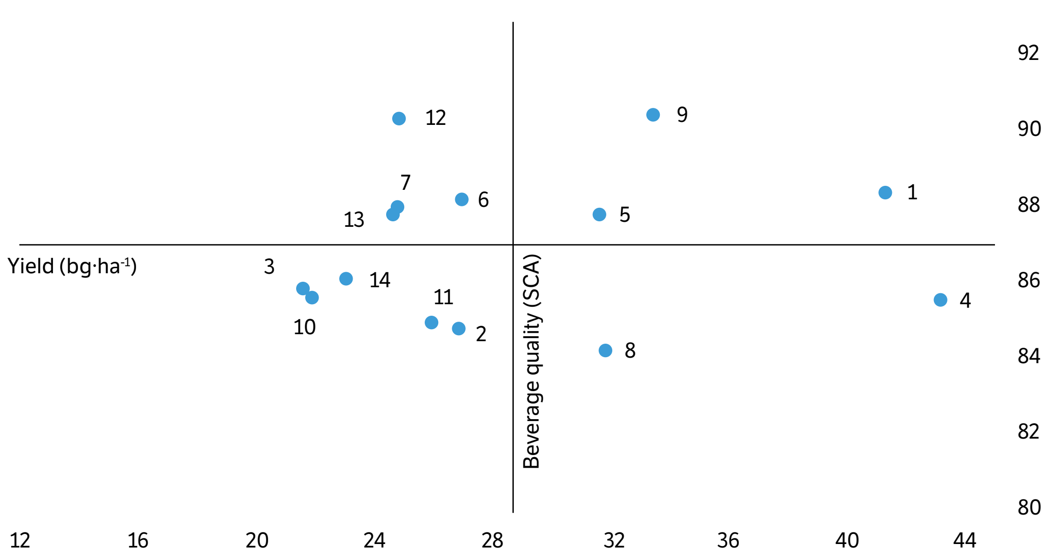

Figure 2. Scatter plot of average values of yield in bags·ha^{-1} and SCA score of 14 strains of Yellow Bourbon.

It is necessary to highlight that these are the results of the first year of harvest and evaluation; continuing the collection in the following years is essential to validate the results. The strains that are arranged on the side of the graph that indicates values lower than the average for yield or quality still have sensory profile characteristics that can be attractive in market niches. In the specialty coffee market, the aroma of the beverage contributes up to 24.5% to price determination. Characteristics such as acidity, bitterness and astringency contribute significantly to the determination of the price of specialty coffee, the latter two with negative contribution. The combination of multiple positive characteristics such as coffee flavor, aroma and body are more relevant to coffee beverage value addition than an isolated factor (Kim and Jung 2016).

Two principal components (PCs) were relevant to the explanation of the variability of the strains as a function of the attributes of coffee growth and yield. Together, the PCs explained 67.33% of the data variability, 43.80% for PC1 and 23.53% for PC2. The relevant variables within PC1, that is, those with eigenvalues above 0.600, were FNH, CaD, PBL, 100GW, PY and sieve 16 (Table 9). The variables CaD and PBL had positive factor loadings, while the others had negative loadings. This indicates that CaD and PBL are directly correlated with each other and inversely correlated with the other variables. Thus, the higher the CaD and PBL, the lower the FNH, 100GW, PY and sieve 16 of the coffee and vice versa. Within PC2, the relevant variables were PH, StD, NNOB and NPB. All these variables had negative factor loadings, that is, they are directly correlated with each other. It is worth pointing out that the PCs are independent, that is, the existence of one does not interfere in the other.

Table 9. Factor loadings of variables within each principal component with eigenvalue above 1.

Variables	PC1	PC2
FNH	-0.674	-0.073
CaD	0.923	0.000
PBL	0.839	0.043
100GW	-0.757	0.015
PY	-0.657	-0.324
Above sieve 16	-0.966	-0.134
PH	-0.535	-0.741
StD	0.358	-0.686
NNOB	0.079	-0.901
NPB	0.498	-0.720
NPN	0.449	-0.304

PC: principal component; FNH; first node height; CaD: canopy diameter; PBL: plagiotropic branch length; 100GW: 100-grain weight; PY: processing yield; PH: plant height; StD: stem diameter; NNOB: number of nodes on the orthotropic branch; NPB: number of productive branches; NPN: number of productive nodes on the branches.

Even though there were no differences in the analysis of variance between the Yellow Bourbon strains for the morphological attributes of coffee (Table 2), it was possible to identify, through the multivariate principal component analysis, the above-average strains for each attribute. By analyzing the biplot between PC1 and PC2, it was possible to identify genetic divergences between the Yellow Bourbon Arabica coffee strains (Fig. 3). The strains with specific characteristics for PC1, that is, those located outside the ellipse, were 1, 2, 9 and 13. Strains 1 and 2 showed the highest values of PBL and CaD, while 9 and 13 had the highest values of 100GW, sieve 16, FNH and PY. In PC2, the strains with specific characteristics were 3 and 12, showing the highest values of PH, NNOB, StD and NPB. In this context, these results can be used in breeding programs when searching for above-average materials for any of these attributes.

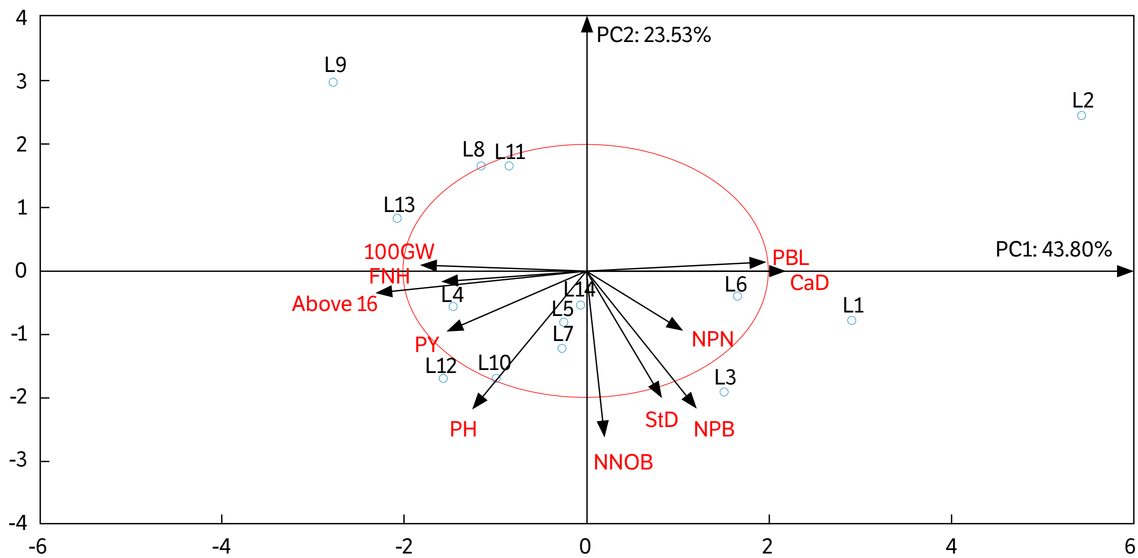

Figure 3. Principal components biplot graph to evaluate dispersion of growth and yield variables and coffee strains (Coffea arabica L.) cv. Bourbon.

PC: principal component; PBL: plagiotropic branch length; CaD: canopy diameter; NPN: number of productive nodes on the branches; NPB: number of productive branches; StD: stem diameter; NNOB: number of nodes on the orthotropic branch; PH: plant height; PY: processing yield; Above 16: above sieve 16; FNH: first node height; 100GW: 100-grain weight.

CONCLUSION

The strains of Yellow Bourbon coffee did not show significant different responses for the morphological evaluations. Furthermore, there were statistical differences in the other agronomic and qualitative analyses in the studied environment. The strains IAC J3-1, IAC J9-16 and IAC J19-18 stood out when the results of yield and physical and sensory quality of grains were combined. The strains IAC J9-16 and IAC J19-18 showed sensory profile repeatability, with floral and honey notes, respectively, which may be an indicator of the genetic expression of Yellow Bourbon for the production of specialty coffees with differentiated cup quality.

The results observed here, especially regarding yield, are preliminary, since coffee is a perennial crop with a biennial production, and high variability may be seen in the next years. However, the results demonstrated that there are genotypes with higher yield and with specific beverage characteristics, associating high yields with excellent cup quality.

AUTHORS' CONTRIBUTION

Conceptualization: Romano, L. S., Giomo, G. S. and Lemos, L. B.; **Methodology:** Romano, L. S., Giomo, G. S. and Lemos, L. B.; **Investigation:** Romano, L. S., Giomo, G. S., Coelho, A. P. and Lemos, L. B.; **Writing – Original Draft:** Romano, L. S., Coelho, A. P. and Filla, V. A.; **Writing – Review and Editing:** Giomo, G. S. and Lemos, L. B.; **Funding Acquisition:** Romano, L. S. and Giomo, G. S.; **Resources:** Giomo, G. S. and Lemos, L. B.; **Supervision:** Giomo, G. S. and Lemos, L. B.

DATA AVAILABILITY STATEMENT

All dataset were generated and analyzed in the current study.

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