Australian Journal of Crop Science AJCS
AJCS 9(4):289-295 (2015) ISSN:1835-2707

Potential of Híbrido de Timor germplasm and its derived progenies for coffee quality improvement

Fabrício Moreira Sobreira*[1], Antonio Carlos Baião de Oliveira[2], Antonio Alves Pereira[2], Ney Sussumu Sakyiama[3]

[1]Instituto Capixaba de Pesquisa Assistência Técnica e Extensão Rural (INCAPER), BR 262 km 94, 29375-000, Venda Nova do Imigrante, ES, Brazil
[2]Embrapa Café/ Empresa de Pesquisa Agropecuária de Minas Gerais (EPAMIG), Vila Gianeti 46, 36570-000, Viçosa, MG, Brazil
[3]Departamento de Fitotecnia, Universidade Federal de Viçosa (UFV), 36570-000, Viçosa, MG, Brazil

***Corresponding author: fabricio.sobreira@incaper.es.gov.br**

Abstract

This work evaluated the Híbrido de Timor germplasm and the potential of its derived progenies as genetic resources to improve coffee quality, with focus on the specialty coffee market. Thirty eight *Coffea arabica* genotypes, comprising Híbrido de Timor genotypes, their progenies and traditional cultivars were studied. The study was conducted in a non-replicated design with intercalated checks where coffee cherry fruits were selectively handpicked and washed. Bean quality (shape and size) was assessed by a set of coffee test screens, while the sensory quality was measured using the attributes of the Specialty Coffee Association of America (SCAA) Cupping Protocols. Simple correlations and principal component analyses (PCA) were applied to analyze the data. There was high correlation for most of the sensory attributes, mainly between flavor and the final score (0.96). Regarding bean quality variables, the bean sieve sizes 19 and 18 correlated positively with the average sieve size (0.84 to 0.93) and negatively with the peaberry sieve (-0.55 to -0.69). The two first principal components illustrated genetic diversity for beans and cup quality. Some Híbrido de Timor and Catimor accessions, including UFV 454-43 and UFV 390-52, respectively, presented greater quality and may meet the interests of coffee breeders. For these, tasters described special nuances related to chocolaty, caramelly, fruity and flowery tastes. The Híbrido de Timor germplasm and its derivatives show potential to be used in coffee breeding programs which seek quality for the specialty coffee market.

Keywords: Specialty coffee; bourbon; flavor; cup quality; genetic resources.
Abbreviations: ACI_ acidity; AFT_aftertaste; ARO_ aroma; ASS_ average sieve size; BAL_ balance; BOD_body; EPAMIG_ Empresa de Pesquisa Agropecuária de Minas Gerais; F19_ flat beans sieve 19/64ths of an inch; FLA_ flavor; FSC_ final score; HT_ Híbrido de Timor; OVE_ overall; P11_ peaberry beans sieve 11/64ths of an inch; PBE_ percentage of peaberry; PCA_ principal component multivariate analysis; UFV_ Universidade Federal de Viçosa.

Introduction

The term "Híbrido de Timor" (HT) was assigned to the coffee genotype from an interspecies outcrossing (*Coffea arabica* L. and *C. canephora* Pierre ex Froehner) found in a Typica cultivar plantation on the island of Timor in 1917 (Bettencourt 1973, Clarindo et al., 2013). These genotype descendants have been used in coffee breeding (Setotaw et al., 2013) for providing resistance to economically important diseases, such as leaf rust (*Hemileia vastatrix*) (Chaves 1976; Romero et al., 2014), Coffee Berry Disease (*Colletotrichum kahawae*) (Gichimu et al., 2014), root-knot nematode (*Meloidogyne exigua*) (Bertrand et al, 2008; Rezende et al., 2013) and bacterial blight (*Pseudomonas syringae*) (Ito et al, 2008; Hindorf and Omondi, 2011).However, because traditional *C. arabica* germplasm has low genetic diversity (Lashemers et al., 1999; Anthony et al., 2002; Zarate et al., 2010) and the HT germplasm has high genetic variability (Setotaw et al., 2010), the HT germplasm can also be an important source of genes for the improvement of other characters of interest, such as coffee quality (Bertrand et al., 2006; Leroy et al., 2006; Dessalegn et al., 2008; Van Der Vossen, 2009).Setotaw et al. (2010), using molecular markers, demonstrated high genetic diversity among Híbrido de Timor accessions. Nevertheless, little is known about their quality traits, limiting their potential use as a source of genes for coffee quality improvement. Although we are unaware of the contributions of HT accessions on coffee beverage quality, recent works have indicated that HT derived cultivars present similar (Bertrand et al., 2006; Van Der Vossen, 2009) or better cup quality (Kitzberger et al., 2011; Pereira et al., 2010) than the best traditional cultivars (Bourbon or Caturra). It was indicated that HT germplasm and its derived progenies could be important sources of variability for coffee quality improvement (Leroy et al., 2006; Dessalegn et al., 2008). Besides the sensory quality, there is an increasing worldwide demand for beans with better visual aspect, especially regarding their shape and size (Leroy et al. 2006). These beans have been sold green or roasted for use in espresso machines, reaching high market prices. The present study

sought to evaluate the potential of Híbrido de Timor germplasm and its derived progenies as genetic resources to improve coffee quality with focus on the specialty coffee market.

Results and Discussion

Correlation between coffee quality traits

Regarding bean quality, there was high phenotypic correlation between most traits (Table 1). For flat beans we observed a high positive correlation between F19 and F18 (0.73). In contrast, high negative correlation was observed from F18 to F16 (-0.80) and F15 (-0.78). Reflecting the relationship between the sizes of flat beans, there was a high positive correlation of Average Sieve Size with F19 (0.84) and F18 (0.93) and negative correlation with F16 (-0.90) and F15 (-0.88).This result indicates that the Average Sieve Size (ASS) can be an explanatory variable for the size of the flat beans. Similarly, the Peaberry variable (PBE) correlated positively with P11 (0.95), P10 (0.62) and P09 (0.44). Between the ASS and PBE variables there was a low negative correlation (-0.55), suggesting their use as a non-redundant component and structurally important variables to explain the genotype diversity for quality (Adams and Wiersma, 1978). Regarding cup quality, there were high positive correlations between the variables (Table 2), and the highest correlation was between the Final Score and Flavor (0.96). Because the score given for Flavor considers the intensity, quality and complexity of the combined taste and aroma (SCAA, 2014), its high correlation with the Final Score is justified. Similarly, the Overall attribute reflects the personal holistic perception of the taster for the integrated beverage attributes, justifying its high correlation (0.95) with Final Score. Dessalegn et al. (2008), when working with a group of accessions collected in Ethiopia, and Kathurima et al. (2009) with accessions from the Coffee Research Center in Kenya, observed high correlation between the sensory attributes. In the same way, Pereira et al. (2010) analyzed the cup quality of some cultivars and found high correlations among sensory attributes. These results agree with our findings, although they were obtained with different genotypes from different environments. Therefore, it is suggested that when the genotype-environment interaction is favorable to a particular sensory attribute, gains in quality might be expected in others.

Multivariate analyses

To study the divergence among genotypes, we discarded the highly correlated variables and kept only those that explained the other, without being high correlated (Table 2). Redundant characters, because they are correlated with others, are dispensable in studies of genetic divergence (Jolliffe, 1972, 1973). According to Adams and Wiersma (1978), only the sufficiently diverse characters which represent the fundamental structure of the biological system studied should be preserved in divergence analysis by principal components. Regarding the correlations and PCA simulations, we kept the Average Sieve Size (ASS), the Peaberry (PBE) and the Final Score (FSC) variables to represent the others which were discarded. Two principal components were established (PC1 and PC2), which explained 85% of the data variation (Table 3). In the first principal component the ASS and PBE variables contributed equally with nearly 50% of the total variation in the component. However, in PC2 the FSC variable accounted for almost all of the data variance (96%).
The variable loading in the first component showed high negative association for the ASS, positive for Peaberry and nearly null for the Final Score (Fig. 1). In the second principal component, the Final Score variable correlated positively, while for the Average Sieve Size and Peaberry variables the association was null. Characters with high loading values in a principal component have a strong contribution. Therefore, the first principal component, explaining nearly 52% of the total data variance, can be associated with bean quality (shape and size). On the other hand, the second principal component, explaining 33.28% of the total data variation, was associated with the coffee cup quality. Given the negative score of the Average Sieve Size and positive score of Peaberry in the first principal component (Table 3), genotypes associated with higher Average Sieve Size and lower Peaberry had negative scores in the PC1 (Table 4). Similarly, accessions with better cup quality showed higher scores in the second principal component. In the first principal component, the UFV 454-43 (code 20) and UFV 441-02 (code 12) HT accessions were most distant, with the highest absolute scores (-2.67 and 2.96, respectively). In PC2, the Catimor UFV 390-52 (code 24) accession and the HT derived cultivar, Araponga MG1 (code CD-3), presented the highest absolute scores (1.97 and -2.17, respectively). The observed distance among these accessions illustrates the diversity found in the HT germplasm and its derivatives (Fig. 2), indicating how important this germplasm could be for quality improvement. Based on the genotype projection in the Cartesian plane, we observed considerable divergence regarding the qualitative aspects of the beans and beverage. Similarity and formation of isolated groups of accessions with narrow genetic backgrounds may be expected. However, the genetic variability observed is justified, since the accessions with highest diversity were selected previously, based on molecular markers (Alvarenga et al., 2005; Setotaw et al, 2010).
According to Setotaw (2009), in the genotypic formation of the evaluated HT accessions there were at least two backcrosses with *C. Arabica*. This author and others (Lashermes et al., 2000) reported that on average, the HT germplasm has 8-27% of *C. canephora* genome introgression. Considering this information, it appears that a range of alleles was inserted during the hybridizations, recombined and fixed in segregating populations. This may explain the diversity in quality observed among the HT and its derivatives. Furthermore, coffee quality as a quantitative trait is influenced by several genes (Leroy et al., 2006). For example, Tessema et al. (2011) observed high dissimilarity of cup quality among *C. arabica* genotypes from different regions of Southwest Ethiopia. This intra-region variability prevented the formation of isolated groups according to the geographical origins of the genotypes. Setotaw et al. (2010), using molecular markers to study the genetic diversity among forty eight HT accessions, observed greatest divergence between groups II and III, respectively, represented by the UFV 450-61 and UFV 440-22 accessions. In the present work, such accessions (coded as 18 and 11, respectively) showed scores of different magnitudes for both components (Fig. 2). This fact indicates the distinct expression of genes for quality traits and corroborates with the previous divergence results reported by Setotaw et al. (2010). Catimor UFV 390-52 (code 24) presented the best cup quality (88 points) based on the second principal component. On the other hand, Catimor UFV 417-97 (code 26) occupied the 33th

Table 1. Coefficients of phenotypic correlation between traits of the beans (size and shape) of Híbrido de Timor and its derived progenies.

Beans shape and size variables†												
	F19	F18	F17	F16	F≥16	F15	F14	ASS	P11	P10	P09	PBE
F18	0.73**											
F17	-0.31	0.06										
F16	-0.67**	-0.80**	0.03									
F≥16	0.64**	0.81**	0.36*	-0.41*								
F15	-0.58**	-0.78**	-0.27	0.80**	-0.62**							
F14	-0.37*	-0.62**	-0.39*	0.51**	-0.61**	0.83**						
ASS	0.84**	0.93**	0.01	-0.90**	0.72**	-0.88**	-0.66**					
P11	-0.45**	-0.54**	-0.28	0.06	-0.85**	0.17	0.20	-0.37*				
P10	-0.52**	-0.71**	-0.27	0.51**	-0.72**	0.62**	0.61**	-0.68**	0.34*			
P09	-0.40*	-0.59**	-0.31	0.41**	-0.63**	0.75**	0.85**	-0.62**	0.19	0.75**		
PBE	-0.55**	-0.69**	-0.33*	0.22	-0.96**	0.37*	0.40*	-0.55**	0.95**	0.62**	0.44**	
Mean.	7.27	20.40	25.54	17.15	70.35	4.72	0.55	17.05	18.03	4.28	0.97	23.27
S.D.	7.40	10.98	5.80	8.56	12.25	3.08	0.55	0.48	8.46	2.69	0.82	10.05

† Flat beans (F19, F18, F17, F16, F15 and F14) and peaberry (P11, P10 and P09) variables; flat beans with sieve greater than or equal to 16/64ths (P≥16, in %); average sieve size (ASS); Peaberry (PBE). *($p < 0.05$) and ** ($p < 0.01$) significative by t-test.

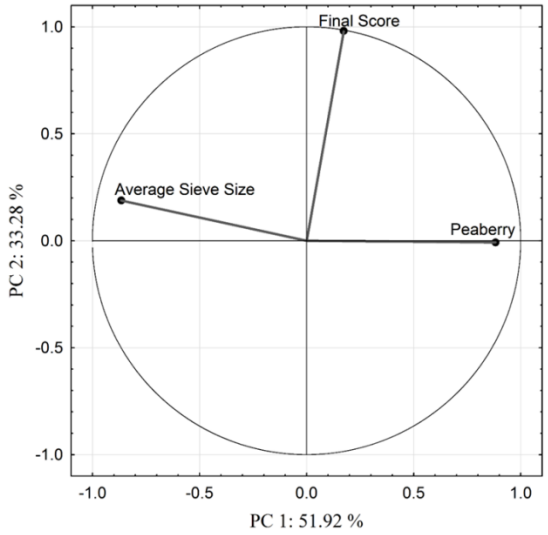

Fig 1. Projection of the variable loading on the principal components plane (1 x 2).

position in PC2 (80 points). Although these genotypes present Catimor germplasm (Caturra x HT), the graphical distance observed among these Catimor accessions (UFV UFV 390-52 and 417-97) can be explained based on the results of Alvarenga et al. (2005). These authors used molecular markers and observed about 53% of genetic distance among the same accessions, using the UPGMA clustering method with genetic distances (42 polymorphic bands) expressed by the complement of the Jaccard index.

Similarly, but highlighting the diversity of bean quality (PC1), the UFV 427-01 (code 6) and UFV 440-22 accessions (code 11) were ranked 4th and 34th, respectively. This is justified since the results of Setotaw et al. (2010) showed 92% of genetic distance between them when they were evaluated within a group of forty-eight HT accessions using combined data of molecular markers (AFLP, RAPD and SSR).

Genetic resources for coffee quality improvement

Among the HT derived cultivars, only the Sacramento cultivar (Catuaí Vermelho IAC 81 x HT UFV 438-52) obtained a Final Score above 80 points and could be considered a producer of specialty coffee (SCAA, 2014). However, among the 20 Híbrido de Timor accessions evaluated whose previous generation presented on average about 10-19% of *C. canephora* gene introgression (Setotaw, 2009), only two presented cup quality below the specialty coffee quality. Similarly, six HT accessions and one Catimor showed bean quality ranked above the best traditional cultivar (Bourbon at 9th). Regarding the overall mean of the genotypes in the Final Score for cup quality (82.33), it was inferred that most HT accessions and their derivatives have genetic potential to produce specialty coffees (SCAA, 2014).

According to Bertrand et al. (2003), genes associated with coffee leaf rust and nematodes (*Meloidogyne exigua*) do not have pleiotropic effect on the cup quality. The same authors inferred that there is a high correlation between performance of the parents and the general combining capacity. The traditional cultivars Bourbon Vermelho (code TC-1), Catuaí Vermelho IAC 15 (TC-2) and Catuaí Vermelho IAC 44 (TC-3) were ranked near each other in the PC2, indicating low variability with regards to the beverage sensory attributes. Although such cultivars are commonly used as control for quality, among the 35 assessed genotypes they occupied some of the lowest positions in the PC2 (27th, 23th and 25th, respectively). This indicates that most of the HT germplasm

Table 2. Simple correlation coefficients between beverage sensory attributes of Híbrido de Timor germplasm and its derived progenies.

Sensory Attributes†								
	Aroma	Flavor	Acidity	Body	Aftertaste	Balance	Overall	Final Score
Flavor	0.86**							
Acidity	0.77**	0.83**						
Body	0.76**	0.84**	0.75**					
Aftertaste	0.81**	0.89**	0.77**	0.82**				
Balance	0.71**	0.85**	0.76**	0.85**	0.81**			
Overall	0.80**	0.90**	0.87**	0.84**	0.86**	0.88**		
Final Score	0.88**	0.96**	0.88**	0.91**	0.92**	0.90**	0.95**	
Mean.	7.41	7.57	7.42	7.53	7.51	7.43	7.41	82.23
S.D.	0.46	0.51	0.42	0.41	0.49	0.40	0.38	2.91

† Aroma (ARO), Flavor (FLA), Acidity (ACI), Body (BOD), Aftertaste (AFT), Balance (BAL), Overall (OVE) and Final Score (FSC).
*(p < 0.05) and ** (p < 0.01) significative by t-test.

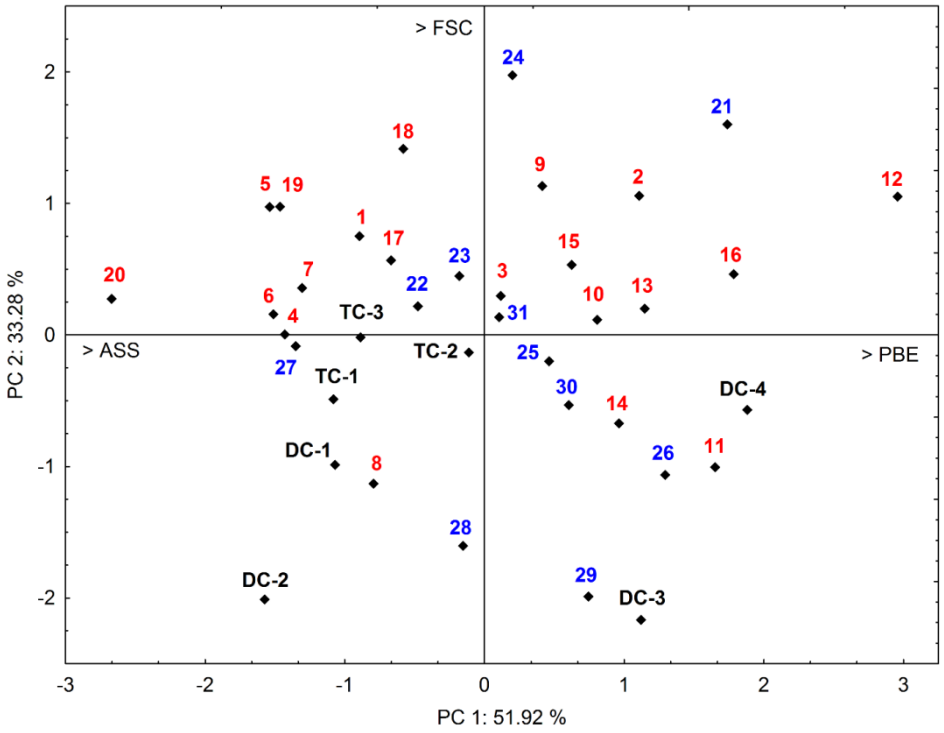

Fig 2. Dispersion of HT accessions (codes in red), HT derived progenies (codes in blue); Traditional Cultivars (codes TC-1, TC-2 and TC-3); and HT derived cultivars (codes DC-1, DC-2, DC-3 and DC-4) in the first two principal components. (Numbers refer to the genotypes codes in Table 4). Variables - ASS: Average Sieve Size; PBE: Peaberry; and FSC: Final Score.

lines and their derivatives, in the environment studied, presented higher cup quality (Fig. 2). The lower performance of cup quality among the traditional cultivars could be related to the elevation where they were evaluated (elev. 650 m) (Bertrand et al., 2011; Bertrand et al., 2012). At higher elevations (1,200 – 1,400 m), Bertrand et al. (2006) showed no significant differences between Arabica hybrids (Sudanese-Ethiopian origins with TC or with HT derived lines) and traditional cultivars. However, the same authors identified 10–20% higher fat concentrations in Arabica hybrids than traditional varieties at low elevations and similar fat concentrations at high elevations. At an elevation of 650 m, Kitzberger et al. (2011) also observed higher cup quality in a modern cultivar derived from HT (IPR 99, see Sera et al., 2013) compared to the traditional variety Bourbon. Pereira et al. (2010) found similar results at an elevation of 900 m. In their work the HT derived cultivar Catiguá-MG2 (Catuaí Amarelo IAC 86 x HT UFV 440-10) presented higher sensory quality than traditional cultivars for two consecutive years (Catuaí Amarelo IAC 62 and Bourbon Vermelho). These reports indicated that Arabic hybrids, as well as HT derived cultivars, can produce better cup quality than traditional cultivars, mainly at lower elevations (600 – 900 m). In an attempt to meet the growing global demand for coffee beans with better visual appearance and higher cup quality, to be sold green or only roasted, currently those most interesting are genotypes with higher percentage of large flat beans (P19 and P18) and higher scores of sensory quality (Leroy et al., 2006; Perosa and Abreu, 2009; Gichimu et al., 2012). In relation to the principal components plot, these genotypes were located in the left upper quadrant (Fig. 2).

Whereas for crosses the best parents should be chosen, those most divergent and complementary, and in the cited quadrant five accessions stood out as promising for breeding programs to improve the quality of coffee. As an example, below are

Table 3. Variable coefficients and explained data variance for each eigenvalue established in the principal component analysis.

Variables	PC1			PC2		
	Score	Loading	Contribution	Score	Loading	Contribution
Average Sieve Size	-0.556045	-0.8660	0.481556	0.188724	0.1884	0.035558
Peaberry	0.566156	0.8818	0.499228	-0.007474	-0.0075	0.000056
Final Score	0.111076	0.1730	0.019216	0.982847	0.9812	0.964387
Eigenvalue	1.5575			0.9983		
Explained var. (%)	51.9165			33.2781		
Acum. expl. var.(%)	51.9165			85.1946		

Table 4. Genotype description, scores and values for beans (ASS and PBE) and beverage characters (FSC) associated with each principal component.

Code†	Description‡	PC1	Rank§	ASS¶	PBE¶	PC2	Rank§	FSC¶
1	UFV 376-12 (HT)	-0.8946	11	17.21	12.35	0.7508	9	84.25
2	UFV 376-57 (HT)	1.1086	30	16.51	25.32	1.0583	5	86.00
3	UFV 377-23 (HT)	0.1164	21	17.37	31.12	0.2947	15	82.75
4	UFV 377-24 (HT)	-1.4285	6	17.68	16.23	0.0029	22	81.50
5	UFV 377-34 (HT)	-1.5380	3	17.77	14.85	0.9715	8	84.25
6	UFV 427-01 (HT)	-1.5106	4	17.63	13.87	0.1571	19	82.00
7	UFV 427-40 (HT)	-1.3049	8	17.49	13.43	0.3561	14	82.75
8	UFV 428-04 (HT)	-0.7940	13	17.37	21.09	-1.1321	34	78.50
9	UFV 438-49 (HT)	0.4137	23	17.36	33.40	1.1325	4	85.25
10	UFV 440-10 (HT)	0.8065	28	16.91	31.53	0.1149	21	82.75
11	UFV 440-22 (HT)	1.6522	34	16.88	44.97	-1.0078	32	79.50
12	UFV 441-02 (HT)	2.9584	38	16.09	42.75	1.0510	6	86.50
13	UFV 442-40 (HT)	1.1471	32	16.92	36.39	0.1991	18	83.00
14	UFV 443-03 (HT)	0.9638	29	17.29	43.41	-0.6740	30	80.00
15	UFV 444-01 (HT)	0.6249	26	16.90	27.72	0.5325	11	84.00
16	UFV 447-49 (HT)	1.7852	36	16.07	26.70	0.4615	12	84.75
17	UFV 449-20 (HT)	-0.6672	14	17.17	15.22	0.5664	10	83.75
18	UFV 450-61 (HT)	-0.5801	15	17.18	14.98	1.4149	3	86.25
19	UFV 451-41 (HT)	-1.4626	5	17.56	11.30	0.9736	7	84.50
20	UFV 454-43 (HT)	-2.6697	1	18.13	7.84	0.2737	16	81.75
21	UFV 345-04 (Catimor)	1.7395	35	16.62	35.52	1.6001	2	87.50
22	UFV 384-03 (Catimor)	-0.4765	16	17.37	22.85	0.2163	17	82.50
23	UFV 387-01 (Catimor x HT832/1)	-0.1791	17	17.09	20.68	0.4463	13	83.50
24	UFV 390-52 (Catimor)	0.2006	22	17.12	23.55	1.9737	1	88.00
25	UFV 416-30 (Catimor)	0.4630	24	16.96	28.30	-0.2018	26	81.75
26	UFV 417-97 (Ct. V. x HT-HW26/5)	1.2944	33	16.27	27.01	-1.0650	33	80.00
27	UFV 349-86 (Sarchimor)	-1.3508	7	17.67	17.36	-0.0851	24	81.25
28	UFV 351-03 (Cachimor)	-0.1529	18	16.59	14.35	-1.6055	35	78.00
29	UFV 308-34 (Caturra V.x H 239/11)	0.7452	27	16.49	25.81	-1.9897	36	77.00
30	UFV 316-15 (Catuaí V. x H 288/14)	0.6045	25	16.53	21.80	-0.5350	28	81.25
31	UFV 319-60 (Catuaí A. x H 65/7)	0.1058	20	16.94	22.16	0.1331	20	82.75
DC-1	Obatã Amarelo (UFV 485-05)	-1.0699	10	17.30	15.25	-0.9892	31	79.00
DC-2	Oeiras MG 6851	-1.5738	2	17.26	9.30	-2.0134	37	76.00
DC-3	Araponga MG1	1.1212	31	16.48	31.23	-2.1677	38	76.50
DC-4	Sacramento MG1	1.8827	37	16.47	38.80	-0.5702	29	81.25
TC-1	Bourbon V. (UFV 332-10)	-1.0817	9	17.27	13.61	-0.4901	27	80.50
TC-2	Catuaí Vermelho IAC 15	-0.1107	19	16.90	18.68	-0.1349	25	82.00
TC-3	Catuaí Vermelho IAC 44	-0.8879	12	17.18	13.47	-0.0194	23	82.00

† Code assigned to each genotype (DC: Híbrido de Timor derived cultivar, TC: Traditional cultivar); ‡ HT: Híbrido de Timor accessions.§ Access rank on the first and second principal component; ¶ Variables: ASS (Average Sieve Size); PBE (Peaberry); FSC (Final Score).

comments of the tasters regarding two cited HT derived accessions and two traditional cultivars.

- UFV 390-52 (cod.24- Catimor): "Excellent coffee, floral aroma, the fruity flavor reminding me of ripe yellow fruit, delicate acidity, soft and mellow body, very sweet and with long and sweet finish"; ASS= 17.12; FSC= 88.00.
- UFV 454-43 (cod. 20 – Híbrido de Timor): "Characteristic aroma, chocolate flavor, medium acidity, full-bodied, and with a good sweetness"; ASS= 18.13; FSC= 81.75.
- Bourbon Vermelho (cod. CT-1): "Balanced coffee, characteristic aroma and flavor, medium acidity and sweetness, bodied, with a dry finish"; ASS= 17.27; FSC= 80.50.
- Catuaí IAC 44 (cod. CT-3): "Good coffee, characteristic aroma, medium acidity and sweetness, light body, very clean and balanced, with medium finish"; ASS= 17.18; FSC= 82.00.

Materials and Methods

Genetic materials and crop environment

Thirty eight *Coffea arabica* genotypes from the germplasm bank of UFV (Universidade Federal de Viçosa) / EPAMIG (Empresa de Pesquisa Agropecuária de Minas Gerais) were assessed (Table 4). Of these 20 Híbrido de Timor (HT) accessions, 11 were HT derived progenies, four were commercial cultivars derived from HT (Obatã IAC 1669-20, Oeiras MG 6851, Sacramento MG1 and Araponga MG1) and three were traditional cultivars, not derived from the HT (Bourbon Vermelho, Catuaí Vermelho IAC 15 and Catuaí Vermelho IAC 44), used for quality control. The germplasm field was disposed in a non-replicated design with intercalated checks (Catuaí Vermelho IAC 15 and Catuaí Vermelho IAC 44) among ten accessions, used to estimate the environmental error. A progeny of 10 adult plants formed each accession plot. We selected the genotypes considering the genealogical origin and previous studies of their molecular genetic diversity (Alvarenga et al., 2005; Setotaw et al., 2010; Setotaw et al., 2013). The genotypes are cultivated in Viçosa-MG (20 ° 45 'S, 42 ° 52' W, elevation 650 m). The region has a Cwb climate type, according to Koppen's classification, with an annual average temperature and precipitation of 19° C and 1200 mm, respectively.

Samples preparation

Twenty liters of fresh coffee fruits were selectively handpicked in the "cherry" stage from each accession plot. They were processed four hours after harvest by the wet processing method (mechanically pulped and desmucilaged-depulper model GAVIOTA NG-600). The remaining residues, bark, and broken and bored beans were removed from the samples. Sequentially, the samples were spread onto suspended yard platforms to dry in layers of about three inches thick according to the process of Borém (2008). As the beans dried in the sun, the moisture level was monitored until it reached 11%. After drying, the beans were placed in double-layered brown paper bags and left at rest for 40 days. Then, samples were processed (Palini & Alves equipment, PA-AMO/30 Model, Serial No. 387), packed in waterproof plastic bags and kept in coolers until the time of assessment.

Evaluated characteristics

Bean shape and size was evaluated by a set of coffee test screens, considering a processed sample of 300 grams. The percentage of flat beans was determined in each of the following sieves: 19 (F19), 18 (F18), 17 (F17), 16 (F16), 15 (F15) and 14/64ths (F14) of an inch. For peaberry beans the 11 (P11), 10 (P10) and 9/64ths (P09) sieve sizes were used. The average sieve size (ASS) was obtained by the ratio between the sum of the mass of flat beans retained in each sieve multiplied by the respective sieve number, with the total mass of beans (Krug, 1940). The percentage of peaberry (PBE) was determined by the summed percentages of peaberries retained in the P11, P10 and P9 sieves. Similarly, the percentage of flat beans on sieves greater than or equal to 16/64ths ($F \geq 16$) was obtained by the sum of the F19, F18, F17 and F16 sieves. Sensory analysis of the beverage was performed in duplicate, by two tasters per sample, using the evaluation methodology of the Specialty Coffee Association of America- SCAA (SCAA, 2014). The green coffee samples were screened through a size 17 sieve and defective beans were discarded. The following attributes were assessed: Aroma (ARO), Flavor (FLA), Acidity (ACI), Body (BOD), Aftertaste (AFT), Balance (BAL), Overall (OVE) and Final Score (FSC). Based on the aforementioned methodology, genotypes presenting more than 80 points in the Final Score were classified as Specialty Coffee.

Statistical analysis

We estimated the Pearson's correlation coefficient between the variables of beans quality and among the sensory quality attributes. Because cup quality data was obtained regarding only beans from the ≥ 16 inch sieve, correlation studies between the beverage quality and bean size were not performed. A principal component multivariate analysis (PCA) was used in order to assess the genotypes dispersion regarding the quality of beans and beverage. After obtaining the correlation results and PCA simulations (variables weights), we kept only the non-redundant components and structurally important variables to explain the genotypes diversity for quality (Adams and Wiersma, 1978). Dissimilarity among genotypes was based on the mean Euclidian distance between the scores obtained in each principal component. These statistical analyses were carried out using the statistical software package Genes (Cruz, 2013).

Conclusions

For the reported environment (low elevation), traditional varieties presented ordinary sensory attributes without complexity of beverage nuances. Although these coffees are sensory classified as specialty, the sensory attributes are commonly found on the market, reducing their value as a specialty coffee. Meanwhile, the HT and its derived genotypes provide new flavors and nuance complexity rarely found on the market. Because coffee quality tends to improve with reduced mean air temperature, usually associated with increasing elevation, the progenies of genotypes identified as promising parents at high elevations will probably show similar or better cup quality than traditional cultivars. The HT germplasm and its derivatives can be used in coffee breeding programs, not just for resistance to pests and diseases, but also to improve coffee quality to meet the demands of specialty coffee consumers.

Acknowledgments

The authors would like to thank the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) and National Council for Scientific and Technological Development for providing the fellowship for the first author. This research was supported by Consórcio Pesquisa Café, Empresa de Pesquisa Agropecuária de Minas Gerais and Universidade Federal de Viçosa.

References

Adams MW, Wiersma JV (1978) An adaptation of principal components analysis to an assessment of genetic distance. Research Report. 347:2-7.

Alvarenga SM, Caixeta ET, Oliveira ACB, Rufino RJN, Brito GG, Pereira AA, Zambolim L, Sakiyama NS (2005) Analysis of the genetic diversity among coffee trees from the UFV/EPAMIG germplasm bank using RAPD markers. In: Proceedings of the IV Simpósio de Pesquisa dos Cafés do Brasil. Londrina. Brazil.

Anthony F, Combes MC, Astorga C, Bertrand B, Graziosi G, Lashermes P (2002) The origin of cultivated *Coffea arabica* L. varieties revealed by AFLP and SSR markers. Theor Appl Genet. 104:894-900.

Bertrand B, Guyot B, Anthony F, Lashermes P (2003) Impact of *Coffea canephora* gene introgression on beverage quality of *C. arabica*. Theor Appl Genet. 107:387-394.

Bertrand B, Vaast P, Alpizar E, Etienne H, Davrieux F, Charmetant P (2006) Comparison of bean biochemical composition and beverage quality of Arabica hybrids involving Sudanese-Ethiopian origins with traditional varieties at various elevations in Central America. Tree Physiol. 26:1239-1248.

Bertrand B, Anthony F, Lashermes P (2008) Breeding for resistance to Meloidogyne exigua in *Coffea arabica* by introgression of resistance genes of *Coffea canephora*. Plant Pathol. 50:637-643.

Bertrand B, Alpizar E, Lara L, SantaCreo R, Hidalgo M, Quijano JM, Montagnon C, Georget F, Etienne H (2011) Performance of Coffea arabica F1 hybrids in agroforestry and full-sun cropping systems in comparison with American pure line cultivars. Euphytica. 181: 147-158.

Bertrand B, Boulanger R, Dussert S, Ribeyre F, Berthiot L, Descroix F, Joet T (2012) Climatic factors directly impact the volatile organic compound fingerprint in green Arabica coffee bean as well as coffee beverage quality. Food Chem. 135: 2575–2583.

Bettencourt A (1973) Considerações gerais sobre o 'Hibrido de Timor'. Circular n^{o} 23. Instituto Agronômico de Campinas, Campinas, Brazil.

Borém FM (2008) Handbook of Coffee Post-Harvest Technology. Editora UFLA, Lavras. Brazil.

Chaves GM (1976) Melhoramento do cafeeiro visando à obtenção de cultivares resistentes à *Hemileia vastatrix* Berk et Br. (In Portuguese, with English abstract.) Revista Ceres. 23:321-332.

Clarindo WR, Carvalho CR, Caixeta ET, Koehler AD (2013) Following the track of "Híbrido de Timor" origin by cytogenetic and flow cytometry approaches. Genet Resour Crop Evol. 60:2253-2259.

Cruz CD (2013) Genes: a software package for analysis in experimental statistics and quantitative genetics. Acta Scientiarum. 35:271-276.

Dessalegn Y, Labuschagne MT, Osthoff G, Herselman L (2008) Genetic diversity and correlation of bean caffeine content with cup quality and green bean physical characteristics in coffee (*Coffea arabica* L.) Society of Chemical Chemistry. J Sci Food Agr**.** 88:1726-1730.

Gichimu BM, Gichuru EK, Mamati GE, Nyende AB (2012) Selection within *Coffea arabica* cv. Ruiru 11 for high cup quality. Afr J Food Sci. 6:456-464.

Gichimu BM, Gicheru EK, Mamati GE, Nyende AB (2014) Variation and association of cup quality attributes and resistance to Coffee Berry Disease in *Coffea arabica* L. composite cultivar, Ruiru 11. Afr J Hortic Sci. 7:22-35.

Hindorf H, Omondi CO (2011) A review of three major fungal diseases of *Coffea arabica* L. in the rainforests of Ethiopia and progress in breeding for resistance in Kenya. J Adv Res. 2: 109-120.

Ito DS, Sera T, Sera GH, Del Grossi L, Kanayama FS (2008) Resistance to bacterial blight in arabica coffee cultivars. Crop Breed Appl Biot. 8:99-103.

Jolliffe IT (1972) Discarding variables in a principal component analysis; I Artificial data. Appl Stat. 22:160-173.

Jolliffe IT (1973) Discarding variables in a principal component analysis; II Real data. Appl Stat. 22:21-31.

Kathurima CW, Gichimu BM, Kenji GM, Muhoho SM, Boulanger R (2009) Evaluation of beverage quality and green bean physical characteristics of selected Arabica coffee genotypes in Kenya. Afr J Food Sci. 3:365-371.

Kitzberger CSG, Scholz MBS, Silva GD, Toledo JB, Benassi M (2011) Caracterização sensorial de cafés arábica de diferentes cultivares produzidos nas mesmas condições edafoclimáticas. Braz J Food Technol. 14:39-48.

Krug CA (1940) O cálculo da peneira média na seleção do cafeeiro. Revista Instituto Café. 26:123-127.

Lashermes P, Combes MC, Robert J, Trouslot P, D'Hont A, Anthony F, Charrier A (1999) Molecular characterisation and origin of the *Coffea arabica* L. genome. Mol Genet Genomics. 261:259–266.

Lashermes P, Andrzejewski S, Bertrand B, Combes MC, Dussert S, Graziosi G, Trouslot P, Anthony F (2000) Molecular analysis of introgressive breeding in coffee (*Coffea arabica* L.). Theor Appl Genet. 100:139-146.

Leroy T, Ribeyre F, Bertrand B, Charmetant P, Dufour M, Montagnos C, Marraccini P, Pot D (2006) Genetics of coffee quality. Braz J Plant Physiol. 18:229-242.

Pereira MC, Chalfoun SM, Carvalho GRD, Savian TV (2010) Multivariate analysis of sensory characteristics of coffee grains (*Coffea arabica* L.) in the region of upper Paranaíba. Acta Scientiarum. 32:635-641.

Perosa JMY, Abreu LHF (2009) Economic aspects and opportunities in the market of quality coffees. Pesq Agrop Trop. 39:144-150.

Rezende RM, Salgado SML, Rezende JC, Carvalho GR, Pereira AA, Lima RR, Ferreira AD (2013) Resistance of *Coffea arabica* progenies in field conditions infested by *Meloidogyne exigua*. Nematropica. 43:233-240.

Romero G, Vásquez LM, Lashermes P, Herrera JC (2014) Identification of a major QTL for adult plant resistance to coffee leaf rust (*Hemileia vastatrix*) in the natural Timor hybrid (*Coffea arabica* x *C. canephora*). Plant Breeding. 133:121-129.

SCAA (2014) SCAA Protocols - Cupping Specialty Coffee. Specialty Coffee Association of America. http://www.scaa.org/PDF/resources/cupping-protocols.pdf (accessed 20 Jun. 2014).

Sera T, Sera GH, Fazuoli LC (2013) IPR 103-Rustic dwarf arabic coffee cultivar more adapted to hot regions and poor soils. Crop Breed Appl Biot. 13:95-98.

Setotaw TA (2009) Genetic diversity and genome introgression in coffee. Ph.D. diss., Universidade Federal de Viçosa. Viçosa, Brazil.

Setotaw TA, Pena GF, Zambolin EM, Pereira AA, Sakiyama NS (2010). Breeding potential and genetic diversity of "Híbrido do Timor" coffee evaluated by molecular markers. Crop Breed Appl Biot. 10:298-304.

Setotaw TA, Caixeta ET, Pereira AA, Oliveira ACB, Cruz CD, Zambolim EM, Zambolim L, Sakiyama NS (2013) Coefficient of Parentage in *Coffea arabica* L Cultivars Grown in Brazil. Crop Sci. 53:1237-1247.

Tessema A, Alamerew S, Kufa T, Garedew W (2011) Genetic Diversity Analysis for Quality Attributes of Some Promising *Coffea arabica* Germplasm Collections in Southwestern Ethiopia. J Biol Sci. 11:236-244.

Van Der Vossen HAM (2009) The cup quality of disease-resistant cultivars of Arabica coffee (*Coffea Arabica*). Exp Agr. 45:323–332.

Zarate LA, Cristancho MA, Moncada P (2010) Strategies to develop polymorphic markers for *Coffea arabica* L**.** Euphytica. 173:243–253.