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CROP PRODUCTION

Beverage quality of *Coffea canephora* genotypes in the western Amazon, Brazil

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ABSTRACT. This study aimed to evaluate the beverage quality of *Coffea canephora* genotypes in different environments of the western Amazon to assist plant selection and new cultivar development. To analyze beverage quality, samples of cherry coffee beans were collected separately for each genotype from clonal competition trials installed in the municipalities of Ouro Preto do Oeste, Alta Floresta do Oeste, Porto Velho, and Ariquemes in Rondônia State and Rio Branco in Acre State (Brazil). The beverage quality was assessed using the Robusta Cupping Protocol, which attribute to each genotype a score in a range from 0 to 100, highlighting nuances. Analysis of variance and principal components using reference points were used to quantify genotype x environment interaction (G x E). The analysis of variance indicated that genotypic and G x E interaction effects were significant ($p < 0.01$). By using a centroid dispersion method, we could identify four clones of low, eight of specific (to favorable or unfavorable environments), and seven of broad adaptability to the environments. The clones BRS 2314, 11, and 17 had average quality scores above 80 in all environments, with potential for specialty coffee production. The clones BRS 1216, BRS 3220, and BRS 3193 presented unstable behavior, with beans of higher quality in some of the evaluated environments. Such inconsistency in clone behavior is caused by unpredictable changes in plant performance in different environments. Our results indicate that both genotypic (clones) and G x E interaction effects are important for the expression of coffee beverage quality. However, the clones BRS 3213, BRS 3210, and BRS 2299 had less prominent nuances, with lower potential for specialty coffee production.

Keywords: Conilon; Robusta; genotype x environments interaction.

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Introduction

Beverage quality characterization is a routine activity performed in breeding programs for scientific and commercial purposes (Aguiar, Fazuoli, Salva, & Favarin, 2005; Pereira et al., 2017; Souza et al., 2018). In 2010, the Robusta Cupping Protocol was developed, which presents specific evaluation criteria for *Coffea canephora* beverages, standardizing beverage quality as a function of changes characteristic of such species (Uganda Coffee Development Authority [UCDA], 2010).

The species *C. canephora* has two distinct botanical varieties, Conilon and Robusta, which are commercially cultivated and have different beverage quality traits (Davis, Tosh, Ruch, & Fay, 2011). While the first has predominance of neutral and less full-bodied beverages, the latter is distinguished by its exotic nuances identified by its fruity, chocolate, and almonds notes (Souza et al., 2018). Differences in drink quality between Conilon and Robusta are expressed in hybrid plants, which may have characteristics of both botanical varieties (Aguiar et al., 2005; Oliveira et al., 2018; Spinelli et al., 2018).

When evaluating 130 accessions from a germplasm bank, Souza et al. (2018) observed that up to 80% of the variability in beverage quality may be of genotypic nature. In the same line, Mori et al. (2018) performed a sensory description of beverages of conilon coffee produced in Espírito Santo and observed that the cultivars Diamante 8112 and Centenária 8132 (Ministério da Agricultura, Pecuária e Abastecimento [MAPA], 2019) had superior quality according to the traditional criteria.

Beverage quality is not only influenced by genotypes but also by environmental factors (Sunarharum, Williams, & Smyth, 2014). Important environmental factors include soil, altitude, cultivar, management practices, ripening, processing, drying, hulling, storage, and roasting, which interact with each other, affecting coffee quality at varied intensities (DaMatta, Cavatte, & Martins, 2012). Thermal sum in degrees-day is directly influenced by day and night temperatures and can speed up maturation cycle, reducing production of secondary metabolites, which are then perceived in beverage quality assessments (Lemos et al., 2020, Pereira et al., 2019).

Significant effects of genotype x environment interaction arise from a non-additive relationship of genotypic and environmental effects, due to changes in plant performance as a function of location (Cruz, Carneiro, & Regazzi, 2014; Resende, 2002). Multivariate methods allow to evaluate adaptability and stability of a high number of genotypes and locations, classifying them according to their performance in both favorable and unfavorable environments. Results can be shown in a scatter plot and compared to 'ideotypes', which act as reference points (Rocha, Muro-Abad, Araújo, & Cruz, 2005; Nascimento et al., 2015). Besides being used to study genotype x environment (G x E) interaction in different crops, the multivariate methods also help select coffee plants with higher productive potential (Oliveira et al., 2018; Moraes et al., 2020).

The current study of coffee beverage quality considered the genetic variability among clones of different genealogies and plant behavior changes among environments. Our goal was to evaluate the beverage quality of *C. canephora* genotypes in different environments of the western Amazon (Brazil) to support plant selection and new cultivar development studies.

Material and methods

In December 2012 and January 2013, six clonal competition trials were installed in different locations of the western Amazon (Brazil). Soil, nutritional, cultural, and phytosanitary management practices were performed according to the recommendations for coffee cultivation in Rondônia (Marcolan et al., 2009).

Test Nº 1 (Ouro Preto do Oeste, Rondônia State). It was conducted at the experimental field of the Brazilian Agricultural Research Corporation (EMBRAPA), which is located at the coordinates 10°43'55.3" S and 62°15'23.2" W, and 245 meters of altitude. The local climate is '*Aw*' type by the Köppen's classification, which stands for humid tropical with dry winters and rainy summer. Annual temperature ranges from 21.2 to 30.3°C, with the highest values in July and August. Annual rainfall is 1,939 mm, and average relative humidity is 81% (Alvares, Stape, Sentelhas, Moraes Gonçalves, & Sparovek, 2013).

Test Nº 2 (Alta Floresta do Oeste, Rondônia State). It was conducted on the coffee farm of Mr. Ademar Schmidt, at the coordinates 12°08'23.06" S and 61°59'29.41" W, and 436 meters of altitude. The local climate is also classified as '*Aw*' type by Köppen. Average annual rainfall is 1,783 mm, with July being the driest month and March the wettest, and average temperature of 23.4°C (Alvares et al., 2013).

Test Nº 3 (Porto Velho, Rondônia State). It was carried out at the experimental field of the EMBRAPA, which is located at the coordinates 8°48'05.5" S and 63°51'02.7" W, and 88 meters of altitude. The prevailing climate in the region is tropical rainy with dry winters, which is classified as '*Am*' type by Köppen, with annual averages of temperature of 26.0°C and precipitation of 2,095 mm. The warmest month is September (27.1°C) and the coldest May (24.9°C) (Alvares et al., 2013).

Test Nº 4 (Ariquemes, Rondônia State). This essay was conducted at the Federal Institute of Rondônia, Campus Ariquemes, which is located at the coordinates 09°57'09.8" S and 62°56'53.7" W, and 128 meters of altitude. The predominant climate is humid tropical of '*Aw*' type (Köppen), with a well-defined dry season from June to August. Water deficit ranges from 200 to 300 mm year^{-1}. Annual averages of rainfall and temperature are 2,181 mm and 25.4°C, respectively, with September being the warmest month and July the driest (Alvares et al., 2013).

Tests 5 and 6 (Rio Branco, Acre State). Both trials were conducted in the Embrapa of Acre State, one under irrigation and the other under dry farming. The local coordinates are 10°1'30.98" S, 67°42'21.77" W, and 180 meters of altitude. The predominant climate is humid tropical, of '*Aw*' type (Köppen), with a well-defined dry season from June to August. Water deficit ranges from 50 to 100 mm year^{-1}, with annual average of rainfall of 1,998 mm. Average temperature is 24.9°C, with October being the warmest month and July the driest (Alvares et al., 2013).

The assays were composed of 16 previously selected hybrid clones, with average yields above 70 bags ha^{-1}, orange rust resistance, and higher vigor. Four clones were used as controls. These belong to a cultivar adapted to tropical conditions and low altitude, i.e., Conilon cv. BRS Ouro Preto (Table 1). Due to their good agronomic performance, the clones identified by the prefix BRS were registered with the Ministry of Agriculture (MAPA, 2019). All 20 treatments were conducted in a randomized block design, with three replications of four plants, and spaced 3 x 1.5 meters.

Table 1. Genotypes evaluated in clonal competition trials installed in six environments of the western Amazon (Brazil).

Genotype	Origin
BRS Ouro Preto - 125	Cultivar BRS Ouro Preto
BRS Ouro Preto - 160	Cultivar BRS Ouro Preto
BRS Ouro Preto - 120	Cultivar BRS Ouro Preto
BRS 2299	Cultivar BRS Ouro Preto
Clone 453	Open pollination
Clone 657	Open pollination
Clone 636	Open pollination
BRS 3193	Open pollination
Hybrid 9	Emcapa 03 x Robusta 640
BRS 3210	Emcapa 03 x Robusta 2258
Hybrid 11	Emcapa 03 x Cpafro 194
Hybrid 12	Emcapa 03 x Robusta 2258
BRS 3213	Emcapa 03 x Robusta 2258
BRS 2314	Emcapa 03 x Robusta 640
Hybrid 15	Emcapa 03 x Robusta 2258
BRS 1216	Emcapa03 x Robusta 1675
Hybrid 17	Emcapa 03 x Robusta 1675
Hybrid 18	Robusta 640 x Cpafro 194
Hybrid 19	Robusta 1675 x Cpafro 194
BRS 3220	Emcapa 03 x Robusta 1675

Coffee fruits were harvested at cherry stage (M3) and washed for removal of buoy fruits and impurities (leaves, stones, sticks, earth). Green fruits and nuts were also separated. Due to its low adaptability to the evaluated environments, no samples were obtained from clone 636. Thus, in 2018, 342 samples from 19 clones harvested from six clonal competition assays were benefited. The fruits were left to dry naturally under a ‘barge-type’ covering (transparent piece of furniture) until the samples reached 11-12% moisture. Coffee fruits were hulled in the laboratory of EMBRAPA Rondônia, campus of Ouro Preto do Oeste, Rondônia State (Brazil). Afterwards, coffee beans were sieved (sieve 15 and larger) and packaged in 500-g samples.

Sensory analysis of the samples was carried out in the laboratory of the ‘Prove Café Company’ in Venda Nova do Imigrante, Espírito Santo State (Brazil) by three judges/cuppers (R Grader), according to the international method of beverage classification for *C. canephora*, the Robusta Cupping Protocol of the Coffee Quality Institute - CQI (UCDA, 2010).

Coffee roasting process was conducted in a roaster (Pinhalense, model TC-02) for about 12 minutes at 190 ± 10°C. The roasting was monitored by a set of Agtron-SCA discs, and the roasting point of samples was between the colors determined by discs # 65 and # 55, for specialty coffees (Specialty Coffee Association of America [SCAA], 2014).

The samples were evaluated between 8 and 24 hours after roasting. Then, they were ground in a Ditting 5.5 electric mill (Ditting Maschinen AG, Bachenbulach, Switzerland) to medium/coarse grain size. Five cups of each coffee batch were tasted, using a concentration of 8.25 g of ground coffee in 150 mL water, in accordance with the midpoint of the balance chart (SCAA, 2014). The infusion point of water occurred after the water reached 92.2 - 94.4ºC. The tasters (judges/cuppers) started evaluations when cup temperature reached 55°C, respecting the time of 4 minutes for tasting after infusion.

The attributes evaluated were fragrance, flavor, acidity, bitterness, mouthfeel, balance, aftertaste, uniform cup, clean cup, and overall attributes (UCDA, 2010). Final beverage quality was scored from the sum of each attribute scoring evaluated individually, on a scale ranging from 0 to 10.

Significance of clone effect on beverage quality in each environment was individually tested, according to the model described by Cruz et al. (2014), as follows:

$$Y_{ij} = m + G_i + E_{ij}$$

wherein: Y_{ij} refers to the observation of the i^{th} genotype in the j^{th} repetition, m is the experimental average, G_i is the effect of the i^{th} genotype (clone), and E_{ij} is the experimental error of all the observations in the experiment.

Afterwards, homogeneity of residual variances was verified, and a joint variance analysis was performed to quantify G x E interaction effect, according to the model described by Cruz et al. (2014), as follows:

$$Y_{ijk} = m + G_i + A_j + GA_{ij} + E_{ijk}$$

wherein: Y_{ijk} refers to the observation of the ith genotype in the jth environment, m is the experimental average, G_i is the effect of the ith genotype (clone), A_j is the effect of the jth environment, GA_{ij} is the effect of the interaction between the ith genotype and the jth environment, and E_{ijk} is the experimental error. The genotypic effect was considered and environmental effect random.

Centroid method was used to estimate stability and adaptability, considering vector data of maximum and minimum genotype performances in each environment. These vectors provided references of 'ideal' minimum, medium, and maximum performances of the genotypes in favorable and unfavorable environments (Rocha et al., 2005; Nascimento et al., 2015). The clones were classified based on the Euclidean distance between the genotype and the known behavior reference (centroids), according to the following model:

$$D_{ik} = \sqrt{\sum_{j=1}^{n}(X_{ij} - C_{jk})^2}$$

wherein: D_{ik} is the Euclidian distance from the ith genotype to the kth centroid (k = 1,2,...n), X_{ij} is the beverage quality final score of the ith-genotype in the jth-environment, and Cjk is the beverage quality final score of the kth-centroid in the jth environment. Based on these distances (D_{ik}), the genotypes were classified as follows: i) overall high adaptability; ii) specific adaptability to favorable environments; iii) specific adaptability to unfavorable environments; and iv) poorly adapted.

The dispersion in the plane was determined by principal component analysis of the beverage quality final score in the different environments. It had a size equal to the number of evaluated genotypes plus four additional ideotypes, corresponding to the reference points (Hair, Black, Babin, Anderson, & Tatham, 2009). All statistical analyses were performed using the GENES software (Cruz et al., 2014).

Results and discussion

Individual variance analyses were interpreted to evaluate quality and accuracy of the experiments in all environments assessed (Table 2). The coefficient of variation (CV) found can be considered as low (CV < 20%), which indicates good experimental conduction, grain collection, and processing. Similar estimates were observed by Drumond Neto et al. (2017), who observed CVs between 1.7 and 6.1% when assessed beverage quality of six genotypes in two environments in the state of Espírito Santo (Brazil). In assessing drink quality of 130 *C. canephora* accessions in a single environment, Souza et al. (2018) estimated a CV of 13.6%, which was due to a higher genetic variability among the evaluated materials.

The environments were classified as favorable or unfavorable for coffee drink quality based on the environmental quality index (Ij), which is defined as the contrast between each environment performance and the mean of all environments (Cruz et al., 2014). Based on this, Alta Floresta do Oeste (E1) and Ouro Preto do Oeste (E3) were classified as favorable for coffee beverage quality, whereas Ariquemes (E2), Porto Velho (E4), irrigated Rio Branco (E5), and dry-farming Rio Branco (E6) had negative environmental effects on beverage quality scoring.

Table 2. Summary of final scores for coffee beverage quality in the municipalities of Alta Floresta do Oeste, Rondônia State, Ariquemes, Rondônia State, Ouro Preto do Oeste, Rondônia State, Porto Velho, Rondônia State, Rio Branco, Acre State, in the western Amazon (Brazil).

Environment	ALT	NF_{med}	NF_{max}	NF_{min}	I_j	CV%	F
Alta Floresta do Oeste - E1	436 m	79.30	86.77	68.60	0.66	4.14	3.58
Ariquemes - E2	126 m	78.64	86.43	70.27	-0.01	4.75	3.76
Ouro Preto do Oeste - E3	243 m	79.47	87.20	75.33	0.82	3.69	2.66
Porto Velho - E4	88 m	78.21	81.27	73.00	-0.43	3.61	1.98
Rio Branco[1] - E5	160 m	77.96	83.00	73.33	-0.67	3.81	1.97
Rio Branco[2] - E6	158 m	78.26	81.70	71.43	-0.38	3.60	3.04

ALT: altitude, NFmed: Average final score, NFmax: Final score of the cultivar with the best adaptation for the environment, NFmin: Final score of the cultivar with the least adaptation for the environment, Ij: environmental index, CV%: coefficient of variation, F: F-test estimates; 1- test under irrigation; 2 - test under dry farming.

The region where coffee is grown in the western Amazon is subject to the *Am* and *Aw* climatic types, which are characterized as typically tropical, humid, and hot climates, with low annual thermal amplitude and expressive daytime thermal amplitude from May to September (Alvares et al., 2013). The coffee growing is conducted in low-lying regions, between 95 and 405 m, where average annual air temperatures are between 25 and 27°C, with maximum temperatures between 30 and 35°C and minimum between 18 and 20°C (Alvares et al., 2013). Several studies indicate that high temperatures associated with low altitudes tend to accelerate fruit ripening, affecting coffee beverage quality. In general, such conditions favor increases in bitterness and dry nuances, along with reduction in positive attributes such as aroma/fragrance and sweetness (Moura et al., 2007).

Among the different environments in Rondônia and Acre states, there was a slight difference between the highest and lowest scores for coffee beverage quality (Table 2). This can be explained by the little variation in altitude among E2, E3, E4, and E5 (maximum of 243 m and minimum of 88 m), as well as temperature and precipitation conditions. Even E1, which has the highest altitude (436 m), showed only little and non-significant differences in the final scores of beverage quality compared to the other environments. Overall, lower altitudes and higher temperatures accelerate fruit ripening; therefore, it is important to select genotypes of higher adaptability and stability to maintain higher beverage quality in such environments (Martins et al., 2020; DaMatta et al., 2012). Drumond Neto et al. (2017) observed significant differences in sensory characteristics of *C. canephora* grains grown in higher altitudes.

Besides the environment, genetic factors also influenced the quality of *C. canephora* beverage. This species is differentiated by its greater adaptation to tropical regions and its genetic variability for beverage quality traits such as uniformity and fruit ripening cycle (Vieira, Ferreira, Partelli, & Viana, 2019; Oliveira et al., 2018). Although several studies on drink quality of *Coffea arabica* can be found in the literature, fewer studies have been performed to assess *C. canephora* drink. It is characterized by lower acidity, higher bitterness, higher alcohol content, caffeine, and higher concentration of soluble solids (Ribeiro et al., 2016; Pinheiro et al., 2019).

In the joint variance analysis, F-test estimates of genotype effects and genotype x environment interaction were significant at 1% probability (Table 3). When there is interaction, clone behavior must be interpreted in each environment individually. Significant effects of genotype x environment interaction on coffee plants have also been observed for other traits such as processed coffee yield (Ribeiro et al., 2016; Rocha, Ramalho, Teixeira, Souza, & Cruz, 2015). Our findings indicate the importance of considering changes in drink quality for clones grown in different environments.

The average score of beverage quality for the evaluated clones was 78.63, which is below the standard for specialty coffees (equal or higher than 80). However, such score represents higher quality than that observed by Souza et al., (2018) and by Galote, Morais Neto, and Ferreira (2013), who evaluated a larger number of accessions in a single environment and observed average scores of 69.5 and 46.6, respectively.

Table 3. Summary of genotypic, environmental, and genotype x environment interaction effects on beverage quality expression of superior clones in the municipalities of Alta Floresta do Oeste, Rondônia State, Ariquemes, Rondônia State, Ouro Preto do Oeste, Rondônia State, Porto Velho, Rondônia State, Rio Branco, Acre State, in the western Amazon (Brazil).

Genetic parameter of beverage quality final score	
F-test (Genotype)	3.56**
F-test (Environment)	1.94^{NS}
F-test (G x E interaction)	2.15**
Average	78.64
Genotypic variance (Vg)	2.85
G x E interaction variance (Vga)	3.38
Residual Variance (Vres)	9.31
Genotypic determination coefficient (H^2)	71.94
Intraclass Correlation (r)	18.35
Coefficient of genetic variation (CVg)	2.15
Coefficient of variation (CVe)	3.88
CVg/CVe ratio	0.55

**significant at 1% probability, *significant at 5% probability, ^{NS}: non-significant, FV: source of variation, DF: degrees of freedom, SS: sum of squares,

Coefficient of genotypic determination (H_2), which is understood as the relationship between genotypic and environmental variations, averaged 71.9% (Table 3). Estimates close to 80% indicate a predominance of the genotypic component in terms of coffee production (Cruz et al., 2014). Likewise, Souza et al. (2018) observed that the genetic component was more important in the expression of quality attributes for *C. canephora* beverage than environmental variation, except for uniform cup and clean cup attributes, which did not have genetic variability in the studied population. The magnitude of the ratio between coefficients of genetic variation and experimental variation (CVg / CVe) was 55%, indicating the importance of both genotypic and environmental effects on quality of drink.

The centroid dispersion method was used to compare the drink quality of each clone with that of known performance ideotypes (Figure 1). By this method, the clones BRS 2314, BRS 3220, BRS 1216, 11, 15, 17, and

19 were all classified in the ideotype I group. This represents an ideal plant, with the best beverage quality in all the environments. Yet, the clones BRS 2299, 120, 125, and 453 showed specific adaptability to favorable environments and were classified as ideotype II. This represents plants with maximum performance in favorable environments and minimum in unfavorable ones. Finally, the clones BRS 3213, BRS 3210, 657, and 18 approached the ideotype IV group, which is characterized by a minimal adaptability and the lowest beverage quality for all the studied environments (Rocha et al., 2005). Clone grouping was performed considering the Euclidean distance of each genotype from the four ideotypes, and the clones with better adaptability and stability in the evaluated environments were classified in the ideotype I group (Figure 1). These results show that, despite the little difference among the studied environments, the evaluated clones have significant genetic variability, which allows to select superior clones for beverage quality.

According to the quality classification proposed by SCAA (2014), the clone BRS 2314 presented a special beverage score, which was above 80 in all the evaluated environments, averaging 83.8 points. This clone stood out in Ouro Preto do Oeste, with 87.2 points, thus indicating its potential for specialty coffee production (Table 4). Its beverage was featured by a sweet flavor and aroma of chocolate with hints of citrus and almonds, besides a pleasant acidity. Such nuances have potential for the special coffee market, characteristic of the Robusta botanical variety.

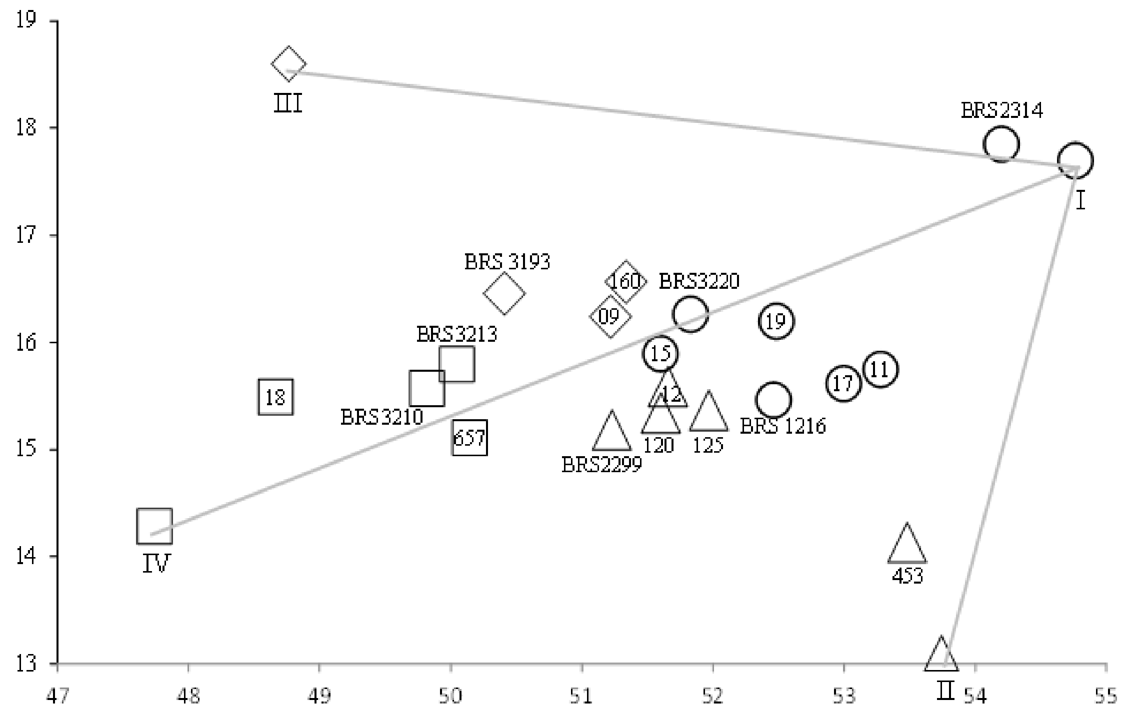

Figure 1. Graphic dispersion of final score for beverage quality of *C. canephora* genotypes in six different environments of the western Amazon (Brazil). Roman numerals represent reference points for general and specific adaptability to the evaluated environments: I: general adaptability (O), II: specific adaptability to favorable environments (Δ), III: specific adaptability to unfavorable environments (◊), IV: low adaptability (□). Genotypes classified in the same group are identified by the same geometric shapes.

The clones 11 and 17 averaged above 80 points in all the environments and had potential for specialty coffee production. Unlike the clone BRS 2314, which had superior drink quality associated with good agronomic performance, the clone 17 is characterized by overgrowth in the field, and the clone 11 has lower productivity (Moraes et al., 2020). According to these authors, the clone 453, which is also characterized by its lower agronomic performance, had good drink quality in all the environments and almond, chocolate, and dry finish traits, except in Alta Floresta do Oeste (Table 4). The lowest score in this environment is probably due to fermentation during sample preparation (Verdin Filho et al., 2016).

The clones BRS 1216 and BRS 3220 had similar traits such as chocolate-flavored and medium-sweet drink standards, with scores of 79.6 and 79.1 points, respectively. These clones showed unstable behavior, having produced ‘fine’ type drink in some of the evaluated environments. These results indicate that cultivation of selected clones may favor a higher beverage quality, with different flavors and aromas.

Table 4. Averages of final score for beverage quality in the six trials in the western Amazon (Brazil). Dotted lines highlight the genotypes featuring beverages classified as 'fine' in all environments.

Clone	E1	E2	E3	E4	E5	E6	Average	Score
BRS 2314	86.8	86.4	87.2	81.3	81.1	80.0	83.8	Fine
11	80.7	83.2	80.1	80.7	80.5	80.7	81.0	Fine
17	80.0	82.8	79.6	80.3	80.0	80.3	80.5	Fine
19	80.0	78.8	81.9	80.8	78.7	79.0	79.9	Very good
BRS 1216	80.0	79.9	78.3	80.0	79.3	80.0	79.6	Very good
453	68.6	81.8	81.1	80.3	83.0	81.4	79.4	Very good
BRS 3220	81.0	80.0	82.0	76.0	77.3	78.0	79.1	Very good
15	81.4	80.0	78.4	78.3	77.2	78.3	78.9	Very good
160	84.3	70.3	78.8	78.5	80.6	80.9	78.9	Very good
125	78.4	78.1	78.7	78.7	77.5	81.7	78.8	Very good
12	79.5	81.3	78.1	79.1	77.8	76.6	78.7	Very good
120	78.0	78.8	78.2	77.8	78.6	78.6	78.3	Very good
9	81.0	71.0	80.3	79.2	76.5	80.1	78.0	Very good
BRS 2299	76.3	77.8	78.3	77.5	77.3	78.8	77.7	Very good
BRS 3193	76.7	78.3	83.0	77.3	76.8	71.4	77.2	Very good
BRS 3213	79.0	82.1	77.9	73.9	75.4	74.5	77.1	Very good
657	77.4	74.3	76.0	75.7	76.0	78.0	76.2	Very good
BRS 3210	78.8	74.8	76.5	77.6	74.5	74.2	76.1	Very good
18	78.6	74.3	75.3	73.0	73.3	74.3	74.8	Very good
Average	79.29	78.62	79.46	78.20	77.96	78.25	78.63	

E1- Alta Floresta do Oeste, E2-Ariquemes, E3- Ouro Preto do Oeste, E4- Porto Velho, E5- Rio Branco using irrigation; E6- Rio Branco under dry conditions. Dotted lines separate clones of high adaptability and stability in the first extract, and clones of high adaptability and low stability in the second extract.

Despite its nuances that favor beverage quality such as chocolate, caramel, and almonds flavors, the clone BRS 3193 had scores lower than those of clones classified in the ideotype I group. If compared to BRS 2314 and BRS 1216, this genotype showed higher precocity and greater unevenness in fruit maturation, which negatively influence coffee beverage quality.

The clones BRS 3213, BRS 3210, and BRS 2299, which stand out for their good agronomic performance according to Moraes et al. (2020), had less potential for producing 'fine' coffee. These clones presented less prominent nuances and were characterized as predominantly neutral flavored beverage, with short finish. Pleasant finishing and short-lasting residual effects are desired characteristics in coffee blends of *C. arabica* and *C. canephora* species (Moura et al., 2007).

Environmental factors, including soil, altitude, cultivar, management practices, ripening and processing practices, interact with each other and affect coffee beverage quality at different intensities (Verdin Filho et al., 2016; Lemos et al., 2020; Pereira et al., 2019). Besides subsidizing plant selection, our findings highlight that genotypic (clones) and genotype x environment interaction effects are significant to coffee drink quality.

Given this scenario, genotype and environment interactions may promote unpredictable changes in beverage quality of genotypes grown in different environments. Thus, selection of clones must consider both high drink quality and greater stability in different environments.

Conclusion

Genotype and environment interaction influenced the expression of beverage quality of the evaluated *Coffea canephora* genotypes in the five environments of the western Amazon (Brazil). The clones BRS 2314, BRS 3220, BRS 1216, 11, 15, 17, and 19 were classified as ideal genotypes, with the best performances for beverage quality in all the environments. The clone BRS 2314 showed good adaptability and stability, with potential for production of specialty coffees in all the evaluated environments. The clones BRS 1216 and BRS 3220 also showed favorable characteristics of beverage quality, but with less stability among the environments.

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