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Research Article

Characterization of *Coffea canephora* Clones and Analysis of Genetic Correlations

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Abstract

The aim was to characterize *Coffea canephora* clones from Incaper active germplasm bank (BAG), analysing morphoagronomic characteristics and investigating genetic correlations to improve indirect selection. The BAG, at the Bananal do Norte Experimental Farm in Cachoeiro de Itapemirim, ES, was set up in 2017 with 500 accessions. In 2019 and 2020, 217 accessions were evaluated for 17 traits, including plant shape, uniformity of maturity, fruit size, vigor, reaction to pests and diseases, and post-harvest yield parameters. Using the REML/BLUP method in the Selegen software and genetic correlations in the R software, genetic variability, resistance to pests/diseases, and genotypes with high yields were identified. Indirect selection was feasible, prioritizing correlated traits such as size, general scale, vigor and fruit size. Genotypes 139, 211, 287, 410, 411, 422 and 436 stood out in multiple aspects, indicating potential for the formation of varieties or controlled crosses.

Keywords: Selection; Indirect Selection; Mixed Models; Conilon/Robusta Coffee Farming

Abbreviations

BAG: Active Germplasm Bank; Incaper: Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural; Aw: Tropical Climate with a Dry Season; FS: Fruit Size; UM: Uniformity of Fruit Ripening; YP: Yield Per Plant; PS: Plant Size; VV: Vegetative Vigor; IR: Incidence of Rust; IC: Incidence of Cercospora Leaf Spot; DB: Drying Out of Plagiotropic Branches; GS: General Scale; IMI: Incidence of Mining Insects; DI: Degree of Inclination; ICR: Incidence of Citrus Mealybug; TS: Top Sieve; BS: Bottom Sieve; CF: Coconut Fruits; PF: Pounding Grains; REML: Restricted Maximum Likelihood; BLUP: Best Unbiased Linear Prediction; LRT: Likelihood Ratio Test

Introduction

Coffee growing is one of the main agricultural activities in the world and is carried out by the most diverse groups of farmers, ranging from family farmers to large producers. It is estimated that more than 125 million small farmers in coffee-producing regions around the world earn direct or indirect income along the coffee production chain from cultivation to marketing [12]. Coffee species belong to the genus *Coffea* of the Rubiaceae family and are grown mainly in tropical regions of the globe [4,15]. The species *Coffea canephora* Pierre ex A. Froehner is native to lowland African rainforests stretching from Guinea in West Africa across the Congo River Basin to Uganda in East Africa [8]. The genus has 130 known species [9] and the coffee market is centered on the species, *Coffea arabica* (arabica coffee tree) and *Coffea canephora* (conilon/robusta coffee tree).

Coffea canephora is a diploid species (2n = 22) with cross-pollination [2] and compared to arabica coffee tree, conilon coffee tree has higher productivity, higher caffeine content, superior development at lower altitudes and better tolerance to biotic and abiotic stresses [7]. In order to develop new varieties, it is necessary to exploit ample genetic variability with properly identified genotypes for direct selection and evaluation in competition trials or the design of controlled crosses to optimize heterosis. Clonal evaluation is a methodology used in many breeding programs to assess genetic variability and select high-yielding clones [29,33]. Superior clones are fundamental in breeding programs for the formation of hybrid cultivars and/or direct variety formation [2]. The lack of information on the agronomic and genetic parameters of the clones under study makes it difficult to select them and incorporate them into breeding programs [2].

The continuous development of coffee varieties requires that the sources of genetic variation within and between genotypes are correctly estimated [16]. In any crop improvement program, knowing the genetic properties of the target traits and their associations is a prerequisite for establishing a successful selection program [2]. Correlation estimates in plant breeding are important because they can help detect associations between target traits, identify new parental combinations in the development of improved varieties, and identify redundancy in trait measurements [37].

Therefore, given the need to optimize the process of developing new varieties of *Coffea canephora*, this work aimed to characterize genotypes from Incaper active germplasm bank in relation to 17 morphoagronomic characteristics relating to production, reaction to pests and diseases and post-harvest yield parameters, as well as estimating the genetic correlations between these characteristics in order to optimize future selection processes through indirect selection.

Materials and Methods

The data collection of this work took place in the Active Germplasm Bank (BAG) established in the Bananal do Norte experimental farm of Incaper, located in the municipality of Cachoeiro de Itapemirim, in the state of Espírito Santo, Brazil (20º45'S, 41º17'W) at 140 meters of altitude. The climate of the region is classified as Aw by Köppen-Geiger. The soil is classified as dystrophic Red-Yellow Latosol. The region presents annual rainfall of 1,200 mm, an average annual temperature of 23 °C and undulating topography.

The BAG was planted in this location in May 2017, at a spacing of three meters between lines and 1.5 meters between plants with 500 accessions and three plants for accession, surrounded by a borderline with different genotypes. Fertilization management follows the recommendation of the fertilization and liming manual for the State of Espírito Santo [23]. Cultural and phytosanitary management were carried out according to the requirement of the crop following the current recommendations for conilon coffee tree [13].

In years, 2020 and 2021 217 BAG accessions (genotypes) were evaluated in relation to 17 agronomic characteristics described below

- **Fruit size (FS):** Phenotypic evaluation of fruit size in the field, estimated using a scale of scores ranging from 1 to 5, following the list of descriptors of the National Service for the Protection of Cultivars, which presents the classes very small, small, medium, large and very large, respectively [18].
- **Uniformity of fruit ripening (UM):** Phenotypic evaluation of the uniformity of ripening of the fruit picked during the harvest, with grade 1 given to genotypes with all ripe fruit; grade 2 to genotypes with ripe and green fruit; grade 3 to genotypes with ripe, green and dry fruit.
- **Yield per plant (YP):** Coffee fruit production per plant estimated in kilograms (kg pl^{-1}).
- **Plant size (PS):** Phenotypic assessment of plant size using a scale of scores from 1 to 3, with 1 being low, 2 intermediate and 3 high. For standardization purposes, clone 02/Incaper, which is medium-sized, and clone 04/Incaper, which is tall, were taken as references.
- **Vegetative vigor (VV):** Phenotypic evaluation on a scale of scores from 1 to 10 on the level of acceptance of the genotype required by coffee growing according to vegetative vigor, where: score 1 very weak; score 3 weak; score 5 intermediate; score 7 vigorous; and score 10 excellent vigor.
- **Incidence of rust (IR):** Caused by the fungus *Hemileia vastatrix* Berk. & Br and evaluated with a scale of scores ranging from 1 to 9 where: score 1 is attributed to asymptomatic plants; score 3 presence of few sporulations; score 6 sporulations plus an onset of defoliation; score 7 sporulations and severe defoliation; and score 9 sporulations and high-level defoliation causing plant depletion.
- **Incidence of cercospora leaf spot (IC):** Caused by the fungus *Cercospora coffeicola* Berk. & Cooke and assessed using a phenotypic scale of scores ranging from 1 to 9 where: score 1 is attributed to asymptomatic plants; score 3 presence of few lesions on leaves; score 6 lesions on leaves and fruit; score 9 high level of lesions on leaves and fruit plus severe plant depletion.
- **Drying out of plagiotropic branches (DB):** A joint phenotypic evaluation of a series of biotic and abiotic factors that cause the loss of leaves at the ends of plagiotropic branches. It is evaluated on a scale of scores from 1 to 9 where: score 1 is assigned to plants with no visible symptoms; score 3 to plants with few dry branches; score 5 moderate level of dry branches; score 7 high level of dry branches indicating plant impoverishment; and score 9 very severe symptoms indicating possible elimination of the plant.
- **General scale (GS):** Phenotypic evaluation on a scale of scores from 1 to 10 on the level of acceptance of the genotype for application in coffee growing: score 1 attributed to genotypes

with a very poor phenotype; score 3 poor; score 5 intermediate level of acceptance; score 7 good phenotypic evaluation; and score 10 excellent phenotype.

- **Incidence of mining insects (IMI):** Phenotypic evaluation on a scale of scores from 1 to 9 on the level of severity of the attack by the insect *Leucoptera coffeella*, where: score 1 no leaves attacked; score 3 few leaves with the presence of necrotic mines; score 6 many leaves attacked with defoliation of the plant; and score 9 defoliation causing depletion of the plant.
- **Degree of inclination (DI):** Assessed using a grading scale in which: grade 1 is assigned to genetic materials with an erect growth habit with 1 to 35% inclination of the orthotropic branches; grade 2 genotypes with a semi-erect growth habit with 36 to 50% inclination of the orthotropic branches; and grade 3 genotypes with a prostrate growth habit with 51 to 100% inclination of the orthotropic branches.
- **Incidence of citrus mealybug (ICR):** Phenotypic assessment of the level of severity of damage and the presence of the rosette mealybug (*Planococcus citri*; P. minor) on a scale of scores from 1 to 5 where; score 1 is attributed to the absence of the pest; 2 identification of few insects and no economic damage; 3 beginning of economic damage; 4 high infestation with easy identification of the insects associated with fruit drop and the presence of fumagina; and 5 severe infestation with fruit drop, loss of beverage quality and high level of fumagina.
- **Percentage of fruit float (float):** Assessment of the percentage of ripe floating fruits in a sample of 100 ripe fruits (%).
- **Top sieve (TS):** Percentage of pounding grains with 12% moisture separated on a classificatory sieve with a mesh equal to or greater than 14, expressed as a percentage (%).
- **Bottom sieve (BS):** Percentage of pounding grains with 12% moisture separated on a classificatory sieve with mesh less than 14, expressed as a percentage (%).
- **Yield of field fruits:** Estimate of the yield of ratio field fruits for coconut fruits (CF) and ratio field fruits for pounding grains (PF). Coconut coffee and pounded coffee at 12% moisture and yields expressed as a percentage (%).

Data analysis was obtained by using the restricted maximum likelihood method and best unbiased linear prediction (REML/BLUP), and the Selegen software [26], applying the basic repeatability model without delineation

$$y = X_m + W_p + e$$

Where y is the data vector, m vector of measurement effects (fixed) added to the general average, p is the vector of permanent plant effects, genotypic effect plus permanent environmental effect (random) and e is the vector of residuals (random). The capital letters represent the incidence matrices for these effects.

Based on this model the variance components were estimated: (σ_p^2) permanent phenotypic variance between plants (genotypic + environmental from one crop to another); (σ_t^2) temporary environment variance; (σ_{phen}^2) individual phenotypic variance; (ρ) individual repeatability; (ρ_m) repeatability of the average of m harvests; (A_{cm}) selection accuracy based on the average of m harvests; (μ) overall experiment average.

The significance of the random effect of the statistical model was tested by deviance analysis using the likelihood ratio test (LRT) according to the following expression

$$LRT = -2\ (\ LogL - LogL_R\ )$$

Where, Log L is the logarithm of the maximum (L) of the restricted likelihood function of the full model; and Log LR is the logarithm of the maximum (LR) of the restricted likelihood function of the reduced model (without the effect being evaluated). The LRT was analyzed considering the chi-square test with a degree of freedom at 1, 5 and 10 % of significance.

Based on the estimated genetic values, the ten best genotypes for each trait were identified. A genetic correlation analysis was carried out for the traits under study. Estimates of the genetic values, variance components and significance of the effects were carried out using the selegen software [26]. The genetic correlations were carried out in the R software [25] in the 'PerformanceAnalytics' package [23].

Results and Discussion

The estimated variance components and the genotypic average of the characteristics evaluated are shown in Table 1. The lowest accuracy and average repeatability values were for the IMI trait and the highest values for PH. According to the classification proposed by [27], the FS, TS, BS, IR and PH traits have high accuracy, PF, DI, GS, IC, YP and VV moderate accuracy and the others low accuracy. According to the classification proposed by the same authors, average repeatability can be described as high for the IR and PH traits, moderate for PF, DI, GS, IC, YP, VV, FS, TS and BS and low for the others. [1] studying populations of conilon coffee trees from the conilon, robusta and hybrid botanical groups, using a complete block design, estimated accuracy values of: 0.89, 0.87 and 0.05 for fruit size; 0.67, 0.59 and 0.55 for yield; 0.56, 0. 59 and 0.67 for plant size; 0.7, 0.58 and 0.6 for vegetative vigor; 0.86, 0.75 and 0.39 for rust incidence; and 0.78 and 0.75 for cercospora incidence in individuals from the conilon, robusta and hybrid groups respectively. The estimated accuracy of FS was higher than that obtained for the hybrid population. The YP and PH traits obtained higher accuracy values than those reported. The accuracy of VV and IR was close to the estimated value for the conilon population and higher than the estimates for the robust and hybrid populations. The accuracy of IC was lower than the reported results.

Component	FS	UM	YP	PH	VV	IR	IC	DPB	GS
	0.2374	0.0718	1.8805	0.3736	0.3119	1.9400	0.4078	0.1837	0.2422
	0.4033	0.4642	4.1769	0.2058	0.6551	2.3185	0.9126	1.7427	0.6486
	0.6407	0.5361	6.0574	0.5794	0.9670	4.2585	1.3204	1.9264	0.8908
ρ	0.3706	0.1340	0.3105	0.6449	0.3226	0.4556	0.3088	0.0954	0.2719
	0.5408	0.2363	0.4738	0.7841	0.4878	0.6260	0.4719	0.1741	0.4275
A_{cm}	0.7354	0.4861	0.6883	0.8855	0.6984	0.7912	0.6870	0.4173	0.6539
μ	2.4194	2.1567	4.8765	1.8041	5.8157	3.7719	3.4793	3.1359	5.3065
Component	IMI	DI	ICM	FLOAT	TS	BS	CF	PF	-
	0.0108	0.1161	0.0774	11.9820	145.3621	149.4469	0.0002	0.0004	-
	0.9008	0.3354	1.1578	118.7854	226.3324	231.6042	0.0018	0.0014	-
	0.9115	0.4515	1.2352	130.7674	371.6945	381.0511	0.0020	0.0018	-
ρ	0.0118	0.2572	0.0627	0.0916	0.3911	0.3922	0.1223	0.2028	-
	0.0234	0.4091	0.1180	0.1679	0.5623	0.5634	0.2179	0.3373	-
A_{cm}	0.1529	0.6396	0.3435	0.4097	0.7498	0.7506	0.4668	0.5808	-
μ	3.2719	1.6912	2.7488	6.6822	35.9557	64.4422	0.4287	0.2184	-

Table 1: Estimates of variance components genetic and environmental parameters for the following characteristics: Fruit size (FS), Uniformity of fruit ripening (UM), Yield per plant (YP), Plant size (PS), Vegetative vigor (VV), Incidence of rust (IR), Incidence of cercospora leaf spot (IC), Drying out of plagiotropic branches (DB), General scale (GS), Incidence of mining insects (IMI), Degree of inclination (DI), Incidence of citrus mealybug (ICR), Percentage of fruit float (Float), Top sieve (TS), Bottom sieve (BS), Yield of ratio field fruits for coconut fruits (CF) and ratio field fruits for pounding grains (PF). Permanent phenotypic variance between plants (genotypic + environmental from one crop to another); : temporary environment variance; : individual phenotypic variance; ρ: individual repeatability; : repeatability of the average of m harvests; A_{cm}: selection accuracy based on the average of m harvests; μ: overall experiment average.

In a study of eight half-sibling families of *Coffea canephora* from Incaper recurrent selection program during the 2013 and 2014 harvests, accuracy values of 0.67 were estimated for grain size, 0.69 for yield, 0.73 for plant size, 0.47 for vegetative vigor and 0.70 for degree of plant inclination [5]. With the exception of the YP trait, which was slightly lower, the others stand out as higher than the values estimated by [4]. In a study on the intercropping of conilon coffee with banana (Musa sp.), pupunheira (Bactris gasipaes Kunth) and agroforestry systems with gliricidia (Gliricidia sepium Jacq. Steud) and ingá (Inga edulis Mart), accuracy values for productivity were estimated at 0.1878, 0.2396, 0.3624 and 0.3547, respectively [31]. The accuracy for the YP trait was 0.6883, a value 1.90 to 3.67 times higher than those obtained by [31] who used the same statistical design.

The Deviance analysis presented in Table 2 shows that the permanent phenotypic variance, which aggregates the genetic variance plus the permanent environmental variance from one harvest to the next, was significant for most of the traits under evaluation. Only the UM trait was significant at 5%, the DPB, IMI, ICM, FLOAT and CF traits were non-significant, and the others were significant at 1%. Based on the accuracy, average repeatability and Deviance values, it is possible to identify candidate genotypes in the database for controlled crosses and, or the composition of experimental trials to select clones for the formation of Coffea canephora varieties. Although the permanent phenotypic variance encompasses the genetic and environmental effects, it is still possible to make valuable inferences in the pre-breeding stage, in the process of identifying, classifying and selecting genotypes for various purposes. Significant effects of genetic parameters for coffee growing estimated by Deviance analysis are reported in the literature as in the works by [1,19,31,32].

The analysis of genetic correlations identified high values of associations between the traits evaluated, with significances of 0.1, 1 and 5%, as shown in Figure 1. The highest correlation value observed was between the traits CF and PF and VV and GS with a value of 0.67 at 0.1%. The second highest correlation value was 0.59 at 0.1% between YP and GS and the third highest correlation value was between the FS and TS characteristics, 0.53 at 0.1%. The lowest correlation value was -0.99 at 0.1% between the TS and BS traits. The second lowest correlation value was -0.57 at 0.1% between VV and DPB and the third lowest correlation value was -0.54 at 0.1% between GS and DPB. Significant effects of genetic correlations have been identified in other research with conilon coffee trees, as reported by other authors such as [2,10,11,32].

These values indicate that indirect selection is a viable option for genetic improvement of the conilon coffee tree, with a strong

Characteristics	Deviance		LRT
	VPP	CM	VPP
FS	250.4232	218.5143	31.9089**
UM	173.4175	169.5037	3.9138*
YP	1220.9206	1199.0281	21.8925**
PH	206.9804	90.8612	116.1192**
VV	428.2516	404.5193	23.7323**
IR	1068.6954	1018.4528	50.2426**
IC	562.8360	541.1852	21.6508**
DPB	725.9721	724.0010	1.9711ns
GS	392.7994	376.2098	16.5896**
IMI	402.5690	402.5409	0.0281ns
DI	99.2889	84.5088	14.7801**
ICM	533.9804	533.1321	0.8483ns
FLOAT	2548.0537	2546.2345	1.8192ns
TS	2958.3649	2922.8110	35.5539**
BS	2996.0445	2960.4734	35.5711**
CF	-2239.9319	-2243.1876	3.2557ns
PF	-2286.3547	-2295.3985	9.0438**

Table 2: Deviance and likelihood ratio test (LRT) for the following characteristics: Fruit size (FS), Uniformity of fruit ripening (UM), Yield per plant (YP), Plant size (PS), Vegetative vigor (VV), Incidence of rust (IR), Incidence of cercospora leaf spot (IC), Drying out of plagiotropic branches (DB), General scale (GS), Incidence of mining insects (IMI), Degree of inclination (DI), Incidence of citrus mealybug (ICR), Percentage of fruit float (Float), Top sieve (TS), Bottom sieve (BS), Yield of ratio field fruits for coconut fruits (CF) and ratio field fruits for pounding grains (PF).

CM: complete model; VPP: permanent phenotypic variance. ns, * and **: not significant, significant at 5% and significant at 1%, respectively, based on the chi-square test with 1 degree of freedom.

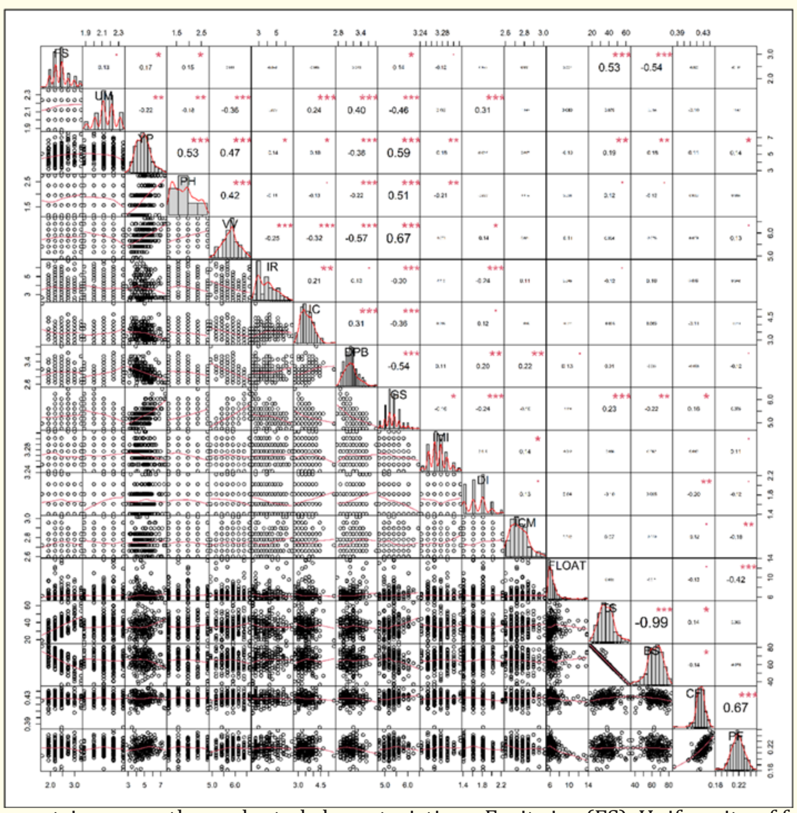

Figure 1: Genetic correlation matrix among the evaluated characteristics: : Fruit size (FS), Uniformity of fruit ripening (UM), Yield per plant (YP), Plant size (PS), Vegetative vigor (VV), Incidence of rust (IR), Incidence of cercospora leaf spot (IC), Drying out of plagiotropic branches (DB), General scale (GS), Incidence of mining insects (IMI), Degree of inclination (DI), Incidence of citrus mealybug (ICR), Percentage of fruit float (Float), Top sieve (TS), Bottom sieve (BS), Yield of ratio field fruits for coconut fruits (CF) and ratio field fruits for pounding grains (PF). °, *, ** and ***: significant at 10%, significant at 5%, significant at 1%, significant at 0.1% respectively.

emphasis on the GS trait. By selecting genotypes based on an ideal phenotype, which is proposed by this trait, the breeder is indirectly selecting coffee trees with larger fruit size, better uniformity of ripening, high fruit production per plant, higher size, superior vigor and lower incidence of pests and diseases. At the same time, it can be seen that there is a correlation that could be explored between the size of the fruit identified in the field and the percentage of beans with a higher sieve. Another association between traits suitable for indirect selection is the genetic correlation between IR and IC, of 0.21 at 1% significance. Other studies have already shown a positive genetic correlation between rust (*H. vastatrix*) and cercospora (*C. coffeicola*), as in the work by [20].

The process of developing new varieties implies the need to know the relationship between the characteristics under study [21]. Genetic correlation optimizes the indirect selection process [28]. Another advantage of using correlations is the elimination of redundant characteristics. It is emphasized that morphological and biometric data are useful for breeding programs [17,35]. Following this line of reasoning in the construction of selection indices for conilon coffee, greater weight should be given to YP, GS and FS, as they will provide indirect gains for other important traits. Additionally, the BS trait can be discarded, as it is redundant with TS.

The PH and VV traits should also be prioritized when designing the indices, as they were correlated with YP and GS. Among the morphological characteristics studied in coffee growing, plant height and vegetative vigor are the most closely related to production [2,3,22,34]. The height of the coffee tree and the canopy has been shown to have a positive correlation with important characteristics such as the total leaf area of the plant, the volume of the canopy and the leaf area index [32]. [10] estimated a correlation of 0.333 between plant yield and plant height in a study evaluating half-sibling families of *Coffea canephora* in Ghana.

By applying the BLUP methodology to each trait under study, a selection index is simultaneously obtained by ranking the genotypes based on their genetic values (Table 3). Among the genotypes highlighted as superior for the traits under study, it can be seen that some were selected as superior for more than one trait (Table 4). Genotypes 139, 211, 287, 410, 411, 422 and 436 are those that stood out in at least four characteristics. A major highlight was genotype 422, which was superior in seven of the 17 characteristics evaluated. Based on the results in Tables 3 and 4, it will be possible to guide controlled crosses in *Coffea canephora* with the aim of developing productive varieties with large grains, resistant to pests and diseases and with a good post-harvest yield. There is therefore a large source of genetic variability to be exploited by Incaper, either to create new genotypic combinations through controlled crosses or to create new varieties through clonal selection. Incaper genetic variability has already been demonstrated by other authors [14,30].

	Trait								
Order	**FS**	**UM**	**YP**	**PH**	**VV**	**IR**	**IC**	**DPB**	**GS**
1	14	392	66	4	2	445	421	218	139
2	102	358	422	13	68	436	411	445	151
3	169	348	287	23	139	422	331	303	422
4	248	334	139	49	227	421	311	299	66
5	287	309	152	50	303	412	291	298	91
6	288	300	79	65	304	411	290	287	154
7	305	270	317	66	308	410	160	228	155
8	342	251	68	79	392	406	144	211	211
9	410	228	70	83	422	397	143	163	287
10	436	211	74	89	49	170	139	161	317
Order	IMI	DI	ICM	FLOAT	TS	BS	CF	PF	-
1	246	422	348	299	76	76	220	276	-
2	130	421	342	282	422	422	59	59	-
3	124	392	328	251	436	436	246	347	-
4	65	366	324	228	411	411	347	364	-
5	62	364	317	174	410	410	364	7	-
6	49	355	291	86	336	336	174	109	-
7	43	353	220	83	59	59	173	308	-
8	32	351	211	73	343	343	53	340	-
9	445	343	180	50	74	388	151	258	-
10	436	342	175	335	388	288	7	50	-

Table 3: Classification of the ten best genotypes based on the best unbiased linear prediction methodology for the following characteristics: Fruit size (FS), Uniformity of fruit ripening (UM), Yield per plant (YP), Plant size (PS), Vegetative vigor (VV), Incidence of rust (IR), Incidence of cercospora leaf spot (IC), Drying out of plagiotropic branches (DB), General scale (GS), Incidence of mining insects (IMI), Degree of inclination (DI), Incidence of citrus mealybug (ICR), Percentage of fruit float (Float), Top sieve (TS), Bottom sieve (BS), Yield of ratio field fruits for coconut fruits (CF) and ratio field fruits for pounding grains (PF).

Genotype	Characteristic	Genotype	Characteristic
7	CF and PF	288	FS and BS
49	PH, VV and IMI	291	IC and ICM
50	PH, FLOAT and PF	299	DPB and FLOAT
59	TS, BS, CF and PF	303	VV and DPB
65	PH and IMI	308	VV and PF
66	YP, PH and GS	317	YP, GS and ICM
68	YP and VV	336	TS and BS
74	YP and TS	342	DI and ICM
76	TS and BS	343	DI, TS and BS
79	YP and PH	347	CF and PF
83	PH and FLOAT	348	UM and ICM
139	YP, VV, IC and GS	364	DI, CF and PF
151	GS and CF	388	TS and BS
174	FLOAT and CF	392	UM, VV and DI
211	UM, DPB, GS and ICM	410	FS, IR, TS and BS
220	ICM and CF	411	IR, IC, TS and BS
228	UM, DPB and FLOAT	421	IR, IC and DI
246	IMI and CF	422	YP, VV, IR, GS, DI, TS and BS
251	UM and FLOAT	436	FS, IR, IMI, TS and BS
287	FS, YP, DPB and GS	445	IR, DPB and IMI

Table 4: Genotypes selected of *Coffea canephora* as superior for two or more characteristics according to the BLUP method evaluated in the Incaper Active Germplasm Bank during the 2020 and 2021 harvests in Cachoeiro do Itapemirim, Espírito Santo. Fruit size (FS), Uniformity of fruit ripening (UM), Yield per plant (YP), Plant size (PS), Vegetative vigor (VV), Incidence of rust (IR), Incidence of cercospora leaf spot (IC), Drying out of plagiotropic branches (DB), General scale (GS), Incidence of mining insects (IMI), Degree of inclination (DI), Incidence of citrus mealybug (ICR), Percentage of fruit float (Float), Top sieve (TS), Bottom sieve (BS), Yield of ratio field fruits for coconut fruits (CF) and ratio field fruits for pounding grains (PF).

Conclusion

Incaper active germplasm bank has genetic variability to be exploited. Sources of resistance to pests and diseases have been identified, as well as genes responsible for controlling traits of interest such as grain size, size, vigor and high post-harvest yield. This information will be exploited in controlled crosses and gene identification work. The indirect selection process is feasible and recommended due to the high levels of genetic correlation and significance. Characteristics such as general scale, vigor, size and fruit size in the field should be evaluated in breeding programs because they are correlated with other characteristics of interest, many of which have low heritability and therefore lower selection gains. In addition, the correlation analysis shows that sieve analysis in coffee breeding programs should focus on quantifying the proportion of beans with sieve 14 or higher, as this characteristic is inversely proportional and approximately linear to sieve with the proportion of beans with sieve 13 or lower. Genotypes 139, 211, 287, 410, 411, 422 and 436 stand out for their superiority in at least four different characteristics and are therefore strong candidates for the formation of varieties or crosses.

Conflict of Interest

There is no financial interest or any conflict of interest related to the subject matter discussed.

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