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REVIEW

Recommendation of *Coffea arabica* genotypes by factor analysis

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Abstract Responsible for approximately 70% of the world's coffee exports, Brazil is increasingly concerned about the quality of the coffees produced, given the growing demand for so-called specialty coffees. With this, the breeders need, besides the agronomic characteristics, to consider the physical and sensorial quality of the beans in the breeding programs. However, the greater the number of characteristics to be considered in the selection process, the higher the difficulty in selecting superior genotypes. In this context, multivariate analyzes can help to overcome this problem. In the light of the facts, the objective was to select *Coffea arabica* genotypes with a high simultaneous potential of variables of commercial interest, in three municipalities belonging to the Matas de Minas region—MG, Brazil, through factor analysis, using their scores as criteria or indices of selection for genotype identification. Multivariate analyzes were performed for each environment individually and, by commonality, three factors were established for each environment. The factors were interpreted as sensorial quality, sieve and vigor, in a similar way in the three environments. The interaction genotype by environment was maintained even after the summary of the variables in factorial complexes. The genotypes Catucaí Amarelo 24/137 and H419-3-3-7-16-4-1 excelled in relation to the factorial complexes, besides showing good adaptability and stability, consequently, they present great potential to improve the coffee production performance in the region of Matas de Minas.

Keywords Adaptability and stability · Ideotype · Multivariate analysis · Network of correlations · Sensorial quality

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Introduction

Brazil is the world's largest producer and exporter of coffee, accounting for approximately 70% of world exports. In recent years there has been increasing demand for the best quality coffees, so-called specialty coffees. Specialty coffees, in general, differ from common coffees by the absence of defects and by presenting distinct qualitative attributes, under the effect of genotype, management and interaction Genotype × Environment, which determines the intrinsic quality of the beans. In the specialty coffee market, the more differentiated a particular coffee is and, of course, the better its sensory quality, the greater its value.

The state of Minas Gerais, Brazil, occupies a prominent place in the production of one of the most cultivated species, the Arabica coffee (*Coffea arabica* L.), being the state responsible for approximately 50% of the Brazilian crop. One of the main producing regions is the Matas de Minas region, which presents characteristics of marked relief and climate favorable to the crop (Barbosa et al. 2010; Zaidan et al. 2017). In this way, it is of great importance that superior cultivars are developed, to the already existent, for that region. However, due to the effect of genotype and environment interaction, genotype recommendation should not be made only based on the average behavior observed in the different environments evaluated in the region, since some of the genotypes present better standards in specific environments (Cardoso et al. 2007; Silveira et al. 2012).

As in other species, the main objective of coffee breeding programs has always been to increase productivity. However, with the increase in the market demand, there is also a big concern about increasing the quality of the beverage produced (Ferreira et al. 2012). Thus, in addition to productivity, other characteristics such as maturation uniformity, maturation cycle, plant architecture, grain size increase, conversion between cherry and beneficiary coffee, reduction of mocha grains percentage and resistance to diseases should also be considered for the selection of superior genotypes.

In this way, the selection considering a set of variables is necessary, aiming at adequate gains, simultaneously, in all the characteristics (Ferreira et al. 2005). However, the higher the number of characteristics to be considered in the selection process, the greater the difficulty of the breeders in the selection of the superior genotypes, due to possible invalidities of the use of conventional statistical analyzes. Using multivariate analyzes, so that there is no loss of data set information and facilitating interpretations of the results, may help to circumvent this problem. Studies on the recommendation of superior genotypes have been carried out based on multivariate statistics, for example those presented in Bertini et al. (2010), Benites et al. (2011) and Nakamura et al. (2013).

A multivariate approach that allows selection of genotypes for various traits and without loss of biological significance is factor analysis, which studies the structure of variability of variables. In the factor analysis we try to understand which common and specific factors act by explaining the set of variables and, in a second moment, isolate these common factors to summarize the information in a smaller number of complexes. Thus, in this analysis it is possible to find determinant common factors of a subset of variables, usually with high correlation within the subgroup that can be established and used as a selection criterion allowing gains by joint selection of variables. Each factor generated has a biological meaning, according to the set of correlated variables that they explain, making it possible to perform the recommendation of genotypes based on the factors.

The objective of this work was to select *C. arabica* genotypes with simultaneous high potential for commercial interest characteristics, for the region of Matas de Minas—MG, Brazil, through the analysis of factors, using factors such as selection indexes for identification of genotypes.

Materials and methods

The field experiments are installed in three municipalities located in the Matas de Minas region, in the State of Minas Gerais—Brazil: Senhora de Oliveira (20°50′32″S, 43°23′34″W, altitude 910 m), Araponga (20°38′48″S, 42°30′41″W, altitude 1100 m) and Paula Cândido (20°48′52″S, 42° 58′37″W, altitude 680 m). The spacings were 2.80 × 0.70, 2.50 × 0.60 and 2.50 × 0.50 m in Senhora de Oliveira, Araponga and Paula Cândido, respectively. The statistical design adopted was randomized blocks, with three replications and plots of 50 or 60 plants.

Nine cultivars and one elite progeny resistant to rust were evaluated, as well as a susceptible cultivar, which was used as control. The field experiments were conducted according to the technical recommendations normally used in the cultivation of arabica coffee (Ribeiro et al. 1999; Sakiyama et al. 2015), with the exception of the chemical control of rust, which was not carried out.

The 26 evaluated characteristics were: Before harvest—Vigor (Vig), average maturation cycle (CMT), maturation uniformity (UMT), fruit size (TFr), incidence of cercosporiosis (Cer), incidence of rust (Fer), plant height (APl), top diameter (DCo), stem diameter (DCa); after hasvest—Production (Prod), defects, sieves (P19, P18, P17, P16, P15, P14), mocha grains (MK), sieve bottom (FUN); and sensory attributes—Fragrance/aroma (FraAr), taste (Sbr), acidity (Acd), body (Crp), finalizes (Fnlz), equilibrium (Equil) and final (Finl).

The grain samples were composed only of cherry grains, that is, completely mature, in order to evaluate the maximum potential of the quality of the drink offered by the genotypes evaluated. Also the lower density fruits, pips and bad granates were eliminated from the samples. In the drying process the grains were spread in sieves with an area of 1 m^2, in a suspended terrarium, to dry in full sun, until the grains reached 11% of umidity (bu). After drying, the parchment grains were packed in double sheet kraft paper bags for a rest period of 30 to 40 days, to standardize the moisture content in the grains. After this period, the samples were benefited and placed in impermeable plastic bags and sent to the physical evaluations of the grains and the sensorial quality of the beverage. The sensorial analyzes of the beverage were carried out by three tasters, following the protocol of the Specialty Coffee Association of America (SCAA 2015).

The coffees were classified in flat beans and mocas, evaluating the retention percentage of each sieve individually and also the grains retained in the bottom of the sieve. The sieves used were from numbers 14–19 for flat grains. The classification of coffee defects was carried out from 300 g of sample according to the Regulamento Técnico de Identidade e de Qualidade para a Classificação do Café Beneficiado Grão Cru (Technical Regulation of Identity and Quality for the Classification of Granted Raw Coffee) (BRASIL 2003), counting the number of defective grains which values were expressed in equivalence of defects.

The analyzes of variance of the variables of sensorial quality were realized in triple factorial scheme, considering genotype as fixed effect and environment, taster and block as random effect. Analyzes of variance of the field and physical variables of the grains were performed in a double factorial scheme, according to the same model, but without taster effect.

$$Y_{ijkm} = \mu + G_i + E_j + T_k + (B + BT)/E_{jkm} + GE_{ij} + GT_{ik} + ET_{jk} + GET_{ijk} + \varepsilon_{ijkm},$$

where Y_ijkm: observed value of genotype i, in environment j, taster k and in block m; μ: average overall; G_i, E_j and T_k: effects of genotypes, environment and taster, respectively; GE_ij, GT_ik and ET_jk: effects of first order interactions between genotypes and environment, genotype and taster, and environment and taster; GET_ijk: effect of triple interaction between genotype, environment and taster; (B + BT)/E_jkm: block effect plus block interaction with taster, both within environment; and ε_ijkm: random error.

The characteristics were summarized in factors, by the multivariate technique of factor analysis, according to Cruz and Carneiro (2003). The factor analysis model used was:

$$X_j = I_{j1} F_1 + I_{j2} F_2 + \cdots + I_{jm} F_m + \varepsilon_j$$

where X_j is the jth evaluated characteristic, with j = 1, 2,… v; I_jk is the factorial load for the jth variable, associated with the kth factor, where k = 1, 2,… m; F_k is the kth common factor and ε_j is the specific factor.

The number of factors m was established so that the average commonality, that is, the average proportion of variance of the characteristics explained by the common factors reached about 70%. The interpretability of factors and the principle of parsimony were also used as criteria to define the number of factors to be adopted, as recommended by Mingotti (2005). In order to maximize the variability of the factor loads and to facilitate the better interpretation of the distribution of the variables in the respective factors, the *Varimax* rotation was used.

An auxiliary technique to visualize the associations between characteristics that led to the establishment of the common factors was the analysis and establishment of the correlation network (Rosado et al. 2017, 2018) constructed from Pearson's correlation matrix, which made it possible to visualize, explicitly, the pattern of relationship between the determinant variables in the explanation of the common factors used as selection criteria. The positive correlations between the variables were represented by green lines and the negative ones by red lines. The thickness of the lines was controlled applying a cut-off value of 0.5, where only | rij | $\geq$ 0.5 had their lines highlighted in a proportional way to the intensity of the correlation. The fine lines have correlations lower than the cutoff point of 0.5, with no highlighting distinguishing them.

After identifying the k factors (F_k) related to the variables X_j, the scores were predicted for each sample unit (genotypes) after rotation by the varimax method, for the selection of the superior genotypes based on latent interpretable variables (factors).

In order to classify the genotypes considering the previously created factors, centroids were created considering all possible combinations between the factors. These centroids were created based on the factor scores according to Table 1.

Subsequently, the genotypes were classified according to the minimum euclidean distance between genotype and the defined centroids. In this study, those centroids that had a favorable response in at least two factors were considered as ideotypes. Specifically, such ideotypes were represented by centroids I, II, III and IV (Table 1).

To verify the existence of interaction between the performance of the genotypes, considering the factorial scores, and the environments, the stability statistic by the Wricke method was calculated, called ecovalence (ωi), which is estimated by:

$$\omega_i = r\sum_j (Y_{ij} - \bar{Y}_{i.} - \bar{Y}_{.j} + \bar{Y}_{..})^2$$

Afterwards, Pearson's correlation of factor scores between the environments was calculated. Statistical analyzes were performed by the Genes portal (Cruz 2013), in integration with the R program (Cruz 2016).

Table 1 Centroids elaborated based on the combination of maximum and minimum values of the factors (scores). An example with three factors

Centroids	First factor	Second factor	Third factor
I (Ideotype)	Maximum	Maximum	Maximum
II (Ideotype)	Maximum	Maximum	Minimum
III (Ideotype)	Maximum	Minimum	Maximum
IV (Ideotype)	Minimum	Maximum	Maximum
V	Maximum	Minimum	Minimum
VI	Minimum	Maximum	Minimum
VII	Minimum	Minimum	Maximum
VIII	Minimum	Minimum	Minimum

Results and discussion

According to the analysis of individual variance, it was observed that most of the variables had a significant effect ($P < 0.05$) of the genotype x environment interaction (Supplementary Tables 1 and 2). The effects of GxA and genotype interaction did not present significant response to the variables yield, incidence of cercosporiosis, plant height, stem diameter, crown diameter and sieve bottom.

Normally the non-significant variables in the individual analysis are not used in subsequent analyzes, since variability among genotypes is indispensable for genetic progress (Rocha et al. 2018). However, considering the possibility of selecting genotypes from the combined selection of variables, since that factor analysis is aimed at grouping correlated variables, it is important to keep these variables in the dataset, both because of the importance of these variables for the improvement of coffee as well as the possibility of adding, in the multivariate context, valuable and correlated information in the phenotypic evaluations.

Thus, multivariate analyzes were performed for each environment individually. According to the average commonality close to 70%, three factors were established for each of the three environments, which, despite being composed by different variables in some factors, presented the same interpretability (Supplementary Tables 3, 4 and 5).

For the three environments, the first factor was interpreted as sensorial quality, since it was more influenced by variables related to sensory analysis. The second factor was interpreted as sieve and was more influenced by the variables referring to grains retained in sieves. The third factor was interpreted as vigor and was influenced by characteristics of health and vegetative vigor (Supplementary Tables 3, 4 and 5).

In the experiment in Araponga the sensorial quality factor grouped the following variables with respective factorial loads, Sieve 17 (− 0.8155), Sieve 14 (0.7017), Fragrance/Aroma (0.8873), Sabor (0.8513), Acidity (0.8087), Body (0.8534), Finalization (0.7125), Equilibrium (0.7978) and End (0.9236).

The sieve factor grouped the variables, defect (0.7610), sieve 19 (0.8165), sieve 18 (0.8554), sieve 16 (− 0.8894) and sieve 15 (− 0.8464). The vigor factor grouped the variables vigor (0.795942), cercosporiosis (− 0.79584) and rust (− 0.80144) (Supplementary Table 3).

In Paula Cândido the sensorial quality factor grouped the variables maturation uniformity (− 0.70752), taste (0.7363), acidity (0.7403), finalization (0.751263), balance (0.916392) and final (0.808769). The sieve factor grouped the variables size of fruit (− 0.8141), sieve 18 (0.7883), sieve 17 (0.7031) and sieve 14 (− 0.8389). The vigor factor grouped the variables rust (− 0.87587), stem diameter (0.862308), defects (− 0.70478) and sieve 19 (− 0.81445) (Supplementary Table 4).

In Senhora de Oliveira, the sensorial quality factor grouped the variables fragrance/aroma (0.9067), Taste (0.8848), Acidity (0.8758), Body (0.8612), Finalization (0.9052), Equilibrium (0.8940) and Final (0.9422). The sieve factor grouped the variables average maturation cycle (− 0.77831), defects (0.723051), sieve 19 (0.928833), sieve 18 (0.915892), sieve 16 (− 0.96475) and sieve 15 (− 0.88188). The vigor factor grouped the variables vigor (− 0.83799) and mocha grains (− 0.73915) (Supplementary Table 5).

Explanatory factors were also found by Ferreira et al. (2005), in the evaluation of 40 genotypes of *C. canephora*, in five harvests and two environments in the state of Espírito Santo. These authors did not evaluate the sensorial quality of the beverages, but obtained interpretable factors such as: Sieve, similar to that observed in the present study, Yield, Grain Type and Chocho. These results demonstrate that the variables evaluated in the improvement of coffee trees present a certain pattern of correlation between the variables and that can be summarized by means of common factors. In this way, the researcher can perform selection based on simplified variables complexes by factor analysis. In addition, these results indicate that, since it is impossible to perform all the evaluations at the same time, the researcher should give preference to those variables belonging to the same group of correlated variables and that the selection of variables of a factor is independent of the evaluations of variables of another factor.

The productivity characteristics (sc.ha-1), plant height, canopy diameter and sieve depth were not explained by any factor in all analyzes, as they reached values of factorial load lower than 0.7. On the other hand, the variables incidence of cercosporiosis, in the municipality of Senhora de Oliveira, and stem diameter, in Araponga, were both explained by the vigor factor in the respective environments (Supplementary Tables 3 and 5). This was possible due to the high correlation with other variables within the factors, making possible their selection (Fig. 1). This fact justifies and enables the non-exclusion of these variables for the realization of the analysis of factors.

From the correlation matrix it was possible to visualize larger correlations between the variables within the factors, mostly higher than 0.5 (|> 0.5|) and smaller correlations between variables belonging to different factors, as expected for the analysis result of factors (Fig. 1). This result also confirms the adequacy of the analysis, since the existence of correlations between the variables of the data set is important for the use of factor analysis, because the objective of the technique is to identify the correlation between the original variables (reference).

In the correlation network, it was verified that the correlations between the variables presented similar pattern in the three municipalities and the characteristics that did not present variability among the genotypes in the ANOVA can be explained by the factors, due to the high association among the variables within the factors, making possible the combined selection between these variables (Fig. 1).

The incidence to cercosporiosis, in the city of Araponga, showed a high and positive correlation with the incidence of rust and both with high and negative correlation with vegetative vigor. Thus, in this environment the genotypes with lower incidence of rust and cercosporiose presented consequently better vigor. In the municipality of Paula Cândido, the crown diameter variable presented high and negative correlations with the variables incidence to rust, number of defects and sieve 19 (Fig. 1).

Since three factors were formed, eight centroids were required for genotype classification. In this way, it was possible to identify the performance of each genotype in relation to the three factorial complexes. All the factors presented positive meaning for the desirable characteristics. Thus, the centroid projection was defined from the combinations of scores, where the maximum values of the scores were always the desirable references for each factor.

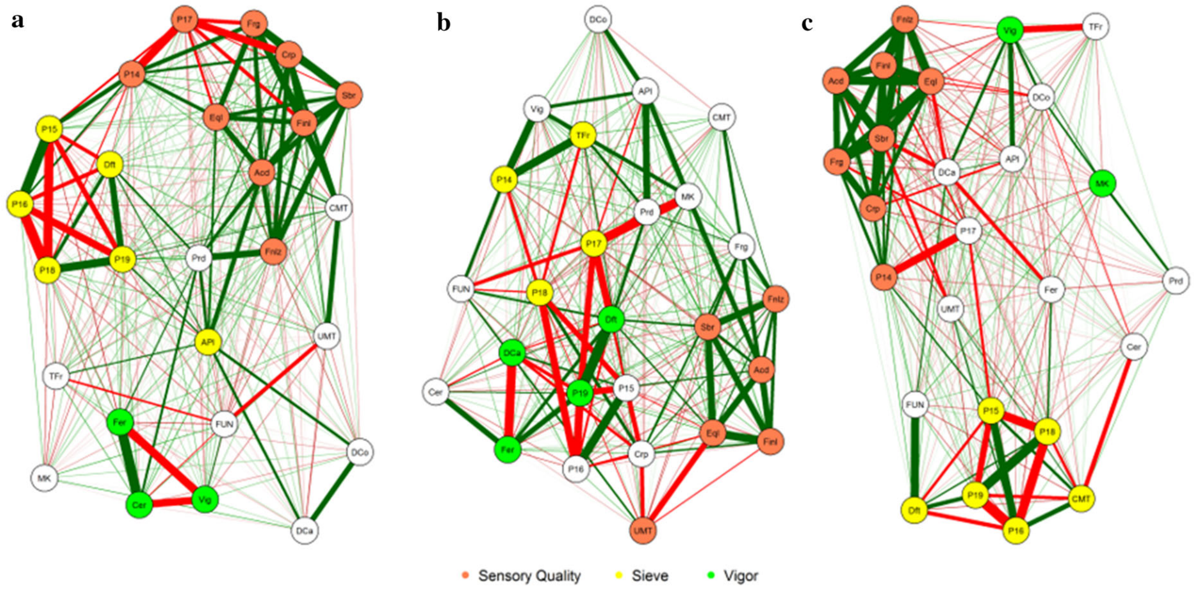

Fig. 1 Network of phenotypic correlations between of field variables vigor (Vig), yield in sacks/hectare (Prod), average maturation cycle (CMT), maturation uniformity (UMT), fruit size (TFr), incidence of cercosporiosis (Cer), incidence of rust (Fer), plant height (APl), crown diameter (DCo) and stem diameter (DCa). Physical variables of the grains: number of defects (Def), sieve size (P19, P18, P17, P16, P15, P14), grains retained at the bottom of the sieve (Fun) and moca grains and sensory attributes: fragrance/aroma (FrA), flavor (Sbr), acidity (Acd), body (Crp), finalization (Finlz), equilibrium (Eql), final (Fin) and total (Ttl), of genotypes in the municipalities of Araponga (a), Paula Cândido (b) and Senhora de Oliveira (c). Distributed in three factors: sensory quality, sieve and vigor, according to factorial loads of factor analysis

In the municipality of Araponga, only the H419-3-3-7-16-4-1 genotype was classified in the ideotype I, with favorable response for the three factors together. Other genotypes that showed good performance were the genotype Catucaí Amarelo 24/137 with favorable response to the sensorial quality and sieve factors, genotypes Catiguá MG1, Catiguá MG2 and Paraíso MG H419-1 for sensorial quality and vigor, and genotypes Catiguá MG3 and Pau -Brasil MG1 for sieve and vigor. In Paula Cândido, no genotype was classified in the favorable performance ideotype for the three factors together. However, genotypes Oeiras MG 6851, Pau-Brasil MG1, Sacramento MG1 and H419-3-3-7-16-4-1 were classified as a favorable response for quality and vigor and the genotype Catiguá MG3 for sieve and vigor. In Senhora de Oliveira, the genotypes Catiguá MG1, Catucaí Amarelo 24/137 and H419-3-3-7-16-4-1 showed desirable responses for the three factorial complexes, the genotypes Catuaí Vermelho IAC 144 and Oeiras MG 6851 for quality and sieve and the genotypes Catiguá MG2, Catiguá MG3, Paraíso MG H419-1 and Pau-Brasil MG1 for quality and vigor (Table 2).

This result demonstrates the genetic potential of the cultivars in which their majority presented satisfactory results for at least two factorial complexes in at least one evaluated environment. Highlight can be given to the genotype H419-3-3-7-16-4-1 which presented performance for the three factors in the municipalities of Araponga and Senhora de Oliveira and was the only genotype with performance for the factors of sensorial quality and vigor in the three environments evaluated.

By the analysis of adaptability and stability by the Wricke method, it was possible to observe that, even after the construction of the scores, the genotype interaction by environment was maintained (Fig. 2). Thus, genotype classifications were distinct among the three environments. Higher correlation values were observed between the scores of the Vigor factor and lower in the scores of the Sieve factor. The vigor factor score showed a correlation of 0.677 between the scores of the municipalities of Araponga and Senhora de Oliveira, 0.533 between Araponga and Paula Cândido and of 0.232 between Paula Cândido and Senhora de Oliveira. The Sieve factor scores had a correlation of 0.414 between the scores of the municipalities of

Table 2 Classification and Euclidean distance of *coffea arabica* genotypes for the centroids (Lower distances are highlighted in bold) in three municipalities belonging to the Matas de Minas region in Minas Gerais

Locality	Genotype	Classification	Centroids							
			I	II	III	IV	V	VI	VII	VIII
Araponga	Araponga MG1	VII	1.17	1.33	1.14	0.60	1.31	0.88	**0.56**	0.85
	Catiguá MG1	III	0.78	1.20	**0.29**	1.15	0.96	1.47	0.89	1.28
	Catiguá MG2	III	1.05	1.25	**0.34**	1.31	0.75	1.47	0.85	1.08
	Catiguá MG3	IV	0.73	1.24	0.97	**0.45**	1.39	1.10	0.77	1.26
	Catuaí Vermelho IAC 144	VIII	1.34	0.90	1.15	1.33	0.58	0.88	1.14	**0.55**
	Catucaí Amarelo 24/137	II	0.53	**0.49**	1.13	1.03	1.11	1.00	1.43	1.42
	Oeiras MG 6851	VIII	1.22	1.01	1.21	0.90	1.01	0.59	0.90	**0.59**
	Paraíso MG H419-1	III	0.90	0.99	**0.54**	1.14	0.68	1.22	0.89	0.98
	Pau-Brasil MG1	IV	0.78	0.94	0.87	**0.72**	1.01	0.89	0.82	0.97
	Sacramento MG1	VII	0.97	1.25	0.94	0.60	1.23	0.99	**0.55**	0.96
	H419-3-3-7-16-4-1	I	**0.54**	0.60	0.87	1.13	0.9	1.16	1.32	1.35
Paula Cândido	Araponga MG1	VI	0.80	0.86	1.28	0.56	1.27	**0.55**	1.15	1.19
	Catiguá MG1	VII	1.13	1.20	0.97	0.81	1.04	0.89	**0.56**	0.70
	Catiguá MG2	VII	1.42	1.67	1.01	1.01	1.34	1.37	**0.11**	0.89
	Catiguá MG3	IV	0.82	1.00	0.83	**0.74**	0.98	0.84	0.75	0.95
	Catuaí Vermelho IAC 144	VI	1.22	0.86	1.22	1.04	0.83	**0.51**	1.05	0.61
	Catucaí Amarelo 24/137	V	1.38	0.96	1.02	1.58	**0.20**	1.05	1.28	0.80
	Oeiras MG 6851	III	0.84	1.04	**0.71**	0.85	0.91	0.93	0.71	0.94
	Paraíso MG H419-1	VII	0.95	1.02	0.84	0.84	0.89	0.83	**0.71**	0.80
	Pau-Brasil MG1	III	0.64	1.14	**0.36**	1.19	0.99	1.34	1.06	1.42
	Sacramento MG1	III	0.74	1.25	**0.57**	0.84	1.13	1.20	0.70	1.22
	H419-3-3-7-16-4-1	III	0.66	0.86	**0.65**	0.98	0.81	0.94	0.97	1.11
Senhora de Oliveira	Araponga MG1	VIII	0.99	0.94	0.90	0.91	0.84	0.85	0.80	**0.74**
	Catiguá MG1	I	**0.40**	1.08	0.86	0.70	1.32	1.22	1.03	1.44
	Catiguá MG2	III	0.68	1.03	**0.41**	1.20	0.87	1.39	1.02	1.28
	Catiguá MG3	III	0.83	0.98	**0.49**	1.17	0.71	1.27	0.95	1.08
	Catuaí Vermelho IAC 144	II	0.76	**0.64**	1.09	0.82	1.01	0.72	1.13	1.06
	Catucaí Amarelo 24/137	I	**0.44**	0.56	1.09	1.09	1.15	1.15	1.48	1.52
	Oeiras MG 6851	II	1.12	**0.52**	1.16	1.35	0.58	0.90	1.37	0.94
	Paraíso MG H419-1	III	1.11	1.18	**0.48**	1.33	0.62	1.39	0.88	0.96
	Pau-Brasil MG1	III	0.71	0.91	**0.50**	1.20	0.77	1.33	1.10	1.24
	Sacramento MG1	VII	1.17	1.33	1.15	0.61	1.30	0.87	**0.56**	0.84
	H419-3-3-7-16-4-1	I	**0.59**	0.73	0.93	0.81	1.02	0.91	1.07	1.15

Araponga and Senhora de Oliveira, 0.043 between Araponga and Paula Cândido and *C. canephora* 0.190 between Paula Cândido and Senhora de Oliveira. The quality factor scores showed a correlation of 0.469 between the scores of the municipalities of Araponga and Senhora de Oliveira, 0.011 between Araponga and Paula Cândido and 0.128 between Paula Cândido and Senhora de Oliveira.

Considering the sensorial quality factor, the genotypes Catucaí Amarelo 24/137 and H419-3-3-7-16-4-1 deserve to be highlighted again, since they were classified into ideotypes that included this factor in the

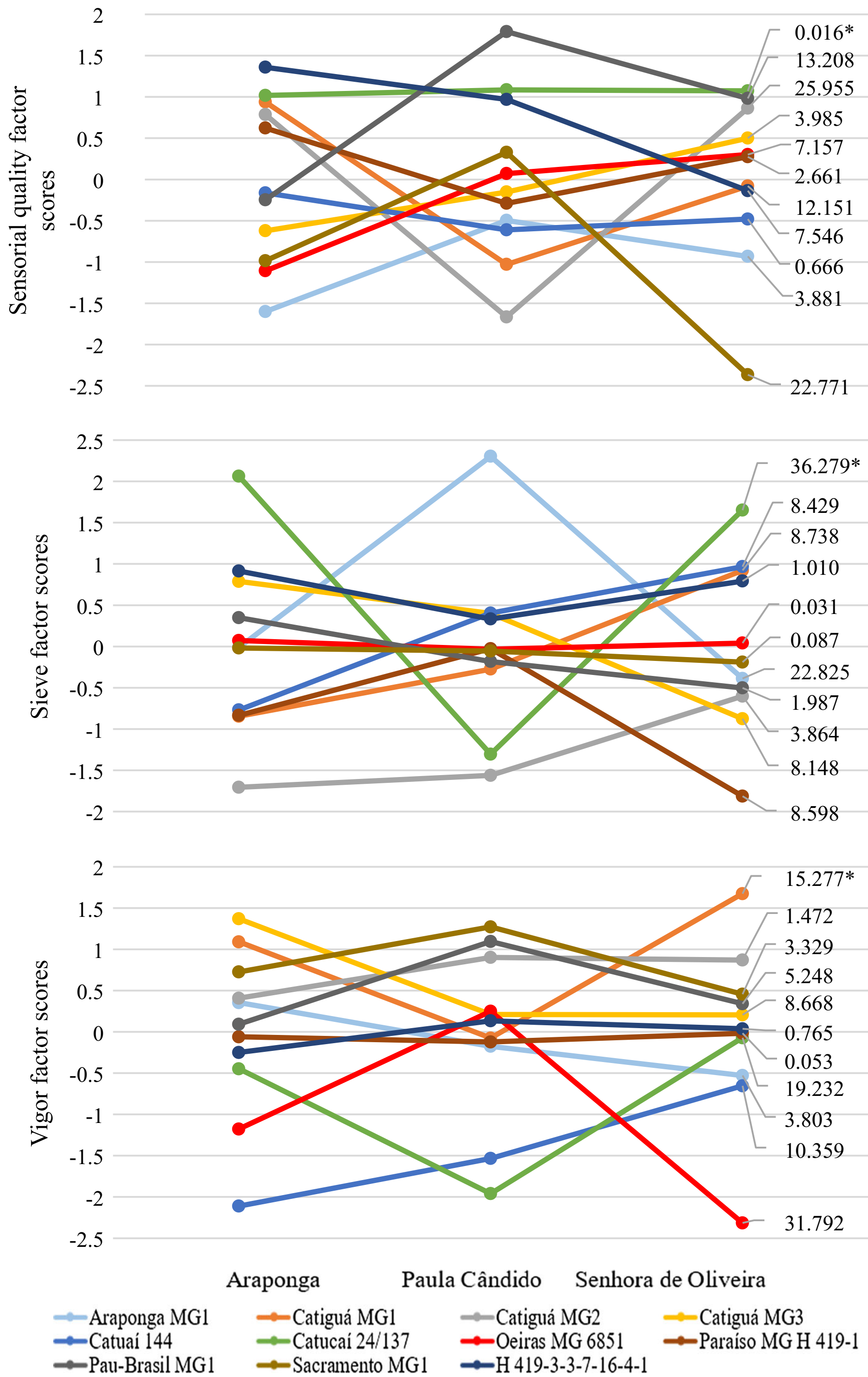

Fig. 2 Scores obtained by the analysis of factors of 11 genotypes of *Coffea arabica* according to three environments in the region of Matas de Minas. *Estimation of the parameters of adaptability and stability of the factor scores, obtained by the Wricke method

three environments (Table 2). In addition, both presented good stability (Fig. 2).

For the sieve factor, no genotype was classified into ideotypes with favorable response in the three environments together (Table 2). This result was confirmed by the stability analysis, where it was observed that the genotypes with higher scores had a low stability value (Fig. 2). For this factor, the H419-

3-3-7-16-4-1 genotype was the one that presented good scores and good stability (Fig. 2).

For the vigor factor, the genotypes Catiguá MG1, Catiguá MG2, Catiguá MG3, Paraíso MG H419-1, Pau-Brasil MG1, Sacramento MG1 and H419-3-3-7-16-4-1 were classified with favorable response in the three environments (Table 2). Among these, genotypes Catiguá MG2, Paraiso MG H419-1, Pau-Brasil MG1, Sacramento MG1 and H419-3-3-7-16-4-1 were the most stable (Fig. 2).

These results indicate that the factors may aid in the selection of genotypes under the interaction with environment effect. Thus, although the genotypes present GxA interaction in the univariate analysis, some genotypes can be selected in general, from factors that explain their performance for a set of biologically related variables.

Conclusion

Factor analysis was efficient to aid in the multivariate selection of superior cultivars. The interaction genotype by environment remains even after the summary of the variables in factorial complexes. The genotypes Catucaí Amarelo 24/137 and H419-3-3-7-16-4-1 stood out among the genotypes and presented good adaptability and stability, therefore, they present great potential to improve the performance of coffee cultivation in the Matas de Minas region.

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