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Full Length Research Paper

Genotypic correlation and path coefficient analysis of organoleptic quality attributes of some Ethiopian specialty coffee (*Coffea arabica* L.) accessions

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The present investigation was carried out to study the correlation and path coefficient analysis in 49 coffee (*Coffea arabica* L.) germplasm accessions, which were collected from Gomma district, at Agaro. Data on eight organoleptic quality traits were recorded by well experienced and trained coffee tasters. Character association of the quality attributing traits revealed overall standard of coffee quality exhibited positive and significant correlation with flavor, aromatic quality, acidity and body. Hence, selection for these traits can improve overall standard of coffee quality. Besides, path coefficient analysis showed that flavor, body, astringency and aromatic intensity exhibited positive direct effect on overall standard of coffee quality. Among these characters, flavor possessed both positive and significant association and high direct effects. Hence, selection for this character could bring improvement in overall standard of coffee quality.

Key words: Organoleptic, correlation, path coefficient analysis, flavor.

INTRODUCTION

Ethiopia is center of origin and diversity of Arabica coffee (*C. arabica* L) (Anthony et al*.,* 2001). Coffee is economically an important cash crop contributing to about 35% of the country's foreign currency earnings, 10% of the gross domestic product and supports 25% of the population livelihoods (Gole and Senebeta, 2008). Ethiopia is the only country among coffee producing countries to satisfy all consumers' choice by supplying the demand of quality coffee standards namely, Sidamo (Spicy flavored), Harar (Mocha flavored), Jimma/Limu (Winy flavored), Lekempti/ Gimbhi (Fruity flavored) and many more coffee types with their respective unique flavor are prides of nation (Desse, 2008), though full exploitation calls for development and mapping of coffee quality profiles and coordinated promotion work.

International coffee markets have a growing demand for specialty coffees. Consumers seek good taste, flavor, sweetness, acidity and body. Besides, there is also a great interest in products with marketable characteristics of production environment and geographic location (Rodrigues et al., 2009). Thus, it is imperative to collect, select and develop specialty coffee varieties which can meet the consumer demand. In line with this, Jimma agricultural research center has collected about 6000 accessions from different coffee producing areas of Ethiopia and generating numerous technologies. However, there are limited research findings on the association among organoleptic quality traits. Yigzaw (2005) has reported highly significant correlation among good coffee quality attributes. Abiyot et al. (2011) and Olika et al. (2011) have also reported positive and highly significant correlation among most important quality traits. Though information is scanty on path coefficient analysis in coffee organoleptic characters, Getu (2009) reported that considering aromatic intensity and flavor as a selection criteria would improve the overall standard of coffee.

Overall standard of coffee cup quality is a complex trait, considerably affected by many factors. *Inter ali*a, aroma,

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Table 1. Geographical origin of the studied coffee (*Coffea ararica L.)*germplasm accessions.

Acc. no	Collection site	Wereda	Acc.no	Collection site	Wereda
L01/05	Chadero Suse	Gomma	L27/05	Bako Kuju	Gomma
L02/05	Chadero Suse	Gomma	L28/05	Bako Kuju	Gomma
L03/05	Chadero Suse	Gomma	L29/05	Bako Kuju	Gomma
L04/05	Chadero Suse	Gomma	L30/05	Bako Kuju	Gomma
L05/05	Gabena Abo	Gomma	L31/05	Bako Kuju	Gomma
L06/05	Gabena Abo	Gomma	L32/05	Debi Kechamo	Gomma
L07/05	Gabena Abo	Gomma	L33/05	Debi Kechamo	Gomma
L08/05	Gabena Abo	Gomma	L34/05	Debi Kechamo	Gomma
L09/05	Gabena Abo	Gomma	L35/05	Debi Kechamo	Gomma
L10/05	Gabena Abo	Gomma	L36/05	Debi Kechamo	Gomma
L11/05	Gabena Abo	Gomma	L37/05	Limu Sapa	Gomma
L12/05	Gabena Abo	Gomma	L38/05	Limu Sapa	Gomma
L13/05	Omo-Boko	Gomma	L39/05	Limu Sapa	Gomma
L14/05	Omo-Boko	Gomma	L40/05	Limu Sapa	Gomma
L15/05	Omo-Boko	Gomma	L41/05	Limu Sapa	Gomma
L16/05	Omo-Boko	Gomma	L42/05	Omo Gobo	Gomma
L17/05	Omo-Boko	Gomma	L43/05	Omo Gobo	Gomma
L18/05	Omo-Boko	Gomma	L44/05	Omo Gobo	Gomma
L19/05	Omo-Boko	Gomma	L45/05	Omo Gobo	Gomma
L20/05	Goja Kemisse	Gomma	L46/05	Omo Gobo	Gomma
L21/05	Goja Kemisse	Gomma	L47/05	Omo Gobo	Gomma
L23/05	Goja Kemisse	Gomma	L48/05	Omo Gobo	Gomma
L24/05	Goja Kemisse	Gomma	744	-	Standard check
L25/05	Goja Kemisse	Gomma	Dessu	-	Standard check
L26/05	Bako-Kuju	Gomma			

body and flavor are the major factors that affect the overall coffee cup quality standard. Hence, complete information on the association among various organoleptic quality attributes has a paramount importance in genetic improvement of coffee quality by shortening the breeding procedure. Hence, this study was carried out to detect correlation and path coefficient analysis of organoleptic quality attributes for increased overall standard of Ethiopian specialty coffee.

MATERIALS AND METHODS

Description of the study site

The experiment was conducted at Agaro Station of the Jimma Agricultural Research Center, which is 45 km far from Jimma and 397 km from Addis Ababa. Agaro is located at latitudinal gradient of 7''50'35 - 7'' 51' 00'' N and longitudinal gradient 36''35'30''E with an altitude of 1650 m above sea level. The mean annual rainfall of the area is 1616 mm with an average maximum and minimum air temperatures of 28.4°C and 12.4°C, respectively (Elias, 2005). The major soil type is Mollic Nitisols with pH of 6.2, organic matter 7.07%, nitrogen 0.42%, phosphorus 11.9 ppm,CEC 39.40 cmol$^{(+)}$/kg (Zebene and Wondwosen, 2008).

Experimental materials

Forty nine C. *arabica* L. germplasm accessions, which have been collected from Gomma wereda of Jimma Zone, were used for this study (Table 1).

Experimental design and management

The study was conducted during 2011/12 cropping season. The experiment was laid out in a 7 x 7 simple lattice design with two replications. All the improved agronomic practices were applied uniformly according to the recommendations (Endale et al*.,* 2008). Samples were prepared from each accession separately following the recommended wet processing procedure of Jimma Agricultural Research Center (JARC).

Sample preparation and data collected

Harvesting

During peak harvesting time, healthy and red-ripe berries were harvested from each accession by hand and

Table 2. Cup quality parameter and their descriptive value.

Scale		Description of each scale					
		0	1	2	3	4	5
Aromatic intensity	0-5	Nill	Very light	Light	Medium	Strong	Very strong
Aromatic quality	0-5	Nill	Very light	Light	Medium	Strong	Very strong
Acidity	0-5	Nill	Very light	Light	Medium	Strong	Very strong
Astringency	0-5	Nill	Very light	Light	Medium	Strong	Very strong
Bitterness	0-5	Nill	Very light	Light	Medium	Strong	Very strong
Body	0-5	Nill	Very light	Light	Medium	Strong	Very strong
Flavor	0-5	Nill	Very light	Light	Medium	Strong	Very strong
Overall standard	0-5	UA	Bad	Regular	Good	Very good	Excellent

processed. For this purpose, 3 - 6 kg were collected from each coffee accession. The whole processing steps were done according to (Behailu et al., 2008).

Pulping

Fully ripened and healthy berries were separated from unripe green cherries and pulped by using hand pulper. Immediately after pulping the parchment were sorted from the pulp and dipped into water to separate the floaters.

Fermentation

The moist parchments were fermented in fermentation plastic box for 48 h. The samples were then stored in fermentation box for additional 24 h to remove the mucilage. The fermented coffee was then washed by soaking with clean water and dried.

Drying

Samples were sun dried using mesh wire, in the meantime, moisture content of the beans was measured and maintained at 10 - 12% for all samples uniformly. The dried parchment were separately labeled and packed. Finally, the parchment was removed and 300 – 600 g of clean green beans were prepared for quality evaluation. A total of 98 samples were prepared. To attain homogeneity, samples were screened on a mesh sieve 15(5.95 mm). Finally samples on 15 and above were used for organoleptic quality analysis.

Roasting

The roaster machine was first heated at about 160 - 200°C and 200 g of clean coffee was prepared for each accession per replication and roasted.

Grinding

Roasted coffee was converted into powder form and weighed and placed in a cup.

Brewing, cup tasting and data collection

Then, boiled water was poured on to the ground coffee up to about half a cup and aromatic quality and intensity parameters were recorded by sniffing. Then, content of cups were stirred to ensure an infusion of all coffee grounds. The cup was then filled to the brim with boiled water and the brew was ready for panelists within 8 mins. Finally, cup tasting was made by a group of experienced and well trained coffee tasters of Jimma Agricultural Research center. Acidity, astringency, bitterness, body, flavor and overall standard of the brew were scored using scale ranging from zero to five (Table 2). The mean of the assessment result given by panelists was used for statistical analysis.

Data analysis

Data of organoleptic characters were subjected to analysis of variance (ANOVA) using SAS version 9.2 (SAS, 2008) to examine the presence of statistically significant differences among accessions for the characters studied.
The phenotypic and genotypic correlation coefficients were estimated using the formula suggested by Johnson et al. (1955) and Singh and Chaudhury (1987).

$$\mathbf{rp} = \mathbf{Pcovxy}/\sqrt{(\mathbf{Vpx.Vpy})}$$

$$\mathbf{rg} = \mathbf{Gcovxy}/\sqrt{(\mathbf{Vgx.Vgy})}$$

Where, rp= Phenotypic correlation coefficient
rg = Genetoypic correlation coefficient
$Pcov_{xy}$ = Phenotypic covariance between traits x and y
$Gcov_{xy}$ = Genotypic covariance between traits x and y
V_px= Phenotypic variance of trait x
V_gx = Genotypic variance of trait x
V_py = Phenotypic variance of trait y
V_gy=Genotypic variance of trait y

Table 3. Mean squares of eight organoleptic traits of 49 coffee germplam accessions grown at Agaro (2011/12).

	Mean square	
Characters	**Treatment**	**Error**
Aromatic intensity	0.081*	0.041
Aromatic quality	0.226**	0.06
Acidity	0.19**	0.04
Astringency	0.05*	0.021
Bitterness	0.085*	0.035
Body	0.108**	0.04
Flavor	0.24**	0.03
Overall standard	0.24**	0.034

** and * represent highly significant (p<0.01) and significant differences(P<0.05), respectively.

The coefficients of correlation were tested using “r” tabulated value at n-2 degree of freedom, at 5% and 1% probability level, where n is the number of treatments (accessions).

Path coefficient analysis was made following the method described by Dewey and Lu (1959).

$$\mathbf{rij = Pij + \Sigma rikpkj}$$

Where: rij = Mutual association between the independent character (i) and dependent

Character (j) as measured by genotypic correlation coefficient.

Pij=Component of direct effects of the independent character (i) on dependent character (j) as measured by genotypic path coefficient and,

∑rikpkj = Summation of components of indirect effect of a given independent character (i) on the given dependent character (j) via all other independent character (k).

The residual effect can be estimated as described in Dewey and Lu (1959).

$$\mathbf{1 = P^2R + \Sigma rikpk}$$

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) revealed that accession differed significantly ($P < 0.05$) for all quality attributes (Table 3). This indicates the presence variability which can be exploited through selection and hybridization in order to improve the quality of this valuable crop. Walyaro (1983) reported the presence of large inherent differences among genotypes for bean and cup quality attributes. Similarly, Vander Vossen (1985) observed variation for cup quality characters among varieties and crosses of Arabica coffee. In conformity of this finding, Selvakumar and Sreenivasan (1989) observed coffee cup quality variation ranging from good to excellent among 54 Arabica coffee accessions collected from Keffa, Ethiopia. The available information in earlier studies on coffee collection and selection in Ethiopia further confirmed the presence of high genetic variability within the Arabica coffee population for quality characters (Bayetta, 1997).

Phenotypic correlation coefficients

The value of phenotypic correlation coefficients indicated that overall standard and flavor had positive and significant phenotypic correlation among each other and with aromatic quality, acidity and body. However, they exhibited negative and significant correlation with bitterness. Both traits exhibited non-significant correlation with aromatic intensity and astringency (Table 4).

Body had positive and significant correlation with aromatic quality and acidity and it also exhibited a positive, but non-significant correlation with aromatic intensity at phenotypic level. On the other hand, this trait had negative and non significant correlation with astringency and bitterness.

Bitterness showed negative correlation with aromatic intensity, aromatic quality, acidity and astringency, although significant negative correlation was observed only with acidity. Astringency had no significant association with all quality attributes.

Acidity also showed positive and significant correlation with good quality attributes like aromatic intensity and aromatic quality. Similarly, aromatic quality exhibited positive and significant correlation with aromatic intensity. Getu (2009) has reported significant and positive phenotypic association among aromatic intensity, aromatic quality, acidity, flavor and overall standard. However, the same author has reported negative and significant association of bitterness and astringency with good cup quality attributes.

Table 4. Phenotypic correlation coefficient among eight quality attributes of coffee (*Coffea arabica L)* germplasm accessions grown at Agaro in 2011/12.

Trait	AI	AQ	AC	AS	BI	BO	FL	OVS
AI	1.000	0.383**	0.251*	0.144	-0.131	0.078	0.159	0.200
AQ		1.000	0.580**	0.169	-0.172	0.332*	0.569**	0.620**
AC			1.000	-0.024	-0.303*	0.458**	0.904**	0.889**
AS				1.000	-0.061	-0.223	-0.083	-0.129
BI					1.000	-0.168	-0.293*	-0.403**
BO						1.000	0.515**	0.572**
FL							1.000	0.912**
OVS								1.000

** and * = highly significant (p<0.01)= 0.34 and significant (p<0.05=24.5), respectively, AI= Aromatic intensity, AQ=Aromatic quality AC= acidity, AS= Astringency, BI=bitterness, BO= body, FL= flavor and OVS= overall standard.

Table 5. Genotypic correlation coefficient among eight quality attributes of coffee (*Coffea arabica L)* germplasm accessions grown at Agaro in 2011/12.

Trait	AI	AQ	AC	AS	BI	BO	FL	OVS
AI	1.000							
AQ	0.782**	1.000						
AC	0.223	0.779**	1.000					
AS	0.616**	0.516**	0.192	1.000				
BI	-0.397**	-0.308*	-0.382**	-0.028	1.000			
BO	0.047	0.506**	0.540**	-0.171	-0.425**	1.000		
FL	0.187	0.741**	0.984**	0.007	-0.356**	0.605**	1.000	
OVS	0.235	0.766**	0.962**	0.023	-0.477**	0.720**	0.974**	1.000

** and * = highly significant (p<0.01= 0.34) and significant (p<0.05=24.5), respectively, AI= aromatic intensity , AQ= aromatic quality AC= acidity, AS= astringency, BI=bitterness, BO= body, FL= flavor and OVS= overall standard.

Genotypic correlation coefficients

In the present study, the genotypic coefficient of correlation (Table 5) was higher than its corresponding value for phenotypic correlation, suggesting true inherent association among the traits. Flavor and overall standard had significant and positive association among each other and with aromatic quality; acidity and body. The significant correlation between overall standard and flavor with aromatic quality, acidity and body indicates that these highly associated traits are controlled by one major gene. Thus, improving one of these traits leads to simultaneous improvement of the others. In other words, the positive and significant correlation among the most important coffee quality traits suggest that coffee germplasm accessions with high aromatic quality, acidity, body and flavor should be selected to improve the overall standard of coffee quality. In contrast, overall standard and flavor exhibited negative and significant association with bitterness and positive and non significant association with astringency and aromatic intensity at genotypic level.

Body showed positive association with aromatic quality, acidity and aromatic intensity, though it had significant association only with aromatic quality and acidity. Body had negative association with astringency and bitterness, but its association was significant only with bitterness. Bitterness showed negative and significant correlation with aromatic intensity, aromatic quality and acidity. However, it had negative and non significant association with astringency. Astringency exhibited positive and significant correlation with aromatic intensity and aromatic quality. Acidity also exhibited positive correlation with aromatic intensity and aromatic quality, though its correlation is significant only for aromatic quality. Aromatic quality also showed positive and significant association with aromatic intensity.

The negative association of the important quality traits with bitterness and the negative and weak positive correlation of astringency with these attributes may show that bitterness and astringency are not important in improving the coffee quality. However, it is known that characters *viz*., flavor, aromatic quality, acidity and body are highly correlated with and overall standard. The positive correlation among these traits and these traits with overall standard is probably due to peliotropy where one gene controls two traits simultaneously. Thus this trait, needs to be considered for indirect selection.

In agreement with the findings of the present study, Yigzaw (2005) has reported highly significant correlation

Table 6. Estimates of direct (bold and diagonal) and indirect effects (off diagonal) at genotypic level of quality attributes on overall standard in 49 Coffee germplasm accessions tested at Agaro (2011/12).

Traits	AI	AQ	AC	AS	BI	BO	FL	rg
AI	0.089	-0.178	-0.070	0.107	0.031	0.011	0.235	0.235
AQ	0.069	-0.228	-0.241	0.090	0.0234	0.118	0.934	0.766**
AC	0.020	-0.177	-0.310	0.034	0.029	0.126	1.240	0.962**
AS	0.055	-0.117	-0.060	0.174	0.002	-0.040	0.009	0.023
BI	-0.035	0.070	0.118	-0.005	-0.077	-0.009	-0.449	-0.477**
BO	0.004	-0.115	-0.167	-0.030	0.033	0.232	0.763	0.720**
FL	0.017	-0.169	-0.304	0.001	0.028	0.141	1.260	0.974**

Residual effect=0.12, AI= aromatic intensity, AQ= aromatic quality, AC= acidity, AS= astringency, BI=bitterness, BO= body, FL= flavor and rg= genotypic correlation coefficient.

among good coffee quality attributes. In a similar work, Getu (2009) has indicated that good quality attributes, like aromatic intensity, aromatic quality, acidity and flavor, showed significant and positive genotypic association with overall standard. Furthermore, Abiyot et al. (2011) and Olika et al. (2011) also reported positive and highly significant correlation among most important quality traits. These authors suggested that flavor, overall standard, aromatic quality, acidity and body have to be considered in coffee quality improvement program.

Path coefficient analysis

Correlations in genotypic terms were analyzed further by path coefficient analysis technique, which involved partitioning of the correlation coefficient into direct and indirect effects via alternative characters or pathways. Overall standard of coffee cup quality, as a complex outcome of various traits, was considered to be the resultant character. The rest, viz, aromatic intensity, aromatic quality, acidity, astringency, bitterness, body and flavor, were the casual characters. The estimates of direct and indirect effects are presented in Table 6.

Flavor, which had significant association with overall standard (r_g = 0.974), exhibited the highest direct effect (P = 1.260). Besides, it showed high positive indirect effects on most characters considered in this study. The genetic coefficient of correlation of flavor with overall standard was almost equal to its direct effect, indicating that it explained the true relation with the overall standard. If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then the correlation would explain the true relationship and a direct selection through this trait would be effective (Albayrak et al., 2003). Flavor exerted maximum direct effect and had positive and significant correlation with overall standard, thus flavor can be used as indirect selection criteria to improve the overall standard of coffee quality. Therefore, flavor could be considered as a major component of selection in a breeding program for high coffee quality.

Agwanda (1999) compared four traits (acidity, body, flavor and overall standard) for their suitability as selection criteria for the genetic improvement of overall liquor quality. Based on correlation, repeatability and sensitivity analysis, flavor rating was recommended as the best selection criterion for genetic improvement of cup quality in Arabica coffee. The present finding partly agrees with the finding of Getu (2009), who reported that considering aromatic intensity and flavor in direct selection and indirect selection through some organoleptic traits would improve the overall standard of coffee.

Acidity had maximum negative direct effect (P = -0.310). Hence, the strong association it had with overall standard largely due to the indirect effect. In other words, the negative direct effect of acidity is nullified through positive indirect effects of flavor and body. Aromatic quality had negative direct effect on overall quality standard (P = -0.228), but exhibited strong correlation with overall standard (rg = 0.766) largely through the positive indirect effects of flavor. Aromatic intensity had negligible positive direct effects (P = 0.089), but it showed higher magnitude of correlation with overall standard though not significant. The positive correlation was mainly due to positive indirect effect of flavor. Thus, simultaneous selection for each acidity, aromatic quality and aromatic intensity with flavor would be effective to improve the overall standard of coffee.

Body also had highly significant and positive correlation with overall standard (rg = 0.72), though it had low positive direct effect (P = 0.232). Therefore, the highly significant correlation it had with overall standard is mainly due to positive indirect effect of flavor.

The positive direct effect of astringency on overall standard (P = 0.174) was influenced through negative indirect effects of aromatic quality, acidity and body and resulted in weak correlation with over all standards. Besides, the negative direct effect of bitterness (P = -0.08) is further influenced by its negative indirect effects through flavor (-0.449), making the correlation between bitterness and overall quality standard negative and significant. The genotypic relationship exhibited between dependent and independent characters was 88% explained by the model.

Conclusion

Traits association showed that there is strong association among organoleptic coffee quality attributes both at phenotypic and genotypic levels. Besides, cause and effect interrelationship have also revealed that flavor is the most important component of overall coffee quality standard as it had a major and pronounced direct effect (1.260). Hence, showing positive and significant correlation and positive direct effect, flavor will be a useful trait for indirect selection to improve the overall organoleptic quality of coffee.

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