American Journal of BioScience
2023; 11(6): 150-158
http://www.sciencepublishinggroup.com/j/ajbio
doi: 10.11648/j.ajbio.20231106.13
ISSN: 2330-0159 (Print); ISSN: 2330-0167 (Online)

Genetic Variability Analysis Among Quality Attributes of Arsi Coffee (*Coffea arabica* L.) Accessions at Mechara

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To cite this article:
Sintayehu Girma, Wassu Mohammed, Ashenafi Ayano. (2023). Genetic Variability Analysis Among Quality Attributes of Arsi Coffee (*Coffea arabica* L.) Accessions at Mechara. *American Journal of BioScience*, *11*(6), 150-158. https://doi.org/10.11648/j.ajbio.20231106.13

Received: November 2, 2023; **Accepted**: November 21, 2023; **Published**: November 29, 2023

Abstract: Ethiopia is naturally endowed with a suitable climate for the production of high quality coffee. Arsi coffee is known to produce Harar C coffee quality grade and known for its unique flavor and aroma. Therefore, this study was conducted to estimate genetic divergence, heritability and genetic advance in Arsi coffee accession for bean quality traits. A total of 56 Arsi coffee accessions and four Hararghe coffee varieties were evaluated for bean physical and organoleptic coffee quality traits using Completely Randomized Design with three replications. The analysis of variance results showed significant variation among Arsi coffee accessions and Hararghe coffee varieties for all traits except astringency, bitterness and odor. The overall quality of Arsi coffee accession was in the range between 75.83 and 87.17% while the four Hararghe coffee varieties had 80.33 to 84% overall quality. Genotypic and phenotypic coefficient of variation ranged from 2.61 to 34.83% and 2.97 to 35.67%, respectively. The heritability in broad sense and genetic advance as percent of mean ranged from 32.50% to 99.88% and 3.94 to 70.15%, respectively. Most of the coffee quality traits had high heritability except aromatic intensity had low heritability. Based on un-weighted pair group method of classification the 60 genotypes were grouped into 14 clusters of which Cluster I was the largest consisted of 26 (43.33%) collections while other clusters consisted of 1 to 8 genotypes. Principal components (PCs) showed that the first three PC explained 89 % of the total variance of which PC1, PC2 and PC3 contributed 56, 26 and 7 %, respectively. The highest contribution of PC1 to total variance was due to the high contribution of organoleptic quality traits; aromatic intensity, aromatic quality, acidity, flavor, overall standard and overall cup quality. The Euclidean distances of 1770 pair of genotypes ranged from 2.0 to 12.06 with 6.79, 1.51 and 22.2% overall mean standard deviation and coefficient of variation, respectively. The Arsi coffee collections with high mean values for varied number of coffee beans physical and organoleptic quality traits distributed across clusters. Some clusters consisted of collections with high mean values for most of the coffee quality traits including for overall coffee quality. The research results suggested the higher chance of selection of genotypes to be developed as varieties for high coffee quality and for crossing of distant collections with distinct quality traits to produce hybrids with high coffee quality.

Keywords: Cluster, Cup Quality, Euclidian Distance, Genetic Variability, Principal Component

1. Introduction

Ethiopia is the home and cradle of biodiversity of Arabica coffee. More genetically diverse landrace of *Coffea arabica* exist in Ethiopia than anywhere else in the world, which has led botanists and scientists to agree that Ethiopia is the center for origin, diversification and dissemination of the coffee plant [1]. The entire genetic diversity of indigenous (wild) Arabica coffee is confined mainly in the Afromontane rain forest located in the West and East of Great Rift Valley [2]. The phenotypic diversity of coffee in Ethiopia is manifested in morphology and bean characters. The inherent genetic traits and conditions that occur within different coffee ecologies influence the type of coffee flavor and natural qualities [3].

Even though, the overall genetic diversity of Coffea arabica is believed to be less polymorphic as compared to its diploid relative species, the populations in its place of origin and diversity, particularly south-western Ethiopia, have a lot of genetic variability for many agronomic characters. This fact has been supported by many studies based on different techniques such as morphological [4, 5] biochemical [6] and DNA-based molecular markers techniques [7-9]. Indigenous cultivars of Arabica coffee in Ethiopia are location specific for adaptability demonstrating the existence of wide genetic variability in natural Arabica coffee populations for the development of location and agro-climate specific improved varieties [10]. The within population genetic diversity decreases as we go from wild population to landraces [11]. Genetic diversity of coffee can be assessed using different techniques that range from the traditional morphological techniques to the modern DNA-based molecular markers. The use of morphological techniques in diversity study of plants is limited by the influence of environmental factors and growth stage of the plant [12].

Assessment of coffee quality is a key step in price setting and determines its export potential in coffee producing countries and to many coffee roasters and distributors [13]. The coffee beans quality assessed both for physical and cup quality distinguished by measurements, visual observation and organoleptic test by professional coffee tasters. Therefore, assessing the diversity of coffee genotypes for coffee quality attributes in each coffee quality grade is the first step to improve the coffee genotypes for the respective grades. In this regard, few researchers conducted research on coffee qualities in Ethiopia [14-21]. However, none of the researchers studied the Arsi coffee genotypes. Therefore, to study the coffee genotypes from Arsi known to produce Harar C coffee quality grade will provide information about the extent and magnitude of genetic diversity of Arsi coffee genotypes. It also generates information about the inherent bean quality attributes difference of genotypes from Arsi and genotypes from Harar A and B grades. The information may help breeders to design breeding methods to improve Arsi coffee genotypes either by selection and/or hybridization. This research was therefore initiated with the objective to estimate genetic variation, heritability and genetic advance in Arsi coffee collections for bean quality traits.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Mechara Agricultural Research Center (McARC) in 2017 cropping season. The center is located near Mechara town in Daro-Labu district of West Hararghe Zone. It is 434 km East of Finfinne and 108 km Southeast of Chiro, the zonal capital. Geographically, it is located between latitude of 8°36'38" North and longitude of 40°19'29" East at an altitude of 1760 m.a.s.l. The soil type is deep, well-drained and slightly acidic Nitosol. The area has an erratic rainfall with high variability in the onset and cessation of the main rainfall season. Generally, the area receives an average annual rainfall of 871mm of which the peak rainfall months are from June to October, while the lowest (dry) months are from November to February. Its annual mean minimum and maximum air temperatures are 14°C and 26°C respectively [26].

2.2. Experimental Materials and Experimental Design

Fifty six arabica coffee promising accessions which have been collected from Arsi zone along with four released Hararghe coffee selections were used for this study (Table 1).

Table 1. *Geographical origin of Arsi coffee (Coffea arabica L.) accessions.*

Acc. no.	Collection area	Woreda	Acc. no.	Collection area	Woreda
Ar04/11	Haro	Gololcha	Ar78/11	Jinka Dhibu	Gololcha
Ar08/11	M/laga Buna	Chole	Ar50/11	Manya Adare	Chole
Ar40/11	M/Warqi Darartu	Gololcha	Ar76/11	Mine Gora	Gololcha
Ar56 /11	Mine Gora	Gololcha	Ar23/11	M/Oda Adi	Chole
Ar07/11	M/laga Buna	Chole	Ar30/11	Darartu	Chole
Ar82/11	Jinka Dhibu	Gololcha	Ar119/11	Mine Gololcha	Gololcha
Ar83/11	Jinka Dhibu	Gololcha	Ar75/11	Mine Gora	Chole
Ar10/11	M/laga Buna	Chole	Ar26/11	M/Oda Adi	Chole
Ar57/11	Mine Gora	Gololcha	Ar72/11	Mine Gora	Gololcha
Ar53/11	Manya Adare	Gololcha	Ar28/11	M/Oda Adi	Chole
Ar52/11	Manya Adare	Chole	Ar74/11	Mine Gora	Gololcha
Ar63/11	Mine Gora	Gololcha	Ar36/11	M/Warqi Darartu	Chole
Ar64/11	Mine Gora	Gololcha	Ar44/11	Manya Adare	Chole
Ar65/11	Mine Gora	Chole	Ar115/11	Mine Gololcha	Gololcha
Ar77/11	Mine Gora	Gololcha	Ar46/11	Manya Adare	Chole
Ar87/11	Jinka Dhibu	Chole	Ar33/11	M/Warqi Darartu	Chole
Ar88/11	Jinka Dhibu	Gololcha	Ar118/11	Mine Gololcha	Gololcha
Ar15/11	M/laga Buna	Chole	Ar47/11	Manya Adare	Chole
Ar18/11	M/laga Buna	Gololcha	Ar69/11	Mine Gora	Gololcha
Ar19 /11	M/laga Buna	Chole	Ar106/11	Geda Seka	Chole
Ar03/11	Jeda Saqa	Chole	Ar102/11	Geda Seka	Chole
Ar84/11	Jinka Dhibu	Gololcha	Ar95/11	Geda Seka	Gololcha
Ar38/11	Darartu	Chole	Ar12/11	M/laga Buna	Gololcha
Ar101/11	Geda Seka	Gololcha	Ar100/11	Geda Seka	Gololcha

Acc. no.	Collection area	Woreda	Acc. no.	Collection area	Woreda
Ar11/11	M/laga Buna	Chole	Ar34/11	Darartu	Chole
Ar93/11	Geda Seka	Gololcha	Ar103/11	Geda Seka	Gololcha
Ar21/11	M/Oda Adi	Chole	Arusa	Standard checks	
Ar66/11	Mine Gora	Gololcha	Mocha		
Ar37/11	M/Warqi Darartu	Chole	Mechara-1		
Ar02/11	Jeda Saqa	Chole	Bultum		

The experiment was conducted in completely randomized design (CRD) with three replications. Selective hand picking method was applied to collect only red ripe cherries from trees selectively leaving behind unripe green beans to be harvested later. Accordingly, more than three harvests were conducted to collect cherries to prepare the required amount of beans for the experiment. The collected fresh cherry accessions were placed on raised bed mesh wire under sun for drying. Fully dried accessions were hulled with mortar. The dried pulp, the parchment skin part of the husk was removed. 100gm of dried green coffee beans was prepared for each accession per replication and roasted for an average of six minutes to medium roast under roasting temperature of 200°C. Grinding was done the roasting accession using coffee electrical grinder (MahlKonig, Germany) with middle adjustment. Finally brewing preparation was made for cup tasting by a group of experienced and well trained coffee tasters of Jimma Agricultural Research center.

2.3. Data Collection

Raw coffee bean quality attributes: A total of 300g of green beans sample were prepared per each accession for raw beans and cup quality attributes analysis. The green bean evaluated for raw beans quality according to the standard established for washed coffee raw quality (CLU, 2007; ECX, 2010). Accordingly, raw coffee bean quality was determined by bean size, shape and make, color and odor traits. Bean size: distribution of coffee bean was determined by conventional screen analysis using perforated plate screens of diameter sizes 14 (5.55mm) [22].

Table 2. *Standard parameters and their values used for coffee raw quality (40%).*

Shape and make (15%)		Color (15%)		Odor (10%)	
Quality	**Points**	**Quality**	**points**	**Quality**	**Points**
Very good	15	Bluish	15	Clean	10
Good	12	Grayish	12	Fair clean	8
Fair good	10	Greenish	10	Trace	6
Average	8	Coated	8	Light	4
Mixed	6	Faded	6	Moderate	2
Small	4	White	4	Strong	0

2.4. Cup Quality Attribute

Three cups per sample in three replications were prepared for each accession and tasting session. The accessions replicated for each accession was arranged at random. The sensory evaluation of each accessions and the cup quality were carried out by three trained and certified professional panelists of Jimma Agricultural Research Center (JARC). The cupping form provides a systematic means of recording eight important quality attributes. These include aromatic intensity, aromatic quality, acidity, astringency, bitterness, body, flavor, and overall standard.

Table 3. *Standard parameters and their values used for liquor quality.*

Parameters	Scale	Description of each scale					
		0	**1**	**2**	**3**	**4**	**5**
Aromatic intensity	0-5	Nil	V. light	Light	Medium	Strong	V. strong
Aromatic quality	0-5	Nil	V. light	Light	Medium	Strong	V. strong
Bitterness	0-5	Nil	V. light	Light	Medium	Strong	V. strong
Astringency	0-5	Nil	V. light	Light	Medium	Strong	V. strong

Parameters	Scale	Description of each scale					
		0	**2**	**4**	**6**	**8**	**10**
Acidity	0-10	Nil	Lacking	Light	Medium	M. pointed	pointed
Body	0-10	Nil	V. light	Light	Medium	M. full	Full
Flavor	0-10	Nil	Bad	Fair	Medium	Good	V. good
Overall standard	0-10	Nil	Bad	Regular	Good	V. good	Excellent

2.5. Data Analysis

Analysis of variance was conducted using R software. The traits that exhibited significant mean squares in general ANOVA were further subjected to variability analyses. The means for genotypes were compared using Duncan multiple range test (DMRT). Genotypic and phenotypic component of variance were estimated from the analysis of variance estimated by Singh and Chaudhary (1977). Heritability in broad sense, Genetic advance and genetic advance as percent of mean was computed using the formula suggested by Allard and Bradshaw (1964). The data was subjected to principal component analysis (PCA) using SAS 9.1 version

2.6. Genetic Distance and Clustering

Genetic distance of 56 coffee accessions were estimated using Euclidean distance (ED) calculated from quantitative traits after standardization (subtracting the mean value and dividing it by the standard deviation) as established by Sneath and Sokal (1973) as follows:

$$\text{EDjk} = \sqrt{\sum_{i=1}^{n}\left(Xij - Xik\right)^{\frac{2}{2}}} \quad \text{(Sneath and Sokal, 1973)},$$

Where; EDjk = distance between genotypes j and k; xij and xik = phenotype traits values of the i^{th} character for genotypes j and k, respectively; and n = number of phenotype traits used to calculate the distance. The distance matrix from phenotype traits was used to construct dendrogram based on the Unweighted Pair-group Method with Arithmetic Means (UPGMA). The result of cluster analysis was presented in the form of dendrogram. In addition, mean ED was calculated for each genotype by averaging of a particular genotype to the other 59 genotypes.

3. Result and Discussion

The results of analysis of variance (ANOVA) showed the presence of significant (P<0.05) differences among the Arsi coffee accessions for raw quality and cup quality traits except bitterness, astringency and odor (Table 4). The presence of significant variations among Arsi coffee accessions for coffee bean quality traits is a good indicator for the existence of exploitable genetic variability for the improvement of Arsi coffee quality through selection and/or crossing of accessions.

Table 4. Mean squares of coffee bean physical and organoleptic quality attributes of Arsi coffee accessions.

Trait	Genotype	EMS	SE	CV%
Acidity	0.68**	0.21	0.51	6.19
Aromatic Intensity	0.22*	0.15	0.42	9.44
Aromatic Quality	0.38*	0.21	0.49	11.09
Astringency	0.16ns	0.38	0.6	14.8
Bitterness	0.22ns	0.49	0.7	17
Body	0.44**	0.18	0.46	5.66
Flavor	0.84**	0.12	0.37	4.8
Overall Standard	0.79**	0.17	0.47	5.58
Total cup quality	20.71**	3.95	2.21	4.31
Bean size	867.10**	1.06	1.17	1.37
Color	0.63*	0.3	0.66	4.29
Odor	0.05ns	0.05	0.23	2.4
Shape and make	2.85**	0.42	0.68	5.44
Total raw	4.31**	0.88	1.12	2.71
Overall Quality	25.29**	4.94	2.33	2.75

3.1. Phenotypic and Genotypic Variations

Genotypic and phenotypic variances ranged between 0.024 to 288.68 and 0.073 to 289.03, respectively. The highest values of genotypic and phenotypic variations were calculated for bean size. Whereas the lowest genotypic and phenotypic values were calculated for aromatic intensity. The calculated values for genotypic and phenotypic variation were closer to each other for most the traits which indicate that genotype could be reflected by the phenotype and selection based on phenotypic performance may be effective to improve the traits. The genotypic coefficient of variation (GCV) ranged from 2.61 for color to 22.69 for bean size while phenotypic coefficient of variation (PCV) ranged from 3.45 for total raw to 22.71 for bean size. The GCV values were lower than that of PCV values. However, the magnitude of the differences between PCV and GCV was <3% for all traits. This suggests that the environmental factors had less influence on the expression of the coffee quality traits. Therefore, selection of genotypes based on phenotypic performance may be effective to develop varieties for desired quality traits [23]. Cup quality (aromatic intensity, aromatic quality, acidity, body, flavor and overall standard) and physical quality (bean color, total raw quality and shape and make) traits had low GCV and PCV. While bean size had high GCV and PCV. Coffee quality traits that had low genotypic coefficient of variations coupled with either low or moderate values of PCV indicated the higher influence of environmental than genetic factors for the expression of the traits. Characters that demonstrate low phenotypic and genotypic coefficient of variations would offer less scope of selection as they are under the influence of environment [24].

3.2. Estimates of Heritability and Expected Genetic Advance

The estimated heritability in broad sense of coffee quality traits ranged from 32.50% for aromatic intensity to 99.88% for Bean size, whereas genetic advance as percent of the mean ranged from 3.94% to 46.79% (table 4). High heritability were observed for flavor, acidity, overall standard quality, total cup quality, shape and make, total raw, bean size and overall coffee quality; which indicates the improvement of the traits could be easily achieved through selection due to relatively smaller contribution of environment to phenotype expression (Singh, 2003). Whereas moderate heritability were observed for aromatic quality, body and bean color indicating that total variability was due to both genetic and environmental effect. Low heritability was observed for aromatic intensity (32.50%). Selection for these traits may be difficult due to the masking effect of environment over the genetic effect. Genetic advance as percent of mean (GAM) values were high for bean size. Whereas moderate for flavor, overall standard and shape and make. The lowest value of genetic advance as percent mean were observed for aromatic intensity, aromatic quality, acidity, body, total cup quality, color, total raw and overall coffee quality.

***Table 5.** Estimates of variability components for bean quality traits of Arsi coffee accessions and four Hararghe coffee varieties.*

Trait	GM	σ^2g	σ^2p	GCV %	PCV%	H^2	GA	GAM 5%
Aromatic Intensity	4.06	0.0236	0.0726	3.78	6.63	32.50	0.18	4.43
Aromatic quality	4.09	0.06	0.13	5.98	8.81	46.15	0.34	8.06
Acidity	7.44	0.16	0.23	5.37	6.41	69.56	0.68	9.14
Body	7.46	0.088	0.148	3.98	5.15	59.46	0.47	6.30
Flavor	7.34	0.24	0.28	6.67	7.20	85.71	0.93	12.67
Overall standard	7.38	0.21	0.26	6.20	6.91	80.76	0.85	11.25
Overall cup quality	46.14	5.59	6.90	5.12	5.69	81.01	4.39	9.51
Shape and make	11.96	0.81	0.95	7.51	8.14	85.26	1.71	14.3
Color	12.69	0.11	0.21	2.61	3.61	52.38	0.5	3.94
Total raw	34.63	1.15	1.43	3.09	3.45	80.4	1.98	5.71
Bean size	74.87	288.68	289.03	22.69	22.71	99.88	35.03	46.79
Overall quality	80.78	6.79	8.43	3.23	3.59	80.54	4.82	5.97

GM=Genetic mean, $\boldsymbol{\sigma}^2$g=genotypic variance, $\boldsymbol{\sigma}^2$p= phenotypic variance, GCV=Genotypic coefficient of variance, PCV=Penotypic coefficient of variance, H^2=broad sense heritability, GA=Genetic advance, GAM=Genetic advance as percent of mean

3.3. Principal Component Analysis

The estimates of the eigenvalues, total variance contributed by each principal components and the cumulative variance for coffee bean quality traits are presented in Table 8. The result of principal component analysis showed that three principal components (PC) PC1, PC2 and PC3 explained 89% of the total variance (Table 8). The first two principal components PC1 and PC2 explained 82% of the total variance with eigenvalues of 6.71 and 3.08, respectively. The first principal component (PC1) accounted for 56% of total variance and had high contribution for organoleptic quality traits (Aromatic intensity, aromatic quality, acidity, flavor, overall standard and overall cup quality) as compared to other two principal component. Therefore, these quality attributes were the cause of genetic variability among Arsi coffee collections. The other traits contributed slightly to principal component one. Characters with largest absolute value closer to unity within the first principal component influence the clustering more than those with lower absolute value closer to zero [25]. The second principal component had contributed highest raw bean quality traits (shape and make, color, total raw and bean size) and accounted 26% of the total variance. While the third principal component accounted for 7% of the total variance and had high contribution to aromatic intensity, aromatic quality and color.

***Table 6.** Eigen vectors, Eigen values, percent variability contributed by each principal component and the cumulative variance for coffee bean quality traits.*

Traits	PC1	PC2	PC3
Aromatic Intensity	-0.30	0.06	0.24
Aromatic Quality	-0.31	0.09	0.28
Acidity	-0.36	0.06	-0.12
Body	-0.36	-0.01	-0.12
Flavor	-0.37	0.03	-0.1
Overall standard	-0.37	0.04	-0.17
Overall cup quality	-0.38	0.03	-0.04
Shape and make	-0.07	-0.53	0.27
Color	0.06	-0.36	-0.74
Total raw	-0.03	-0.56	-0.06
Bean size	0.00	-0.47	0.41
Overall quality	-0.36	-0.20	-0.06

Traits	PC1	PC2	PC3
Eigen value	6.71	3.08	1
Variance (%)	56	26	7
Cumulative (%)	56	82	89

3.4. Genetic Distance Analysis

The genetic distance of Arsi coffee accessions was estimated using Euclidean distance (ED) and the accessions showed wide range of distances. The calculated Euclidean distance ranged from 2.0 to 12.06 with a mean distance (MD) and a standard deviation (SD) of 6.79 and 1.51, respectively.. The highest distance was calculated between Ar56/11and Ar119/11 (12.06) followed by Ar19/11 and Ar64/11 (12). However, the lowest distance was recorded between Ar57/11, Ar77/11, Ar103/11, Ar115/11 and Ar65/11. The mean Euclidean distance results showed that the distant accessions to others were Ar72/11 (8.92) and Ar23/11 (8.71), whereas the closest collections to others were Ar47/11 (5.35), Ar02/11 (5.49), Ar37/11 (5.51) and Ar57/11 (5.51). The computed pair wise distance of 1770 pair accesions had showed significant difference from distance mean. 899 pair accessions had significantly lower than distance mean, whereas 835 pair accessions had significantly higher than mean distance. The remaining of pair accessions (37) had near or equal to mean distance of Arsi coffee accessions. Ar04/11 and Ar64/11, Ar19/11 and Ar72/11, Ar21/11 and Ar64/11, Ar28/11 and Ar83/11, Ar56/11 and Ar64/11, Ar40/11 and Ar72/11, Ar23/11 and Ar100/11 were found to be close with each other in respect of different combinations, which indicate apparent strong genetic relationship among these accessions. The result of this study indicated that significant genetic distances were observed among Arsi coffee accessions which suggested that the opportunity of crossing distant accession to produce heterotic hybrids. This is because, the more the distant the parents the higher chance of obtaining heterotic hybrids [1].

3.5. Cluster Analysis of Accessions

Cluster analysis confirmed the presence of variation among Arsi coffee accesions. Fifty six Arsi coffee accessions and four Hararghe coffee varieties were grouped into 14 major clusters (Figure 1). The number of accessions belonging to each cluster was different. The majority of accessions (45 or 75%) were classified in to four clusters (26, 8, 6 and 5 accessions) in clusters I, X, VI and VIII, respectively. Most of cluster I accesions were collected from Gololcha woreda. All accessions grouped in cluster VIII (Ar34/11, Ar44/11, Ar46/11, Ar52/11 and Ar106/11) were collected from Chole woreda at the same altitude. This indicates the accessions had close similarity within the group.

The four Hararghe coffee varieties, Mocha and Mechara-1 were grouped under Cluster I with 25 Arsi coffee collections and Cluster II with one Arsi coffee accesions, respectively. Arusa and Bultum coffee varieties clustered under Cluster III with one Arsi coffee accesions. Cluster IX and XII contained two accesions (3.33%). Whereas cluster IV, V, VII, XI, XIII and XIV were constructed by single accesions (1.66%) indicating huge variation among accesions with regard to their clustering pattern. The result of the study indicated the presence of genetically wide variation among Arsi coffee accessions for coffee quality traits.

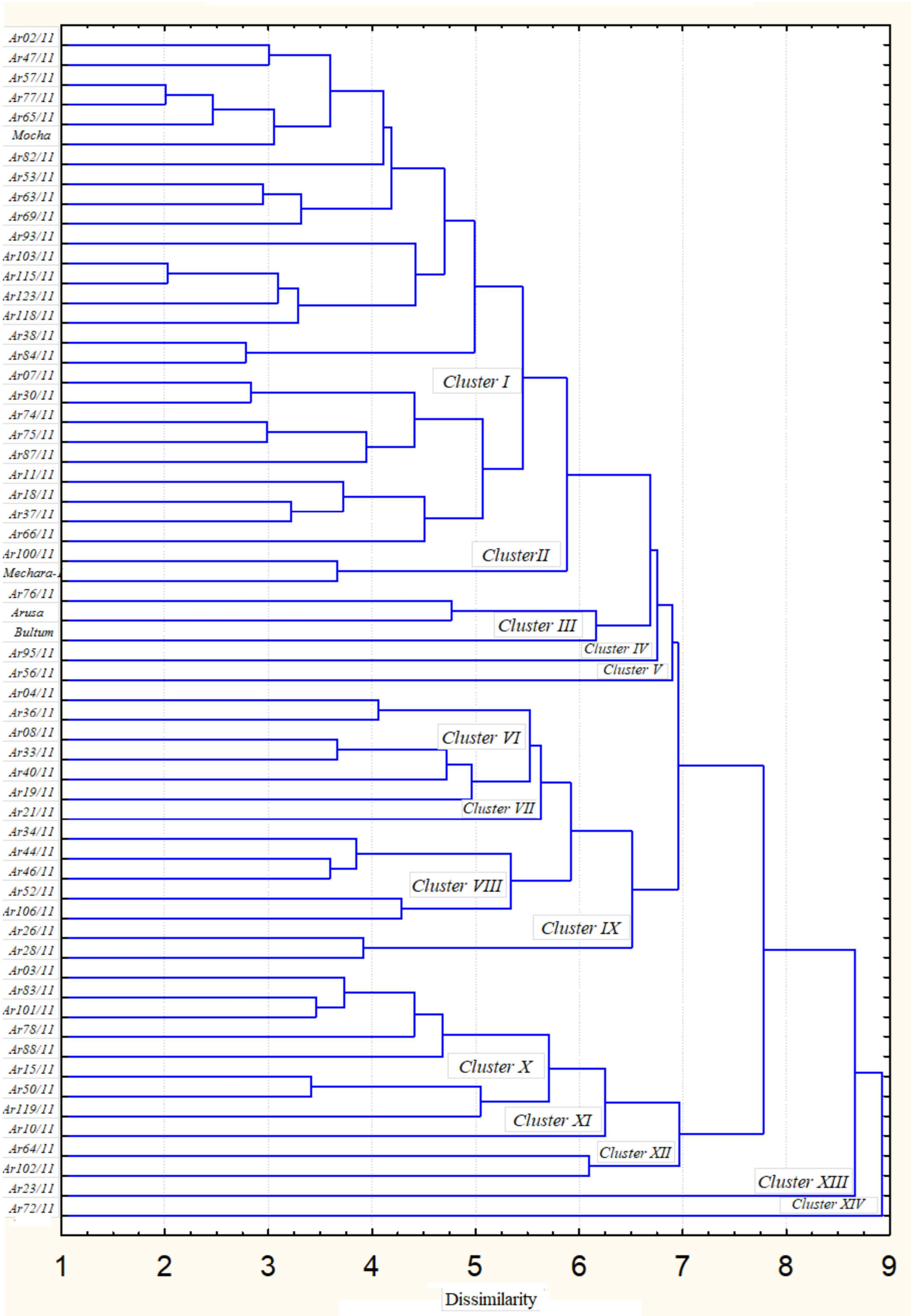

Figure 1. *Dendrogram generated based on UPGMA clustering method depicting genetic relationships among Arsi coffee collections and four Hararghe coffee varieties based on green bean physical and cup quality attributes of coffee quality.*

Table 7. *The distribution of accessions into fourteen clusters.*

Cluster no.	No. of accession	Acession
I	26	Mocha, Ar02/11, Ar47/11, Ar57/11, Ar77/11, Ar65/11, Ar82/11, Ar53/11, Ar63/11, Ar69/11, Ar93/11, Ar103/11, Ar115/11, Ar12/11, Ar118/11, Ar38/11, Ar84/11, Ar07/11, Ar30/11, Ar74/11, Ar75/11, Ar87/11, Ar11/11, Ar18/11, Ar37/11 and Ar66/11
II	2	Mechara-1 and Ar100/11
III	3	Ar76/11, Arusa and Bultum
IV	1	Ar95/11
V	1	Ar56/11
VI	6	Ar04/11, Ar08/11, Ar19/11, Ar36/11, Ar33/11 and Ar40/11
VII	1	Ar21/11
VIII	5	Ar34/11, Ar44/11, Ar52/11, Ar46/11and Ar106/11
IX	2	Ar26/11 and Ar28/11
X	8	Ar15/11, Ar03/11, Ar50/11, Ar78/11, Ar83/11, Ar88/11, Ar101/11and Ar119/11
XI	1	Ar10/11
XII	2	Ar64/11 and Ar102/11
XIII	1	Ar23/11
XIV	1	Ar72/11

3.6. Cluster Mean Analysis

The means of the clusters are given in Tables 8 and 9 for physical bean quality and cup quality attributes of 56 Arsi coffee accessions and four Hararghe coffee varieties. The highest number of accesions were grouped under Cluster I and characterized by lowest aromatic intensity and aromatic quality and highest mean values for acidity, body, flavor, bean color. Cluster II which contained two collections and characterized by its highest aromatic quality, aromatic intensity, acidity, body, flavor, overall standard, total cup quality, shape and make, bean color, total raw, and overall quality. Cluster III which consists of one Arsi accesions and two Hararghe varieties; Ar76/11, Arusa and Bultum was characterized by high aromatic quality, aromatic intensity, bean color and total raw quality. Cluster IV, V, VII, XI, XIII and XIV possessed only one accession. Accesions grouped under Cluster VIII were characterized by lowest flavor, overall standard and total raw. Cluster IX, which consists of two accesions; Ar26/11 and Ar28/11 was characterized by lowest acidity, flavor and overall standard. Cluster X was characterized by maximum values of organoleptic quality traits (aromatic intensity (4.46), aromatic quality (4.63), acidity (8.21), flavor (8.27), body (8.08), overall standard (8.21) and total cup quality (50.6), while raw bean quality (bean color and shape and make) was recorded in cluster XII and XIV. Cluster XI, Ar10/11 possess highest aromatic intensity (4.5), Flavor (8), acidity (8), overall standard (8), highest body (7.83), aromatic quality (4.5) and overall quality (83.17). Cluster XII had the highest mean values for shape and make (13.5), total raw quality, and acidity (8), overall quality (84.5), aromatic intensity, aromatic quality, body, flavor, and overall standard. The result of this study suggested that selection to be made in cluster X might be resulted from the higher chance of improving Arsi coffee quality. Crossing to be made between collections in Cluster X and XII may produce heterotic hybrids that combined high mean values of raw bean and cup quality attributes from their parents. This is because the two Clusters X and XII consisted of accessions having high mean values for cup and quality raw bean attributes, respectively.

Table 8. *Mean of 14 clusters consisting Arsi coffee collection and four Hararghe coffee varieties for coffee quality traits.*

Cluster	I	II	III	IV	V	VI	VII
Traits							
Aromatic intensity	3.98	4.17	4.17	3.83	3.33	4.03	4.33
Aromatic quality	3.96	4.33	4.11	3.83	3.33	3.94	4.33
Acidity	7.35	7.5	7.28	7	7	7.25	7.33
Body	7.44	7.58	7.33	7.17	7.17	7.25	7.33
Flavor	7.23	7.5	7.06	7	7	7.17	7.17
Overall standard	7.28	7.5	7.22	7.17	7	7.17	7.33
Overall cup quality	45.58	47.08	45.67	44.17	42.33	44.89	46.5
Shape and make	12.44	13	12.56	12.33	12.67	10.72	11
Color	12.87	12.75	13.06	13.33	13	12.75	13.17
Total raw	35.28	35.75	35.61	35.67	35.33	33.36	34.17
Bean size	82.8	95.03	74.02	97	95.2	56.03	55.6
Overall quality	80.86	82.83	81.28	79.83	77.67	78.25	80.67

Table 9. Mean of 14 clusters consisting Arsi coffee collection and four Hararghe coffee varieties for coffee quality traits.

Cluster	VIII	IX	X	XI	XII	XIII	XIV
Traits							
Aromatic intensity	3.97	3.92	4.46	4.5	4.08	3.83	4.17
Aromatic quality	4.03	3.83	4.63	4.5	4.33	3.67	4.33
Acidity	7.13	6.83	8.21	8	8	7.33	7.5
Body	7.1	7	8.08	7.83	7.83	7.17	7.33
Flavor	6.9	6.83	8.27	8	7.83	7	7.17
Overall standard	6.9	6.92	8.21	8	7.83	7.17	7.5
Overall cup quality	44.27	43	50.6	49.5	48.5	44.5	46.67
Shape and make	11.03	10.5	11.65	11	13.5	10.33	12.83
Color	12.1	12.83	12.23	12.67	12.67	11.67	12.67
Total raw	33.13	33.67	33.88	33.67	36	32	35.5
Bean size	59.36	56.83	70.08	49	87.85	59.2	88.35
Overall quality	77.4	76.67	84.48	83.17	84.5	76.5	82.17

4. Conclusions

Generally, the research results indicated that the presence of wide variations among Arsi coffee collections for bean physical and organoleptic quality traits. About six Arsi coffee collections showed superiority for over all coffee quality of Harar type than the Harar coffee varieties. Genetic advance as percent of mean suggested the presence of high chance to develop varieties either through selection and/or hybridization within Arsi coffee collections or crossing to be made between Arsi coffee collections and Harar coffee varieties.

Data Avalability

The data for this research will be available upon request from the corresponding author.

Acknowledgments

I am very grateful to Oromia Agricultural Research Institute (OARI), for financial support. I am thankful to Mechara Agricultural Research Center for material support. I am very thankful to the staff of Jimma Agricultural Research Center, especially panelists in Coffee processing and liquoring unit (Mr. Abrar Sauleh, Mr. Negussie Mekonin, Mr. Kelifa Nesir, Mr. Jafar Dawuid and Ms Saida Abdu) for analysis of samples in the laboratory.

Conflicts of Interests

The authors declare that they have no conflicts of interest.

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