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Phenotypic Classification of Coffee (*Coffea arabica* L.) Germplasm in Southern Ethiopia

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Abstract: Ethiopia is the homeland and center of genetic diversity of arabica coffee (*Coffea arabica* L., Rubiaceae). Although Ethiopia is known as a primary center for *Coffea arabica* diversity. Identification and characterization of coffee accessions in the base population is important in order to a successful conservation and utilization of genetic resources. Getting more information on genetic variability is a prerequisite for further improvement of coffee (*Coffea arabica* L.). A field experiment was conducted at Awada Agricultural Research Sub-Center, Ethiopia, to study the magnitude of phenotypic diversity among southern coffee (*Coffea arabica* L.) germplasm accessions based on qualitative traits. A total of 104 entries consisting of 100 accessions from southern parts of Ethiopia and four standard cultivars were evaluated using augmented design with five blocks. The main objective of the study was to assess morphological variation among germplasm based on phenotypic qualitative characters. Estimates of frequency distribution and Shannon Index based on 13 qualitative traits revealed the existence of genetic variability among 104 coffee germplasm. The highest diversity index (H') was found for the growth habit followed by the angle of insertion of the primary branches, leaf shape, stipule shape, fruit shape, fruit ribs, fruit color, leaf apex shape, leaf tip color and stem habit. The phenotypic similarities of 104 coffee genotypes were assessed by average linkage methods of cluster analysis using 13 qualitative traits with proc cluster of SAS. Based on the result of this analysis the coffee accessions were classified into five clusters with cluster-I was the largest and consisted of 66 accessions (63.46%) followed by cluster-II consisted of 12 accessions (11.54%), cluster-III consisted of 24 accessions (23.08%), cluster-IV and cluster V consisted of 01 accessions for each (0.96% for each). Thus, there is a chance to develop hybrid vigor through crossing diverged parents found in a different cluster. Generally, the present study revealed the existence of immense genetic variability among coffee germplasm for various important morphological qualitative traits. Hence, there is an opportunity to exploit these traits to improve genotypes that perform better than the existing varieties for the upcoming coffee improvement program.

Keywords: *Coffea arabica*, Genetic Variability, Cluster Analysis, Shannon Index, Qualitative Traits, Frequency Distribution

1. Introduction

Coffee is a perennial field crop which belongs to the genus Coffea in the Rubiacea family, and is mostly cultivated in the tropical and subtropical regions [4]. The genus Coffea comprises nearly 124 well identified species [7]; of which only two species, *Coffea arabica* Linnaeus (Arabica coffee) and Coffea canephora Pierre (Robusta coffee) are the two commercially important species. Arabica coffee accounts for the most important commercial species and contributes to more than 70% of world coffee production [13]. *Coffea arabica* is a self-fertile allotetraploid (2n=4x= 44), while others are diploid (2n=2x=22) and self-infertile [19].

Arabica coffee is the highly preferred non-alcoholic international beverage, and is a very important source of foreign exchange income for many countries. Some estimated that the entire coffee supply chain provides a livelihood for 125 million people worldwide [5] and is the second most exported commodity after oil worldwide [7]. Specifically, it is one of the most essential commodities and source of income to several Latin American, African and Asian countries. Particularly, it is an integral part of cultural and nucleus of the Ethiopian economy which accounts for 55 percent of the countries exports [2].

Ethiopia is the highest producer of coffee in Africa and the fifth major exporter in the world next to Brazil, Vietnam, Colombia and Indonesia, contributing to 4.2% of the total world coffee production [15]. It is mostly produced in the Southern, Southwestern and Eastern parts of the country. The estimated area of land covered by coffee is about 700,474.69 hectares, whereas the estimated annual national clean coffee production is about 469,091.1 tons [6]. Ethiopia is not only the foremost producer and exporter of Arabica coffee, but also origin and center of genetic diversity in the southwestern highlands of the country. Such existence of genetic diversity provides immense opportunity for coffee improvement [18]. However, despite the vast area of cultivation, wealth of tremendous genetic diversity and importance to the domestic economy, the productivity of coffee is very low (about 669.6 Kgha-1) [6]. Different researchers have reported major contributing factors for such low yields, such as use of unimproved coffee landraces, conventional husbandry, processing practices and the direct and indirect impacts of climatic variability [12, 24]. Furthermore, despite the availability of coffee genetic diversity in the country, coffee genetic resources are under serious threats of extinction, mainly due to deforestation, replacement of traditionally grown landrace by a few new released improved varieties, environmental degradation and change in land use [25]. Thus, it is pertinent and need of the day to collect, select and promote coffee varieties which are high yielder, disease resistant and best quality which can meet the consumers demand. About 5731 accessions are conserved at Institute of Biodiversity Conservation [24] and 6721 accessions at Jimma Agricultural Research Center field gene bank [23].

Information about genetic diversity among genotypes of any crop is fundamental to estimate the potential of genetic gain in a breeding program and effective conservation and utilization of available genetic resources, which help for selecting promising parental lines in hybrid variety development [3]. [9, 10, 21, 26], who reported the existence of genetic variability among the coffee germplasm for most of the traits studied. Furthermore, despite tremendous coffee genetic resources in the crop species, the country is still not yet fully utilizing its coffee genetic resources as expected in terms of improving coffee productivity and detailed information on the extent of genetic diversity in the southern part is not yet available. Keeping this in view, the present study aimed to estimate the genetic diversity among coffee germplasm accession based on several qualitative traits.

2. Metdology

2.1. Description of the Experimental Area

The study was conducted at Awada Agricultural Research Sub-Center (AARSC), which was established in 1998 GC. It is found at 315 km from Addis Ababa in southern Ethiopia nearby yirgalem town. The sub-center is situated in the moderate to cool semi-arid mid highland agro-ecology of southern Ethiopia. Geographically, it is located at 6°3'N Latitude and 38°E Longitude at an altitude at an elevation of about 1740 m.a.s.l. The area has a semi-bimodal rainfall distribution characterized by double wet and dry seasons with annual average minimum and maximum precipitation of 858.1 mm and 1676.3 mm while the annual average minimum and maximum air temperatures are 11°C and 28.4°C, respectively. The major soil types of the center are nitisol and chromatic-cambisols that are highly suitable for coffee production [20].

2.2. Genotypes

The study was carried out on the established 100 *C. arabica* genotypes including four standard checks. The coffee genotypes were collected from the potential and representing areas in the southern coffee growing part of Ethiopia. Collections were planted in the germplasm maintenance block of Awada Agricultural Research Sub-center. Details of geographical origin of the collected genotypes were given in Table 1.

Table 1. *Description of the genotypes.*

Genotype	Districts	Specific location	Altitude (m.a.s.l)	Total no collected
Aw 05/06, Aw 59/06, Aw 94/06, Aw 111/06	Bensa	Tibiro	1750 – 1800	4
Aw 64/06, Aw 103/06	Bensa	Silinga	1740 – 1770	2
Aw 81/06, Aw 66/06, Aw 12/06, Aw 99/06	Bensa	Ware	1850 – 1210	4
Aw 92/06, Aw 96/06, Aw 106/06	Bensa	Bensha	1700 – 1930	3
Aw 79/06	Bensa	Hedamo	1800	1
Aw 58/06, Aw 29/06, Aw 107/06	Bensa	Segera	1750 – 1930	3
Aw 97/06, Aw 100/06, Aw 67/06, Aw 108/06, Aw 04/06	Bensa	Setamo	1790 – 2015	5
Aw 30/06, Aw 93/06, Aw 104/06	Bensa	Golisa	1800	3
Aw 71/06, Aw 98/06, Aw 89/06, Aw 78/06, Aw 73/06	Bensa	Shema lega	1790 – 2020	5
Aw 10/06, Aw 62/06, Aw 91/06, Aw 84/06, Aw 28/06, Aw 95/06	Bensa	Gungvma	1720 – 1790	6
Aw 27/06, Aw 68/06, Aw 83/06, Aw 72/06	Bensa	Hatese	1750 – 1810	4
Aw 02/06, Aw 88/06, Aw 90/06	Bensa	Micharo-2	1720 – 1800	3
Aw 69/06, Aw 112/06	Bensa	Mulke	1750 – 1760	2
Aw 60/06, Aw 61/06, Aw 109/06	Bensa	Abaye	1740 – 1750	3
Aw 08/06, Aw 22/06, Aw 26/06, Aw 74/06, Aw 76/06	Bensa	Leleno	1750 – 1830	5
Aw 14/06	Bensa	Mike	1780	1
Aw 105/06	Bensa	Agensa	1980	1
Aw 34/06, Aw 65/06	Dara	Chire	1800	2
Aw 16/06, Aw 75/06, Aw 80/06	Dara	Kisho	1770	3

Genotype	Districts	Specific location	Altitude (m.a.s.l)	Total no collected
Aw 01/06, Aw 07/06, Aw 41/06, Aw 51/06	Dara	Wachi cha	1800	4
Aw 24/06	Dara	Boreta	1750	1
Aw 21/06	Dara	Doke	1750	1
Aw 23/06	Dara	Olone	1750	1
Aw 19/06, Aw 57/06, Aw 85/06	Dara	HalelaDaka	1750	3
Aw 49/06, Aw 54/06, Aw 87/06	Dara	Buna Tawaba	1740	3
Aw 53/06, Aw 56/06, Aw 63/06, Aw 77/06	Dara	Loya	1750	4
Aw 11/06, Aw 25/06, Aw 42/06, Aw 55/06	Dara	Chiro	1800	4
Aw 06/06, Aw 39/06, Aw 52/06, Aw 70/06	Dara	Shilicho	180 – 1810	4
Aw 32/06, Aw 40/06, Aw 43/06	Dara	Babe Kombolcha	1830	3
Aw 31/06, Aw 38/06, Aw 46/06	Dara	AlemeKancha	1750 – 1800	3
Aw 17/06, Aw 18/06, Aw 45/06, Aw 82/06	Dara	Bango Markos	1750 – 1875	4
Aw 03/06, Aw 09/06	Dara	Dubancho	1760 – 1800	2
Aw 15/06, Aw 20/06, Aw 86/06,	Dara	Megenecho	1740 – 1760	3
Checks				
744, 7440, 75227, 1377				

2.3. Treatments and Experimental Design

Treatments consisted of 100 coffee accessions and field established at the Awada Agricultural Research. Moreover, four released varieties (75227, 744, 7440 and 1377) were included as standard checks. The experiment was laid down in the field using augmented design, which is used with replicated controls (checks) to assess the performance of non-replicated accession in complete block designs [21] in five blocks. A single row (plot) consisting of ten trees per plot. The plant-to-plant spacing used was two meters by two meters, while spacing between blocks were four meters. All the recommended agronomic practices were applied uniformly to all the plots [8].

2.4. Data Collection

Data was collected on morphological qualitative traits was conducted. Character-descriptors adopted from the International plant genetic research Institute [16] were used. All the accessions were evaluated for 13-qualitative traits score described below (Tabel 2). Qualitative descriptors were scored by observing the whole trees of accessions in a plot, taking representative five trees from each accession.

Table 2. *Qualitative traits and their description.*

Traits	Scores	Description
Growth habit	1	Open
	2	Intermediate
	3	Compact
Leaf Shape	1	Obovate
	2	Ovate
	3	Elliptic
	4	Lanceolate
Calyx limb persistence	0	No
	1	Yes
Fruit shape	1	Round
	2	Obovate
	3	Ovate
	4	Elliptic
	5	Oblong
Leaf apex shape	1	Round
	2	Obtuse
	3	Acute
	4	Acuminate
	5	Apiculate
	6	Spatulate
Leaf tip color	1	Greenish
	2	Green
	3	Brownish
	4	Beddish-brown
	5	Bronzy
Stipule shape	1	Round
	2	Ovate
	3	Triangular
	4	Deltate (equilaterally triangular)
	5	Trapeziform

Traits	Scores	Description
Stem Habit	1	Stiff or strong
	2	Flexible
Fruit Colour	0	Yellow
	1	Light red
	2	Dark red
Overall appearance	1	Elongated conical
	2	Pyramid
Branching habit	1	Very few branches (primary)
	2	Many branches (primary) with few secondary branches
	3	Many branches (primary) with many secondary branches
Fruit ribs	0	Absent
	1	Present
Angle of insertion of primary branches	1	Drooping
	2	Horizontal or spreading
	3	Semi- erect

2.5. Methods of Data Analysis

2.5.1. Frequency Distribution and Shannon-weaver Diversity Index (H')

The frequency distribution is a systematic way to order a set of data from the lowest to the highest value showing the number of occurrences of each value or range of values. Then, frequency distribution and the number of phenotypic classes were used to compute the Shannon-Weaver Diversity Index (H') for each qualitative trait as per the formula described by [14]. Shannon-Weaver Diversity Index, (H') which has been widely used in measuring the diversity of germplasm collections [17] was estimated on the frequency data. The Shannon-Weaver Diversity Index, H', is defined as follows:

$$H' = -\sum Pi \ln Pi$$

Where, pi is the proportion of total number of individuals (genotypes) in the i^{th} class and n is the number of phenotypic classes. The Shannon-Weaver Diversity Index (H') can range from 0 to 1. A value near 0 indicates that every individual belongs to one and the same class. Conversely, value 1 indicates maximum diversity.

2.5.2. Cluster Analysis Is Based on Qualitative Traits

Qualitative variables were quantified by using appropriate scale [16]. Cluster analysis is numerical classification technique that defines a group of clusters of individuals. Clustering of coffee genotypes was done to separate 104 genotypes into different groups using proc cluster of SAS, average linkage method was used and based on agglomerative hierarchical clustering procedure.

3. Results and Discussion

3.1. Estimates of Phenotypic Frequency and Diversity Index

3.1.1. Frequency Distribution of Qualitative Traits

Estimates of the frequency distribution and Shannon Index of 13 morphological qualitative traits are presented in (Table 3). The result of frequency distribution of the phenotypic classes showed that the coffee accessions were grouped based on 13 qualitative traits. According to percent of frequency distribution, the predominated traits shared among the majority of coffee germplasm were stiff stem (64.42%), without calyx limb persistence (97.12%), open growth habit (51.92%), obovate fruit shape (65.38), bronzy young leaf tip color (64.42%), acuminate leaf apex shape (55.77%), ovate stipule shape (61.54%), light red fruit color (67.31%) and ovate leaf shape (56.73%), pyramid over all appearance (80.77%), many branches (primary) with many secondary branches in branching habit (70.19%), absent of fruit ribs (86.54%), horizontal or spreading angle of insertion of primary branches (67.31%). The result of this distribution pattern was comparable to those observed in [10].

Frequency distribution of qualitative traits showed the presence of variation among the coffee genotype studied (Table 3). Growth habits recorded from coffee genotypes were open for spreading branch (51.92%), intermediate (39.42%) and compact type (8.65%). In addition, coffee genotypes with strong and flexible stem were observed with the proportion of (64.42%) and (35.58%), respectively. The leaf shape observed was ovate (56.73%), lanceolate (40.38%) and obovate (2.88%). In addition, young leaf tip colors in the accessions were greenish (35.58%), bronze (64.42%). The fruit shape observed was elliptic (31.73%), obovate (65.38%), ovate (0.96%), oblong (1.92%). Fruit color observed in accessions was yellow (2.88%), light red (67.31%) and dark red (29.81%). Calyx limb persistence showed the accessions were no calyx limb persistence (97.12%) and presence of calyx limb persistence (2.88%). The leaf apex shape recorded from coffee genotypes was acuminate (55.77%) and apiculate (44.23%). The stipule shape in the accessions was ovate (61.54%), triangular (35.58%) and equilaterally triangular (2.88%), Over all appearance recorded from the coffee accessions were elongated conical (19.23%) and pyramid (80.77%), Branching habit recorded in the coffee accessions were very few branches (primary) (5.77%), many branches (primary) with few secondary branches (24.04%) and many branches (primary) with many secondary branches (70.19%). Fruit ribs recorded in the coffee accessions were absent (86.54%) and present (13.46%). In addition, angle of insertion of primary branches recorded in the coffee accessions was drooping (13.46%), horizontal or spreading (67.31%) and semi- erect (19.23%). The predominance of the open growth habit is the manifestation of suitability of such trait for ease of management practice, and permits uniform exposure and better interception of sunlight for all leaves and other vegetative parts. It will also create a less favorable environment for disease development, as compared to compact types. The current observation is in line with the report of [10] who found intermediate (61.22%) and open (38.72%) growth habit, stiff (51.10%) and flexible (48.9%) stem habit, among 49 Lemu coffee accessions. The present finding is further in harmony with [11].

3.1.2. Shannon-Weaver Diversity Index (H')

The estimated Shannon-index for individual qualitative traits were indicated in (Table 3). Analysis of diversity index revealed the existence of significant diversity among coffee qualitative traits observed. Polymorphism was common in varying degrees for most traits, implying the existence of a wide range of variation within the coffee accessions. [22]. The value of diversity index increased with polymorphism in traits and reaches its maximum value when all phenotypic classes had equal frequency [22]. The diversity index (H') values ranged from 0.131 to calyx limb persistence (lowest polymorphic) up to 0.919 for growth habit (highly polymorphic). Relatively, the highest diversity was found for growth habit (0.919) followed by angle of insertion on (0.852), leaf shape (0.790), stipule shape (0.769), fruit shape (0.763), branching habit (0.756), fruit color (0.729), leaf apex shape (0.687), leaf tip color (0.651), stem habit (0.651), over all appearance (0.490), fruit ribs (0.395) and calyx limb persistence (0.131). Low diversity was observed in calyx limb persistence (0.131) and fruit ribs (0.395). This low diversity value implies that most of the population tend to fall within the same state, signifying the possibility of close association between coffee genotypes for this trait. A low H` indicates unbalanced frequency classes for an individual trait and lack of diversity in the trait [14]. Similarly, [26] and [1] were reported that the Shannon-Weaver diversity values were variable among coffee qualitative traits and ranged from 0.410 to 0.989 and 0.168 to 0.386, respectively. Traits such as growth habit had greater value of H` followed by stipule shape, fruit shape, leaf shape, fruit color and leaf apex shape were more diverse as compare to leaf tip color, stem habit and calyx limb persistence. Furthermore, diversity indices of all qualitative traits suggesting the presence of adequate variability for these traits among evaluated genotypes.

3.2. Cluster of Arabica Coffee Genotypes Using Qualitative Characters

The phenotypic similarities of 104 coffee genotypes were assessed by average linkage methods of cluster analysis using nine qualitative traits with proc cluster of SAS. Based on the result of this analysis the coffee accessions were classified into five clusters with the numbers of accessions in each cluster I, II, III, IV and V being 66, 12, 24, 01 and 01, respectively (Table 4). The 104 coffee accessions were clustered into 05 distinct groups based on nine qualitative traits. Cluster-I was the largest and consisted of 66 accessions (63.46%) followed by cluster-II consisted of 12 accessions (11.54%), cluster-III consisted of 24 accessions (23.08%), cluster-IV and cluster V consisted of 01 accessions for each (0.96% for each) (Table 4).

Cluster means are given in (Table 5). In cluster I, 66 accessions were grouped under cluster I have predominately intermediate growth habit, strong (stiff) stem, lanceolate leaf shape, bronze-tipped young leaves, ovate fruit shape, ovate stipule shape, no calyx limb persistence, acuminate leaf apex shape, light red fruit color, pyramid over all appliance, Many branches (primary) with many secondary branches branching habit, absent fruit ribs and Horizontal or spreading Angle of insertion of primary branches. In addition, 12 accessions were grouped under cluster II, these accessions typically possess predominantly intermediate growth habit, stiff or strong stem, green- tipped young leaf tip color, lanceolate leaf shape, ovate fruit shape, acuminate leaf apex shape, ovate stipule shape, no calyx limb persistence, light red fruit color, pyramid over all appliance, many branches (primary) with few secondary branches branching habit, absent fruit ribs and horizontal or spreading angle of insertion of primary branches. Under cluster III, 24 accessions were grouped, these accessions typically possess predominantly intermediate growth habit, stiff or strong stem, green- tipped young leaf tip color, ovate leaf shape, obovate fruit shape, acuminate leaf apex shape, ovate stipule shape, no calyx limb persistence, light red fruit color, pyramid over all appliance, many branches (primary) with many secondary branches branching habit, absent fruit ribs and horizontal or spreading angle of insertion of primary branches. Finally, one-one accession grouped in cluster IV and V (AW-05 and 75227). Accessions falling in to cluster IV and V were characterised by possess predominantly open and compact growth habit, flexible and stiff or strong stem habit, green and bronze - tipped young leaf tip color, obovate and lanceolate leaf shape, yes and no calyx limb persistence, acuminate and apiculate leaf apex shape, many branches (primary) with many secondary branches and very few branches (primary) branching habit, respectively in addition to this they had elliptic fruit shape, equilaterally triangular stipule shape, light red fruit color, pyramid over all appriance, absent fruit ribs and horizontal or spreading angle of insertion of primary branches in common (Table 5). The result of classification based on qualitative traits revealed that there were distinct grouping of the accessions. The current result was in accord with previous work of [11].

Table 3. *Phenotypic classes, frequency distribution and Shannon-index for 13 morphological qualitative traits for 104 coffee germplasm accessions.*

Character	Scores	Description	No. of observation	Percent (%)	H
Growth habit	1	Open	54	51.92	
	2	Intermediate	41	39.42	
	3	Compact	9	8.65	
		Total	104	100.00	0.919
Leaf shape	1	Obovate	3	2.88	
	2	Ovate	59	56.73	
	3	Elliptic	0	0.00	
	4	Lanceolate	42	40.38	
		Total	104	100.00	0.790
Calyx limb persistence	0	No	101	97.12	
	1	Yes	3	2.88	
		Total	104	100.00	0.131
Fruit shape	1	Round	0	0.00	
	2	Obovate	68	65.38	
	3	Ovate	1	0.96	
	4	Elliptic	33	31.73	
	5	Oblong	2	1.92	
		Total	104	100.00	0.763
Leaf apex shape	1	Round	0	0.00	
	2	Obtuse	0	0.00	
	3	Acute	0	0.00	
	4	Acuminate	58	55.77	
	5	Apiculate	46	44.23	
	6	Spatulate	0	0.00	
		Total	104	100.00	0.687
Leaf tip color	1	Greenish	0	0.00	
	2	Green	37	35.58	
	3	Brownish	0	0.00	
	4	Beddish-brown	0	0.00	
	5	Bronzy	67	64.42	
		Total	104	100.00	0.651
Stipule shape	1	Round	0	0.00	
	2	Ovate	64	61.54	
	3	Triangular	37	35.58	
	4	Deltate (equilaterally triangular)	3	2.88	
	5	Trapeziform	0	0.00	
		Total	104	100.00	0.769
Stem habit	1	Stiff or strong	67	64.42	
	2	Flexible	37	35.58	
		Total	104	100.00	0.651
Fruit colour	0	Yellow	3	2.88	
	1	Light red	70	67.31	
	2	Dark Red	31	29.81	
		Total	104	100.00	0.730
Overall appearance	1	Elongated conical	20	19.23	
	2	Pyramid	84	80.77	
		Total	104	100.00	0.490
Branching habit	1	Very few branches (primary)	6	5.77	
	2	Many branches (primary) with few secondary branches	25	24.04	
	3	Many branches (primary) with many secondary branches	73	70.19	
		Total	104	100.00	0.756
Fruit ribs	0	Absent	90	86.54	
	1	Present	14	13.46	
		Total	104	100.00	0.395
Angle of insertion of primary branches	1	Drooping	14	13.46	
	2	Horizontal or spreading	70	67.31	
	3	Semi- erect	20	19.23	
		Total	104	100.00	0.852

Table 4. *Clustering patterns of 104 coffee germplasm accessions based on 13 qualitative traits.*

Cluster	No. of accessions	% of genotypes	Name of accessions in each cluster
I	66	63.46	AW-93, AW-91, AW-10, AW-02, AW-30, AW-76, AW-22, AW-12, AW-80, AW-98, AW-23, AW-108, AW-43, AW-111, AW-107, AW-92, AW-97, AW-95, AW-90, AW-109, AW-74, AW-04, AW-65, AW-64, AW-19, AW-42, AW-96, AW-11, AW-60, AW-40, AW-06, AW-38, AW-29, AW-09, AW-07, AW-58, AW-72, AW-51, AW-20, AW-31, AW-99, AW-106, AW-81, AW-83, AW-78, AW-34, AW-49, AW-85, AW-55, AW-46, AW-45, AW-21, AW-25, AW-59, AW-73, AW-112, AW-87, AW-39, AW-52, AW-79, AW-61, AW-16, AW-54, AW-01, AW-66,1377
II	12	11.54	AW-26, AW-53, AW-100, AW-08, AW-57, AW-63, AW-70, AW-14, AW-18, AW-86, AW-75, AW-104
III	24	23.08	AW-94, AW-67, AW-28, AW-41, AW-71, AW-24, AW-27, AW-77, AW-103, AW-89, AW-105, AW-62, AW-88, AW-03, AW-68, AW-84, AW-69, AW-56, AW-32, AW-17, AW-82, AW-15, 744,7440
IV	01	0.96	75227
V	04	0.96	Aw-05
Total	104	100	

Table 5. *Cluster means of 104 coffee accessions based on 13 qualitative traits.*

Cluster No.	GH	SH	LTC	LS	LAS	FS	SS	CLP	FC	OAA	BH	FR	AIP	Mean
I	1.55	1.33	5.00	2.88	4.45	2.77	2.00	0.00	1.29	1.82	2.65	0.12	2.03	2.15
II	1.67	1.50	2.00	4.00	4.50	2.67	2.00	0.00	1.00	1.83	2.33	0.42	2.08	2.00
III	1.54	1.33	2.00	1.92	4.38	2.42	2.00	0.08	1.38	1.75	2.83	0.04	2.13	1.83
IV	1.00	2.00	2.00	1.00	4.00	4.00	4.00	1.00	1.00	2.00	3.00	0.00	2.00	2.08
V	3.00	1.00	5.00	4.00	5.00	4.00	4.00	0.00	1.00	2.00	1.00	0.00	2.00	2.46
Mean	1.75	1.43	3.20	2.76	4.47	3.17	2.80	0.22	1.13	1.88	2.36	0.12	2.05	2.10

GH (growth habit): Open with spreading branch (1), Intermediate (2) and compact (3); SH (stem habit): Stiff or strong (1) and Flexible (2); LTC(young leaf tip color): Greenish (1), Green (2), Brownish (3), Beddish-brown (4) and Bronze (5); LS (leaf shape): Obovate (1), Ovate (2), Elliptic (3) and Lanceolate (4); FS (fruit shape): Round (1), Obovate (2), Ovate(3), Elliptic(4) and Oblong(5); FC (fruit color): Yellow (0), light red (1) and dark red (2); CLP (calyx limb persistence): No(0) and Yes(1); Leaf apex shape: Round(1), Obtuse(2), Acute(3), Acuminate(4), Apiculate(5) and Spatulate(6); SS (stipule shape): Round(1), Ovate(2), Triangular(3), Deltate (equilaterally triangular) (4) and Trapeziform(5), Overall appearance: Elongated conical (1) and Pyramid(2); Fruit ribs: absent(0) and present(1); Branching habit: Very few branches (primary)(1), Many branches (primary) with few secondary branches(2), Many branches (primary) with many secondary branches (3); Angle of insertion of primary branches: Drooping (1), Horizontal or spreading (2) and Semi- erect (3).

4. Summary and Conclusion

The present study illustrated the existence of wide ranges of variations for all qualitative traits studied for arabica coffee accessions, which provides good opportunities for genetic gain through selection or hybridization. Estimates of frequency distribution and Shannon Index based on 13 morphological qualitative traits revealed the existence of genetic variably among 104 coffee accessions. The highest diversity index (H') was found for the growth habit followed by the angle of insertion of the primary branches, leaf shape, stipule shape, fruit shape, fruit ribs, fruit color, leaf apex shape, leaf tip color and stem habit.

The phenotypic similarities of 104 coffee genotypes were assessed by average linkage methods of cluster analysis using qualitative traits. Based on the result of this analysis the coffee accessions were classified into five clusters with the numbers of accessions in each cluster I, II, III, IV and V being 66, 12, 24, 01 and 01, respectively. To sum up, the existence of genetic variability and association among traits in the base population is an important resource to exploit through selection and cross breeding in crop improvement program. The present study confirmed the existence of enormous genetic variability among coffee genotypes germplasm for various important morphological traits. Hence there is an opportunity to exploit these traits in order to develop genotypes that perform better than the existing varieties for the upcoming coffee improvement program. However, additional accessions with other traits of interest should be studied over a year. Furthermore, in order to confirm the present encouraging result, the current findings must be further studied with the support of advanced molecular techniques which provide immense potential to ensure effective utilization, conservation and development of improved varieties in the country.

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