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Phenotypic Diversity of Ethiopian Coffee (*Coffea arabica* L.) Accessions Collected from *Gomma* District in *Jimma Zone* for Qualitative Traits

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ABSTRACT

Forty-nine Coffea arabica. L. germplasm accessions,which were collected from Gomma district, were evaluated at Agaro research sub center with the objective of assessing the variability among the accessions using qualitative traits. The experiment was conducted in simple lattice design with two replications. Data on13 qualitative traits were recorded and frequency distribution and Shannon- weaver diversity index were estimated. The frequency distribution results revealed that the majority of the accessions were dominated by intermediate canopy nature (61.22%), stiff stem (51.1 %), dropping angle of insertion of primaries (38.78%), green young leaf color (73.47%), elliptic leaf shape (91.84),acuminate leaf apex shape (80%), ovate stipule shape (51.02%), roundish fruit shape (48.98%), red fruit color (44.90%), with calyx limb persistence (53.06), obolong bean shape (63%), uniform seed (57%) and medium bean size (96%). Moreover, the existence of variability among these accessions was further confirmed by Shannon-Weaver Diversity index (H') analysis. The highest H' values were recorded for angle of insertion of primaries (1.08), fruit color (1.04), stipule shape (0.83) and fruit shape (0.83) as compared to the other traits, indicating the presence of adequate variability for qualitative traits among the evaluated coffee accessions. Ingeneral, as considerable variability was observed among the accessions for most these traits, it recommended that these accessions should be properly conserved for future breeding work. However, the morphological diversity observed in this study must be further confirmed using molecular characterization techniques.

Keywords: *Fruit Color, Gomma district, Qualitative traits, Shannon-Weaver Diversity Index*

INTRODUCTION

Coffee belongs to the family *Rubiaceae* and the genus *Coffea* (Coste, 1992). The first botanical description of a coffee tree, under the name *Jasminum arabicanum*, was made in 1713 by A. de Jussieu, who studied a single plant originating from the botanic garden of Amsterdam (Wintgens, 2004). The basic chromosome number for the genus *Coffea* is n = 11. Arabica coffee is the only polyploid and self-fertile species of the genus *Coffea*, with chromosome number 2n = 4x = 44, while others are diploid (2n = 2x = 22) and self-infertile (Silvarolla *et al*., 2004)**.**The *Coffea* genus comprises about 124 species (Davis *et al*, 2011). *Coffea arabica* L., as it has been written and rewritten, finds its birthplace in southwestern Ethiopian forests evenif Linnaeus did not mention Ethiopia in the scientific name he gave to coffee in 1753. Coffee production in the center of origin, Ethiopia, has vital role for the economy, ecology, socio-cultural and spiritual life of the people. Nationally, it is estimated that 5.27 million households are involved in coffee production activities (CSA, 2017/18). It accounts for 5% of the GDP of the country and also provides an income for about 25 million people who are engaged in coffee production, processing, distribution, trading, exporting and other related activities (Tadesse, 2015). Despite the importance of coffee to the country's economy, despite Arabica coffee quality is superioras compared to other coffee species and although Ethiopia is endowed with huge coffee genetic resources, the existing potential and opportunityhas notbeen fully utilized with regard to developing coffee cultivars with high yield and superior quality and consequently the yield and the quality is low. This low average coffee yield and quality have been mainly attributed, according to Taye (2010), to the use of unimproved coffee landraces, traditional coffee management, improper harvesting and post-harvest practices.

Therefore, as thereis a huge coffee genetic resource in this country, collection and characterization of the available coffee genetic resource is essentialto alleviate this problem.

According to Jain *et al*. (1975), knowledge on the pattern of variation for important morpho-agronomic traits is essential for a proper management and a better exploitation of the gene pool. In view of this, the earlier investigators characterized Ethiopian coffee accessions. For instance, Olika (2011), Solomon (2017) and Masreshaw (2018) reported the existence of variability for qualitative traits among coffee accessions collected from *Limu kosa, east Wollega* and *Yayu* forest of Ethiopia, respectively. However, although coffee from *Gomma* district is known for its peculiar winey flavor and fetches premium price in the world market, the 49 coffee accessions, which were collected form this area, are not yet systematically characterized for qualitative traits and detailed information on the extent of genetic diversity is not yet available. Therefore, this study was conducted to assess the extent of genetic variation existed among the coffee accessions collected from *Gomma* district in *Jimma zone*.

MATERIALS AND METHODS

Description of the Study Site

The experiment was conducted at *Agaro* agricultural research sub center. *Agaro* is located at $7^0$50’ 35’’- $7^0$51’ 00’’ N latitude and 36^0 35’30’’ E longitude and at an altitude of 1630 meters above sea level (masl). It is located 397 km southwest ofAddis Ababaand about 50 km west of *Jimma* town. The mean annual rainfall of the area is 1616 mm with an average maximum and minimum air temperatures of 28.4 ^{0}C and 12.4^{0}C, respectively. 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 mol (+)/kg (Elias, 2005).

Experimental Material

Forty seven C. *arabica* L. accessions collected in the year 2005 from the *Gomma* district in *Jimma zone* and two standard checks that are maintained in the ex-situ field gene bank of *Agaro* agricultural research sub center were used for this study. The experiment was superimposed on six year old trees which were planted in July, 2006 and grown under uniform shade of *Sesbania sesban*.

Experimental Design, Management and Season

The study was conducted during 2011/12 cropping season. The experiment was laid out in a 7X7 simple lattice design with two replications and with seven genotypes per each incomplete block.Spacing between trees and plots was two meter andspacing between replications was 3 meter. All the agronomic practices were applied uniformly according to the recommendations (Endale *et al.*, 2008).

Data Collected

Datawere collected on 13 qualitative traits using the coffee descriptors of international plant genetic resource institute (IPGRI, 1996) (Table 1).

Table1. *Qualitative characters studied and their description as per IPGRI, 1996*

	Characters and their descriptive values
1	Growth habit: 1 (open) , 2 (intermediate), 3 (compact)
2	Stem habit: 1 (stiff), 2 (flexible)
3	Angle of insertion of primaries: 1 (drooping) , 2 (horizontal spreading, 3 (semi- erect)
4	Young leaf tip color: 1 (greenish) , 2 (green), 3 (brownish), 4 (reddish brown), 5 (bronzy)
5	Leaf shape : 1 (obovate), 2 (ovate), 3 (elliptic), 4 (lanceolate)
6	Leaf apex shape: 1 (round), 2 (obtuse),3 (acute), 4 (acuminate), 5 (apiculate), 6 (spatulate)
7	Stipule shape : 1 (round), 2 (ovate), 3 (triangular), 4 (deltate), 5 (trapezium)
8	Fruit shape : 1(round), 2 (obovate), 3 (ovate), 4 (elliptic), 5 (obolong)
9	Fruit color: 4 (light red), 5 (red), 6 (dark red)
10	Calyx limb persistence : 0 (not persistent), 1(persistent)
11	Seed shape : 1(Round), 2 (Obovate), 3 (Ovate), 4 (Elliptic), 5 (Obolong) 6 (Other)
12	Seed uniformity: 1(uniform), 2 (Mixed)
13	Bean size: 1(small), 2 (medium), 3(large)

Data Analysis

Frequency Distribution

Frequencies of the various categories of 13 qualitative traits were computed using Microsoft XL

Shannon-Weaver Diversity Index

The Shannon-Weaver diversity index (H’) was computed using the phenotypic frequencies to assess the overall phenotypic diversity for each character. The number of phenotypic classes used in Shannon-Weaver Diversity index (H’),

normalized by the maximum value (log n) in each case (Hennink and Zeven, 1991) were computed as a measure of diversity. For an 'n' class trait, the observed normalized H' was obtained as:

$$H' = -\sum pi\ ln\ (pi)$$

Where H'= Shannon-Weaver Diversity index, *Pi*= the relative abundance of each trait.

ln (pi) = the natural log of relative abundance.

RESULTS AND DISCUSSION

Frequency Distribution Based on Qualitative traits

The coffee accessions were characterized using 13 qualitative traits.Most of the characterized descriptors displayed a broad range of phenotypic variation among the evaluated accessions and the frequency distribution of these traits is presented in Table 2and Fig. 1.

Growth Habit, Stem Nature and Angle of Insertion of Primaries

Growth habit varied among the accessions with the lion share of these accessions (61.22%) had intermediate growth habit, while remaining (38.78%) had open growth habit. However, in this population no accession was observed with compact growth habit.

Similarly, two types of stem nature were observed in the populationwith 51.1 % of the accessions had stiffstem habit and the rest (48. 9%) had flexible stem habit. Angleofinsertion of primaries alsodemonstrated variation among the accessions and out of the total 49 accessions, 38.78.3%, 36.73 % and 24.49 % had drooping, horizontal spreading and semi-erect types of angle of insertion, respectively (Table2).

In general, coffee accessions with intermediate canopy, stiff tem habit and drooping typeangle of insertion of primaries were dominant in the population. In this regard, Masreshaw (2018) has reported the same findings.

Leaf Characteristics

The 49 Coffee accessions were classified in to three groups based on young leaf color.The proportions of coffee accessions in young leaf color were 73.47 % and 20.41%for green and greenish color, respectively. However, only 6.12 % of the accessionsshowed bronzy type of young leaf color, indicating that the majority of the accessions had green young leaf color (Table 2). For leaf shape, the majority of the accessions were elliptic (91.84%) type, whereas the proportions of lanceolate and ovate leaf shape accessions were 6.12 %, and 2.04 %, respectively, showing that the elliptic leaf shape was dominant in this population. As far as the tip leaf shape is concerned, the majority of the accessions (80%) were accuminate type, whereas the remaining 20% was apiculate type.Overall, accessions with green young leaf color, elliptic leaf shape and accuminate leaf apex were dominant. In agreement with the current findings, Olika (2011) and Solomon (2017) have also reported the existence of variability for leaf characteristics among Limu and East Wollega coffee accessions, respectively.

Fruit Characteristics

Coffee fruit characteristics displayed variation among the accessions. For stipulate shape, the ovate shaped accessions (51.02%) were dominant as compared to deltate and triangular shaped accessions, while the 22 and two accessions grouped under the latter two groups comprised of 44.9 % and 4.08 % of the accessions, respectively. There was also variation in fruit shape among the accessions with roundish (48.98%) and elliptic shape (46.94%) being the predominant ones, while the proportion of ovate shaped accessions was only 4.08%. Similarly, appreciable fruit color diversity was observed among the accessions with the majority of the accessions showed red fruit color (44.90%), while the remaining accessions showed light red (36.73%) and dark red color (18.37%).For calyx limb persistence, in the majority of the accessions (53.06%), calyx limb was present but for the remaining accessions (46.94 %) calyx limb was absent (Table 2). This indicates that there was considerable variability among the accessions for fruit characteristics with accessions having ovate stipulate shape, roundish fruit shape, red fruit color and calyx limb persistence were dominant in the population. The results of this findings is partly in agreement with findings of Masreshaw (2018) who have reported lager proportion of roundish fruit shape and red fruit color among coffee accessions collected from Yayu forest of Ethiopia

Coffee Green Bean Characteristics

Coffee green bean characteristics also showed variation among the accessions. The 49 coffee accessions were classified into two distinct groups in terms of seed shape with 63% and

37% of these accessions had obolong and round shape, respectively. Similarly, the accessions were also grouped under two distinct classes for seed uniformity with the largest proportion of the accessions (57%) had uniform seed, whereas the remaining (43 %) had mixed seed. Similar to seed shape and uniformity, bean size also showed two distinct classes with the largest proportion (96%) of the accessions had medium seed size, whereas only 4%had large seed (Table 2). This implies that there was considerable variability among the accessions for seed shape and uniformity as compared to bean size. In general, accessions with obolong, uniform and medium sized beans were predominant in the population. The higher proportionof medium bean sized coffee accessions observed in this study is in agreement with the finding of Akpertey *et al*. (2019) who reported higher proportion of medium sized coffee bean among *Coffea robsuta* genotypes.

Table2. *Percentage of phenotypic class values for 13 qualitative traits of 49 coffee germplasm accessions*

Phenotypic class	Code	Fre.	%	Phenotypic class	Code	Fre.	%
Growth habit				**Fruit shape**			
Open	1	19	38.78	Roundish	1	24	48.98
Intermediate	2	30	61.22	Ovate	3	2	4.08
Total		**49**	**100**	Elliptic	4	23	46.94
Stem habit					**Total**	**49**	**100**
Stiff	1	25	51.10	**Fruit color**			
flexible	2	24	48.9	Light red	4	18	36.73
Total		**49**	**100**	Red	5	22	44.90
Angle of lateral insertion				Dark red	6	9	18.37
Drooping	1	19	38.78		**Total**	**49**	**100**
Horizontal spreading	2	18	36.73	**Calyx limb persistence**			
Semi- erect	3	12	24.49.	absent	0	23	46.94
Total		**49**	**100**	Present	1	26	53.06
Young leaf color					**Total**	**49**	**100**
Greenish	1	10	20.41	**Seed shape**			
Green	2	36	73.47	round	1	18	37
Bronzy	5	3	6.12	Obolong	5	31	63
Total		**49**	**100**		**Total**	**49**	**100**
Leaf shape				**Seed uniformity**			
Ovate	2	1	2.04	uniform	1	28	57
Elliptic	3	45	91.84	Mixed	2	21	43
lanceolate	4	3	6.12		**Total**	**49**	**100**
Total		**49**	**100**	**Bean size**			
Leaf apex shape				Medium	2	47	96
Accuminate	4	39	80	Large	3	2	4
Apiculate	5	10	20		**Total**	**49**	**100**
Total		**49**	**100**				
Stipulate shape							
Ovate	2	25	51.02				
Triangular	3	2	4.08				
Deltate	4	22	44.90				
Total		49	100				

Shannon-Weaver Diversity Index

The Shannon-Weaver Diversity Index (H') as normalized by the maximum value in each case was calculated as the measure of phenotypic diversity for 13 qualitative characters and presented in Table 2.

Low H' estimate (nearer to zero than to one) indicates a low level of diversity and unevenness in the distribution and vice versa (Hennink and Zevan, 1991).

The estimation of H' values indicated large variations among the 49 coffee accessions for the observed phenotypic classes, ranging from 0.17 for screen size to 1.08 for angle of insertion of primary branches.

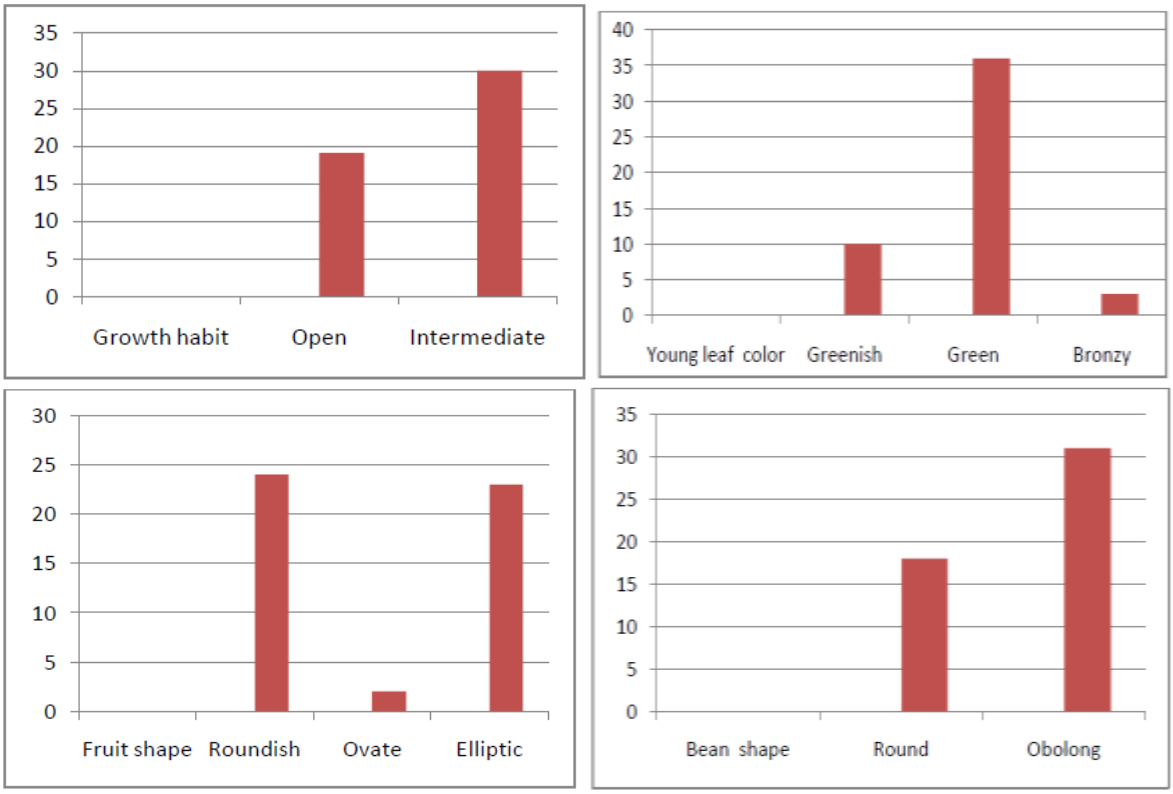

Fig1. *Bar graphs showing the frequencydistribution of growth habit, young leaf color, fruit shape and bean shape*

Among the qualitative traits, angle of insertion of primary branches (H'=1.08), fruit color (H'=1.04), stipule shape (H'=0.83), fruit shape (H'=0.83), young leaf color (H'=0.71) , clayx limb persistence (H'= 0.69), stem habit (H'=0.69), seed uniformity (H'= 0.68) ,growth habit (H'=0.67) and seed shape (H'=0.66) showed a high level of diversity and evenness. However, leaf apex shape (H'=0.50), leaf shape (H'=0.32) and bean size (H'=0.17) showed low level of diversity (Table 3). This indicated that among the qualitative traits, angle of insertion of primary branches, fruit color, fruit shape, stipule shape and young leaf tip color showed higher diversity among the accessions as compared to other traits.In a similar other work, Yigzaw (2005) has reported adequate variability among the tested genotypes for nine qualitative traits. Moreover, Olika(2011) has also reported high level of diversity (H'>0.5) for growth habit, stipule shape, branching habit, angle of insertion of primaries, fruit shape and stem habit. However, in contrast to this finding, the same worker reported high level of diversity for leaf shape and leaf apex shape, and low level of diversity (H'<0.5) for young leaf color and seed shape.This difference could probably be attributed to differences in coffee genetic materials used for the studies

Table3. *Estimates of Shannon- Weaver diversity index (H') for `13 qualitative traits of 49 coffee accessions*

Character	Shannon-Weaver diversity index (H')
Growth habit	0.67
Stem habit	0.69
Angle of insertion of primaries on main stem	1.08

Young leaf color	0.71
Leaf shape	0.32
Leaf apex shape	0.50
Stipule shape	0.83
Fruit shape	0.83
Fruit color:	1.04
Calyx limb persistence	0.69
Seed shape	0.66
Seed uniformity	0.68
Beansize	0.17

CONCLUSION

The present study exhibited the presence of genetic diversity for several qualitative traits. The existence of genetic diversity is a potential resource for improvement of the crop through selection and hybridization. Therefore, the observed variability should be exploited in order to improve the desired traits based on the breeding interest. However, the morphological diversity observed in this study must be further confirmed using molecular techniques of characterization.

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