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Agro-Morphological Characterization of Sidama Coffee (Coffea Arabica L.) Germplasm Accession under its Specialty Coffee Growing Area, Awada, Southern Ethiopia

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ABSTRACT

In the study area, coffee is the major growing crop as compared to the other annual and perennial crops, because of its suitable agro ecology and the farmers have closed cultural coffee production system. Thus, the experiment was conducted at Awada Agricultural Research Sub Center, Southern Ethiopia. One hundred twenty coffee germplasm and four standard checks were evaluated by twenty six quantitative and seven qualitative traits using augmented design with four replications. The aim of this study was to characterize and evaluate the coffee germplasm based on agro-morphological trait and identify superior coffee genotypes to be advanced for further breeding program. The coffee green bean yield and yield related traits were recorded for each of the five years (2009-2013). The analysis of variance was showed significance difference. In addition, a wide range was observed in the agro-morphological traits. The average of the five years showed that the check 1377 was the highest yielding in all years except in 2010 when check 75227 was the best yielder. Accession AW-113 was superior to the best checks in all five years and should be advanced further testing in different coffee growing areas for registration as a variety. Clustering based on quantitative characters grouped the 124 genotypes into 10 groups of different sizes, ranging from 1 entry in cluster XI and X to 47 entries in cluster II. On the other hand, high diversity index (>0.60) was observed for each of the seven qualitative traits.

Keywords: *Coffee arabica L, coffee germplasm, quantitative trait, qualitative trait, cluster analysis and diversity index;*

INTRODUCTION

The coffee bean is obtained from the fruit of the coffee plant, an evergreen shrub belonging to the genus *Coffea*, in the Rubiaceae family, which is one of the largest tropical angiosperm families. According to Davis et al (2006), there are 103 coffee species, all exclusively are restricted to the tropical forests of Africa, Madagascar and Islands of the Indian Ocean. Of these species, only the three species used in the production of the beverage coffee: *C. arabica* (Arabica coffee), *C. canephora* (Robusta coffee) and *C. liberica* (Liberian or Liberica coffee, or excels coffee). From the three, *C. arabica* is the most important commercial species and is the only allopolyploid (2n = 4x = 44) coffee species and self-fertile at approximately above 95 % (Silvarolla et al., 2004; Lashermes et al., 1999). The other *Coffea* species are diploid (2n = 2x =22) and self-sterile, except for *C. heterocalyx* and *C. Moloundou*, which are diploid but self-fertile (Coulibaly et al., 2002).

Arabica coffee is both its origin and diversity in Ethiopia, and plays a vital role in the country's overall the economy and has lion share in earning foreign currency. It is mainly produced, processed and exchanged in the Southwest, Southeast, South, East parts of the country. In these areas are found the famous coffee types known internationally by the names, Yirgacheffe, Sidama, Harar, Limmu, Gimbi etc.; coffee types which fetch a premium price (EIPO, 2011; Taye, 2010). The total area of land devoted to coffee production is estimated around 700,000 hectares, of which 538, 466.80 hectares are estimated to be productive (CSA 2013/14; Taye, 2013).

Considerable phenotypic difference was observed in cultivated and traditionally recognized landraces of arabica coffee in Ethiopia (Dessalegn, 2002). Many important characteristics were observed in Ethiopian coffee, such as resistance to leaf rust, nematodes, coffee berry disease (Bayetta, 2001; Ermias, 2005), as well as variation in green bean biochemical compounds composition, tree size and shape, bean size, shape and color and in cup quality (Silvarolla et al., 2004; Yigzaw, 2005). Thus, the phenotypic variations as well as cultivation under diverse environmental conditions indicate the presence of Arabica coffee genetic diversity in Ethiopia (Bayetta, 2001; Yigzaw, 2005).

On the other side, the efforts have been made to collect, conserve and utilize Ethiopian coffee germplasm was carried out by national coffee collection program. A total of around 12,448 arabica coffee germplasm accessions have been collected from the different areas, ex- situ conserved and maintained on research plots of the Jimma Research Center and its sub-centers 6,717 accessions. On the field gene banks of the Institute of Biodiversity Conservation 5,731 accessions have been conserved in Ethiopia (Bayetta and Labouisse, 2006; Taye, 2013). However, its productivity is limited due to lack of improved varieties, biotic and abiotic factors.

Thus, different efforts and strategies are necessary to maximize the potential of coffee production. In depth to utilize the available coffee genetic resources characterization and evaluation of germplasm is the crucial step in the improvement process following different methods. Such as morphological, biochemical characteristics and molecular markers have utilized to characterize this rich coffee germplasm. In Ethiopia, Mesfin and Bayetta (2008) and Abdi (2009) used morphological traits to characterize arabica coffee collections from Harerge. Ermias (2005) used the same method on coffee collections from Wellega while Olika et al. (2011) characterized coffee collections from Limmu. All these authors have indicated the presence of high genetic diversity in these coffee collections. Similarly, genetic diversity analyses of cup quality and biochemical characteristics of Arabica coffee conducted in Ethiopia by Yigzaw (2005), Abeyot et al. (2011), Olika et al. (2011) and in Kenya by Kathurima et al. (2009) has confirmed the existence of rich genetic diversity in these characteristics.

Adequate characterization for agronomic and morphological traits is necessary to facilitate utilization of germplasm by breeders. But, apart from very few observations no data has been recorded to enable the systematic characterization of coffee germplasm collected from the Dale and Aleta Wondo woredas, Sidama Zone. Moreover, intensive data collected on agro-morphological traits could give sufficient information for the characterization and evaluation of these coffee accessions. Such an intensive and extensive study can also justify the economic benefits of the high cost of ex-situ maintenance of such a large coffee accessions. The present study was, therefore, carried out with the following objectives: to characterize and evaluate morphological difference among coffee germplasm accessions collected from the two woredas of Sidama Zone, South Nation Nationality and People Regional State, Ethiopia and to identify superior coffee genotypes to be advanced further in the breeding program.

MATERIALS AND METHODS

Experimental Site

Field experiment was conducted at Awada Agricultural Research Sub-Center (AARSC). AARSC is found 45 km South of Hawassa in Sidama Zone and is located at 6°3'N Latitude and 38°E Longitude at an altitude of 1750 m.a.s.l. The area receives an annual minimum and maximum rainfall 858.1 and 1676.3 mm, respectively. The annual average minimum and maximum air temperatures are 11.0^{0}C and 28.4^{0}C, respectively. The major soil types of the center are eutric-nitosol and chromotic-cambisols that are highly suitable for coffee production (Mesfin and Bayetta, 2008).

Treatments and Experimental Design

One hundred twenty coffee land race and four released varieties (75227, 744, 7440 and 1377) were used as standard checks for the study (Appendix 1), field established in 2006 at the AARSC. These coffee land races collected from different agro-ecologies of Dale and Aleta Wondo Woredas since, 2005. The experiment was laid down in the field using augmented design, which is used with replicated checks to assess the performance of non-replicated accession in complete block designs in four blocks (Sharma, 2006). A single row consisting of ten trees per plot and plant-to-plant spacing used was two meters by two meters, while spacing between blocks was four meter. The recommended agronomic practices were uniformly and properly applied for nursery and field operations.

Data Collection and Statistical Analysis

Data were recorded for 26 quantitative characters, namely: plant height (cm), stem diameter (cm), number of main stem nodes (no), angle of primary branches (degrees), canopy diameter (cm), average inter node length of main stem (cm), average length of primary branches (cm), average girth of primary branches (cm), average inter node length of longest primary branches (cm), number of primary branches(no), number of secondary branches (no), percentage of coffee bearing primary branches (%), height up to first primary branches (cm), leaf length (cm), Leaf width (cm), leaf area (cm^2), fruit length (mm), fruit width (mm), fruit thickness (mm),hundred green bean weights (g), green bean yield per tree (g), bean length (mm), bean width (mm), bean thickness (mm), coffee berry disease (%) and coffee leaf rust (%) and 7 qualitative characters, namely: growth habit, stem habit, branching habit, leaf shape, young leaf color, fruit shape and fruit color, were recorded from each accession using the standard procedures of (IPGRI, 1996).

Analysis of variance of the traits was computed level using SAS computer program and treatment means were also computed using least significant difference (LSD) test at 5% of probability (SAS, 2002). The clustering of coffee genotypes was done to separate genotypes into different groups using proc cluster of SAS, average linkage option was used. The frequency distribution is a systematic way to order a set of data from the lowest to the highest value showing the number of occurrence at 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 Hennink and Zeven (1991).

$H' = -\frac{\sum p_{ij} ln_{pi}}{\ln n}$ Where, p_i 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 belong to one and the same class. Conversely, a value 1 indicates maximum diversity i.e. the numbers of individuals are evenly distributed among the n class.

Results and Discussion

Coffee Yield

The coffee mean yield (g/tree) of the 120 accessions was higher than the mean of the four checks in all years except in 2010; 262.5 vs 148.9 in 2009, 36.6 vs 45.9 in 2010, 644.8 vs 495.7 in 2011, 288.5 vs 152.1 in 2012, 594 vs 361.2 in 2013 and 365.3 vs 240.8 for the mean yield over the five years (Appendix 2). The coffee germplasm accessions collected from Dale and Aleta Wondo Woredas of SNNPRS gave mean green bean yield per tree higher than the mean of the four released varieties by 51.7%. This is an indication that the best coffee varieties specifically adapted to coffee growing areas similar to Dale and Aleta Wondo Woredas of SNNPRS could only be developed by appropriate selection among coffee germplasm collections.

ANOVA of green bean yield for each of the five years (2009-2013) and for the average of the five years has revealed that the check 1377 was the highest yielding check in all years except in 2010 when check 75227 was the best yielder (Appendix 2). However, check 1377 was surpassed by 23 accessions in 2009, by 15 accessions in 2011, by 10 accessions in 2012 and by 89 accessions in 2013. In 2010 the best check 75227 was surpassed by 23 accessions. This shows the possibility of identifying genotypes among collections from Dale and Aleta Wondo woredas which are higher yielding than the varieties already released by the national program.

Among the 18 accessions whose mean green bean yield (g/tree) over five years was higher than that of the best check 1377 (510.98), accession AW-113 (873.76) was superior to the best checks in all 5 years and should be advanced further testing in different ago-ecology for verification (Appendix 2). Other accessions which were superior to the best checks in four of the five years are accessions AW-81(762.45), AW-78 (714.00), AW-09 (703.80), AW-113 (691.90), AW-16 (684.25), AW-04 (676.60), AW-21 (661.30), AW-05 (647.70), and AW-79 (629.85). The following accessions were superior to the best checks in three of the five years and gave high mean yields. Accessions AW-113 (2048.50), AW-06 (1796.48), AW-76 (1621.80), AW-77 (1598.00), AW-123 (1596.30), AW-40 (1557.20), AW-14 (1400.80), AW-47 (1392.73), AW-13 (1385.08) and AW-110 (1371.90) also might be proposed to further testing in different agro-ecology. These results agree with the statements of renowned coffee breeders (Antonio et al., 2010), who suggested that the high yield years are best suited for selection for bean yield in arabica coffee progenies.

Mean Performance of Genotypes

The ranges and means for green bean yield in g/tree over five consecutive years (2009-2013) and their average, and for 25 characters studied

(Table 1). The result showed that there was wide range of variation for most of the traits. Such as, wide ranges were recorded for green bean yield per tree in 2009 (2.13-684.25), in 2010 (0.00-236.73), in 2011 (9.56 -2048.5), in 2012 (21.25-762.45), in 2013 (94.35-1287.75) and their average yield (64.18-873.76) wide ranges were recorded. Plant height (129.13-411.25), number of primary branches (35.75-140.75), number of secondary branches (63.91-472.28), average length of primary branches (28.74-136.47), percentage of bearing primaries branches (43.76-100.00), canopy diameter (121.76-262.13), coffee berry disease (4.53-85.71) and coffee leaf rust reaction (1.84-47.31) have founded wide range. Some of these important agronomic traits, such as average green bean yield per tree in different years, number of primary branches, number of secondary branches, percentage of bearing primaries branches, coffee berry disease and coffee leaf rust reaction, had the highest range between the tested genotypes.

In general, the range and mean in this study indicated the existence of variability among the tested accessions for the major characters studied and there is considerable potential for coffee improvement program in the future. The present findings is in agreement with the findings of Yigzaw (2005) who reported wide range of variation for average green bean yield per tree, tree height, canopy diameter, number of primary branches and number of secondary branches. According to Abdi (2009), the extent of variability was higher for the characters like plant height number of internodes on main stem, inter node length of main stem, diameter of main stem, number of primary branches, length of primary branches, number of internodes on primary branches (14 to 26.70), internodes length of primary branches and number of secondary branches on 49 arabica coffee genotypes collected from West Harerge, Ethiopia.

Table1. *Range and mean of quantitative characters for the 124 coffee germplasm accessions studied*

Characters	Minimum Value	Maximum Value	Range unit	Mean
Green bean yield per tree in 2009 (g)	2.13	684.25	682.12	258.87
Green bean yield per tree in 2010 (g)	0.00	236.73	236.73	36.92
Green bean yield per tree in 2011 (g)	9.56	2048.50	2038.94	691.72
Green bean yield per tree in 2012 (g)	21.25	762.45	741.20	288.83
Green bean yield per tree in 2013 (g)	94.35	1287.75	1193.40	586.47
Average green bean yield per tree (g) for 5 years	64.18	873.76	809.58	372.56
Plant height (cm)	129.13	411.25	282.12	304.69
Stem diameter (cm)	1.22	8.41	7.19	5.12
Number of main stem nodes	17.30	45.86	28.56	30.90
Angle of primaries branches (degree)	38.64	102.02	63.38	70.23
Canopy diameter (cm)	121.76	262.13	140.37	194.14
Average inter node length of main stem (cm)	2.33	7.93	5.60	5.10
Average length of primary branches (cm)	28.74	136.47	107.73	82.43
Average girth primary branches (cm)	0.40	1.24	0.84	0.88
Average inter node length of primary branches (cm)	0.17	4.93	4.76	2.59
Number of primary branches	35.75	140.75	88.28	86.14
Number of secondary branches	63.91	472.28	408.37	228.50
Percentage of bearing primaries branches	43.76	100.00	71.88	81.42
Height up to first primary branches (cm)	3.11	36.17	33.06	18.58
Leaf length (cm)	6.53	15.60	9.07	11.42
Leaf width (cm)	1.77	6.59	4.82	4.69
Leaf area (cm^2)	9.71	54.62	44.91	37.34
Fruit length (mm)	12.17	19.21	7.04	14.92
Fruit width (mm)	8.30	14.53	6.23	10.47
Fruit thickness (mm)	7.62	12.12	4.50	10.08
Bean thickness (mm)	6.69	11.44	4.75	8.84
Bean length (mm)	4.88	7.00	2.12	5.88
Bean width (mm)	2.74	4.69	1.95	3.76
Hundred green bean weights (g)	7.74	24.21	16.47	17.01
Coffee berry disease (%)	4.53	85.71	90.24	18.29
Coffee leaf rust (%)	1.84	47.31	49.15	13.07

Clustering of Genotypes using Quantitative Traits

The similarity of 124 coffee genotypes was assessed by cluster analysis using 19 quantitative characters. Cluster analysis confirmed the presence some variation among genotypes. The grouped 124 coffee genotypes in to ten clusters indicated in Table 3. The size of genotypes in each varied from 1 accession in cluster XI and X to 47 accessions in cluster II. The clustering pattern of the accessions revealed the existence of genetic diversity in the coffee accessions for the characters studied. Similarly, Olika et al. (2011) has made cluster analysis based on 22 quantitative traits grouped 49 Limmu coffee genotypes in to four clusters.

Table2. *Distribution of coffee accessions in collected location into 10 clusters*

Woredas	Passant association	Cluster									
		I	II	III	IV	V	VI	VII	VIII	IX	X
Aleta-Wondo	Shecha	0	3	0	0	0	0	0	0	0	0
	Gidibo	0	1	0	1	0	0	0	0	1	0
	Futaye	3	0	0	0	0	0	0	0	0	0
	Lela wamerera	2	0	0	0	0	0	1	0	0	0
	Weto	0	3	2	0	0	0	0	0	0	0
	Bultuma	1	1	1	1	0	0	0	0	0	0
	Korkie	2	2	2	0	0	1	0	0	0	0
	Gunde	1	1	1	0	0	0	0	0	0	0
	Dibicsa	0	2	0	0	0	0	0	1	0	0
	Chuko lemla	0	4	2	0	0	0	0	0	0	0
	Chuko woyama	2	2	0	0	0	0	0	0	0	0
	Debeka	0	0	2	4	0	0	0	0	0	0
	Rufo chancho	1	5	0	0	0	0	0	0	0	0
	Mekela	5	2	0	0	0	0	0	0	0	0
	Sheecha	0	1	1	0	0	0	0	0	0	0
Sub-total		**17**	**27**	**11**	**6**	**0**	**1**	**1**	**1**	**1**	**0**
Dale	Fero I	4	2	0	1	0	0	0	0	0	0
	Gejaba	1	1	0	1	0	0	0	0	0	0
	Menafesha	0	2	0	3	0	0	0	0	0	0
	Hale kera	2	2	0	0	0	1	0	0	0	0
	Mamena	0	1	1	1	0	0	0	1	0	0
	Hunkuti	0	2	0	1	0	0	1	0	0	1
	Kileye	2	3	0	0	0	0	0	0	0	0
	Shefina	0	3	3	0	0	0	0	0	0	0
	Boa-Bedegelo	0	0	1	1	1	0	0	0	0	0
	Manche	1	2	0	0	0	0	0	0	0	0
	Foka	1	0	2	0	1	0	0	0	0	0
	Foka-Bedelicha	2	1	2	0	0	0	0	0	0	0
Sub-total		**13**	**19**	**9**	**8**	**2**	**1**	**1**	**1**	**0**	**1**
Keffa	Near to Washi	0	0	3	0	0	0	0	0	0	0
Wonago	Kotti	0	1	0	0	0	0	0	0	0	0
Total		**30**	**47**	**23**	**14**	**2**	**2**	**2**	**2**	**1**	**1**

The frequency of accessions on various location in a specific cluster (Table 2). This was done to see if accessions from one woreda group in to the same cluster. The clusters contain accessions from two woredas have showed a grater number of accessions in the clusters come only from Aeta-Wondo Woreda than Dale Woreda. So clustering has revealed that coffee accession was not only clustered according to area of collection. This could be attributed to the unrestricted movement of coffee seed or seedling from area to area (Yigzaw, 2005).

In addition, Esayas (2005) reported based on molecular marker analysis clustering of coffee populations on the bases of their geographic origin but failed to cluster according to their respective populations due to the presence of substantial gene flow between local populations in the form of young coffee plants. Thus, this gene flow in coffee can be further attributed to human interference due to the fact that the coffee accessions were collected from area. This area is always under human pressure with respect to movement of coffee seeds that are distributed by government extension workers and non-governmental organization and planted by the farmers.

Moreover, considerable differences in cluster means were noticed for 19 quantitative traits (Table 4). As far as coffee bean yield was concerned, accessions in cluster-VII the highest green bean yield per tree in 2013 year, number of primary branches and number of secondary branches exhibited 732.70, 122.64 and 449.78, respectively. Most of the high yielding ability coffee accessions were grouped in cluster-VII. This indicated that we can cross accessions in cluster with each other. The lowest green bean yield per tree in 2013 year (374.85, 196.35 and 289.85) number of primary branches (41.71, 72.08 and 144.14) and medium number secondary branches (90.47, 63.91 and 408.28) was for cluster V, X and XI, respectively.

The range of plant height among clusters was 138.63 to 400.63 for cluster-V and cluster-VIII in the same order and angle of primaries branches (91.39) were also in cluster-VIII. Cluster-XI had low angle of primaries branches and Cluster-VI had low average inter node length of main stem, bean width (mm) coffee berry disease (%) and coffee leaf rust (%), from cluster-VI indicating that disease resistance genotypes were grouped in this cluster. Meanwhile, the present study suggested that the germplasm accessions from cluster-VII and cluster-VI could offer relatively better potential line that, when intercrossed, could produce hybrid with maximum heterotic value.

Table3. *Clustering patterns of 124 coffee accessions based on 19 quantitative traits*

Cluster	No. of accessions in each cluster	% of genotypes in cluster	Name of accessions in each cluster
I	30	24.19	AW-87,AW-24,AW-77,AW-43,AW-07,AW-76,AW-68,AW-73,AW-09,AW-11,AW-66,AW-12,AW-62,AW-64,AW-67,AW-71,AW-21,AW-79,AW-61,AW-114,AW-122,AW-10,AW-90,AW-27,AW-45,AW-123,AW-30,AW-100,AW-120,AW-101
II	47	37.90	AW-115,AW-78,AW-01,AW-05,AW-65,AW-59,AW-33,AW-81,AW-18,AW-34,AW-26,AW-75,AW-46,AW-70,AW-58,AW-47,AW-63,AW-102,AW-31,AW-99,AW-105,AW-20,AW-94,AW-85,AW-98,AW-79,AW-104,AW-15,AW-36,AW-74,AW-103,AW-37,AW-108,AW-60,AW-125,AW-88,AW-03,AW-57,AW-28,AW-84,AW-38,AW-16,AW-55,AW-106,AW-116,AW-41,AW-02,1377
III	23	18.55	AW-92,AW-22,AW-14,AW-53,AW-29,AW-25,AW-69,AW-39,AW-17,AW-112,AW-121,AW-40,AW-117,AW-50,AW-110,AW-107,AW-124,AW-118,AW-32,AW-109,744,75227,7440
IV	14	11.29	AW-96,AW-06,AW-48,AW-91,AW-113,AW-83,AW-82,AW-54,AW-52,AW-51,AW-19,AW-72,AW-84,AW-80
V	2	1.61	AW-119,AW-111
VI	2	1.61	AW-23,AW-86
VII	2	1.61	AW-95,AW-13
VIII	2	1.61	AW-35,AW-93
XI	1	0.81	AW-04
X	1	0.81	AW-97

Cluster-VII had highest number of main stem nodes (33.68) and minimum in cluster-XI (24.30). Canopy diameter ranged from 121.91to 241.76 cm in cluster-X and cluster-XI, respectively. The highest leaf area (45.92), leaf length (11.81) and leaf width (5.52) were recorded for cluster-VIII and the lowest to Cluster-X that is leaf area (9.71), leaf length (6.98) and leaf width (3.23). On the other hand, hundred green bean weights were highest for cluster-IV (20.30) and cluster-V (20.30) in similar fashion and minimum for Cluster-XI (6.17). Therefore, the present study confirmed the presence of substantial variability among Dale and Aleta-Wondo coffee accessions by considering cluster analysis.

Frequency Distribution of Qualitative Traits

The frequency distribution of qualitative characters showed the presences of variation among the coffee genotype studied (Table 4). The character growth habit varied from accession to accession. The growth habits recorded from coffee genotypes were open with spreading branch (13.71%), intermediate (70.16%) and compact type (16.13%). In addition, coffee genotypes with strong and flexible stem were observed with proportion of 78.22% and 21.78%, respectively.

The branching habits showed in the accessions were very few primary branches (1.61%) many primary branches with few secondary branches (0.81%), many primary branches with many secondary branches (48.97%), many primary branches with many secondary and tertiary branches (48.61%). The leaf shape observed in coffee accessions was obovate (1.61%), ovate (41.13%), elliptic and lanceolate (57.26%). In addition, young leaf colors in the accessions were greenish (33.87%), brownish (47.77%), bronze (18.36%), fruit shape, round (25.81%), obovate (74.19%). Fruit color observed in accessions was yellow (1.61%), light red (64.52%) and dark red (33.87%).

Shannon-Weaver Diversity Index (H')

Diversity for each of the seven qualitative descriptors was observed and high diversity values were obtained in accessions i.e. above 0.600. The estimates of Shannon-Weaver diversity (H') of qualitative traits studied genotypes is presented in table 5. For all the traits, the minimum value of H' was 0.66707 for branching habit and the maximum value was 0.97717 for leaf shape. Similarly, Yigzaw (2005) and Abdi (2009) 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. A low H` indicates unbalanced frequency classes for an individual trait and lack of diversity for the trait (Hennink and Zevan, 1991). Traits such as leaf shape had greater value of H` followed by young leaf color, fruit shape, stem habit and growth habit and were more diverse as compare to fruit color and branching habit. Furthermore, the diversity indices of all qualitative traits suggesting the presence of adequate variability for these traits among evaluated genotypes.

Table4. *Cluster means of 124 coffee accessions studied for 19 quantitative traits.*

SN	Traits	I	II	III	IV	V	VI	VII	VIII	XI	X
1	Green bean yield per tree in 2013 (g)	594.42	614.86	584.84	519.68	374.85	623.48	732.70	657.90	289.85	196.35
2	Plant height (cm)	249.25	370.72	218.23	382.15	138.63	165.32	276.25	400.63	183.75	365.63
3	Stem diameter (cm)	5.15	5.12	4.86	5.43	3.67	6.34	3.88	6.85	3.93	6.88
4	Number of main stem nodes	30.27	32.32	27.82	33.57	22.93	32.08	33.68	31.80	24.30	29.11
5	Angle of primaries branches (degree)	71.06	71.97	63.18	76.18	40.80	86.00	63.42	91.39	53.27	58.42
6	Canopy diameter (cm)	195.45	191.13	184.97	219.03	138.01	224.97	196.08	212.33	241.76	121.91
7	Average inter node length of main stem (cm)	4.14	6.23	3.73	6.22	2.89	3.09	4.07	6.50	2.33	6.49
8	Average length of primary branches (cm)	83.10	83.97	76.89	88.10	30.62	105.37	88.86	97.83	99.51	34.65
9	Number of primary branches	84.45	88.18	75.86	95.32	41.71	64.74	122.64	120.64	144.14	72.08
10	Number of secondary branches	255.57	214.17	150.71	293.53	90.47	288.35	449.78	447.66	408.28	63.91
11	Percentage of bearing primaries branches	86.04	81.57	92.13	82.88	96.2	90.6	63.93	75.37	61.90	56.91
12	Leaf length (cm)	11.21	12.25	11.33	9.99	11.80	9.52	9.78	11.81	11.48	6.98
13	Leaf width (cm)	4.61	4.84	4.78	4.35	4.37	4.09	4.46	5.52	4.58	3.23
14	Leaf area (cm^2)	36.92	40.16	38.48	29.71	36.54	23.68	37.66	45.92	36.63	9.71
15	Fruit length (mm)	14.98	15.00	14.88	14.72	13.42	16.08	14.30	14.21	15.17	16.12
16	Bean width (mm)	5.88	5.87	5.99	5.82	5.85	5.67	5.30	6.15	6.70	5.73
17	Hundred green bean weights (g)	19.18	18.58	18.96	20.30	20.30	9.77	12.67	9.80	6.17	23.11
18	Coffee berry disease (%)	20.38	16.38	21.45	16.36	6.82	4.67	24.53	16.36	3.43	55.99
19	Coffee leaf rust (%)	13.75	10.06	14.36	15.13	18.78	4.59	26.17	19.42	24.36	31.16

Table5. *Frequency distribution and Shannon-Weaver diversity indices (H') of seven qualitative traits of coffee accessions*

SN	Traits	Description	Frequency (%)	H'
1	Growth habit	1 Open with spreading branch	13.71	0.74056
		2 Intermediate	70.16	
		3 Compact	16.13	
2	Stem habit	1 Stiff or strong	78.22	0.74087
		2 Flexible	21.78	
3	Branching habit	1 Very few branches (primary)	1.61	0.66707
		2 Many branches (primary) with few secondary branches	0.81	
		3 Many branches (primary) with many secondary branches	48.97	
		4 Many branches (primary) with many secondary and tertiary branches	48.61	
4	Young leaf color	1 Greenish	33.87	0.93991
		2 Brownish	47.77	
		3 Bronze	18.36	
5	Leaf shape	1 Obovate	1.61	0.97717
		2 Ovate	41.13	
		3 Elliptic	-	
		4 Lanceolate	57.26	
6	Fruit shape	1 Round	25.81	0.82381
		2 Obovate	74.19	
7	Fruit color	0 Yellow	1.61	0.67241
		1 Light red	64.52	
		2 Dark red	33.87	

Conclusions and Recommendation

The significant different were exhibited among the accessions for most of the yield and yield contributing characters considered. Most of the accessions mean value for yield and different growth characters exceeded the mean value of the check cultivars. This indicates the higher performance of the accession for tree vigor than the check cultivars and the indigenous coffee types are location specific and give maximum growth and yield performance in areas where they adapt best. The ranges of mean values for most of the morphological characters were large showing the existence of variations among the tested accessions.

Moreover, the agro-morphological traits among evaluated arabica coffee genotypes have been confirmed the presence of district character to study further. The existence of dissimilarity is potential resource for improvement of coffee through selection. Therefore, based on the major findings of the study direct selection, among the 18 accessions whose mean bean yield over five years was higher than that of the best check (1377), accession AW-113 was superior in all 5 years and could be promoted further breeding program. Other accessions superior to the best checks in four of the five years were AW-81, AW-78, AW-09, AW-16, AW-04 AW-21, AW-05 and AW-79. And accessions superior to the best checks in three of the five years were AW-06, AW-76, AW-77, AW-123, AW-40, AW-14, AW-47, AW-13 and AW-110. These accessions should be subjected to further testing in different potential coffee growing agro ecologies.

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Appendix1. *Sidama Zone (Aleta Wondo and Dale woredas) coffee land races and their original place of collection used for study*

No	Coffee Acc.	PA	Location	Woredas	Remarks	No.	Coffee Acc.	PA	Location	Woredas	Remarks
1	AW-01	Shecha	Illeecho	A.wondo		63	AW-68	Mekela	Bensha	A.wondo	
2	AW-02	Shecha	Illeecho	A.wondo		64	AW-69	Sheecha	Tulicha	A.wondo	
3	AW-03	Shecha	Illeecho	A.wondo		65	AW-70	Sheecha	Tulicha	A.wondo	
4	AW-04	Gidibo	Dolima	A.wondo		66	AW-71	Fero I	Fero	Dale	

									Service		
5	AW-05	Gidibo	Dolima	A.wondo		67	AW-72	Fero I	Fero Service	Dale	
6	AW-06	Gidibo	Dolima	A.wondo		68	AW-73	Fero I	Fero	Dale	
7	AW-07	Futaye	Rikata	A.wondo		69	AW-74	Fero I	Fero Service	Dale	
8	AW-09	Futaye	Rikata	A.wondo		70	AW-75	Ferro I	Toucho	Dale	
9	AW-10	Futaye	Rikata	A.wondo		71	AW-76	Fero I	Toucho	Dale	
10	AW-11	Lela wamerera	Hatawo	A.wondo		72	AW-77	Fero I	Toucho	Dale	
11	AW-12	Lela wamerera	Hatawo	A.wondo		73	AW-78	Gejaba	Gejaba	Dale	
12	AW-13	Lela wamerera	Hatawo	A.wondo		74	AW-79	Gejaba	Gejaba	Dale	
13	AW-14	Weto	Metero	A.wondo		75	AW-80	Gejaba	Gejaba	Dale	
14	AW-15	Weto	Metero	A.wondo		76	AW-81	Menafesha	Gereshe	Dale	
15	AW-16	Weto	Metero	A.wondo		77	AW-82	Menafesha	Gereshe	Dale	
16	AW-17	Weto	Galada	A.wondo		78	AW-83	Menafesha	Gejaba	Dale	
17	AW-18	Weto	Hadessa	A.wondo		79	AW-84	Menafesha	Gereshe	Dale	
18	AW-19	Bultuma	Herbaye	A.wondo		80	AW-85	Menafesha	Gereshe	Dale	
19	AW-20	Bultuma	Herbaye	A.wondo		81	AW-86	Hale kera	Hulisa	Dale	
20	AW-21	Bultuma	Herbaye	A.wondo		82	AW-87	Hale kera	Hulisa	Dale	
21	AW-22	Bultuma	Herbaye	A.wondo		83	AW-88	Hale kera	Hulisa	Dale	
22	AW-23	Korkie	Sabola	A.wondo		84	AW-89	Hale kera	Hulisa	Dale	
23	AW-24	Korkie	Sabola	A.wondo		85	AW-90	Hale kera	Hulisa	Dale	
24	AW-25	Korkie	Sabola	A.wondo		86	AW-91	Mamena	Goma	Dale	
25	AW-26	Korkie	Sabola	A.wondo		87	AW-92	Mamena	Goma	Dale	
26	AW-27	Korkie	Boyasine	A.wondo		88	AW-93	Mamena	Gone	Dale	
27	AW-28	Gunde	Arjamo	A.wondo		89	AW-94	Mamena	Shemore	Dale	
28	AW-29	Gunde	Arjamo	A.wondo		90	AW-95	Hunkuti	Gotano	Dale	
29	AW-30	Gunde	Arjamo	A.wondo		91	AW-96	Hunkuti	Shemore	Dale	
30	AW-31	Korkie	Buda	A.wondo		92	AW-97	Hunkuti	Guta	Dale	
31	AW-32	Korkie	Buda	A.wondo		93	AW-98	Hunkuti	Guta	Dale	
32	AW-33	Dibicsa	Dibicsa	A.wondo		94	AW-99	Hunkuti	Guta	Dale	
33	AW-34	Dibicsa	Dibicsa	A.wondo		95	AW-100	Kileye	Mike	Dale	
34	AW-35	Dibicsa	Dibicsa	A.wondo		96	AW-101	Kileye	Mike	Dale	
35	AW-36	Chuko lemla	Yadito-Elelcho	A.wondo		97	AW-102	Kileye	Mike	Dale	
36	AW-37	Chuko lemla	Yadito-Elelcho	A.wondo		98	AW-103	Kileye	Mike	Dale	
37	AW-38	Chuko lemla	Elelcho	A.wondo		99	AW-104	Kileye	Mike	Dale	
38	AW-39	Chuko lemla	Elelcho	A.wondo		100	AW-105	Shefina	Woyeba	Dale	
39	AW-40	Chuko lemla	Elelcho	A.wondo		101	AW-106	Shefina	Woyeba	Dale	
40	AW-41	Chuko lemla	Elelcho	A.wondo		102	AW-107	Shefina	Woyeba	Dale	
41	AW-43	Chuko woyama	Bedeclca	A.wondo		103	AW-108	Shefina	Woyeba	Dale	
42	AW-45	Chicho woyama	Debecha	A.wondo		104	AW-109	Shefina	Woyeba	Dale	
43	AW-46	Chicho woyama	Debecha	A.wondo		105	AW-110	Shefina	Woyeba	Dale	
44	AW-47	Chicho woyama	Debecha	A.wondo		106	AW-111	Boa-Bedegelo	Bankancho	Dale	
45	AW-48	Debeka	Sike	A.wondo		107	AW-112	Boa-Bedegelo	Bankancho	Dale	
46	AW-50	Debeka	Sike	A.wondo		108	AW-113	Boa-	Bankanch	Dale	

								Bedegelo	o		
47	AW-51	Debeka	Gerari	A.wondo		109	AW-114	Manche	Godimo	Dale	
48	AW-52	Debeka	Gerari	A.wondo		110	AW-115	Manche	Godimo	Dale	
49	AW-53	Debeka	Gerari	A.wondo		111	AW-116	Manche	Godimo	Dale	
50	AW-54	Debeka	Gisa Horo	A.wondo		112	AW-117	Foka	Kotite	Dale	
51	AW-55	Rufo chancho	Hara	A.wondo		113	AW-118	Foka	Kotite	Dale	
52	AW-57	Rufo chancho	Hara	A.wondo		114	AW-119	Foka	Kotite	Dale	
53	AW-58	Rufo chancho	Hara	A.wondo		115	AW-120	Foka	Kotite	Dale	
54	AW-59	Rufo chancho	Hara	A.wondo		116	AW-121	Foka Bedelicha	Bedelicha	Dale	
55	AW-60	Rufo chancho	Hara	A.wondo		117	AW-122	Foka Bedelicha	Bedelicha	Dale	
56	AW-61	Rufo chancho	Hara	A.wondo		118	AW-123	Foka Bedelicha	Bedelicha	Dale	
57	AW-62	Mekela	Shala	A.wondo		119	AW-124	Foka Bedelicha	Bedelicha	Dale	
58	AW-63	Mekela	Degala	A.wondo		120	AW-125	Foka Bedelicha	Bedelicha	Dale	
59	AW-64	Mekela	Degala	A.wondo		121	744	Near to Washi		Keffa	check
60	AW-65	Mekela	Degala	A.wondo		122	75227	Near to Washi		Keffa	check
61	AW-66	Mekela	Degala	A.wondo		123	1377	Near to Wonago		Wonago	check
62	AW-67	Mekela	Bensha	A.wondo		124	7440	Near to Washi		Keffa	check

PA= Peasant Association

Appendix2. *Mean of green bean yields per tree over five consecutive years for the studied coffee genotypes*

SN	Coffee Acc.	GBYT09(g)	GBYT10(g)	GBYT11(g)	GBYT12(g)	GBYT13(g)	AvGBYT(g)
1	AW-87	92.44	3.19	241.83	221.85	123.25	136.51
2	AW-04	283.69	0.00	647.49	676.6	289.85	379.53
3	AW-95	161.5	16.15	551.86	368.9	436.9	307.06
4	AW-92	96.69	10.63	707.63	153	693.6	332.31
5	AW-24	394.19	0.00	846.18	334.9	596.7	434.39
6	AW-13	535.71	4.25	1385.08	79.05	1028.5	606.52
7	AW-96	216.75	8.50	403.11	492.15	289	281.9
8	AW-23	417.78	0.00	1010.23	40.8	468.35	387.43
9	AW-35	291.55	4.25	967.09	209.1	756.5	445.7
10	AW-06	450.71	0.00	1796.48	252.45	351.05	570.14
11	AW-48	313.86	0.00	388.03	142.8	475.15	263.97
12	AW-22	70.13	10.63	529.34	181.9	295.8	217.56
13	AW-77	482.38	0.00	1598	186.15	1110.95	675.5
14	AW-91	208.25	68.38	841.93	610.3	609.45	467.66
15	AW-14	506.78	0.00	1400.8	261.8	393.55	512.59
16	AW-43	478.34	0.00	1119.88	413.1	1002.15	602.69
17	AW-07	368.9	4.25	983.24	169.15	374.85	380.08
18	AW-115	372.09	14.88	922.89	244.8	595.85	430.1
19	AW-93	175.53	14.88	825.35	152.15	559.3	345.44
20	AW-53	243.53	16.15	352.54	85.85	302.6	200.13
21	AW-29	684.25	14.88	1247.16	108.8	902.7	591.56
22	AW-76	122.4	8.50	1621.8	256.7	656.2	533.12
23	AW-113	479.19	17.00	2048.5	691.9	1132.2	873.76
24	AW-68	343.06	65.88	687.65	567.8	454.75	423.83

25	AW-73	148.75	0.00	596.49	171.7	346.8	252.75
26	AW-25	14.88	236.73	277.95	456.45	148.75	226.95
27	AW-78	163.63	55.25	1235.05	714	302.6	494.11
28	AW-09	359.76	2.13	208.68	703.8	94.35	273.74
29	AW-11	337.03	8.50	723.99	608.6	686.8	472.98
30	AW-69	159.38	0.00	123.89	503.2	135.15	184.32
31	AW-01	325.55	61.63	1071.85	586.5	810.9	571.29
32	AW-39	141.53	4.25	174.68	204.85	637.5	232.56
33	AW-05	280.08	100.00	981.75	647.7	541.45	510.2
34	AW-65	138.13	14.88	924.8	451.35	416.5	389.13
35	AW-59	150.45	112.75	345.74	56.95	334.05	199.99
36	AW-33	464.53	127.20	282.2	261.8	352.75	297.7
37	AW-81	212.5	51.00	1267.78	762.45	961.35	651.02
38	AW-86	175.31	93.50	490.03	457.3	778.6	398.95
39	AW-18	154.49	38.25	1013.63	231.2	754.8	438.47
40	AW-83	68.64	99.88	290.28	61.2	291.55	162.31
41	AW-82	413.53	99.88	1236.33	50.15	570.35	474.05
42	AW-66	486.63	109.18	219.3	185.3	220.58	244.2
43	AW-34	572.35	8.50	433.29	70.55	447.95	306.53
44	AW-26	596.54	8.50	1268.2	225.25	959.65	611.63
45	AW-12	299.84	0.00	257.34	56.95	751.4	273.11
46	AW-75	429.25	10.63	452.41	143.65	275.4	262.27
47	AW-62	152.58	103.40	493.43	175.1	989.4	382.78
48	AW-64	535.08	21.25	374.64	117.3	713.15	352.28
49	AW-46	128.78	14.88	722.93	519.35	835.55	444.3
50	AW-70	163.63	0.00	529.98	437.75	438.6	313.99
51	AW-58	40.38	46.96	370.39	80.75	417.35	191.17
52	AW-54	63.11	0.00	777.33	454.75	510.43	361.12
53	AW-47	429.98	0.00	1392.73	160.65	1156.85	628.04
54	AW-63	320.24	0.00	563.55	252.45	731	373.45
55	AW-67	35.06	8.50	682.55	372.3	315.35	282.75
56	AW-52	14.88	8.50	813.88	153.85	441.15	286.45
57	AW-102	239.06	12.75	728.66	163.2	678.3	364.4
58	AW-51	238	124.63	753.1	137.7	244.8	299.65
59	AW-31	449.65	0.00	507.24	34	403.75	278.93
60	AW-97	133.03	12.75	131.75	105.4	196.35	115.86
61	AW-99	229.93	0.00	169.79	274.55	193.8	173.61
62	AW-105	484.08	4.25	740.35	188.7	515.1	386.5
63	AW-20	427	0.00	956.89	326.4	379.1	417.88
64	AW-94	508.77	10.63	656.63	226.1	472.6	374.94
65	AW-19	499.8	44.63	889.95	186.15	448.8	413.87
66	AW-85	282.63	40.38	712.3	107.1	695.3	367.54
67	AW-17	454.54	8.50	1080.78	188.7	583.95	463.29
68	AW-98	188.28	93.50	866.58	332.35	1048.9	505.92
69	AW-71	348.5	62.00	386.75	389.3	369.75	311.26
70	AW-89	278.8	3.40	423.73	317.05	1026.8	409.96
71	AW-104	391	0.00	819.4	224.4	767.55	440.47
72	AW-15	442.3	0.00	821.95	142.8	276.25	336.66
73	AW-36	314.5	0.00	453.05	286.45	1020	414.8
74	AW-72	566.1	5.31	1207.64	506.6	643.45	585.82
75	AW-74	485.56	0.00	943.08	116.45	767.55	462.53
76	AW-103	159.38	21.25	618.38	208.25	510	303.45
77	AW-37	453.9	0.00	287.51	231.2	374.85	269.49
78	AW-108	319.69	67.53	241.61	481.95	499.8	322.12
79	AW-60	206.13	161.88	714.43	222.7	774.35	415.9
80	AW-125	199.75	4.25	946.05	60.35	965.6	435.2
81	AW-88	105.19	4.25	902.7	305.15	820.25	427.51
82	AW-03	429.25	34.00	476.85	578.85	626.45	429.08
83	AW-57	204	31.88	145.56	181.9	351.05	182.88

84	AW-28	263.5	16.15	118.79	183.6	340.85	184.58
85	AW-84	382.38	29.75	605.41	583.95	865.3	493.36
86	AW-38	410.13	8.50	619.23	587.35	732.7	471.58
87	AW-16	447.1	76.50	617.1	684.25	555.05	476
88	AW-21	366.35	72.25	722.93	661.3	196.35	403.84
89	AW-112	14.88	89.25	606.9	501.5	969.85	436.48
90	AW-79	36.34	99.63	225.46	629.85	651.1	328.48
91	AW-61	55.25	81.15	215.9	82.45	343.4	155.63
92	AW-121	187	214.75	904.83	198.9	735.25	448.15
93	AW-114	160.65	124.9	1079.71	204.85	1179.8	549.98
94	AW-55	2.13	51.21	78.2	75.65	561	153.64
95	AW-106	187.43	29.75	320.88	249.9	737.8	305.15
96	AW-122	207.83	129.58	557.18	62.9	758.2	343.14
97	AW-40	164.05	51.00	1557.2	36.55	1287.75	619.31
98	AW-80	182.33	55.25	534.65	251.6	402.9	285.35
99	AW-116	82.66	89.01	136.43	237.15	159.8	141.01
100	AW-10	291.55	76.5	240.76	311.95	419.9	268.13
101	AW-41	196.35	27.63	804.95	421.6	973.25	484.76
102	AW-90	270.51	0.00	466.86	293.25	631.55	332.44
103	AW-117	113.9	23.38	711.45	307.7	968.15	424.92
104	AW-27	104.98	4.25	147.9	124.95	524.45	181.31
105	AW-45	174.68	6.38	469.63	339.15	605.2	319.01
106	AW-123	65.88	72.25	1596.3	392.7	1025.1	630.45
107	AW-02	175.1	38.25	677.45	533.8	963.05	477.53
108	AW-30	186.36	78.2	323.85	298.35	747.15	326.78
109	AW-50	75.23	24.44	655.35	153.85	808.35	343.44
110	AW-100	32.3	31.88	427.13	402.05	499.8	278.63
111	AW-120	246.5	60.78	745.03	213.35	647.7	382.67
112	AW-110	446.55	101.13	1371.9	476.85	967.3	672.75
113	AW-107	93.5	6.38	887.61	312.8	657.9	391.64
114	AW-101	310.25	0.00	639.63	111.35	796.45	371.54
115	AW-124	122.83	12.75	222.06	63.75	145.35	113.35
116	AW-118	171.06	44.63	1133.05	540.6	1057.4	589.35
117	AW-32	249.48	27.63	157.25	78.2	379.95	178.5
118	AW-109	177.23	27.63	337.66	56.1	310.25	181.77
119	AW-119	36.13	35.06	98.81	175.1	469.2	162.86
120	AW-111	9.56	0.00	9.56	21.25	280.5	64.18
121	744	61.68	46.58	596.75	221.43	353.35	255.96
122	75227	71.24	74.47	873.27	158.31	354.26	306.31
123	1377	439.41	3.98	1229.42	507.24	374.83	510.98
124	7440	23.16	58.54	745.72	306.43	362.5	299.27
	Mean	258.87	36.92	691.72	288.83	586.47	372.56
	LSD	209.47	76.26	616.89	311.86	524.49	211.33

GBYT09, GBYT10, GBYT11, GBYT12 and GBYT13 = coffee green bean yield per tree (g) in 2009, 2011, 2012 and 2013, respectively and AvGBYT= Average green bean yield per tree over the five years.

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