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Genetic Diversity Analysis of Limmu Coffee (*Coffea arabica* L.) Collection using Quantitative Traits in Ethiopia

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ABSTRACT

To estimate the extent of genetic diversity among Limmu Coffee collection, *Coffea arabica* accessions from Limu (Jimma) were planted in simple lattice design with two replications. Clustering of the 49 accessions for 22 quantitative characters was performed using the method of average linkage clustering strategy of observations. Genetic divergence between clusters was determined using the generalized Mahalanobis D^2 statistics Analysis of variance indicated the presence of significant ($p<0.05$) variability for most of quantitative traits. However, non significant variation was observed for stem diameter, canopy diameter, internode length of stem, average length of primary branch, internode length of primary branch, number of primary branch and percentage of bearing primary branches. Moreover, clustering analysis grouped the accessions in to four genetic divergent classes. The smallest inter cluster distance ($D^2 = 5.24$) was observed between clusters I and III while the highest and highly significant inter cluster distance ($D^2 = 93.74$) was between cluster III and cluster IV suggesting the coffee materials among clusters were divergent from each other. Furthermore, principal component analysis indicated that about 85.74% of the variation present among accessions was explained by ten principal components. Over all, the study confirmed the presence of trait diversity in Limu coffee accessions and this could be exploited in the genetic improvement of the crop through hybridization and selection.

Key words: *Coffea arabica*, limmu coffee, cluster analysis, genetic divergent, principal component analysis

INTRODUCTION

Ethiopia is well-known for being the home of Arabica coffee (*C. arabica*) which is highly-regarded for its very fine quality, unique aroma and flavor. The coffee types that are acclaimed for having such unique characteristics include Sidamo, Yirgachefe, Hararge, Ghimbi and Limu (Kebede and Bellachew, 2008; Workafes and Kassu, 2000). In Ethiopia coffee contributes largely to the national foreign currency income and accounts for more than 35% of the total major export commodities earnings (FAO/WFP, 2008).

In Ethiopia the estimated area of land covered by coffee is about 600,000 hectares whereas the estimated annual national production of clean coffee is about 1.7 tons ha^{-1} (Alemayehu *et al*., 2008).

Arabica coffee is cultivated in most parts of the tropics, accounting for 80% of the world's coffee market and about 70% of the production (Woldemariam *et al*., 2002) and it is also important source of income and employment in developing countries such as Latin America, Africa and Asia (Anthony *et al*., 2001).

In Ethiopia, the crop is adapted to an altitude from 550 to 2600 m above sea level and with mean annual rainfall of 1000-2000 mm (Bayetta, 2001). However, the suitable production areas with bulk of coffee production in Ethiopia has been indicated as the Eastern, Southern and Western parts of the country which have altitudes ranging from 1,300 to 1800 m above sea level. The phenotypic variation as well as adaptation under different environmental conditions shows the presence of high arabica coffee genetic diversity in Ethiopia (Melaku, 1988). Presently coffee genetic resource is under threat mostly due to deforestation of its natural habitat for timber and food crop production, replacement of the farmers variety by a few high yielding and disease resistant varieties, establishment and expansion of modern plantation and illegal and legal settlements (Geletu, 2006).

To reduce such genetic erosion, efforts to collect and conserve Ethiopian coffee germplasm was carried out by Jimma Agricultural Research Center (JARC) and about 5175 accessions have been collected from the different coffee growing areas of the country and maintained at the JARC and its sub-centers (Bayetta and Labouisse, 2006).

The economic value of a population (in this case coffee population) is related to morphology, agronomic performance, seed quality and nutritional qualities and efficient utilization of indigenous germplasm required knowledge of biodiversity of economic interest (Beer *et al*., 1993). Although the country is highly endowed with suitable environments, the productivity and production of coffee per unit area remains very low as compared to world average. This is mainly attributed to lack of adaptable cultivars for each ecological zone of the different regions for each of the very diverse environment (Bayetta, 2001). Efficient utilization of the genetic potential held in germplasm collections requires detailed knowledge about the collections (Beuselinck and Steiner, 1992), including genetic diversity studies, evaluation and classification.

Several workers have estimated the extent of genetic diversity present from the different sources of Arabica coffee germplasm collections. For example, a study by Kebede and Bellachew (2008) on Arabica coffee collections from Hararge indicated the presence of high genetic diversity. Similarly, the genetic diversity analysis carried out by Yigzaw (2005) by employing morphological characters, biochemical characteristics and molecular markers on coffee Arabica genotypes from Ethiopia displayed the existence of genetic diversity.

Even if from observations of variety trial there are indications of genetic variation in Limu coffee no systematic diversity analysis has been carried out to quantify and verify the level of genetic diversity. Further, it is indispensable to extract detailed information about the individual germplasm accessions considered in the study so that they can be used in the future breeding program. Keeping this in view, the present study was carried out with the objective of estimating the genetic diversity among some Limu coffee germplasm accessions based on quantitative traits thereby avoid handling of large number of duplicates and of facilitating their use in coffee Arabica breeding programs.

MATERIALS AND METHODS

Description of the study area: The experiment was conducted at Agaro Agricultural Research Sub Center. It is located at 45 km in the south west of the Jimma town at an altitude of 1630 m

Table 1: Geographical origin of coffee accessions used in the study

Accession	Region	Zone	Wereda	Collection place	Altitude
L-1/2003 L-2/2003 L-3/2003 L-4/2003 L-5 /2003	Oromiya	Jimma	Limu kossa	Miaa	1670
L6 /2003					
L7 /2003 L8 /2003	Oromiya	Jimma	Limu kossa	Cheraki	1640
L9 /2003 L10/2003	Oromiya	Jimma	Limu kossa	Babo	1610
L11/2003 L12 /2003 L13 /2003					
L14/2003 L15/2003 L16/2003 L17/2003	Oromiya	Jimma	Limu kossa	Kosa sate farm	1610-1850
L20/2003 L22/2003 L23/2003	Oromiya	Jimma	Limu kossa	Tenebo	1650
L24/2003 L25/2003 L26/2003 L27/2003 L28/2003	Oromiya	Jimma	Limu kossa	Buya	1650-1680
L29/2003 L30/2003 L32/2003 L33/2003	Oromiya	Jimma	Limu kossa	Ajamo	1680
L34/2003 L35/2003 L47/2003 L48/2oo3	Oromiya	Jimma	Limu kossa	Genji	1640-1720
L36/2003 L37/2003	Oromiya	Jimma	Limu kossa	Bidaru	1640
L38/2003 L39/2003	Oromiya	Jimma	Limu kossa	Gindacha	1640
L40/2003 L41/2003 L42/2003	Oromiya	Jimma	Limu kossa	Alge	1690
L43/2003 L44/2003 L45/2003 L46/2003	Oromiya	Jimma	Limu kossa	Kelecha	1670-1690
L49/2003 L50/2003 51/2003	Oromiya	Jimma	Limu kossa	Sombo	1710-1720
744 SNNP			Bonga	1770	
F-59 SNNP			Bonga	1770	

a.s.l. It is situated at 7 50'35" -7 51'00"N latitude and 36°35'30"E longitude. The mean annual rainfall of the area is 1616 mm with average maximum and minimum temperatures of 28.4 and 12.4°C, respectively. The major soil type is Mollic Nitisols with soil pH 6.20, Organic mater 7.07%, nitrogen 0.42%, phosphorus 11.9 ppm and CEC 39.40 mol (+) kg^{-1} (Elias, 2005).

Experimental material, design and management: The study was carried out in Oromiya Estate in Jimma District, at Agaro Agricultural Research Sub Center, Ethiopia from 2004 to 2009. The coffee germplasm accessions were collected in 2003 from the potential and representing areas in the Limu-Kossa wereda of Jimma zone. The collections were planted in August 2004 (Table 1).

The study was conducted forty nine coffee germplasm accessions including standard checks (744 and F-59). The experiment was planted in a 7×7 simple lattice design with 2 replication and seven accessions per incomplete block. Six trees per accessions were planted in 2×2 m spacing. All the management practices such as shading, weeding and fertilization were uniformly applied to all plots as per the recommendation (IAR, 1996).

Data collected: Data on 22 quantitative traits were recorded on tree basis with three trees from each accession by random sampling method. These quantitative data includes bean length (mm), bean width (mm), fruit length (mm), fruit width (mm), fruit thickness (mm), hundred bean weight (gm), yield (kg), plant height (cm), stem diameter (cm), angle of primary branches, number of stem nodes, canopy diameter (cm), average internodes of stem (cm), average length of primary branches (cm), average internode length of primary branches (cm), number of primary branches, number of secondary branches, percentage bearing primary branches, leaf length (cm), leaf width (cm), leaf area (cm^2) and height up to first primary branches (cm).

Data analysis: In order to identify the variability among coffee germplasm accessions, all the 22 quantitative character considered in the study were statistically analyzed using Lattice design analysis of variance format by using the statistical procedures described by Gomez and Gomez

(1984). All statistical and data processing were performed using SAS version 9.2 software and Genes (Cruz, 2009) version 7.0 soft ware. The relative efficiency of simple lattice design over RCB design and CV (%) of both design was estimated and found that the use of the 7×7 simple lattice designs estimated to have increased the experimental precision over that which would have been obtained with a RCB design. Therefore, due to this, the quantitative data were analyzed using simple lattice design.

Clustering of the 49 accessions for 22 quantitative characters was performed using the proc cluster procedure of SAS version 9.2 by employing the method of average linkage clustering strategy of observations. The number of clusters was determined by following the approach suggested by Copper and Milligan (1988) by looking into three statistics namely, pseudo F, pseudo t^2 and the Cubic Clustering Criteria (CCC). The number of cluster was decided where the CCC and pseudo F statistics combined with a small value of the pseudot^2 statistics and large pseudo t^2 statistics for the next cluster fusion.

Genetic divergence between clusters was determined using the generalized Mahalanobis D^2 statistics. Mahalanobis (1936) developed this method to determine divergence prevailing among population in terms of generalized group distance (Sharma, 1998). Testing the significance of D^2 values obtained for a pair of clusters were taken as the calculated value of chi-square (χ^2) and tested against the tabulated value of χ^2 for P degrees of freedom (P is the number of characters) (Singh and Chaudhary, 1985) at appropriate probability level, that was considered.

Principal component analysis was performed using correlation matrix by employing procedure SAS in order to examine the relationships among 22 quantitative characters that are correlated among each other's by converting in to uncorrelated traits called principal components. Important characters in each principal component were identified by using the formula suggested by Johnson and Wichern (1988).

RESULTS AND DISCUSSION

Analysis of variance for the 22 quantitative analysis indicated that there was significant ($p<0.05$) variation between the accessions for most of the measured quantitative characters. However, the results not indicated variation for characters such as stem diameter, canopy diameter, average internode length of stem, average length of primary branches, average internode length of primary branches, number of primary branches and percentage of bearing primary branches (Table 2). These significant variations among test materials for the characters studied indicated that existence of variability to have an effective selection. In view of this, it may be reasonable to state that there is a good chance to improve coffee accessions through selection and crossing. Such a view was supported by Leroy *et al.* (1993) and Catter (1992).The prevalence of such variability in an autogamous species like *C.arabica* appears to be important. This may be attributed either to the evolutionary tendencies as the species is native to Ethiopia or to the natural mutation occurring to the population of the crop (Avise and Hamrick, 1997; Hedrick, 2000). Moreover, the variations observed for measured quantitative characters in this study were in agreement with the earlier findings of Bayetta (1991) who reported the presence of significant variation in coffee growth characters and Kebede and Bellachew (2005) who reported the significant difference among the genotypes in 100 Hararge coffee accession germplasm using 14 quantitative characters. These results are also in agreement with the findings of Kebede *et al.* (2007) who reported the significant difference on forty one Ethiopian coffee selection evaluated for seven morphological agronomic character and yield. Similarly, Gichimu and Omondi (2010)

Table 2: Mean square for 22 characters in 49 coffee germplasm accessions

	Mean square		
Characters	Treatment unadjusted	Treatment adjusted	Error (intrablock)
BL	0.49	0.42**	0.09
BW	0.21	0.18**	0.03
FL	1.03	0.89**	0.31
FW	0.96	0.94**	0.33
FT	1.05	0.89*	0.42
HBW	7.55	6.64**	0.84
PLH	899.45	560.87*	255.14
SD	0.64	0.35ns	0.33
APB	39.09	30.91**	10.63
NSN	29.62	18.24ns	10.54
CD	427.39	379.78ns	376.57
AILS	0.84	0.68ns	0.51
ALPB	75.29	52.98ns	54.97
AILPB	0.38	0.29ns	0.16
NPB	129.07	83.19ns	51.38
NSB	11614.00	9114.90*	3794.94
Yld	0.17	0.14*	0.06
PBPB	68.38	51.07ns	49.08
LL	0.96	0.68*	0.37
LW	0.47	0.36**	0.11
LA	68.41	44.73*	24.61
HPB	31.71	33.33*	13.39

*, **: Significantly different at probability level of 0.05 and 0.01 values, respectively; NS: Non-significant degrees of freedom for treatments adjusted, un adjusted and intra block error for all the 22 characters were 48,48 and 36, respectively. BL: Bean length, BW: Bean width, FL: Fruit length, FW: Fruit width, FT: Fruit thickness, HBW: Hundred bean weight, Yld: Yield, PLH: Plant height, SD: Stem diameter, APB: Angle of primary branch, NSN: Number of main stem nodes, CD: Canopy diameter, AILS: Average internodes length of main stem, AILPB: Average internode length of primary branch, ALPB: Average length of primary branch, NPB: Number of primary branches, NSB: Number of secondary branches, PBPB: Percentage of bearing primary branches, LL: Leaf length, LW: Leaf width, LA: Leaf area, HPB: Height up to first primary branch

reported that morphological characterization of five newly developed lines of arabica coffee as compared to commercial cultivars in Kenya. However, Dar and Sharma (2011) reported highly significant differences among the genotypes for all the characters studied in tomatoes. Moreover, Singh *et al.* (2011) also reported similar finding in field pea.

Grouping of *Coffea arabica* accessions for morphological quantitative traits using Agglomerative hierarchical clustering of determining similarity between accessions using Mahalanobis distance method for quantitative trait presented in Table 3. Cluster analysis based on coffee quantitative traits grouped 49 coffee genotypes in to four clusters. The first, second, third and fourth groups consisted 26 (53%), 7 (14.29%), 15 (30.61%) and 1 (2.04%) accession, respectively indicating that coffee accessions of the same cluster group were at least morphologically similar. The clustering pattern of the accessions revealed the existence of genetic diversity in the coffee accessions for the characters studied (Table 3). Interestingly, genotypes were not only clustered according to area of collection. This can be substantiated by the fact that accession collected from collection place such as Mia, Babo, Kossa state farm, Tenebo, Buya, Genji, Bidaru, Gindacha, Alge, Sombo were clustered in cluster I. Likewise accessions collected from Kossa state farm, Tenebo, Alge, Kelecha

Table 3: Distributions of 49 coffee genotypes over four clusters using quantitative trait

Cluster I		Cluster II	Cluster III	Cluster IV
744*	L32/2003	F59*	L01/2003	L17/2003
L02/2003	L33/2003	L15/2003	L03/2003	
L04/2003	L34/2003	L20/2003	L07/2003	
L05/2003	L35/2003	L42/2003	L08/2003	
L06/2003	L36/2003	L43/2003	L11/2003	
L09/2003	L37/2003	L47/2003	L12/2003	
L10/2003	L38/2003	L48/2003	L13/2003	
L14/2003	L40/2003		L28/2003	
L16/2003	L41/2003		L29/2003	
L22/2003	L49/2003		L30/2003	
L23/2003	L50/2003		L39/2003	
L24/2003	L27/2003		L44/2003	
L25/2003	L26/2003		L45/2003	
			L46/2003	
			L51/2003	
26 (53%)		7 (14.29%)	15 (30.61%)	1 (2.04%)

*:Represents standard checks used for the study

and Genji were also clustered together in cluster II. Finally, Accessions collected from Mia, Cheraki, Kossa state farm, Buya, Ajamo, Gindacha, Kelecha and Sombo were grouped in cluster III. This could be attributed to the unrestricted movement of coffee seed from area to area by man as well as wild animals (Yigzaw, 2005). This gene flow in coffee can be further attributed to human interference due to the fact that the coffee accessions were collected from area which 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. Similarly Alsemaan *et al.* (2011) reported the existence of genetic diversity within *Rosa damascena* cultivated in Syria. 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. Furthermore, Chakauya and Tongoona (2008) studied 47 pearl millet landraces from Zimbabwe using microsatellites and obtained marked duplication of the germplasm in genetic relationships.

The standard check improved cultivar, F-59 with medium (Intermediate open type) of growth habit was grouped in cluster I whereas 744 (open growth habit) was grouped in cluster II. Bayetta, 2001) reported that morphological variation is more important than variation in geographical origin as an indicator of genetic diversity in Coffee. The present study was in agreement with Kebede and Bellachew (2005) who studied 100 Harrarge coffee accessions for phenotypic diversity under field condition and identified six main groups in the coffee accession. Seyoum *et al.* (2004) also evaluated 81 coffee accessions of the Ethiopian coffee germplasm for fifteen seedling parameters based on cluster analysis grouped the accessions in to six major groups consisting of one to fifty-four accessions at Jimma Agricultural Research Center. Kebede *et al.* (2007) clustered the 41 south Ethiopian coffee selection and the two south west Ethiopian origin CBD resistant cultivar using seven morphological characters and yield in to 9 clusters suggesting the prevalence of wide phenotypic variation in the coffee population.

Table 4: Cluster means for quantitative traits

Traits	I	II	III	IV
BL	9.53	10.01**	9.61	9.02*
BW	6.65*	6.89**	6.75	6.72
FL	15.45	15.87**	15.59	14.60*
FW	13.65**	13.50	13.58	12.55*
FT	9.53**	9.34	9.35	8.59*
HBW	16.19	18.24 **	17.13	14.15*
Yld	0.87**	0.82	0.69	0.53*
PLH	293.44	304.55	287.04*	318.33**
SD	5.12	5.52	4.79*	6.76**
APB	61.53	59.08*	63.49	63.77**
NSN	37.12	40.17	34.96*	43.17**
CD	207.22	213.63	205.94*	228.42**
AILS	7.20	6.97	7.59**	6.52*
ALPB	77.96	83.48**	78.63	77.63**
ILPB	4.56	4.46	4.78**	3.57*
NPB	63.12	70.40	57.87*	77.50**
NSB	253.58	356.19	182.69*	545.50**
PBPB	84.63	83.06	82.37*	86.62**
LL	12.56**	12.48	12.55	12.35*
LW	5.22**	5.11	5.17	4.83*
LA	44.25**	43.76	43.76	39.42*
HPB	31.31	30.81*	30.81*	38.17**

*.**: Represents lowest and highest values, respectively. BL: Bean length, BW: Bean width, FL: Fruit length, FW: Fruit width, FT: Fruit thickness, HBW: hundred bean weight, Yld: Yield, PLH: Plant height, SD: Stem diameter, APB: Angle of primary branch, NSN: Number of main stem nodes, CD: Canopy diameter, AILS: Average internodes length of main stem, AILPB: Average internode length of primary branch, ALPB: Average length of primary branch, NPB: Number of primary branches, NSB: Number of secondary branches, PBPB: percentage of bearing primary branches, LL: Leaf length, LW: Leaf width, LA: Leaf area, HPB: Height up to first primary branch

All clusters were characterized by different 22 quantitative characteristics (Table 4). Considerable differences in cluster means were noticed for all quantitative traits. Accessions in cluster one were characterized by the highest mean value for fruit thickness, fruit width, yield per tree, leaf length, leaf width and leaf area and by the lowest bean width. Likewise, cluster II was characterized with the highest mean value of bean length, bean width, fruit length, hundred bean weight and average length of primary branches while by the lowest mean values of angle of primary branches and height up to first primary branches. The highest average internode length of stem and internode length of primary branches and the lowest plant height stem diameter, number of stem node, canopy diameter and number of secondary branches, percentage bearing primary branches and height up to first primary branches. Finally, the highest mean values of plant height, stem diameter, angle of primary branches, total number of nodes on main stem, canopy diameter, number of primary branches, number of secondary branches, height up to first primary branches and average percentage of bearing primary branches also characterized cluster IV and by the lowest values of all the rest of characters except bean width. The present study was in agreement with Kebede and Bellachew (2005) who studied 100 Harrarge coffee accessions for phenotypic diversity under field condition.

Mahalanobis distance (D^2) of the 4 clusters of 49 coffee accessions based on 22 quantitative traits is given in Table 5. The inter cluster distance (D^2) analysis showed a highly significant

Table 5: Mahalanobis distance (D^2) of the 4 clusters of 49 coffee accessions based on 22 quantitative traits

	Distance between pairs of clusters		
	I	II	III
II	8.76		
III	5.24	21.14	
IV	61.92**	48.04*	93.74**

*: Significant at $p<0.05$ (χ^2) = 46.19, **: Significant at $p<0.01$((χ^2) = 53.49

($p<0.01$) and significant ($p<0.05$) difference between clusters I and IV (61.92), cluster II and IV (48.04) and III and IV (93.74) (Table 5), respectively. The smallest inter cluster distance (5.24) was observed between clusters I and III while the highest and highly significant inter cluster distance (93.74) was between cluster III and IV suggesting the coffee materials among clusters were divergent from each other. The significant inter cluster distances indicated that there is a high opportunity for obtaining transgressive segregates and maximizing heterosis by crossing accessions belonging to different clusters as there is a higher probability that unrelated genotypes would contribute unique desirable alleles at different loci (Peeters and Martinelli, 1989).

Souza and Sorrells (1991) pointed out that categorizing germplasm accessions in to morphologically similar, more particularly genetically similar groups is useful for selecting parents for crossing. Falconer (1981) reported that genetic diversity has probably arisen through diversity in origin (geographical separation), ancestral relationship, gene frequencies and morphology. These workers indicated that plants differing in either one or more of these factors would differ by a significant number of genes. Similarly, Van der Graaff (1981) reported that the discovery of coffee berry disease resistant cultivars and superior hybrids are practical evidences for the presence of genetic diversity.

Eigenvalues, percent of total variance, percent of total cumulative variance and eigenvectors for 22 quantitative characters in 49 coffee accessions were given in Table 6. Principal component analysis was performed to assess the relative importance of each quantitative character for characterization of accessions and results were given in Table 6. About 85.74% of the variation present among accessions was explained by ten principal components. The first principal component which accounted for 17.96% of the total variability among accessions were due to discriminatory traits like number of primary branches, plant height, canopy diameter, average length of primary branches, number of main stem nodes and number of secondary branches. Quantitative characters such as fruit length, fruit width, hundred bean weight, fruit thickness, bean length, average length of primary branches, leaf length, leaf width and leaf area contributed chiefly to the variation of principal component two (14.55%). The third principal component that explained 10.36% of the variability among genotypes was attributed to variation in bean length, bean width, fruit length and hundred-bean weight. The traits internode length of stem, leaf area, leaf width, leaf length, internode length of primary branches contributes variations in principal component four (9.41%). The characters explained 7.27% variation in principal component five were intern ode length of primary branches, average length of primary branches, intern ode length of stem and bean length. Percentage of bearing primary branches, angle of primary branches and yield contributed variations most to principal component six (6.73%). Quantitative characters bean length, stem diameter, leaf length, leaf width and leaf area explained (5.09%) variation for principal component seven. Fruit width, fruit thickness, internodes length of primary branches, height up to first primary branches contributes (5%) variations in principal component eight. The variation (4.73%)

Table 6: Eigen values, total variance, cumulative variance and eigenvectors for 22 quantitative characters

	Eigen vector									
Trait	PC1	PC2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10
BL	0.06	0.21	0.24	-0.06	0.31	0.08	0.22	0.08	-0.19	-0.17
BW	0.06	0.14	0.27	-0.13	0.12	-0.15	-0.04	-0.40	0.06	0.09
FL	0.06	0.23	0.34	0.05	0.20	0.07	0.17	0.06	-0.06	-0.03
FW	0.03	0.24	0.21	0.09	-0.30	-0.03	-0.02	0.27	0.17	0.10
FT	0.05	0.24	0.20	0.03	-0.31	0.01	-0.01	0.32	0.15	-0.15
HBW	0.07	0.25	0.33	-0.17	0.22	0.04	-0.03	-0.09	0.07	0.08
Yld	0.12	0.13	0.04	0.10	-0.06	0.27	-0.34	-0.10	0.23	-0.44
PLH	0.31	0.04	-0.08	0.11	-0.01	0.24	0.15	0.01	0.15	0.03
SD	0.26	0.05	-0.18	-0.10	0.09	-0.14	0.28	0.18	-0.05	-0.18
APB	0.06	0.01	0.01	0.02	-0.08	0.46	0.17	-0.13	-0.04	0.59
NNS	0.31	0.09	-0.16	-0.18	-0.08	0.09	0.15	-0.16	-0.04	0.03
CD	0.25	0.09	-0.19	0.14	0.17	-0.06	-0.08	0.14	-0.08	0.09
AILS	-0.16	-0.09	0.15	0.31	0.23	0.05	-0.02	0.02	0.17	-0.01
ALPB	0.18	0.17	-0.24	0.12	0.32	-0.07	-0.18	0.10	0.09	0.09
ILPB	-0.20	0.04	-0.08	0.28	0.32	0.09	-0.07	0.20	0.16	-0.04
NPB	0.34	0.09	-0.13	-0.16	-0.06	0.06	0.09	-0.07	0.08	0.05
NSB	0.23	0.07	-0.09	-0.19	0.02	-0.31	0.06	-0.02	-0.07	-0.25
PBPB	0.15	0.08	-0.04	0.01	-0.11	0.41	-0.21	-0.18	-0.14	-0.37
LL	0.01	0.21	-0.06	0.29	-0.17	0.01	0.27	-0.05	-0.13	-0.05
LW	0.01	0.20	-0.01	0.38	-0.07	-0.16	0.21	-0.16	-0.10	-0.05
LA	-0.02	0.21	-0.02	0.39	-0.14	-0.15	0.25	-0.19	-0.10	-0.06
HPB	0.09	-0.12	0.04	0.06	0.04	0.35	-0.03	0.41	-0.44	0.01
Eigenvalues	3.95	3.20	2.28	2.07	1.60	1.48	1.12	1.10	1.04	1.02
% Total variance	17.96	14.55	10.36	9.41	7.27	6.73	5.09	5.00	4.73	4.64
% Cumulative variance	17.96	32.51	42.87	52.28	59.55	66.28	71.37	76.37	81.10	85.74

BL: Bean length, BW: Bean width, FL: Fruit length, FW: Fruit width, FT: Fruit thickness, HBW: Hundred bean weight, Yld: Yield, PLH: Plant height, SD: Stem diameter,APB: Angle of primary branch, NSN: Number of main stem nodes, CD: Canopy diameter, AILS: Average internodes length of main stem, AILPB: Average internode length of primary branch, ALPB: Average length of primary branch, NPB: Number of primary branches, NSB: Number of secondary branches, PBPB: Percentage of bearing primary branches, LL: Leaf length, LW: Leaf width, LA: Leaf area, HPB: Height up to first primary branc

explained in principal component nine was contributed by yield per tree, fruit width and internodes length of primary branches. Finally, for the variation (4.64%) explained in principal component ten contributed by characters angle of primary branches and height up to first primary branches. Amongst characters studied, bean length, hundred green coffee bean weight, leaf length and leaf width contributed to the variations in three principal components out of the ten principal components (Table 6). Thus, these characters were identified as the main source of variation among Limu coffee accessions. This finding is similar with the finding of Tikader *et al.* (1999).

The present study confirmed that Limu coffee accessions showed variations for the characters studied. This trait diversity evident among the Limu coffee accessions suggests presence of opportunities for genetic improvement through selection directly from the accessions and or selection of diverse parents for hybridization programs and conservations of the germplasm for future utilization. The existence of broad morphological and agronomic diversity among coffee accessions is in agreement with the previous study of Kebede and Bellachew (2008) and Yigzaw (2005).

CONCLUSION

Ethiopia is endowed with immense potential of diverse coffee materials and contrasting ecological condition for coffee cultivation. Characterizations of germplasm accessions based on the quantitative traits using the average linkage method of hierarchical cluster analysis of observations resulted in grouping of the germplasm accessions into four at 75% of similarity level while the standard checks fell into different clusters for quantitative traits. The significant inter- cluster distances between clusters I and IV, II and IV, III and IV indicated that there is a high opportunity for obtaining transgressive segregates and maximize heterosis by crossing germplasm accessions belonging to these clusters.

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