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Variability of Quantitative Traits in Limmu Coffee (*Coffea arabica* L.) in Ethiopia

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ABSTRACT
The aim of this study was to estimate the extent of genetic variation and association among yield and yield-related traits. Forty nine *Coffea arabica* accessions from Limu (Jimma, Ethiopia) were tested at Agaro Agricultural Research Sub Center, Ethiopia from 2004 to 2009 in simple lattice design with two replications. Variances component method was used to estimate genetic variation, broad sense heritability and genetic advance. Association of traits was also estimated using standard method. The germplasm accessions differ significantly for most of the traits. Relatively high phenotypic (45.11 and 30.18%) and genotypic coefficient of variation (25 and 24.90%) were observed for yield and number of secondary branches in the order of magnitude. Hundred bean weight (81.13%) showed the highest heritability. Yield per plant showed significant positive phenotypic correlation with percentage of bearing primary branches (r = 0.53) while it revealed significant positive genotypic correlation with bean width (r = 0.47), fruit length (r = 0.61), hundred bean weight (r = 0.59), plant height (r = 0.28), canopy diameter (r = 0.29), leaf length (r = 0.30) and percent of bearing primary branches (r = 0.62). 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*, genetic divergent, variability, heritability, correlation analysis

INTRODUCTION
Coffee is the back bone of Ethiopia's economy and contributes largely to the national foreign currency income and accounts for more than 35% of the total major export commodities earnings (FAO/WFP, 2008). Furthermore, coffee plays a vital role both in the cultural and socio-economic life of people of the country (Workafes and Kassu, 2000). 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).

The Ethiopian coffee is also important source of coffee genetic resources for the world coffee industry. As a matter of fact, Ethiopia is the single known center of origin and genetic diversity for arabica coffee (*C. arabica*) (Workafes and Kassu, 2000; Kebede and Bellachew, 2008). It 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 like Latin America, Africa and Asia (Anthony *et al*., 2001).

In Ethiopia, coffee grows under different environmental conditions with an altitude ranging from 550 to 2600 m above sea level and with annual rainfall of 1000-2000 mm which makes fineable existence of different agro-types of coffee and wide ecology in the country (Paulos and Teketay, 2000; Bayetta, 1991). However, the bulk of coffee is produced in 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 (Bayetta and Labouisse, 2006) as well as adaptation under different environmental conditions shows the presence of high arabica coffee genetic diversity in Ethiopia (Paulos and Teketay, 2000). Presently coffee genetic resource is under threat mostly due to deforestation of its natural habitat for timber and food crop production, replacement of the farmer's variety by a few high yielding and disease resistant varieties, establishment and expansion of modern plantation and illegal and legal settlements (Woldemariam *et al*., 2002).

To reduce such threats, efforts to collect, conserve and utilize Ethiopian coffee germplasm was carried out by national coffee collection program and about 5175 accessions have been collected from the different coffee growing areas of the country and maintained at the Jimma Research Center and its sub-centers (Bayetta and Labouisse, 2006). In addition, the Biodiversity conservation of Ethiopia preserved over 4000 accessions in *ex-situ* coffee gene bank at Choche biodiversity unit in Jimma Zone, Southwest Ethiopia (Paulos and Teketay, 2000). The collections were also established in field gene banks in several African and Latin America countries (Anthony *et al*., 2001; Yigzaw, 2005). After these missions, a national programme was set up to organize exploration and conservations of coffee genetic resources in Ethiopia.

Morphological and agronomical traits as well as resistance to biotic and abiotic stresses that are known to individual accessions increase the importance of the germplasm. The economic value of a population is related to plant morphology, agronomic performance, seed quality and nutritional qualities. Efficient utilization of indigenous germplasm required knowledge of biodiversity of economic interest (Beer *et al*., 1993). Though the country is highly endowed with suitable environments, the productivity of coffee per unit area remains very low as compared to world average. One of the major factors contributing to low yield includes 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 characterization, evaluation and classification. However, apart from some observations based on the variety trials, there has been no systematic diversity analysis carried out in Limu coffee germplasm collection and this might have resulted in the handling of a large degree of duplicated germplasm in collection (Seyoum, 2007). Similarly, there is no detailed information on the extent and nature of interrelationships among characters. Keeping this in view, the present study was carried out to characterize some Limu coffee germplasm accessions based on morphological trait, identify the nature and magnitude of variability of traits and their association with each other.

MATERIALS AND METHODS

Description of the study area: The experiment was conducted at Oromiya Estate in Jimma District, at Agaro Agricultural Research Sub Center, Ethiopia from 2004 to 2009. The site is located at 45 km in the south west of the Jimma town at an altitude of 1630 m 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 millimeters 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 on the batch II forty nine Limu coffee trial. The coffee germplasm accessions were collected in 2003 from the potential and representing areas in the Limu-Kossa wereda of Jimma District. The collections were planted in August 2004 (Table 1).

The study was conducted on forty nine coffee germplasm accessions including standard checks (744 and F-59). The experiment was laid out in a 7×7 simple lattice design with 2 replication and seven accessions per incomplete block. Six trees per accessions were planted in 2 m×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 collection: Data on 22 quantitative traits were recorded on tree basis with three trees from each accession by random sampling method. These quantitative date 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).

Statistical 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 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 design estimated had increased the experimental precision over that of RCB design.

The quantitative data were analyzed using simple lattice design. For characters having significant mean differences, the difference between treatment means was compared using LSD at 5% of probability level.

The phenotypic variances and coefficients of variations were estimated as per Singh and Chaudhary (1985).

Heritability in the broad sense for all character (22 quantitative characters) was computed using the formula suggested by Singh and Chaudhary (1985).The genetic advance expected under selection, assuming selection intensity of the superior 5% of the genotypes was estimated in accordance with the methods illustrated by Johnson *et al.* (1955) and Allard (1960).

Phenotypic and genotypic correlations were computed following the method described in Singh and Chaudhary (1985).

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

No	Accession	Region	Zone	Wereda	Collection place	Altitude
1	L-1/2003	Oromiya	Jimma			
	L-2/2003					
	L-3/2003			Limu kossa	Miaa	1670
	L-4/2003					
	L-5 /2003					
	L6 /2003					
2	L7 /2003	Oromiya	Jimma			
	L8 /2003			Limu kossa	Cheraki	1640
3	L9 /2003	Oromiya	Jimma			
	L10/2003			Limu kossa	Babo	1610
4	L11 /2003	Oromiya	Jimma			
	L12 /2003					
	L13/2003					
	L14/2003			Limu kossa	Kosa sate farm	1610-1850
	L15/2003					
	L16/2003					
	L17/2003					
	L18/2003					
	L19/2003					
5	L20/2003	Ormoiya	Jimma			
	L22/2003			Limu kosa	Tenebo	1650
	L23/2003					
	L24/2003	Oromiya	Jimma			
	L25/2003					
	L26/2003			Limu kossa	Buya	1650-1680
	L27/2003					
	L28/2003					
6	L29/2003	Oromiya	Jimma			
	L30/2003			Limu kossa	Ajamo	1640-1720
	L32/2003	Oromiya	Jimma			
	L33/2003					
	L34/2003			Limu kossa	Genji	1640-1720
	L35/2003					
	L47/2003					
	L48/2003					
7	L36/2003	Oromiya	Jimma			
	L37/2003			Limu kossa	Bidaru	1640
8	L38/2003	Oromiya	Jimma			
	L39/2003			Limu kossa	Gindacha	1640
9	L40/2003	Oromiya	Jimma			
	L41/2003			Limu kossa	Alge	1690
	L42/2003					
10	L43/2003	Oromiya	Jimma			
	L44/2003					
	L45/2003			Limu kossa	Kelecha	1670-1690
	L46/2003					
11	L49/2003	Oromiya	Jimma			
	L50/2003			Limu kossa	Sombo	1710-1720
	L51/2003					
12	744	SNNP			Bonga	1770
13	F-59	SNNP			Bonga	1770

RESULTS AND DISCUSSION

Analysis of variance for the 22 quantitative characters 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. And the prevalence of such variability in an autogamous species like *C. arabica* appears to be important. The variations observed for measured quantitative characters in this study were in agreement with the earlier findings of Kebede and Bellachew (2005) who reported the significant difference among the genotypes in 100 Hararge coffee accession germplasm using 14 quantitative characters. Similarly, Dar and Sharma (2011) found that significant variation between quantitative character

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(mm), BW: Bean width (mm), FL: Fruit length(mm), FW: Fruit width(mm), FT: Fruit thickness(mm), HBW: Hundred bean weight (gram), Yld: Yield (kg), PLH: Plant height (cm), SD: Stem diameter (cm), APB: Angle of primary branch (degree), NSN: Number of main stem nodes, CD: Canopy diameter (cm), AILS: Average internodes length of main stem (cm), AILPB: Average internode length of primary branch (cm), ALPB: Average length of primary branch (cm), NPB: Number of primary branches, NSB: Number of secondary branches, PBPB: Percentage of bearing primary branches (%), LL: Leaf length (cm), LW: Leaf width (cm), LA: Leaf area (cm^2), HPB: Height up to first primary branch (cm)

among 60 genotypes pf tomatoes. Furthermore, Singh *et al.* (2011) also reported similar finding in field pea. On the other hand, Gichimu and Omondi (2010) reported that morphological characterization of five newly developed lines of arabica coffee as compared to commercial cultivars in Kenya and they found non significant difference for internodes length.

The range and mean for the 22 quantitative traits are given in Table 3. A great genetic variability among the coffee accessions was verified, as indicated by results obtained from the characters studied. The results of range revealed a wide range of variation in traits like stem diameter (3.56 -6.75 cm), number of secondary branch (91.50-545.50), height up to first primary branches (21.66-42.16 cm) and yield (0.13-1.43 kg per tree) indicating that their greatest role to the total variability observed among the coffee accessions. Moreover, the differences between the minimum and maximum mean values for other characters were also high, indicating the availability of variation for improvement through selection.

Based on mean value, the average mean value was almost twice of the minimum mean value for traits like, green bean yield of coffee per tree and secondary primary branches indicating that their maximum contribution to the total variability observed among the coffee accessions. The

Table 3: Variability parameters for quantitative traits in coffee germplasm accessions

	Range									
Parameters	Min	Max	Grand mean	δ^2 P	δ^2 g	PCV (%)	GCV (%)	H^2 (%)	GA	GA(%)
BL	8.45	10.78	9.61	0.34	0.26	6.11	5.31	76.29	0.92	9.57
BW	6.15	7.53	6.72	0.18	0.12	6.31	5.21	65.08	0.58	8.60
FL	14.20	17.35	15.54	0.57	0.36	4.86	3.86	64.57	0.98	6.30
FW	12.03	15.75	13.59	0.56	0.56	5.51	4.42	64.57	0.99	7.28
FT	8.02	11.68	9.43	0.58	0.24	8.11	5.21	40.78	0.65	7.00
HBW	12.80	21.95	16.73	3.76	3.05	11.59	10.44	81.13	3.24	19.37
PHT	256.33	333.00	293.58	450.46	286.35	7.23	5.76	63.57	27.79	9.47
SD	3.56	6.75	5.11	0.39	0.125	12.22	7.11	32.09	0.41	8.02
AP B	51.76	69.73	61.83	19.49	9.47	7.14	4.98	48.60	4.42	7.15
NSN	26.50	44.50	37.01	15.15	8.42	10.52	7.84	55.59	4.46	12.05
CD	174.00	248.08	208.18	212.23	1.61	7.21	0.61	1.51	0.22	0.11
AIL S	6.31	7.98	7.27	0.45	0.07	9.23	3.64	0.09	0.22	3.03
ALPB	59.67	90.51	78.95	37.56	8.14	7.76	3.61	16.03	2.74	3.47
AILPB	3.56	5.43	4.59	0.26	0.13	11.11	7.71	50.08	0.53	11.55
NPB	43.83	77.16	62.84	63.79	35.78	12.71	9.52	56.09	9.23	14.69
NSB	91.50	545.50	252.49	5805.82	3952.83	30.18	24.90	68.08	106.86	42.32
PBPB	65.76	94.43	83.75	35.15	3.62	7.08	2.27	10.30	1.27	1.52
LL	11.17	13.93	12.54	0.49	0.19	5.58	3.48	38.79	0.56	4.47
LW	4.09	6.16	5.18	0.25	0.14	9.63	7.22	54.97	0.58	11.21
LA	32.98	54.56	43.75	34.09	16.43	13.35	9.26	48.21	0.51	1.21
HPB	21.66	42.16	30.79	15.89	9.54	12.95	10.03	60.06	4.93	77.64
Yld	0.13	1.43	0.80	0.13	0.04	45.11	25.00	27.48	0.23	28.75

BL: Bean length (mm), BW: Bean width (mm), FL: Fruit length (mm), FW: Fruit width (mm), FT: Fruit thickness (mm), HBW: Hundred bean weight (gram), Yld: Yield (kg), PLH: Plant height (cm), SD: Stem diameter (cm), APB: Angle of primary branch (degree), NSN: Number of main stem nodes, CD: Canopy diameter (cm), AILS: Average internodes length of main stem (cm), AILPB: Average internode length of primary branch (cm), ALPB: Average length of primary branch (cm), NPB : Number of primary branches, NSB: Number of secondary branches, PBPB: Percentage of bearing primary branches (%), LL: Leaf length (cm), LW: Leaf width (cm), LA: Leaf area (cm^2), HPB: Height up to first primary branch (cm) variations observed for measured quantitative characters in this study were in agreement with the findings of Yigzaw (2005). This high range and mean value for each trait of interest suggests that great opportunity to improve the various desirable traits without much effort through selection as short term strategy and through hybridization as long term strategy.

Genotypic and phenotypic variance ranging from 0.04 to 3952.83 and 0.13 and 5805.82, respectively were found for the traits considered in this study (Table 3). Consequently, the maximum phenotypic variance value of 5805.82 was noted for number of secondary branch and 450.46 for plant height. Similarly, the genotypic variances for these characters were also high indicating that the genotype could be reflected by the phenotype and the effectiveness of selection based on the phenotypic performance for these characters. The estimate of genotypic and phenotypic coefficient of variations is presented in Table 3.

According to Deshmukh *et al.* (1986), phenotypic and genotypic coefficient of variation values greater than 20% are considered as high, whereas values less than 10% are to be low and values between 10 and 20% as medium. Accordingly, characters which showed high phenotypic and genotypic coefficients of variation were number of secondary branches and yield per tree. And medium phenotypic and genotypic coefficients of variation were recorded for hundred beans weight and height up to first primary branches. All other characters grouped under low phenotypic and genotypic coefficients of variation. This result is in agreement with the findings of Yigzaw (2005) in arabica coffee.

The estimate of the broad sense heritability is presented in Table 3. According to Verma and Agarwal (1982), heritability values greater than 50% are considered as high, whereas values less than 20% are to be low and values between 20 and 50% as medium. Based on this, characters which showed high heritability values were bean length (76.29%), bean width (65.08), fruit length (64.57%), fruit width (64.57%), plant height (63.57%), number of secondary branches (68.08) and height up to first primary branches (60.06%), number of primary branches 56.09), average internode length of primary branches (50.08), number of stem nodes 55.59), hundred bean weight (81.13) ,and leaf width 54.97), suggesting that effect of environment on the phenotypic expression of these characters is minimum which is good for improvement through selection. Medium heritability values were recorded for stem diameter (32.09%), angle of primary branches (48.6%), leaf length (38.79%) and leaf area (48.21%). yield of green bean clean coffee (27.48%) and fruit thickness (40.78%). The result is in agreement with Walyaro and Vossen (1979) who reported medium heritability values of quantitative characters in coffee. However, canopy diameter (1.51%), average internode length of stem (0.09%), average length of primary branches (16.03%) and percentage of bearing primary branches were grouped under low heritability. The result was contradictory to Kebede and Bellachew (2005) who reported high broad sense heritability estimates for all these quantitative characters measured in coffee arabica.

Genetic Advance (GA%) that could be expected from selecting the top 5% of the genotype as percent of mean varied between 0.11 to 77.64% (Table 3). The characters height up to first primary branches, number of secondary branches, hundred green coffee bean weight and yield of clean green coffee per tree (28.75) in arabica coffee accessions showed higher heritability and genetic advance indicating their easy for selection. These results are in agreement with the findings of Yigzaw (2005) in coffee arabica. Jalata *et al.* (2011) also reported that high heritability coupled with high genetic advance was recorded in thousand kernel weight in Ethiopian barley.

The phenotypic and genotypic correlation coefficients for 22 quantitative characters are presented in Table 4. The analysis showed positive and significant association at $p<0.05$ among the

Table 4: Estimates of genotypic (below diagonal) and phenotypic (above diagonal) correlation coefficients in coffee accessions

	Trait	1	2	3	4	5,	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	BL	-	0.22	0.72**	0.01	0.05	0.66**	0.11	0.16	-0.20	-0.02	0.03	0.17	0.14	0.13	0.09	0.03	0.01	0.03	0.18	0.09	-0.01	-0.01
2	BW	0.14	-	0.47**	0.15	0.12	0.48**	0.15	0.12	0.02	0.17	0.14	-0.08	0.03	-0.13	0.19	0.15	0.04	0.17	0.17	0.21	-0.12	0.16
3	FRL	0.93**	0.54**	-	0.34*	0.34	0.69**	0.16	-0.06	0.12	0.02	0.04	0.13	0.09	0.03	0.06	-0.09	0.16	0.29*	0.29*	0.23	0.12	0.15
4	FW	-0.07	0.1	0.32*	-	0.83**	0.34*	0.01	-0.04	0.05	0.03	-0.08	-0.11	-0.07	-0.23	0.08	-0.15	-0.04	0.27*	0.26*	0.30	-0.15	0.15
5	FT	-0.04	-0.04	0.57**	0.34**	-	0.26*	0.16	0.02	0.01	0.06	-0.01	-0.08	-0.09	-0.25*	0.11	-0.08	0.08	-0.07	0.24*	0.22	0.02	0.24
6	HBW	0.71**	0.63**	0.84**	0.48**	0.56**		-0.01	0.04	0.08	0.12	-0.02	-0.09	0.09	-0.14	0.21	-0.01	0.11	0.25*	0.01	-0.06	-0.14	0.14
7	PLH	0.04	0.16	0.17	0.06	0.01	-0.05	-	0.42**	0.34*	0.68**	0.48**	-0.11	0.38**	-0.16	0.69**	0.25*	0.37**	0.02	0.01	0.09	0.19	0.22
8	SD	0.15	-0.13	-0.48**	-0.27*	-0.03	-0.13	0.71**	-	-0.04	0.59**	0.47**	-0.33*	0.39**	-0.33*	0.60**	0.63**	0.13	0.05	-0.07	-0.06	0.07	0.01
9	APB	-0.15	-0.11	0.18	0.07	-0.34**	0.24	0.31	-0.27*	-	0.25*	0.02	-0.12	-0.06	-0.07	0.21	-0.24**	0.18	0.08	-0.06	0.02	0.22	0.08
10	NSN	-0.03	0.03	-0.08	-0.01	-0.29*	0.13	0.86**	0.90**	0.13	-	0.41**	-0.67**	0.36**	-0.49**	0.89**	0.45**	0.38**	0.12	-0.10	-0.05	-0.02	0.17
11	CD	0.39**	0.16	0.17	0.56**	0.04	-0.05	0.26*	0.41**	0.41**	0.42**	-	-0.13	0.66**	-0.01	0.49**	0.23	0.10	0.15	0.15	0.14	0.21	0.11
12	AILS	0.69**	0.19	0.32*	0.01	0.42**	-0.31	-0.44*	- 0.91**	0.18	-0.83**	0.06	-	-0.03	0.46**	-0.59**	-0.29**	-0.22	0.12	0.16	0.21	0.02	-0.14
13	ALPB	0.17	-0.28*	-0.05	-0.40**	-0.57*	0.04	0.42**	0.09	-0.35*	0.24*	0.14	0.82**	-	0.21	0.30	0.18	0.20	0.14	0.15	0.09	-0.02	0.05
14	ILPB	0.19	-0.30*	0.07	-0.31*	-0.41**	-0.28*	0.85**	-0.25**	-0.15	-.91*	0.48**	0.68**	-0.38**	-	-0.42**	-0.38**	-0.21	0.09	0.19	0.09	0.09	-0.11
15	NPB	-0.01	0.09	0.05	0.16	-0.09	0.23	-0.48**	0.98**	0.14	0.96**	0.15	-0.85**	0.27*	-0.98**	-	0.51**	0.34**	0.02	-0.09	-0.08	0.02	0.15
16	NSB	0.01	0.17	-0.17	-0.29*	-0.05	-0.01	0.41**	0.99**	-0.57**	-0.57**	-0.13	-0.98**	-0.03	-0.70**	0.75**	-	0.01	-0.19	-0.14	-0.19	-0.07	-0.15
17	PBPB	0.14	0.16	0.29**	-0.36*	-0.27*	0.84**	0.42**	0.93**	0.51**	0.51**	-0.48**	0.58**	0.67**	-0.31*	0.95**	0.42**	-	0.16	-0.05	-.0.01	0.26*	0.53*
18	LL	0.01	0.16	0.19	0.49**	0.29*	-0.15	0.01	0.43**	0.11	0.11	-0.27*	0.65**	0.86**	0.63**	0.09	-0.14	0.01	-	0.50*	0.73**	-0.08	0.13
19	LW	0.33*	0.31*	0.48**	0.31*	0.25*	0.05	0.14	0.16	-0.17	-0.17	-0.04	0.80**	0.49**	0.59**	-0.27*	-0.16	-0.75**	0.43**	-	0.86**	-0.13	0.05
20	LA	0.16	0.43**	0.36**	0.54**	0.17	-0.11	0.48**	0.24*	0.00	0.01	-0.13	0.97**	0.52**	0.44**	-0.22	-0.15	-0.52**	0.72**	0.91**	-	-0.23	0.12
21	HPB	-0.07	-0.09	0.35**	-0.22	0.19	-0.26*	0.28*	-0.01	0.48**	0.48**	0.14	0.32*	-0.11	0.18	0.07	-0.21	0.98**	0.09	-0.14	-0.39**	-	0.04
22	Yld	0.13	0.47**	0.61**	0.24	0.21	0.59**	0.28*	0.14	-0.17	-0.17	0.29*	0.23	0.14	0.09	0.11	-0.44**	0.62**	0.30*	-0.24	0.27*	0.40**	-

*, **: Significant at probability level of 0.05 (r = 0.246) and 0.01 values (r = 0.342), 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: Averageinternode 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

characters both at phenotypic and genotypic level. Nevertheless, the frequency of positive and significant phenotypic correlation was less compared to genotypic correlation. This may be attributed to considerable influence of environment on the expressions of characters. Such a view is endorsed by the reports of earlier researchers (Sylva and Carvalho, 1997).

Among the characters plant height, stem diameter, canopy diameter, hundred green coffee bean weights and number of main stem nodes per plant in particular showed positive and significant correlations with majority of the characters both at phenotypic and genotypic levels. Percentage of bearing primary branches was the only characters that showed positive and significant phenotypic correlation with clean coffee yield per tree. Furthermore, positive and significant correlations were obtained between coffee yield per tree and percentage of bearing primary branches both at phenotypic and genotypic level. However, significant positive correlations were obtained between coffee arabica yield, bean width, fruit length, hundred bean weights, plant height and canopy diameter, leaf area, leaf length and height up to primary branches, at genotypic level. But significant and negative correlations were obtained between clean coffee yield and number of secondary branches at genotypic level only.

In general, it was observed that the genotypic correlation coefficients were found to be higher in magnitude than the corresponding phenotypic ones. It was obvious that association of characters at phenotypic level was less pronounced as compared to that of genotypic level in terms of significance. This may be attributed to considerable influence of environment on the expressions of traits. Such a view is approved by the reports of earlier researchers (Sylva and Carvalho, 1997). Accordingly, percentage of bearing primary branches was the only characters that positively and significantly correlated with twelve of quantitative characters (Table 4). Leaf area and leaf width each correlated positively and significantly with ten characters. Likewise yield of clean coffee per tree positively and significantly correlated with nine quantitative characters.

Quantitative characters, canopy diameter and plant height each positively and significantly correlated with eight characters. Stem diameter and number of main stem node each positively and significantly correlated with seven characters. Except for leaf width, leaf area, height up to primary branches and number of secondary branches, the rest of the quantitative characters manifested positive and significant association with more than two characters at genotypic level. In view of this, it may be reasonable to conclude that percentage of bearing primary branches, leaf area and leaf width, yield of clean coffee per tree, canopy diameter and plant height, stem diameter and number of main stem node are the most important characters with respect to characterization. Similar view is held by other workers (Leroy *et al.*, 1993).

Selection for a character based on its close association (positive and significant) with other characters is very useful for simultaneous improvement of all the associated characters. On the other hand, for characters, manifesting negative association, simultaneous improvement of characters could be quite difficult and independent selection may have to be carried out to improve such characters (Sylva and Carvalho, 1997). For instance, selection for stem diameter based on the results of this study is likely to result in simultaneous improvement of the characters plant height, number of stem nodes, canopy diameter, number of primary branches, number of secondary branches and percentage of bearing primary branches, since these characters exhibited positive and significant association with stem diameter both at phenotypic as well as genotypic level (Table 4). This is in agreement with the observations of Walyaro (1983). However, selection for number of primary branches per plant could affect the improvement of plant height, average internode length of stem and internode length of primary branches per plant negatively as these characters showed negative and significant correlation with number of primary branches per plant. Likewise, selection for internode length of primary branches per plant could affect the improvement of bean width, fruit width, fruit thickness, hundred green coffee bean weight, stem diameter, number of stem nodes, average length of primary branches, number of primary branches and number of secondary branches negatively as these characters showed negative and significant correlation with internode length of primary branches per plant. Likewise, selection for number of secondary branches could affect the improvement of fruit width, angle of primary branches, number of stem nodes, average internode length of stem, internode length of primary branches negatively as these characters showed negative and significant correlation with number of secondary branches per plant.

Selection for percentage of bearing primary branches could affect the improvement of fruit width, fruit thickness, canopy diameter, internode length of primary branches negatively as these characters showed negative and significant correlation with percentage of bearing primary branches per plant. In the same way, selection for leaf area could affect the improvement of canopy diameter negatively as these characters showed negative and significant correlation with leaf area per plant. Selection for leaf width could affect the improvement of number of primary branches, percentage bearing primary branches negatively as these characters showed negative and significant correlation with leaf width per plant. Moreover, selection for leaf area could affect the improvement of percentage bearing primary branches negatively as these characters showed negative and significant correlation with leaf area per plant. Selection for quantitative trait such as height up to first primary branches could affect the improvement of hundred green coffee bean weight and leaf area negatively as these characters showed negative and significant correlation with height up to first primary branches per plant. Selection for yield could affect the improvement of number of secondary branches and leaf width negatively as these characters showed negative and significant correlation with clean coffee yield in kilogram per tree. Selection for number of stem node could affect the improvement of fruit thickness, average internode length of stem and internodes length of primary branches negatively as these characters showed negative and significant correlation with number of stem node per tree.

Selections for angle of primary branches could affect the improvement of fruit thickness, stem diameter and number of secondary branches negatively as these characters showed negative and significant correlation with angle of primary branches per tree. Selection for stem diameter could affect the improvement of fruit length fruit width average internode length of stem and internode length of stem negatively as these characters showed negative and significant correlation with stem diameter per tree. This finding was in line with the work of Nikhila *et al.* (2008) who reported that length of primary branches , number of primary branches, intermodal length and bush spread are the character that should be given premium importance while carrying out crop improvement programmes in robusta coffee.

Finally, selections for fruit thickness could affect the improvement of internode length of primary branches negatively as these characters showed negative and significant correlation with fruit thickness per tree. This implied that the selection for any one of these characters is not likely to result in improvement of the others.

CONCLUSION

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. This is an indication for Limu coffee is of a restricted environmental importance. Moreover, the germplasm accessions considered in the present study represented collections from Limu and these were some of accession only. It is, however, necessary that the expression of different characters need to be studied with additional accessions and characterization results need to be confirmed. In such an effort, consideration of yield and pest/disease reactions must receive due attention.

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