Full Length Research Paper

Genetic variability, heritability and genetic advance for quantitative traits in coffee (Coffea arabica L.) accessions in Ethiopia

Getachew Weldemichael¹*, Sentayehu Alamerew² and Taye Kufa¹

¹Jimma Agricultural Research Center, P. O. Box, 192, Jimma, Ethiopia.
²College of Agriculture and Veterinary Medicine, Jimma University, P. O. Box, 307, Jimma, Ethiopia.

Received 9 December, 2016; Accepted 18 January, 2017

Estimation of genetic parameters is pertinent as variability within population determines the extent of improvement achieved through crop improvement methods. In view of this, forty-nine coffee (Coffea arabica L.) germplasm accessions, which were collected from Gomma Woreda, were evaluated at Agaro with the objectives of assessing genetic variability, heritability and genetic advance for morphological traits. The experiment was conducted in simple lattice design with two replications. Data on 26 quantitative characters were recorded. The result revealed significant differences (p<0.05) among the accessions for most of the traits studied. The phenotypic coefficients of variation (PCV) was greater than genotypic coefficients of variation (GCV) for all the characters studied, this shows the influence of environmental factors on the characters. Estimates of variability indicated that high phenotypic (PCV) and genotypic coefficients of variation (GCV) were recorded for coffee berry disease (CBD) severity and yield per tree. High heritability was recorded for hundred bean weight (80.21%), number of nodes of primary branches (67.89%), stem diameter (67.16%), height up to first primary branch (66.6%), bean length (62.79%), bean width (61.43%), average inter node length of primary branches (58.33%), angle of primary branches (53.32%), leaf width (52.94%) and canopy diameter (51.95%). The high GAM were recorded for coffee berry disease reaction (88.86%), clean coffee yield per tree (24.03%), number of secondary branches per tree (22.34%), height up to first primary branch (20%) and hundred bean weight (20%). High heritability was coupled with high genetic advance as percent of mean for characters such as hundred bean weight and height up to first primary branch. The high heritability with high genetic advance as percent of mean observed for these characters is due to the lesser influence of environment in expression of the characters and additive gene effects. The present study indicated the presence of variability for some important morphological traits among the accessions. Therefore, the variability observed for yield, disease resistance and other important traits should be utilized to improve Gomma woreda coffee. However, since high morphological variation between accessions is not a guarantee for a high genetic variation, molecular and biochemical studies need to be considered as complementary to morphological variability. On the other hand, as most of the traits exhibited low GCV and/or low GAM, there is no opportunity to improve these traits using simple selection. Therefore, heterosis breeding should be applied to improve these traits.

Key words: Coffee germplasm, genetic variability, disease resistance, simple lattice, hundred bean weight.
INTRODUCTION

Coffee (Coffea arabica L.) belongs to the family Rubiaceae and the genus Coffea (Coste, 1992). The basic chromosome number for the genus Coffea is n = 11. Arabica coffee is the only polyploid and self-fertile species of the genus Coffea, with chromosome number 2n = 4x = 44, while others are diploid (2n = 2x = 22) and self-infertile (Silvarolla et al., 2004). The Coffea genus comprises more than one hundred different species between which a large variation in terms of chemical composition is observed (Clifford, 1985). Coffee (Coffea arabica L.) is indigenous to Ethiopia and comprises about 73% of world coffee production due to its superior quality (Orozco-Castillo et al., 1994). C. arabica utilization has a longer history than C. canephora, probably more than 1,500 years ago and is now the most widespread species cultivated throughout the world (Coste, 1992).

Coffee is at the center of Ethiopian culture and economy, and contributes to about 35% of country’s foreign currency earnings. It accounts for 10% of the gross domestic product, and support the livelihoods of about 25% of the population of Ethiopia (representing around 20 million people) in one way or another (Gole et al., 2008). However, despite the vast area of cultivation, wealth of tremendous genetic diversity and importance to the national economy, the productivity of coffee is very low (about 0.71 t/ha) (Alemayehu et al., 2008). Although many factors hampered production and yield per unit area, the major factors contributing to such low coffee yield include predominant use of unimproved local coffee landraces, as well as conventional husbandry and processing practices, which in turn seriously hampers the overall national coffee production and productivity of the smallholder coffee farmer in the country (Taye, 2010). Hence, it is imperative to improve the productivity of coffee using selection and cross breeding.

Assessment of variability for yield and its component characters becomes absolutely essential before planning for an appropriate breeding strategy for genetic improvement. Characterization of this variability in a population is pertinent since genetic diversity within population and within species determines the rates of adaptive evolution and the extent of response in crop improvement (Solomon, 2009). Genetic parameters such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are useful in detecting the amount of variability present in the germplasm. Heritability indicates the effectiveness with which selection of accessions can be based on phenotypic performance. However, heritability alone provides no indication of the amount of genetic improvement that would result from selection of individual genotypes. Hence, heritability coupled with high genetic advance would be more useful tool in predicting the resultant effect in selection of the best genotypes for yield and its attributing traits.

The heritability of various morphological traits of coffee has been estimated in C. arabica L. Mesfin (1980) evaluated 68 coffee germplasm accession of national coffee collection during the year 1975-1977 at Jimma and reported broad sense heritability values of 55% for coffee yield. Cilas et al. (1998) also reported that yield, stem girth and tree height had high heritability. Bayetta (2001) has also reported high heritability estimates between 71.43 and 97.32% for all morphological characters measured in C. arabica L., suggesting that the effect of environment on phenotypic expression of the characters was small. Moreover, Yigzaw (2005) conducted a research at Finoteselam, Ethiopia, to see the heritability of 18 morphological traits of 16 coffee accessions and has reported high heritability values for hundred bean weight, number of secondary branches and canopy diameter. However, he reported low heritability for bean thickness; percent of bearing primary branches, average inter node length of primary branches and petiole length.

Although, valuable achievements have been registered by coffee research in Ethiopia, characterization and evaluation of coffee germplasm have not been systematic and exhaustive, for example, among 200 Limu accessions collected and conserved at Agaro station, 49 accessions characterized by Olika et al. (2011) have been reported for the existence of variability for morphological traits among these accessions. Besides, Lemi and Ashenafi (2016) characterized 64 Limu coffee accessions and reported high broad sense heritability estimates coupled with high genetic advance for number of main stem nodes, stem diameter and internodes length. However, the remaining accessions are not characterized in detail.

Thus, with the above back ground information, the present investigation aimed to evaluate variability, heritability and genetic advance of coffee morphological characters in 49 Limu coffee accessions collected from Gomma woreda of southwestern Ethiopia.

MATERIALS AND METHODS

Description of the study site

The experiment was conducted at Agaro Station of the Jimma
Agricultural Research Center. The center was established in 1973 on land area of 27 ha near Agaro town, 45 km far from Jimma and 397 km from Addis Ababa. Agaro is located at 7°50'35" - 7°51'00" N latitude and 36°35'30"E longitude and at an altitude of 1650 m above sea level. The mean annual rainfall of the area is 1616 mm with an average maximum and minimum air temperatures of 28.4 and 12.4°C, respectively. The major soil type is Mollic Nitisol with pH of 6.2, organic matter 7.07%, nitrogen 0.42%, phosphorus 11.9 ppm, CEC 39.40 cmol+ /kg (Zebene and Wondwosen, 2008)

Experimental materials

Forty seven C. arabica L. germplasm accessions which have been collected from the Gomma woreda of Jimma Zone and two standard checks that are maintained in the ex situ field gene bank of Agaro station were used for this study. The experiment was superimposed on six year old coffee trees (Table 1) of the 49 accessions and grown under uniform coffee shade tree (Sesbania sesban) conditions.

Experimental design, management and season

The experiment was laid out in a 7x7 simple lattice design with two replications and with seven genotypes per each incomplete block. Each plot was comprised of four coffee trees.Spacing between trees and plots was 2 m and spacing between replications was 3 m. All the improved agronomic practices were applied uniformly according to the recommendations (Endale et al., 2008).

Data collected

Data on 26 quantitative characteristics, namely: Height up to first primary branch (cm), total plant height (cm), number of main stem nodes (no), average inter node length of main stem (cm), main stem diameter (cm), angle of primary branches (deg), number of primary branches (no), average length of primary branches (cm), number of nodes of primary branches (no), average Inter node length of primary branches (cm), percentage of bearing primary branches (%), number of secondary branches (no), canopy diameter (cm), leaf length (cm), leaf width (cm), leaf area (cm²), fruit length (mm), fruit width (mm), fruit thickness (mm), bean length (mm), bean width (mm), bean thickness (mm), hundred bean weight (g), yield per tree (kg), coffee berry disease (%) and rust incidence (%), were collected from each accession using the standard procedures (IPGRI, 1996).

Statistical analysis

Data for quantitative characters were subjected to analysis of variance (ANCOVA) using SAS version 9.2 (SAS, 2008) to examine the presence of statistically significant differences among accessions for the characters studied. Least significant difference (LSD at P = 0.05) was employed to identify accessions that are significantly different from each other.

Estimation of genotypic and phenotypic coefficients of variation

The variability of each quantitative trait was estimated by simple measures such as mean, range, standard deviation, phenotypic and genotypic variances, and coefficients of variation. The phenotypic and genotypic coefficients of variation were computed based on the formula suggested by Burton and de Vane (1953) as follows:

Phenotypic variance ($\sigma_p^2$) = $\sigma_g^2 + \sigma_e^2$

Where: $\sigma_g^2$ = genotypic variance; $\sigma_e^2$ = environmental variance.

Genotypic variance ($\sigma_g^2$) = ($\text{MSt} - \text{MSe}$)/r

Where: MSt = mean square due to genotypes; MSe = environmental variance (error mean squares); r = the number of replication; Environmental variance ($\sigma_e^2$) = error mean squares

Phenotypic Coefficient of Variation (PCV) = $\frac{\sqrt{\sigma_p^2}}{\bar{x}} \times 100$

Genotypic Coefficient of Variation (GCV) = $\frac{\sqrt{\sigma_g^2}}{\bar{x}} \times 100$

Where: $\bar{x}$ = mean of the character.

Estimation of heritability and genetic advance

Broad sense heritability and expected genetic advance were estimated according to the following formula.

**Heritability in the broad sense**

Broad sense heritability values were estimated using the formula given by of Falconer (1989) as follows:

$H^2b = \left(\frac{\sigma_g^2}{\sigma_p^2}\right) \times 100$

Where: $H^2b$ = heritability in the broad sense; $\sigma_p^2$ = phenotypic variance; $\sigma_g^2$ = genotypic variance.

**Expected genetic advance**

Expected genetic advance for each character at 5% selection intensity was computed using the methodology described by Johnson et al. (1955).

$GA = k * \sigma_p * H^2b$

Where: $GA$ = the expected genetic advance under selection; $\sigma_p$ = the phenotypic standard deviation; $H^2b$ = heritability in broad sense and k is selection intensity.

**Genetic advance per population mean**

Genetic advance as percent of mean was calculated to compare the extent of predicted advance of different traits under selection using following formula of Johnson et al. (1955).

$GAM = \frac{GA}{\bar{x}} \times 100$

Where: GAM = genetic advance as percent of population mean; GA = the expected genetic advance under selection; $\bar{x}$ = mean of the character.
Table 1. Geographical origin of the studied coffee (C. arabica L.) germplasm accessions at Agaro research station.

| Farmers association where coffee was collected | Woreda/district | Number of accessions collected |
|-----------------------------------------------|----------------|-------------------------------|
| Chedero Suse                                  | Gomma          | 4                             |
| Gabena Abo                                    | Gomma          | 8                             |
| Omo Boko                                      | Gomma          | 7                             |
| Goja Kemissie                                 | Gomma          | 5                             |
| Bako Juju                                     | Gomma          | 6                             |
| Debi Kechamo                                  | Gomma          | 5                             |
| Limu Sapa                                     | Gomma          | 5                             |
| Omo Gobo                                      | Gomma          | 7                             |
| Standard check varieties                      |                | 2                             |
| Total                                         |                | 49                            |

RESULTS AND DISCUSSION

Analysis of variance

Mean squares for the 26 quantitative traits from analysis of variance (ANOVA) are presented in Table 2. Significant (P<0.05) differences among the coffee germplasm accessions were observed for all traits except for percent of bearing primary branches, leaf area, bean thickness and rust incidence and these traits are dropped from subsequent analysis.

Range and mean values

The range and mean values for the 22 quantitative traits are given in Table 3. Relatively wide ranges were recorded for average yield per tree (0.23 - 1.45 kg clean coffee), CBD severity (0 to 75.09%), NSB (57.26 to 210.93), NPB (39 to 79), HPB (25.53 to 45.50 cm), HBW (13.31 to 22.88 g), NNHPB (17 to 27), SD (4.26 to 6.46 cm) and BL (7.68 to 11.37 mm). Some of these important agronomic traits, such as average coffee yield per tree, CBD resistance level and number of secondary branches, had the highest range between the tested materials. The ranges for the above important characters were more than two fold of their respective grand means. 18 accessions (37%) had mean yield greater than the grand mean. Similarly, 25 accessions (51%) had CBD severity level less than the grand mean.

The range and mean in this study indicated the existence of variability among the tested accessions for majority of the characters studied and there is considerable potential for coffee improvement program in the future. Yigzaw (2005) reported that average green bean yield per tree varied from 144.6 - 566.7 g and 100 green bean weight ranged from 9.3 - 16.0 g. Tree height varied from 107.5 - 182.8 cm, canopy diameter from 137.1 - 246.5 cm, trunk diameter from 24.6 - 39.6 mm, number of primary branches per tree from 35.7 - 62.0 and number of secondary branches per tree from 21.3 - 117.7. The present finding is also partly in agreement with the finding of Olika et al. (2011) who reported wide range of variation for stem diameter, number of secondary branches and yield per tree among Limu coffee accessions.

Genotypic and phenotypic coefficients of variation

The estimates of phenotypic and genotypic variances and phenotypic (PCV) and genotypic coefficients of variation (GCV) are presented in Table 4. According to Deshmuk et al. (1986), PCV and GCV values greater than 20% are regarded as high, whereas values less than 10% are considered to be low and values between 10 and 20% to be medium. Accordingly, high PCV and GCV values were recorded for CBD reaction and yield per tree with PCV values of 91.48 and 41.67% and with GCV values of 62.82 and 22.05%. High PCV (30%) and moderate GCV (18.03) were recorded for number of secondary branches, suggesting the existence of high genetic variability among the accessions for effective selection. In the present study, the PCV values were higher than the corresponding GCV, suggesting the existence of environmental variation.

Moderate PCV and GCV were recorded for height up to first primary branch and hundred bean weights with PCV values of 14.57 and 12.07% and with GCV values of 11.9 and 10.81%, respectively. Moderate phenotypic and low genotypic coefficients of variation were recorded for number of primary branches, stem diameter, number of main stem nodes and number of nodes of primary branches with PCV values of 14.79, 10.68, 10.46 and 10.12% and GCV values of 9.28, 8.69, 6.22 and 8.34%, respectively.

Total plant height, average inter node length of main stem, angle of primary branches, average length of primary branches, average inter node length of primary branches, canopy diameter, leaf length, leaf width, fruit
length, fruit width, fruit thickness, bean length and bean width showed low phenotypic and genotypic coefficients of variation.

Except CBD reaction, average yield per tree, number of secondary branch, height up to first primary branches and 100 bean weights, the GCV values for most of the traits in the present study is low. This low level of variation might have resulted from natural selection in rather similar agro ecological condition of the collection areas/site, considering environmental conditions (Porceddu and Damania, 1992).

The narrow gap between PCV and GCV for hundred bean weight, number of nodes of primary branches, stem diameter, bean length and bean width, suggesting that the influence of environment in phenotypic performance is minimal. However, the wider gap between PCV and GCV for yield per tree, coffee berry disease severity, number of primary branches, number of secondary branches and number of main stem node, indicates the importance of environment in influencing the traits. The present finding is in agreement with findings of Seyoum and Bayetta (2007) and Olika et al. (2011) who reported high PCV and GCV values for yield and number of secondary branches; moderate PCV and GCV values for

---

### Table 2. Analysis of variance (mean squares) for 26 quantitative characters of 49 coffee germplasm accessions grown at Agaro.

| Trait       | Treatment | Error | LSD  |
|-------------|-----------|-------|------|
| HUP         | 38.86**   | 7.79  | 6.00 |
| TPH         | 757.11**  | 272.62| 35.14|
| NMSN        | 19.51     | 9.32  | 6.66 |
| AILMS       | 0.41**    | 0.17  | 0.89 |
| SD          | 0.56**    | 0.11  | 0.57 |
| APB         | 42.89**   | 13.06 | 7.76 |
| NPB         | 121.37**  | 52.76 | 14.60|
| ALPB        | 49.48     | 22.80 | 10.45|
| NNPB        | 7.79**    | 1.49  | 2.63 |
| AILPB       | 0.19**    | 0.05  | 0.47 |
| PBPB        | 28.24     | 27.55 | 10.55|
| NSB         | 1933.00   | 905.65| 64.86|
| CD          | 375.06**  | 118.6 | 23.91|
| LL          | 1.54      | 0.64  | 1.75 |
| LW          | 0.26**    | 0.08  | 0.64 |
| LA          | 73.28     | 32.53 | 12.53|
| FL          | 0.77**    | 0.27  | 1.12 |
| FW          | 0.48*     | 0.23  | 0.55 |
| FT          | 0.56*     | 0.27  | 0.80 |
| BL          | 0.7**     | 0.16  | 0.80 |
| BW          | 0.18**    | 0.043 | 0.42 |
| BT          | 0.054     | 0.033 | 0.36 |
| HBW         | 7.83**    | 0.86  | 1.98 |
| CBD         | 452.11**  | 162.37| 28.14|
| Rust        | 134.65**  | 90.43 | 20.51|
| Yd/tr       | 0.08*     | 0.045 | 0.43 |

*, ** and ns = significant, highly significant and non-significant, respectively. HUP= height up to first primary branches. TPH= total plant height, NMSN= number of main stem nodes, AILMS= average inter node length of main stem, SD= stem diameter, APB= angle of primary branches, NPB= number of primary branches, ALPB= average length of primary branches, NNPB= number of nodes on primary branches, AILPB= average inter node length of primary branches, NSB=number of secondary branches, CD= canopy diameter, LL= leaf length, LW= leaf width, FL= fruit length, FW= fruit width, FT= fruit thickness, BL= bean length, BW= bean width, HBW= hundred bean weight, CBD =coffee berry disease, Yd/tr= yield per tree

### Table 3. Estimates of range and mean for 22 morphological characters at Agaro.

| Trait       | Range      | Mean |
|-------------|------------|------|
|             | Min        | Max  |      |
| HUP         | 25.53      | 45.50| 33.14|
| TPH         | 215.5      | 285.11| 250.78|
| NMSN        | 30.81      | 42.63| 36.29|
| AILMS       | 5.03       | 7.12 | 6.21 |
| SD          | 4.26       | 6.46 | 5.46 |
| APB         | 57.88      | 75.22| 67.35|
| NPB         | 39.0       | 79.00| 63.13|
| ALPB        | 77.52      | 97.81| 87.57|
| NNPB        | 17.00      | 27.00| 21.29|
| AILPB       | 3.45       | 4.84 | 4.14 |
| NSB         | 57.26      | 210.93| 125.70|
| NNPB        | 17.00      | 27.00| 21.29|
| AILPB       | 3.45       | 4.84 | 4.14 |
| LL          | 12.67      | 16.92| 14.50|
| LW          | 5.29       | 6.85 | 5.96 |
| FL          | 14.34      | 17.47| 15.62|
| FW          | 11.65      | 14.34| 12.69|
| FT          | 8.37       | 11.38| 10.11|
| BL          | 7.68       | 11.37| 9.66 |
| BW          | 6.21       | 7.69 | 6.79 |
| HBW         | 13.31      | 22.88| 17.27|
| CBD         | 0.00       | 75.09| 19.16|
| Yd/tr       | 0.23       | 1.45 | 0.61 |

HUP= height up to first primary branches. TPH= total plant height, NMSN= number of main stem nodes, AILMS= average inter node length of main stem, SD= stem diameter, APB= angle of primary branches, NPB= number of primary branches, ALPB= average length of primary branches, NNPB= number of nodes on primary branches, AILPB= average inter node length of primary branches, NSB=number of secondary branches, CD= canopy diameter, LL= leaf length, LW= leaf width, FL= fruit length, FW= fruit width, FT= fruit thickness, BL= bean length, BW= bean width, HBW= hundred bean weight, CBD =coffee berry disease, Yd/tr= yield per tree
height up to first primary branch and hundred bean weight. Lemi and Ashenafi (2016) also reported high values of phenotypic coefficient of variation but medium genotypic coefficient of variation for yield and with higher GCV values for number of main stem nodes.

**Heritability and genetic advance**

The estimates of broad sense heritability ($H^2$) for quantitative traits are presented in Table 4. According to Verma and Agarwal (1982), heritability values $>$50% are considered as high, whereas values less than 20% are regarded as low and values between 20 and 50% are moderate. According to this cut point, high heritability ($>$50%) was recorded for hundred bean weight (80.21%), number of nodes of primary branches (67.89%), stem diameter (67.16%), height up to first primary branch (66.6%), bean length (62.79%), bean width (61.43%) and average inter node length of primary branches (58.33%), angle of primary branches (53.32%), leaf width (52.94%) and canopy diameter (51.95%). The estimated high heritability for these traits, suggest the greater effectiveness of selection and improvement to be expected for these characters in future breeding program. Characters such as fruit length (48.08%), Coffee berry disease severity (47.15%), plant height (47.05 %), average inter node length of main stem (41.38%), leaf length (41.28%), number of primary branches (39.4%), average length of primary branches (36.91%), number of secondary branches (36.19%), number of main stem nodes (35.35%), fruit length (34.94%) and clean coffee yield per tree (28.0%) exhibited moderate heritability.

The present finding partly agree with findings of Gilas et al. (1998) who reported high heritability for stem girth,

### Table 4. Estimates of phenotypic and genotypic variance, phenotypic (PCV) and genotypic coefficient of variation (GCV), broad sense heritability ($H^2$), genetic advance (GA) and expected genetic advance as percent of mean (GAM%) for 22 morphological characters.

| Trait  | $\sigma^p$ | $\sigma^g$ | PCV | GCV | $H^2$ | GA | GAM |
|--------|------------|------------|-----|-----|-------|----|-----|
| HUP    | 23.33      | 15.54      | 14.57 | 11.90 | 66.60 | 6.63 | 20.00 |
| TPH    | 514.87     | 242.25     | 9.05  | 6.21  | 47.05 | 21.99 | 8.77  |
| NMSN   | 14.42      | 5.10       | 10.46 | 6.22  | 35.35 | 2.76  | 7.62  |
| AILMS  | 0.29       | 0.12       | 8.67  | 5.58  | 41.38 | 0.46  | 7.39  |
| SD     | 0.34       | 0.23       | 10.68 | 8.69  | 67.16 | 0.80  | 14.67 |
| APB    | 27.98      | 14.92      | 7.85  | 5.74  | 53.32 | 5.81  | 8.63  |
| NPB    | 87.07      | 34.31      | 14.79 | 9.28  | 39.40 | 7.57  | 11.99 |
| ALPB   | 36.14      | 13.34      | 6.87  | 4.17  | 36.91 | 4.57  | 5.22  |
| NNPB   | 4.64       | 3.15       | 10.12 | 8.34  | 67.89 | 3.01  | 14.15 |
| AILPB  | 0.12       | 0.07       | 8.37  | 6.39  | 58.33 | 0.42  | 10.05 |
| NSB    | 1419.3     | 513.68     | 30.0  | 18.03 | 36.19 | 28.09 | 22.34 |
| CD     | 246.8      | 128.23     | 7.71  | 5.56  | 51.95 | 16.81 | 8.25  |
| LL     | 1.09       | 0.45       | 7.20  | 4.63  | 41.28 | 0.89  | 6.12  |
| LW     | 0.17       | 0.09       | 6.92  | 5.03  | 52.94 | 0.45  | 7.54  |
| FL     | 0.52       | 0.25       | 4.62  | 3.20  | 48.08 | 0.71  | 4.57  |
| FW     | 0.36       | 0.13       | 4.70  | 2.79  | 35.21 | 0.43  | 3.41  |
| FT     | 0.42       | 0.15       | 6.37  | 3.77  | 34.94 | 0.46  | 4.59  |
| BL     | 0.43       | 0.27       | 6.79  | 5.38  | 62.79 | 0.85  | 8.78  |
| BW     | 0.11       | 0.07       | 4.92  | 3.90  | 61.43 | 0.42  | 6.22  |
| HBW    | 4.35       | 3.49       | 12.07 | 10.81 | 80.21 | 3.44  | 20.00 |
| CBD    | 307.24     | 144.87     | 91.48 | 62.82 | 47.15 | 17.03 | 88.86 |
| Yd/tr  | 0.063      | 0.018      | 41.67 | 22.05 | 28.00 | 0.14  | 24.03 |

$\sigma^p$ = Phenotypic variance, $\sigma^g$= genotypic variance, GCV = genotypic coefficient of variation, PCV= phenotypic coefficient of variation, $H^2$= heritability in broad sense, GA= genetic advance, GAM= genetic advance as percent of mean. HUP= height up to first primary branches. TPH= total plant height, NMSN= number of main stem nodes, AILMS= average inter node length of main stem, SD= stem diameter, APB= angle of primary branches, NPB= number of primary branches, ALPB= average length of primary branches, NNPB= number of nodes on primary branches, AILPB= average inter node length of primary branches, NSB=number of secondary branches, CD= canopy diameter, LL= leaf length, LW= leaf width, FL= fruit length, FW= fruit width, FT= fruit thickness, BL= bean length, BW= bean width, HBW= hundred bean weight, CBD =coffee berry disease, Yd/tr= yield per tree.
tree height and yield. Bayetta (2001) also reported high heritability estimates between 71.43 and 97.32 for all characters measured, suggesting that the effect of environment on phenotypic expression of the characters was small. Moreover, Yigzaw (2005) has reported high heritability values for hundred bean weight, number of secondary branches and canopy diameter. However, he reported low heritability for bean thickness, percent of bearing primary branches, average inter node length of primary branches and petiole length.

The high heritability for bean characteristics, such as hundred bean weight, bean length, and bean width in the present study is in agreement with the findings of Olika et al. (2011). The observed low heritability value for yield is in agreement with the findings of Ermiyas (2005) and Olika et al. (2011). However, in contrast to this finding, Mesfin (1980) and Bayetta (2001) reported high heritability for yield. This is probably due to the differences in test materials and the environment.

Genetic gain (GAM) that could be expected from selecting the top 5% of the genotypes as percent of the mean, varied from 3.41% for fruit width to 88.86% for CBD reaction (Table 4). According to Johnson et al. (1955), genetic advance as percent of the mean was categorized as high (≥20%), moderate (10-20%) and low (0-10%). Accordingly, the high GAM were recorded for coffee berry disease reaction (88.86%), clean coffee yield per tree (24.03%), number of secondary branches per tree (22.34%), height up to first primary branch (20%) and hundred bean weight (20%).

The characters that exhibited moderate (10 to 20%) level of genetic advance as percent of mean were stem diameter (14.67%), number of nodes of primary branches (14.15%), number of primary branches (11.99%) and average inter node length of primary branches (10.05%). The other traits, such as total plant height, number of main stem nodes, average internodes length of main stem, angle of primary branches, average length of primary branches, canopy diameter, leaf length, leaf width, fruit length, fruit width, bean length and bean width, had low level of GA as percent of mean (<10%). This low estimate of genetic advance as percent of mean arises from low estimates of phenotypic variability and heritability. Selection based on those traits with a high level GAM will result in improvement of the performance of the germplasm accessions for those traits.

In the current study, high heritability coupled with high genetic advance as percent of mean was observed for characters such as hundred bean weight and height up to first primary branch. This indicates the lesser influence of environment in expression of the characters and prevalence of additive gene action in their inheritance. In addition, both traits had medium genetic coefficient of variation, hence are amenable for simple selection.

CBD severity had high genotypic coefficient of variation (62.82), moderate heritability (47.17%) and high genetic advance as percent of mean (88.86), indicating that selection will be effective to improve this important trait. Contrarily, stem diameter, number of nodes of primary branches, and average inter node length of primary branches showed high heritability coupled with moderate genetic advance and the scope for their improvement was restricted by the low range of genetic variability present in the population. Besides, high heritability with low genetic advance was recorded for angle of primary branches, canopy diameter, leaf width, bean length and width, indicating less influence of environment but prevalence of non-additive gene action for which simple selection will be less effective. Hence, heterosis breeding would be recommended for the improvement of such traits. Mesfin (1980) reported genetic advance for yield to be 1.4 kg fresh cherry/tree from indigenous coffee collections grown at Jimma. In Ethiopia, some reports indicated that genetic advance through selection for yield at 20% selection intensity was up to 2.2 kg of fresh cherry per tree, confirming the presence of high genetic variability within Arabica coffee population. Therefore, the opportunity to bring a reasonable improvement through selection is high (Bayetta, 1997). Lemi and Ashenafi (2016) reported high broad sense heritability estimates coupled with high genetic advance in percentage of mean for number of main stem nodes, stem diameter and internodes length.

Conclusion

The present study exhibited the existence of variability for some morphological traits among coffee germplasm accessions. Some of the important traits showed high and moderate PCV and GCV, suggesting the incidence of variability and thus offers scope for genetic improvement through selection. Besides, traits coupled with high/moderate heritability and high/moderate estimates of genetic advance, and careful selection may lead to improvement of these traits. Hence, provides better opportunities for selecting plant material for these traits in coffee. Therefore, the observed variability should be exploited in order to improve the coffee productivity. However, most of the traits exhibited low GCV and/or low genetic advance as percent mean, indicating these traits could not be improved through simple section but through heterosis breeding.

Conflicts of Interests

The authors have not declared any conflict of interests

ACKNOWLEDGMENT

The authors are grateful for assistance of Agro Research
Sub Center Coffee Breeding staff.

REFERENCES

Alemyehu T, Esayas K, Kassu K (2008). Coffee Development and Marketing Improvement Plan. In: Girma Adugna, Bayetta Belachew, Tesfaye Shimber, Endale Taye and Taye Kufa (eds.). Coffee Diversity and Knowledge. Proceedings of a National Workshop Four Decades of Coffee Research and Development in Ethiopia, 14-17 August 2007, Addis Ababa, Ethiopia, pp. 375-381.

Bayetta B (1997). Arabica coffee breeding in Ethiopia: A review. ASIC Nairobi, Kenya. 17:406-414.

Bayetta B (2001). Arabica coffee breeding for yield and resistance to Coffee Berry Disease (Colletotrichum Kahawae) sp. nov). APhD dissertation submitted to the Imperial College of Wye University of London 272 p.

Burton GW, de Vane HE (1953). Estimating heritability in tall festuca (Festuca arundinacea) from replicated clonal material. Agron. J. 45:478-481.

Solomon C, Hallu T, Singh H (2009). Genetic variability, heritability and trait relationships in recombinant inbred lines of tef [Eragrostis tef (Zuc.) Trotter]. Res. J. Agric. Biol. Sci. 5(4):474-479.

Cillas C, Bouharmont P, Boccaro M, Eskes AB, Boradat PH (1998). Prediction of genetic value for coffee production in Coffea arabica from a half diallel with lines and hybrids. Euphytica 104:49-59.

Clifford MN (1985). Chemical and physical aspects of green coffee and coffee products. pp. 305-374. In: M.N. Clifford and K.C. Willson (Eds.), Coffee botany, biochemistry, and production of beans and beverage. Croom Helm, London.

Coste R (1992). Coffee: The Plant and the Product. MacMillan Press, London.

Deshmuk SN, Basu MS, Reddy PS (1986). Genetic variability, character association and path coefficient analysis of quantitative traits in vijinia bunch varieties of groundnut. Indian J. Agric. Sci. 56:515-518.

Endale T, Taye K, Antenhe N, Tesfaye S, Alemseged Y, Tesfaye A (2008). Research on coffee field management. In: Girma Adugna, Bayetta Belachew, Tesfaye Shimber, Endale Taye and Taye Kufa (eds.). Coffee Diversity and Knowledge. Proceedings of a National Workshop Four Decades of Coffee Research and Development in Ethiopia, 14-17 August 2007, Addis Ababa, Ethiopia. pp. 187-195.

Ermias H (2005). Evaluation of Wellega coffee germplasm for yield, yield component and resistant to coffee berry disease at early bearing stage. An MSc thesis submitted to school of graduate studies of Alemye University 69 p.

Falconer DS (1989). Introduction to Quantitative Genetics. Longman Scientific and Technical.Jhony Wiley and Sons, Inc. Newyork 438p.

Gole TW, Senebeta F (2008). Sustainable management and promotion of forest coffee in Bale, Ethiopia. Bale Eco-Region Sustainable Management Programme SOS Sahel/FARM-Africa, Addis Ababa.

IPGRI (International Plant Genetic Resource Institute) (1996). Diversity for development. Rome, International Plant Genetic Resources Institute.

Johnson HW, Robinson HF, Comstock RF (1955). Estimates of genetic and environmental variability in Soya bean. Agron. J. 47:314-318.

Lemi B, Ashenafi A (2016). Genetic Variability, Heritability and Genetic Advance for Yield and Yield Components of Limmu Coffee (Coffea arabica L.) Accessions in South Western Ethiopia. Middle-East J. Sci. Res. 24(6):1913-1919.

Mesfin A (1980). Yield assessment of indigenous coffee grown at Jimma research station, Eth. J. Agric. Sci. 2:69-71.

Olika K, Sentayehu A, Taye K and Weyessa G (2011). Variability of quantitative Traits in Limu Coffee (Coffea arabica L.) in Ethiopia. Int. J. Agric. Res. 6:482-493.

Orozco-Castillo C, Chalmers KJ, Waugh R, Powell W (1994). Detection of genetic diversity and selective gene introgression in coffee using RAPD markers. Theor. Appl. Gen. 87:934-940.

Porceddu E, Damania AB (1992). Sampling Variation in Genetic Resources of Seed Crops: A Review. Gen. Resour. Crop Evol. 39:39-49.

SAS (2008). Statistical analysis system (version 9.2), SAS Institute, Cary, NC,USA.

Seyoulm S, Bayetta B (2007). Variability and inter relationships between coffee (Coffea arabica L.) seedlings character and their implication in selection. 21st international conference on coffee science 11-15 October, 2004, Bangalore, India 91 p.

Silvarolla MB, Mazzaferra P, Fazuoli LC (2004). A naturally decaffeinated Arabica coffee. Nature 429:826.

Taye K (2010). Environmental Sustainability and Coffee Diversity in Africa. Available at: http://dev.ico.org/event_pdfs/wcc2010/presentationswcc-2010-kufanotes-pdf/ accessed date November 10/2011/

Verma PS, Agarwal VK (1982). Genetics. S. Chand and Co. Ltd., Ram Nagar, New Delhi. P 555.

Yigzaw D (2005). Assessment of genetic diversity of Ethiopian Arabica coffee genotypes using morphological, biochemical and molecular markers. A PhD dissertation, University of the free state, South Africa 197 p.

Zebene M, Wondwosen T (2008). Potential and constraints of Nitosol and Acrisol. In: Girma Adugna, Bayetta Belachew, Tesfaye Shimber, Endale Taye and Taye Kufa (eds.). Coffee Diversity and Knowledge. Proceedings of a National Workshop Four Decades of Coffee Research and Development in Ethiopia, 14-17 August 2007, Addis Ababa, Ethiopia. pp. 209-216.