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Genetic Diversity Assessment of Okra (*Abelmoschus esculentus* (L.) Moench) Collections in Ethiopia Using Multivariate Analysis

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ABSTRACT

Okra is a traditional vegetable crop in Ethiopia but it has not given research attention and considered a minor crop. Thus this research was conducted to assess genetic diversity among Ethiopia okra collections based on agro-morphological traits using multivariate analysis for further utilization of the crop and contribute to develop high yielding varieties and to improve the quality. A total of 35 okra landraces from three districts (Guba, Mandura and Dangure) were evaluated for 23 agro-morphological and eight qualitative traits in 2017 at Pawe Agricultural Research Center in randomized complete block design. Results of analysis of variance showed significant differences among okra landraces for all traits. Results of principal component analysis indicated the first four principal component axes (PCA1 to PCA4) accounted 65.59% of the total variation, of which PCA1 and PCA2 had larger contribution of 22.09 and 19.34%, respectively. The 35 okra landraces were grouped into 12 distinct clusters from Euclidean distances matrix using Unweighted Pair-group Methods with Arithmetic Means (UPGMA) of which Cluster IX consisted of 6 (17.14%), Cluster II, VI and X consisted each five and other clusters consisted of 1 and 3 landraces. The study results showed the presence of genetic diversity among landraces for all traits suggested that selection could be effective to develop okra varieties for high fruit yield and other traits.

Keywords: Principal component, genetic distance, cluster

1. Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is the most important vegetables and it belongs to Malvaceae family. The geographical origin of okra based on ancient cultivation in East Africa, suggested that it is originated somewhere around Ethiopia, and it was cultivated by the ancient Egyptians by the 12th century BC (Benchasri, 2012). The plant is cultivated in tropical, subtropical, and a warm temperate region around the world.

Okra is mainly grown for its young immature fruits, which are consumed as a vegetable, raw, cooked or fried, soups and sauces (Habtamu *et al.,* 2014). It is a multipurpose crop due to its various uses. Okra has a prominent position among fruits, vegetables due to its multiple virtues like high nutritive and medicinal value, ease of cultivation, wide adaptability, year round cultivation, good portability, export potential and bountiful returns (Thirupathi *et al.,* 2012). In Ethiopia the economic importance of okra is minor. The species is cultivated and utilized as vegetable in some parts of the country while in other parts of the country, it is grown as wild plant and its utilization is very limited. For generation, communities in Gambella and Beneshangul Gumuz have been cultivating for its fruit and leaf to use as a food and medicine of different diseases (Tesfa and Yosef, 2016). However, the crop has a potential to be used for food security and tackling the crucial malnutrition problem. It has also a potential to be export commodity to the neighboring and Arab countries which are known as a heavy consumers and importers of the crop (Wassu *et al.,* 2017).

Even though, the potential contribution of okra for food security and export purpose is very well, there is no improved varieties development so far for cultivation in Ethiopia. There is no information about the genetic and morphological divergence or proximity of Ethiopian landraces or improved okra varieties of other

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countries is also unavailable. The present study aimed to assess genetic diversity among Ethiopia okra collections based on agro-morphological traits using multivariate analysis for further utilization of the crop and contribute to develop high yielding varieties and to improve the quality.

2. Materials and Methods

2.1. Description of Experimental Site

The experiment was conducted at Metekel Zone, Pawe district which is located 575 km from Addis Ababa. The experimental site was located at Pawe Agricultural Research Center and has an elevation of 1120 meters above sea level at latitude of 11°18′ N and longitude of 36°24′ E. Pawe was situated in the hot humid agro-ecological zone that was well known for okra cultivation by the farmers. The experiment was conducted on vertisol soil type with a pH of 6.5. The area was characterized by a long season of rainfall which the main rainy season falls primarily from early May to late October with mean annual rainfall of 980-1587mm per year and the average annual minimum and maximum temperatures are 16°C and 32°C, respectively.

2.2. Experimental Materials and Design

Thirty-five okra landraces, which have been collected by Pawe Agricultural Research Center, were used for this study in 2017 rainy season. The landraces were planted in a Randomized Complete Block Design (RCBD). Each landraces was sown in single-row plot to minimize environmental variations associated with large plots and in three replications. Each row was 6.3 m long with a row-row distance of 1 m and 45 cm plant-to-plant. With 45 cm plant-to-plant, spacing there were 14 plants per row.

2.3. Data Collection

Quantitative traits data were recorded from 12 plants per row left the two plants grown at both end of the rows as border plants. The 10 plants, which were grown at the center of each row, were used to record growth, phenology and tender fruits characters and to estimate tender fruit yield. International Plant Genetic Resources Institute (IPGRI, 1991) descriptor list for okra species was used to record the quantitative traits.

Quantitative traits: Phenology and growth traits recorded from days to 50% flowering, days to maturity, plant height (cm), stem diameter (mm), number of primary branches per stem, number of internodes, internodes length (cm), leaf length (cm), leaf width (cm) and number of epicalyxes. Fruit and yield traits were recorded from peduncle length (cm), fruit length (cm), fruit diameter (cm), average fruit weight (g), number of tender fruits per plant, number of ridges on fruit, yield per hectare (t/ha), number of matured pods per plant, dry weight of matured pods per plant (g/plant), number of seeds per pod and hundred seed weight (g).

2.4. Data Analysis

2.4.1. Analysis of Variance

Data on quantitative characters were subjected to analysis of variance (ANOVA) using SAS version 9.4 (SAS, 2019) to test the presence of significant differences among accessions for the traits measured. Duncan's Multiple Range (DMRT) at $P<0.05$ was employed to identify landrace that were significantly different mean squares from each other. The traits that exhibited significant mean squares in general ANOVA were further subjected to genetic analyses.

2.4.2. Genetic Divergence and Clustering Analysis

Frist the data was standardizes by subtracting the mean and dividing by the standard deviation for each variable. Genetic dissimilarity matrix estimation and agglomerative hierarchical clustering (AHC) analyses among landraces were performed using XLSTAT 2014 statistical package (XLSTAT, 2014). Un-weighted pair-group average linkage agglomeration method was used to estimate the Euclidean distance and clustering operations produced a binary clustering tree (dendrogram), whose root was the cluster that contained all the landraces. This dendrogram represents a hierarchy of partitions truncated at 5.078 levels. The upper tail approach is a simple procedure in which the mean and the standard deviation of distance values at the fusion points are used to calculate the optimal number of clusters (Franco *et al.,* 1997). An acceptable cluster is defined as a group of two or more genotypes with

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a within-cluster genetic distance less than the overall mean genetic distance and between cluster distances greater than their within cluster distance of the two clusters involved (Brown *et al.,* 2000).

2.4.3. Principal Component Analysis

Principal Component Analysis (PCA) was used to find out the characters, which accounted more to the total variation. The data was standardized to mean zero and variance of one before computing principal component analysis. Principal components based on correlation matrix will be calculated using XLSTAT software (XLSTAT, 2014).

3. Results and Discussion

3.1. Analysis of Variance

Analysis of variance computed for 22 quantitative traits revealed the presence of highly significant ($P<0.01$) differences among the 35 landraces (Table 1). The presence of significant variations among landraces might give a good opportunity for breeders to identify genotypes for high fruit yield and other desirable traits. Muluken *et al.* (2016), Mihretu *et al.* (2014) and Tesfa and Yosef (2016) also observed highly significant differences among okra genotypes for most of the traits.

Table 1: Mean squares from analysis of variance for quantitative traits of okra landraces

Traits	Replication (2)	Landraces (34)	Error (68)	CV (%)
Days to 50% flowering	28.4	648.85**	10.92	3.83
Days to maturity	591.43	1008.64**	99.53	9.09
Plant height (m)	0.03	0.49**	0.02	9.54
Stem diameter (cm)	0.03	0.24**	0.05	10.12
Number of primary branches per stem	0.52	1.87**	0.06	9.79
Internodes number	31.01	13.62**	3.7	9.85
Internodes length (cm)	0.73	8.62**	0.25	8.52
Leaf length (cm)	60.32	12.26**	1.82	8.12
Leaf width (cm)	94.88	22.41**	2.33	7.2
Number of epicalyxes	0.08	0.85**	0.38	6.38
Number of ridges	0.24	1.94**	0.05	2.61
Peduncle length (cm)	0.05	0.29**	0.05	8.05
Fruit length (cm)	0.41	3.25**	0.38	8.35
Fruit diameter (cm)	0.03	0.03**	0.02	6.91
Average fruit weight (g)	2.15	25.69**	1.75	9.00
Number of matured fruits per plant	0.99	174.90**	2.83	10.81
Weight of matured fruits per plant (g)	42.18	17466.00**	206.54	8.34
Dry weight of matured fruits per plant (g)	12.97	3161.74**	12.64	4.24
Number of seeds per fruit	40.83	1020.69**	8.62	5.54
100 seed weight (g)	0.08	1.91**	0.24	7.61
Number of tender fruits per plant	3.26	253.14**	2.79	10.05
Yield per hectare (t/ha)	2.52	100.12**	0.94	10.28

**, significant at $P<0.01$; NS= Nonsignificant, Numbers in parenthesis represent degree of freedom for the respective source of variation and CV (%) = Coefficient of variation in percent.

3.2. Principal Component Analysis

The results of principal component analysis for 22 traits of 35 okra landraces are presented in Table 2. The four principal component axes; PCA1, PCA2, PCA3 and PCA4 accounted 65.59% of the total variation with Eigenvalue of 4.86, 4.26, 2.93 and 2.39 for PCA1, PCA2, PCA3 and PCA4, respectively. The four PCAs were retained in analysis because each PCA had Eigen values are >1 and >10% contribution to total variability. The others factors having Eigen value < 1 were ignored. These were ignored due to Gutten's lower bound principle that Eigen values <1 should be ignored (Kumar *et al.,* 2011).

Table 2: Factor loadings, contribution of traits and Eigen values of four principal component axes in 35 okra landraces evaluated at Pawe in 2017.

Quantitative trait	PCA1	PCA2	PCA3	PCA4
Days to 50% flowering	0.098 (0.14%)	-0.47 (5.19%)	0.48 (7.92%)	**-0.59 (14.74%)**
Days to maturity	-0.21 (0.89%)	**-0.72 (12.11%)**	0.314 (4.05%)	-0.39 (6.36%)
Plant height	-0.45 (4.22%)	0.01 (0.00%)	**0.55 (10.35%)**	0.22 (1.99%)
Stem diameter	**0.60 (7.39%)**	-0.26 (1.65%)	0.16 (0.88%)	-0.51 (10.83%)
Number of primary branches/stem	-0.22 (1.02%)	-0.23 (1.22%)	0.21 (1.51%)	-0.37 (5.78%)
Internodes number	-0.43 (3.88%)	-0.08 (0.15%)	**0.55 (10.22%)**	-0.35 (5.21%)
Internodes length	-0.31 (1.99%)	-0.09 (0.20%)	0.53 (9.44%)	**0.55 (12.86%)**
Leaf length	**0.66 (8.84%)**	-0.04 (0.03%)	0.06 (0.11%)	-0.24 (2.51%)
Leaf width	**0.53 (5.83%)**	-0.05 (0.05%)	0.45 (6.85%)	-0.02 (0.02%)
Number of epicalyxes	0.25 (1.29%)	-0.18 (0.79%)	0.13 (0.55%)	**0.49 (10.17%)**
Number of ridges	**0.82 (13.71%)**	-0.28 (1.80%)	0.19 (1.27%)	0.20 (1.70%)
Peduncle length	**0.57 (6.58%)**	-0.06 (0.08%)	-0.40 (5.54%)	-0.07 (0.19%)
Fruit length	**0.47 (4.56%)**	-0.45 (4.85%)	-0.38 (5.05%)	-0.32 (4.31%)
Fruit diameter	0.29 (1.71%)	-0.31 (2.33%)	**0.55 (10.31%)**	0.52 (11.12%)
Average fruit weight	**0.77 (12.13%)**	-0.39 (3.57%)	-0.07 (0.17%)	0.23 (2.26%)
Number of matured fruits per plant	-0.16 (0.54%)	**0.78 (14.35%)**	0.33 (3.81%)	-0.24 (2.32%)
Weight of matured fruits per plant	0.45 (4.25%)	**0.62 (9.06%)**	0.43 (6.26%)	-0.12 (0.56%)
Dry weight of matured fruits/plant	0.31 (1.95%)	0.52 (6.41%)	**0.56 (10.90%)**	-0.23 (2.21%)
Number of seeds per fruit	**0.61 (7.67%)**	-0.37 (3.26%)	0.28 (2.75%)	0.25 (2.54%)
100 seeds weight	0.43 (3.84%)	**0.52 (6.32%)**	0.18 (1.09%)	0.19 (1.47%)
Number of tender fruits/plant	0.26 (1.42%	**0.82 (15.80%)**	0.00 (0.00%)	-0.07 (0.23%)
Yield per hectare (t/ha)	0.55 (6.13%)	**0.68 (10.77%)**	-0.17 (0.97%)	-0.13 (0.69%)
Eigenvalue	4.86	4.26	2.93	2.39
Contribution to variability (%)	22.09	19.34	13.31	10.85
Cumulative contribution (%)	22.09	41.44	54.74	65.59

PCA = Principal Component Axes
The numbers in bracket indicated contribution of the traits in percent in building the principal components

Principal component analysis (PCA) is one of the multivariate statistical techniques which are a powerful tool for investigating and summarizing underlying trends in complex data structures (Legendre and Legendre 1998). This analysis reflects the importance of the largest contributor to the total variation at each axis for differentiation (Sharma, 1998). Mohammadi and Prasanna (2003) suggested standard criteria permit to ignore components whose variance explained are less than 1 when a correlation matrix is used.

The first three principal components PCA1, PCA2 and PCA3 with values of 22.09%, 19.34% and 13.31% respectively, contributed more to the total of 54.74% variation. Similar result was reported by Amoatey *et al.* (2015), Shivaramegowda *et al.* (2016) and Khalid (2017). According to Chahal and Gosal (2002), characters with largest absolute values closer to unity with in the first principal component influence the clustering more than those with lower absolute values closer to zero. Therefore, in this study, differentiation of the landraces in to different cluster was because of a cumulative effect of several traits rather than the contribution of specific few traits (±0.001 - 0.816).

The two-dimensional ordinations of 35 okra landraces and 22 quantitative traits on biplot axes PC1 and PC2 (Figure 1) and biplot axes PC3 and PC4 (Figure 2), revealed scattered diagram of landraces and

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quantitative traits distribution pattern on axes with cumulative variations 41.44% and 24.15% respectively. Both the scattered diagram showed that 65.59% of cumulative total variations were contributed by first 4 principal components, collectively.

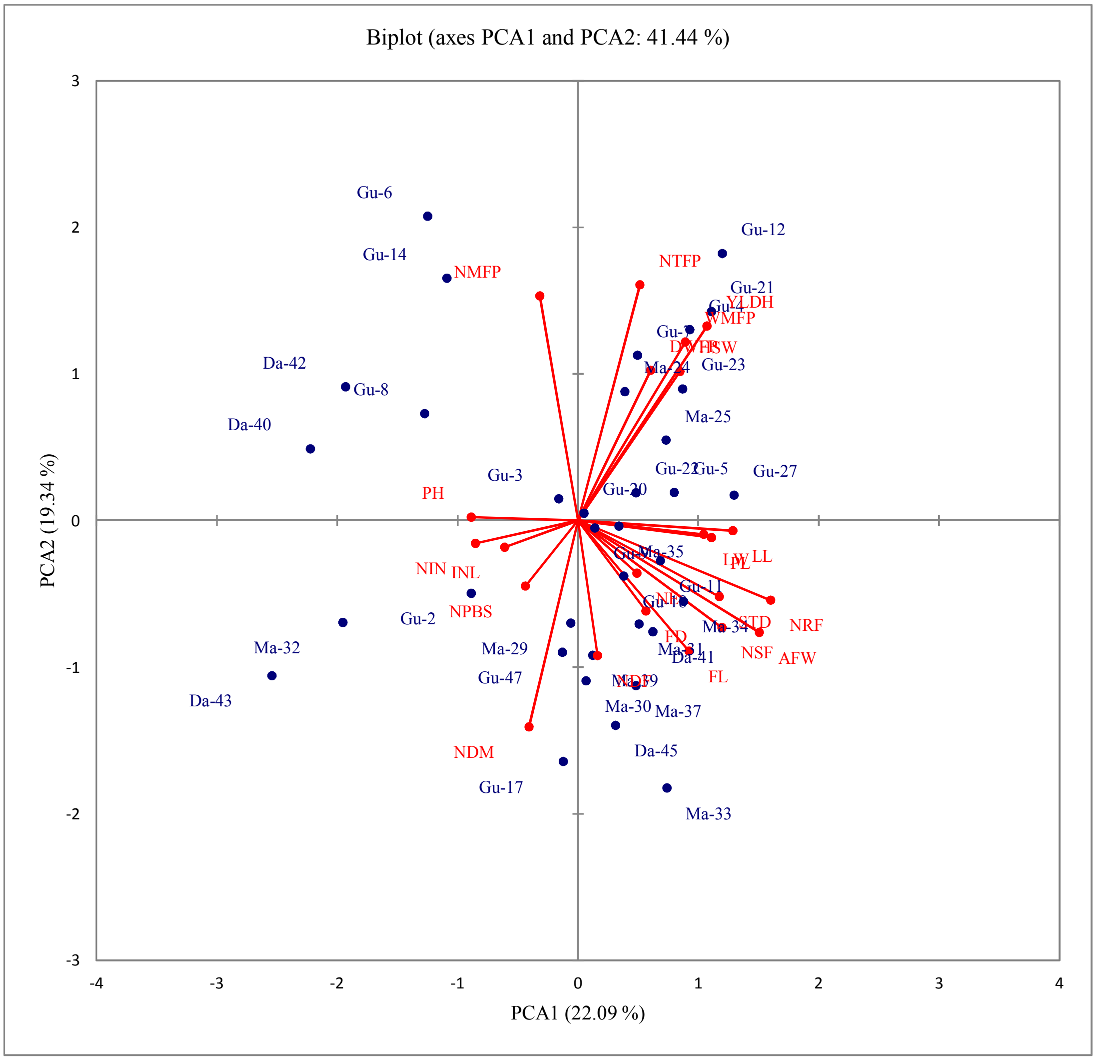

Fig. 11: Scattered diagram 35 okra landraces by 22 quantitative traits using two dimensional ordinations traits on PCA1 and PCA2.

PCA = Principal Component Axes; DFF= Days to 50% flowering; NDM=Days maturity; PH= Plant height (m); STD= Stem diameter; NPBS= Number of primary branches per stem; NIN= Number of internodes; INL= Internodes length; LL= Leaf length; LW= Leaf width; NEP= Number of epicalyxes; NRG= Number of ridge; PDL= Peduncle length; FL= Fruit length; FD= Fruit diameter; AFW= Average fruit weight; NMFP= Number of matured fruits per plant; WMFP= Weight of matured fruits per plant; DWMFP= Dry weight of matured fruits per plant; NSF= Number of seeds per fruit; HSW=hundred seed weight; NTFP= Number of tender fruits per plant and YLPH= Yield in ton per hectare.

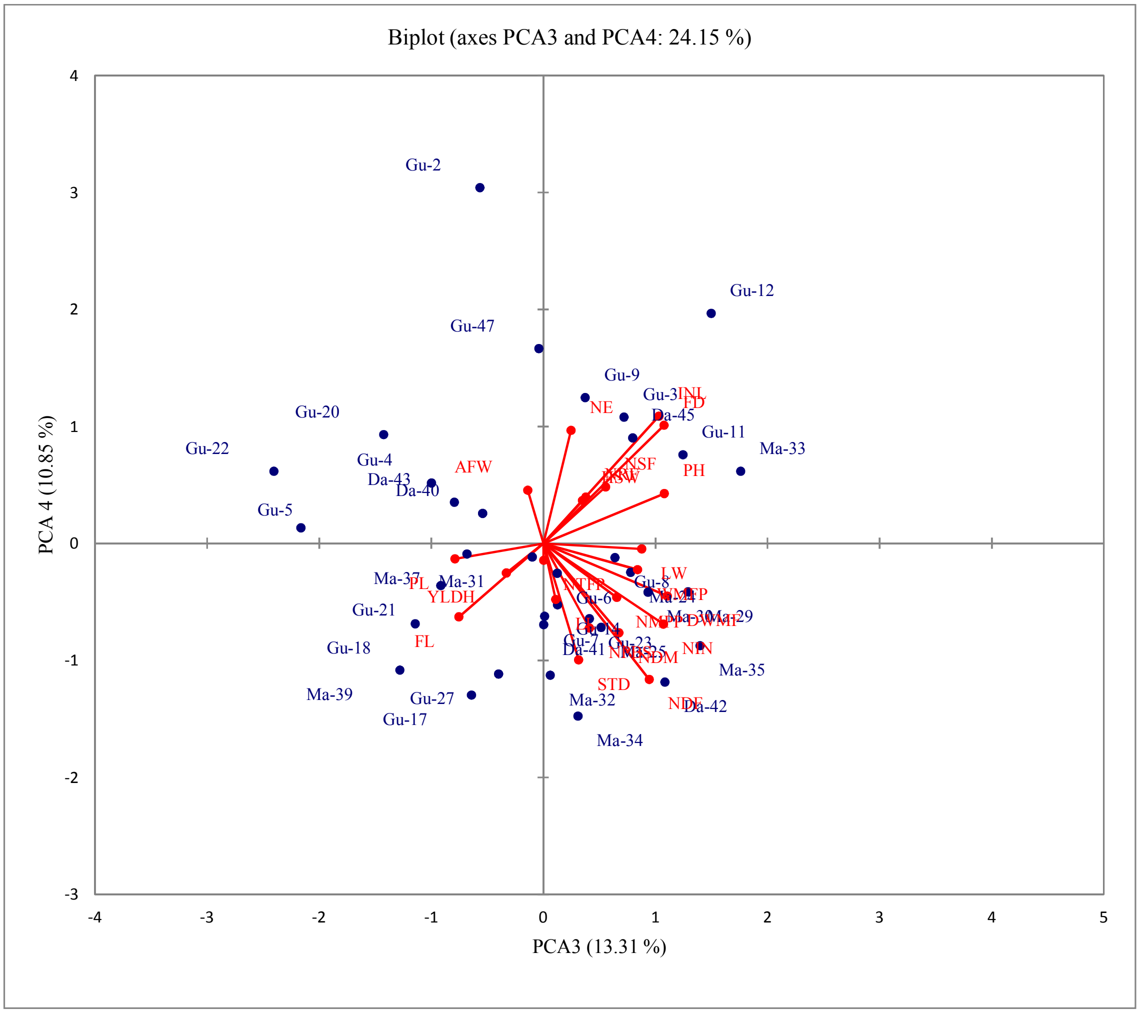

Fig. 2: Scattered diagram by using two dimensional ordinations of 35 okra landraces and 22 quantitative traits based on PC (principal component) axes 3 and 4.

PCA = Principal Component Axes; DFF= Days to 50% flowering; NDM=Days maturity; PH= Plant height (m); STD= Stem diameter; NPBS= Number of primary branches per stem; NIN= Number of internodes; INL= Internodes length; LL= Leaf length; LW= Leaf width; NEP= Number of epicalyxes; NRG= Number of ridge; PDL= Peduncle length; FL= Fruit length; FD= Fruit diameter; AFW= Average fruit weight; NMFP= Number of matured fruits per plant; WMFP= Weight of matured fruits per plant; DWMFP= Dry weight of matured fruits per plant; NSF= Number of seeds per fruit; HSW=hundred seed weight; NTFP= Number of tender fruits per plant and YLPH= Yield per hectare.

Landraces Gu-23 and other five landraces with traits stem diameter, leaf length, leaf width, number of ridge, peduncle length, fruit length, average fruit weight and seed per fruit were contributed substantially to genetic variance in axis PCA1. Major yield components such as date of maturity, number of matured fruits per plant, weight of matured fruits per plant, hundred seed weight, number of tender fruits per plant and yield per hectare with landraces Gu-12 and other twelve landrace were made the greatest contribution to variation in the principal component axis PCA 2 (figure 1). Traits which are plant height, number of internodes, fruit diameter and dry weight of matured fruits per plant with landraces Gu-5 and other six landraces were contributed to genetic variance in axis PCA 3. Whereas, the variation in the principal component axis PCA 4 was made by landraces Ma-34, Gu-9 and Gu-2 with traits days to 50% flowering, internodes length and number of epicalyxes (figure 2).

Traits having relatively higher value in the first PCA were number of ridges (13.71%), average fruit weight (12.13%), leaf length (8.84%), number of seeds per fruit (7.67%), stem diameter (7.39%), peduncle length (6.58), and leaf width (5.83%) and had more contribution to the total differentiation of okra landraces into twelve clusters. Traits like days to maturity (12.11%), number and weight of matured fruits per plant (14.35% and 9.06% respectively), hundred seed weight (6.32%), number of tender fruits per plant (15.80%) and yield per hectare (10.77%) had contributed a lot for PCA2. Plant height (10.35%), number of internodes (10.22%), fruit diameter (10.31%) and dry weight of matured fruits per plant (10.90%) had contributed in the third PCA3 while days to 50% flowering (14.74%), internodes length (12.86%) and number of epicalyxes (10.17%) in the fourth PCA4. The above results are in conformity with the works done by Kumari *et al.* (2019).

Nwangburuka *et al.* (2012) reported that days to flowering, branches per plant, fruit diameter and seeds per pod had relatively high in the principal axes. Ahiakpa (2012) also reported that plant height, 50% germination and number of pods per plant were relatively high in the principal axes. Mudhalvan and Senthilkumar (2018) reported number of fruits per plant followed by number of branches per plant, fruit girth, days to fruit maturity and days to first flowering contributed maximum towards the genetic divergence.

3.3. Genetic Distances among Okra Landraces

Genetic distances of all possible pairs of 35 okra landraces were estimated by Euclidean distance from 22 traits and the results are presented (Table 3, Appendix Table 1). The genetic distances for all possible pairs of 35 okra landraces ranged from 2.92 to 11.28 with mean, standard deviation and CV% of 6.48, 0.16 and 2.51 respectively. The most distant landraces were Gu-12 and Da-43 (11.28) followed by Gu-12 and Ma-32 (10.46), Gu-21 and Da-43 (10.37), Gu-12 and Gu-17 (10.28). The lowest genetic distance was exhibited between G-23 and Ma-24 (2.92) followed by Gu-5 and Gu-22 (2.93), Gu-7 and Ma-25 (3.21), Gu-7 and Ma-24 (3.23). This finding was supported by Muluken *et al.* (2015) who reported that Ethiopia okra collections exhibited wide genetic distances in the range between 5.16 and 11.14. This suggested that the higher chance of improving the crop production through collection, characterization, evaluation and selection of okra landraces from different regions of Ethiopia.

The mean genetic distances of landraces (Table 3) showed that Da-43 (7.99) were the most distant to others and followed by Gu-12 and Gu-2 with mean Euclidean distance of 7.92 and 7.64 respectively. In contrast, Gu-23, Ma-29, Ma-25, Gu-7, Da-41, Ma-35, Gu-3 and Gu-20 with mean Euclidean distance in between 5.85 to 6.06 were closest to others. Seven okra landraces from Guba district and two from Mandura and Dangure districts each had mean Euclidean distances above average distances (6.64 to 7.45) and other four landraces from Guba district, three from Mandura and one from Dangure districts had near to average distances of 6.10 and 6.46. Also, minimum mean Euclidean distances were observed two from Guba and three from Mandura districts.

The extent of diversity present between landraces determines the extent of improvement gained through selection and hybridization. The more divergent the two landraces are the more will be the probability of improving through selection and hybridization. This result is supported by Wassu *et al*. (2017) who reported that the presence of diverse okra genotypes with wide range of genetic distances which enables the researchers to improve the okra tender fruit yield and other desirable traits either through direct selection of genotypes or crossing of okra genotypes having different desirable traits.

Thus, selection of genotypes for hybridization between the genetically diverse parents in further breeding programs may produce large variability and better recombinants in the segregating generations. High degree of divergence among the genotypes within a cluster would produce more segregating breeding material and selection within such cluster might be executed based on maximum mean value for the desirable characters (Prakash, 2017).

Table 3: Mean genetic distances of 35 okra landraces as measured by Euclidean distance

Accession	Minimum	Maximum	Mean	SD	CV (%)
Gu-2	5.19	8.92	7.64	0.90	11.81
Gu-3	4.49	7.78	6.04	0.87	14.45
Gu-4	5.04	9.75	7.30	1.19	16.34
Gu-5	2.93	9.42	6.76	1.39	20.61
Gu-6	3.38	9.99	7.24	1.36	18.72
Gu-7	3.21	9.09	5.92	1.23	20.79
Gu-8	5.14	8.48	6.92	0.96	13.88
Gu-9	4.03	7.55	5.66	0.85	14.94
Gu-11	4.03	9.03	6.15	1.32	21.45
Gu-12	5.53	11.28	7.92	1.34	16.98
Gu-14	3.38	9.21	6.64	1.21	18.29
Gu-17	4.05	10.28	6.81	1.33	19.53
Gu-18	3.68	8.34	5.81	1.17	20.06
Gu-20	3.79	7.88	6.06	0.97	16.03
Gu-21	4.24	10.37	6.87	1.36	19.79
Gu-22	2.93	8.87	6.46	1.32	20.47
Gu-23	2.92	9.19	5.85	1.34	22.99
Ma-24	2.92	8.42	5.49	1.20	21.80
Ma-25	3.19	9.42	5.89	1.35	23.00
Gu-27	3.99	9.42	6.37	1.44	22.68
Ma-29	3.38	7.86	5.86	1.22	20.89
Ma-30	3.50	7.96	5.69	1.27	22.26
Ma-31	3.68	7.81	5.62	1.17	20.86
Ma-32	4.39	10.46	6.85	1.31	19.09
Ma-33	4.45	9.99	7.45	1.53	20.57
Ma-34	3.99	8.81	6.40	1.32	20.68
Ma-35	3.38	8.22	6.04	1.23	20.36
Ma-37	4.02	8.45	6.12	1.25	20.37
Ma-39	4.05	9.52	6.10	1.26	20.60
Da-40	4.55	9.80	7.18	1.31	18.24
Da-41	4.21	8.40	5.94	1.32	22.15
Da-42	4.28	9.42	7.22	1.35	18.64
Da-43	4.39	11.28	7.99	1.41	17.58
Da-45	4.51	8.81	6.41	1.29	20.05
Gu-47	4.53	8.08	6.25	1.06	16.91
Overall	2.92	11.28	6.48	0.16	2.51

SD = standard deviation and CV (%) = coefficient of variation in percent.

3.4. Clustering of Genotypes

The Euclidean distance matrix for all possible pair of okra landraces estimated from quantitative traits was used to construct dendrograms based on the Unweighted Pair-group methods with Arithmetic Means (UPGMA). The 35 okra landraces were grouped into 12 distinct clusters at cut point 5.08 (overall mean Euclidean distance of landraces minus standard deviation) with 45.41 and 54.59% variation within and between clusters, respectively, as variance decomposition for the optimal classification (Table 4, Figure 3).

Cluster IX consisted of six (17.14%), Cluster II, VI and X consisted each five (14.29%) and Cluster IV, V and XI consisted each 3 (8.57%) landraces. Whereas Cluster I, III, VII and VIII were solitary each represented one growing area of Guba district and cluster XII also solitary from Mandura district (Table 4, Figure 3). Cluster IX comprised of six landraces from Guba, Mandura and Dangure districts of three, two and one, respectively. Cluster II comprised of four and one landraces from Guba and Dangure districts, respectively, and Cluster VI comprised from Guba and Mandura districts of three and two landraces, respectively, while Cluster X comprised of four and one landraces from Mandura and Guba districts, respectively. Cluster V comprised three landraces (two landraces from Guba and one from Dangure districts), while Cluster XI comprised of two and one landraces from Dangure and Mandura districts, respectively, Cluster IV comprised of landraces from Guba district.

The result suggested that the landraces grouped under same cluster had similarity for many traits but dissimilarity to other landraces in other clusters with one or more traits. The distribution pattern of landraces into twelve clusters confirmed the existence of diversity among the landraces. This result agrees with Pradip *et al.* (2010) and Muluken *et al.* (2015) that considerable number of clusters consisted of one okra genotype each and was solitary clusters. Cluster analysis sequestrates genotypes into clusters which exhibit high homogeneity within a cluster and high heterogeneity between clusters (Mohammadi and Prasanna 2003).

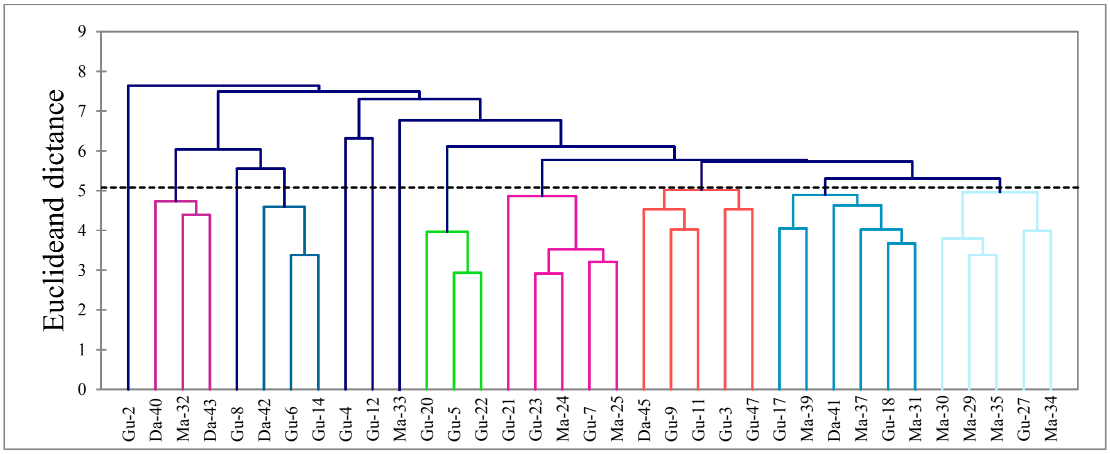

Fig. 3: Dendrogram showing clustering pattern among 35 okra landraces based on 22 quantitative traits evaluated

Table 4: Clusters of 35 okra landraces based on 22 quantitative traits

Cluster	Number of landraces	Landraces name
I	1	Gu-2
II	5	Gu-3, Gu-9, Gu-11, Da-45 and Gu-47
III	1	Gu-4
IV	3	Gu-5, Gu-20 and Gu-22
V	3	Gu-6, Gu-14 and Da-42
VI	5	Gu-7, Gu-21, Gu-23, Ma-24 and Ma-25
VII	1	Gu-8
VIII	1	Gu-12
IX	6	Gu-17, Gu-18, Ma-31, Ma-37, Ma-39 and Da-41
X	5	Gu-27, Ma-29, Ma-30, Ma-34 and Ma-35
XI	3	Ma-32, Da-40 and Da-43
XII	1	Ma-33

3.5. Cluster mean analysis

The mean value of the 22 quantitative traits in each cluster is presented in (Table 5). Cluster I was showed longest internodes length (8.56 cm) and wider fruit diameter (2.47 cm), narrow stem diameter (1.54 cm) and leaf width (17.11 cm), short leaf length (12.81 cm), short fruit length (5.43 cm) and minimum dry weight of matured fruits per plant (36.37 g). Cluster II had the tallest plant height (1.95 cm). Cluster III had shown maximum weight of matured fruits per plant (323.16 g) and dry weight of matured fruits per plant (116.48 g) early for days to 50% flowering (62.67), short plant height (0.67 cm) and few number of internodes (15.66). Cluster IV had shown earliness for days to maturity (83.37) with narrow fruit diameter (1.54 cm). Cluster V was showed large number of internodes (23.04) and number of mature fruits per plant (29.48) and the least number of ridges per fruit (7.36). Cluster VII had small number of primary branches per plant (1.67), number of epicalyxes (8.93), number of seeds per fruit (15.72) and Yield per hectare (2.80 t h^{-1}).

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Table 5: Cluster means for 22 quantitative traits of 35 okra landraces at Pawe in 2017

Traits	Cluster											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
DFF	63.33	82.11	62.67	62.88	80.96	87.67	95.67	75.67	99.44	97.00	84.41	103.33
NDM	104.33	105.19	87.00	83.37	99.22	104.27	117.22	84.33	124.50	119.90	123.47	138.33
PH	1.19	1.95	0.67	1.31	1.82	1.41	1.65	1.73	1.16	1.40	1.91	1.89
STD	1.54	2.27	2.36	2.21	2.01	2.31	2.19	2.21	2.44	2.55	1.93	2.49
NPBS	2.59	2.39	2.42	1.85	2.90	2.05	1.67	2.27	2.54	3.77	3.06	1.79
NIN	16.81	19.55	15.66	16.30	23.04	19.29	17.77	17.83	19.19	20.44	21.08	22.67
INL	8.56	7.72	3.64	5.03	5.88	5.14	7.97	7.47	4.32	4.99	6.59	8.15
LL	12.81	16.85	14.00	18.16	15.31	18.34	15.00	16.37	16.78	16.98	14.18	19.73
LW	17.11	22.39	17.71	21.25	20.01	22.34	21.10	24.25	21.65	21.71	17.34	24.53
NE	9.93	9.96	10.71	9.84	9.31	9.16	8.93	10.93	9.69	9.73	9.44	10.40
NRG	9.08	9.32	8.79	8.66	7.36	9.29	7.61	9.34	8.89	9.48	7.43	9.49
PDL	2.63	2.95	2.64	3.04	2.49	3.01	2.33	2.76	3.05	2.73	2.37	2.33
FL	5.43	6.96	8.35	8.70	6.21	6.98	6.30	5.57	8.20	7.92	6.87	9.12
FD	2.47	2.07	1.79	1.54	1.65	1.81	1.76	2.42	1.82	1.97	1.61	2.37
AFW	17.54	15.24	17.21	15.92	10.00	14.30	10.48	17.23	16.03	16.23	9.82	19.52
NMFP	8.22	9.47	24.67	9.89	29.48	19.03	23.67	29.17	9.57	18.44	13.96	6.67
WMFP	84.99	160.72	323.16	113.57	166.45	256.15	236.97	310.21	108.49	222.38	81.47	141.28
DWMFP	36.37	85.99	116.48	47.77	105.63	115.68	102.73	115.15	62.93	101.52	40.79	86.57
NSF	50.48	70.53	57.85	47.71	27.39	49.80	15.72	62.57	55.32	67.28	31.22	80.66
HSW	6.13	6.43	7.17	6.09	6.65	7.03	7.47	8.13	6.20	5.98	5.10	6.53
NTFP	10.33	11.62	25.17	18.12	28.40	24.28	7.83	36.54	11.66	15.40	10.09	6.00
YLDH	6.70	7.00	15.96	14.08	12.98	17.57	2.80	21.98	9.32	10.49	4.31	4.57

DFF= Days to 50% flowering; NDM=Days maturity; PH= Plant height (m); STD= Stem diameter (mm); NPBS= Number of primary branches per stem; NIN= Number of internodes; INL= Internodes length (cm); LL= Leaf length (cm); LW= Leaf width (cm); NEP= Number of epicalyxes; NRG= Number of ridge; PDL= Peduncle length (cm); FL= Fruit length (cm); FD= Fruit diameter (cm); AFW= Average fruit weight (g); NMFP= Number of matured fruits per plant; WMFP= Weight of matured fruits per plant (g); DWMFP= Dry weight of matured fruits per plant (g); NSF= Number of seeds per fruit; HSW=hundred seed weight (g); NTFP= Number of tender fruits per plant; YLPH= Yield in ton per hectare

Cluster VIII showed the largest number of epicalyxes (10.93) and number of tender fruits per plant (36.54), the highest hundred seed weight (8.13 g) and Yield per hectare (21.98 t h^{-1}). Cluster IX had the smallest peduncle length (3.05 cm). Cluster X had shown wider stem diameter (2.55 cm), large number primary branches per plant (3.77). Cluster XI had shown small average fruit weight (9.82), weight of matured fruits per plant (81.47 g) and hundred seed weight (5.10 g). Among all the clusters, in cluster XII was observed smaller peduncle length (2.33 cm), little number of matured fruits per plant (6.67) and number of tender fruits per plant (6.0), late for days to 50% flowering (103.33) and days to maturity (138.33), large leaf length (19.73 cm), fruit length (9.12 cm) and number of ridges per fruit (9.49), wide leaf width (24.53 cm), high average fruit weight (19.52 g) and much number of seeds per fruit (80.66). Based on cluster means, it is evident from the data (Table 5) that landraces falling in cluster I, VIII, X and XII showed higher performance for the traits of interest viz., internodes length, fruit diameter, number of epicalyxes, hundred seed weight, number of tender fruits per plant, Yield per hectare, stem diameter, number of primary branches, fruit length and average fruit weight. On the other hand, cluster VII, which is consisted of one landrace was the least in performance for most quantitative traits studied (Table 4). For example, the landraces grouped under this cluster gave the least number of primary branches, number of epicalyxes, number of seeds per fruit and Yield per hectare. The result also pointed out that the importance of landraces in cluster VII for their exploitation in fruit yield improvement appeared limited in view of their poor performance for many of the traits of interest. This indicated that different clusters have different breeding values that enable breeders to improve different traits and parental selection should be made based on the relative merits of each cluster for each trait depending on the objective of the breeding program.

4. Conclusion

The study results showed the presence of genetic variation among landraces for all traits suggested that selection could be effective to develop okra varieties for high fruit yield and other traits. This result indicated the presence of considerable genetic diversity for the studied morphological traits. Traits having relatively higher value were number of ridges followed by average fruit weight had a maximum contribution while number of epicalyxes tender had a relatively low contribution. This result suggested the importance of further study on genetic diversity of okra genotypes in the country.

However, further agro-morphology study along with the molecular study since agro-morphological characteristic of the landraces is mostly influenced by environment for measuring genetic distance among Ethiopian okra landraces.

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Appendix Table 1: Euclidean distance matrix as estimates of genetic distances of 35 okra landraces estimated from 22 quantitative traits

Landraces	Gu-3	Gu-4	Gu-5	Gu-6	Gu-7	Gu-8	Gu-9	Gu-11	Gu-12	Gu-14	Gu-17	Gu-18	Gu-20	Gu-21	Gu-22	Gu-23	Ma-24	Ma-25	Gu-27
Gu-2	6.44	8.07	8.36	8.56	8.22	7.62	5.95	7.81	8.24	8.25	8.10	7.20	6.74	8.92	6.92	8.43	7.19	8.42	8.51
Gu-3		6.80	7.04	6.66	5.67	6.87	4.49	5.06	6.24	5.90	6.69	6.42	5.22	6.96	6.57	5.68	4.85	5.75	6.39
Gu-4			6.80	7.78	6.04	7.95	6.69	8.05	6.31	7.35	8.39	5.81	5.75	5.95	6.06	6.19	5.66	7.57	5.04
Gu-5				7.97	5.82	8.08	6.09	6.44	8.65	6.95	7.31	5.39	4.13	5.33	2.93	5.76	6.47	5.93	6.51
Gu-6					5.51	5.79	6.71	7.81	7.69	3.38	9.26	7.73	7.09	6.72	7.35	6.20	5.66	6.22	8.01
Gu-7						5.56	5.33	5.71	6.29	5.35	6.92	5.06	6.02	4.24	6.05	4.15	3.23	3.21	5.30
Gu-8							5.87	6.60	8.40	5.62	7.70	6.48	6.87	7.67	7.96	6.76	5.14	6.14	8.38
Gu-9								4.03	6.10	6.11	6.32	5.53	4.41	6.15	5.54	5.03	4.80	5.23	6.27
Gu-11									6.67	7.09	7.33	6.26	5.71	6.41	6.84	4.82	4.78	4.41	6.87
Gu-12										7.25	10.28	8.34	7.84	7.23	8.31	5.78	5.53	6.84	7.32
Gu-14											8.16	6.79	6.23	6.66	6.85	5.31	5.12	5.86	7.50
Gu-17												4.79	6.55	8.09	6.94	7.33	7.02	6.83	6.34
Gu-18													4.79	5.86	4.67	5.22	4.88	5.22	4.46
Gu-20														6.00	3.79	5.69	5.94	6.39	6.28
Gu-21															5.49	5.28	5.12	4.80	5.59
Gu-22																5.78	6.32	6.22	5.82
Gu-23																	2.92	3.54	4.24
Ma-24																		3.19	4.52
Ma-25																			5.49
Gu-27																			