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Cluster analysis for evaluation of genetic diversity inEnset *(Enset ventricosum*(Welw.) Cheesman) clones at Areka Condition

MikiasYeshitila Haile

Department of Plant and Horticultural Sciences, College of Agriculture, Hawassa University, Awassa, Ethiopia

Email address:
mikiasyes@yahoo.com

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Abstract: 279accessions of *Enset ventricosum* were tested at ArekaAgriculturalResearchCenterin a non-replicated field. The objectives of the study were to assess the diversity of these accessions based on key morphological descriptors and evaluate the accessions based on yield and yield related traits. Data on six qualitative and 22 quantitative traits were collected and subjected to various statistical analyses. Cluster analysis based on qualitative characters indicated the formation of six clusters and existence of variability, based on their leaf, midrib and petiole traits. The result of Shannon-Weaver diversity index (H`) showed thatlowlevels of diversity existed among the 279 *Enset ventricosum*accessions based on the frequency of the phenotypic characterconsidered. Analysis of variance for quantitative characters indicated significant variation among the accessions in all the 22 yield and yield components of an enset plant. Cluster analysis based on quantitative characters indicated the formation of six clusters and showing cluster five with the highest values for yield and yield components for the majority of the characters followed by cluster IV. The cluster and distance analysis of quantitative characters pointed out the distance between most of the clusters were highly significant ($P < 0.01$) suggesting diversity among accessions in different clusters. The maximum inter-clusters distance ($D^{2} = 256.45$) was noticed between cluster III and V followed by I and V ($D^{2} = 228.59$) and II and V ($D^{2} = 206.10$) suggesting diversity between these groups. Correlation study between various quantitative characters showed highly significant association among characters. Maturity time has a negative correlation with yield and yield components of an enset plant.

Keywords: *Enset ventricosum*, Cluster Analysis, Diversity, Association

1. Introduction

The pattern of genetic relationships between and within accessions can be shown by multivariate analyses. Clustering analysis is a useful statistical tool for studying the relationships among closely related accessions. In cluster analysis, accessions are arranged in hierarchy by agglomerative algorithm according to the structure of a complex pairwise genetic proximity measure. The hierarchies emerging from the cluster analysis are highly dependent on the proximity measures and clustering algorithm used [1].

Phenotypic variation is the variation due to genetics as well as environment such as year, location, season and soils. The information on phenotypic diversity and its distribution is important for genetic conservation, plant breeding and efficient utilization of plant genetic resources [2]. Many research reports indicated that there is phenotypic variation among different accessions of different crop collections. A wide phenotypic variation among enset clones collected from different agro-ecological zones of the country was also indicated in previous morphological study [3].

Genetic distance (D^2) is the extent of gene difference between cultivars as measured by allelic frequency at a sample locus. Different approaches to measure genetic distance have been proposed over the past few decades to suit various objectives [4]. D^2 statistics is used in the identification of genetically different genotypes so that, grouping and characterization for their morphological characteristics can be carried out accordingly. This technique has been widely used to assess genetic diversity in crop plants. Various researchers have also observed that Mahalanobis' D^2 statistics is a powerful tool in discriminating between lines based on a number of phenotypic and genotypic traits. Analytical methods such as discriminant analysis, clustering, etc. use Mahalanobis'

D^2statistics.

Cluster analysis is a numerical classification technique that defines groups of clusters of individuals. There are two type of cluster classification. The first is non- hierarchical classification, which assigns each item to a class. The second type is hierarchical classification, which groups the individuals into clusters and arranges these in to a hierarchy for the purpose of studying relationships in the accessions [5]. Qualitative and quantitative morphological characters can be used for clustering the accessions in to homogeneous groups. Both sets of data, qualitative and quantitative, are collected on individual traits and each trait is used in cluster analysis to determine the variability among the accessions. Accessions within the same cluster are more similar. Accessions in different clusters are more dissimilar [6].

The purpose of characterization is to study genetic variability of certain characters in relation to their geographical distribution in order to develop new and more adequate collection strategies for further collection of useful germplasm in the same or similar areas; to study the genetic variability present in the collections, especially within samples and develop the most appropriate techniques and strategies to maintain the genetic integrity of such diversity; to understand the genetic diversity of crops through inter-specific, intra-specific and inter-generic hybridization and mutation. Furthermore, it is essential to screen the collection for traits which, from time to time, are considered important for breeding programs aiming to improve agriculture in a given country, region or geographical area[7].

Different enset (*Enset ventricosum*) vernaculars/clones are recognized in different growing areas which are growing in mixture. Each enset vernaculars/clones as identified by the farmers, has its own name that is uniformly spread across the region that speaks the same language [8, 9, 10]. However, it is not certain whether there is a genetic variation among vernaculars or not.

According toMahalanobis[11] the basis for the existence of different vernaculars was color (as dark green, light green, brown, light brown, red, pinkish, etc.) and height (as tall, medium, short, very short, etc.). As previous phenotypic evaluation indicated there are similar clones known by different vernaculars and there are also different clones known by similar vernaculars [12].

Moreover, according to study conducted on morphological characterization of enset (*Enset ventricosum*) clones and the association of yield with different traits by Endale[3], clones with similar phenotypic appearance were clustered in the same classes. Thus, there is a probability to cluster similar clones together which will help to minimize a large number of vernaculars grown in different growing areas. Accordingly D^2 analysis is also used to estimate the existing genetic distant among Enset germplasm. Hence, this proposal is initiated with the following objectives.

1) To assess the diversity within collection of *Enset ventricosum* accessions based on key morphological descriptors andgroup phenotypically similar clones together and
2) To estimate the genetic distant (genetic variability) of enset clones grown in Ethiopia

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Areka (the research center's experimental field) which is located 7^0 09' N latitude and 37^0 47' E longitudes at an elevation range of 1750 and 1820 masl[13].

Based on five years data, the average annual rainfall is 1615.2 mm with a minimum/maximum mean air temperature of 13.9^0C/25.6^0C and 63% relative humidity [14, 15]. The soil is silt clay loam with a pH value of 5.2 [16]

2.2. Treatments, Experimental Design andManagement

A total number of 279different enset clones from the six major enset growing areas of Southern Ethiopia (44 from Gamo-Gofa, 33from Guragie, 37 from Wolaita, 42 from Sidamo, 48 from Waka and 75 from Kembata/Hadiya) were used for this study. All the enset clones collected were planted on 7-10 March, 1998 at the research center's experimental field with a spacing of 1.5m and 3m between plants and rows respectively and on single observation plot basis having eight plants per plot. The clones' name and areas of collections are presented in Table 1.

Two plants per each plot were used for quantitative data collection. Single plant was considered for qualitative data collection. Cultivation and weeding were carried out when necessary and no fertilizer was applied.

Table 1.*Name of the enset clones and their areas of collection*

GAMO-GOFA COLLECTIONS		GURAGIE COLLECTIONS		WOLAITA COLLECTIONS		SIDAMO COLLECTIONS		WAKA COLLECTIONS		KEMBATA/HADIYA COLLECTIONS	
No.	**NAME**	**No.**	**NAME**	**No.**	**NAME**	**No.**	**NAME**	**No.**	**NAME**	**No.**	**NAME**
1	Shibr	1	Nechuwe	1	Erasha	1	Hekacha	1	Mecha-boza	1	Goemerrie
2	Babiso	2	Temoyise	2	Gefetenewa	2	Sediso	2	Berjiye	2	Disho
3	Ketene	3	Mishirate	3	Adinona	3	Sirriro	3	Aguasa(ta)	3	Shelekie
4	Dolla	4	Esmaele	4	Akacha	4	Ado	4	Erentiya	4	Mesmesa
5	Dellea	5	Mayimote	5	Bulua	5	Gena	5	Meziya	5	Heilla

GAMO-GOFA COLLECTIONS		GURAGIE COLLECTIONS		WOLAITA COLLECTIONS		SIDAMO COLLECTIONS		WAKA COLLECTIONS		KEMBATA/HADIYA COLLECTIONS	
No.	**NAME**	**No.**	**NAME**	**No.**	**NAME**	**No.**	**NAME**	**No.**	**NAME**	**No.**	**NAME**
6	Bergude	6	Ayiwegne	6	Gena	6	Adame-ado	6	Busuriye	6	Gimbo
7	Haleko	7	Ameratiye	7	Kucharkie	7	Kulo	7	Bota-meziya	7	Astara
8	Dellea	8	Geziwet	8	Fenku	8	Astara	8	Dika	8	Mariya
9	Ayissade	9	Wered	9	Ankiegena	9	Gulama	9	Keteniya	9	Wohie
10	Shalda	10	Yegendiye	10	Mochie	10	Chelako	10	Shemera	10	Kerbo
11	Butta	11	Yekimech	11	Pokuwa	11	Tunaka	11	Bukuniye	11	Dirbo
12	Tsisse	12	Kanchiwe	12	Tuzuma	12	Sidiramo	12	Hasa-bedadiye	12	Gishera
13	Bossa-gena	13	Astara	13	Locha	13	Gemechalla	13	Hoendiye	13	Abatmerza
14	Pello	14	Sebara	14	Gemorcha	14	Gerbo	14	Zergesa	14	Etinie
15	Dellulle	15	Gumbar	15	Dirbuwa	15	Waniwassa	15	Gimira-arkiya	15	Tesa
16	Mesho-gemo	16	Anikefiye	16	Bedadia	16	Awusho	16	Aeluwa	16	Weshmeda
17	Zinke-bukema	17	Guariye	17	Agina	17	Serena	17	Argema	17	Zeriyie
18	Banga	18	Yibiye	18	Mattie	18	Hekecha	18	Dorta	18	Onjamo
19	Golia	19	Weka	19	Osogurzo	19	Gussello	19	Kekere	19	Abato
20	Kesseta	20	Jobiro	20	Kikiro	20	Derassa-dimela	20	Shelekuma	20	Kessiet
21	Werzia-macho	21	Shertiye	21	Botya	21	Welanticho	21	Kazia	21	Zebro
22	Dimo	22	Cherkimad	22	Banga	22	Dubano	22	Banga	22	Wellachie
23	Unknown	23	Weretea	23	Posha	23	Hawe	23	Sanka	23	Fechachie
24	Unknown2	24	Engidawork	24	Shemeroy	24	Serane	24	Akachiya	24	Henuwa
25	Unknown3	25	Gurebeshelga	25	Shedodiniy a	25	Alenticho	25	Elore	25	Ashura
26	Wenadia	26	Sherite	26	Ginawa	26	Buzzare	26	Buba	26	Sesikila
27	Morketa	27	Bishkanchiwe	27	Genesa	27	Bulle	27	Tena	27	Bishato
28	Zoa-zinke	28	Eminiye	28	Ankuwa	28	Gerdicho	28	Trey	28	Keberichie
29	Fello	29	Egendiye	29	Dokozuwa	29	Bezeze	29	Bumbe	29	Boela
30	Keteme	30	Kinke	30	Goderia	30	Buaecho(Guragies)	30	Fenchariya-yepa	30	Oniya
31	Pello-2	31	Nechuwe-2	31	Woisha	31	Walantiche-II	31	Goshindiya	31	Lekaka
32	Dokaze	32	Yesherakinke	32	Kembata	32	Seddisse	32	Donkolola	32	Digomerza
33	Fekekie	33	Zinike	33	Messa	33	Benje	33	Ayina	33	Sessa
34	Sorte			34	Kualia	34	Ewisho	34	Yesha	34	Gotedirbo
35	Ketisse			35	Chamia	35	Kerase	35	Hala-a	35	Bikamo
36	Bundo			36	Eslamia	36	Barbo-dancho	36	Gulumo	36	Kembat
37	Gena-2			37	Gezetiya	37	Walanticha-I	37	Erpha6	37	Wenadie
38	Fosho					38	Astara	38	Erpha7	38	Nechiwe
39	Beshera					39	Dinke	39	Erpha19	39	Tebuttie
40	Argozo					40	Ontosha	40	Erpha20	40	Ored
41	Kekera					41	Demela	41	Erpha12	41	Ososa
42	Pemia					42	Wanigaro	42	Erpha13	42	Keshkeshiya
43	Checho-1							43	Erpha3	43	Guarye
44	Checho-2							44	Erpha8	44	Manduluka
								45	Erpha14	45	Airo
								46	Erpha18	46	Ferezia
								47	Erpha2	47	Bedadeda
								48	Erpha18	48	Tegaded
										49	Hiniba
										50	Bedediet

GAMO-GOFA COLLECTIONS		GURAGIE COLLECTIONS		WOLAITA COLLECTIONS		SIDAMO COLLECTIONS		WAKA COLLECTIONS		KEMBATA/HADIYA COLLECTIONS	
No.	NAME	No.	NAME	No.	NAME	No.	NAME	No.	NAME	No.	NAME
										51	Wechered
										52	Shower
										53	Jegeda
										54	Zerfisha
										55	Bossie
										56	Dengicho
										57	Gureza
										58	Ferchasa
										59	Fugatesa
										60	Senkutie
										61	Kerkerie
										62	Gulfe
										63	Hankuchie
										64	Menera
										65	Becherota
										66	Azenora
										67	Korttie
										68	Chereka
										69	Gozeza
										70	Ginjena
										71	Hargamo
										72	Denticho
										73	Beleka
										74	Kinchie
										75	Sheleketa

Table 2.*Qualitative characteristic descriptors of Enset ventricosum*

No.	Qualitative Characters	Acronym	Descriptors	Index
1	UPPER MIDRIB COLOR	MUP	Light to Medium Green	1
			Light to Medium Green with Spots/Patches	2
			Light to Medium Green with Streaks/Strips	3
			Light to Medium Green with Streaks/Strips and Spots/Patches	4
			Tinged Red Purple with Green	5
			Tinged Red Purple with Green and Spots	6
			Pink to Brown Purple	7
			Red Purple with Green line	8
			Red Purple with Green line and Spots	9
			OTHER	10
2	UPPER PETIOLE COLOR	PUP	Light to Medium Green	1
			Light to Medium Green with Spots/Patches	2
			Light to Medium Green with Streaks/Strips	3
			Light to Medium Green with Streaks/Strips and Spots/Patches	4
			Pink to Brown Purple	5
			Red Purple with Green line	6
			Red Purple with Green line and Spots	7
			OTHER	8

No.	Qualitative Characters	Acronym	Descriptors	Index
3	UNDER MIDRIB COLOR	MUD	Light to Medium Green	1
			Light to Medium Green with Spots/Patches	2
			Light to Medium Green with Streaks/Strips	3
			Light to Medium Green with Streaks/Strips and Spots/Patches	4
			Tinged Red Purple with Green	5
			Tinged Red Purple with Green and Spots	6
			Pink to Brown Purple	7
			Red Purple with Green line	8
			Red Purple with Green line and Spots	9
			OTHER	10
4	UNDER PETIOLE COLOR	PUD	Light to Medium Green	1
			Light to Medium Green with Spots/Patches	2
			Light to Medium Green with Streaks/Strips	3
			Light to Medium Green with Streaks/Strips and Spots/Patches	4
			Pink to Brown Purple	5
			Red Purple with Green line	6
			Red Purple with Green line and Spots	7
			Red Purple with Green line and Streaks	8
			Red Purple with Patches/spots	9
			OTHER	10
5	LEAF COLOR	L	Light to Medium Green	1
			Green to Dark Green	2
			Green with Red Purple	3
			Pink to Brown Purple	4
			OTHER	5
6	LEAF TIP & EDGE COLOR	LTE	Light to Medium Green	1
			Green to Dark Green	2
			Pink to Brown Purple	3
			OTHER	4

2.3. Data Collection

2.3.1. Qualitative Data

Since there is no standardized descriptor developed for enset (*Enset ventricosum*), all the possible color data were arranged in their similar groups as a descriptor for the qualitative characters (Table 2). Mounsell color chart for plant tissue was used to describe colors. Six different qualitative characters were used to characterize the accessions. In quantitative characters, the mean value of the two observations per plant were used for statistical analysis, while for qualitative the single observation per clone was considered.

2.3.2. Quantitative Characters

A total of 22 quantitative traits (Table 3)were used for characterization. The data were collected from two individual plants per clone and the mean of the two was taken for the analysis.

Table 3.*Quantitative characteristics of Enset ventricosum*

No.	Quantitative Characters
1	Maturity Time
2	Plant Height
3	Pseudostem Height
4	Pseudostem Circumference
5	Leaf Number
6	Leaf Height
7	Leaf Width
8	Leafsheath Number
9	Leafsheath Weight Before Decortication in Kg per plant
10	Leafsheath Weight After Decortication in Kg per plant
11	Central Shoot Weight Before Grating in Kg per plant
12	Corm Weight Before Grating in Kg per Plant
13	Bulla Yield in Kg Per Plant
14	Fiber Height

No.	Quantitative Characters
15	Fiber Yield in Kg Per Plant
16	Fermented Unsqueezed Kocho Yield in Kg Per Plant
17	Fermented Squeezed Kocho Yield in Kg Per Plant
18	Unfermented Kocho Yield in Ton per hectare per Year
19	Fermented Unsqueezed Kocho Yield in Ton Per Hectare Per Year
20	Fermented Squeezed Kocho Yield in Ton Per Hectare Per Year
21	Bulla Yield in Ton Per Hectare Per Year
22	Fiber Yield in Ton Per Hectare Per Year

2.3.3. Measurements

2.3.3.1. Height and Circumference Measurements

Height and circumference measurements of the enset plant were measured form the ground level to the tip of the longest leaf. Pseudostem height was measured from ground level to the start of the leaf petiole and pseudostem circumferenceat the middle height point of the enset pseudostem. For leaf length all the phosynthetic green leaves were considered and their mean taken. Tape meter was used to measure all the height measurements.

2.3.3.2. Weight Measurements

i Leafsheath weight before and afterdecortications

Leaf-sheaths (tightly or loosely overlapping part of pseudostem) were measured for their weight before and after decortications using a weight balance.

ii Central shoot and corm weight before grating

The central shoot which is the part of the enset plant emerging along with flower bracts and the corm which is the underground swollen part and the main component in the kocho mixture were measured for their weights before grating using a weight balance.

iii Unfermented kocho yield

The unfermented kocho yield per plant (weight of mixture of the three decorticated leafsheath, grated central shoot and grated corm before fermentation) was finally converted to yield per year per hectare basis using the formula below. The same formula was also applied to convert the bulla, fiber, fermented unsqueezed and fermented squeezed kocho yields to yield per hectare per year basis.

$$KochoYield(tonha^{-1}\,year^{-1}) = \frac{(KochoYield(kgplant^{-1}) * 10000\,m^2)}{\sum(year * spacing(m^2))}$$

i. Fermented unsqueezed kocho yield

After the unfermented kocho yield is left in the pit for some time usually 30 days it will be fermented and this fermented kocho was directly measured for its weight before squeezing it to determine fermented unsqueezed kocho yield.

ii. Fermented squeezed kocho yield

The fermented unsqueezed kocho yield is squeezed usually by applying human force till it loses all its moisture content as much as possible and measured for its weight.

iii. Fiber

Fiber yield was measured by weighing all the fiber left, soon after decorticating the leafsheath.

2.4. Statistical Analysis

For clustering the quantitative and qualitative characters in to their similar groupings clustering method using SAS Software Version 9 was used. Clustering was done using SAS based on the generalized D^2 distances by average linkage method of hierarchical clustering called Un-weighted Pair Group Methods with Arithmetic-average (UPGMA). Appropriate number of clusters was determined from the values of pseudo F and pseudo T^2 statistics using the SAS statistical software.

Frequency distributions and the number of phenotypic classeswere used to calculate the Shannon-Weaver diversity index (*H*') for each character. The index is defined as:

$$H' = \frac{-\sum p_i \ln p_i}{lnn}$$

Where $p_i$isthe proportion of the total number of individuals (genotypes) in the i^{th}classand*n* is the number of phenotypic classes.

The Shannon weaver index values (H') can ranges from 0 to ~ 4.6 using the natural log (versus log10). A value near 0 indicated that every species in the sample is the same. Conversely, a value near 4.6 indicated the numbers of individuals are evenly distributed between the species.

Genetic distance between clusters was calculated using the generalized Mahalanobis's D^2 statistics. The D^2 value obtained for pairs of clusters was considered as the calculated value of Chi-squire (χ^2) and was tested for significance at the required level of probability against the tabulated values of χ^2 for p degrees of freedom, where p is the number of characters considered. SAS software was employed for the analysis. The D^2 is defined as:

$$D^2_{ij} = (X_i - X_j)\,{}^{1}\,S^{-1}\,(X_i - X_j)$$

Where, D^2_{ij} = is the distance between two groups i and j; X_i and X_j are the two vector mean of the traits for i^{th} and j^{th} groups respectively, and S^{-1} is the inverse of the pooled covariance [4].

3. Results and Discussion

3.1. Qualitative Traits

3.1.1. Clustering

The accessions of enset were clustered into six distinct groups based on six qualitative characters (Table 5). The characters used for clustering are midrib upper side color,petiole upper side color, midrib under side color, petiole under side color, leaf color and leaf tip & edge color.

Cluster III was the largest and consisting of 101 accessions (36.20%), followed by clusters II, I, IV, V and VI consisting of 92 (32.97%), 75 (26.88%), 5 (1.79%), 4 accessions (1.43%) and 2 accessions (0.72%) respectively. The details of each clusters is indicated below in Table 4.

The cluster means of 22 quantitative characters were calculated based on clusters formed by 6 qualitative characters and showed that cluster III had the highest leaf and leaf sheath number, weight of central shoot before grating, weight of fermented unsqueezed and squeezed kocho and bulla weight (in ton/hectare/year)(Table 4).

3.1.2. The Shannon-Weaver Diversity Index (H')

In this study, Shannon-Weaver diversity index (H') was considered to measure the diversity of *Enset ventricosum* accessions based on the frequency distributions of the six qualitative morphological characters (Table 6). The result of H' values for all observed phenotypic characters showed low levels of diversity among the 279 *Enset ventricosum* accessions, which ranged from 0.31 for leaf surface color to 0.95 for midrib upper-side color (Table 6). Moreover, the overall mean of H'value of 0.69 of confirmed that the existence of low level of phenotypic diversity among *Enset ventricosum* accessions.The wider accessions of enset vernaculars could be due to the different naming of the same clone by different enset growing areas of the country.

Table 4. *Cluster means of 22 quantitative characters of Enset ventricosum based on qualitative characters*

CLUSTERS	CHARACTERS																					
	MT	PH	PSH	PSC	LN	LH	LW	LSN	LSBD	LSAD	CSBG	COBG	B1	FH	F1	FUKY1	FSKY1	UKY	FUKY2	FSKY2	B2	F2
I	4.4	5.4	1.7	1.2	10.1	3.3	0.7	18.5	53.9	26.0	13.9	28.2	0.3	1.1	0.3	25.6	17.5	34.9	13.3	9.0	0.4	0.2
II	4.3	5.5	1.7	1.2	9.7	3.4	0.7	18.4	56.5	27.9	14.6	26.1	0.3	1.2	0.3	26.6	18.0	37.2	14.5	9.7	0.5	0.1
III	4.1	5.5	1.7	1.2	10.4	3.3	0.7	19.1	61.2	28.6	15.7	27.3	0.3	1.1	0.3	27.4	18.5	41.4	15.8	10.6	0.6	0.2
IV	4.0	5.2	1.7	1.0	9.3	3.2	0.7	16.2	40.5	21.5	12.2	20.9	0.3	1.0	0.6	24.3	16.6	30.8	14.0	9.5	0.4	0.4
V	4.1	5.8	1.8	1.2	9.3	3.5	0.7	17.1	59.6	28.4	14.5	27.0	0.2	1.2	0.4	25.6	17.6	37.8	14.1	9.6	0.3	0.2
VI	5.3	5.5	1.7	1.3	8.3	3.3	0.6	17.3	70.5	29.0	11.6	40.1	0.2	1.0	0.3	29.9	22.8	34.6	13.3	9.8	0.3	0.1

Table 5.*Clusters of Enset ventricosum accessions based on qualitative traits and areas of collections*

Cl	No. of Accessions in each cluster	Collections	No. of accessions in each	Serial No.	Name of accessions in each cluster	Major characteristics
1	75	Kembata	16	214, 219, 229, 233, 234, 239, 245, 246, 247, 249, 252, 256, 262, 265, 269, 278	Kerbo, Tesa, Ashura, Boela, Oniya, Bikamo, Ososa, Keshkeshiya, Guarye, Airo, Tegaded, Shower, Ferchasa, Kerkerie, Becherota, Kinchie	MUP=Light to Medium Green, Light to Medium Green with Spots/Patches/
		Waka	13	161, 163, 170, 171, 176, 177, 178, 179, 186, 188, 192, 193, 201	Meziya, Bota-meziya, Zergesa, Gimira-arkiya, Shelekuma, Kazia, Banga, Sanka, Fenchariya-yepa, Donkolola, Gulumo, Erpha6, Erpha14	PUP=Light to Medium Green, Light to Medium Green with Spots/Patches
		Gamogofa	14	1, 4, 6, 7, 9, 11, 16, 18, 25, 32, 33, 35, 36, 38	Shibr, Dolla, Bergude, Haleko, Ayissade, Butta, Mesho-gemo, Banga, Unknown3, Dokaze, Fekekie, Ketisse, Bundo, Fosho	MUD=Light to Medium Green, Light to Medium Green with Spots/Patches, Light to Medium Green with Streaks/Strips
		Guragie	7	51, 56, 65, 68, 69, 74, 76	Ameratiye, Kanchiwe, Shertiye, Engidawork, Gurebeshelga , Kinke, Yesherakinke	PUD=Light to Medium Green, Light to Medium Green with Spots/Patches, Light to Medium Green with Streaks/Strips
		Wolaita	10	78, 80, 82, 85, 86, 87, 90, 94, 107, 109	Erasha, Adinona, Bulua, Fenku, Ankiegena, Mochie, Locha, Agina, Goderia, Kembata	L=Light to Medium Green, Green to Dark Green
		Sidamo	15	115, 118, 121, 125, 127, 136, 139, 144, 146, 147, 149, 151, 152, 153, 155	Hekacha, Ado, Kulo, Tunaka, Gemechalla, Dubano, Alenticho, Buaecho(Guragies), Seddisse, Benje, Kerase, Walanticha-I, Astara, Dinke, Demela	LTE=Light to Medium Green, Green to Dark Green, Pink to Brown Purple
2	92	Kembata	25	205, 206, 209, 210, 211, 212, 217, 218, 220, 221, 223, 224,	Goemerrie, Disho, Heilla, Gimbo, Astara, Mariya, Abatmerza, Etinie, Weshmeda, Zeriyie, Abato, Kessiet, Zebro, Wellachie, Fechachie,	MUP=Tinged Red Purple with Green, Red Purple with Green line, Red Purple with Green line and Spots

Cl	No. of Accessions in each cluster	Collections	No. of accessions in each	Serial No.	Name of accessions in each cluster	Major characteristics
3	101	Waka	19	225, 226, 227, 228, 231, 237, 240, 241, 248, 250, 258, 271, 275 157, 158, 159, 162, 164, 165, 166, 167, 173, 174, 175, 183, 184, 185, 190, 194, 197, 199, 200	Henuwa, Bishato, Sessa, Kembat, Wenadie, Manduluka, Ferezia, Zerfisha, Korttie, Hargamo Mecha-boza, Berjiye, Aguasa(ta), Busuriye, Dika, Keteniya, Shemera, Bukuniye, Argema, Dorta, Kekere, Tena, Trey, Bumbe, Yesha, Erpha7, Erpha12, Erpha3, Erpha8	PUP=Light to Medium Green, Light to Medium Green with Spots/Patches, Light to Medium Green with Streaks/Strips and Spots/Patches, Red Purple with Green line, Red Purple with Green line and Spots
		Gamogofa	14	2, 3, 14, 17, 20, 22, 23 24, 28, 29, 30, 31, 40, 41	Babiso, Ketene, Pello, Zinke-bukema, Kesseta, Dimo, Unknown, Unknown2, Zoa-zinke, Fello, Keteme, Pello-4, Argozo, Kekera	MUD=Pink to Brown Purple, Red Purple with Green line, Red Purple with Green line and Spots
		Guragie	17	46, 47, 49, 50, 52, 53, 54, 55, 57, 58, 62, 63, 66, 67, 72, 73, 75	Temoyise, Mishirate, Mayimote, Ayiwegne, Geziwet, Wered, Yegendiye, Yekimech, Astara, Sebara, Yibiye, Weka, Cherkimad, Weretea, Eminiye, Egendiye, Nechuwe-2	PUD=Pink to Brown Purple, Red Purple with Green line, Red Purple with Green line and Spots, Red Purple with Green line and Streaks, Red Purple with Patches/spots
		Wolaita	6	95, 96, 101, 112, 113, 114	Mattie, Osogurzo, Shemeroy, Chamia, Eslamia, Gezetiya	L=Light to Medium Green, Green to Dark Green
		Sidamo	11	119, 122, 128, 129, 132, 133, 135, 138, 142, 143, 156	Gena, Astara, Gerbo, Waniwassa, Hekecha, Gussello, Welanticho, Serane, Gerdicho, Bezeze, Wanigaro	LTE=Light to Medium Green, Pink to Brown Purple
		Kembata	30	207, 208, 213, 215, 216, 222, 230, 232, 235, 236, 244, 251, 253, 254, 255, 257, 259, 261, 263, 264, 266, 267, 268, 270, 272, 273, 274, 276, 277, 279	Shelekie, Mesmesa, Wohie, Dirbo, Gishera, Onjamo, Sesikila, Keberichie, Lekaka, Digomerza, Ored, Bedadeda, Hiniba, Bedediet, Wechered, Jegeda, Bossie, Gureza, Fugatesa, Senkutie, Gulfe, Hankuchie, Menera, Azenora, Chereka, Gozeza, Ginjena, Denticho, Belek	MUP=Light to Medium Green, Light to Medium Green with Spots/Patches, Light to Medium Green with Streaks/Strips, Light to Medium Green with Streaks/Strips and Spots/Patches, Tinged Red Purple with Green
		Waka	16	160, 168, 169, 172, 180, 181, 182, 187, 189, 191, 195, 196, 198, 202, 203, 204	Erentiya, Hasa-bedadiye, Hoendiye, Aeluwa, Akachiya, Elore, Buba, Goshindiya, Ayina, Hala-a, Erpha19, Erpha20, Erpha13, Erpha18, Erpha2, Erpha18	PUP=Light to Medium Green, Light to Medium Green with Spots/Patches, Light to Medium Green with Streaks/Strips
		Gamogofa	12	5, 8, 12, 13, 15, 19, 26, 27, 34, 37, 39, 42	Dellea, Dellea, Tsisse, Bossa-gena, Dellulle, Golia, Wenadia, Morketa, Sorte, Gena-4, Beshera, Pemia	MUD=Light to Medium Green with Streaks/Strips and Spots/Patches, Tinged Red Purple with Green, Tinged Red Purple with Green and Spots, Red Purple with Green line
		Guragie	7	45, 59, 60, 64, 70, 71, 77	Nechuwe, Gumbar, Anikefiye, Jobiro, Sherite, Bishkanchiwe, Zinike	PUD=Light to Medium Green, Light to Medium Green with Spots/Patches, Light to Medium Green with Streaks/Strips and Spots/Patches, Red Purple with Green line, Red Purple with Green line and Spots
		Wolaita	21	79, 81, 83, 84, 88, 89, 91, 92, 93, 97, 98, 99, 100, 102, 103, 104, 105, 106, 108, 110, 111	Gefetenewa, Akacha, Gena, Kucharkie, Pokuwa, Tuzuma, Gemorcha, Dirbuwa, Bedadia, Kikiro, Botya, Banga, Posha, Shedodiniya, Ginawa, Genesa, Ankuwa, Dokozuwa, Woisha, Messa, Kualia	L=Light to Medium Green, Green to Dark Green
		Sidamo	15	116, 117, 120, 123, 124, 126, 130, 131, 134,	Sediso, Sirriro, Adame-ado, Gulama, Chelako, Sidiramo, Awusho, Serena, Derassa-dimela, Hawe, Buzzare,	LTE=Light to Medium Green, Pink to Brown Purple

Cl	No. of Accessions in each cluster	Collections	No. of accessions in each	Serial No.	Name of accessions in each cluster	Major characteristics
4	5	Kembata	0	137, 140, 141, 145, 148, 154	Bulle, Walantiche-II, Ewisho, Ontosha	MUP=Tinged Red Purple with Green, Tinged Red Purple with Green and Spots, Red Purple with Green line, Red Purple with Green line and Spots
		Waka	0			PUP=Light to Medium Green, Light to Medium Green with Spots/Patches
		Gamogofa	4	10, 21, 43, 44	Shalda, Werzia-macho, Checho-1, Checho-2	MUD=Red Purple with Green line
		Guragie	0			PUD=Light to Medium Green with Spots/Patches
		Wolaita	0			L=Light to Medium Green
		Sidamo	1	150	Barbo-dancho	LTE=Pink to Brown Purple
5	4	Kembata	2	238, 243	Gotedirbo, Tebuttie	MUP=Light to Medium Green with Spots/Patches, Tinged Red Purple with Green, Red Purple with Green line
		Waka	0			PUP=Red Purple with Green line, Red Purple with Green line and Spots
		Gamogofa	0			MUD=Red Purple with Green line
		Guragie	2	48, 61	Esmaele, Guariye	PUD=Light to Medium Green with Spots/Patches
		Wolaita	0			L=Light to Medium Green
		Sidamo	0			LTE=Pink to Brown Purple
6	2	Kembata	2	242, 260	Nechuwe, Dangicho	MUP=Light to Medium Green with Spots/Patches
		Waka	0			PUP=Red Purple with Green line and Spots
		Gamogofa	0			MUD=Light to Medium Green, Light to Medium Green with Streaks/Strips
		Guragie	0			PUD=Light to Medium Green with Spots/Patches
		Wolaita	0			L=Light to Medium Green
		Sidamo	0			LTE=Pink to Brown Purple

MUP=Midrib upper side, PUP=Petiole upper side, MUD=Midrib under side, PUD=Petiole under side, L=leaf and LTE=Leaf tip and edge colors

Table 6.*Frequency distribution and Shannon-Weaver diversity indices (H') of 6qualitative traits of Enset ventricosum*

No.	Qualitative character		Index and description adopted	Frequency (%)	H'
1	Midrib Upper-side color	1	Light to Medium Green	0.30	0.95
		2	Light to Medium Green with Spots/Patches	0.24	
		3	Light to Medium Green with Streaks/Strips	0.03	
		4	Light to Medium Green with Streaks/Strips and Spots/Patches	0.03	
		5	Tinged Red Purple with Green	0.08	
		6	Tinged Red Purple with Green and Spots	0.01	
		7	Red Purple with Green line	0.22	
		8	Red Purple with Green line and Spots	0.09	
2	Petiole Upper-side color	1	Light to Medium Green	0.32	0.76

No.	Qualitative character		Index and description adopted	Frequency (%)	H'
		2	Light to Medium Green with Spots/Patches	0.42	
		3	Light to Medium Green with Streaks/Strips	0.01	
		4	Light to Medium Green with Streaks/Strips and Spots/Patches	0.02	
		5	Red Purple with Green line	0.15	
		6	Red Purple with Green line and Spots	0.08	
		1	Light to Medium Green	0.18	
		2	Light to Medium Green with Spots/Patches	0.07	
		3	Light to Medium Green with Streaks/Strips	0.03	
		4	Light to Medium Green with Streaks/Strips and Spots/Patches	0.01	
3	Midrib Underside color	5	Tinged Red Purple with Green	0.07	0.83
		6	Tinged Red Purple with Green and Spots	0.01	
		7	Pink to Brown Purple	0.02	
		8	Red Purple with Green line	0.55	
		9	Red Purple with Green line and Spots	0.05	
		1	Light to Medium Green	0.03	
		2	Light to Medium Green with Spots/Patches	0.33	
		3	Light to Medium Green with Streaks/Strips	0.05	
		4	Light to Medium Green with Streaks/Strips and Spots/Patches	0.06	
4	Petiole Underside color	5	Pink to Brown Purple	0.02	0.94
		6	Red Purple with Green line	0.09	
		7	Red Purple with Green line and Spots	0.35	
		8	Red Purple with Green line and Streaks	0.03	
		9	Red Purple with Patches/spots	0.05	
5	Leaf color	1	Light to Medium Green	0.76	0.31
		2	Green to Dark Green	0.24	
		1	Light to Medium Green	0.20	
6	Leaf Tip and Edge color	2	Green to Dark Green	0.02	0.33
		3	Pink to Brown Purple	0.78	
	Overall Mean				**0.69**

Table 7.*ANOVA of 22 quantitative characters of Enset ventricosum accessions with Means, standard errors and ranges*

Parameters		Min.	Max.	Mean	MSE of Accessions	MSE of Error	S.E.±	CV
MT	Years	2.11	7.55	4.24	2.49***	0.23	0.48	11.5
PH	m	2.33	7.65	5.45	1.52***	0.39	0.63	11.47
PSH	m	0.75	2.90	1.71	0.21***	0.10	0.32	18.44
PSC	m	0.58	2.04	1.17	0.08***	0.04	0.2	16.8
LN	Number	4.50	17.00	10.03	7.93***	3.50	1.87	18.56
LH	m	1.09	4.71	3.36	0.62***	0.19	0.43	12.81
LW	m	0.37	0.98	0.69	0.02***	0.01	0.08	11.96
LSN	Number	9.00	48.50	18.61	31.1***	11.99	3.46	18.5
LSBD	Kg/plant	10.00	156.50	57.37	1213.86***	344.77	18.57	31.95

Parameters		Min.	Max.	Mean	MSE of Accessions	MSE of Error	S.E.±	CV
LSAD	Kg/plant	3.00	67.00	27.52	281.90***	91.85	9.58	34.44
CSBG	Kg/plant	2.00	60.50	14.73	66.49***	22.85	4.78	32.37
COBG	Kg/plant	5.00	88.00	27.12	310.23***	71.76	8.47	31.43
B1	Kg/plant	0.10	1.44	0.29	0.13***	0.03	0.17	59.32
FH	m	0.11	1.98	1.14	0.14***	0.04	0.19	17.03
F1	Kg/plant	0.10	1.39	0.31	0.08***	0.05	0.21	69.66
FUKY1	Kg/plant	4.75	83.50	26.58	224.74***	81.31	9.02	33.76
FSKY1	Kg/plant	2.75	51.00	18.05	123.65***	41.10	6.41	35.4
UKY	Ton/ha/year	7.09	95.51	37.97	511.40***	112.36	10.6	27.6
FUKY2	Ton/ha/year	1.93	42.34	14.62	90.99***	26.48	5.15	34.74
FSKY2	Ton/ha/year	1.29	25.89	9.82	43.24***	13.24	3.64	36.61
B2	Ton/ha/year	0.01	7.08	0.48	0.95***	0.13	0.36	73.08
F2	Ton/ha/year	0.04	0.99	0.16	0.022***	0.01	0.11	65.71

***= Highly significant at 0.01 level of probability level.

Table 8.*Cluster means for 22 quantitative traits of Enset ventricosum accessions*

CLUSTERS	CHARACTERS																					
	MT	PH	PSH	PSC	LN	LH	LW	LSN	LSBD	LSAD	CSBG	COBG	B1	FH	F1	FUKY1	FSKY1	UKY	FUKY2	FSKY2	B2	F2
I	4.4	5.1	1.6	1.1	9.5	3.2	0.7	17.4	44.2	21.3	12.5	23.3	0.3	1.1	0.3	22.2	14.9	30.0	11.7	7.8	0.3	0.2
II	3.8	6.1	1.8	1.4	11.3	3.8	0.8	21.4	85.3	40.9	19.2	33.7	0.3	1.2	0.2	34.4	23.7	54.9	20.2	13.8	0.8	0.2
III	3.9	6.9	2.0	1.6	10.4	4.2	0.8	23.9	134.1	56.9	19.5	47.4	0.3	1.4	0.2	52.4	38.6	71.3	30.6	22.3	1.0	0.1
IV	4.1	6.5	2.2	1.5	10.8	3.7	0.8	18.0	77.0	42.6	37.0	75.0	0.4	1.4	0.3	75.3	45.3	80.6	39.2	23.6	0.9	0.1
V	5.2	7.2	2.4	2.0	10.0	4.4	0.9	21.5	121.0	67.0	60.5	72.5	0.2	1.5	0.2	74.0	51.0	83.6	30.7	21.3	0.4	0.1

Table 9.*Distribution of the 279 Enset ventricosum accessions into five clusters*

Cl	No. of Accessions in each cluster	Collections	No. of accessions in each	Serial No.	Name of accessions in each cluster
I	197	Kembata	49	205, 206, 208, 210, 211, 212, 213, 218, 219, 220, 221, 222, 223, 224, 225, 227, 228, 230, 234, 235, 237, 238, 239, 240, 242, 247, 249, 250, 251, 252, 254, 255, 256, 257, 258, 259, 260, 261, 263, 265, 266, 267, 268, 269, 270, 275, 276, 278, 279	Goemerrie, Disho, Mesmesa, Gimbo, Astara, Mariya, Wohie, Etinie, Tesa, Weshmeda, Zeriyie, Onjamo, Abato, Kessiet, Zebro, Fechachie, Henuwa, Sesikila, Oniya, Lekaka, Sessa, Gotedirbo, Bikamo, Kembat, Nechiwe, Guarye, Airo, Ferezia, Bedadeda, Tegaded, Bedediet, Wechered, Shower, Jegeda, Zerfisha, Bossie, Dengicho, Gureza, Fugatesa, Kerkerie, Gulfe, Hankuchie, Menera, Becherota, Azenora, Hargamo, Denticho, Kinchie, Sheleketa
		Waka	33	157, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 170, 171, 172, 173, 174, 175, 176, 177, 179, 180, 181, 182, 183, 187, 188, 190, 191, 192, 194, 197, 199, 202	Mecha-boza, Aguasa(ta), Erentiya, Meziya, Busuriye, Bota-meziya, Dika, Keteniya, Shemera, Bukuniye, Hasa-bedadiye, Zergesa, Gimira-arkiya, Aeluwa, Argema, Dorta, Kekere, Shelekuma, Kazia, Sanka, Akachiya, Elore, Buba, Tena, Goshindiya, Donkolola, Yesha, Hala-a, Gulumo, Erpha7, Erpha12, Erpha3, Erpha18
		Gamogofa	37	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, 35, 36, 37, 38, 40, 42, 43, 44	Shibr, Babiso, Ketene, Dolla, Dellea, Bergude, Haleko, Dellea, Ayissade, Shalda, Butta, Tsisse, Bossa-gena, Pello, Dellulle, Zinke-bukema, Banga, Golia, Kesseta, Werzia-macho, Dimo, Unknown2, Unknown3, Wenadia, Morketa, Zoa-zinke, Fello, Keteme, Pello-4, Ketisse, Bundo, Gena-4, Fosho, Argozo, Pemia, Checho-1, Checho-2
		Guragie	21	45, 47, 48, 49, 50, 51, 56, 57, 59, 61, 62, 63, 64, 65, 66, 67, 69, 70, 75, 76, 77	Nechuwe, Mishirate, Esmaele, Mayimote, Ayiwegne, Ameratiye, Kanchiwe, Astara, Gumbar, Guariye, Yibiye, Weka, Jobiro, Shertiye, Cherkimad, Weretea, Gurebeshelga , Sherite, Nechuwe-2, Yesherakinke, Zinike

Cl	No. of Accessions in each cluster	Collections	No. of accessions in each	Serial No.	Name of accessions in each cluster
		Wolaita	28	78, 79, 80, 81, 82, 84, 85, 87, 88, 89, 90, 91, 93, 94, 95, 96, 97, 98, 99, 100, 101, 103, 104, 106, 108, 110, 111, 112	Erasha, Gefetenewa, Adinona, Akacha, Bulua, Kucharkie, Fenku, Mochie, Pokuwa, Tuzuma, Locha, Gemorcha, Bedadia, Agina, Mattie, Osogurzo, Kikiro, Botya, Banga, Posha, Shemeroy, Ginawa, Genesa, Dokozuwa, Woisha, Messa, Kualia, Chamia
		Sidamo	29	115, 116, 118, 121, 122, 123, 125, 126, 127, 130, 131, 132, 133, 135, 136, 138, 140, 142, 143, 144, 146, 148, 149, 150, 151, 152, 153, 155, 156	Hekacha, Sediso, Ado, Kulo, Astara, Gulama, Tunaka, Sidiramo, Gemechalla, Awusho, Serena, Hekecha, Gussello, Welanticho, Dubano, Serane, Buzzare, Gerdicho, Bezeze, Buaecho(Guragies), Seddisse, Ewisho, Kerase, Barbo-dancho, Walanticha-I, Astara, Dinke, Demela, Wanigaro
		Kembata	24	207, 209, 214, 215, 216, 217, 226, 229, 231, 232, 233, 241, 243, 244, 245, 246, 253, 262, 264, 271, 272, 273, 274, 277	Shelekie, Heilla, Kerbo, Dirbo, Gishera, Abatmerza, Wellachie, Ashura, Bishato, Keberichie, Boela, Wenadie, Tebuttie, Ored, Ososa, Keshkeshiya, Hiniba, Ferchasa, Senkutie, Korttie, Chereka, Gozeza, Ginjena, Beleka
		Waka	12	158, 169, 178, 185, 189, 193, 195, 196, 198, 200, 201, 203	Berjiye, Hoendiye, Banga, Bumbe, Ayina, Erpha6, Erpha19, Erpha20, Erpha13, Erpha8, Erpha14, Erpha2
II	73	Gamogofa	6	16, 23, 32, 33, 34, 41	Mesho-gemo, Unknown, Dokaze, Fekekie, Sorte, Kekera
		Guragie	12	46, 52, 53, 54, 55, 58, 60, 68, 71, 72, 73, 74	Temoyise, Geziwet, Wered, Yegendiye, Yekimech, Sebara, Anikefiye, Engidawork, Bishkanchiwe, Eminiye, Egendiye, Kinke
		Wolaita	9	83, 86, 92, 102, 105, 107, 109, 113, 114	Gena, Ankiegena, Dirbuwa, Shedodiniya, Ankuwa, Goderia, Kembata, Eslamia, Gezetiya
		Sidamo	10	117, 119, 124, 128, 129, 137, 139, 141, 147, 154	Sirriro, Gena, Chelako, Gerbo, Waniwassa, Hawe, Alenticho, Bulle, Benje, Ontosha
		Kembata	2	236, 248	Digomerza, Manduluka
III	6	Waka	2	186, 204	Fenchariya-yepa, Erpha18
		Sidamo	2	120, 134	Adame-ado, Derassa-dimela
IV	2	Waka	1	184	Trey
		Sidamo	1	145	Walantiche-II
V	1	Gamogofa	1	39	Beshera

3.2. Quantitative Traits

3.2.1. ANOVA of Quantitative Traits

The analysis of variance of quantitative characters showed significant difference ($P < 0.01$) among the accessions for all the 22 characters examined indicating the existence of substantial amount of variability for the characters (Table 7).

3.2.2. Cluster Analysis Based on Quantitative Characters

In this study, accessions were grouped into five distinct clusters of different sizes. Cluster means of 22 quantitative traits used for clustering are presented in Table 8. The clustering patterns of the accessions based on quantitative characters are presented in Table 9.

The cluster means of the 22 quantitative characters were calculated and showed that cluster V had the highest score in the majority of yield and yield components followed by cluster IV which has highest score on corm weight per plant, fermented unsqueezed kocho yield per plant and on both fermented unsqueezed & squeezed kocho yields per hectare per year bases (Table 8).

3.2.3. Distance Analysis between Clusters Based on Quantitative Characters

The pair wise generalized square distances (D^2) between the clusters (Table 10) showed that the distance between most of the clusters were highly significant ($P < 0.01$) suggesting diversity among accessions in different clusters. The maximum inter-clusters distance (D^2 =256.45) was noticed between cluster III and V followed by I and V (D^2 =228.59) and II and V (D^2 = 206.10)suggesting diversity between these groups.Hence, inter-mating between accessions included in these clusters may give high heterotic response and thereby better segregantsin view of the genetic diversity.

Table 10.*Pairwise generalized squared distances between the five clusters of Enset ventricosum*

Cluster	I	II	III	IV	V

I	14.04	68.36	107.11	228.59
II		33.39	98.91	206.10
III			128.03	256.45
IV				117.39
V				

*= Significant at 0.05 probability level (χ^2_{20} =31.41)
**= Highly significant at 0.01 probability level (χ^2_{20}= 37.57)

3.2.4. Association among Yield Components

Considering the association among yield components, each yield component has a significant impact on all the other yield components except for bulla yield per plant (B1) and fiber yield per hectare (F2) as indicated below on Table 11.

Maturity time (MT) also has a significant effect on the yield and yield components of an enset plant. However, as opposed to the others, the relation of maturity time with yield and yield components of an enset plant is a negative correlation indicating the decrement of productivity of an enset plant with the lengthening of maturity time. This research finding is also in contradict with the one indicated by the research finding by Endale[3]suggesting, maturity time as having no impact on yield and yield components of an enset plant.

Table 11.*Correlation coefficientamong the 22 yield components of Enset ventricosum*

	MT	**PH**	**PSH**	**PSC**	**LN**	**LH**	**LW**	**LSN**	**LSBD**	**LSAD**	**CSBG**
MT	1	-0.2***	0.04	-0.05	-0.5***	-0.2***	-0.15**	-0.4***	-0.3***	-0.3***	-0.3***
PH		1	0.77***	0.57***	0.39***	0.86***	0.29***	0.28***	0.66***	0.68***	0.52***
PSH			1	0.37***	0.19***	0.62***	0.16***	0.06	0.42***	0.44***	0.33***
PSC				1	0.34***	0.57***	0.34***	0.43***	0.75***	0.72***	0.60***
LN					1	0.44***	0.19***	0.45***	0.41***	0.37***	0.38***
LH						1	0.05	0.34***	0.66***	0.65***	0.51***
LW							1	0.20***	0.36***	0.40***	0.28***
LSN								1	0.60***	0.46***	0.35***
LSBD									1	0.89***	0.64***
LSAD										1	0.67***
CSBG											1
COBG											
B1											
FH											
F1											
FUKY1											
FSKY1											
UKY											
FUKY2											
FSKY2											
B2											
F2											

***, ** and * are significant at 1 percent, 5 percent and 10 percent probability level, respectively.

Table 11.*continued*

	COBG	**B1**	**FH**	**F1**	**FUKY1**	**FSKY1**	**UKY**	**FUKY2**	**FSKY2**	**B2**	**F2**
MT	0.37***	-0.15**	-0.02	0.32***	-0.08*	0.01	-0.56**	-0.53**	-0.46**	-0.35**	-0.12**
PH	0.47***	0.04	0.31***	-0.3***	0.63***	0.59***	0.64***	0.60***	0.58***	0.24***	-0.1
PSH	0.49***	0.03	0.19**	-0.10*	0.49***	0.44***	0.35***	0.34***	0.31***	0.13*	-0.09
PSC	0.57***	0.01	0.22***	-0.19**	0.65***	0.67***	0.65***	0.57***	0.62***	0.24***	-0.12*
LN	0.02	0.12	0.13*	-0.2***	0.28***	0.23***	0.50***	0.46***	0.43***	0.27***	-0.01
LH	0.40***	0.04	0.28***	-0.3***	0.56***	0.53***	0.60***	0.54***	0.52***	0.27***	-0.10
LW	0.15*	0.01	0.12*	-0.06	0.32***	0.31***	0.37***	0.36***	0.37***	0.15*	0.03

	COBG	B1	FH	F1	FUKY1	FSKY1	UKY	FUKY2	FSKY2	B2	F2
LSN	0.05	0.06	0.11	-0.23**	0.34***	0.33***	0.50***	0.48***	0.49***	0.26***	-0.07
LSBD	0.46***	0.06	0.25***	-0.3***	0.70***	0.69***	0.81***	0.72***	0.74***	0.36***	-0.09*
LSAD	0.51***	0.07	0.22**	-0.3***	0.78***	0.74***	0.86***	0.78***	0.77***	0.41***	-0.10
CSBG	0.40***	0.07	0.14*	-0.20**	0.64***	0.59***	0.79***	0.67***	0.65***	0.31***	-0.04
COBG	1	-0.06	0.16***	-0.07	0.68***	0.70***	0.40***	0.34***	0.38***	-0.0007	-0.19**
B1		1	-0.5***	0.11	-0.06	-0.15*	0.12*	0.03	-0.08	0.78***	0.15*
FH			1	-0.2***	0.33***	0.41***	0.14*	0.26***	0.36***	-0.42**	-0.13*
F1				1	-0.2***	-0.2***	-0.3***	-0.3***	-0.3***	-0.01	0.82***
FUKY1					1	0.94***	0.71***	0.85***	0.84***	0.16***	-0.14*
FSKY1						1	0.63***	0.76***	0.85***	0.04	-0.17**
UKY							1	0.89***	0.84***	0.48***	0.004
FUKY2								1	0.95***	0.34***	-0.01
FSKY2									1	0.19***	-0.05
B2										1	0.16**
F2											1

***, ** and * are significant at 1 percent, 5 percent and 10 percent probability level, respectively.

4. Conclusion

Cluster analysis based on qualitative characters indicated the formation of six clusters and existence of variability, based on their midrib upper & under side, petiole upper & under side, leaf as well as leaf tip & edge colors of an enset plant.

The result of Shannon-Weaver diversity index (H`) showed that low levels of diversity existed among the 279 *Enset ventricosum* accessions based on the frequency of the phenotypic characters considered.The value of H' ranged from 0.31 for leaf surface color to 0.95 for midrib upper-side color with the overall mean of H'value of 0.69 of confirmed that the existence of low level of phenotypic diversity among *Enset ventricosum* accessions.

Analysis of variance for quantitative characters indicated significant variation among the accessions in all the 22 yield and yield components of an enset plant. The range values were 2.11-7.55 years for maturity time, 0.75-2.9m for pseudostem height, 0.58-2.04m for pseudostem circumference, 1.93-42.94 ton/ha/year for fermented unsqueezed kocho yield and 1.29-25.89 ton/ha/year for fermented squeezed kocho yield.

Cluster analysis based on quantitative characters indicated the formation of six clusters and showing cluster five with the highest values for yield and yield components for the majority of the characters followed by cluster IV. The cluster and distance analysis of quantitative characters pointed out the distance between most of the clusters were highly significant ($P < 0.01$) suggesting diversity among accessions in different clusters. The maximum inter-clusters distance ($D^{2} = 256.45$) was noticed between cluster III and V followed by I and V ($D^{2} = 228.59$) and II and V ($D^{2} = 206.10$) suggesting diversity between these groups. Hence, inter-mating between accessions included in these clusters may give high heterotic response and thereby better segregatesin view of the genetic diversity.Correlation study between various quantitative characters showed highly significant association among characters. Maturity time has a negative correlation with yield and yield components of an enset plant.Significant and positive correlation existed among the other quantitative characters of enset.

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