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Ethnic-based diversity and distribution of enset (*Ensete ventricosum*) clones in southern Ethiopia

Z. Yemataw[1], H. Mohamed[2], M. Diro[3], T. Addis[4]* and G. Blomme[5]

[1]Southern Agricultural Research Institute, Areka Agricultural Research Center, P. O. Box 79, Areka, Ethiopia.
[2]Hawassa University, Awassa College of Agriculture, P. O. Box 05, Hawassa, Ethiopia.
[3]Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia (CASCAPE), Addis Ababa, Ethiopia.
[4]Southern Agricultural Research Institute, Awassa Agricultural Research Center, P. O. Box 06, Hawassa, Ethiopia.
[5]Bioversity International Uganda Office, P. O. Box 24384, Kampala, Uganda.

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Enset cultivation in southern and south-western Ethiopia is practiced mainly in densely populated areas. A survey covering 280 farm households and seven districts was conducted in seven zones of southern Ethiopia with the main objective of assessing the diversity and distribution of enset clones. Interviews using structured and semi-structured questionnaires were conducted to generate data. A total of 218 enset clones were recorded in the surveyed areas. The number of clones cultivated on individual farms ranged from two to 26 (mean of 8.9 ± 0.9). The highest richness of enset was recorded in Hadiya (59 clones) whereas the lowest was in Sidama zone (30); the mean richness being 39.7 ± 3.8 clones per zone. Exchange of clones among farmers in different ethnic groups in enset growing regions revealed that strong cultural and linguistic similarities exist between zones. Farmers reported that clones such as Gena and Mazia are replacing previously grown clones due to their resistance to *Xanthomonas* wilt. Several enset clones previously known by farmers have disappeared in recent years due to disease, extended drought and wild animals, pointing to genetic erosion and the necessity of genetic conservation.

Key words: Abundance, Gurage, Kembata, Mazia, richness, Wolaita.

INTRODUCTION

The genus *Ensete* belongs to the order Schistaminae and Musaceae family and comprises several species that grow in Africa and Asia (Bezuneh, 1984). Wild *Ensete ventricosum* can be found in Africa from the Ethiopian highlands to Malawi. However, domesticated enset (*E. ventricosum*) Welw. (Cheesman) is only cultivated in Ethiopia

The Ethiopian highlands are a center of genetic diversity for enset, tef, sorghum, barley and finger millet (Engels and Hawkes, 1991). The enset farming system supports over 15 million people with food, fiber, medicine and animal feed (Brandt et al., 1997).

*Corresponding author. E-mail: temesgen_addis@yahoo.com, t.addis@e-nema.de. Tel: 004917628697052.

The major food types obtained from enset are *kocho*, *bulla* and *amicho*. *Kocho* is fermented starch obtained from decorticated (scraped) leaf sheaths and grated corms. *Bulla* is a liquid which is obtained when leaf sheaths and corms are pulverized; the liquid containing starch is squeezed out from scraped leaf sheathes and grated corm and the resultant starch allowed to concentrate into white powder. *Amicho* is boiled enset corm/rhizome pieces that are prepared and consumed in a similar manner to other root and tuber crops (Brandt et al*.,* 1997).

Reports of landrace diversity in enset are numerous. Alemu and Sandford (1991) reported names of 99 enset clones in the North Omo area, while Shigeta (1990) listed 78 vernacular names of cultivated enset clones in the Ari region of southern Ethiopia. Negash (2001) reported that farmers maintain and enrich the diversity of enset, and select or classify clones for various uses. Tesfaye (2002) indicated that enset landraces are not evenly distributed across the region mainly due to altitude variations. Tsegaye (2002) reported that numerous enset clones were identified in each region and the variations in the number of clones were attributed to a combination of socio-cultural and agro-ecological factors. Furthermore, Birmeta (2004) reported that the observed genetic diversity in cultivated enset in a particular area appears to be related to the extent of enset cultivation and the culture and distribution pattern of the different ethnic groups.

Some limited work has been done to evaluate, analyze and document clonal identity. Clonal names reported in the literature are associated with only limited phenotypic data provided by farmers (Shigeta, 1990). In enset, molecular characterization of clones has been done using amplified fragment length polymorphism (Negash, 2001; Negash et al., 2002; Tsegaye, 2002) and random amplified polymerphic DNA (RAPD) techniques (Birmeta, 2004). These earlier studies of enset diversity were limited to one or a few ethnic groups or a specific and limited growing region. However, a study encompassing many enset growing regions and ethnic groups has previously not been carried out, although knowledge on the level of morphological diversity of enset across a large number of ethnic groups or a large geographical area is important to assess the number of enset clones in the country and in the same time to develop a strategy for better genetic diversity conservation. Therefore, the objective of this study was to investigate farm level diversity and distribution of enset clones in seven (out of 16) major enset production areas in southern Ethiopia.

MATERIALS AND METHODS

The study area

The Southern Nations, Nationalities and Peoples' Regional State (SNNPRS) has a total area of 117,506 km², with altitudes ranging from 378 to 4,207 m above sea level (masl) (Abebe, 2005). The study was conducted in seven administrative zones: Wolaita, Kembata, Hadiya, Sidama, Gamo Gofa, Gurage and Dawro. One district was selected in each zone. The selection was based on the prominence of enset cultivation and information about enset distribution obtained from the Departments of Agriculture of the respective zones.

Sampling and data collection

A household-level survey covering the seven zones was conducted from August 2008 to February 2009. In each zone, two peasant associations (PAs) (PA; this is the lowest tier of civil administration, equivalent to a village) were selected. Twenty households were randomly selected from each PA, giving a total of 280 households across the seven zones. Farmers were asked to name and describe each enset clone present on their farm.

In order to quantify on-farm genetic diversity, in all the directly monitored farms, a participatory zigzag sampling in diagonal direction of the plot was made in all 280 enset farms. All encountered clones were counted and discussions were made with farmers. For further verification of the clones, sample plants were taken from each clone to Areka research center for further on station assessment of selected quantitative and qualitative traits (Yemataw et al., 201)

Data analysis

Simpson (1949) and Shannon and Weaver (1949) diversity indices are the two most widely used measures of heterogeneity (Magurran, 1988). Both of them were calculated for all the zones. Simpson's index (D) measures the probability that two individuals, randomly selected from a sample, belong to the same category (Simpson, 1949) and hence, as D increases, diversity decreases. This is neither intuitive nor logical, so to get over this problem, D is often subtracted from 1 to give Simpson's Index of Diversity (1 – D). The value of this index ranges between 0 and 1; the greater the value, the greater the sample diversity. The index was computed for all the zones and all the clones using the function:

Simpson's Index of Diversity (1-D) = $1-\sum (n/N)^2$

$$D = \sum_{i-1}^{n} \frac{(n_i\,(n_i - 1)}{(N(N-1)}$$

Where, n_i= the frequency of the i^{th} clone, frequency being the number of farms in which the clone is found in the district, and N = the total number of farms surveyed in the district.

The Shannon–Weaver diversity index (Shannon and Weaver, 1949) and Evenness measure (E) are commonly used tools that incorporate both richness and the evenness of abundance (Magurran, 1988). The Shannon diversity index (*H'*) is high when the relative abundance of the different species in the sample is even, and is low when few species are more abundant than the others. Shannon–Weaver diversity index takes into account both number and evenness of categories considered and can be increased either by greater evenness or more unique species or clones in this case.

It was calculated using the formula, $H' = -\Sigma\, pi \ln pi$ (Magurran, 1988).

Where pi, the proportional abundance of the i^{th} clone = $(\frac{ni}{N})$.

Although Shannon's index takes into account evenness of the abundance of clones, evenness can be calculated separately as a measure of the observed diversity to the maximum diversity. It is defined by the function E = H'/lnS, where H' is the Shannon index and S refers to the number of clones described in each zone. A high

Table 1. Distribution of households by number of enset plants.

Number of enset plants/household	Number of households	Percent
≤500	59	21
501-1000	80	29
>1000	141	50
Total	280	100

N	Minimum	Maximum	Mean	Standard error
280	60	15000	2018	147

Table 2. Variation in the number of enset clones planted per farm in the seven zones.

Number of enset clones per farm	Number of farms								Mean number (%) of farms
	S*	W	GG	K	H	D	G	Total	
≤ 5 clones	6	2	9	1	2	3	6	27	4.1(10.3)
6-10 clones	19	22	24	39	31	26	23	184	26.3 (65.8)
11-15 clones	12	14	6	0	2	11	9	54	7.7 (19.3)
≥15 clones	3	2	1	0	5	0	2	10	1.9 (4.8)
Total	40	40	40	40	40	40	40	280	

*S = Sidama; W = Wolaita; GG = Gamo Gofa; K = Kembata; H = Hadiya; D = Dawro; G = Gurage.

evenness, resulting from all clones having equal abundance, is normally equivalent to high diversity (Magurran, 1988).

Measures of similarity/variation are almost as numerous as measures of species diversity. The purpose of these functions is to quantify the similarity between two or more sampling sites. The expected variation in clone composition that exists between sites was analyzed using Sorenson's similarity coefficient (Cs) (Sorenson, 1948):

$$Cs = \frac{2J}{a+b}$$

Where, *a* is the number of clones at site A, *b* is the number of clones at site B, and *J* is the number of clones common to both locations.

Sorenson's similarity coefficient ranges in value from zero (no similarity) to one (complete similarity).

Clone diversities (Simpson's and Shannon-Weaver diversity indices) were measured separately for each zone. Pearson's correlation coefficient was used to compare diversity and distribution values at different sites. A tree diagram was constructed based on Euclidean distances developed by an unweighted pair-group method based on arithmetic averages (Nei, 1987). The SAS computer program (SAS, 2002) was employed for data analysis.

RESULTS AND DISCUSSION

Enset clone richness

The number of enset plants per farm household ranged from 60 to 15,000 and depended on farm size and availability of labor. The mean number of enset plants per household was 2,018 ± 147 (Table 1). Half (50-4%) of farm households have more than 1,000 enset plants on their farm. A farmer with a large number of enset plants and a wide diversity of clones is considered food secure and a model farmer in the locality. This study agrees with the study of Brandt et al. (1997) and Negash (2001) who observed large number of enset plants and clones in wealthy farmers' fields. Majority of the farms surveyed (65.8%) constitute 6-10 enset clones per farm (Table 2).

Based on the total number of different clones recorded (richness of the zone) and the number of enset clones per farm, Hadiya was the richest zone with a total of 59 clones, followed by Kembata (43), Dawro (41) Wolaita (39), Gamo Gofa (34) and Gurage (31) (Table 3). The lowest richness was found in Sidama zone with 30 clones. In previous studies, comparable results were reported by Tsegaye (2002), who described 146 different enset clones from three zones (52 clones from Sidama, 55 clones from Wolaita and 59 clones from Hadiya). Negash (2001) recorded 146 different enset clones from four zones (65 clones from Kefa-Sheka, 30 clones from Sidama, 45 clones from Hadiya and six clones from Wolaita). Moreover, Birmeta (2004) described 111 enset clones from nine growing areas of Ethiopia and Tesfaye (2002) studied 79 clones from the Sidama zone of the southern region. Although two zones (Dawro and Kembata) of our geographical study region were different from previous studies, 23 of the Sidama clones reported in our study were also listed by Tesfaye (2002). Out of the 59 enset clones of the Hadiya zone reported in this study, 36 were also reported by Tsegaye (2002). Of the clones in Wolaita studied by Tsegaye (2002), 18 clones were different from those included in

Table 3. Enset clone diversity in the seven zones, Southern Ethiopia, expressed as richness, Simpson (1-D) and Shannon (H') diversity indices, and Evenness.

Districts	Richness (%)	Mean richness/farm	Minimum richness	Maximum richness	Number of unique landraces	1-D	H'	Evenness
Sidama	30 (10.8*)	9.47	3	18	24	0.97	3.58	0.97
Wolaita	39 (14.02)	10.25	4	19	22	0.98	3.67	0.10
GamoGoffa	34 (12.23)	7.95	3	17	23	0.97	3.59	0.97
Kembata	43 (15.5)	7.53	4	10	24	0.98	3.64	0.99
Hadiya	59 (21.2)	9.3	2	26	33	0.97	3.61	0.98
Dawro	42 (15.1)	8.95	3	15	29	0.97	3.61	0.98
Gurage	31 (11.15)	8.95	2	24	23	0.98	3.63	0.98
Mean±SE	39.7 ± 3.8	8.94 ± 0.94						

*Calculated on the basis of the 278 clones described throughout the study area.

our study.

This indicated that the number of clones in any zone is not fully established and is underestimated by the survey methods used in independent studies. Further study including many enset growing area within the same time is very important. Many studies have been conducted to assess the patterns of genetic diversity in landraces of different crops using different methods and identifying promising accessions for different traits that could be utilized in breeding programmes. Examples include studies on tef (Bekele, 1996); wheat (Negassa, 1985), barley (Demissie and Bjørnstad, 1996), and sorghum (Ayana and Bekele, 1998).

The number of clones cultivated on individual farms ranged from two to 26 (mean of 8.94 ± 0.94) (Table 3). Average number of clones per farm ranged between 10.25 for Woalita to 7.53 for Kembata Sidama (9.47) and Hadiya (9.3) had high farm level diversity, followed by Dawro and Gurage with 8.95 clones per farm. This is because they have many farms with 11-15 clones, while other zones such as Kembata have few such clones, although the total number of clones in the zone was the highest (Table 3).

Diversity indices for the seven zones studied were computed from the numbers of clones present on the 40 farms within the zone (Table 2). Although zones differed in richness, they were similar in diversity. The Simpson's 1-D ranged between 0.971 (Sidama) to 0.977 (Wolaita), H′ ranged between 3.58 for Sidama to 3.67 for Wolaita, while evenness also had a very narrow range: 0.97 for Gamo Gofa to 0.99 for Wolaita (Table 3). All these values indicate the high enset diversity in these seven zones.

In the seven zones, a total of 218 clones with distinct names were recorded. During the survey, we were able to confirm that each farmer is determined to maintain as much enset diversity as possible as long as he/she has enough land. It was possible to verify the existence of up to 26 different enset clones maintained by one household. During discussion with the farmers it was also observed that there were more than 100 enset clones grown in each locality a few years back, however, farmers reported that most of the clones were lost due to disease and wild animals such as mole rat, porcupine and wild pigs. Tesfaye (2002) also found out that in Sidama, farmers reported names of 20 enset clones which were not encountered in any of the farms that were visited. Some enset landraces might have been totally lost from farmers' fields.

Hadiya and Kembata zones shared 17 clones (Table 4), while Wolaita and Gamo Gofa, and Wolaita and Dawro had 11 clones in common. These zones are adjacent to each other and the Kembata and Hadiya, and Wolaita and Dawro zones were until recently one administrative area.

Strong cultural and linguistic similarities exist between Kembata and Hadiya, and between Wolaita, Dawro and Gamo Gofa. This justification was noticeably confirmed by Fleming (1975), who stated that Dawro, Gamo Gofa and Wolaita peoples of the Southern Ethiopia belong to Omotic people who have a dialect of the central Omotic languages.

This may be reflected in the observed high similarity in cultivated clones. Clustering of the seven zones using the Sorenson's similarity index grouped the seven zones into four clusters (Figure 1) as follows: i) Kembata and Hadiya, ii) Wolaita, Dawro and Gamo Gofa, iii) Sidama and iv) Gurage. It is interesting to note that Sidama and Gurage do not share many clones with neighboring zones

These findings, however, noticeably differ from those of Tesfaye (2002), who reported that 52% of enset clones in Sidama zone were shared among farmers of the study area suggesting that informal exchanges among farmers are limited within narrowly defined ethnic groups. The informal exchange of planting material among farmers mainly occurs within the geographical zone occupied by an ethnic group and it is hence difficult, to compare values with results of previous surveys due to differences in the number of locations and ethnic considerations.

In agreement with Tabogie (1997), duplication of clone names was observed. The same enset clone was given different names in different areas and vice versa (different enset clones were given the same name in different localities) (Tabogie, 1997). Tsegaye (2002) also showed that duplication of clone names was related to different

Table 4. Number of shared clones (above diagonal) and Sorenson similarity indices (below diagonal) between pairs of zones.

Zones	Sidama	Wolaita	Gamo Gofa	Kembata	Hadiya	Dawro	Gurage
Sidama	--	3	1	2	2	3	1
Wolaita	*0.06	--	11	1	4	11	1
Gamo Gofa	0.06	0.27	--	0	1	6	0
Kembata	0.03	0.02	0.026	--	17	0	2
Hadiya	0.07	0.08	0.02	0.35	--	2	8
Dawro	0.06	0.3	0.16	0	0.04	--	0
Gurage	0.03	0.03	0	0.05	0.18	0	--

*=Sorenson's similarity index.

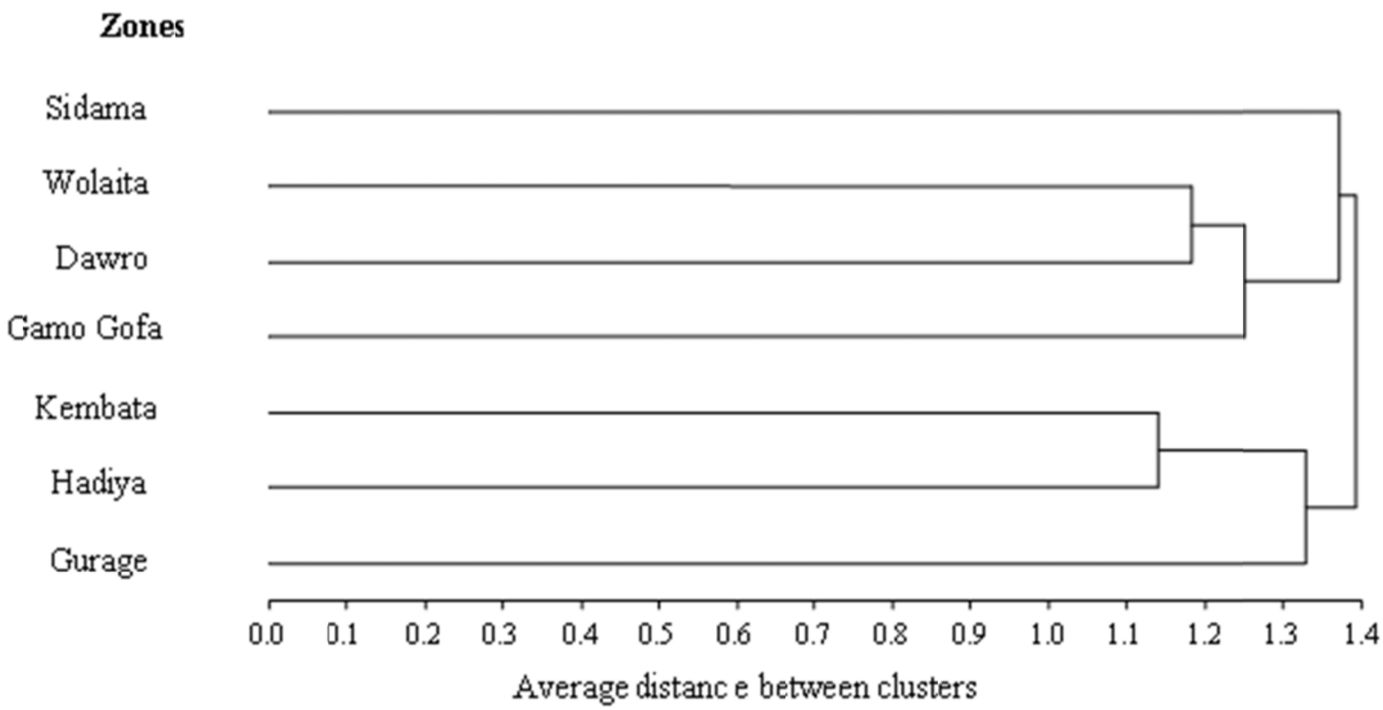

Figure 1. Dendrogram of the seven zones based on Sorenson's similarity index.

utilization purposes of clones and the changing of vernacular names after exchange of clones between different ethnic groups.

Distribution and abundance of clones

Large differences were evident between clones in their abundance and distribution. Some clones had a rather patchy distribution, that is they had a very high local abundance at one or two locations and were absent from the rest. For example, 'Shodedenia' was encountered on all the 40 (100%) of the farms visited in Dawro (Table 5). It was not found in any other zones surveyed. This is an abundant clone with a narrow distribution. The same was true for 'Amerate' in Gurage and Genticha in Sidama which were recorded on 33 and 27 of the 40 farms, respectively (Table 5). On the other hand a relatively small number of clones played a dominant role in more than one zone. These were 'Mazia', 'Gena', 'Astara' and 'Badedea' (Table 5). Mazia was the most abundant clone as it was recorded on 89 (32%) of all the farms surveyed, and also in a much higher proportion of the 40 farms surveyed in the three zones where it was found: Wolayita, Gamo Gofa and Dawro zones 17 (7%), 35 (12%) and 37 (13%) respectively) (Table 5). However, there was overall a significant correlation between distribution and abundance of the clones ($r = 0.66$, $p \leq 0.0001$). Clones that are used by many famers in any zone tend to be found in other zones and have wider distribution.

There was also a considerable difference among the clones with respect to their distribution across the zones

Table 5. Numbers of farmers growing widely distributed and the most abundant enset clones in each zone.

Clone	H†	K	G	W	GG	S	D	TOT	Zones
Astara	13	22	14			10		59	4
Sabara	16	8	16					40	3
Mochea	13	2		5				20	3
Badadea	10		3	8			2	23	4
Gena	1			14	14	20	10	55	5
Katania				11	5		3	19	3
Agena				7		10	9	26	3
Switia				8	4		4	16	3
Kekerwa				7	9		6	22	3
Mazia				17	35		37	89	3
Banga				9	2		7	18	3
Shodedenia							40	40	1
Amerate			33					33	1
Genticha						27		27	1

†= H = Hadiya, K = Kembata, G = Gurage, W = Wolaita, GG = Gamo Gofa, S = Sidama, D = Dawro, TOT = Total number of farmers.

Table 6. Distribution of enset clones across the seven zones

Number of zones	Number of enset clones (%)
One	178 (82)
Two	29 (13)
Three	8 (4)
Four	2 (1)
Five	1 (<1)
Six	0
Seven	0
Total	218

covered by this study. Out of the 218 clones, 178 (82%) were observed in only one zone. Twenty nine (13%) of the clones were present in two zones. Eight clones (4%) were present in three zones. Two clones (1%) were present in four of the seven zones and only one clone (Gena) was present in five of the seven zones (Tables 5 and 6). Household characteristics, distance from one location to another and ethnic preferences in few locations for few number of clones bring high clonal diversity, while for more number of clones that do not fulfill the selection criteria of each ethnic group brings clonal paucity.

To classify the total abundance and distribution of the whole clone into four quadrant plane, a clone having an equal abundance x distribution point was selected. Based on that, if we designate a clone that is present in at least 15 of the 40 farms in a given zone having an average abundance of 0.38, then all the 218 clones can be categorized into four groups on the abundance x distribution plane (Table 7 and Figure 2). The first category (widely distributed and abundant clones) applies only to 'Mazia'. The second category (localized but abundant clones) included 23 enset clones. The highest numbers of enset clones (183) were grouped in the third category which is the localized and rare clones. The fourth group (widely distributed but rare clones) included 11 clones.

The abundance of clones across sites within a zone and the distribution of clones across the seven zones were generally uneven, because of a limited number of widespread and dominant clones. The hierarchical nature of the spatial distribution of enset clones with a small number of highly abundant clones which are also grown throughout the region and a much larger number of moderately common and rare ones has been documented for enset (Tesfaye, 2002), and several other crops including cassava (Boster, 1985) and yam (Tamiru, 2006).

Conclusion

A large number of enset clones was recorded in the southern region. However, the diversity of enset clones is not spread evenly across the region. A small number of highly abundant clones are grown throughout the region, while a much larger number of moderately common and rare clones characterize the distribution-abundance pattern. The widespread distribution of some clones challenges the view that traditional farming systems are isolated and closed, with limited exchange of germplasm. The findings of this study and similar studies depict a system that is rather open and dynamic, where local knowledge exists for exchange of planting materials across wider areas and heterogeneous environments. The unequal distribution and abundance of clones reflect

Table 7. Classification of the 218 clones into four groups based on their abundance and distribution.

Quadrant	Category	Number of clones in the category
I	Widely distributed and abundant clones	1
II	Localized but abundant clones	23
III	Localized and rare clones	183
IV	Widely distributed but rare clones	11

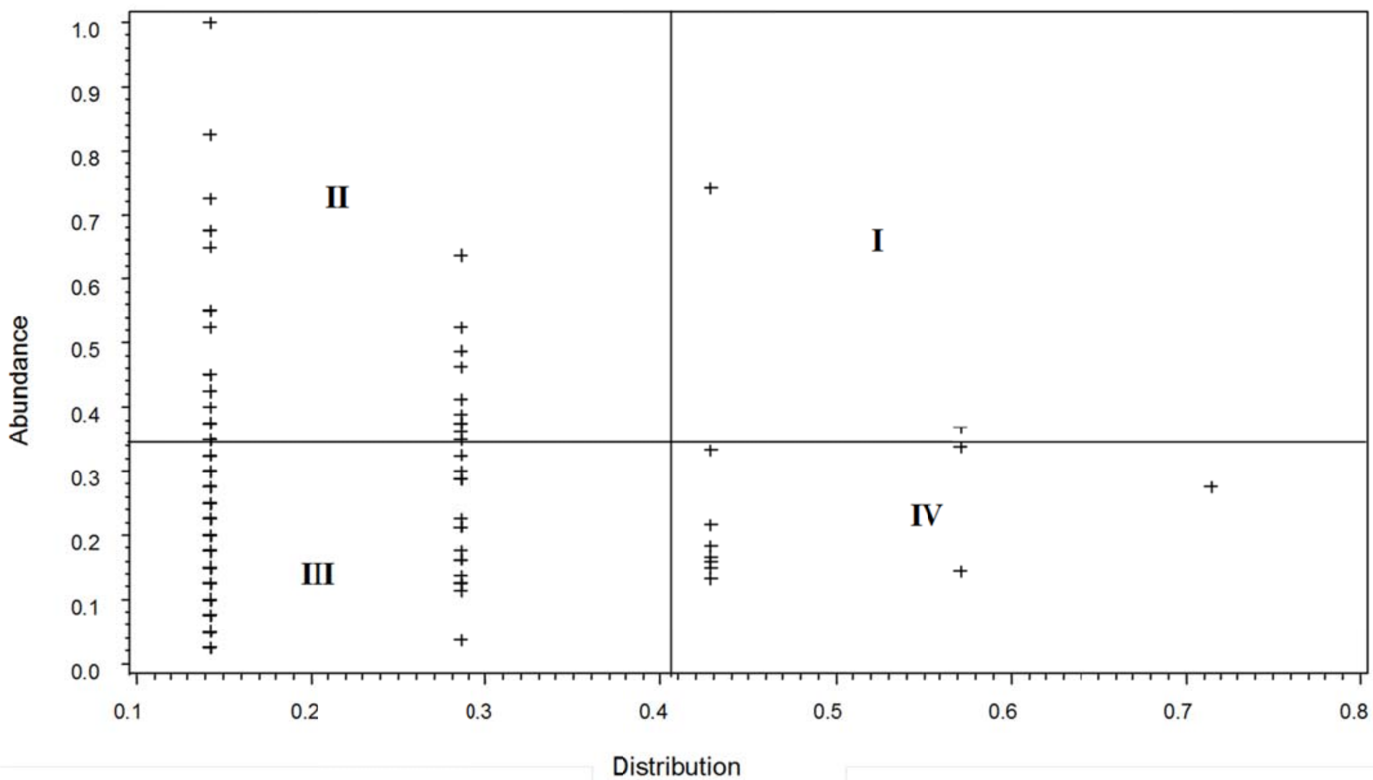

Figure 2. Classification of the 218 enset clones into 4 groups using their scatter in abundance X distribution plane. (a lot of clones are hidden).

their relative importance to farmers and provide strong evidence for selection. Highland regions have a high concentration of diverse and unique enset landraces and should be given priority in efforts aimed at collection and *in situ* germplasm conservation.

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REFERENCES

Abebe T (2005). Diversity in homegarden agro-forestry systems of southern Ethiopia. PhD dissertation, Wageningen University, The Netherlands. 143 pp.

Alemu K, Sandford S (1991). Enset in North Omo Region. Farmer's Res. Project Technical Pamphlet No. 1. Farm Africa, Addis Abeba. 49 pp.

Ayana A, Bekele E (1998). Geographical patterns of morphological variation in sorghum (*Sorghum bicolor* (L.) Moench) germplasm from Ethiopia and Eritrea: qualitative characters. Hereditas 129:195-205.

Bekele E (1996). Morphological analysis of *Eragrostis teff*: Detection for regional variation. *Sinet*: Ethiopian J. Sci. 19:117-140.

Bezuneh T (1984). Evaluation of some *Ensete ventricosum* clones for food yield with emphasis on the effect of length of fermentation on carbohydrate and calcium content. Trop. Agr. 61:111-116.

Birmeta G (2004). Genetic variability and biotechnological studies for the conservation and improvement of *Ensete ventricosum*. Doctoral thesis, Swedish University of Agricultural Sciences, Alnarp. 91 pp.

Boster J (1985). Selection for perceptual distinctiveness: evidence from Aguarina cultivars of *Manihot esculenta*. Econ Bot. 39:310-325.

Brandt SA, Spring A, Hiebsch C, McCabe ST, Tabogie E, Diro M, Welde-Michael G, Yentiso G, Shigeta M, Tesfaye S (1997). The 'Tree Against Hunger'. Enset-based Agricultural Systems in Ethiopia. American Association for the Advancement of Science. 56 pp.

Demissie A, Bjørnstad A (1996). Phenotypic diversity of Ethiopian barley in relation to geographical region, altitudinal range, and agro-ecological zones: As an aid to germplasm collection and conservation strategy. Hereditas 124:17-29.

Engels J, Hawkes J (1991) .The Ethiopian gene centre and its genetic diversity. In: Engels J, Hawkes J, Worede M (eds). Plant Genetic Resources of Ethiopia. Cambridge University Press, Cambridge

Fleming H (1975). Recent Research in Omotic-Speaking Areas. In: Marcus H.G (ed.). Proceedings of the First United states Conference on Ethiopian Studies, 1973. East Lansing: Michigan State University. pp. 261-278.

Magurran A (1988). Ecological diversity and its measurement. Croom Helm, London. 125 p.

Negash A (2001). Diversity and conservation of enset (*Ensete ventricosum* Welw. Cheesman) and its relation to household food and livelihood security in South-western Ethiopia. PhD dissertation, Wageningen University, The Netherlands. 247pp.

Negash A, Tsegaye A, Van Treuren R, Visser B (2002). AFLP analysis of Ensete clonal diversity in south and southwestern Ethiopia for conservation. Crop Sci. 42:1105-1111.

Negassa M (1985). Patterns of phenotypic diversity in an Ethiopian barley collection and the Arsi-Bale high land as a center of origin of barley. Hereditas 102:139-150.

Nei M (1987). *Molecular evolutionary genetics*. Colombia University Press, New York.

SAS (2002). Statistical Analysis Systems SAS/STAT user's guide Version 9 Cary NC: SAS Institute Inc. USA.

Shannon C, Weaver W (1949). The mathematical theory of communication. University of Illinois, Urbana, IL 117pp.

Shigeta M (1990). Folk *in situ* conservation of enset (*Enset ventricosum* (Welw.) Cheesman): Towards the interpretation of indigenous agricultural science of the Ari, south western Ethiopia. Afr Stud Monogr 10:93-107.

Simpson E (1949). Measurement of diversity. Nature 163:688.

Sorenson T (1948). A method of establishing groups of equal amplitude in plant sociology based on similarity of species content, and its application to analysis of the vegetation on Danish commons. K dan Vidensk Selsk Biol. Skr. 5:1-34.

Tabogie E (1997). Morphological Characterization of enset (Ensete ventricosum (Welw.) Cheesman) clones and the association of yield with different traits. M.Sc. Thesis. Alemaya University of Agriculture, Alemaya, Ethiopia. 89 pp.

Tamiru M (2006). Assessing diversity in yam (*Dioscorea spp.)* from Ethiopia based onmorphology, AFLP marker and tuber quality, and farmers' management of landraces. Ph.D. thesis, George -August University. Germany. 155pp.

Tesfaye B (2002). Studies on landrace diversity, *in vivo* and *in vitro* regeneration of enset (*Enset ventricosum* Welw.). PhD dissertation, Humboldt University, Berlin, Germany, 129 pp.

Tsegaye A (2002). On indigenous production, genetic diversity and crop ecology of enset (Enset ventricosum (W elw.) Cheesman) . PhD dissertation, W ageningen University, The Netherlands. 197pp.

Yemataw Z, Mohamed H, Diro M, Addis T, Blomme G (2014). Enset (*Ensete ventricosum*) clone selection by farmers and their cultural practices in southern Ethiopia. Genet Resour Crop Ev. 61(3): DOI 10.1007/s10722-014-0093-6.