A COMPARATIVE GENETIC DIVERSITY STUDY FOR FOUR MAJOR CROPS MANAGED UNDER ETHIOPIAN CONDITION

Tesema Tanto* and Abebe Demissie*

*Institute of Biodiversity Conservation and Research
P.O. Box 30726, Addis Ababa, ETHIOPIA
Tel. 251 1 612244, Fax.251 1 613722
E-mail tesematan@hotmail.com

Abstract

Ethiopia is a center of origin and diversity for many cultivated crops and their wild relatives. The country is located near Equator, but due to altitudinal variation it experiences a temperate climate, especially at altitudes of more than 2000 meters above sea level. Altitude ranges below sea level at Dallol depression, to 4620 meters above sea level at the top of mount Ras Dashen. In addition, soil variation, ecological diversity, substantial temperature and rainfall variations, and diverse social and cultural conditions have produced suitable environments for genetic variation of crop varieties. The objectives of this study were, [1] to analyze the existing morphological diversity for the four crops of which two crops have Ethiopia as their center of origin (sorghum and tef) and two crops have Ethiopia as a secondary center of diversity (barley and wheat) in the country, [2] to compare the level of the existing morphological diversity with previous studies and analyze the change over space (regions) and time and [3], to analyze the distribution of farmers' varieties across regions and altitude ranges.

The diversity was measured by number of farmers' varieties grown for each crop and their distribution across the regions by applying diversity indices of Simpson and Shanon-Weaver across altitudinal ranges, and ecological regions. It was found that there was high diversity for the crop plants of Ethiopian origin than crops where Ethiopia is a secondary gene center in diversity.

1. Introduction

Ethiopia is a diverse country in terms of altitude, temperature, rainfall and soil types. One can sense such diversity within a short distance in a given locality. Such diversity of environmental elements was the cause for the existence of diverse vegetation, crop species and farmers varieties of crops that are observed in farmers' fields in most part of the country (Vavilov, 1951).

Ethiopia is a center of origin and diversity for many cultivated crops and their wild relatives. The country is located near Equator, but due to higher altitude it experiences a temperate climate, especially at altitudes of more than 2000 meters above sea level. Altitude ranges from below sea level at Dallol depression to 4620 meters above sea level at the top of mount Ras Dashen. In addition, soil variation, ecological diversity, substantial temperature and rainfall variations, and diverse social and cultural conditions are some of the possible explanations for the existence of tremendous genetic variation of crop varieties in the country.

Plant genetic diversity is a useful character in plants that can be transmitted genetically from parents to offspring. The sources of tremendous variation in plants support all other forms of life on land. Plant genetic diversity covers a wide range, at both the evolutionary

and ecological level. Ecologically the variation ranges from the components of very primitive ecosystem to the modern agricultural level. At the crop evolutionary level it covers a wide range of diversity from wild ancestors to the modern cultivars.

The diversity in plants is the basis for food and other human needs for millennia and it continues to do so for the development of plant characters useful to human needs. These heritages remain an asset and a tool to promote national, regional and international economies in all nations of the world. It is also a key to support agriculture and have a major role in world trade.

Our forerunner farmers, in the process of struggle for survival, domesticated, selected and produced crop species, which are unique to the country. Due to environmental variation and seed exchange from one farmer to another in mosaic environments within the country, variation has been generated for different crops. Among these: disease and pest resistance, tolerance to salinity and acidity soil conditions, grain quality, phenologic characters, yield potential, etc.

Diversity study has been conducted by several authors for these crop types, Barley (Bekele, E. 1983a; Negassa, M. 1985; Demissie, A, and BjØrnstad, A. 1997; Alemayehu, F. 1995; Asfaw, Z. 1989; Tolbert, DM et al. 1979 and others), Sorghum (Ayana, A. and Bekele, E. 1998; Teshome, A .et al. 1997;), tef (Bekele, E. 1996), and wheat (Bechere, et al. 1996; Bekele, E. 1996; Tesfaye, T. et al. 1991; Kebebew, F. et al. 2001).

The current study mainly deals with comparative diversity study among these crop types and their farmers' varieties across regions and altitudinal ranges.

The objectives of this study were, [1] to analyze the existing genetic diversity among four crops of farmers' variety across regions and altitude ranges, [2] to compare the level of diversity with previous studies and analyze changes over space and time, [3] to analyze the distribution of farmers' variety across regions and altitude ranges.

2. Materials and Methods

2.1. Plant materials

The plant materials used for the study were 771 farmers' varieties of barley, 359 farmers' varieties of wheat, 267 farmers' varieties of sorghum and 604 farmers' varieties of tef crops collected by the Institute of Biodiversity Conservation and Research.

2.2. Methods

2.2.1. Data collection

Basic agro-morphological characters were taken using standard descriptor lists developed by International Plant Genetic Resources Institute (IPGRI) for barley, wheat, sorghum and tef crops. These crops were grown at Holleta, Akaki, Arsi-Negelle and Debrezeit Research centers respectively. The research centers are all ideal sites for the crops to

express their genetic potential. The characterization and evaluation data was taken for qualitative characters on basis of farmers' variety for each crop. The qualitative characters are believed to be less influenced by environment and used to study diversity since the crops were grown on non replicated plots. On average, fifteen individual plants per farmers' varieties of each crop were taken to study the diversity within and between farmers' varieties of crops.

The farmers' varieties of each crop were grown on single plot with an area of six rows with row length of two meters and intra row space of 20 cm for barley, wheat and tef and 75 cm for sorghum. Standard checks of modern varieties were planted on every tenth plot for comparison in each crop.

2.2.2. Data analysis

The collected data were analyzed based on frequency distribution of farmers' varieties across regions and altitude ranges for the four crop types.

Simpson's evenness ($S'=1-\Sigma pi2$) and Shannon-Weaver diversity indices ($H'=\Sigma pi \ln pi/\ln pi$), diversity indices, were applied to determine evenness that measures how similar in frequencies are the farmers' varieties of crops across the regions and altitude ranges.

Using both Simpson and Shannon-weaver diversity indices qualitative characters of each crop varieties were analyzed. The qualitative traits for barley includes: kernel color, lemma color, Kernel row number and seed color, while for sorghum presence and absence of awndness, endosperm texture, glume color, glume cover, kernel color, midrib color, panicle type, sub coat and threshability. For durum wheat qualitative characters like, glume color, panicle type, glume hairiness, kernel color, spike density and vitrousness were analyzed.

3. Results and Discussion

3.1. Results

Table. 3.1.1. Distribution of farmers' varieties of crops across the Regions.

Region	Barley	Sorghum	Tef	Durum wheat
Arsi	134	5	21	31
Bale	108	6	23	31
Gamo-goffa	36	46	48	9
Gojam	9	12	54	34
Gonder	11	18	26	22
Harer	21	56	14	13
Illubabor	7	12	4	*
Keffa	*	17	18	*
Shewa	145	25	98	108
Sidamo	12	5	12	*
Tigray	164	12	130	62
Welega	44	28	119	6
Welo	80	25	37	43

*Regions where farmers' varieties of a crop not observed

Farmers' varieties names and its meaning shared among farmers with some peculiar traits that express quality, maturity, origin, use values, and yield to distinguish them from other improved varieties is shown below in table.

Table 3.1.2. Farmers' varieties name and meanings

Crop type	Farmers' variety name	Meaning of farmers' variety name
Sorghum	Wetet begunche/mar-chuke	milky /high lysine content
	Ganseber	High fermentation value
	Wof aybelash	Large gluem/bird tolerant
	Tinkish	Juicy stalk
	Zengada	Long maturing
	Sinde lemene	As good as wheat for bread
	Kitgn ayfere	Tolerant to Striga weed
	Asham demoze	Higher yield and tasty
	hafukagne	Alwas produce head
	Dalile	High quality seed
Tef	bunign	Early maturing/short stalk
	magna	High quality/White seeded
	Tsada teff	White seeded
	Dima teff	Brown seeded
	Abat teff	High yielder
	Mariye teff	Sweet bread like honey
	Mitazoa	Erect panicle
	Mesno	Grows under residual moisture
Durum wheat	Menze	Originated from menz locality
	Konteb	Long maturing
	Aybo	White like cheese
	Seso	Late maturing
	Shemet	Thin spike
	Tikur sinde	Black seeded
	Gojam gura	Identified from Gojam region
	Set akuri	Quality bread
Duru wheat	Mariye	Sweaty
	Gosh ginbar	Flat and wide spike
Barley	Gerbu guracha/duda	Black seeded with compact panicle
	Gealemie	Early type/two months
	Luka guracha/kaport	Easily threashible
	Liji azel	With many tillers
	Abat gebs	Ancient type
	tegadime	Frost tolerant/bending panicle type
	Falibaye	Hard glume type
	Aruso-bale	Originated from Arsi and Bale regions
	Feres-gamma	Long awns/mane of horse
	Awra gebs	Big seeded

Table. 3.1.2. Distribution of farmers' varieties for the four crops across altitudinal ranges.

Altitude range	Barley	Sorghum	Tef	Wheat
500-1000m	*	**6**	*	*
1001-1500	*	**41**	**104**	**2**
1501-2000	**99**	**156**	**250**	**38**
2001-2500	**296**	**50**	**189**	**173**
2501-3000	**258**	**14**	**61**	**141**
More than 3000m	**118**	*	*	**5**

*Altitude ranges where farmers' varieties of a crop not observed

Table. 3.1.3. Mean Shanon-Weaver diversity index for qualitative traits of the four crops of farmers' varieties across the regions

Region	Barley		Sorghum		Tef		Durum wheat	
	H'	S.E	H'	S.E	H'	S.E	H'	S.E
Arsi	0.79	±0.09	0.47	±0. 05	0.72	±0.09	0.64	±0.09
Bale	0.49	±0.16	*	*	0.58	±0.08	0.68	±0.13
GamuGofa	0.53	±0.22	0.72	±0.05	0.70	±0.17	0.60	±0.05
Gojam	0.52	±0.22	0.58	±0.08	0.87	±0.05	0.63	±0.20
Gonder	0.56	±0.16	0.54	±0.09	0.79	±0.08	0.53	±0.22
Harer	0.42	±0.19	0.61	±0.09	0.74	±0.16	0.49	±0.14
Illubabor	0.37	±0.17	0.57	±0.10	0.61	±0.12	*	*
keffa	*	*	0.54	±0.07	0.61	±0.12	*	*
Shewa	0.61	±0.16	0.51	±0.10	0.50	±0.19	0.67	±0.07
Sidamo	0.64	±0.19	0.51	±0.09	0.69	±0.12	*	*
Tigray	0.53	±0.18	0.64	±0.09	0.70	±0.09	0.65	±0.11
Welega	0.41	±0.17	0.58	±0.10	0.77	±0.09	0.54	±0.16
Welo	0.50	±0.19	0.61	±0.06	0.77	±0.11	0.66	±0.09
total	0.61	±0.18	0.74	±0.07	0.78	±0.09	0.71	±0.11

*Regions where farmers' varieties of a crop not observed

Table. 3.1.4. Mean Shannon-Weaver diversity index for qualitative characters of four crops of farmers' varieties across altitude ranges.

Altitude range in meters	Barley		Sorghum		Tef		Durum wheat	
	H'	S.E	H'	S.E	H	SE	H'	S.E
500-1000	*	*	0.52	±0.11	*	*	*	*
1001-1500	*	*	0.77	±0.08	0.75	±0.08	0.26	±0.16
1501-2000	0.50	±0.21	0.74	±0.07	0.79	±0.09	0.67	±0.09
2001-2500	0.59	±0.19	0.63	±0.11	0.76	±0.08	0.77	±0.08
2501-3000	0.65	±0.16	0.50	±0.09	0.72	±0.09	0.73	±0.08
>3000m	0.56	±0.16	*	*	*	*	0.46	±0.21
Total	0.61	±0.18	0.74	±0.08	0.78	±0.09	0.76	±0.08

* Altitude ranges where farmers' varieties of a crop not observed

Table. 3.1.5. Mean Simpson diversity index (s') for qualitative characters of four crops of farmers' varieties across regions

Region	Barley		Sorghum		Tef		Durum wheat	
	S'	S.E	S'	S.E	S'	S.E	S'	S.E
Arsi	0.65	±0.18	0.56	0.12	0.75	±0.03	0.64	0.10
Bale	0.47	±0.17	*	*	0.55	±0.10	0.64	0.13
Gamogofa	0.53	±0.22	0.77	0.06	0.55	±0.17	0.61	0.04
Gojam	0.53	±0.22	0.64	0.10	0.84	±0.04	0.60	0.13
Gonder	0.57	±0.15	0.59	0.10	0.82	±0.02	0.51	0.10
Harar	0.45	±0.20	0.64	0.11	0.62	±0.18	0.53	0.14
Illubabor	0.35	±0.17	0.65	0.11	0.50	±0.17	*	*
Keffa	*	*	0.60	0.08	0.35	±0.20	*	*
Shewa	0.58	±0.18	0.58	0.11	0.65	±0.11	0.67	0.06
Sidamo	0.62	±0.20	0.60	0.09	0.67	±0.09	*	*
Tigray	0.51	±0.19	0.73	0.10	0.64	±0.07	0.65	0.11
Welega	0.38	±0.17	0.64	0.12	0.70	±0.07	0.65	0.17
Welo	0.49	±0.20	0.65	0.08	0.69	±0.10	0.55	0.12
Total	0.61	±0.18	0.76	0.09	0.70	±0.08	0.72	0.10

*Regions where farmers varieties of a crop not recognized.

Table. 3.1.6. Mean Simpson diversity index (s') for qualitative characters of four crops of farmers' varieties across altitude range

Altitude in meters	Barley		Sorghum		Tef		Durum wheat	
	S'	S.E	S'	S.E	S'	S.E	S'	S.E
500-1000	*	*	0.63	±0.11	*	*	*	*
1001-1500	*	*	0.79	±0.09	0.79	±0.07	0.40	±0.24
1501-2000	0.49	±0.21	0.75	±0.09	0.81	±0.09	0.63	±0.11
2001-2500	0.56	±0.21	0.66	±0.12	0.78	±0.09	0.73	±0.09
2501-3000	0.45	±0.19	0.58	±0.11	0.80	±0.07	0.69	±0.09
>3000	0.52	±0.17	*	*	*	*	0.47	±0.10
Total	0.56	±0.19	0.75	±0.10	0.80	±0.09	0.72	±0.10

*Altitude ranges where farmers' varieties of a crop not observed.

4. Discussion

4.1. Frequency distribution across regions and altitude ranges

Frequency distribution of farmers' varieties for the two crops of which Ethiopia is a center of origin (sorghum and tef) and other two crops of which Ethiopia is a secondary gene center (barley and durum wheat) was analyzed across regions and altitude ranges. For sorghum high variation was observed in Harar, Gamo-Gofa, Welega, Welo and Shewa regions. While for tef Tigray, Welega, Shewa, and Gojam regions are with highest variations.

It was observed that for barley there is high variation in Tigray, Shewa, Arsi, and Bale regions. The highest variation seen in Tigray may probably be due to intensive rescue collections made by the Institute; otherwise Shewa, Arsi and Bale regions have highest variation for barley. This region was affected by recurrent draught in the past. Durum wheat showed highest variation in Shewa, Tigray, Welo, Arsi and Bale.

The altitude range with highest mean diversity for sorghum and tef is 1501-2000 meters above sea level. This range is suitable for sorghum and tef growth and development. Because sorghum and tef crops need warmer temperature with more degree-days for optimum growth and development in order to show variation within species.

Barley and wheat require cooler temperature of higher altitudes, which is somewhat similar to the temperate regions. Barley and wheat crops have showed higher variation at altitude range of 2001-2500 meters above sea level. At the lower hot temperature that is up to 1500 meters above sea level, barley is rare in occurrence, except two-rowed early types. However, it grows well over 3000 meters above sea level with extended maturity days of seven to eight months. At higher altitudes of more than 3000 meters above sea level wheat variation has greatly reduced (Table 3.1.2.).

4.2. Diversity study using Shannon-Weaver index

To study diversity using Shannon-Weaver index, qualitative characters of each crop were analyzed across regions and altitude ranges. Accordingly, for sorghum the Shannon-Weaver total diversity is 0.74±0.11, while for tef it is 0.78±0.09 across the regions. This shows that sorghum and tef crops for which Ethiopia is a center of origin have higher diversity compared to barley and durum wheat crops (0.61±0.18 and 0.71±0.11 respectively) where Ethiopia is a secondary gene center.

The highest mean diversity is observed for sorghum at 1001-1500 meters above sea level, while for tef at 1501-2000 meters above sea level. The highest diversity is observed for barley at 2501-3000 meters above sea level and for durum wheat at 2001-2500 meters above sea level. Tef exceptionally showed high diversity uniformly from 1000-3000 meters above sea level. This shows that the crop has wide adaptation across the altitude ranges.

4.3. Diversity study using Simpson diversity index

Similar result to Shannon-Weaver diversity index was observed in Simpson index (Tables 3.1.5 and 3.1.6). Again sorghum and tef showed highest diversity compared to barley and wheat both across regions and altitude ranges. However, durum wheat diversity is higher than barley in both across regions and altitude ranges. The variation of barley is reducing through time, as the crop suffers from replacement by bread wheat and tef due to their high price in local markets. The other problem it faces is that, being replaced by wild oat at central highlands of the country due to its severe competition.

5. Conclusion

The mean diversity index for sorghum at regional level indicates that extensive collections across the regions and altitude ranges is necessary rather than intensive collections in specific regions in order to capture valuable genes circumvented by biotic and abiotic factors that leads to genetic erosion of the crop. The biotic factors include disease resistant, high lysine content and yield, which can be used for future crop improvement. The abiotic factors like drought, salinity and acidity of soils, etc are major forces which led the crop to evolve and withstand them. Tef is highly demanded crop in local markets and staple food for most Ethiopians especially for those living in the urban areas. Therefore, better attention shall be given to satisfy the local demand. The yield of this crop is lower as compared to other cereals like wheat and maize. Therefore, intensive collections and evaluation across the regions and altitude ranges is required in order to tap the existing genetic potential of the crop for its improvement and since it is an alternate crop to recurrent drought.

Barley diversity seen by Demissie and BjØrnstad was (0.71), while in our current study it is 0.61±0.18 using total Shanon-Weaver diversity index value of the country. This shows it tends to reduce in diversity mainly due to its replacement by bread wheat and tef as well as severe competition it has with wild oats. Therefore special attention shall be given in order to rescue the crop from further extinction. Making intensive collections especially on high barley diversity regions of Arsi, Bale, Shewa, Tigray and Welo can avert the risk.

Durum wheat diversity studied using Shannon-Weaver index by Bechere et al 1996, showed the total diversity in north -central highlands was 0.70±0.07, and another study made by Kebebew et al 2001 was 0.81±0.01, while in this study it was observed that 0.76±0.08 considering the whole country. This shows that the diversity in wheat is relatively the same. However, due to rapid dissemination of improved bread wheat varieties through extension package program, durum wheat is being replaced by bread wheat. Therefore, an extensive collection across the regions and altitude ranges is required to conserve the existing farmers' varieties of durum wheat.

It is only in nature that plant diversity at genetic, species and eco-system level can be conserved on long term basis. The current *in situ* conservation initiative that serves as a dynamic system of conservation of genetic variability of specific populations of species acting as a natural reservoir of genes under constant selection pressure, has to be promoted in additional agro-ecological zones of the country in order to rescue crops from

continues genetic erosion. Unless crop plant populations are conserved in the on-farm, which is natural habitats, in viable breeding populations, they run out of extinction in some cases and reduction in diversity in most of the cases. In summary both *in situ* and *ex situ* conservation strategies shall be implemented to complement each other for sustainable conservation and utilization of crop plants.

References

Asfaw, Z. 1989. Relationship between spike morphology, hordeins and altitude within Ethiopian barley, *Hordeum vulgare* L. Hereditas 110: 203-209.

Ayana, A. and Bekele, E. 1999. Geographical patterns of morphological variation of sorghum (*Sorghum bicolor*) (L) Moench) germ plasm from Ethiopia and Eritrea. Euphytica in press

Bechere, E. Belay G, Mitiku D, and Merker A. 1996. Phenotypic diversity of tetraploid wheat landraces from north-central regions of Ethiopia. Hereditas 124:165-172.

Bekele, E. 1983. Some measures of gene diversity analysis on landrace populations of Ethiopian barley, Hereditas 98: 127-143.

Bekele, E. 1984. Analysis of regional patterns of phenotypic diversity in the Ethiopian tetraploid and hexaploid wheats. Hereditas 100: 131-154.

Bekele, E. 1996. Morphological analysis of Eragrostis tef: detection for regional patterns of variation. SINET: Eth. J. Sci. 19: 117-140.

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

Negassa, M. 1985. Patterns of phenotypic diversity in an Ethiopian barley collection and the Arsi-bale highland as a center of orgin of barley. Hereditas 104: 41-48.

Tesfaye, T. Getachew B and Worede M. 1991. Morphological diversity in tetraploid wheat landrace populations from centeral highlands of Ethiopia. Hereditas 114: 171-176.

Teshome, A.Baum BR, Fahrig, L, Torrance, JK, Arnason, TJ and Lambert JD. 1997. Sorghum (Sorghum bicolor (L) Moench) landrace variation and classification in North Shewa and South Welo, Ethiopia. Euphytica 97: 255-263.

Tolbert DM, Qualset CO, Jain SK and Craddock JC. 1979. A diversity analysis of the world collection of barley. Crop Sci. 19: 789-794.

Vavilov, N.I. 1951. Phytogeographic basis of plant breeding. In: The origin, variation, Immunity and breeding cultivated plants. Chron. Bot. 13: 13-54.