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*Full Length Research Paper*

# Qualitative traits diversity and eco-geographical distribution in finger millet (*Eleusine coracanaGURE* subsp*. Coracana*) landraces from eastern and south eastern Africa: An implication for germplasm collection and conservation

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**One hundred and forty four finger millet landraces collected from different regions of Ethiopia and some introduced from Kenya, Eritrea, Zambia and Zimbabwe were planted with six improved varieties in randomized complete block design at Gute and Arsi Negele (Ethiopia) during 2011 to assess genetic diversity for qualitative traits with respect to geographic location and agro-ecologies. Erect type growth habit, open ear type, light green ear (glumes) color, enclosed grains by glumes, lower spikelet density and purple black seed color was predominant phenotypic classes for the traits recorded in the present study. At 75% similarity level, finger millet populations from Ethiopia and Eritrea were grouped together; Kenyan, Zambian and Zimbabwe's landraces formed the second cluster. Agro-ecological proximity was manifested in clustering of landraces on the basis of altitude classes. The resemblance probably implies either similarities in climatic and other edaphic factors of those geographical locations and agro ecologies; selection by farmers were practiced for the same traits, or same primary seed source. Shannon diversity analysis indicated that variation was highest at the lowest level (among landraces), followed by within regions, among regions or countries, within altitudes, with the least similarities appear among altitudes. This implied that intensive collection and *in situ* genetic conservation should be given due attention at lower class than the subsequent classes.**

**Key words:** *Eleusine coracana*, finger millet, qualitative traits, Shannon diversity index.

## INTRODUCTION

Finger millet [*Eleusine coracana* (L.) Gaertn] is cultivated for human food in Africa and South Asia. Precise global area under finger millet is not known because this crop had often been clubbed with other millets. The estimated global area under millets is 36.29 million hectare. Out of this land, the Consultative Group on International Agricultural Research (CGIAR) has estimated that 10% of the area under millets is cultivated with finger millet (Hari et al., 2006). The crop has a wide range of seasonal adaptation, and is grown in lands almost at sea level (in parts of Andhra Pradesh and Tamil Nadu, India) to about 2400 m.a.s.l. in hills of Uttaranchal (India), and similarly at high altitudes in Uganda, Kenya and Ethiopia (Hari et al., 2006).

The major attributes of finger millet are, its adaptability to adverse agro-ecological conditions with minimal inputs, tolerant to moisture stress, can be produced on marginal land where other crops cannot perform, and tolerant to

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**Table 1.** Number of finger millet landraces collected from different countries/regions and altitudinal classes.

| No. | Country/Region | Altitude classes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ≤1241 | 1242-1382 | 1383-1523 | 1524-1664 | 1665-1805 | 1806-1946 | 1947-2087 | ≥2088 | Sub total |
| 1 | Amhara/Ethiopia | 0 | 0 | 0 | 1 | 2 | 16 | 9 | 4 | 32 |
| 2 | B/Gumuz/Ethiopia | 0 | 1 | 2 | 0 | 1 | 2 | 0 | 0 | 6 |
| 3 | Eritrea | 0 | 0 | 0 | 1 | 7 | 1 | 0 | 0 | 9 |
| 4 | Kenya | 0 | 0 | 4 | 3 | 0 | 0 | 0 | 0 | 7 |
| 5 | Oromia/Ethiopia | 0 | 3 | 9 | 4 | 5 | 8 | 2 | 3 | 34 |
| 6 | SNNP/Ethiopia | 0 | 0 | 3 | 1 | 0 | 0 | 1 | 1 | 6 |
| 7 | Tigray/Ethiopia | 0 | 0 | 4 | 6 | 4 | 8 | 2 | 3 | 27 |
| 8 | Zambia | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| 9 | Zimbabwe | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 13 |
| **Sub total** | | 5 | 9 | 35 | 16 | 19 | 35 | 11 | 11 | 144 |
| Released varieties | | | | | | | | | | 6 |
| Grand total | | | | | | | | | | 150 |

acidic soil (Barbeau and Hilu, 1993). Moreover, it has high nutritional value and excellent storage qualities (Dida et al., 2007). In a trial of nine summer cereal species (rice, Job's tears, pearl millet, sorghum, maize, common millet, barnyard millet, foxtail millet and finger millet); finger millet was most resistant to water logging after rice (Kono et al., 1988). Therefore, finger millets represent one of the critical plant genetic resources for the agriculture and food security of poor farmers that inhabit arid, infertile and marginal lands.

Genetic diversity is expressed as the genetic differences between species, sub species, varieties, population or individuals (Jarvis et al., 2000). Species with greater genetic diversity are more likely to be able to evolve in response to a changing environment than those with low genetic diversity. Populations that lack genetic diversity may experience low fertility and high mortality among offspring even in the environments that are fairly stable (Hunter, 1996).

Studying the genetic variation of a crop species is essential for effective utilization of germplasm in plant breeding programs, devising appropriate sampling procedures for germplasm collection and conservation, obtaining some collections for efficient germplasm management and explicating the taxonomy, evolution and origin of crop species (Assefa et al., 2002; Bekele, 1985, 1983; Demissie and Bjonstrand, 1996).

There are several countries where finger millet is a common crop. India, Uganda, Tanzania, Kenya, Ethiopia, Rwanda, Zaire, Zambia, Zimbabwe, Eritrea, Somalia, China, and Myanmar are some of them. Compared to other cereal crops such as wheat, maize, barley, rice, and sorghum, comprehensive study on finger millet biodiversity using morphological or molecular markers are limited particularly in African countries (Gopal et al., 2009; Hari et al., 2006). This study was initiated, therefore, to evaluate and characterize finger millet landraces for further utilization in the breeding programs, to assess the regional and altitudinal patterns of genetic variations, and provides a clue for germplasm collection and conservations.

## MATERIALS AND METHODS

Field experiment was conducted at Arsi Negele research sub site (altitude: 1947 m a.s.l, N: 07°19"29.9 and E: 38°39"27.2) and Gute sub site (altitude: 1906 m a.s.l, N: 09°00"53.6 and E: 36°38"24.3) in 2011 main cropping season. A total of one hundred and forty four finger millet landrace collected from Ethiopia (Oromia, Amhara, Tigray, B/Gumuz and SNNP regional states), some introduced materials from Kenya, Eritrea, Zambia and Zimbabwe and 6 released varieties were used (Table 1). The design was Randomized Complete Block Design (RCBD) with two replication, and plot size was single row of 2 m long and 50 cm between row spacing. Each block was folded in to two. Spacing between plants within row was adjusted to 10 cm. Four improved finger millet varieties released from Bako Agricultural Research Center (Ethiopia) namely; "Boneya" (KNE 411), "Wama" (KNE 392), "Gute" (Acc.229373) and "Bareda" (BRC 336-1); and two varieties released from Melkasa Agricultural Research Center ("Tadesse" and "Padet") were included for comparison. Eight altitude classes were used to group finger millet landraces with relative resemblance of agro-climatic origin following Agrawal (1996) using the formula:

$K = 1+3.32\log_{10}n$ and $W= (L-S)/K$

Where K = number of class interval, W = width of class interval, L = the largest value, S = the smallest value and n = sample size (in this case the number of landraces). Data were recorded on qualitative traits such as growth habit, ear shape, ear (glume) color, grain coverage by glumes, spikelet density and grain color following finger millet descriptors (IBPGR, 1985). The percentage frequency distribution of qualitative traits across regions and altitude classes were manipulated using excel computer program. Hierarchal clustering of accessions was performed regionally and altitudinally using MINITAB statistical software (version 14.13.0.0, Minitab Inc.) after standardizing the data to mean zero and unity variance. The amount of genetic variation was determined using the Shannon-

Weaver diversity index, following the formula described by Jain et al. (1975):

$$H' = -\sum_{i=1}^{n} Pi \log ePi$$

Where n is the number of phenotypic classes for a character and $P_i$ is the genotypic frequency as the percentage proportion of the total entries in the $i^{th}$ class. The diversity index was estimated at population level, regional level and altitudinal level.

## RESULTS

### Percentage frequency distribution of qualitative traits at regional and altitudinal level

In the present study, three phenotypic classes of growth habit (erect, prostrate and decumbent), four phenotypic classes for ear shape (droop, open, semi compact and compact), four phenotypic classes for ear/glumes color (light green, purple, yellow green and white), three phenotypic classes of grain covered by glumes (enclosed, intermediate and exposed), three phenotypic classes of spikelet density (high, intermediate and low) and five classes of grain color (white, light- brown, dark-brown, purple-black and cream) were observed in finger millet landraces used in the present study. White colored ear/glumes were absent from all countries and regions of Ethiopia other than Amhara and southern regions of Ethiopia. Similarly, dark-brown seed color is absent in Kenya and Zambia and yellow-green ear color is absent in landraces from altitude range of 1947 – 2087 and ≥2088 m a.s.l.

Erect type growth habit is predominant in all countries (Table 2) followed by decumbent type. Compact ear shape is predominant in Zimbabwe (59.7%), Zambia (52.3%) and Kenya (47.9%) (Table 2). However, open type is popular in Eritrea (58.6%) and Ethiopia (51.7%). Open ear type is common across all regions of Ethiopia except in Southern nation, nationalities and peoples, where semi compact is popular (57.7%). Light green ear (glumes) color is abundant across all the study countries and regions. Purple colored ear (glumes) is relatively popular in Kenya, Zimbabwe and Oromia region (Table 2).

Among the five phenotypic classes of grain color, purple-black colored seed was abundant in Eritrea (71.2%), and Ethiopia (42.2%), white seed color was dominant in Zambia (38.3%), light brown colored seed in Kenya (41.1%) and Zimbabwe (43.9%) (Table 2). Except for Zambia, white colored seed is limited in other countries. Regionally, purple-black colored seed took maximum percentage in Tigray (49.4%), SNNP region (46.7%), Amhara (43.2%) and Oromia (35.4%). Light-brown colored seed is dominant for Benishangul Gumuz region (45.0%) (Table 2).

Altitudinaly, higher diversity in ear shape, grain covering by glumes, ear color and spikelet density were observed in altitude classes between 1383 – 1523 m a.s.l. Diversified landraces for grain color was observed in altitude class ≥2088 m a.s.l. and for growth habit in the range of 1947 – 2087 m a.s.l. All released varieties are monomorphic for a given traits. However, there are differences in phenotypic classes among the varieties (Table 3).

### *Cluster analysis*

Country-wise, two clusters were formed at 75% similarity level (Figure 1). Finger millet populations collected from Ethiopia and Eritrea was categorized in the first cluster (left to right) and collection from Kenya, Zambia and Zimbabwe were grouped together in the second (Figure 1). Based on regional data, three clusters and four solitary groups were formed at 80% similarity level. All the five administrative regions of Ethiopia and Eritrea were aggregated in the first cluster. Whereas; populations from Kenya, Zambia and Zimbabwe grouped in the second cluster (Figure 2). Due to their monomorphic nature in the different characters (Table 3), all released varieties share minimum percentage similarity with finger millet populations of all countries and regions (Figure 2). Altitudinaly, finger millet populations collected from all the eight altitude classes were grouped in to two, and two altitude class (1383 – 1523 m.a.s.l and 1524 – 1664 m.a.s.l) remain solitary (Figure 3).

### *Shannon-Weaver diversity index (H') analysis*

Based on the mean Shannon index of individual population for the six traits, the H' value ranges from 0.151 for accession 214993 of Zambia collected from altitude region of 1340 m.a.s.l. to 0.387 for accession 229731 m.a.s.l of Ethiopia (Amhara region) collected from 1950 m.a.s.l. Besides, accession 230102 (0.172) and 230110 (0.173) both from Eritrea of 1850 and 1700 ma.s.l, respectively, accession AAUFM-20 (0.176) from Ethiopia (Tigray) and accession BKFM0048 (0.182) from Ethiopia (Oromia) are some of the landraces with minimum Shannon diversity index. However, relatively higher Shannon diversity was observed for accession 203543 (0.365) of Kenya, accession AAUFM-32 (0.369) of Tigray region (Ethiopia), accession BKFM0051 (0.372) and accession 216057 (0.385) both from West Wollega of Oromia region (Ethiopia) and accession 229731 (0.387) of Amhara region (Ethiopia) (data not shown).

Shannon indices among countries/regions of collection showed that maximum diversity for growth habit was observed in Eritrea (0.485) and minimum in Zimbabwe (0.302). Shannon diversity for ear shape ranges from 0.245 (Amhara region of Ethiopia) to 0.345 (Kenya). Grain covering by glumes and spikelet density was abundant in Oromia (0.335) and SNNP (0.338) regions of

**Table 2.** Percentage distribution of six major qualitative traits of 144 landraces collected from five Eastern and south eastern African countries and five finger millet producing Ethiopian regional states.

| Country | Region | Growth habit | | | Ear shape | | | | Ear (glumes) color | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ER | PR | DC | DP | OP | SC | CM | LG | PP | YG | WT |
| Ethiopia | - | 53.1 | 15.6 | 31.4 | 20.8 | 51.7 | 21.9 | 5.5 | 91.2 | 7.3 | 0.5 | 1.0 |
| Eritrea | - | 37.8 | 25.6 | 36.7 | 38.2 | 58.6 | 0.7 | 2.5 | 95.6 | 1.4 | 3.1 | 0.0 |
| Kenya | - | 70.5 | 9.3 | 20.2 | 1.1 | 7.0 | 44.1 | 47.9 | 49.6 | 48.9 | 1.4 | 0.0 |
| Zambia | - | 64.6 | 9.4 | 26.0 | 2.3 | 17.4 | 28.1 | 52.3 | 83.0 | 9.1 | 7.9 | 0.0 |
| Zimbabwe | - | 71.7 | 5.9 | 22.4 | 1.3 | 2.6 | 36.4 | 59.7 | 48.3 | 42.1 | 9.6 | 0.0 |
| **Mean** | | **59.5** | **13.2** | **27.3** | **12.7** | **27.5** | **26.2** | **33.6** | **73.5** | **21.8** | **4.5** | **0.2** |
| Ethiopia | Amhara | 39.8 | 20.4 | 39.7 | 28.3 | 67.4 | 3.6 | 0.7 | 97.1 | 2.1 | 0.1 | 0.8 |
| | B/Gumuz | 44.0 | 22.5 | 33.5 | 22.1 | 63.3 | 10.0 | 4.6 | 99.6 | 0.4 | 0.0 | 0.0 |
| | Oromia | 65.6 | 11.6 | 22.8 | 8.1 | 46.0 | 35.6 | 10.3 | 71.3 | 28.3 | 0.4 | 0.0 |
| | SNNP | 71.7 | 4.8 | 23.5 | 7.3 | 23.1 | 57.7 | 11.9 | 89.6 | 4.2 | 2.1 | 4.2 |
| | Tigray | 44.3 | 18.5 | 37.3 | 38.4 | 58.8 | 2.8 | 0.0 | 98.6 | 1.4 | 0.0 | 0.0 |
| | **Mean** | **53.1** | **15.6** | **31.4** | **20.8** | **51.7** | **21.9** | **5.5** | **91.2** | **7.3** | **0.5** | **1.0** |

| Country | Region | Grain covering by glumes | | | Spikelet density | | | | Grain color | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | EX | IM | EC | H | IM | L | WT | LB | DB | PB | OR |
| Ethiopia | - | 7.1 | 18.1 | 74.8 | 11.0 | 24.3 | 64.6 | 12.5 | 28.6 | 7.2 | 42.2 | 9.4 |
| Eritrea | - | 2.2 | 2.8 | 95.0 | 4.4 | 8.3 | 87.2 | 2.8 | 18.3 | 3.3 | 71.7 | 3.9 |
| Kenya | - | 51.1 | 40.2 | 8.8 | 52.7 | 38.6 | 8.8 | 15.4 | 41.1 | 0.0 | 9.3 | 34.3 |
| Zambia | - | 35.5 | 35.4 | 29.1 | 41.6 | 36.6 | 21.8 | 38.3 | 11.8 | 0.0 | 10.0 | 39.0 |
| Zimbabwe | - | 63.0 | 23.4 | 13.7 | 55.6 | 34.6 | 9.8 | 17.7 | 23.9 | 0.4 | 13.5 | 44.6 |
| **Mean** | **-** | **31.8** | **24.0** | **44.3** | **33.1** | **28.5** | **38.4** | **17.3** | **24.7** | **2.2** | **29.3** | **26.2** |
| Ethiopia | Amhara | 2.8 | 8.8 | 88.4 | 3.1 | 12.0 | 84.9 | 19.0 | 24.8 | 8.5 | 43.2 | 4.5 |
| | B/Gumuz | 3.8 | 8.3 | 87.9 | 5.0 | 13.3 | 81.7 | 6.7 | 45.0 | 5.4 | 36.3 | 6.7 |
| | Oromia | 20.7 | 27.0 | 52.3 | 19.2 | 34.3 | 46.5 | 10.3 | 21.8 | 1.8 | 35.4 | 30.7 |
| | SNNP | 2.9 | 30.8 | 66.3 | 23.5 | 41.5 | 35.0 | 15.0 | 20.0 | 15.0 | 46.7 | 3.3 |
| | Tigray | 5.2 | 15.7 | 79.1 | 4.4 | 20.5 | 75.1 | 11.7 | 31.6 | 5.3 | 49.4 | 2.0 |
| | **Mean** | **7.1** | **18.1** | **74.8** | **11.0** | **24.3** | **64.6** | **12.5** | **28.6** | **7.2** | **42.2** | **9.4** |

Growth habit: ER = Erect, PR = Prostrate, DC = Decumbent; Ear shape: DP = Droop, OP = Open, SC = Semi-compact, CM = Compact; Ear (glumes) color: LG = light green, PP = purple, YG = yellow green, WT = white; Grain covered by Glumes: EX = exposed, IM = Intermediate, EC = Enclosed; Spikelet density = high, IM = Intermediate, L = low; Grain color: WT = white, LB = light brown, DB = Dark brown, PB = purple black, OR = Orange-red, SNNP = Southern Nation, Nationalities and Peoples Region.

Ethiopia. Grain color showed greater abundance in landraces collected from Kenya (0.403). On trait basis, minimum mean diversity within regions were observed for ear/glumes color (0.199) and maximum for growth habit (0.377) followed by grain color (0.353). The pooled mean diversity indices for the six traits were comparatively higher for Kenyan collection (0.320), Benishangul Gumuz region (Ethiopia) (0.302), Oromia region (Ethiopia) (0.294), Zambia (0.289) and Zimbabwe (0.287) (Table 4). Attitudinally, relatively high mean H' values were noted for finger millet populations collected from altitude classes between 1383 – 1523 m a.s.l for ear/glumes color (0.239), grain covering by glumes (0.294) and grain color (0.388). Lower mean diversity was observed for ear color (0.198), but higher diversity was recorded for growth habit (0.370) and seed color (0.329). The pooled mean diversity for those six traits were lower for altitude region between 1524-1664 m.a.s.l and higher for 1383 – 1523 m.a.s.l. (Table 5).

## DISSCUSSION

Although the degree of diversification varies, the presence of majority of the phenotypic classes for each trait in the landraces collected from different corners of Ethiopia and some African countries implied that diversified germplasm is available per region and per country. The abundance of erected growth habit of finger millet landraces for all countries and regions of Ethiopia

**Table 3.** Percentage proportion of six major qualitative traits in 144 finger millet landraces collected from eight altitude classes and 6 released varieties.

| Altitude | Growth habit | | | Ear shape | | | | Ear (glumes) color | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ER | PR | DC | DP | OP | SC | CM | LG | PP | YG | WT |
| ≤1241 | 59.3 | 12.0 | 28.8 | 3.3 | 12.0 | 31.3 | 53.5 | 79.0 | 7.3 | 13.8 | 0.0 |
| 1242-1382 | 69.9 | 5.7 | 24.4 | 2.2 | 29.9 | 32.6 | 35.3 | 81.3 | 17.6 | 1.1 | 0.0 |
| 1383-1523 | 64.9 | 10.3 | 24.9 | 9.9 | 25.1 | 33.1 | 32.0 | 62.5 | 32.6 | 4.2 | 0.7 |
| 1524-1664 | 60.6 | 11.9 | 27.6 | 20.2 | 42.1 | 28.9 | 8.8 | 82.5 | 17.3 | 0.2 | 0.0 |
| 1665-1805 | 46.6 | 20.5 | 32.9 | 26.5 | 53.1 | 15.9 | 4.6 | 89.3 | 9.2 | 1.5 | 0.0 |
| 1806-1946 | 46.7 | 16.5 | 36.7 | 26.1 | 64.9 | 5.6 | 3.4 | 94.2 | 4.8 | 0.4 | 0.7 |
| 1947-2087 | 39.0 | 23.5 | 37.5 | 31.9 | 60.2 | 6.3 | 1.6 | 98.0 | 2.0 | 0.0 | 0.0 |
| ≥2088 | 52.2 | 18.9 | 28.9 | 28.0 | 52.2 | 15.7 | 4.1 | 91.3 | 8.8 | 0.0 | 0.0 |
| **Sub mean** | **54.9** | **14.9** | **30.2** | **18.3** | **42.5** | **21.3** | **17.9** | **84.8** | **12.4** | **2.6** | **0.2** |
| Padet | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 |
| Tadesse | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | 100.0 |
| Wama | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 |
| Bereda | 100.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 |
| Gute | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 |
| Boneya | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 100.0 | 0.0 | 0.0 |

| Altitude | Grain covering by glumes | | | Spikelet density | | | | Grain color | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | EX | IM | EC | H | IM | L | WT | LB | DB | PB | OR |
| ≤1241 | 38.3 | 38.3 | 23.5 | 39.0 | 45.5 | 15.5 | 38.0 | 14.0 | 0.0 | 2.0 | 46.0 |
| 1242-1382 | 26.3 | 31.9 | 41.8 | 35.7 | 31.8 | 32.5 | 24.7 | 13.1 | 0.8 | 15.8 | 45.6 |
| 1383-1523 | 36.2 | 25.3 | 38.5 | 33.8 | 34.9 | 31.3 | 13.6 | 27.1 | 3.2 | 21.0 | 35.1 |
| 1524-1664 | 17.9 | 26.8 | 55.3 | 20.2 | 29.8 | 50.1 | 10.2 | 33.6 | 4.4 | 33.6 | 18.3 |
| 1665-1805 | 8.4 | 14.0 | 77.6 | 7.8 | 19.9 | 72.4 | 12.5 | 27.1 | 3.2 | 45.3 | 12.0 |
| 1806-1946 | 6.1 | 9.4 | 84.5 | 6.1 | 14.7 | 79.2 | 12.9 | 24.7 | 4.7 | 52.6 | 5.1 |
| 1947-2087 | 4.3 | 15.4 | 80.4 | 5.7 | 16.3 | 78.0 | 6.3 | 27.5 | 9.8 | 51.3 | 5.2 |
| ≥2088 | 9.3 | 18.7 | 72.1 | 10.8 | 21.7 | 67.5 | 26.7 | 19.2 | 6.7 | 35.8 | 11.7 |
| **Sub mean** | **18.3** | **22.5** | **59.2** | **19.9** | **26.8** | **53.3** | **18.1** | **23.3** | **4.1** | **32.2** | **22.4** |
| Padet | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 |
| Tadesse | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 |
| Wama | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 |
| Bereda | 0.0 | 0.0 | 100.0 | 0.0 | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 |
| Gute | 0.0 | 100.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 |
| Boneya | 0.0 | 100.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 |

Growth habit: ER = Erect, PR = Prostrate, DC = Decumbent; Ear shape: DP = Droop, OP = Open, SC = Semi-compact, CM = Compact; Ear (glumes) color: LG = light green, PP = purple, YG = yellow green, WT = white; Grain covered by Glumes: EX = exposed, IM = Intermediate, EC = Enclosed; Spikelet density = high, IM = Intermediate, L = low; Grain color: WT = white, LB = light brown, DB = Dark brown, PB = purple black, OR = Orange-red.

might be, due to selection of those types by farmers for ease of spotting the weed under the crop (the major bottleneck for finger millet production) and other management practices. Similarly, erect type growth habit was dominant for the 909 finger millet germplasms collected from different East African countries (Upadhyaya et al., 2007). In contrast, decumbent types were dominant followed by prostrate type in landraces collected from some of the former Ethiopian administrative regions (Wollega, Gojam, Gamu Gofa, Gonder, Tigray and Eritrea) (Bezaweletaw et al., 2006). The difference observed across location and among genotypes collected from different regions could be due to the genetic factors, edaphic factors (soil and soil related factors) or other environmental condition of the area that influence the adaptive role of the traits.

The abundance of open type ear shape, lower spikelet density and grains enclosed by glumes in Ethiopian and Eritrean landraces, but compact ear shape, exposed grain and higher spikelet density for Kenyan, Zambian

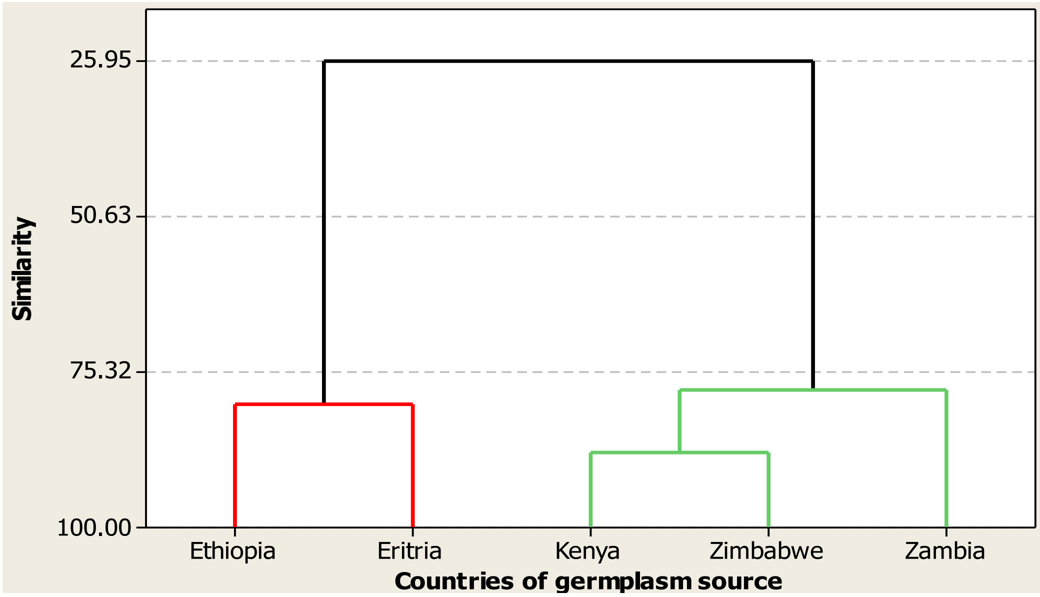


**Figure 1.** Genetic similarity and differences between 144 finger millet landraces collected from 5 countries and evaluated for 6 qualitative traits.

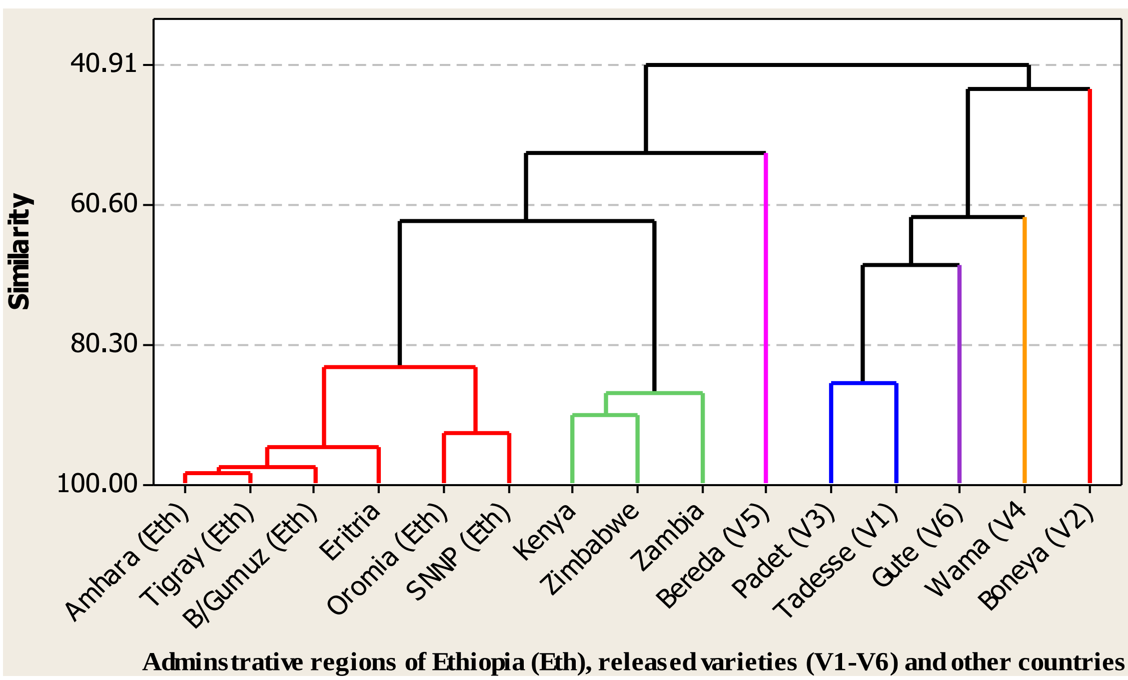


**Figure 2.** Similarities for F. millet landraces among regions of Ethiopia, African countries and released varieties evaluated for 6 qualitative traits.

and Zimbabwe collection indicated that selection is in favor of those traits due to their adaptive nature and agro-ecological fitness. In other words, the wide range of agro-climatic condition of those African countries could lead to the development of different races of finger millet. Open and droopy shaped finger is a typical characteristic of race *coracana* (De Wet et al., 1985). This can also gives a clue that *E. coracana* was primarily domesticated in East Africa, particularly Ethiopia (Gopal et al., 2009; Hilu et al., 1979).

Droop and open ear shape are mainly characterized by lower number of spikelet per a centimeter length of middle part of finger. Inflorescence morphology was associated with grain yield and is used by the farmers to

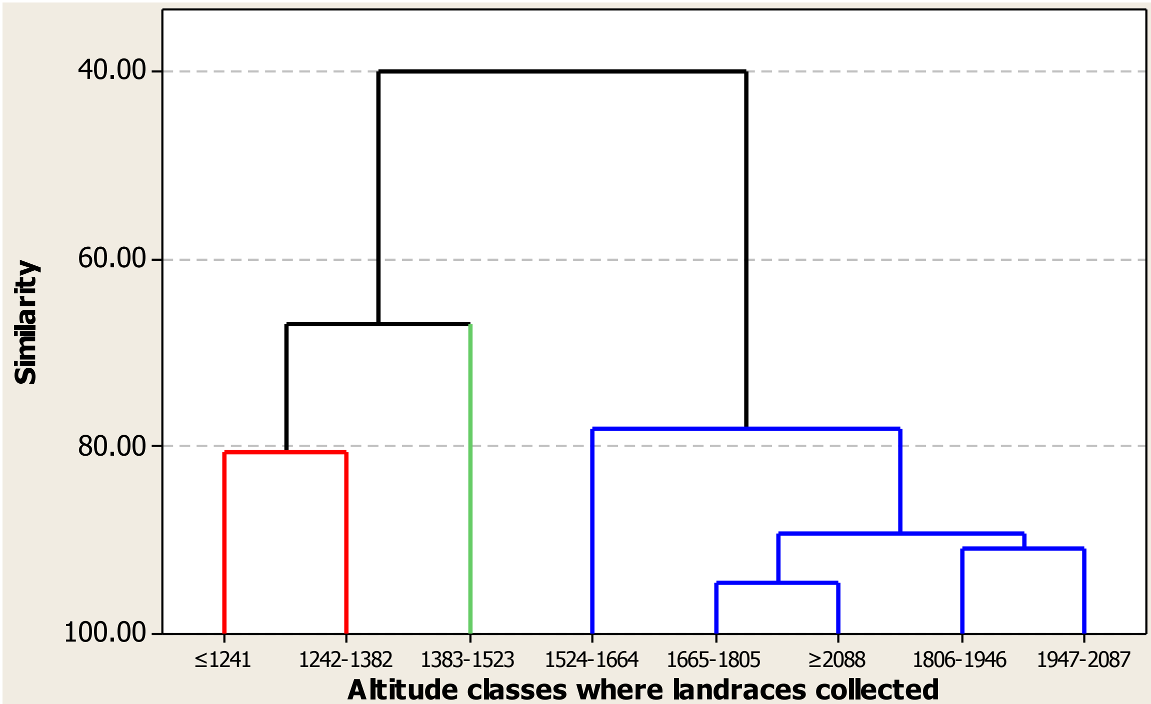


**Figure 3.** Dendrogram showing similarities among agro-ecologies of collection of 144 F. millet landraces for 6 qualitative traits.

**Table 4.** Shannon-Weaver diversity indices (H') and standard error of mean (± SE) of finger millet population collected from 5 regions of Ethiopia and 4 east and south east African countries for 6 qualitative traits.

| Country/region | Qualitative characters | | | | | | Mean ± SE |
|---|---|---|---|---|---|---|---|
| | GH | ESH | EC | GCG | SPD | SC | |
| Amhara/Ethiopia | 0.426 | 0.245 | 0.212 | 0.239 | 0.238 | 0.312 | 0.279 ± 0.033 |
| B/Gumuz/Ethiopia | 0.427 | 0.253 | 0.159 | 0.260 | 0.338 | 0.377 | 0.302 ± 0.040 |
| Oromia/Ethiopia | 0.329 | 0.246 | 0.255 | 0.335 | 0.299 | 0.296 | 0.294 ± 0.015 |
| SNNP/Ethiopia | 0.391 | 0.279 | 0.194 | 0.236 | 0.289 | 0.326 | 0.286 ± 0.043 |
| Tigray/Ethiopia | 0.423 | 0.277 | 0.157 | 0.238 | 0.288 | 0.325 | 0.284 ± 0.033 |
| Eritrea | 0.458 | 0.305 | 0.055 | 0.111 | 0.243 | 0.243 | 0.236 ± 0.060 |
| Kenya | 0.317 | 0.345 | 0.291 | 0.234 | 0.330 | 0.403 | 0.320 ± 0.024 |
| Zambia | 0.325 | 0.297 | 0.182 | 0.284 | 0.312 | 0.337 | 0.289+ 0.240 |
| Zimbabwe | 0.302 | 0.293 | 0.282 | 0.264 | 0.283 | 0.353 | 0.287 ± 0.012 |
| **Mean** | **0.377** | **0.282** | **0.199** | **0.244** | **0.291** | **0.330** | 0.287±0.045 |

SNNP = Southern Nation, Nationalities and Peoples region, GH = growth habit, ESH = ear shape, EC = Ear/glumes color, GCG = Grain covering by glumes, SPD = Spikelet density, SC = seed color.

distinguish complexes of cultivars (De Wet et al., 1985). Genotypes with grain enclosed in glumes are better resistant to bird, minimize grain spoilage due to mold particularly in areas where there is high humidity or rain fall and tolerate shattering. The exposed groups are easy for thrashing and seed cleaning, particularly in removing the husk from grain. Farmer's preference of grain color depends on the adaptability of a variety to climate and edaphic factors of the area, yielding ability, major use of the grain or cultural role and ease of production. Accordingly, purple-black colored seed is dominant in Northern part of Ethiopia due to the fact that farmers linked this type of finger millet with high yield and hard tolerant such as moisture stress and poor soil fertility. Similar results were reported by different authors (Bezaweletaw et al., 2006; Tsehaye and Kebebew, 2002). Over all, countries or regions with better distribution of the different phenotypic classes of a given character or trait is said to have better diversity for the trait. Hence, finger millet populations sampled from

**Table 5.** Shannon-Weaver diversity indices (H') and standard error of mean (± SE) of finger millet population collected from 8 altitude classes (agro-ecologies) of different regions for 6 qualitative traits.

| Altitude | Qualitative characters | | | | | | Mean ± SE |
|---|---|---|---|---|---|---|---|
| | GH | ESH | EC | GCG | SPD | SC | |
| ≤1241 | 0.329 | 0.348 | 0.234 | 0.242 | 0.342 | 0.305 | 0.300 ± 0.058 |
| 1242-1382 | 0.316 | 0.296 | 0.170 | 0.289 | 0.284 | 0.305 | 0.277 ± 0.035 |
| 1383-1523 | 0.367 | 0.288 | 0.239 | 0.294 | 0.326 | 0.388 | 0.317 ± 0.038 |
| 1524-1664 | 0.371 | 0.239 | 0.184 | 0.200 | 0.279 | 0.339 | 0.269 ± 0.043 |
| 1665-1805 | 0.396 | 0.282 | 0.190 | 0.259 | 0.281 | 0.294 | 0.284 ± 0.042 |
| 1806-1946 | 0.416 | 0.231 | 0.186 | 0.242 | 0.266 | 0.264 | 0.268 ± 0.038 |
| 1947-2087 | 0.433 | 0.260 | 0.189 | 0.267 | 0.247 | 0.377 | 0.295 ± 0.051 |
| ≥2088 | 0.376 | 0.277 | 0.194 | 0.198 | 0.290 | 0.304 | 0.273 ± 0.041 |
| **Mean** | **0.370** | **0.278** | **0.198** | **0.255** | **0.287** | **0.329** | **0.286 ± 0.041** |

GH = growth habit, ESH = ear shape, EC = Ear/glumes color, PP = plant pigmentation, GCG = Grain covering by glumes, SPD = Spikelet density, SC = seed color.

Ethiopia showed better diversity for ear shape, ear (glumes) color and seed color, landraces from Zambia was diversified for grain coverage by glumes and spikelet density, Eritrean collections were diverse in growth habit. The abundance in ear shape, grain covering by glumes, ear color and spikelet density observed in altitude classes between 1383–1523 m a.s.l. Therefore; altitude class between 1383 – 1523 m a.s.l were identified as the zone possessing the highest diversity of finger millet landraces and hence deserve due attention for germplasm collection with appropriate sampling procedures to capture maximum diversity and *in situ* genetic conservation.Cluster analysis showed that neighboring regions, countries and proximity in altitude classes shared strong similarity. The similarity could be either due to fact that farmer's selection criteria for a given traits might be uniform particularly based on the adaptive role of traits for the environment, or the original source of seeds might be the same, or seed exchange among neighboring farmers. Other possibilities could be inter- and intra-country/regional migration and gene flow. Similarly, finger millet landraces collected from Kenya, Tanzania and Uganda were grouped together, but landraces from Ethiopia and Burundi were in a separate cluster each (Gopal et al., 2009). Supportive results were also reported by different authors (Bezaweletaw et al., 2006; Tsehaye and Kebebew, 2002). Shannon diversity indices indicated that higher diversity for growth habit was observed in Eritrea and Ethiopia, wider diversity for ear shape and grain color in Kenya, and grain covering by glumes and spikelet density is abundant in Ethiopia (Oromia and SNNP region). The pooled mean diversity indices for the six traits were comparatively higher for Kenyan collection followed by Ethiopia (Benishangul Gumuz and Oromia region). Generally, analysis of Shannon diversity index for six qualitative traits in finger millet landraces indicated that diversity is higher between landraces, followed by within region or within country, among regions or countries, within altitude classes, and least between altitude classes.

Such results can provide insight into area of focus for possible germplasm collection and conservation. Besides, it leads to suggest, taking more samples within a locality or population would be a better approach to capture the range of variation in finger millet population. Similar results were reported for different crops. For instance, the total phenotypic variation for bread wheat was highest at the lowest level (within localities), followed by difference among populations within a region, and the least among regions (Barbeau and Hilu, 1993). Besides, the extent of genetic variation in tef landraces is highest among accessions, followed by within regions and with altitudes but lower among regions and among altitudes (Lule et al., 2011). Contradicting results were reported for bread wheat, where diversity was higher among district than among population within district (Tadesse et al., 1991). Therefore, pattern of germplasm biodiversity is crop-dependent.

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